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IMPACT OF OCEANOGRAPHIC CONDITIONS ON DISTRIBUTION AND ABUNDANCE OF LARVAL FISH IN NORTHERN BRAZIL

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Contents

ABSTRACT

This study presents a qualitative and quantitative description of ichthyoplankton related to the parameters temperature, salinity and dissolved oxygen of the coastal and oceanic waters of the state of Maranhão/Brazil. The samples were collected in 67 stations during the dry season (11 and 12/1997, 7 and 9/2001) and the rainy season (6/1999) using a bongo net with mesh apertures of 500 µm. The depth of the tows varied from 20 m above the bottom at shallow stations up to 200 m at offshore stations. The fish larvae were examined to be identified up to the level of species. Only families with a frequency of occurrence of more than 40% were used in this analysis. A combination of univariate and multivariate analyzing techniques was used to define the community structure of the fish larvae.

In the oceanic region during the dry season occur the highest average values of temperature (21.3-28.4°C) and salinity (35.2-37.0psu). During the rainy season on stations near the coast occur the lowest average values of salinity (34.2-35.2psu) and the highest average value of temperature (28.0 °C). The average values of dissolved oxygen on these stations are as well high (5.0 $ml \cdot L^{-1}$) as low (4.0 $ml \cdot L^{-1}$).

A total of 4.131 fish larvae were collected, representing 57 families. The Gobiidae, Myctophidae, Carangidae, Scaridae, Bothidae and Scombridae are the taxa with a frequency of occurence of more than 40% and represent 77% of the relative abundance of the whole catch. These six most frequent families present 74 species with 3.195 individuals.

The results show an association of fish larvae constituted of a lot of rare species and a small amount of species with a big quantity in the costal and oceanic region of the Maranhão. The most frequent species are the gobiid *Gobionellus saepepallens* (63%), bothid *Bothus ocellatus* (49%) and scarid *Sparisoma* sp. (48%). *Gobionellus saepepallens* is considerated to ecological importance, while *Bothus ocellatus* and *Sparisoma* sp. have more comercial importance.

In the oceanic region occur the highest values of density of fish larvae and the responsible taxa for these values are the gobiids *Gobionellus oceanicus*, *Gobionellus saepepallens* and *Coryphopterus* sp..

The cluster analysis resulted in ten distinct station groups with alterations in taxonomic composition between the coastal und oceanic waters and generally low density values. The bigger assemblages are the C2, C6, C7 e C10.

The cluster C2 is classified as transition assemblage and stands out by the presence of the highest density values and a diversified group of fish larvae. The gobiids *G. oceanicus* and *G. saepepallens* are the dominant taxa in this assemblage. The results revealed by the Canonical Correspondence Analysis (CCA) of this assemblage show the influence of the Tropical Water (TW) mass with its high salinity and high dissolved oxygen values on the increase of density of these species.

The myctophids *Diaphus* sp., *Lepidophanes guentheri*, *Myctophum obtusirostre*, the gobiid *Gobionellus saepepallens*, carangid Carangidae A and the scarid *Sparisoma* sp. are dominant taxa in the transition assemblage C6. The CCA results of this assemblage indicate the influence of the cold and low saline South Atlantic Central Water (SACW) on the increase of density of these species.

The transition assemblage C7 is dominated by the gobiid *Gobionellus saepepallens*, carangids *Chloroscombrus chrysurus*, *Caranx crysos* and scarid *Sparisoma* sp.. The CCA results of this assemblage indicate a strong influence of the Subtropical Shelf Water (STSW) on the increase of density of these species. This mixed water is formed by the great estuarine discharge, the high rainfall together with the penetration of the SACW on the continental shelf, resulting in low dissolved oxygen and low temperature values.

The coastal epipelagic *Decapterus punctatus* and *Chloroscombrus chrysurus* are dominant in the coastal assemblage C10. The dominance of the coastal epipelagic in this assemblage shows clearly the existence of a pelagic environment rich in nutrients due to the influence of the Coastal Water (CW) with high temperature and low salinity values as indicated by CCA. This result is consequence of the estuarine flow and a high amount of rainfall during the rainy season, which allies the high temperature and low salinity values and favours the high density of these species.

The variation of density of ichthyoplankton and its dependance on the distance from the shore is observed in the present study. The values of density of C2 reach a total of 444.25 larvae/100m^3, while C10 reaches a total of 40.89 larvae/100m^3.

The oceanographical parameter values show the differences between the offshore and inshore region: offshore under influence of the TW salinity and temperature present high values, inshore under influence of the CW temperature is high and salinity values are low.

The oceanographical parameters present favourable conditions to the survival and the density of the fish larvae, especially to the gobiids, wich is the taxa responsible for high density offshore.

Between the occidental and oriental side inshore cluster 10 shows a variation of the fish larvae density too, as well as a difference of the oceanographical parameter values. The biggest values of density of this cluster are observed on the occidental side, where the mangrove estuarines flow and strong rain fall is evident. The resulting high temperature and low salinity values can favour the fish larvae density.

The results obtained here may serve as guide to future studies of ichthyoplankton related to oceanographycal conditions on the Maranhense coast, thus enlarging the knowledge about the potential of fishery of the region.

ZUSAMMENFASSUNG

Diese Arbeit präsentiert eine qualitative wie quantitative Beschreibung der Abhängigkeit des Ichthyoplanktons von den Parametern Temperatur, Salzhaltigkeit und gelöster Sauerstoff der Küsten- und Ozeangewässer des brasilianischen Staates Maranhão. Die Gesamtzahl von 67 Proben wurden während der Trocken- (11 und 12/1997 sowie 7 und 9/2001) und einer Regenzeit (6/1999) mit einem Bongonetz gezogen. Das Netz mit einer Maschenöffnung von 500 µm wurde schräg bei 2 Knoten Geschwindigkeit jeweils 20 Minuten gezogen. Die Fangtiefe variierte von 20m über dem Grund bei Flachwasser-Stationen bis zu 200m Tiefe bei Stationen in der offenen See. Die Fischlarven wurden bis zum Spezien-Niveau identifiziert. Nur Familien mit einer Erscheinungsfrequenz von mehr als 40% wurden für die Analyse verwendet. Ein Kombination von uni- und multivarianten Analyse-Techniken wurde angewandt, um die Gesellschaftsstruktur der Larven zu definieren.

Während der Trockenzeit sind in der ozeanischen Region die höchsten mittleren Werte von Temperatur (21.3°C - 28.4°C) und Salzhaltigkeit (35.2 - 37.0 psu) festzustellen. Während der Regenzeit auf küstennahen Stationen ergeben sich die niedrigsten Salzhaltigkeits-Durchschnittswerte (34.2-35.2 psu) und die höchsten Temperatur-Durchschnittswerte (28.0 °C). Die durchschnittlichen Werte des gelösten Sauerstoffs auf diesen Stationen erreichen sowohl hohe (5.0 $ml \cdot L^{-1}$) als auch niedrige Werte (4.0 $ml \cdot L^{-1}$).

Insgesamt wurden 4.131 Fischlarven gesammelt, die 57 Familien repräsentieren. Die Gobiidae, Myctophidae, Carangidae, Scaridae, Bothidae und Scombridae sind die Taxa mit einer Erscheinungsfrequenz von über 40% und repräsentieren 77% der relativen Abundanz des gesamten Fanges. Diese sechs hochfrequenten Familien setzen sich aus 74 Spezien mit 3.195 Individuen zusammen.

Die Ergebnisse zeigen eine Zusammensetzung der Fischlarvenpopulation in der Küsten- und Ozeanregion des Maranhão, die aus vielen raren Spezien und einer kleinen Anzahl von Spezien mit großer Quantität besteht. Die Spezien mit der höchsten Frequenz sind die Gobiidae *Gobionellus saepepallens* (63%), Bothidae *Bothus ocellatus* (49%) und Scaridae *Sparisoma* sp. (48%). *Gobionellus saepepallens* wird für ökologisch bedeutend gehalten während *Bothus ocellatus* und *Sparisoma* sp. eher kommerzielle Bedeutung haben.

In der ozeanischen Region ist die Larven-Dichte am höchsten, was auf die Werte der Gobiidae *Gobionellus oceanicus*, *Gobionellus saepepallens* und *Coryphopterus* sp. zurückzuführen ist.

Die Cluster-Analyse ergab zehn getrennte Gruppen von Stationen mit unterschiedlicher taxonomischer Zusammensetzung und generell niedrigen Dichte-Werten. Die größeren Assoziationen sind die Cluster C2, C6, C7 und C10.

C2 ist ein transitionaler Cluster und sticht hervor wegen der in ihm auftretenden höchsten Dichte-Werte und einer vielfältigen Larvenpopulation. Die Gobiidae *Gobionellus oceanicus* und *G. saepepallens* sind die dominanten Taxa dieser

Gruppe. Die kanonische Korrespondenz Analyse (CCA) für diese Gruppe zeigt die Relation von hohen Salzgehaltwerten und hohen Werten von gelöstem Sauerstoff der Tropischen Wasser (TW) zum Ansteigen der Dichte dieser Spezien.

Die Myctophidae *Diaphus* sp., *Lepidophanes guentheri*, *Myctophum obtusirostre*, die Gobiidae *Gobionellus saepepallens*, Carangidae Carangidae A und die Scaridae *Sparisoma* sp. sind die dominanten Taxa im transitionalen Cluster C6. Die CCA für diese Gruppe zeigt die Relation von niedrigen Temperaturen und Salzgehaltwerten der Zentralen Südatlantischen Wassermassen (SACW) zum Ansteigen der Dichte dieser Spezien.

Die transitionale Assoziation C7 wird dominiert durch die Gobiidae *Gobionellus saepepallens*, die Carangidae *Chloroscombrus chrysurus, Caranx chrysurus* und die Scaridae *Sparisoma* sp. Die CCA Ergebnisse für diese Gruppe zeigen einen starken Einfluß der Subtropischen Plattform Wasser (STSW) auf das Ansteigen der Dichte dieser Spezien. Dieses Mischwasser setzt sich zusammen aus dem großen Ausstoß der Flußmündungen, starken Regenfällen und einem starken Einfluß der SACW auf der Kontinentalplattform mit resultierendem niedrigem Sauerstoffgehalt und niedrigen Temperaturen.

Die der Gruppe der epipelagischen Spezien zugeordneten *Decapterus punctatus* und *Chloroscombrus chrysurus* sind dominant im Cluster C10. Die Dominanz dieser Spezien wie auch die CCA weisen deutlich auf eine nährstoffreiche pelagische Umgebung, beeinflusst durch die Küsten Wasser (CW) mit hohen Temperaturen und niedrigem Salzgehalt, Ergebnis des Ausstoßes der Flußmündungen und des starken Niederschlages in der Regenzeit, die die höhere Dichte dieser Spezien begünstigen.

Die Verschiedenheiten der Dichte-Werte des Ichtyoplanktons und deren Abhängigkeit von der Entfernung zur Küste wird in dieser Arbeit gezeigt. Die Dichte-Werte von C2 erreichen in der Summe 444.25 larvae/100m^3, denen 40.89 larvae/100m^3 des küstennahen Clusters C10 gegenüberstehen.

Die Werte der ozeanografischen Parameter zeigen die Unterschiede zwischen der Küsten- und der ozeanischen Region auf: Die küstenfernen Gebiete unter dem Einfluß der Tropischen Wasser (TW) weisen hohe Salzgehalt- und Temperaturwerte auf, küstennah, unter Einfluß der Küsten-Wasser (CW), ist der Salzgehalt niedrig und die Temperatur hoch.

Die Werte der ozeanografischen Parameter zeigen zudem begünstigende Bedingungen für Überleben und hohe Dichte der Fisch-Larven, speziell der Gobiidae auf. Die Gobiidae sind die verantwortliche Taxa für die hohen Dichte-Werte in der ozeanischen Region.

Auch zwischen der westlichen und der östlichen Küste sind unterschiedliche Dichte-Werte zu festzustellen, wie der Cluster 10 zeigt, ebenso wie unterschiedliche Parameter-Werte. Cluster 10 hat die höchsten Dichte-Werte an der westlichen Küste mit ihren Mangroven-Flußmündungen und starken Regenfällen. Die sich ergebenden hohe Temperatur-Werte und der niedrige Salzgehalt könne die Dichte der Fischlarven begünstigen.

Die Resultate dieser Arbeit sollen als Ansatz für weiterführende Studien des Verhältnisses von Ichtyoplankton zu ozeanografischen Parametern an der Küste des Maranhão dienen, um so die Kenntnisse über das Fangpotential der Region zu erweitern.

RESUMO

Este estudo apresenta uma descrição qualitativa e quantitativa do ictioplâncton em relação a temperatura, salinidade e oxigênio dissolvido das águas costeiras e oceânicas do Estado do Maranhão/Brasil. As amostras foram coletadas em um total de 67 estações durante o período de seca (11 e 12/1997 e 7 e 9/2001) e durante o período de chuva (6/1999) usando rede de Bongo com 500 µm de abertura de malha. A profundidade dos arrastos variou de 20 m em estações rasas na costa para 200m em estações longe da costa. A identificação das larvas de peixes foi realizada até o nível de espécie, considerando as famílias com freqüência de ocorrência maior do que 40% para esta análise. Uma combinação de técnicas de análises univariadas e multivariadas foi usada para definir a estrutura da comunidade de larvas de peixes.

Nas estações oceânicas durante o período de seca ocorrem os maiores valores médios de temperatura (21.3-28.4 °C) e salinidade (35.2-37.0 psu). Durante o período de chuva, nas estações mais próximas da costa ocorrem os menores valores médio de salinidade (34.2-35.2 psu) e o maior valor médio de temperatura (28.0 °C). O oxigênio dissolvido apresenta valores médios altos (5.0 ml·L^{-1}) e baixos (4.0 ml·L^{-1}) nestas mesmas estações.

Um total de 4.131 larvas de peixes, representando 57 famílias foram coletadas. Os Gobiidae, Myctophidae, Carangidae, Scaridae, Bothidae e Scombridae são os taxas com freqüência de ocorrência acima de 40% e representam 77% de abundância relativa do total das larvas capturadas. Estas 6 mais freqüêntes famílias estão representadas por 74 espécies com 3.195 indivíduos.

Os resultados mostram que a associação de larvas de peixes na região costeira e oceânica do Maranhão é constituída de muitas espécies raras e poucas espécies em largo número. As mais freqüentes espécies são o gobiideo *Gobionellus saepepallens* (63%), bothideo *Bothus ocellatus* (49%) e scarideo *Sparisoma* sp. (48%). *Gobionellus saepepallens* é considerada de importância ecológica, enquanto *Bothus ocellatus* e *Sparisoma* sp. são consideradas de interesse comercial.

Na região oceânica está presente os maiores valores de densidade de larvas de peixes, os quais são representados pelos gobiideos *Gobionellus oceanicus*, *Gobionellus saepepallens* e *Coryphopterus* sp..

A análise de cluster revelou a presença de dez associações distintas com mudanças na composição taxonômica, no geral com valores baixos de densidade. Os clusters C2, C6, C7 e C10 representam as maiores associações.

O cluster C2 é classificado como associação de transição e destacam-se pela presença de altos valores de densidade e por apresentar o mais diverso grupo de larvas de peixes. Os gobiideos *G. oceanicus* e *G. saepepallens* são os taxa dominantes nesta associação. Os resultados revelado pela Análise de Correspondência Canônica (ACC) para esta associação mostram a influencia da massa de água com alta salinidade e alto teor de oxigênio dissolvido, Água Tropical (AT), sobre o aumento de denisdade destas espécies.

Os myctophideos *Diaphus* sp., *Lepidophanes guentheri* e *Myctophum obtusirostre* e o gobiideo *Gobionellus saepepallens*, carangideo Carangidae A e o scarideo *Sparisoma* sp. são os taxa dominantes na associação de transição C6. Os resulatdos da ACC para esta associação, indica a influência da fria e menos salina Água Central do Atlântico Sul (ACAS) sobre o aumento de densidade destas espécies.

A associação de transição C7, é dominada pelo gobiideo *Gobionellus saepepallens*, carangideos *Chloroscombrus chrysurus* e *Caranx crysos* e sacrideo *Sparisoma* sp.. Os resultados da ACC para esta associação indica uma forte influência da Água de Plataforma Subtropical (APST) sobre o aumento de densidade destas espécies. Esta água de mistura está formada pela grande descarga estuarina, elevada pluviosidade e pela penetração da ACAS sobre a plataforma continental resultando em valores baixos de oxigênio dissolvido e temperatura.

Os epipelágicos costeiros *Decapterus punctatus* e *Chloroscombrus chrysurus* são dominantes na associação costeira C10. A dominância de epipelágicos costeiros nesta associação mostra claramente a existência de um ambiente pelágico rico em nutrientes devido a influência da Água Costeira (AC) com elevada temperatura e baixa salinidade como indicado pela ACC.

Este resultado é conseqüência do fluxo estuarino e da elevada pluviosidade durante o período de chuva, que aliadas a elevada temperatura e baixos valores de salinidade favorece a alta densidade destas espécies.

A variação de densidade de ictioplâncton e sua dependência sobre a distância da costa é observada no presente estudo. Os valores de densidade do C2 atingem um total de 444.25 larvae/100m3, enquanto que os do C10 atingem um total de 40.89 larvae/100m3.

Os valores dos parâmetros oceanográficos mostraram diferença entre as regiões costeira e oceânica: Região oceânica sobre influência da AT, com elevados valores de salinidade e temperatura. Na região costeira sobre influência da AC, com valores elevados de temperatura e baixos valores de salinidade.

Os parâmetros oceanográficos apresentam favoráveis condições para a sobrevivência e densidade de larvas de peixes, especialmente para os gobiideos, que são os taxas responsáveis para a alta densidade na região oceânica.

Entre os lados ocidental e oriental na região costeira é observada uma variação de densidade como mostra a associação do cluster 10, bem como uma diferença de valores dos parâmetros oceanográficos. Este cluster apresenta maiores valores de densidade no lado ocidental, onde o fluxo dos estuários dos manguezais e a elevada pluviosidade são evidentes. Os valores elevados de temperatura e baixos valores de salinidade podem favorecer a densidade de larvas de peixes.

Os resultados obtidos aqui podem servir como guia para estudos futuros de ictioplâncton relacionados para condições oceanográficas na costa maranhense, contribuíndo assim, para o aumento de conhecimento sobre o potencial pesqueiro da região.

1 INTRODUCTION

1.1 General aspects of ichthyoplankton and environmental conditions

Ichthyoplankton studies have a key role in understanding ecology and evolution of fish fauna and their constituent populations (Moser and Smith, 1993). Demand for the knowledge on distribution and abundance of ichthyoplankton has increased in fishery research to predict fisheries yields (Lessa et al., 1999).

The study of ichthyoplankton, especially its specific composition, structure of community, dynamics, abundance and biomass depends directly on hydrographical characteristics of water masses and their regional and seasonal variations (Yoneda, 2000).

In the last few years, several studies in different geographical areas have focused on different aspects of the behavior of fish larvae, their physical environment and their contribution to formation and composition of ichthyoplankton assemblages (Moser and Smith, 1993; Richards et al., 1993).

Distribution patterns of fish larvae in any region of the ocean are related to the reproductive activity of the adult population and to topographic and hydrographic features that affect the dispersal of the larvae. A study of the distribution patterns of fish larvae contributes to understand the interrelationships among fish species during their early life stages, as well as to understand adult spawning patterns. In addition, information can be obtained on the reproductive strategies adopted by these fish in response to the physical and biological processes of the region. Distribution patterns among ichthyoplankton species arise from the synchronized reproductive activities of different species that have been developed during evolutionary adaptation to geographic and oceanographic conditions. These informations are important for a rational use of fishery resources and also for an understanding of the ecological status of the species component in a marine ecosystem (Nonaka et al., 2000).

It is generally suggested that spawning time and location of fish species are involved in a way to make sure that the meroplanktonic early life stages emerge into an environmental regime suitable for their survival (Cushing, 1969).

Favourable larval habitats have been defined by both their biological (e. g. high abundance of food, low abundance of predators) and physical (e. g. circulation patterns promoting retention or transport to nursery areas) characteristics (Heath, 1992). However, at the time of egg and larval development the environmental conditions may differ from year to year, due to variation in the environmental characteristics, changes in timing of emergence of eggs and larvae or a combination of both (Page and Frank, 1989).

Circulation patterns could also potentially influence the distribution of larval fish assemblages, as they influence among others the recruitment of the adult population (Somarakis et al., 2002).

Variations in the oceanographic environment on an annual scale may cause interannual changes in both the distributional range of the adult fish and the features of their spawning environment, such as timing, duration and location of spawning (Doyle et al., 1993). The release of the spawning is initially set by the adults, but a combination of physical and biological factors (such as water movement and temperature, distribution and abundance of prey and predators) act directly on the larvae influencing their distribution, abundance, growth and survival (Heath, 1992).

Examining spatial and temporal patterns in distribution and abundance of ichthyoplankton in relation to oceanographic conditions may provide insight into the adaptation of spawning strategies and the prevailing physical and biological processes as well as into the effect of the variability in these processes on year-class strength (Heath, 1992).

Fish communities in coastal zone habitats may benefit from the interaction between physical parameters like temperature, salinity, dissolved oxygen, currents, water masses and estuarine discharge that can result in a higher productivity of nutrients for their own nutritional needs. Many marine species in shallow coastal waters are linked to ecosystems like river estuaries or mangrove forests (Ekau et al., 1999). They use these areas as refuge for their young stages and as feeding grounds throughout their development (Robertson and Duke, 1987). It is well accepted, that mangrove forests influence the productivity of coastal waters, and with this also the biomass production of commercially important organisms (Ekau et al., 1999).

On the other hand, oceanic regions in tropical zones are usually oligotrophic, owing to minimal vertical flow of nutrients and subsequent low biological productivity (Longhurst and Pauly, 1987). Such characteristics may be explained by the existence of a warm surface layer above a colder and denser sub-surface layer, which effectively creates a permanent thermocline. This tends to inhibit the upward flow from nutrient rich deeper layers, restricting primary production in surface waters (Travassos et al., 1999). In some areas, interaction between oceanic currents and geomorphologic features allows the mixing of these layers (Rogers, 1994).

Previous studies have demonstrated that coastal areas are commonly used as spawning and nursery areas by varieties of species that are otherwise ecologically different, whether they live in various habitats as adults (e.g. pelagos, benthos and intertidal zone) or exhibit distinct spawning habitats (e.g. demersal, pelagic or beach spawning) (Frank and Leggett, 1983; Doyle et al., 1993; McGowen, 1993).

According to Dittmar (1999), mangroves have an important role in the energy transfer between river and the sea. The coastal region, influenced by the nutrient exportation of the magrove ecosystem and the presence of the edge shelf upwelling gives shelter to an elevated density of eggs and fish larvae (Nonaka et al., 2000).

This region is characterized by a higher disponibility of alimentation and a low abundance of predators (Frank and Leggett, 1983) beyond the circulation patterns which favor the retention of ichtyoplankton stages (Castillo et al., 1991). In the northeast of Brazil some studies about fish larvae show the importance of estuarine influenced costal waters on the reproduction of pelagic, demersal and coralreef-associated fish inhabiting the continental shelf, beyond the mesopelagics, which are living near the slope and move to the coast for reproduction, thus making the continental shelf an area abundant of ichtyoplankton (Ekau et al., 1999; Mafalda et al., 2004).

In the north of Brazil, Maranhão State, the coastal region is characterized by lots of estuaries which are influencing the dynamics of the physical and oceanographic factors as well as the ecology of the local biota. In this region exists a great fish diversity and it is well known for its richness of demersal fish stocks, some of them highly exploited, even though its existing variety is generally unknown up to now (Paiva, 1997).

This region actually has not been studied in terms of taxonomy ichthyic species, their geographic distributions and areas of spawnings with the exception of one study by Silveira (2003) about ichthyoneuston, which compared the oceanic and coastal region and registered the highest fish larvae density in the coastal region. The question that arose from this studies was whether the coastal region of the study area serves as a nursery area for the fish larvae community.

The present study was undertaken to examine the relationship and the influence of environmental conditions on the community of fish larvae. This project focussed on the neritic and oceanic region of the State Maranhão. Such studies are necessary as baseline for the delimitation of the endemic areas and the establishment of adequate management measures of the fishing resources.

1.2 Maranhense coastal structure, oceanography and seasons

The Maranhense coast is the second extended of the coasts of Brazilian states with a total length of 640 km. This coast has the planet‵s largest area of continuous mangrove forest. The mangrove forest covers an area of about 5.414.31 km^2 (Souza Filho, 2005). The dominance of the Maranhense mangrove forest is due to high sediment loads and high tidal regimes. The tidal range is approximately 8 m. In places along the Maranhense coast mangrove trees may be as tall as 45 m and an aboveground forest biomass of 280 ton/ha is estimated (Lacerda and Schaeffer-Novelli, 1992; IBAMA, 2006).

The Maranhense coast is divided by the Maranhense Gulf in an occidental and an oriental section. This gulf itself is separated by the São Luis island in two bays: The São Marcos bay, where two of the biggest maranhense rivers discharge, the Mearim and the Pindaré river, and the São José do Ribamar bay, where the Itapecuru and Munim river discharge (Fig. 1) (SUDENE, 1976).

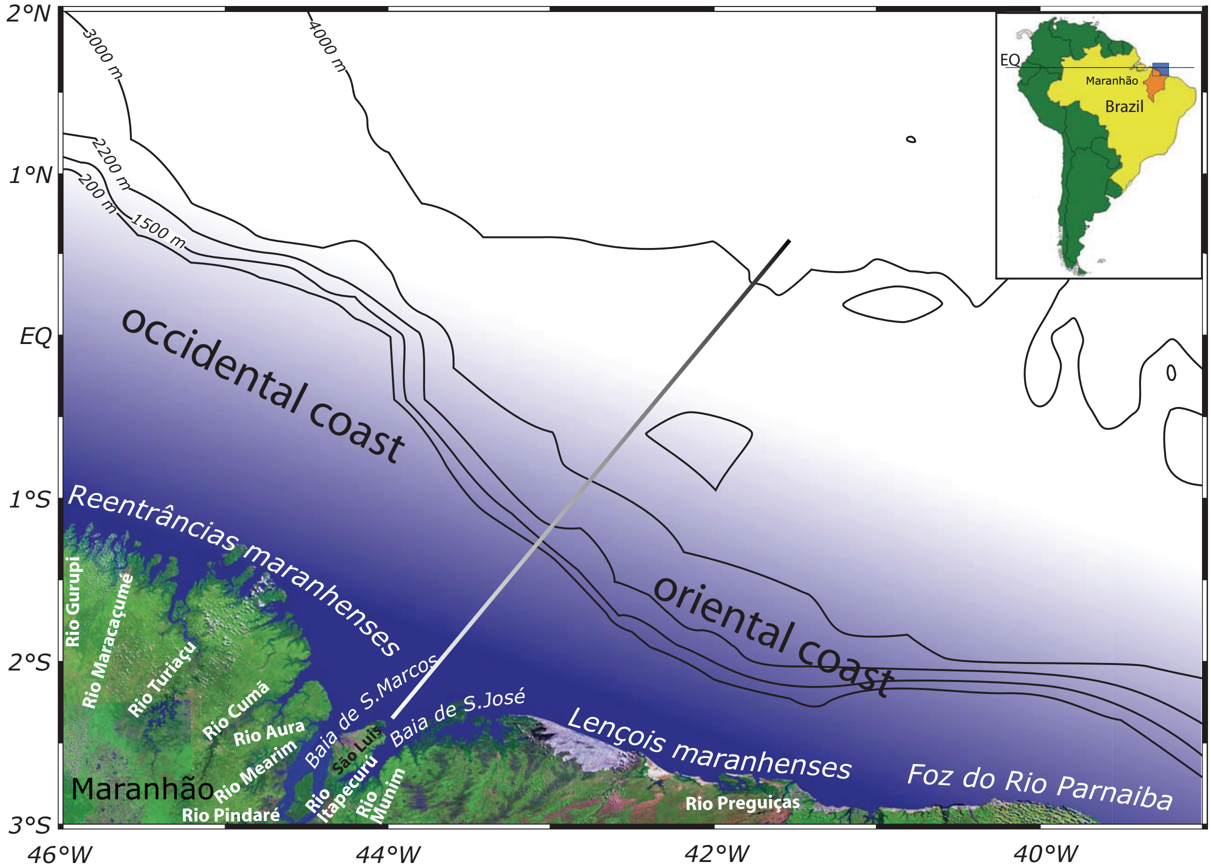

Fig. 1 - **The coastal area of Maranhão**, indicating the occidental and the oriental side
Source: Ministério da Agricultura, Pecuária e Abastecimento, Brazil

The occidental coast, which means the area between the mouth of the Gurupí River down to the Maranhense Gulf is formed by a series of bays and estuaries. These are linked or interlinked by canals through the mangrove forests and innumerable mangrove creeks and islands, separated from the continent by small straits. It is called "Reentrâncias Maranhenses". (SUDENE, 1976; PROJETO REMAC, 1979).

The "Reentrâncias Maranhenses Environmental Protection Area" is an area of incomparable beauty with remarkable natural caracteristics. This region is representative of both littoral and pre-Amazon regions. Vast mangroves support the abundance of fish, crustacean and mollusc, which are important food sources especially for birds. Mangroves also act as protection barrier and contribute therefore to increase the fish production - a major source of food and income for the people living along the coast and rivers (SEMA-CPE, 2002).

The occidental coastline of the Maranhão is very irregular with the estuaries being covered extensively by mangrove forests representing 60% of the total mangrove area of the whole state. The predominant mangrove genera are *Rhizophora* and *Avicennia*. The region is a low lying and geomorphologically very diversed area strongly influenced by the tides. There is a great sediment movement on the coast, which gives some instability to the sandbanks and islands and fills mud over the vegetation cover depending to dune movement (SEMA-CPE, 2002).

The oriental coast, which extends from the Maranhense Gulf down to the delta of the Parnaíba River, is formed by a mangrove area continuing the "Reentrâncias Maranhenses" and a vast area covered by coastal sand dunes more regular, the so called "Lençois Maranhenses" (SUDENE, 1976; PROJETO REMAC, 1979).

These "Lençois Maranhenses" are characterized by a nearly straight coastline with a large number of dunes, always formed and reformed by the wind. On this side the distinguishing feature of the oceanic waters is their great transparency. Only a few rivers reach the sea and the continental shelf is much smaller than in the western region. The maximal extension of the shelf is 75 km. In this region the whole shelf has a sandy ground which supports the formation of dunes (SUDENE, 1979; PROJETO REMAC, 1979 MMA/SECIRM/IBAMA, 1995).

The climate of the maranhense coast is tropical-humid with a rainy season from January to June and a dry season from July to December. The months with intense rain are March, April and May. The annual pluvial precipitation is higher on the occidental coast with maximal 6.000 mm, diminishing on the oriental coast with annual pluvial precipitation between 1.500 mm to 1.750 mm (Stride et al., 1992).

The offshore areas of the Maranhão state present several seamounts with depths at the summit ranging from 20 to 250 m, and a great variability in size and shape (Fig. 2). The Maranhense costal waters are dominated by the North Brazil Current (NBC)(Fig. 3). This current is a branch of the South Equatorial Current (SEC). The NBC is one of the three most important equatorial currents, together with the North Equatorial Current (NEC) and the North Equatorial Countercurrent (NECC) (Richardson and Walsh, 1986; Peterson and Stramma, 1991).

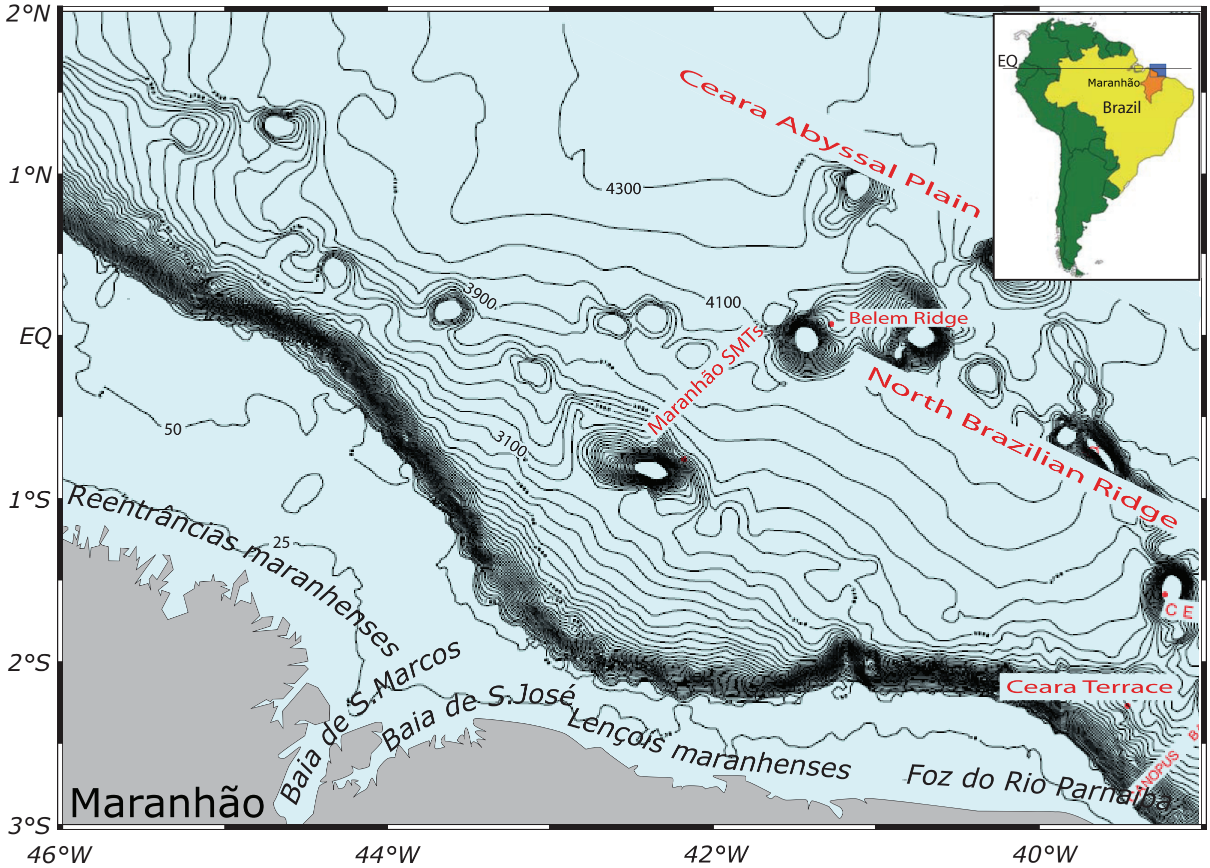

Fig. 2 **Maranhense continental margin and its topography**
Source: PETROBRAS/E & P, Brazil

The North Brazil Current (NBC) follows an east-western direction to Guinea, with a slight break at the mouth of the Amazon and one of its branches helps to form the Guinea Current (GC), (Garrison, 1995). It presents velocities of 30 up to 50 cm$*$s^{-1} in the beginning of the year, and reaches up to 100 cm$*$s^{-1} in the middle of the year (Richardson and Mckee, 1984). This current is influenced by trade winds, dominating this region nearly the whole year through (Proposta Regional de Trabalho - Subcomitê Regional da Costa Norte, 1996; Brandini et al., 1997; Castro and Miranda, 1998).

The North Brazil Current (NBC) mixes with the great continental discharge, mainly of the Amazon River, Parnaíba River Delta and the Maranhão Gulf, that brings a big load of organic matter from the continental shelf (Castro and Miranda, 1998). The North Brazil Current transports a water mass that constitutes one of the main fishing grounds of northern Brazil, accounting for almost the entire catch of pelagic species in this region (Hazin, 1993).

The North Equatorial Current (NEC) is characterized by a large and uniform flow which takes the western direction near 15°N, transporting warm and saline waters from the Canarian Current to the tropics. The North Equatorial Countercurrent (NECC) is a seasonal current with the direction W - E, located between 3°N and 10°N, fed by the NBC (Garrison, 1995). The NEC and the NECC have no influence on the area of collection of the present study.

Throughout the period from May to October, which corresponds to the seasons of winter and spring in the southern hemisphere, the south-eastern trade winds are blowing harder, this way supporting and boosting the SEC and the NBC. The shifting of these winds in direction to the northern Inter-Tropical Convergence Zone (ITCZ) gives them a higher intensity and makes them one of the reasons to form the NECC. In this period nearly 70% of the Amazon discharge is taken to the Guianian coast and to the east by the NECC (Becker, 2001)(Fig. 3). The Amazon river plume does not reach the Maranhense coast (Fig. 3).

Throughout the months from November to April, which correspond to the seasons of summer and autumn in the southern hemisphere, the ITCZ changes place in southern direction and the southeastern trade winds are weaker, which causes weaker appearence and finally disappearance of the NECC and gives a retroflexion to the NBC. In this period the NEC is stronger and the Amazon discharge flows in northwestern direction as part of the GC (Becker, 2001) (Fig. 3).

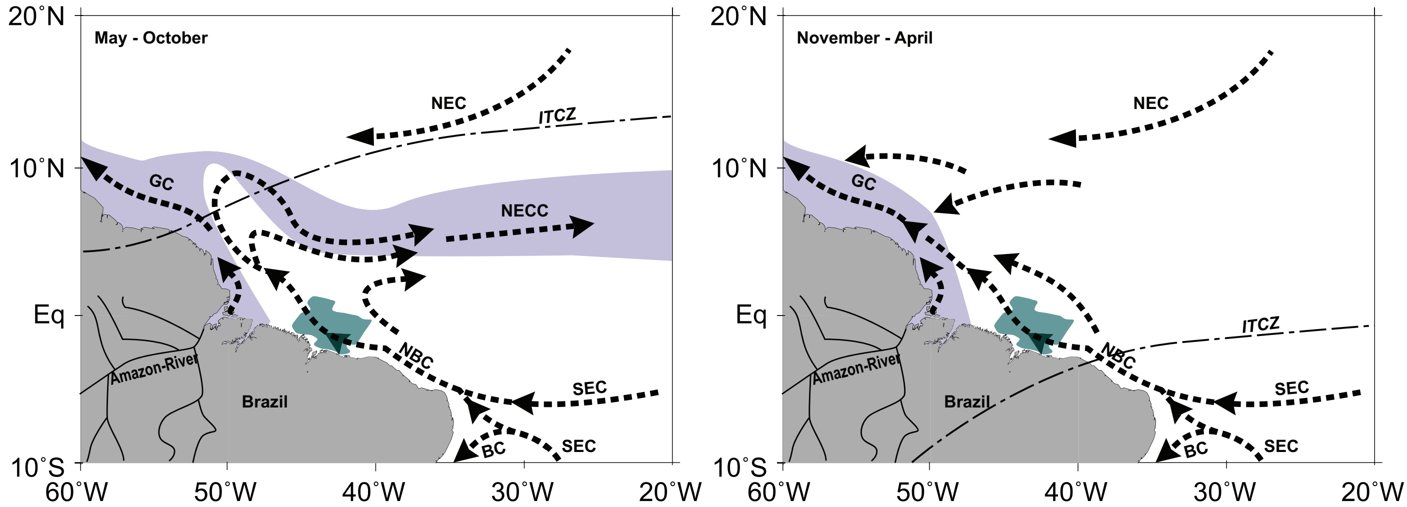

Fig. 3 **Superficial currents of the eastern equatorial atlantic ocean**: North Equatorial Current (NEC), South Equatorial Current (SEC), North Equatorial Countercurrent (NECC), North Brazil Current (NBC), Brazil Current (BC), Guinea Current (GC). Light blue: Amazon plume; light green: area of collection stations of the present study (Source: Vink, A. et al., 2000)

From the hydrographical characteristics, as well as from the small number of examinations about the pelagic ecosystem of the northern coast, is to presume that the pelagic environment on the continental shelf is of oligotrophic kind and physically stratified without costal upwelling. The contribution of macronutrients is an exclusive one, derived by the innumerable amount of estuaries in the region, which concentrate generally low on the surface and high on the ground, with temporal and spatial variations rarely documented (Brandini et al., 1997; Castro and Miranda, 1998).

1.3 Artisanal fishery

The Maranhão State has a production of marine fish, crustaceans and clams of more than 59.000 tons per year, being one of the main producers of the Northeast and North Brazilian region (IBAMA, 2005). Although Maranhão has a great potential of these goods, its exploration still is made predominantly by methods and equipments of artisanal fishery in accordance with the social-economic reality (Almeida et al., 2007). Stride et al. (1992) estimate a total of 80.000 artisanal fishermen, about 15% of the working population of the Maranhão State.

The artisanal capture is dominated by estuarine species, particularly of the Ariidae and Sciaenidae. *Mugil* sp., *Benyatremus luteus*, *Centropomus* spp., *Scomberomurus brasiliensis* are captured as well. The mainly captured demersal teleosts are sciaenids: *Cynoscion acoupa*, *Cynoscion microlepis*, *Macrodon ancylodon*, *Micropogonias furneiri* and the catfish of the Ariidae family: *Arius quadriscutis*, *Arius herzbergii*, *Arius proops* and *Arius parkeri*. The snappers of the Lutjanidae and Serranidae of the Epinephelus genera are fished in the banks and sea reefs, mainly on the edge of the continental shelf (Stride, 1992).

Acting on the coast and internal shelf, fishery in the Maranhão has particular importance for the Reentrâncias Maranhenses area. This activity is mainly carried out by sculling or sailing boats (Almeida et al., 2007). It has a reduced number of boats that use engines. Most of them have engines smaller than 7-20 Hp. There is a small fleet of so called "semi-industrial" vessels fishing snappers (Lutjanidae) and lobsters.

One of the few activities in Brazil that requires little or no professional qualification is fishery. In accordance with Silva (1980) the Maranhão state, with low cost of equipment and free access to resources, allowed a duplication of the number of fishermen which exploit the ecosystems: from 100.000 to 200.000 in the last 24 years. This intensification of fishery can cause impacts on the resources as well as on the environment (Almeida et al., 2007).

Considering this growing pressure of fishery activities, this study with its qualilitative and quantitative investigation of fish larvae may contribute to estimate the fishery potential. An optimization of the exploitation of commercially important species could even lead to a fishery management, with the aim to use these resources in a lasting way and in harmony with the environment.

Therefore, studies on ichtioplankton are an important instrument to identify alterations of the fish population, which finally permits to estimate the adult population and its reproductiv success (Ahlstrom and Moser, 1976).

1.4 Objectives

The present study is part of the Brazilian National Program "Evaluation of Sustainable Potential of Living Resources from the North Brazilian Exclusive Economic Zone" (REVIZEE program). The aim of this program is to evaluate the sustainable biota stocks in relation to environmental factors, as a basis to analyze the possibilities of exploration and conservation of living resources in the economic zone.

The general objective of the present study is to describe, qualify and quantify the ichthyoplankton of the coastal and oceanic region of the State Maranhão in relation to oceanographic parameters (temperature, salinity, dissolved oxygen, currents and water masses). This study contributes to the evaluation of the biomasses and the potentials of sustainable capture of fish inside of the North Brazilian Exclusive Economic Zone.

Hypothesis

The abundance of fish larvae is depending on the distance from the coast and the presence/absence of coastal vegetation.

To achieve the objective described above and verify the hypothesis, the following investigations have been performed:

- Detailed description of the ichthyoplankton community structure.
- Description and comparison of the oceanographic parameters
- Determination of larval density and species composition in different regions according to the distance from the coastline and the presence of coastal vegetation

2 MATERIALS AND METHODS

2.1 Study area

The study area is situated on the coast of the Maranhão State, North Brazil, between the geographic coordinates 45°37.00�much W, 00°32.40‛ S, 40°03.00‛ W and 00°12.60‛ S (Fig. 4). The samples of this study were collected during the REVIZEE program on board of the oceanographic ship Antares of the Brazilian Navy.

The samples were collected during a dry season (13th to 18th November and 01th to 04th Dezember, 1997) with 14 stations along the oceanic region (Fig. 4), a rainy season (08th to 28th June, 1999) with 41 stations along the oceanic and neritic region (Fig. 4) and another dry season (12th to 16th July and 06th to 09th September, 2001) with 12 stations along the oceanic and neritic region (Fig. 4), totaling 67 stations and samples on three cruises.

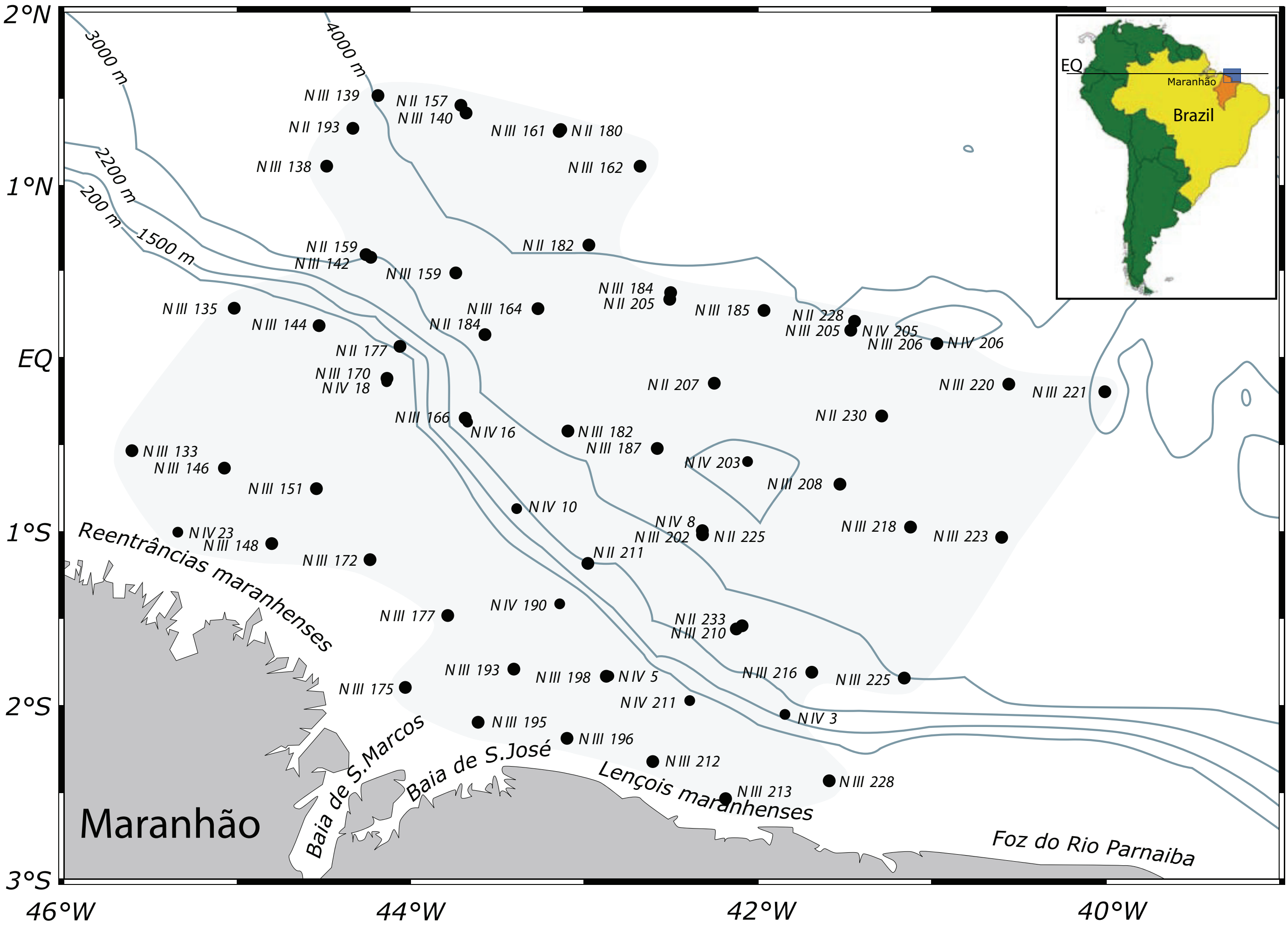

Fig. 4 **Map of the coast** of the Maranhão State/North Brazil showing the study area (light-grey), sampling locations indicated.
Dry season - N II (North II cruise, 11.1997 - 12.1997)
Rainy season - N III (North three cruise, 06.1999)
Dry season - N IV (North IV cruise, 07.2001 - 09.2001)

At each station, the equipment was routinely launched to collect information on the different abiotic and biotic characteristics of the water column. The transects were positioned perpendicular to the coast and in front of river mouths, mangrove areas and dunes. The plan of the stations was elaborated to observe the supposed continental influence on the oscillations of abundance and diversity to the taxa in the different areas.

The separation of coastal and oceanic regions was reconciled with the stations depth, in which coastal regions can reach - according to Peres (1968) - a depth up to 200 m. Regions with more than 200 m depth are defined as oceanic (Tab A1, Appendices).

During the dry seasons there was no sampling of ichthyoplankton in the coastal region because of logistical problems of the project.

2.2 Sample collection

The collections on the stations were made by day and by night. The zooplankton samples were collected using 60-cm Bongo nets with mesh apertures of 300 μm and 500 μm (Fig. 5). This study is based on the 500 μm samples only. The nets were towed obliquely at approximately 2 knots during a 20 minutes period in each station. The depth of the tows varied from 20 m above the bottom at shallow stations and up to 200 m at offshore stations. In the mouth of the net a calibrated flowmeter was attached (Hydrobios Propeller) to determine the volume of water filtered by the nets. The samples were preserved immediately after the catch in 4% buffered formaldehyde.

Fig. 5 **Bongo nets**, mesh apertures 300 μm and 500 μm, used in zooplankton collection.

The numbers of fish larvae in each tow were standardized to number per 100 m^3 of filtered water. The calculation of the filtered water volume to a standardised amount of flow-through resulted from the following equation:

$$V = R * 0.3 * a * 100$$

with V (volume in m^3), R (number propeller rotations per station), 0.3 (factor of calibrated flowmeter) and a (net mouth area).

2.3 Oceanographical parameters

Vertical profiles of temperature and salinity were obtained by a Sea-Bird CTD (Conductivity-Temperature-Depth) profiler (Sea-Bird Electronics SBE 911plus) (Fig.6A) during each collection on every station. The profiler was used up to a depth of 1000 m with a descending velocity of 1 $m*s^{-1}$ and a measurement frequency of 24Hz. In this study the data of this profiler were used until the upper 200m water layer, which corresponds to the maximum depth of the plankton hauls.

These data were provided by the fisic oceanographical group (Universidade Federal do Pará) of the SCORE–N (Subcomitê Regional Norte/REVIZEE).

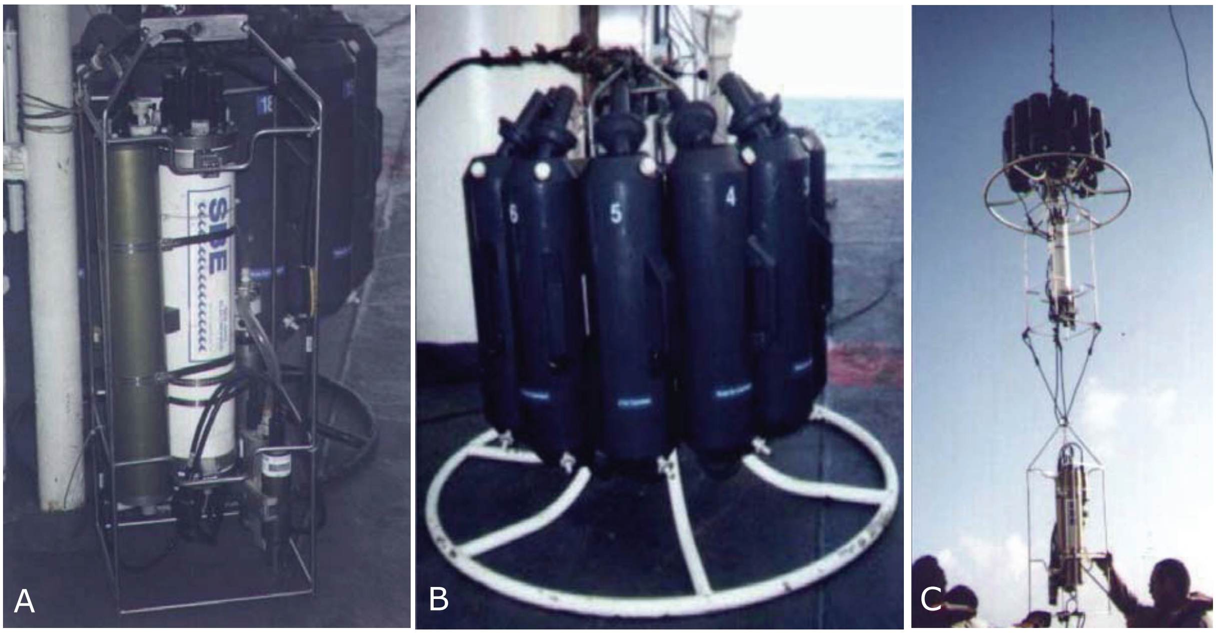

Fig. 6 **Research equipement** A: Sea-Bird Profiler SBE 911plus, B: Niskin bottle rosette with 12 niskin bottles, C: assembled equipement ready to be submerged

A Niskin bottle rosette was used to measure the dissolved oxygen (Fig. 6B). This rosette contains 12 Niskin bottles with a capacity of 5 dm^3 each (model SBE 32). The rosette was operated together with the CTD profiler (Fig.6C), which was connected by glass fibre cables encircled by a steel cable to the laboratory computer of the ship. The glass fibre cables allowed the fast transport of data about depth, conductivity, temperature and density as well as the signal to close the bottles. The whole data were processed by the software SEASOFT 4,217.

The dissolved oxygen data was provided by the chemistry oceanographical group (Universidade Federal do Pará) of the SCORE–N (Subcomitê Regional Norte/REVIZEE).

2.3.1 Data analysis

The vertical distribution of the salinity and temperature values were used to elaborate a T-S diagram to determine the types of water mass and mixed water in the study area. The determination of the water masses was based on the intervals of temperature and salinity shown in Tab. 1:

Tab. 1 **Water masses,** defined by their values of salinity and temperature. Tropical Water (TW), South Atlantic Central Water (SACW), Coastal Water (CW) following Castro and Miranda (1998), Salinity Maximum Water (SMW) defined by Stramma and Schott (1999).
Inshore and offshore of the Maranhão/North Brazil.
(11.1997-12.1997/06.1999/07.2001-09.2001)

Water Mass	Temperature °C	Salinity psu
Tropical Water (TW)	> 18.0	> 36.0
South Atlantic Central Water (SACW)	< 18.0	< 36.0
Coastal Water (CW)	26.0 - 29.0	34.0 - 35.6
Salinity Maximum Water (SMW)	> 18.0	> 37.0

Following Stramma and Schott (1999) the Salinity Maximum Water (SMW) is imbedded in the TW.

A mixed water present in the study area is the Subtropical Shelf Water (STSW), characterized by the mixture of the coastal water of shelf (CW) and subtropical waters (SACW) (Piola et al., 2000).

The dissolved oxygen was analysed by the Winkler method modified and developed by Strickland and Parsons (1972).

2.4 Ecologic classification of the fish larvae

The identified families were classified in 7 categories, in accordance to the most frequented environment (habitat) of the adult stages, based on the publications of Nelson (2006), Figueiredo et al. (2002), Moser et al. (1984), Fahay (1983), Leis and Rennis (1983):

- Epipelagic – occurring between the water surface and 200 m of depth
- Mesopelagic – occurring between 200 m and 1000 m of depth
- Reef – occurs associated to reefs and/or rocky formations
- Demersal – occurs associated to non solid substratum as mud, sand and gravel
- Coastal – occurs in the continental shelf region
- Estuarine – occurs in the estuaries
- Oceanic – occurs in the open ocean, offshore.

2.5 Separation and identification of the fish larvae

In the zooplankton laboratory of the Department of Oceanography and Limnology (Federal University of Maranhão, Brazil) the ichthyoplankton was separated from other zooplankton groups. The separated larvae were identified on the taxonomic level of family.

At the ZMT laboratory (Zentrum für Marine Tropenökologie, University of Bremen, Germany), the ichthyoplankton was re-examined to identify the larvae until the level of species. Only families with a frequency of occurrence of more than 40% were used in this analysis.

The identification of the larvae was performed according to several authors and publications: Richards, 2005; Boltovskoy, 1999; Moser, 1996; Oxenford et al., 1995; Olivar and Fortuño, 1991; Matarese et al., 1989; Okyama, 1988; Moser, 1984; Arhlstrom Symposium, 1983; Fahay, 1983; Smith, 1979; Staiger, 1965; among others.

The identification was confirmed by a combination of meristic and developmental characters which permitted a definitive identification:
- counting myomere and rays of dorsal fins, tail, pelvis and chest;
- body pigmentation
- presence of photophore and the second membrane dorsal fin, evaluating the proportion between the fins and measuring the length of specimen.

Methods of counting and landmarks for measurements are defined by Leis and Carson-Ewart (2000) and Moser (1996). Body parts measured include: body length, snout-anus length, body depth, head length, head width, snout length, eye diameter, pectoral fin length and pelvic fin length.

Larval hatching sizes, information concerning the different stages (preflexion, flexion, postflexion and transforming), main diagnostic features, and meristic information including fin ray counts were given. According to these descriptions, larval lengths always refer to body length. Measurements were accomplished with a stereo microscope.

2.5.1 Data analysis

The samples of the three cruises N II, N III and N IV were combined for a general analysis of the larval fish community in the study area.

2.5.1.1 Frequency of occurrence (f)

Calculated with the formula (Omori and Ikeda, 1984):

Def: f = Frequency in %
ts = is the number of samples in which the taxon is present
t = is the total number of samples

$$f = ts * 100 / t$$

The results are presented in percentage (%).

2.5.1.2 Density (larvae/100 m^3)

The calculations of density (larvae/100m^3) were made using the expression below.

Def: N = number of larvae per station
V = filtered water volume

$$N/100\ m^3 = (N/V)*100$$

The obtained density values were located in a map according to the geographic coordinates of the stations obtained by the board diary, using Ocean Data View 3.0 program (Schlitzer, 2005).

2.5.1.3 Relative Abundancy (Ar)

Calculated with the formula (Omori and Ikeda, 1984):

Def: Ar = relative abundance
n = total number of organisms of each taxon in the sample
ns = total number of organisms in the sample.

$$Ar = n * 100 / ns$$

The results are presented in percentage (%).

2.5.1.4 Fish larvae community structure analysis

Multivariate analysis, based on the more frequent species collected in the study area, were used to examine spatio-temporal (horizontal dimension and dry-rainy season) patterns of the larval fish assemblages.

Cluster analysis and multidimensional scaling (MDS) were performed with the computer software package PRIMER 5.2.2 - Plymouth Routines in Multivariate Ecological Research- (Clarke and Gorley, 2001) to examine similarities between species (Clarke and Warwick, 1994). The data matrix is based on the density (larvae/100 m^3) for species with an occurrence higher than 3%. To further examine spatial patterns of the larval fish assemblages and to calculate the similarities between stations and species, a clustering was performed by group-averaging linking based on the Bray-Curtis similarity coefficient that was calculated using log (x+1) on the density (larvae/100 m^3). The log (x+1) transformation was used to reduce the contribution from numerically dominant species (Field et al., 1982).

Multidimensional scaling (MDS) is the attempt to represent the (multidimensional) similarities between species by distance in a two dimensional plot. The same similarity matrix was used for MDS and cluster dendrogram. Goodness-of-fit of the MDS plot is represented by a stress value. A low (<0.2) MDS stress coefficient indicates that the multivariate similarity pattern is represented by the plot without much distortion. The PRIMER program was used for these analyses (Clarke and Warwick, 1994).

2.5.1.5 Community analysis and relation to environmental parameters

The Canonical Correspondence Analysis (CCA) of the MVSP 3.1 software (Kovach, 2006) was used to examine relationships between the density variation of species of the assemblages and the oceanographical parameters. This ordination is considered to be a powerful multivariate technique, which is useful to extract synthetic environmental gradients from ecological data (Ter Braak and Verdonschat, 1995).

This analysis was based on the biotic and abiotic data present in the stations of the biggest assemblages. Each assemblage was analysed individually with the intention of explain the relation between the oceanographical parameters and the fish larvae species.

For this analysis two matrices were elaborated. A biotic matrix containing the species density of all species from the biggest assemblages in the different stations and a abiotic matrix containing the oceanographical parameters (temperature, salinity and dissolved oxygen).

Due to logistic limitations, a bongo-net was used to collect the fish larvae, therefore depth specific data is not available to compare with the abiotic parameters. For this reason, in the abiotic matrix, the values of salinity, temperature and dissolved oxygen from different depths were averaged per station to relate them to the biotic matrix.

3 RESULTS

3.1 Oceanographical conditions

3.1.1 Vertical distribution

A T/S diagram is given for the upper 200 m water layer (Fig. 7), which corresponds to the maximum depth of the plankton hauls. In this way the origin of the captured fish larvae are from 4 different water masses: Coastal Water (CW), Tropical Water (TW), South Atlantic Central Water (SACW) (Castro and Miranda, 1998) and Salinity Maximum Water (SMW) (Stramma and Schott, 1999) and of 1 mixed water: Subtropical Shelf Water (STSW) (Piola et al., 2000).

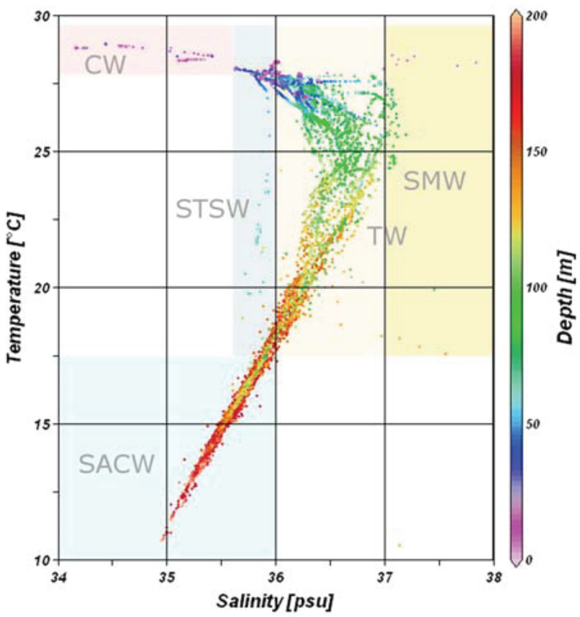

Fig. 7 **Diagram T-S related to depth**, showing the identification of four water masses: Costal Water (CW), Tropical Water (TW), South Atlantic Central Water (SACW) and Salinity Maximum Water (SMW) and one mixed water: Subtropical Shelf Water (STSW). Inshore and offshore of the Maranhão/North Brazil (11.1997 - 12.1997; 06.1999; 07.2001 - 09.2001)

A coastal water (CW) mass with warmer and less saline waters, resulting of the mixture of the continental discharge of fresh waters with those of the continental shelf (Castro and Miranda, 1998) (Fig. 7) shows a limited influence during the dry season in the intern part of the oriental continental shelf (Fig. 8A). This water mass during the rainy season ocupies great parts of the surface water layer of continental shelf in the occidental up to a part of the oriental region with its estuarine presence together with the Subtropical Shelf Water (STSW). The STSW can be registered until the oceanic region in the occidental and part of the oriental region. (Fig. 9A).

The warm and saline tropical water (TW) mass which is carried to the area by the NBC (Castro and Miranda, 1998) occupies the surface down to 150 m depth, and embedded in this water mass the Salinity Maximum Water (SMW) is found (Stramma and Schott, 1999) (Fig. 7).

The TW during the dry season is present on nearly the whole continental shelf surface water layer and in the whole oceanic region (Fig. 8A). The influence of this water mass in the whole oceanic region until the continental shelf break is obvious in the depth of 100 m (Fig. 8B). The SMW is present on the surface water layer of continental shelf in the oriental side during the dry season (Fig. 8A).

During the rainy season the influence of TW is limited to the continental shelf surface water layer, even though it is present in the whole oceanic region (Fig. 9A). In the depth of 100 m this water mass is present in the whole oceanic region until the continental shelf break (Fig . 9B).

From 100 to 200 m depth it is possible to verify the influence of South Atlantic Central Water (SACW) mass with cold and less saline waters (Castro and Miranda, 1998)(Fig. 7). This water mass is present throughout the oceanic region until the continental shelf break during the two seasons (Fig. 8C and 9C).

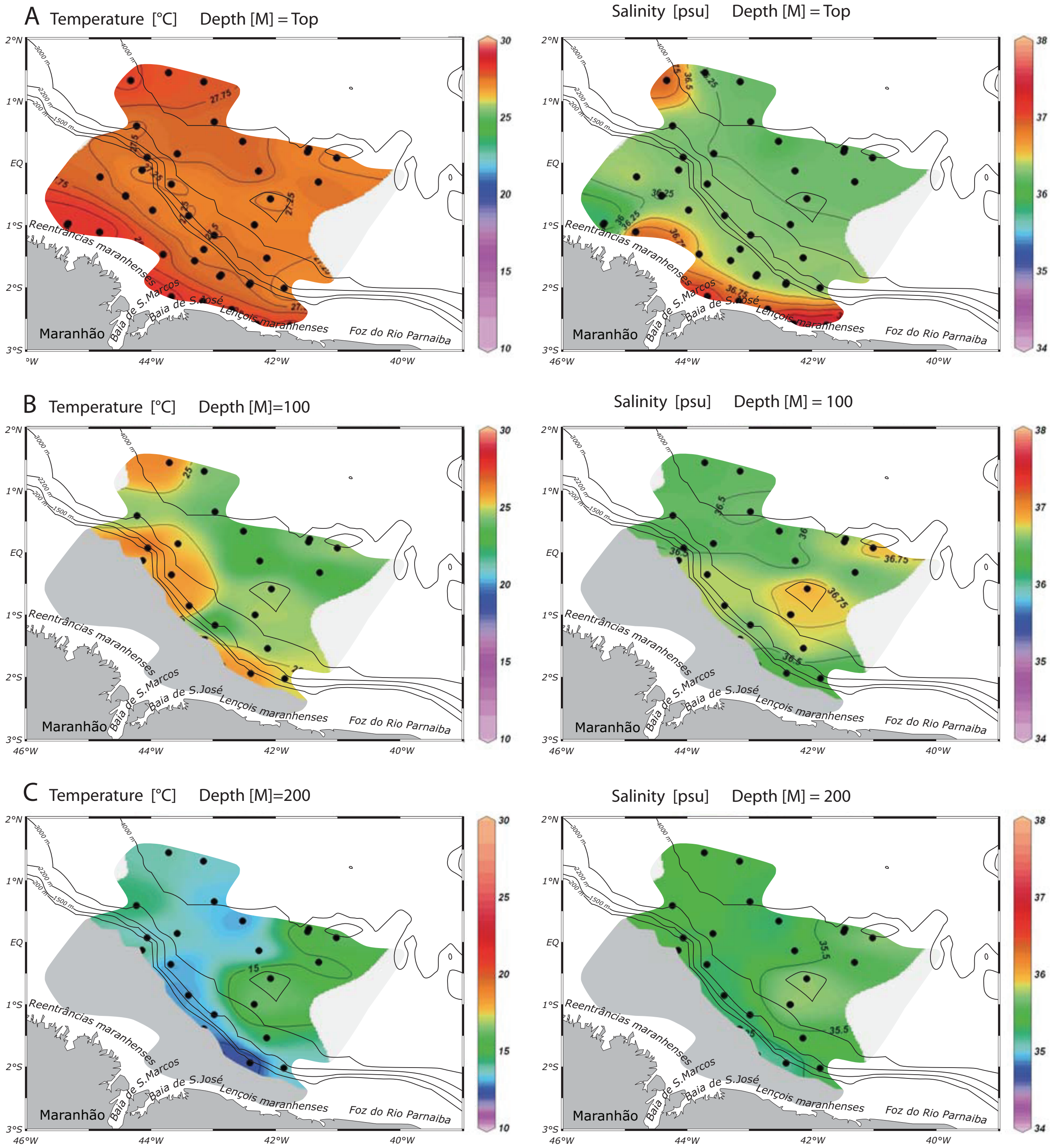

Fig. 8 **Abiotic parameters at different depths during the dry season** inshore and offshore of the Maranhão/North Brazil (temperature °C [t], salinity psu [s]). A: surface; B: 100m; C: 200m. Black dots correspond to the collection stations. Date of collection: 11.1997-12.1997 / 07.2001-09.2001

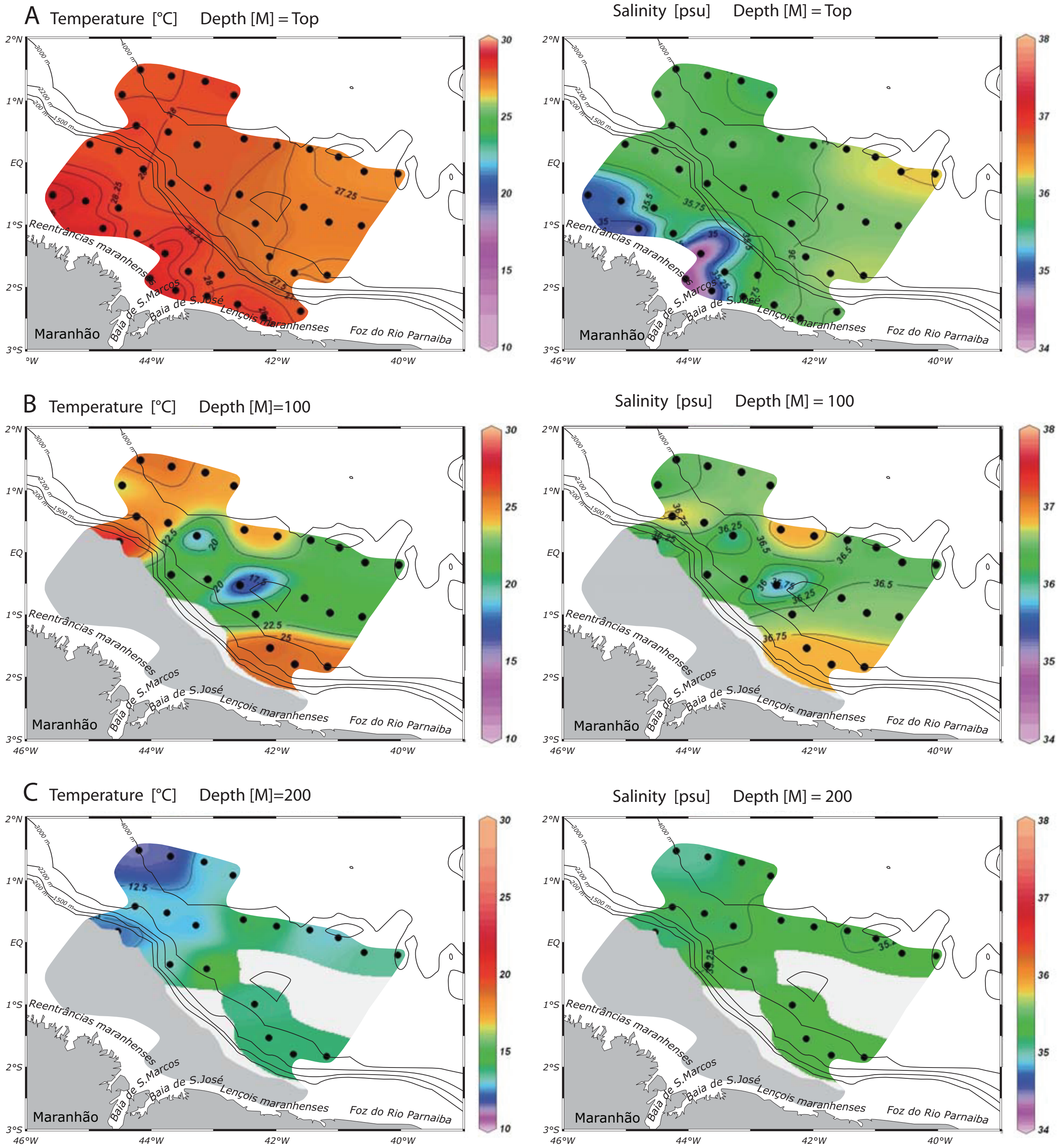

Fig. 9 **Abiotic parameters at different depths during the rainy Season** inshore and offshore of the Maranhão/North Brazil (temperature °C [t], salinity psu [s]). A: surface; B: 100m; C: 200m. Black dots correspond to the collection stations. Date of collection: 06.1999

3.1.2 Horizontal distribution

The average temperature of the stations during the dry season varies from 21.3 °C to 28.4 °C, with maximum value in the oceanic region and the minimum value inshore (Fig. 10A). The maximum value (28.9 °C) of average temperature during the rainy season occurs inshore and the minimum value (19.1 °C) in the oceanic region (Fig. 10B).

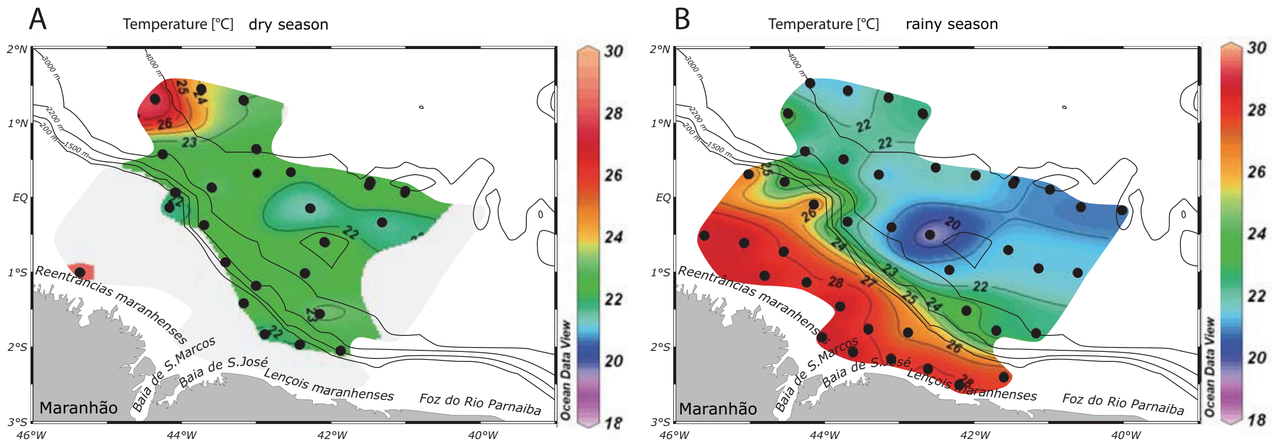

Fig. 10 **Average temperature (° C) per station** measured during the dry (A) and the rainy (B) season inshore and offshore of the Maranhão/North Brazil. Black dots correspond to the collection stations. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

The average salinity of the stations during the dry season varies from 35.2 psu to 37.0 psu. The maximum value occurs in the oceanic region and the minimum value inshore (Fig. 11A).

During the rainy season the average salinity of the stations varies from 34.2 psu to 36.2 psu, with the minimum value inshore and the maximum value in the oceanic region (Fig. 11B).

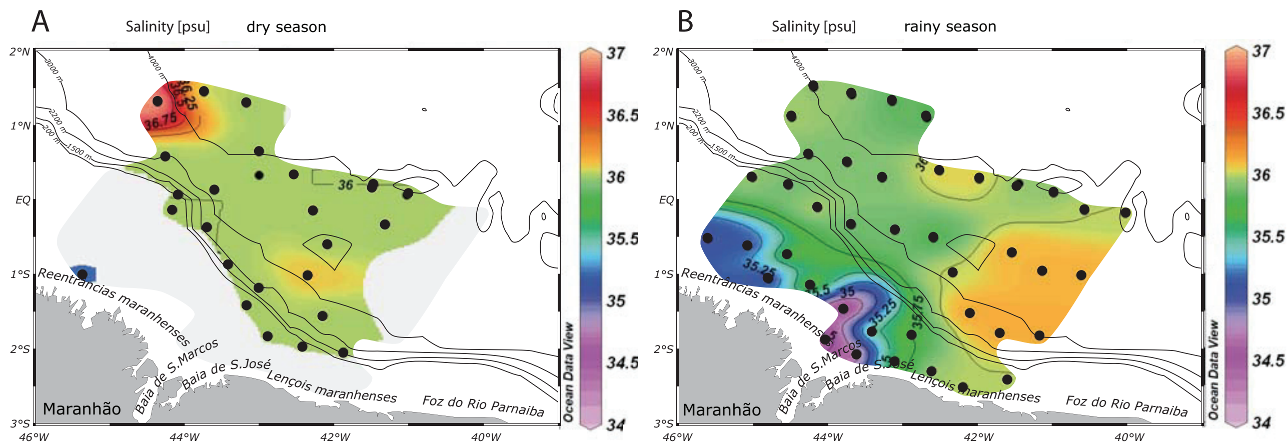

Fig. 11 **Average salinity (psu) per station** measured during the dry (A) and the rainy (B) season inshore and offshore of the Maranhão/North Brazil. Black dots correspond to the collection stations. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

The average dissolved oxygen of the stations presents concentrations between 4.0 ml.L^{-1} and 5.2 ml.L^{-1} during the dry season. The maximum value appears inshore and the minimum value in the oceanic region (Fig. 12A).

The rainy season presents concentrations of average dissolved oxygen of the stations between 4.0 ml.L^{-1} and 5.4 ml.L^{-1}, with the minimum and maximum value inshore (Fig. 12B).

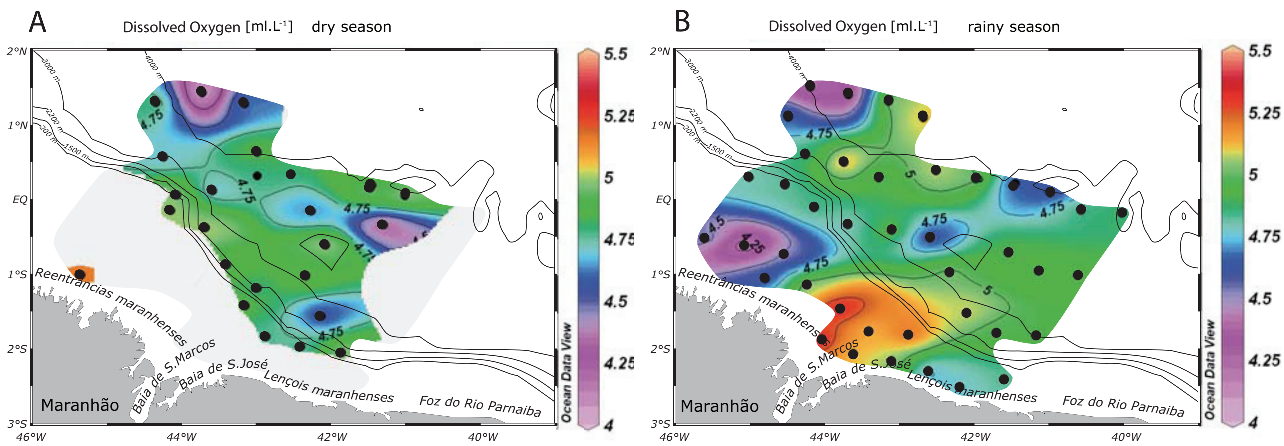

Fig. 12 **Average dissolved oxygen (ml.L-1) per station** measured during the dry (A) and the rainy (B) season inshore and offshore of the Maranhão/North Brazil. Black dots correspond to the collection stations.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

3.2 Biological results

3.2.1 Analysis of the fish larvae community structure

This section describes the composition, abundance, frequency of occurrence, density and distribution of the fish larvae assemblages inshore and offshore of the Maranhão during the cruises N II, N III and N IV. The samples of these three cruises are combined for a general analysis of the larval fish community in the study area.

3.2.1.1 Taxonomic composition and occurrence

In the samples a total of 4.131 fish larvae have been found. 98% of these are identified up to family level. The identification of 0.3% is only possible in level of order (Anguiliformes) and 0.02% are identified only in level of class (Stomiatoidea). 1.5% are unidentified larvae (Tab. 2).

Tab. 2 **Number** (N), **relative abundance** (Ar (%)), **frequency of occurrence** (f (%)) and categories of taxa caught throughout the shore and offshore of the Maranhão/North Brazil.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

FAMILY	N	Ar(%)	f(%)	category
GOBIIDAE	1815	43.94	79.10	r, d
CARANGIDAE	378	9.15	65.67	ep, c
MYCTOPHIDAE	607	14.69	58.21	m, o
SCARIDAE	184	4.45	55.22	r, d
BOTHIDAE	120	2.90	52.24	d
SCOMBRIDAE	91	2.20	46.27	ep, c, o
PARALEPIDIDAE	174	4.21	38.81	m, o
GONOSTOMATIDAE	142	3.44	38.81	m, o
PARALICHTHYIDAE	64	1.55	32.84	d, c
CALLIONYMIDAE	48	1.16	31.34	d, c
POMACENTRIDAE	36	0.87	26.87	r
UNIDENTIFIFIED	63	1.53	22.39	
SERRANIDAE	27	0.65	19.40	r, c
BREGMACEROTIDAE	26	0.63	19.40	m
CLUPEIDAE	45	1.09	16.42	ep, e, c
OPHICHTHIDAE	32	0.77	13.43	d
ACANTHURIDAE	19	0.46	13.43	r
SCORPAENIDAE	11	0.27	13.43	r, c, d
BRAMIDAE	10	0.24	11.94	ep
LABRIDAE	15	0.36	10.45	r, c
ANGUILIFORMES	14	0.34	10.45	d

Categories of taxa:
c (coastal)
d (demersal)
e (estuarine)
ep (epipelagic)
m (mesopelagic)
o (oceanic)
r (reef)

Tab. 2 - (continuation)

FAMILY	N	Ar(%)	f(%)	category
GEMPYLIDAE	11	0.27	10.45	m, o
ENGRAULIDAE	74	1.79	8.96	ep, e
PRIACANTHIDAE	9	0.22	8.96	r, d
SYNODONTIDAE	19	0.46	5.97	d, c
CYNOGLOSSIDAE	8	0.19	5.97	d, c
HOLOCENTRIDAE	6	0.15	5.97	r, c
MORINGUIDAE	4	0.10	5.97	d
MUGILIDAE	5	0.12	4.48	ep, e
CONGRIDAE	4	0.10	4.48	d
MURAENIDAE	4	0.10	4.48	d, c
OSTRACIIDAE	4	0.10	4.48	r
MONACANTHIDAE	4	0.10	4.48	r, c
BALISTIDAE	3	0.07	4.48	r, o
ALBULIDAE	3	0.07	4.48	d, c
STOMIIDAE	6	0.15	2.99	m
TRICHIURIDAE	4	0.10	2.99	m
PHOISICHTHYIDAE	4	0.10	2.99	m, o
NOMEIDAE	2	0.05	2.99	ep, o
BATHYLAGIDAE	2	0.05	2.99	ep, o
DIODONTIDAE	2	0.05	2.99	r, c
TETRAODONTIDAE	2	0.05	2.99	r, c
NETTASTOMATIDAE	2	0.05	2.99	d
ISTIOPHORIDAE	2	0.05	2.99	ep, o
ACROPOMATIDAE	2	0.05	2.99	d, o
CORYPHAENIDAE	7	0.17	1.49	ep
SCIANIDAE	2	0.05	1.49	d, e, c
LABRISOMIDAE	2	0.05	1.49	c, d
MELANOSTOMIDAE	2	0.05	1.49	m
DIRETMIDAE	1	0.02	1.49	m, o
STOMIATOIDEA	1	0.02	1.49	m, o
APOGONIDAE	1	0.02	1.49	r, c
PLEURONECTIDAE	1	0.02	1.49	d, e, c
STOMIATIDAE	1	0.02	1.49	m, o
DACTYLOPTERIDAE	1	0.02	1.49	d
COTIIDAE	1	0.02	1.49	e, d, c
OPHIDIIDAE	1	0.02	1.49	r, c
ONEIRODIDAE	1	0.02	1.49	m
SCOMBROLARACIDAE	1	0.02	1.49	m
HEMIRAMPHIDAE	1	0.02	1.49	ep, c
TOTAL	**4.131**			

A total of 60 taxa are found in the study area, 57 families are identified and 4.131 individuals are registered. The Gobiidae, Myctophidae, Carangidae, Scaridae, Bothidae and Scombridae are the most frequent in the studied area, representing 77% (3.195 larvae) of the total larvae. The remaining 23% (936 larvae) include several families (Tab. 2). The 6 most frequent families have been analysed up to species level and represent 74 species (Tab. 3).

Tab. 3 **Number** (N), **relative abundance** (Ar (%)) and **frequency of occurrence** (f (%)) of species caught throughout the shore and offshore of the Maranhão/North Brazil Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

FAMILY	**SPECIES**	**N**	**Ar (%)**	**f (%)**
Gobiidae	*Gobionellus saepepallens*	1008	31.55	62.69
Scaridae	*Sparisoma* sp.	163	5.10	47.76
Bothidae	*Bothus ocellatus*	103	3.22	49.25
Myctophidae	*Diaphus* sp.	215	6.73	38.81
Gobiidae	*Coryphopterus* sp.	161	5.04	38.81
Gobiidae	*Gobionellus oceanicus*	638	19.97	35.82
Carangidae	Carangidae A	95	2.97	31.34
Carangidae	*Chloroscombrus chrysurus*	71	2.22	32.84
Myctophidae	*Myctophum obtusirostre*	62	1.94	25.37
Myctophidae	*Ceratoscopelus* sp.	66	2.07	23.88
Myctophidae	*Lepidophanes guentheri*	98	3.07	22.39
Scombridae	*Katsuwonus pelamis*	23	0.72	19.40
Carangidae	*Decapterus punctatus*	127	3.97	17.91
Myctophidae	*Diaphus rafinesqui*	43	1.35	17.91
Myctophidae	*Hygophum taaningi*	28	0.88	17.91
Carangidae	*Caranx crysos*	50	1.56	16.42
Myctophidae	*Lampanyctus* sp.	18	0.56	16.42
Scombridae	*Euthynnus alletteratus*	17	0.53	11.94
Myctophidae	*Lampanyctus nobilis*	13	0.41	10.45
Bothidae	*Engyophrys senta*	13	0.41	8.96
Scaridae	*Cryptotosmus roseus*	9	0.28	8.96
Scombridae	*Auxis rochei*	20	0.63	7.46
Myctophidae	*Myctophum asperum*	16	0.50	7.46
Carangidae	Carangidae B	12	0,38	7.46
Carangidae	*Naucrates ductor*	8	0.25	7.46
Scaridae	Scaridae E	4	0.13	5,97
Scombridae	*Auxis thazard*	11	0.34	4.48
Scombridae	Scombridae A	6	0.19	4.48
Myctophidae	*Myctophum selenops*	6	0.19	4.48
Myctophidae	*Lampadena* sp.	5	0.16	4.48
Scaridae	*Scarus* sp.	4	0.13	4.48
Scombridae	*Thunnus Albacares*	4	0.13	4.48
Bothidae	*Bothus* sp.	3	0.09	4.48
Myctophidae	*Myctophidae* sp.	14	0.44	2.99
Scombridae	*Lepidophanes* sp.	3	0.09	2.99
Myctophidae	*Diogenichthys atlanticus*	3	0.09	2.99
Gobiidae	Gobiidae C	2	0.06	2.99
Gobiidae	Gobiidae D	2	0.06	2.99
Carangidae	*Selene vomer*	2	0.06	2.99
Carangidae	*Seriola zonata*	2	0.06	2.99

FAMILY	SPECIES	N	Ar (%)	f (%)
Scaridae	Scaridae F	2	0.06	2.99
Myctophidae	*Nannobrachium* sp.	2	0.06	2.99
Scombridae	*Thunnus obesos*	2	0.06	2.99
Scombridae	*Sarda* sp.	2	0.06	2.94
Carangidae	*Seriola* sp.	4	0.13	1.49
Gobiidae	Gobiidae B	3	0.09	1.49
Myctophidae	Myctophidae F	2	0.06	1.49
Myctophidae	Myctophidae E	2	0.06	1.49
Scaridae	*Sparus* sp.	2	0.06	1.49
Scombridae	*Thunnus thynnus*	2	0.06	1.49
Myctophidae	Myctophidae A	1	0.03	1.49
Myctophidae	Myctophidae B	1	0.03	1.49
Myctophidae	Myctophidae C	1	0.03	1.49
Myctophidae	Myctophidae D	1	0.03	1.49
Myctophidae	Myctophidae G	1	0.03	1.49
Myctophidae	*Bolinichthys distofax*	1	0.03	1.49
Myctophidae	*Myctophum* sp.	1	0.03	1.49
Myctophidae	*Benthosema* sp.	1	0.03	1.49
Myctophidae	*Myctophum nitidulum*	1	0.03	1.49
Myctophidae	*Lampadena luminosa*	1	0.03	1.49
Myctophidae	*Diaphus metopoclampus*	1	0.03	1.49
Carangidae	Caragidae C	1	0.03	1.49
Carangidae	Caragidae D	1	0.03	1.49
Carangidae	Caragidae E	1	0.03	1.49
Carangidae	Caragidae F	1	0.03	1.49
Carangidae	Caragidae G	1	0.03	1.49
Bothidae	Bothidae A	1	0.03	1.49
Carangidae	*Elagatis bipinulatus*	1	0.03	1.49
Carangidae	*Trachurus trachurus*	1	0.03	1.49
Gobiidae	Gobiidae A	1	0.03	1.49
Scombridae	*Acanthocybius solandri*	1	0.03	1.49
Scombridae	*Scombrolax heterolepis*	1	0.03	1.49
Scombridae	*Scomberomorus* sp.	1	0.03	1.49
Scombridae	*Scomber japonicus*	1	0.03	1.49
TOTAL		**3.195**		

Tab. 3 - (continuation)

The most frequent family is the Gobiidae, which accounts for 79%, followed by Carangidae (66%), Myctophidae (58%), Scaridae (55%), Bothidae (52%) and Scombridae (46%) (Fig. 13). The other families are represented by a frequency of occurrence below 40% (Tab. 2). Gobiidae is also the most abundant family comprising 44% (7 species) of the catch, followed by Myctophidae (15%; 28 species), Carangidae (9%; 16 species), Scaridae (4%; 6 species), Bothidae (3%; 4 species) and Scombridae (2%;

13 species) (Fig. 14, Tab. 2 and Tab. 3). Therefore it is observed, that the Gobiidae is very frequent and dominant in the study area.

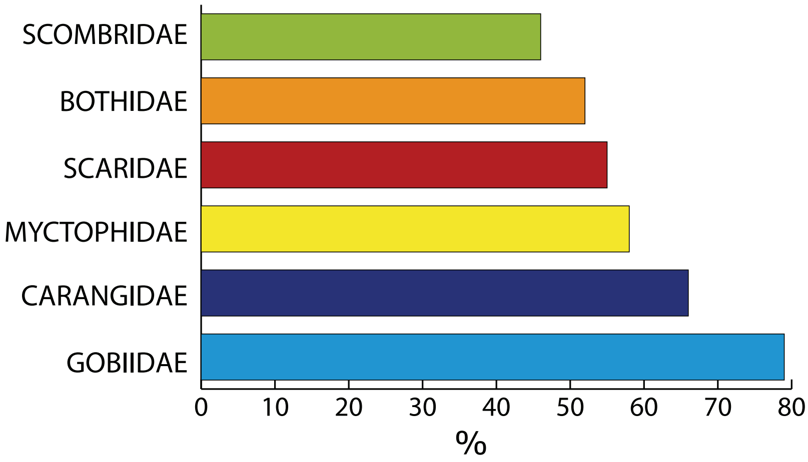

Fig. 13 **Frequency of occurrence** (f %) of the fish larvae family, inshore and offshore of the Maranhão/North Brazil.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

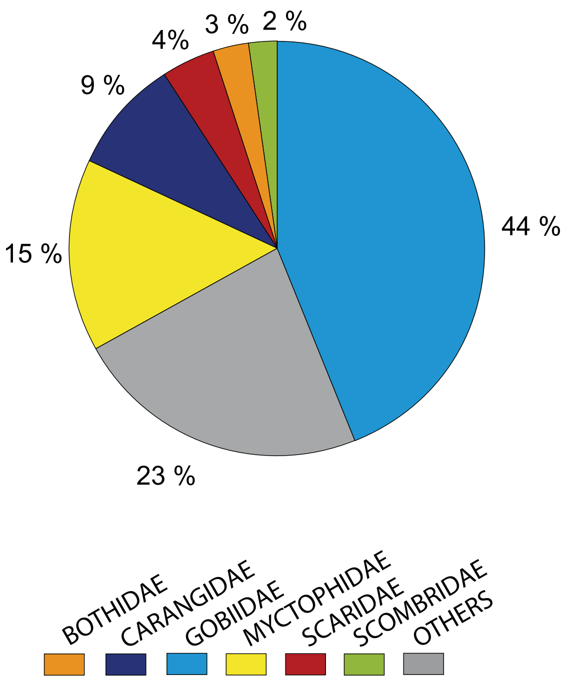

Fig. 14 **Relative abundance** (Ar %) of the fish larvae families inshore and offshore of the Maranhão/North of Brazil.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

The most frequent species in the study area are the gobiid *G. saepepallens* (63%), bothid *B. ocellatus* (49%) and scarid *Sparisoma* sp. (48%) (Fig. 15). The other species are represented by a frequency of occurrence below 40% (Tab. 3). The most abundant species throughout the study area are the gobiids *G. saepepallens* (32%) and *G. oceanicus* (20%), followed by the myctophid

Diaphus sp. (7%), the scarid *Sparisoma* sp. (5%), the gobiid *Coryphopterus* sp. (5%), the carangid *D. punctatus* (4%), the bothid *B. ocellatus* (3%), the myctophid *L. guentheri* (3%) and the carangid Carangidae A (3%) (Fig. 16).

The most abundant species comprise 82% of the whole catch. The other species are represented by only a few individuals, which can be considered as incidental. The species composition inshore and in the oceanic region of the Maranhão is constituted by many rare species and only a few species in large numbers. The percentage of contribution of the dominant taxa is illustrated in figure 16.

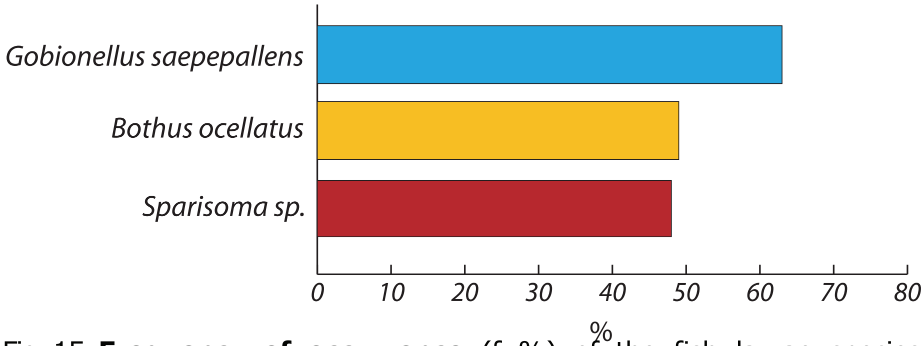

Fig. 15 **Frequency of occurrence** (f %) of the fish larvae species inshore and offshore of the Maranhão/North Brazil.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

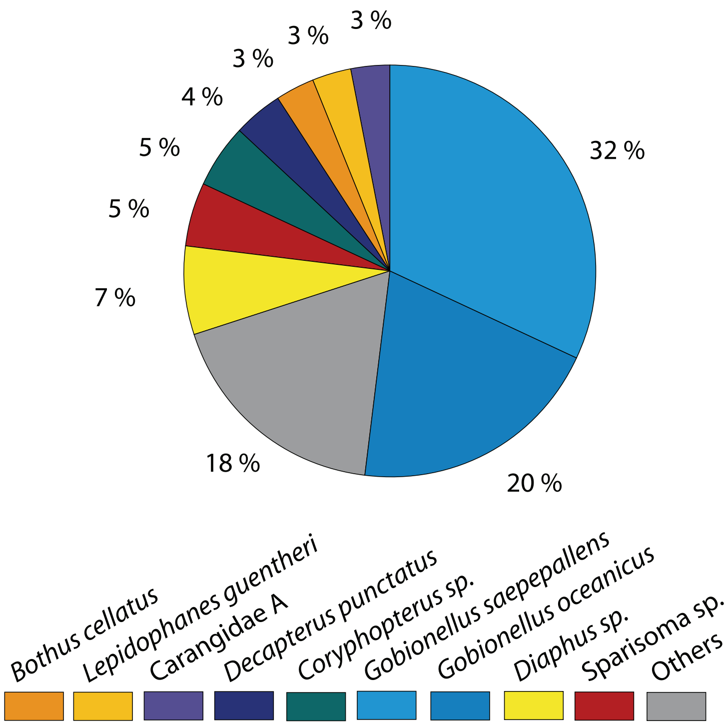

Fig. 16 **Relative abundance** (Ar %) of the dominant fish larvae species inshore and offshore of the Maranhão/North Brazil.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

3.2.1.2 Density and distribution of the fish larvae

The distribution of the fish larvae occurs throughout the whole study area. It is influenced inshore on the occidental side by CW and STSW, similar to the influence of TW and SMW on part of the oriental side. In the oceanic region it is influenced by the STSW and the TW in the superficial layer of the water column and the SACW in deeper layers.

The density of the larvae presents a variation from 0.04 to 156.03 larvae/100 m^3, with the minimal and maximal value in the oceanic region (Fig. 17).

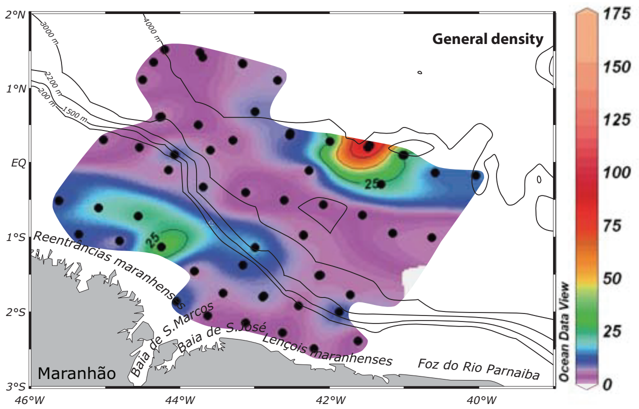

Fig. 17 **Density** (larvae/100 m^3) of the fish larvae inshore and offshore of the Maranhão/ North Brazil. Black dots correspond to the collection stations.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

The gobiids *G. oceanicus* (113.68 larvae/100 m^3) (Fig. 18A), *G. saepepallens* (97.95 larvae/100 m^3) (Fig. 18B) and *Coryphopterus* sp. (17.63 larvae/100 m^3) (Fig. 18C) present the higher density values of the larvae. These high values were measured in the oceanic stations 228 N II and 205 N IV (dry season), in which the presence of the TW in superficial layers and of the SACW in deeper layers is observed.

G. saepepallens shows further high density values (15.94 larvae/100 m^3) (Fig. 18B) on station 211 N II (dry season) near the continental shelf break with influence of the TW in superficial layers and the SACW in deeper layers and on the coastal station 151 N III (rainy season) (10.31 larvae/100 m^3) (Fig. 18B) in the occidental region of the study area, influenced by the CW.

D. punctatus has a high density value (18.07 larvae/100 m^3) (Fig. 17D) on the coastal station 146 N III (rainy season) with influence of the CW. Similar to *C. crysos,* which presents a high density value (12.29 larvae/100 m^3)

(Fig. 17E) on station 172 N III (rainy season). The myctophid *L. guentheri* presents a high density value (3.18 larvae/100 m^3) (Fig. 17F) on station 170 N III (rainy season) influenced by the STSW.

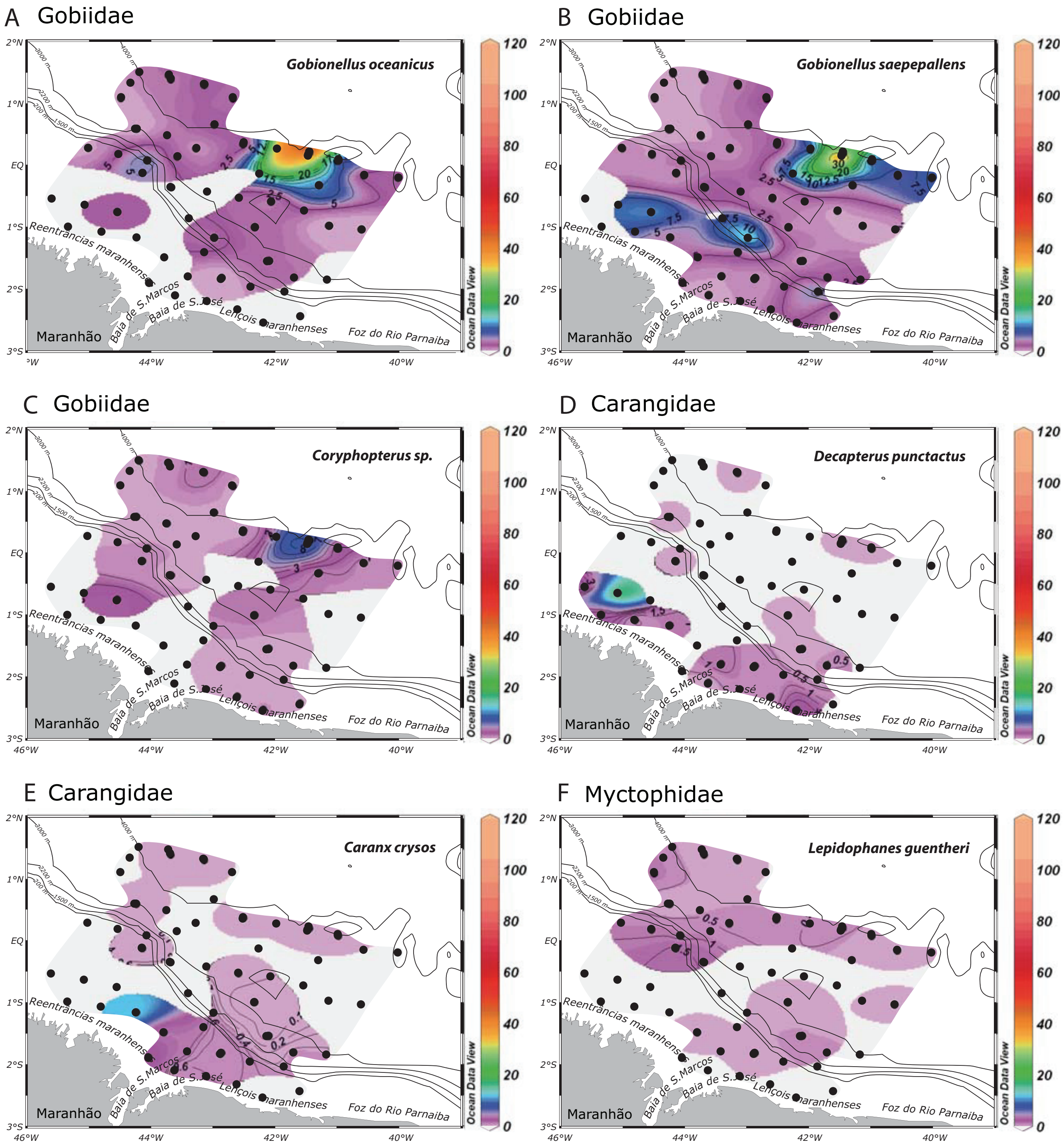

Fig. 18 **Density** (larvae/100 m^3) of the fish larvae species inshore and offshore of the Maranhão/North Brazil. Black dots correspond to the collection stations. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001
A - *G. oceanicus*, B - *G. saepepallens*, C - *Coryphopterus* sp., D - *D. punctatus*, E - *C. crysos*, F - *L. guentheri*

3.2.2 Cluster analysis and MDS

The species similarity matrix for 33 taxa (> 3% occurrence), resulted in ten clusters. The multidimensional scaling (MDS) shows the ordination of the different stations in addition to the ten clusters. Seven single stations (N II 159, N IV 18, N III 172, N IV 211, NIII 177, N III 148 and N III 212) are separated from the main clusters (Fig. 19).

The ten groups are determined by cluster analysis at the 30% similarity level. Cluster 1 (C1), cluster 3 (C3), cluster 4 (C4), cluster 5 (C5), cluster 8 (C8) and cluster 9 (C9) are represented by 2 stations each. The biggest assemblages are represented by the clusters 2 (C2), formed by 19 stations, 6 (C6), formed by 15 stations, 7 (C7) by 4 stations and 10 (C10) by 6 stations (Fig. 19).

The clusters C1, C6, C7 and C8 are formed by stations of the rainy season (N III), while the clusters C2, C3, C4, C5, C9, C10 are formed by stations of the dry (N II and N IV) as well as the rainy season (N III). These results dont show an evident seasonal difference of the assemblages.

The MDS of the same similarity matrix (stress level = 0.19) (Fig. 19B) shows good agreement with the samples cluster dendrogram (Fig. 19A). The ten groups recognized in the MDS plot could also be found in the cluster diagram and as well show that there is no clear seasonal difference between the assemblages.

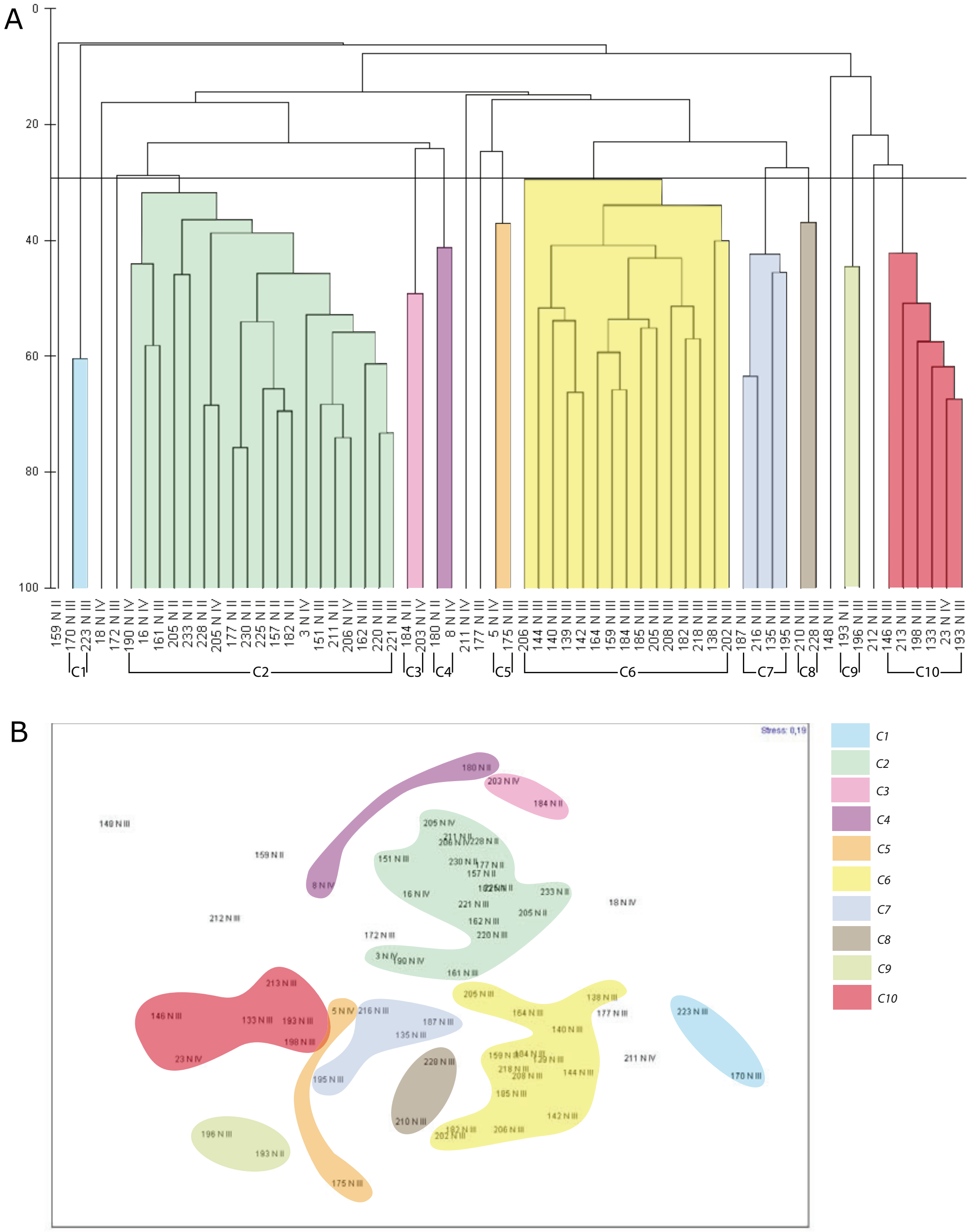

Fig. 19 **Dendrogram** (A) showing the analysis of the species based on the density and **ordenation** in 2 dimensions (B) using MDS on the same similarity matrix. Inshore and offshore of the Maranhão/North Brazil.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

The geographical arrangement of the ten clusters (Fig. 20) shows the distribution of the fish larvae assemblage along the studied area.

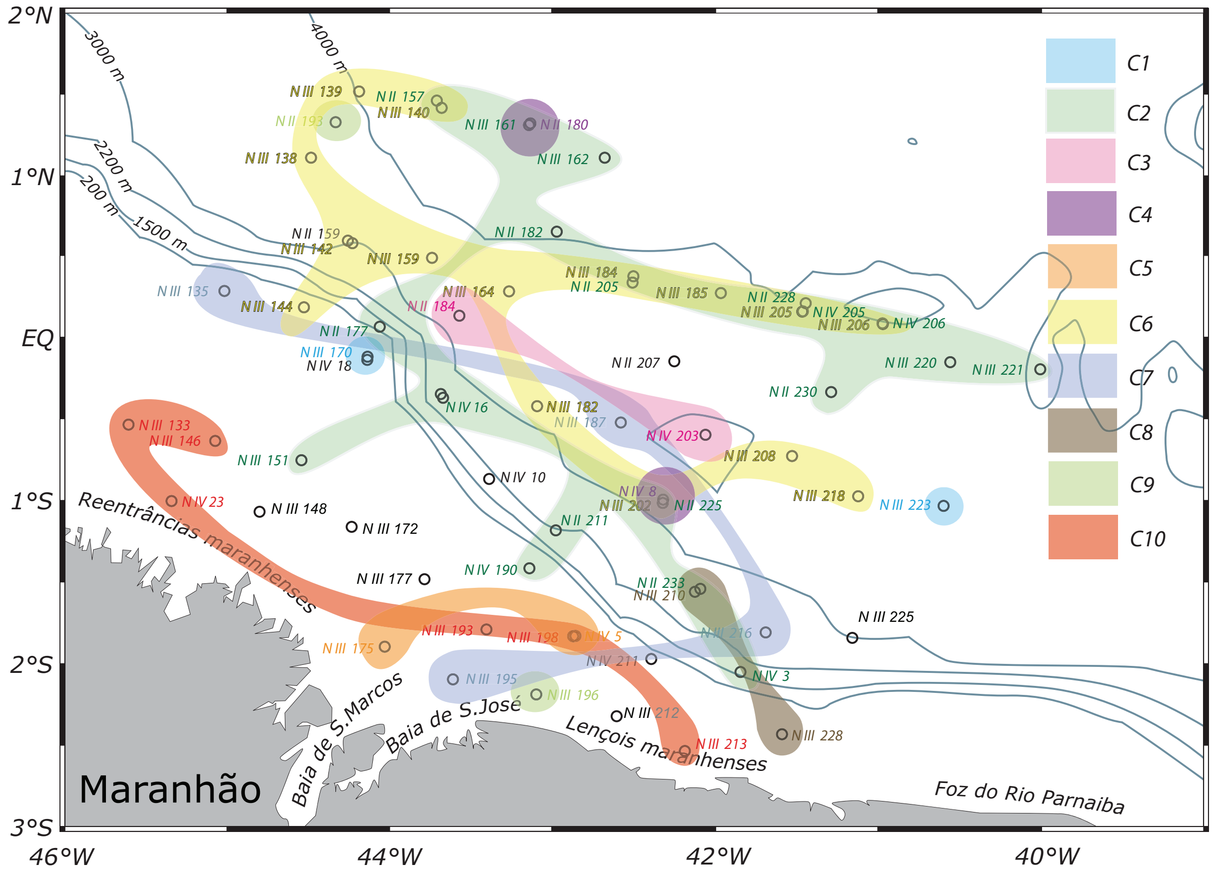

Fig. 20 **Geographical arrangement** of station groups found with cluster and MDS analysis. Inshore and offshore of the Maranhão/North Brazil.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

The geographical arrangement of the fish larvae assemblages shows the distribution of the clusters C1, C2, C6, C7, C8 and C9 between the continental shelf and oceanic region. These clusters are classified as transition assemblages. The clusters C3 and C4 are distributed only in the oceanic region and because of this classified as oceanic assemblages. Only the clusters C5 and C10 may be classified as costal assemblages being distributed on the continental shelf.

The transition assemblage C2 presents the highest density values (Tab. 5), which are found in the oceanic stations of this cluster (Fig. 17 and 20). This result shows a dependence of fish larvae density on the distance from the shore.

The second assemblage with high density values is the coastal C10 (Tab. 5), the high values are found on the occidental part of the study area (Fig. 17 and 20). On this side the influence of the mangrove-area with its estuarines is evident. The result shows a dependence of fish larvae density on the presence of mangrove estuarines.

The biggest assemblages C2, C6, C7 and C10 are analysed in relation to the water masses present in the region. Table 4 shows the water masses and mixed waters present in the geographical regions of the 10 clusters.

The stations on the continental shelf, continental shelf break and the oceanic region corresponding to C2 are characterized by influence of STSW in the surface layers of the water column up to 150 m depht. The TW influences from the surface of the oceanic region until 150 m of depht. The SMW influences from aproximately 125 m of depht on in the oceanic region. The SACW is observed below of 100 m until 200 m depht in the oceanic region (Fig. 21A, Tab. 4). In this assemblage the taxa with highest density values are the gobiids *G. oceanicus* (177.01 larvae/100 m^3) and *G. saepepallens* (176.48 larvae/100 m^3) (Tab. 5).

The C6 also is located in the area of influence of the STSW in the upper surface layers of the water column up to 125 m of depht on the continental shelf break and oceanic region. The influence of TW is verified in the surface until 125 m depht. The SMW is verified in 100 m depht. The SACW is verified below 100 m until 200 m of depht. These three water masses are observed in the oceanic region (Fig. 21B, Tab. 4). In this assemblage the taxa with the highest density values are myctophid *Diaphus* sp. (6.88 larvae/100 m^3), followed by gobiid *G. saepepallens* (4.01 larvae/100 m^3), by carangid Carangidae A (2.81 larvae/100 m^3) and by myctophid *L. guentheri* (2.72 larvae/100 m^3) (Tab. 5).

The C7 is influenced by the CW in the upper suface layers of water column in the continental shelf and by STSW in 60 m depht in the continental shelf break and around 150 m depht in the oceanic region. The TW is present in this assemblage in the upper suface layers of the water column until 140 m of depht. The SACW shows influence on this assemblage from 80 m until 200 m of depht. The last two water masses are observed in the oceanic region (Fig. 21C, Tab. 4). The gobiid *G. saepepallens* (2.35 larvae/100 m^3), followed by scarid *Sparisoma* sp. (1.33 larvae/100 m^3) and carangid *C. chrysurus* (1.04 larvae/ 100 m^3) are the taxa with the highest density values (Tab. 5) of this assemblage.

The C10 is influenced by the CW in the upper suface layers of the water column, by STSW aproximately between 30 m and 60 m of depht and by TW in the upper surface layers of the water column until 20 m of depht, both in the continental shelf (Fig. 21D, Tab. 4). The carangid *D. punctatus* (26.29 larvae/ 100 m^3) have the highest density in this assemblage (Tab. 5).

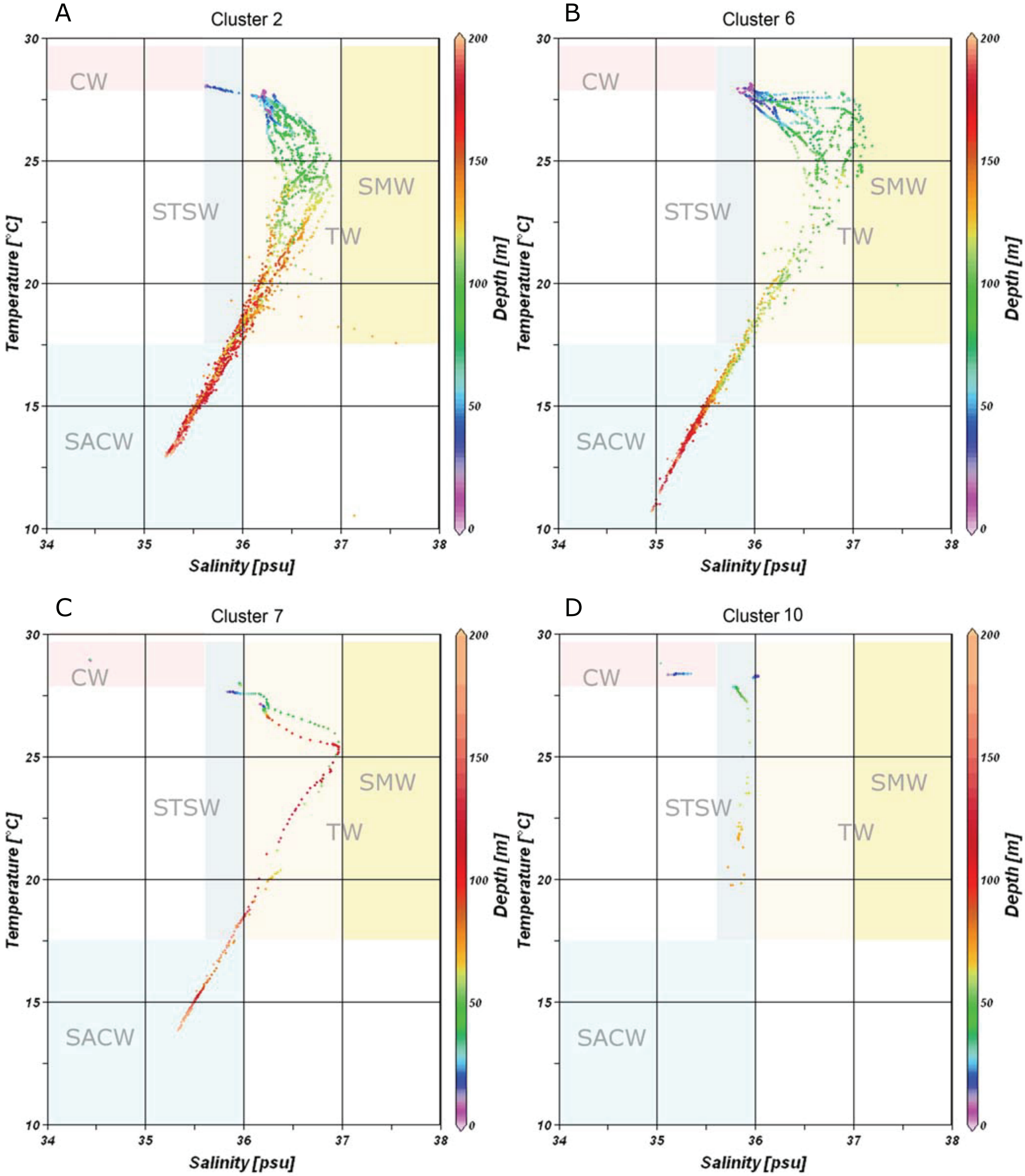

Fig. 21 **Diagram T-S related to depth**, showing the identification of four water masses: Costal Water (CW), Tropical Water (TW), South Atlantic Central Water (SACW), Salinity Maximum Water (SMW) and one mixed water: Subtropical Shelf Water (STSW). Cluster 2 (A), Cluster 6 (B), Cluster 7 (C), Cluster 10 (D); based on the abiotic data of the concerned stations. Maranhão/North Brazil.
Date of collection: 11.1997 - 12.1997; 06.1999; 07.2001 - 09.2001

Tab. 4 **Water masses and mixed water** present in the geographical regions of the 10 clusters. Water masses: Costal Water (CW), Tropical Water (TW), South Atlantic Central Water (SACW), Salinity Maximum Water (SMW) and mixed water: Subtropical Shelf Water (STSW). Inshore and offshore of the Maranhão/North Brazil.
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

Region	oceanic region (oriental)		oceanic region (occidental)		continental shelf break	coastal region	
Depth (m)	0-150	100-200	0-150	100-200	0-200	0-60	60-150
Cluster	Water Masses and Mixed Water						
C 1	TW	SACW	TW	SACW	STSW		
C 2	STSW / TW / SMW	SACW	STSW	SACW	STSW	STSW	STSW
C 3/C 4	TW	SACW	TW	SACW			
C 5						CW / TW	TW / STSW / SACW
C 6	STSW / TW / SMW	SACW	STSW	SACW	STSW		
C 7	TW / STSW	SACW	STSW/TW	SACW	STSW / SACW	CW	
C 8	TW / SMW	SACW	TW	SACW		TW	TW
C 9	TW	SACW	TW	SACW		CW	
C 10						CW / TW / STSW	STSW

Table 5 shows the taxonomic composition of the ten groups found by the analyses of cluster and MDS. Each cluster is analysed individually and the species are sorted according to abundance to discover the most frequently occurring species responsible for the grouping.

- The C1 is formed by 5 taxa. However only one species, the demersal bothid *B. ocellatus,* is dominant with 94%.

- The oceanic assemblage C2 is formed by 27 taxa, and this is the most diverse group. The most dominant taxa are the gobiids *G. oceanicus* (40%) and *G. saepepallens* (40%). *G. oceanicus* is demersal and *G. saepepallens* is reef related.

- The C3, an oceanic assemblage, is formed by 4 taxa. It is dominated by the gobiid *G. oceanicus* (43%), followed by carangid *N. ductor* (26%) and scombrid *A. rochei* (11%). *N. ductor* is coastal and epipelagic, *A. rochei* is classifies as oceanic epipelagic.

- The oceanic assemblage C4 is formed by 5 taxa. The gobiids *Coryphopterus* sp. (44%) and *G. oceanicus* (40%) are the dominant species. *Coryphopterus* sp. is reef related.

- Formed by 11 taxa cluster 5 is dominated by the carangid *C. crysos* (42%), the scombrid *A. rochei* (14%) and the carangid *C. chrysurus* (13%). *C. crysos* and *C. chrysurus* are classified as coastal epipelagic.

- C6, an oceanic assemblage, is formed by 26 taxa, and this is the second high diverse group. It is dominated by myctophid *Diaphus* sp. (24%), followed by gobiid *G. saepepallens* (14%), carangid *Carangidae A* (10%), myctophid *L. guentheri* (9%), scarid *Sparisoma* sp. (9%) and myctophid *M. obtusirostre* (6%). *Diaphus* sp., *L. guentheri* and *M. obtusirostre* are classified as oceanic and mesopelagic. *Carangidae A* is classified as coastal epipelagic. *Sparisoma* sp. is demersal and reef related.

- Formed by 12 taxa, cluster 7 is dominated by gobiid *G. saepepallens* (30%), followed by scarid *Sparisoma* sp. (17%), carangid *C. chrysurus* (14%) and *C. crysos* (11%).

- Cluster 8 is formed by 9 taxa, and the gobiids *G. saepepallens* (27%) and *Coryphopterus* sp. (19%) are dominants, followed by the carangids *Carangidae B* (18%), *Carangidae A* (8%) and scarid *Sparisoma* sp. (8%). The carangid *Carangidae B* is classified as coastal epipelagic.

- Cluster 9 is formed by 2 taxa. The carangid *C. chrysurus* (80%) is dominant.

- Cluster 10 is formed by 12 taxa. The carangid *D. punctatus* (64%) is dominant, followed by carangid *C. chrysurus* (19%). *D. punctatus* is classified as coastal epipelagic.

Tab. 5 **Taxonomic composition** of the ten different fish larvae assemblages found along the inshore and offshore of the Maranhão/North Brazil, taxa sorted by density (larave/100 m^3).
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

SPECIES	**Categories**	**Cluster**										**Stations**						
		C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	N II 159	N IV 18	N III 172	N IV 211	N III 177	N III 148	N III 212
		(larvae/100m^3)																
Bothus ocellatus	d	12.22	0.97	0.29		0.47	0.10	0.04			0.68			0.88	0.29	0.44		
Bothus sp.	d		2.63								0.08							
Engyophrys senta	d		2.11										0.29					
Chloroscombrus chrysurus	ep, c		3.15		0.29	1.34	0.50	1.04	0.09	1.35	7.68							
Caranx crysos	ep, c					4.22	0.18	0.83			0.17			12.29		0.66		
Decapterus punctatus	ep, c		0.29					0.80			26.29			0.88			0.19	0.52
Naucrates ductor	ep, c		0.94	1.36	0.29					0.33								
Carangidae A	ep, c	0.10	0.24			0.51	2.81	0.25	0.12						0.29			
Carangidae B	ep, c					0.58			0.27		1.03							
Gobionellus oceanicus	d	0.06	177.01	2.23	4.17		0.44	0.27										
Gobionellus saepepallens	r		176.48			0.87	4.01	2.35	0.42		0.34		0.29	3.51				
Coryphopterus sp.	r		36.11		4.53		0.27		0.29		0.49		0.87					0.26
Sparisoma sp.	d, r		7.45				2.65	1.33	0.12		1.05	0.26		2.63				
Cryptotosmus roseus	d, r		1.02		0.83											0.22		
Scaridae E	d, r		0.89				0.05											
Scarus sp.	d, r		0.10				0.08											
Auxis rochei	ep, o		0.33	0.58		1.44		0.46			1.88						0.75	
Auxis thazard	ep, o						0.03											
Euthynnus alletteratus	ep, o					0.29	0.41				0.42							
Katsuwonus pelamis	ep, o		0.77			0.29	0.41		0.09				0.58					
Thunnus albacares	ep, o						0.14											
Scombridae A	ep, o		0.50				0.08				0.78							
Lampanyctus nobilis	m, o		1.37				0.28						0.87					
Lepidophanes guentheri	m, o	0.48	3.55			0.29	2.72						3.18			0.22		
Hygophum taaningi	m, o		0.95				0.74											
Diaphus rafinesqui	m, o		3.83				1.05								0.29			
Diaphus sp.	m, o		4.36				6.88	0.10						0.88		0.44		
Ceratoscopelus sp.	m, o		5.49				1.26	0.08										
Myctophum obtusirostre	m, o	0.19	1.04				1.72		0.05				0.58					
Lampanyctus sp.	m, o		0.36				0.53	0.09										
Myctophum selenops	m, o		0.69			0.29	0.05											
Myctophum asperum	m, o		0.38				0.88											
Lampadena sp.	m, o						0.13		0.05									
Total larvae		**13.05**	**444.25**	**5.14**	**10.40**	**10.13**	**28.77**	**7.70**	**1.53**	**1.68**	**40.89**	**0.26**	**6.65**	**21.07**	**0.87**	**1.97**	**0.94**	**0.78**

Categories of taxa: c (coastal), d (demersal), ep (epipelagic), m (mesopelagic), o (oceanic), r (reef)

3.2.3 Relation between the oceanographical parameters and the species of the assemblages

Cluster 2 (C2)

The Canonical Correspondence Analysis (CCA), applied to the density data of species of the oceanic assemblage C2 and the oceanographical parameters, allows to explain 19% of variance of the fish larvae densities. "Eigenvalues", measures of importance for CCA axis that may vary between zero and one, are low for axis 1 and 2. However, species-environmental correlations are high for both axis (Tab. 6), indicating that environmental variables for the first two axes are useful in identifying gradients.

Inter-set correlation and canonical coefficients are used to identify the environmental variables that best explain the gradients for each axis. On axis 1 the oceanographical parameters temperature and salinity show the higher inter-set correlation values (Tab. 7). On axis 2 the oceanographical parameters salinity and dissolved oxygen show higher inter-set correlation values (Tab. 7). Gradients in some oceanographical parameters, like temperature, salinity and dissolved oxygen are correlated with the densities of the dominant taxa in the CCA (Tab. 6).

Tab. 6 **Canonical coefficients** for the density of fish larvae and environmental variables in the cluster 2 (C2) .
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

Environmental variable	**Axis 1**	**Axis 2**
Temperature	0.854	0.407
Salinty	-0.331	0.744
Dissolved oxygen	0.080	-0.562
Statistical Resume of Axis 1 and 2		
Eigenvalues	0.229	0.137
Percentage	11.905	7.117
Spec.-env.correlations	0.920	0.847

Tab. 7 **Inter-set correlations** of the environmental variables with CCA axis. Bold values are indicated for variables with high inter-set correlation values in the cluster 2 (C2).
Maranhão/North Brazil. Date of collection:11.1997-12.1997/06.1999/07.2001-09.2001

	Correlations	
Environmental variable	**Axis 1**	**Axis 2**
Temperature	**0.943**	0.313
Salinty	**-0.623**	0.634
Dissolved oxygen	-0.141	**-0.713**

The species ordenation in the diagram produced by CCA (Fig. 23) shows that *C. chrysurus* and *Bothus* sp. are directly related to high values of temperature, while *Coryphopterus* sp. is directly related to low values of this parameters. Carangidae A and *Sparisoma* sp. are related to high values of dissolved oxygen. Scaridae A, *H. taaningi*, *K. pelamis*, *D. punctatus*, *C. roseus*, *E. senta*, *L. nobilis*, *M. asperum*, *B. ocellatus*, *G. saepepallens Ceratoscopelus* sp. and *M. obtusirostre* are related to low values of this environmental variable (Fig. 23). *M. selenops*, *N. ductor*, *A. rochei*, *D. rafinesqui*, *L. guentheri*, *Sparisoma* sp., *G. oceanicus*, *Diaphus* sp., *Lampanyctus* sp. and Scaridae E show correlation with low salinity values (Fig. 23).

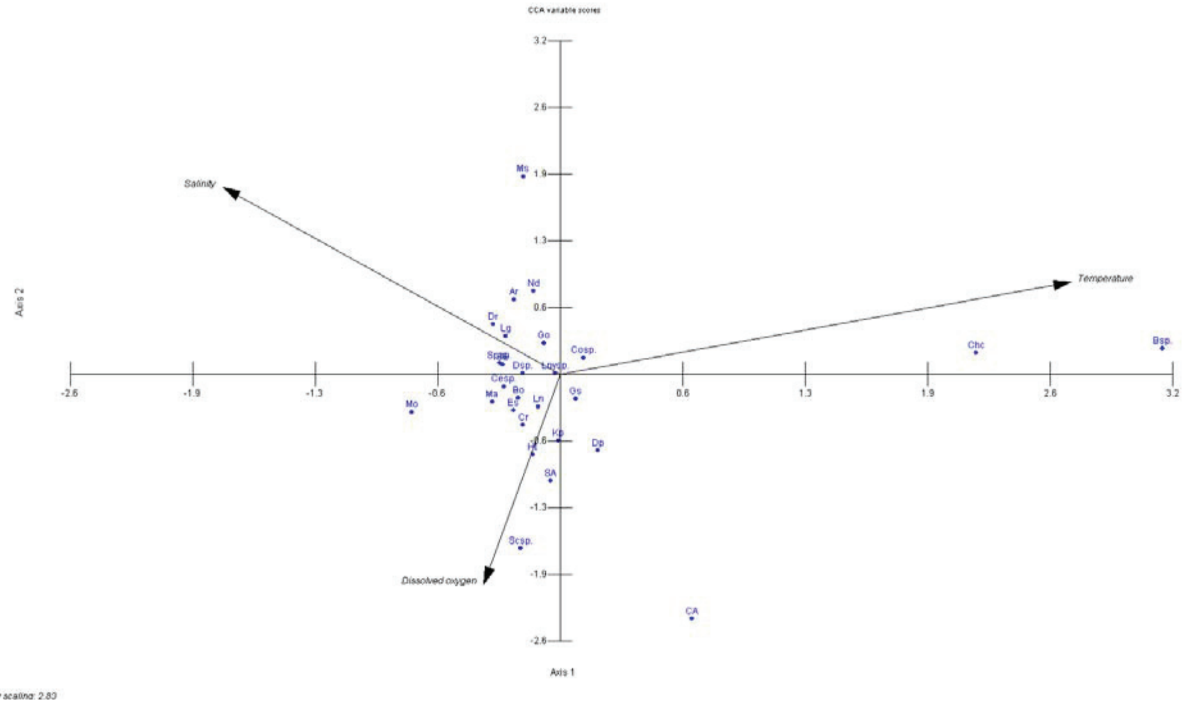

Fig. 22 **Ordenation diagram of species of the C2 assemblage** produced by the CCA, based on the density data of 27 species vs. average values of the oceanographic parameters. The species are represented by blue points and their abbreviated names (Tab. 8) and the oceanographical parameters by vectors.
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

Tab. 8 **Abbreviated names of species** as used in the CCA graphics of this chapter

Auxis rochei	Ar	*Decapterus punctatus*	Dp	*Lampanyctus* sp.	Lnysp
Auxis thazard	At	*Diaphus rafinesqui*	Dr	*Lepidophanes guentheri*	Lg
Bothus ocellatus	Bo	*Diaphus* sp.	Dsp	*Myctophum asperum*	Ma
Bothus sp.	Bsp	*Engyophrys senta*	Es	*Myctophum obtusirostre*	Mo
Carangidae A	CA	*Euthynnus alletteratus*	Ea	*Myctophum selenops*	Ms
Carangidae B	CB	*Gobionellus oceanicus*	Go	*Naucrates ductor*	Nd
Caranx crysos	Cc	*Gobionellus saepepallens*	Gs	Scaridae E	SE
Ceratoscopelus sp.	Cesp	*Hygophum taaningi*	Ht	*Scarus* sp.	Scsp
Chloroscombrus chrysurus	Chc	*Katsuwonus pelamis*	Kp	Scombridae A	SA
Coryphopterus sp.	Cosp	*Lampadena* sp.	Ldesp	*Sparisoma* sp.	Spsp
Cryptotosmus roseus	Cr	*Lampanyctus nobilis*	Ln	*Thunnus albacares*	Ta

Cluster 6 (C6)

The results of the CCA are shown in table 9, table 10 and figure 24. "Eigenvalues", measures for axis 1 and 2, are low. These two axes explain 26% of variance of the fish larvae densities. High species-environmental correlations are indicating for both axes (Tab. 9) that environmental variables are useful to identify gradientes.

Based on inter-set correlation and canonical coefficients, temperature and dissolved oxygen are the most important variables defining the two axes. These two parameters explain the variability of data. Gradients in these parameters are correlated with the densities of the dominant taxa in the CCA (Tab. 9, Tab. 10).

Tab. 9 **Canonical coefficients** for the density of fish larvae and environmental variables in the cluster 6 (C6) .
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

Environmental variable	**Axis 1**	**Axis 2**
Temperature	0.826	0.610
Salinty	0.055	-0.370
Dissolved oxygen	-0.893	0.616
Statistical Resume of Axis 1 and 2		
Eigenvalues	0.259	0.107
Percentage	18.319	7.553
Spec.-env.correlations	0.940	0.942

Tab. 10 **Inter-set correlations** of the environmental variables with CCA axis. Bold values are indicated for variables with high inter-set correlation values in the cluster 6 (C6).
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

	Correlations	
Environmental variable	**Axis 1**	**Axis 2**
Temperature	**0.515**	**0.745**
Salinty	-0.124	-0.192
Dissolved oxygen	**-0.584**	**0.677**

As revealed by the results of CCA (Fig. 24), the relation between fish larvae and oceanographical parameters for 19 stations of C6 show that Scombridae A presents relation with high temperature and low salinity values, while *L. nobilis, M. asperum, D. rafinesqui, L. guentheri, G. oceanicus, Ceratoscopelus* sp., *G. saepepallens, M. obtusirostre, Lampanyctus* sp., *Lampadena* sp. and *B. ocellatus* are related to low temperature and salinity values. *C. crysos* and *Scarus* sp. are related to salinity (Fig. 24). *C. chrysurus,* Scaridae E, *E. alletteratus, H. taaningi, T. albacares, K. pelamis, Coryphopterus* sp., Carangidae A, *Diaphus* sp., *Sparisoma* sp., *M. selenops* and *A. thazard* are related to low dissolved oxygen values (Fig. 24).

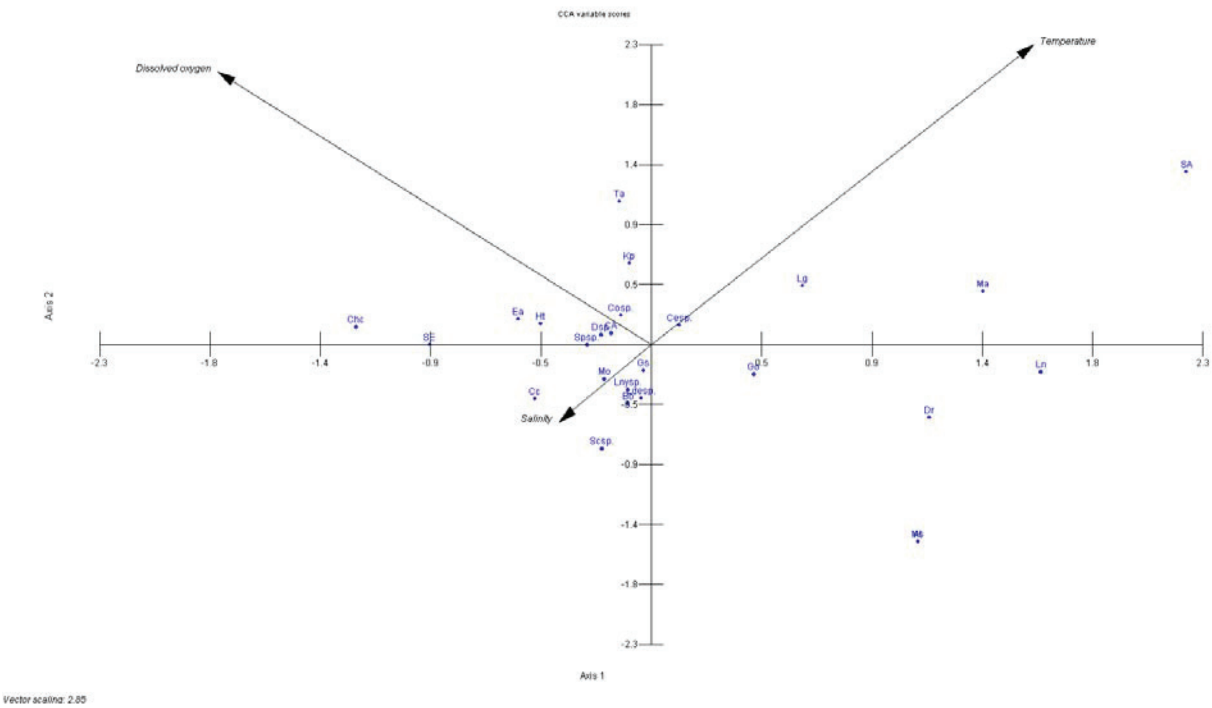

Fig. 23 **Ordnation diagram of species of the C6 assemblage** produced by the CCA, based on the density data of 26 species vs. average values of the oceanographic parameters. The species are represented by blue points and their abbreviated names (Tab. 8) and the oceanographical parameters by vectors.
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

Cluster 7 (C7)

Low "Eigenvalues" are measured for axis 1 and 2. These explain 88% of variance of the fish larvae densities. High species-environmental correlations (Tab. 11) indicate that environmental variables for the first two axes are useful in identifying gradientes. Inter-set correlation shows on axis 1 that the temperature is the most importante variable (Tab. 12). On axis 2 dissolved oxygen, followed by temperature, are the most important variables (Tab. 12). Gradients in some oceanographical parameters, like temperature, dissolved oxygen and salinity are correlated with the densities of the dominant taxa in the CCA (Tab. 11).

Tab. 11 **Canonical coefficients** for the density of fish larvae and environmental variables in the cluster 7(C7) . Maranhão/North Brazil
Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

Environmental variable	**Axis 1**	**Axis 2**
Temperature	1.440	-0.164
Salinty	0.055	-0.127
Dissolved oxygen	-0.893	1.053
Statistical Resume of Axis 1 and 2		
Eigenvalues	0.364	0.268
Percentage	50.724	37.282
Spec.-env.correlations	1.000	1.000

Tab. 12 **Inter-set correlations** of the environmental variables with CCA axis. Bold values are indicated for variables with high inter-set correlation values in the cluster 7 (C7).
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

	Correlations	
Environmental variable	**Axis 1**	**Axis 2**
Temperature	**0.724**	**0.574**
Salinty	0.042	-0.392
Dissolved oxygen	0.118	**0.992**

The ordination diagram resulting of the CCA for species of C7 (Fig.25) shows that *G. oceanicus* presents relation with high temperature values, while *G. saepepallens*, Carangiadae A, *C. chrysurus*, *A. thazard* and *Sparisoma* sp. are related to low temperature values. *D. punctatus*, *Lampanyctus* sp. and *C. crysos* are related to low dissolved oxygen values (Fig. 25). *Ceratoscopelos* sp. and *Diaphus* sp. are related to salinity (Fig. 25).

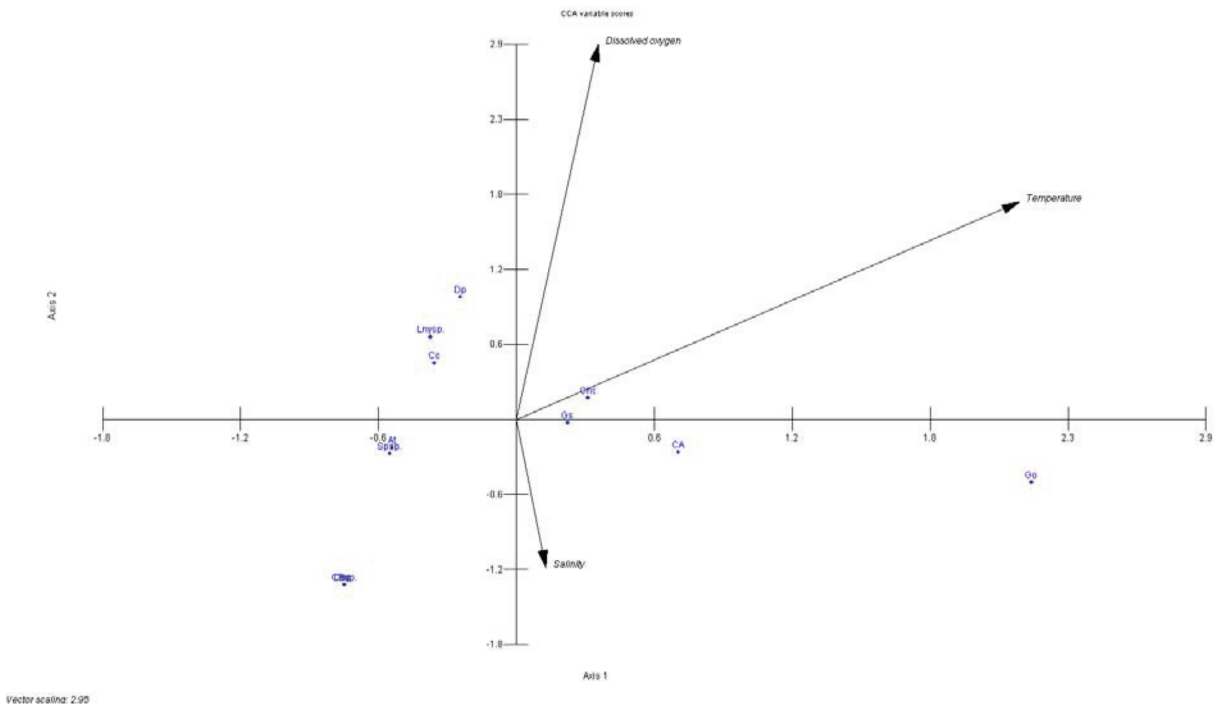

Fig. 24 **Ordination diagram of species of the C7 assemblage** produced by the CCA, based on the density data of 12 species vs. average values of the oceanographic parameters. The species are represented by blue points and their abbreviated names (Tab. 8) and the oceanographical parameters by vectors.
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

Cluster 10 (C10)

The CCA applied to the fish larvae density and the oceanographical parameters explain 50% of variance of the fish larvae densities (Tab. 13). Low "Eigenvalues" are measured for axis 1 and 2. However, species-environmental correlations are high for both axes (Tab. 13), which indicates that environmental variables for the axes are useful in identifying gradients.

Salinity and dissolved oxygen are the most important variables defining the first axis as shown by the inter-set correlation (Tab. 14). On the second axis temperature and dissolved oxygen are the most important variables (Tab. 14). These three parameters explain the variability of data. Gradients in these parameters are correlated with the densities of the dominant taxa in the CCA (Tab. 13).

Tab. 13 **Canonical coefficients** for the density of fish larvae and environmental variables in the cluster 10 (C10) .
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

Environmental variable	**Axis 1**	**Axis 2**
Temperature	0.707	-0.981
Salinty	0.973	-0.739
Dissolved oxygen	0.585	0.451
Statistical Resume of Axis 1 and 2		
Eigenvalues	0.326	0.249
Percentage	28.512	21.782
Spec.-env.correlations	0.995	0.891

Tab. 14 **Inter-set correlations** of the environmental variables with CCA axis. Bold values are indicated for variables with high inter-set correlation values in the cluster 10 (C10).
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

	Correlations	
Environmental variable	**Axis 1**	**Axis 2**
Temperature	-0.349	**-0.739**
Salinty	**0.873**	0.159
Dissolved oxygen	**0.672**	**0.629**

The ordination diagram for species of the C10 produced by CCA (Fig. 26) shows that *Bothus* sp. and *C. crysos* present relation to high dissolved oxygen values, while *E. alletteratus, B. ocellatus* and *G. saepepallens* are related to low values of this environmental variable. *C. chrysurus* is related to low salinity and dissolved oxygen values (Fig. 26). *Coryphopterus* sp., *Sparisoma* sp., Carangidae B and Scombridae A are related to low salinity values, while *A. rochei* presents relation to high temperature values and *D. punctatus* presents relation to low values this parameters (Fig. 26).

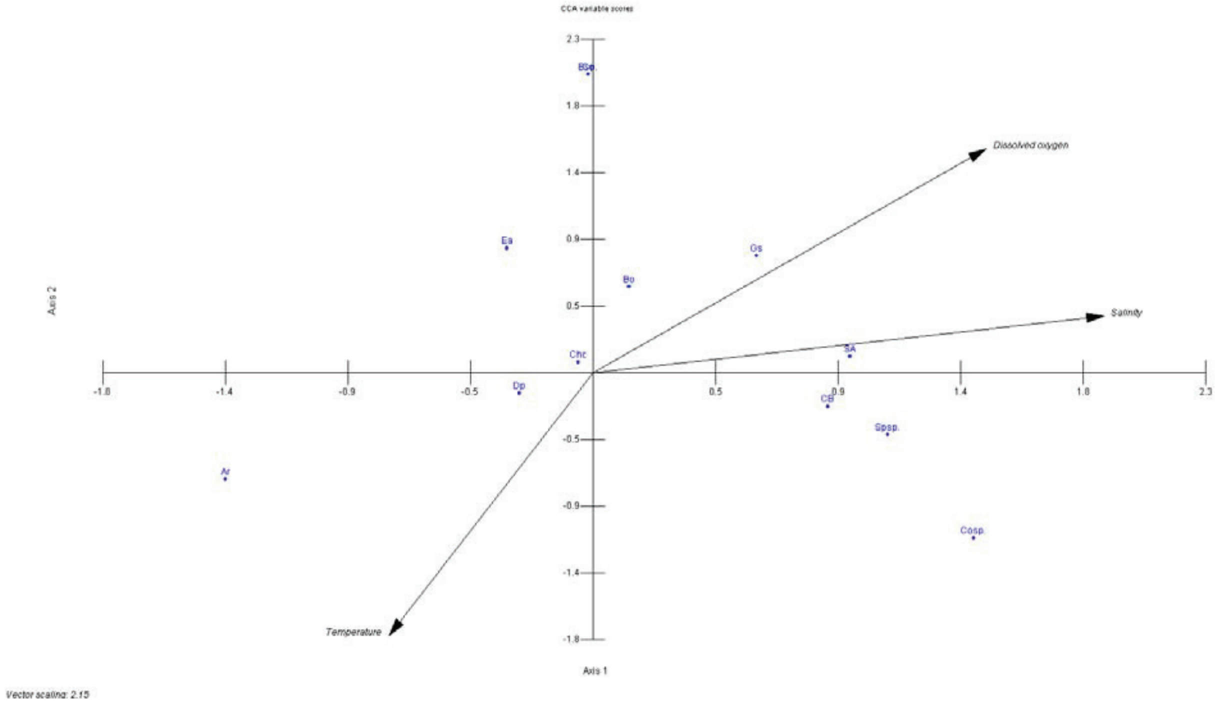

Fig. 25 **Ordenation diagram of species of the C10 assemblage** produced by the CCA, based on the density data of 11 species vs. average values of the oceanographic parameters. The species are represented by blue points and their abbreviated names (Tab. 8) and the oceanographical parameters by vectors.
Maranhão/North Brazil. Date of collection: 11.1997-12.1997/06.1999/07.2001-09.2001

4 DISCUSSION

4.1 Oceanographical characterisation

The Maranhense coast is influenced by the North Brazil Current (NBC), which results from a bifurcation of the South Equatorial Current (SEC). In accordance with the vertical analysis of the abiotic data (temperature and salinity) of the area of study, the Tropical Water (TW) is located in the surface down to 150 m depth, embedded in this water mass the Salinity Maximum Water (SMW) is found. The cold South Atlantic Central Water (SACW) occupies the subsurface layer beneath the Tropical Water mass down to 200 m depth. The Coastal Waters (CW) are sufficiently evident in the occidental and a small part of the oriental side of the studied area with its innumerable mangrove estuarine, as well as the mixed Subtropical Shelf Water (STSW).

A further influence on the oceanographical parameters are the seasonal cycles. At the maranhense coast they are defined by two climate stations: the dry season with lower preciptation, and the rainy season with higher preciptation (Stride et al., 1992).

This difference can be observed during the rainy season. In this season the water temperature is high and the salinity is low inshore on the occidental side of the study area, however offshore the temperature is low and the salinity is high. During the dry season the presence of the CW mass is not evident and salinity and temperature are higher inshore than offshore.

On the oriental side inshore of the Maranhense coast the continental shelf is narrower and the oceanographical standard is determined by the warm and salty TW mass carried by the NBC, which has oligotrophycal characteristics due to the scarse tenor of nutrients (Castro and Miranda, 1998).

The oriental part of the study area is similar to the North-Eastern Brazilian region because of its oceanographic conditions. Ekau et al. (1999) observed in studies in the North-Eastern Brazil a restricted influence of Coastal Waters, appearing only in a narrow part (within 5 - 10 km distance) along the coast. Ekau and Knopper (1999) comment that throughaut the shelf and slope of the North-Eastern Brazilian region the biggets part of water masses is tropical with high temperature and low tenor of nutrients.

In the surface waters of the oceanic region temperature and salinity values are almost constant in the dry as well as in the rainy season. In 100 m depth the temperature shows a higher variation, making evident the presence of a termocline, while salinity maintains static throughout the two seasons.

The difference of the oceanographical conditions between the two sides of the study area possibly can be promoting significant differences in the fish larvae density. The high density registred on the occidental side suggests the influence of the favourable oceanographical conditions to the survival of the fish larvae. The low sanility values on the occidental side during the rainy season are consequence of the great fresh water discharge of rivers like the Munim and Itapecuru rivers and high preciptation in this season (PROJECT REMAC, 1979). The high temperature values results of the high concentration of suspended material which causes a minor penetration of light and generates a rise of temperature in the surface waters.

The higher temperature increases the metabolism of fish larvae (Blatexter, 1992), decreases the egg development time and enhances larval growth (Pepin, 1991). In addition, greater larval food production and abundance may be associated with warmer water, which further the reproduction and enhances the growth rates of larvae (Frank and Legget, 1982; Taggart and Legget, 1987; Carmouze, 1994; Machado et al., 1997).

The horizontal distribution of the parameter dissolved oxygen does not show a great seasonal difference. Its highest oscillation is associated to spatial distribution. In the inshore waters in front of the São Marcos and São José Bay during the rainy season the highest values of dissolved oxygen are registered. These high values may appear due to the local hydrodynamism.

The differences of the oceanographical conditions inshore and offshore possibly can be promoting differences in the fish larvae density. The high density registred offshore suggests the influence of the favourable oceanographical conditions to the survival of the fish larvae. The relation between spatial and temporal density patterns of fish larvae and abiotic parameter variations possibly have influence on larval recruitment and survival (Laprise and Pepin, 1995; Espinosa-Fuentes and Flores-Coto, 2004).

4.2 Fish larvae community structure

Studies on ichthyoplankton in the North of Brazil, mainly on the Maranhão State coast, are scarce. Silveira (2003) registered 23 families for ichthyoneuston. However, this study represents a first comprehensive analysis on the level of community of ichthyoplankton in the coastal and oceanic region of Northern Brazil.

By this study 57 families of fish larvae of two seasonal collections were identified. The number of families increased by 34 families of fish larvae compared with former studies of Silveira (2003). The Exocoetidae, Syngnathidae and Ceratiidae families of the earlier study have not been present in the bongo net collection of the present study.

The number of fish larvae families registered in this study is similar to registered families in the studies of Mafalda Jr. (2004) in North-Eastern Brazil, in which he registered 60 fish larvae families and to the results of Sinque and Muelbert (1997) on the South Brazilian coast, which registered 57 fish larvae families. Nevertheless Ekau et al. (1999) registered 74 families in investigations in North-Eastern Brazil, and Nonaka (1999) 77 families in the Brazilian Central coast.

Its worthwhile to underscore that families of high frequency in this study were also well represented in other areas of the Brazilian coast. The mentioned studies show evidently the ample distribution of these families on the Brazilian coast.

The greatest frequency of occurrence and abundance of fish larvae registered in the study area is represented almost totally by coral reef associated fish larvae (Gobiidae), followed by epipelagic (Carangidae) which is frequent, but not very abundant compared with the mesopelagic (Myctophidae), which is frequent and abundant. Nevertheless, Ekau et al. (1999) in North-Eastern Brazil as well as Nonaka (1999) at the Brazilian Central coast registered the mesopelagic larvae (Myctophidae) dominating the coral reef associated larvae (Gobiidae), while at the Brazilian South coast (Matsuura and Sato, 1981; Matsuura et al., 1992; Katsuragawa et al., 1993) and in the Angola-Benguela Front and the Benguela upwelling areas (Ekau et al., 2001) the epipelagic larvae (Carangiade) were dominant.

The reef community of fish larvae is known for beeing one of the most diverse in species of the various tropical ecosystems (Longhurst and Pauly, 1987). However, the importance of the mesopelagics in the formation of the fish larvae community is bigger than that of the reef related, because of their great abundance, their ample distribution in world-wide scale and their bigger richness of species, thus being the main components of ichthyofauna of the tropical oceans (Ahlstrom et al., 1984; Moser et al., 1984; Longhurst and Pauly 1987; Rodríguez and Castro, 2000).

The great abundance of the mesopelagics constitutes an important food source for the great epipelagic fish, being the primary forage in the ocean and therefore of vital importance in the food chains (Moser and Ahlstrom, 1970; Moser et al., 1984)**.** Several authors (Castro and Huber, 2000; Rodríguez and Castro, 2000) quote the importance of the vertical migration system developed by these fish, which constitutes an important mechanism of energy transfer for the deep layers.

The families with high frequency in this study were also registered by Rocha et al. (2001) in the adult stage in the Parcel Manuel Luiz (Marine State Park). These authors registered families with high richness of species, with the Carangidae (9 species) and Scaridae (8 species) and especially the *Sparisoma* being well represented. A similar result is presented for the fish larvae in the present study.

Floeter et al. (2001) comment that scarids are poor or not represented in the South Atlantic oceanic sites. They however registered the *Sparisoma* near the offshore islands on the Brazilian coast. The same authors reported that the presence of this genus in this environments is possibly reflecting its broader feeding habits, which includes not only algae but sponges as well (Deloach, 1999). The scarids, which are usually associated with coral reefs (Leis and Rennis, 1983) were also registered by Smith et al. (1999) in temperate waters on the Sydney Shelf. According to these authors this occurrence indicates the southward advection of tropical species.

Rocha et al. (2001) also registered the occurrence of gobiids (e. g. *G. saepepallens*) in the Parcel Manuel Luiz, which present high frequency of occurrence in the present study. In Brazil the gobiids are common in coral reefs regions (Menezes and Figueiredo, 1985).

The bothids, too, are registered in the Parcel Manuel Luiz, even though the *B. ocellatus*, a frequent species in this study, was not present in the adult phase in the registers of Rocha et al. (2001), which is probably due to the estuarine habits of this species with no direct dependance on reef environments (Araújo and Feitosa, 2003). Nevertheless, fish larvae of this species are registered with high abundance in the Southwestern Atlantic (Macedo et al., 2005).

The contribution of the more abundant species is concentrated in a small area in the oceanic region and another small one in the coastal region. This high larvae concentration in a small area Stretta (1991) called "spot" region . It is suggested that there is an influence of the physical and oceanographical parameters on this result.

In the oceanic region there is a concentration of the highest fish larvae density values. Silveira (2003) observed contrary results to this study in the same area, using a neuston net. As this net was used only in the superficial layers of the water column, the catch was limited to the epipelagic zone. The present study is based on the use of a bongo net in superficial and deeper layers of the water column, which probably increased the catch in this region.

In the oceanic "spot" region the gobiids (*G. oceanicus*, *G. saepepallens* and *Coryphopterus* sp.) present the highest density values. The high values concentrate near the Belem Ridge and the North Brazilian Ridge from where these larvae supposedly are carried by the currents. Stretta (1991) registered higher abundance values occuring generally on the ebbtide of the current in regions of banks and islands in whose physiographical features it inserts, which is due to the influence exerted by the topography on the oceanic current. This influence tends to cause nutrial enrichment of the superficial layer and forms a "spot" region, which corroborates with the results observed in the present work.

In the oceanic region of North-Eastern Brazil, Bezerra Jr. (1999) registered a great abundance of Gobiidae larvae, which he explains as being possible because of the great occurrence of larvae of this family in the North Brazilian Amount. This is where the NBC seems to carry the larvae.

Most coral reef species have a pelagic larval stage (Leis, 1991a), lasting several weeks or months (Brothers et al., 1983; Wellington and Victor, 1989a), and the potencial for long-distance transport by ocean currents. This is in consensus with the fact that planctonic larvae are dispersed from their spawning sites (Planes, 2002).

In the coastal "spot" region on the occidental side *D. punctatus*, *C. crysos* and *G. saepepallens* contribute to the high density values. Silveira (2003) in this same area and season, in horizontal hauls, also registered high fish larvae density on this region. In this region the influence of the coastal waters becomes evident with a high temperature value and a low salinity value.

Coastal environments may be characterized by circulation features, which enhance retention of planktonic stages of fish (Laprise and Pepin, 1995). The coastal area of the present study shows a stability of the water column, which can be observed as a result of the penetration of Coastal Water masses, with a more pronounced stability on the occidental side, where a fish larvae retention probably exists. Environmental stability implies small amplitude of environmental variables like salinity, temperature and storm frequency in short term (Levinton, 1995).

The enhanced stability of the water column on the occidental side is due to the continuous influx of freshwater from the rivers, which intensifies during the rainy season due to the rainfall. This situation can explain the presence of high density values in this region. Margalef (1989) explained that a stable environment provides a higher organization degree of the food web.

The importance of physical oceanographic processes on biologic interactions is cited by Sinclair and Iles (1985) to explain spatial distribution patterns. Espinosa-Fuentes and Flores-Coto (2004) comment variations in location during the year as probably depending on physical processes. Especially the discharge of continental waters and the mixing processes exerts forces in depht, separating a relatively homogenous superficial layer from a lower stratified layer.

Sinclair and Iles (1985) comment that feeding conditions in areas of larval distribution are of secundary importance to the survival, and that larval retention in stable areas is the most important factor for regulating the sucess of the reproductive unit. These authors concluded that the spawning and larval distribution areas are a function of the location of physical characteristics associated to larval retention. This commentary corroborates the results of the present thesis, in which the highest density values are found in the "spot" regions with the occurrence of a stable water column. It is suggested that both "spot" regions have a function as nursery areas.

Many studies indicate a variation of density of ichthyoplankton depending on its distance from the shore (Mafalda Jr., 1995; Thorrold and Williams, 1996; Mafalda Jr., 2000; Ekau et al., 2001; Silveira, 2003; Hickford and Schiel, 2003). In this study the biggest values of density of fish larvae occur in the oceanic region and the responsible taxa for these values are the reef associated gobiids (*G. oceanicus*, *G. saepepallens* and *Coryphopterus* sp.). Nonaka et al. (2000) on the Eastern coast of Brazil also registered high density of the Gobiidae. In the Western North Atlantic ocean *G. oceanicus* larvae occur commonly in oceanic waters and *G. saepepallens* larvae in slope sea waters (Fahay, 1996). In the coastal region of the present study the carangids *D. punctatus* and *C. crysos* present the highest density values, while in the transition area between continental shelf break and oceanic region the demersal myctophid *L. guentheri* have the highest density.

Several studies have found that nearshore larvae hatch is more abundant from non-pelagic eggs, while those more widely distributed are generally derived from pelagic eggs (Leis and Miller, 1976; Gray, 1998). The nearshore abundance of larvae hatched from non-pelagic eggs is thought to be due to the absence of passive drift during the egg phase (Hickford and Schiel, 2003).

In this study the myctophid (*L. guentheri*), which hatch from pelagic eggs are widely dispersed, supporting therefore these patterns, while the carangids (e. g. *D. punctatus* and *C. crysos*), representing pelagic spawning, are limited at the coast. However the gobiids (e.g *G. oceanicus*, *G. saepepallens* and *Coryphopterus* sp.), which hatch from demersal eggs are widely dispersed, therefore not supporting these patterns.

The fish larvae community of the Maranhense coast also represents typical estuarine taxa, which suggests a mangrove estuarine influence on the coast. In case of the Mugilidae, Scianidae and Engraulidae, families of high commercial interest as well as highly exploited by the artesanal fishery of the Maranhense coast, the present study registers a low frequency of occurence and abundance. This result is considered to be consequence of the growing fishery activity. The capture of the scianid *Macrodon ancylodon* could explain the results. During the months of April until August the capture of this species is high (Almeida et al., 2007), exactly the period when the adults approach the coast to spawn (Isaac et al., 2007). This could explain the low occurrence and abundance of scianid larvae.

The Maranhense coast presents a community of fish larvae composed by diverse habitat forms. Therefore it can be considered as favourable for the development of the first stages of the cycle of life of a great number of species with diverse origins.

4.3 Fish larvae assemblage and oceanographical parameters

The high density presented by the dominant species of the C2 transition assemblage is related primarily to the saline, warm water mass (TW) with higher tenor of dissolved oxigen (Castro and Miranda, 1998). This water mass is evident in the oceanic stations where this species show high density values. The CCA revealed a negative relation to low salinity values of the *G. oceanicus* and a negative relation to low dissolved oxygen values of the *G. saepepallens*. This result is consequence of the predominance of the TW in the upper surface layers of the water column in the oceanic region corresponding to this assemblage, which is leading to high density values of these species.

The Gobiidae have a great amount of marine species, but they are also the most abundant fish in freshwaters on oceanic islands. Some gobiid species occuring in freshwater are spawning in the ocean and are therefore catadromous (Nelson, 2006).

In the C2 assemblage a zone of stability in the water column could be observed as a result of the penetration of the cooler SACW over the continental shelf. In accordance to Freitas and Muelbert (2004) a stability of the oceanic water column is known to be favorable for larval development. The mixture of the SACW with the CW is observed for this assemblage, resulting in the mixed water STSW (Piola et al., 2000) on the continental shelf. This mixed water is causing a pick up of demersal, coastal and reef related larvae. Ekau et al.

(1999) comment a slightly higher biomass and number of fish larvae on the shelf in a North-Eastern area of Brazil as possible result of the influence of the seafloor and the mixing between the ESW (Equatorial Surface Water), SACW and bottom or coastal water.

The coastal assemblage C5 is dominated by the coastal and oceanic epipelagic species *C. crysos, A. rochei* and *C. chrysurus.* This cluster emphasizes a particular difference between the Maranhense coast and the coastal region of North-Eastern Brazil (Ekau and Westhaus-Ekau, 1996; Ekau and Matsuura, 1996; Ekau et al., 1999; Mafalda Jr. et al., 2004, Mafalda Jr. et al., 2006) as well as the east coast of Brazil (Nonaka et al., 2000), where the dominance of coral reef associated fish larvae has been registered.

The ichthyoplankton of the coastal region of North-Eastern Brazil (Mafalda Jr. et al., 2004) in the areas influenced by CW mass is characterized by the absence of mesopelagics. In the present study C5 highlights the different situation on the Maranhense coast, as it presents mesopelagics (myctophids) too. This result evidences the penetration of the SACW on the continental shelf. The SACW is transporting myctophid larvae to the coast and mixes with the CW, since the station position of this assemblage and the season (rainy) favours the mixture of these water masses.

In cluster 5 the distribution of *C. chrysurus* is ample inshore and *A. rochei* has a limited distribution on the occidental side. *C. chrysurus* and *C. crysos* are registered in their adult phase throughout the Maranhense coast (SUDENE, 1976; Almeida et al., 2007) and found in several Maranhense estuaries (SEMATUR, 1991; Castro 1997) in adult stage. Therefore it seems, that these species use the whole coastal region of the Maranhão as spawning place and growth area. Moyle and Cech (1982) commented that coastal epipelagic fish can complete their whole life cycle in coastal regions, while the oceanic epipelagics, such as Scombridae, use coastal waters only as nursery.

The cluster 6 stands out by a diverse fish larvae group, which is dominated by oceanic mesopelagic, reef related and coastal epipelagic fish larvae. *Diaphus* sp., Carangidae A and *Sparisoma* sp., as revealed by the CCA, have negative relation with low dissolved oxygen values. *G. saepepallens*, *L. guentheri* and *M. obtusirostre* present positive relation with low temperature values, indicating the influence of the SACW. In this cluster a zone of stability in the water column could be observed as a result of the mixture between SACW and CW. The influence of the SACW on this assemblage favours the pick up of many oceanic mesopelagic species.

According to Rubin (1997b), the Myctophidae spawn in the oceanic region, however in this study the myctophids *Diaphus* sp., *L. guentheri* and *M. obtusirostre* show ample distribution in the oceanic region, suggesting therefore too the spawning of these species in this region. Moyle and Cech (1982) comment that the transport of myctophid larvae in direction towards the coast occurs due to the influence of the oceanic current, which can be an explanation for the occurrence of myctophids on the continental shelf of the study area.

The dominant myctophids (*Diaphus* sp., *L. guentheri, M. obtusirostre*) in the present study are registered as dominant in other areas of the Brazilian coast (Nonaka et al., 2000) too. These myctophids, with the exeption of *L. guentheri,* are registered as dominant as well in the Gulf of Mexico, the Caribbean Sea (Rodríguez- Varela et al., 2001; Espinosa-Fuentes and Flores-Coto, 2004) and in the Angola-Benguela Front and Benguela upwelling areas (Ekau et al., 2001).

The C7 assemblage is dominated by reef related, demersal and coastal epipelagic fish larvae. The CCA revealed that the dominant species of this assemblage are related to low temperature values (*G. saepepallens*, *C. chrysurus* and *Sparisoma* sp.) and low dissolved oxygen values (*C. crysos*). This result indicates the influence of the STSW, which is formed by the great estuarine discharge, high rainfall during the rainy season and penetration of the cooler SACW on the continental shelf and leads to the low dissolved oxygen and temperature values.

Cluster 7 presents an inshore station, which is localized in the Maranhense Gulf. The appearence of a big discharge of estuarine water mixed with the SACW is increasing the amount of coastal epipelagic, demersal, oceanic mesopelagic and reef related species.

The coastal epipelagic species *D. punctatus* and *C. chrysurus* are dominant in the C10 assemblage. The dominance of the coastal epipelagic in this cluster shows clearly the existence of a pelagic environment rich in nutrients due to the influence of the CW with higher temperature and low salinity values (Castro and Miranda, 1998), as indicated by CCA. The observed result is consequence of an estuarine flow and of high rain fall during the rainy season, which allies the high temperature and low salinity values and favours the high density of these species.

The density presented in C10 is higher than the density in C5, both clusters of coastal assemblages. This difference can be explained by the ample inshore distribution of C10, including the „Reentrâncias Maranhenses" area. In this area the presence of the mangrove estuarine is evident and the presence the CW too evidencing a strong coastal impact of great importance on the increase of fish larvae density. This probably is the reason for a concentration of higher density values, favouring the epipelagic spawning. This area is not present in C5, a probable reason for the density differences.

5 CONCLUSION AND OUTLOOK

The Maranhense coast presents a community of fish larvae with diverse habitat forms. The pelagic, demersal, coastal, reef-associated, oceanic and estuarine taxa are present on the maranhense coast. The Gobiidae larvae are the most frequent, abundant and dense family.

The high density values of fish larvae are concentrated in a small area in the oceanic region and another small one in the coastal region. These small areas are classified as "spot" regions.

In the oceanic "spot" region the gobiids *G. oceanicus*, *G. saepepallens* and *Coryphopterus* sp. present the highest density values.

In the coastal "spot" region the carangids *D. punctatus* and *C. crysos* and the gobiid *G. saepepallens* contribute to the high density values.

The highest density values in the "spot" regions suggest that both have a function as nursery areas.

The variation of density of ichthyoplankton and its dependance on the distance from the shore is observed in the present study. The values of density of C2 reach a total of 444.25 larvae/100m^3, including an oceanic "spot" region while C10 reaches a total of 40.89 larvae/100m^3 within a "spot" region in the coastal region.

The cluster C2 is classified as transition assemblage and stands out by the presence of the highest density values and by having the most diverse group of fish larvae. This assemblage is influenced by the presence of the STSW, TW, SMW and SACW within a stable water column, which favours the density of fish larvae. The C2 is dominated by gobiids *G. oceanicus* and *G. saepepallens*.

The oceanographical parameter values show the difference offshore and inshore: Offshore under influence of the TW salinity and temperature present high values. Inshore under influence of CW temperature is high and salinity values are low.

The oceanographical parameters present favourable conditions to the survival and the density of the fish larvae, especially to the gobiids, wich are the taxa responsible for high density offshore.

Between the occidental and oriental side inshore a variation of the fish larvae density is observed too, as well as a difference of the oceanographical parameters values. The coastal assemblage C10 is the assemblage with the second biggest values of density of fish larvae and these values are observed on the occidental side, where the mangrove estuarines flow and strong rain fall are evident. The resulting high temperature and low salinity values can favour the fish larvae density.

These results however support the hypothesis that the abundance of fish larvae is depending on the distance from the coast and the presence of coastal vegetation.

The results of the cluster analysis dont show an evident seasonal difference between the assemblages, which probably is due to the lack of collections in the coastal area during the dry season. It is suggested for future studys to collect in the two seasons in this area with the intention to manage a comparation between the seasons.

The fishery throughout the Maranhense coast is artisanal and appears at the coast itself and on the continental shelf, especially in regions like the „Reentrâncias Maranhenses‟. In the last two decades the fishing fleet increased by 30%, which can cause impacts on the resources as well as on the environment. The existing industrial fishery in the region is realized by fleets with origins in Ceará, Piauí, Rio Grande do Norte and Pará. There is no control about the realized captures of these fleets and there are no data about the volume of fish from the Maranhense coast which is taken to the bigger centers, thus difficulting the obtaining of data of the total fishery production, which is necessary to evaluate the stocks (Almeida et al., 2007).

The results of this study probably reflect this intensification of fishery, as the results about estuarine taxas present a low frequency. Especially the spawning period of fishes suffers from the fishery activities. It is obviously necessary to develop strategies for a sustainable management and use of resources to preserve and conserve the coastal area from anthropogenic impacts as well as a responsable quotation on the resources of the offshore fishery.

The whole Maranhense coast is an area of ambiental protection and there is neither monitoring nor management for this region. As there is no governmental presence, there is no control about exploitation and exploiters.

Policy initiatives are required for the preservation and conservation of the region. Continued investigation, focusing on topics such as biodiversity, species distribution, life cycles, adaptation to environmental factors and ichthyic communities, is essential for the preservation of the region.

The results obtained here may serve as guide to future studies of ichthyoplankton related to oceanographycal conditions on the Maranhense coast, thus enlarging the knowledge about the potential of fishery of the region.

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Tab. A1 General information of the collections inshore and offshore of the Maranhão/North Brazil. Cruise, stations of collection, date, time, latitude, longitude, bottom (m), depth (m), location.

Cruise	Station	Date	Time	Latitude	Longitude	Bot. Depth [m]	Depth [m]	Location
NO_II	157	15.11.97	11:00	01° 27,67' N	43° 44,43' W	4177	200	oceanic
NO_II	159	13.11.97	15:00	00° 35,74' N	44° 15,37' W	3303	200	oceanic
NO_II	177	16.11.97	11:00	00° 04,70' N	44° 04,05' W	3202	200	oceanic
NO_II	180	16.11.97	18:00	01° 18,83' N	43° 10,49' W	4236	200	oceanic
NO_II	182	19.11.97	14:00	00° 40,08' N	42° 59,03' W	4028	200	oceanic
NO_II	184	18.11.97	08:00	00° 08,59' S	43° 35,05' W	3299	200	oceanic
NO_II	193	17.11.97	10:00	01° 20,22' S	44° 22,83' W	2300	200	oceanic
NO_II	205	30.11.97	23:32	00° 21,90' N	42° 31,50' W	3936	200	oceanic
NO_II	207	1.12.97	11:46	00° 08,22' S	42° 16,35' W	3757	200	oceanic
NO_II	211	1.12.97	21:51	01° 10,00' S	42° 59,20' W	2535	200	oceanic
NO_II	225	3.12.97	10:44	01° 00,11' S	42° 21,68' W	4244	200	oceanic
NO_II	228	4.12.97	02:29	00° 13,35' N	41° 28,71' W	3966	200	oceanic
NO_II	230	4.12.97	09:35	00° 19,11' S	41° 18,37' W	3753	200	oceanic
NO_II	233	4.12.97	22:11	01° 33,31' S	42° 08,14' W	2853	200	oceanic
NO_III	133	08.06.99	19:28	00° 32,40' S	45° 37,00' W	30	20	coastal
NO_III	135	09.06.99	04:07	00° 17,00' S	45° 02,60' W	74	60	coastal
NO_III	138	09.06.99	15:35	01° 06,50' N	44° 28,20' W	3986	200	oceanic
NO_III	139	09.06.99	22:20	01° 31,50' N	44° 12,00' W	4050	200	oceanic
NO_III	140	10.06.99	04:43	01° 25,10' N	43° 41,40' W	4179	200	oceanic
NO_III	142	10.06.99	13:20	00° 35,60' N	44° 15,50' W	4126	200	oceanic
NO_III	144	10.06.99	18:15	00° 11,00' N	44° 32,80' W	32	20	coastal
NO_III	146	11.06.99	09:45	00° 38,10' S	45° 06,90' W	33	20	coastal
NO_III	148	11.06.99	17:50	01° 05,00' S	44° 49,00' W	36	20	coastal
NO_III	151	12.06.99	03:10	00° 45,40' S	44° 34,90' W	44	30	coastal
NO_III	159	12.06.99	23:35	00° 28,70' N	43° 43,90' W	3812	200	oceanic
NO_III	161	13.06.99	09:55	01° 18,40' N	43° 08,90' W	4236	200	oceanic
NO_III	162	13.06.99	15:00	01° 05,50' N	42° 41,00' W	4208	200	oceanic
NO_III	164	14.06.99	01:50	00° 15,80' N	43° 15,80' W	3737	200	oceanic
NO_III	166	14.06.99	09:00	00° 21,30' S	43° 41,50' W	2920	200	oceanic
NO_III	170	14.06.99	17:10	00° 07,11' S	44° 09,40' W	50	40	coastal
NO_III	172	14.06.99	22:05	01° 10,50' S	44° 15,30' W	38	30	coastal
NO_III	175	19.06.99	01:15	01° 54,50' S	44° 03,50' W	33	20	coastal
NO_III	177	15.06.99	02:05	01° 29,15' S	43° 48,30' W	38	30	coastal
NO_III	182	15.06.99	17:00	00° 27,00' S	43° 06,00' W	3200	200	oceanic
NO_III	184	16.06.99	05:20	00° 22,30' N	42° 30,90' W	3941	200	oceanic
NO_III	185	16.06.99	12:25	00° 16,20' N	41° 59,00' W	3992	200	oceanic
NO_III	187	16.06.99	21:40	00° 32,20' S	42° 33,70' W	3188	200	oceanic
NO_III	193	17.06.99	14:40	01° 47,00' S	43° 24,80' W	40	30	coastal
NO_III	195	17.06.99	18:35	02° 06,50' S	43° 38,20' W	38	30	coastal
NO_III	196	17.06.99	23:40	02° 11,05' S	43° 07,20' W	29	20	coastal
NO_III	198	18.06.99	03:40	01° 50,20' S	42° 52,90' W	76	60	coastal
NO_III	202	22.06.99	09:50	01° 00,70' S	42° 18,90' W	3136	200	oceanic
NO_III	205	24.06.99	04:00	00° 13,20' N	41° 27,10' W	3969	200	oceanic
NO_III	206	24.06.99	09:10	00° 05,10' N	40° 58,90' W	3792	200	oceanic
NO_III	208	24.06.99	17:45	00° 44,40' S	41° 33,40' W	3558	200	oceanic
NO_III	210	25.06.99	02:10	01° 33,80' S	42° 07,70' W	2840	200	oceanic
NO_III	212	25.06.99	11:15	02° 19,00' S	42° 39,00' W	22	20	coastal
NO_III	213	25.06.99	15:15	02° 32,00' S	42° 12,20' W	25	20	coastal
NO_III	216	25.06.99	23:15	01° 49,70' S	41° 43,00' W	2392	200	oceanic
NO_III	218	26.06.99	11:15	01° 00,20' S	41° 08,70' W	3493	200	oceanic
NO_III	220	26.06.99	20:25	00° 10,90' S	40° 34,00' W	3926	200	oceanic
NO_III	221	27.06.99	01:00	00° 12,60' S	40° 03,00' W	4039	200	oceanic
NO_III	223	27.06.99	10:00	01° 02,20' S	40° 37,50' W	3629	200	oceanic
NO_III	225	27.06.99	19:25	01° 51,70 'S	41° 11,80' W	2844	200	oceanic
NO_III	228	28.06.99	04:00	02° 26,10' S	41° 35,70' W	25	20	coastal
NO_IV	3	12.07.01	07:16	02° 01,90' S	41° 50,80' W	1572	200	oceanic
NO_IV	5	13.07.01	17:24	01° 49,40' S	42° 51,90' W	48	30	coastal
NO_IV	8	14.07.01	08:10	00° 59,80' S	42° 19,57' W	3147	200	oceanic
NO_IV	10	14.07.01	21:55	00° 51,50' S	43° 23,69' W	2467	200	oceanic
NO_IV	16	15.07.01	09:20	00° 21,18' S	43° 41,54' W	2807	200	oceanic
NO_IV	18	16.07.01	04:50	00° 07,11' S	44° 09,40' W	50	20	coastal
NO_IV	23	16.07.01	21:05	00° 58,75' S	45° 21,47' W	24	20	coastal
NO_IV	190	06.09.01	20:32	01°24,70' S	43° 09,20' W	65	40	coastal
NO_IV	203	07.09.01	16:00	00° 35,90' S	42° 04,00' W	3238	200	oceanic
NO_IV	205	08.09.01	04:38	00° 11,30' N	41° 28,30' W	3984	200	oceanic
NO_IV	206	08.09.01	16:20	00° 05,10' N	41° 00,80' W	3787	200	oceanic
NO_IV	211	09.09.01	15:20	01° 57,50' S	42° 24,20' W	78	60	coastal