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Identifying priority areas for humpback whale conservation at Eastern Brazilian Coast

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ABSTRACT

One of the humpback whales' stocks uses the Brazilian Coast as breeding and calving ground during the austral winter. The species is recovering from commercial hunting and re-occupying previous breeding areas. Aerial surveys conducted to estimate the species density and abundance along the continental shelf of the Eastern Brazilian Coast revealed important core areas at the southern portion of the Abrolhos Bank. The rapid growth of human activities in these coastal areas motivated the use of Geographic Information Systems as a tool to guide the identification of priority areas for the species conservation. The species distribution was modelled using a kernel density estimator. The corresponding layer was used to identify areas of overlay with components of maritime traffic and with hydrocarbon exploitation areas. The resulting risk map was overlaid with existent Marine Protected Areas, allowing the cartography of areas where management measures still need to be undertaken to ensure habitat protection. These areas were identified as priorities for the species conservation as they encompass important breeding concentrations that were completely overlain by areas used to hydrocarbon exploitation and/or as navigation corridors. The present work gives support to an ecosystem-based management and ocean zoning of this portion of the Brazilian coast.

1. Introduction

The humpback whale (*Megaptera novaeangliae*) is a cosmopolitan migratory species that spends the summer in high latitudes feeding grounds and breeds in tropical waters during winter (Clapham and Mead, 1999). For management purposes, the International Whaling Commission (IWC) divided the species in seven breeding stocks (identified by letters from "A" to "G"). Humpback whales' breeding stock "A" uses the Brazilian Coast during the austral winter (IWC, 1998). Current information on distribution shows that the species is abundant in the Abrolhos Bank (16°40′–19°30′S), a region that was pointed out as the main concentration area for the species in the Southwestern Atlantic Ocean (Siciliano, 1997; Martins et al., 2001; Andriolo et al., 2006, 2010), corresponding to their breeding and calving ground. The species is recovering from commercial hunting and re-occupying previous breeding areas along the Eastern Brazilian Coast. This portion of the Brazilian coast presents an important coral reef ecosystem, which present a high degree of endemic species (Leão et al., 2003; Moura, 2003).

While in the breeding area, humpback whales are exposed to several anthropogenic activities, which may represent a threat to the species. Despite their apparent recovery over the last three decades, the western South Atlantic population is still low relative to pre-exploitation size and requires continued conservation efforts (Zerbini et al., 2011). Maritime traffic and hydrocarbon exploration are of special concern as they can have direct effects in the population structure or indirectly, by causing changes in their habitat utilization patterns in medium and long term (Schick and Urban, 2000). Increasingly probabilities of ship strikes, continued noise disturbance, and water chemical pollution are possible consequences of these human activities. Ship strikes are an important cause of mortality for baleen whales (Laist et al., 2001). However, most of the incidents are unreported by pilots and are kept

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anonymous (Kraus et al., 2005). Besides, only a small percentage of the dead animals strand in coastal areas and most of them are in advanced state of decomposition, which precludes determining the causes of death.

In addition to the intrinsic collision risk, vessels are major contributors to the overall background noise in the sea, given their large numbers, wide distribution, and mobility (Richardson et al., 1995). Sound pollution could have deleterious effects on marine mammals (Richardson et al., 1995). This could happen through interference with the mammals' ability to detect calls from conspecifics, echolocation pulses, or other important natural sounds (Richardson et al., 1995; Hatch et al., 2008). Low-frequency vessel noise masked fin whale social sounds, and higher-frequency outboard noise masked minke whales sounds (Richardson et al., 1995). Studies on the response of humpback whales to approaching boats indicated that the duration of some song elements were altered (Norris, 1994; Sousa-Lima et al., 2002; Sousa-Lima and Clark, 2008), and that vocal behaviour could be interrupted (Tyack, 1981). The consequences of this disruption on individual and population level are poorly understood, but they may interfere with social ordering, sexual behaviour, care of young, and also with cooperative activities (Richardson et al., 1995).

Hydrocarbon exploration in the marine environment might have a double effect in marine mammal populations. Besides being a source of acute and chronic water pollution, this activity is developed in strong relationship with the marine traffic: seismic boats to identify hydrocarbon sources and monitor the extraction, ships charged of the installation process, supporting boats in the case of habitable platforms, to name a few. From 1999 and annually, the Brazilian National Petroleum Agency (ANP) auction areas designated for hydrocarbon exploration. They are called exploration blocks and consist of areas from which no previous knowledge about oil and gas occurrence is available, or from which current knowledge is not enough to characterize its potential. Once a block is bought it could pass by three stages – seismic, perforation, and production - and for each of them there are specific rules to be observed. However, the environmental impacts of each stage are analysed separately as if they were not different stages of the same activity. Besides, any kind of risk analysis is needed prior the establishment of exploration blocks along the Brazilian Coast and neither the ecosystem characteristics are taken into account.

Geographic Information Systems (GIS) are pointed out as a major tool for landscape management and planning, and as a support to decision-making for environmental zoning (Villa et al., 2002; Matthies et al., 2007). GIS provides a data structure for efficiently store and manage ecosystems data; perform analysis at multiple scales; identify environmentally sensitive areas; support spatial statistical analysis; manipulate remote-sensing information; and provide input for ecosystem modelling (Stow, 1993; Ninyerola et al., 2000). It is designed to support decision-making because of its analytical capabilities combined to its heuristic research potentialities. Capable of managing a large amount of geotagged data for diagnosis and modelling (Hjalmars et al., 1998; Palumbi et al., 2003; Friedlander et al., 2007) and the possibility to incorporate perception, knowledge and opinions of stakeholders about environmental issues, it can play an important role mainly in the mediation of conflicts relative to resources management and land-use policies (Villa et al., 2002; Teles and Saito, 2009). Additionally, GIS final products (resultant maps) are considered of easy understanding, capable of promoting visual insights, and can be directly employed by decision makers (Goodchild et al. 1992; Audet and Abegg, 1998; Goodchild and Haining, 2004). In the present study we aimed to identify risk areas for humpback whales' conservation along the Eastern Brazilian Coast related to marine traffic and hydrocarbon exploration by using GIS capabilities. Additionally, to identify where management effort is needed to ensure that human development will not decrease the quality of essential habitats used by the species as breeding and calving ground.

2. Material and methods

2.1. Study area

The survey area comprised the continental shelf between 12°10′S and 20°42′S that corresponds to the coastal waters of Bahia and Espirito Santo States. Following the geographic criteria adopted by the Living Resources in the Exclusive Economic Zone Program (REVIZEE) the study area is almost entirely comprised in the Eastern Brazilian Coast (EBC), which covers the continental shelf from 13° to 22°S covering 1324 km of coastline (Ekau and Knoppers, 1999). We recognize three sub-divisions along the EBC: Salvador to Belmonte (13–16°S) characterized by the presence of a bay and of fringing reefs (473 km of coast line); Abrolhos Bank (16–19°30′S) characterized by fringing and bank reefs and comprising 514 km of coastline; and Regencia to Cape São Tome (19°30′–22°S) characterized by river deltas and covering 337 km of coastline (Ekau and Knoppers, 1999).

Oceanographically the study area was characterized as Eastern Brazilian Shelf from 8 to 15° S and as Abrolhos-Campos Region from 15 to 23°S (Castro and Miranda, 1998). The Eastern Brazilian Shelf presents a very narrow continental shelf having a typical width of 15 km and shelf-breaks depths that vary between 50 and 60 m. Sea-surface temperatures show a slight decrease from north to south, the values usually being in the range 25–28 °C. Very complex topographic features characterize the Abrolhos-Campos region. A broad continental shelf is limited in the north by shallow banks that emerge from great depths. From a width of 35 km in its northern part, the continental shelf widens up to 110 km near the Royal Charlote Banks, narrows to 45 km between banks, widens again to 190 km in the Abrolhos Bank area, and narrows southward, reaching 80 km in the Campos region. Shelf-break depth lies between 60 and 100 m throughout most of the region. Average winter sea surface temperature ranges from 22 to 24 °C, and shows a weak vertical gradient.

The study area encompasses the most biologically diverse coral reefs of the entire South Atlantic Ocean, and is the only place where all species of the Brazilian coral reef fauna occur (e.g. Leão et al., 2003; Moura, 2003). The coral reefs of the region show a high degree of endemism, and the main reef-building species (genus Mussismilia) is itself endemic of Brazil (Leão et al., 2003). In addition, the region supports extensive mangroves, atlantic coast restingas and tropical forests. The economy of the coastal communities is based on artisanal fishery and tourism.

2.2. Humpback whale data

Humpback whales' distribution data was gathered as part of a regional scale assessment of the species. Survey design and data collection protocol were described in Andriolo et al. (2006, 2010). All sightings were recorded following line transect distance sampling protocol (Buckland et al., 1993) and were used to estimate the species density and abundance in the area (Andriolo et al., 2006, 2010).

Perpendicular distance (pdist) from the aerial transect line to a humpback whale group,

$$\text{pdist} = \text{Htan}(90 - \theta)$$

was calculated from the aircraft altitude (H) (500 ft) and the tangent of the angle (θ) between the horizon and the humpback

whale group, which was measured in the field with a clinometer. The geographic position of each group sighted was corrected using the perpendicular distance and the waypoint recorded with a hand-held Global Positioning System (GPS). Corrected positions were plotted on digital nautical charts using ArcGIS ® software version 8.3.

A density analysis was performed using a non-parametric fixed Kernel estimator (Worton, 1989) considering each year independently. The analysis was performed using the Spatial Analyst Extension (ArcGIS® software version 8.3). A search radius of 27 nautical miles (~50 km) was used to guarantee the integration of data from at least two transect lines, since they were spaced of 25 km. In addition to a density model, the method allows the extraction of density contours. A kernel density contour identifies the smallest area that includes the desired percentages (here 30, 50 and 90%) of all available positions. This means that the 90% density contour includes 90% of all observations, thus represents almost the entire range of the species distribution, while the 30% density contour represents the species core area with the highest density. Using the Raster Calculator operator of Spatial Analyst (ArcGIS® software version 8.3) an average density map was obtained from the raster files of the independent years (kernel2001, kernel2002, kernel2003). As aerial surveys represent an instantaneous picture of the animals' distribution at the peak of the breeding season, the species' core area was not at the same place in each different year. We assumed that the average model represents well the species range (kernel 90%) and core areas (kernel 50 and 30%) for the entire breeding season.

2.3. Risk analysis

We utilized the resulting average density map raster file, reclassified in four density intervals, to run a risk analysis in order to identify risk areas to humpback whales conservation in the Eastern Brazilian Coast. The risk areas were obtained from the overlay of the three components of the marine traffic and existent areas to oil and gas exploration (scenario of the year 2004). Marine traffic was subdivided in three components: coastal routes, off shore navigation corridors, and harbour areas. Hydrocarbon exploitation areas were considered without taking into account the development stage (seismic, perforation, or production).

The ArcGIS® software version 8.3 was chosen to create and manipulate the GIS layers. The *Xtools* extension (Delaune, 1997) was used to create some of the features. The tool Raster Calculator of the *Spatial Analyst* extension was used to identify the risk areas.

2.3.1. Coastal routes

Two barges carrying eucalyptus from Belmonte (Bahia State) and Caravelas (Bahia State) to Barra do Riacho (Espirito Santo State) started to operate in 2002. Their routes were constructed with *Xtools* extension based on the inflexion points gathered with the enterprises. For both routes we created two buffer areas, one with five nautical miles (nm), for each side of the route, and one of 10 nm. We did not consider the route *per se* but its buffer zones, as we assumed that the impact of a navigation lane are not restricted to the lane itself but to a surrounding area. Besides, at the establishment of the lanes only two barges were operating but at least four were planned to operate from each departure port.

2.3.2. Navigation corridors

Data on ship traffic were not available for the study area. Large ships were systematically recorded during the aerial surveys conducted to estimate humpback whales' density. A total of 152 ships were recorded (47 in 2001, 49 in 2002, and 56 in 2003) and at least five categories were represented: cargo boats, tugboats, tankers, platform ships, and barges. Data were used to identify the navigation channel by calculating a density index. The Kernel estimator was applied with the same search radius used to analyze whales' density but without distinction among years. The resulting raster map was used for the risk analysis.

2.3.3. Harbour and port areas

The geographic location of all eight harbours (five at Bahia State (BA), and three at the Espirito Santo State (ES)) and six ports (3 BA, 3 ES) existent in the study area up to 2004 were considered for analysis. Some of them – that were in close proximity – were grouped before the analysis. Three buffer areas (10, 20 and 30 nautical miles) were created to represent their influence area.

2.3.4. Proposed areas for oil and gas exploration

The geographic coordinates of the exploration blocks located from 10°S to 22°S were downloaded from the homepage of the Brazilian National Petroleum Agency (ANP) (ANP, 2004). The analysis of risk considered the block area itself and two buffer rings (10 and 60 nautical miles). The choice of the influence extent was based on the risk of an accidental oil spill in the area (Marchioro and Nunes, 2003).

2.3.5. Classification of risk areas

For each humpback whale density interval and each anthropogenic activity (and its adjacencies) a value was assigned (Table 1). Density intervals assumed increasing values from 1 to 4 (higher the density, higher the value), while anthropogenic factors assumed decreasing values (from the factor itself to each considered adjacency). For the analysis related to the navigation corridor, the resulted kernel density map was classified in three levels (0–0.3 ships/nm^2, 0.3–0.5 ships/nm^2, >0.5 ships/nm^2) for the risk analysis. The analysis of each anthropogenic activity influence area was made individually. After the individual analyzes, all areas classified with mid to higher risk (Table 2) were displayed together and were assumed to represent the thematic map of risk areas to the species conservation. When there was any overlap of different risk level at the same area, the higher risk prevailed. It was assumed that beyond the influence areas here defined the influence of the factor under analysis was of minor importance to the species conservation.

2.4. Marine Protected Areas & priority areas definition

Up to 2004, four Marine Protected Areas (MPA's) were identified in the study area: Abrolhos National Marine Park (ANMP), Ponta da Baleia – Abrolhos MPA, Corumbau Marine Extractive Reserve and Litoral Norte MPA. Their extent (as polygons) was used to identify which portion of the species range was already under legal

Table 1
Adopted classification for the analysis of risk and priority areas for humpback whales conservation (humpback whale density category (Dc); Anthropogenic Activity category (AAc); *related only to barge routes; # related only to harbour and port areas).

Whale density	Dc	Anthropogenic Activity (AA)	AAc
Low density of occurrence	1	AA or its first adjacency*# ship density >0.5 ships/nm^2	4
Moderate density of occurrence	2	First or second adjacency*# ship density0.3–0.5 ships/nm^2	3
High density of occurrence (kernel 50%)	3	Second or third adjacency# ships density <0.3 ships/nm^2	2
Highest rate of occurrence (kernel 30%)	4	Third or fourth adjacency	1

Table 2
Legend adopted to map the overlap of humpback whales density model and anthropogenic activities (AA) considered in the analysis ($\sum$ = summation of density category (Dc) and AA category (AAc) at each pixel).

$\sum$(Dc + AAc)	Legend
2	Lower risk or potential
3	Low risk or potential
4	Mid-low risk or potential
5	Middle risk or potential
6	Mid-high risk or potential
7	High risk or potential
8	Higher risk or potential

protection. A buffer of 20 nm was created around the ANMP, as this MPA category allows the definition of a buffer zone as part of its management plan (Brasil, 2000).

In order to identify priority areas for the species conservation along the Eastern Brazilian Coast we overlaid the global risk areas map to that of proximity to MPA's. Here, it was assumed that the habitats within the MPA's and the 20 nm buffer around the ANMP were already legally protected. Thus, the areas without a legal protection were classified with different levels of priority for the species conservation. The degree of priority attributed to a given area was dependent on the degree of exposure to human activities (as resulted from the risk analysis) (Table 2).

3. Results

3.1. Humpback whale data

Fig. 1 presents the species distribution from 2001 to 2003 and the average distribution model. The density values and the kernel percentage contour (30, 50 and 90%) highlight the core areas used by the species in each different year. Each aerial survey realization reflects the spatial distribution of the species at the moment of the survey and do not account for temporal variations. For this reason, the average distribution map and its core areas were assumed to be a better representation of the species habitat use to serve as baseline for the risk analysis.

3.2. Risk analysis

3.2.1. Coastal routes

Considerable overlap exists between both barge routes and important core areas for the species (Fig. 2). The coastal route deserves special attention close to Caravelas city which is near one of the identified core areas for humpback whales. The whole offshore route was classified as *high* and *higher* risk, and its inflexion in the southeastern portion of the ANMP deserves special attention.

3.2.2. Navigation corridors

The map with the index of ships density allowed us to identify the main navigation corridors that cross the study area, information that was not yet available for managers (Fig. 2). The main lane crosses the Abrolhos Bank from southwest to northeast and overlaps important core areas. The main overlap area, which was located at east and southeastern portion of the ANMP was classified as *higher* risk to the whales' conservation.

3.2.3. Harbour and port areas

The surroundings of the existent harbour and port areas were not classified as a risk to the species conservation. Only small and very localised nucleuses of overlap were identified in the proximity of Luciano Vilas Boas harbour (Caravelas city), Ilheus Port, Regência Harbor and Vitoria city (Fig. 2).

3.2.4. Proposed areas for oil and gas exploration

Between Salvador and Belmonte we find a high concentration of proposed areas to oil and gas exploration (Fig. 2). South of Salvador, portions of exploration blocks were classified as *mid-high* risk to the species. At the southern portion of the Abrolhos Bank the analysis revealed a completely overlap between two blocks and areas of high density of whales (30% kernel contour). Not only the blocks but also their adjacencies of 10 nm are of concern. The risk offered by a coastal block near Caravelas, due to its proximity to the species' core area that encompasses the ANMP, is also of extreme relevance.

3.2.5. Final thematic map of risk areas

The resulted thematic map of all combined anthropogenic activities revealed that the *high* and *highest* risk areas to the humpback whales' conservation in relation to the four considered factors were located in the Abrolhos Bank area (Fig. 2). The most important overlaps were located in the east and southeastern portion of the ANMP (related to ships traffic) and in the southern portion of the Abrolhos Bank (related to oil and gas exploration activities).

3.3. Marine Protected Areas & priority areas definition

The MPAs' network formed by the Abrolhos National Marine Park, Ponta da Baleia – Abrolhos MPA and Corumbau Marine Extractive Reserve guarantee the protection of the species core area closest to the Abrolhos Archipelago. However, they do not guarantee the conservation of the southern Abrolhos Bank's (Espirito Santo State) core area. This analysis highlighted the need of other instruments to guarantee the protection of the species' habitat conservation in Espirito Santo State. The southern portion of the Abrolhos Bank presents the most important conflicting areas due to a convergence of factors: high density of whales, lack of MPA's and the presence of oil and gas exploration areas (Fig. 3).

4. Discussion

4.1. Coastal routes, navigation corridors & harbour and port areas

The risk areas identified along the existent barge routes have a strong relation with the way the routes were conceived, highlighting the importance of detailed studies prior the establishment of new navigation corridors in the coastal areas. The coastal route was defined in collaboration with the Brazilian Humpback Whale Institute aiming to avoid the species main concentration areas based on the results of two years of aerial surveys (2001 and 2002 aerial surveys presented here), while the offshore barge route was defined based only in navigation priorities. A formal procedure should be developed and incorporated in formal environmental impact assessments as a response to the increasing volume of marine traffic worldwide and the recovery of large whales' populations.

The offshore barge route and the navigation corridor are of special concern to the species' recovery as they cross the Abrolhos Bank. The Bank presents perfect conditions for the species' breeding and calving activities and presents the highest frequencies of mother and calf groups (Martins et al., 2001; Morete et al., 2003). The navigation corridor represents short to long-term risk to the species conservation due to raising collision probabilities and continued noise disturbance.

Collision between large ships and humpback whales are common (Laist et al., 2001). Lethal or severe injuries are usually caused by ships 80 m or longer; whales are not seen beforehand or are seen too late to be avoided; and most lethal or severe injuries involve ships travelling 14 kn or faster (Laist et al., 2001). Among the stranding cases reported to the area, just few animals show marks

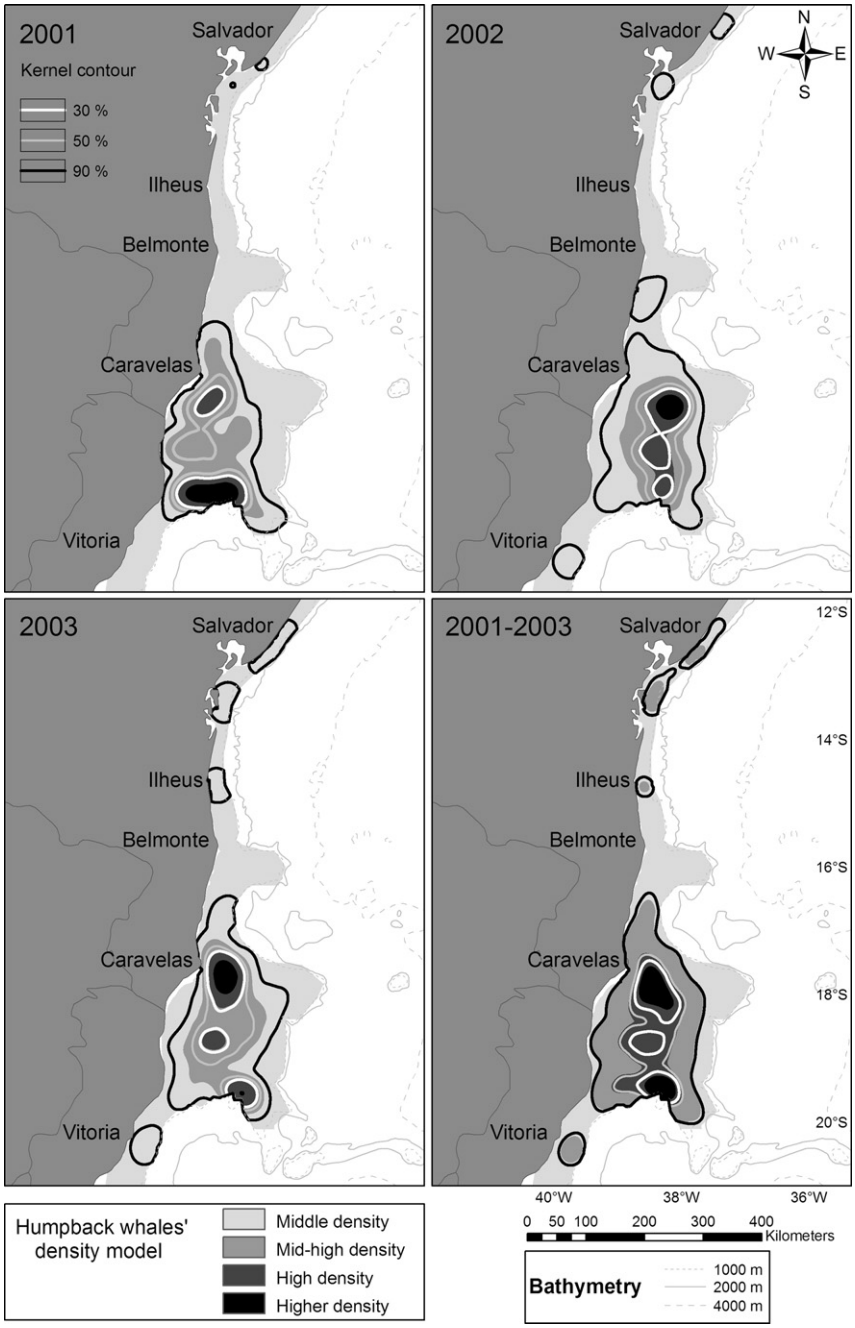

Fig. 1. Humpback whale distribution at the Eastern Brazilian Coast during the aerial surveys of 2001, 2002 and 2003 and the average distribution model along with the kernel percentage contours of 30, 50 and 90%.

of ship interaction (Milton Marcondes personal communication), but recently, two stranded animals were confirmed to be a result from ship strike (Marcondes and Engel, 2009). Worldwide the impact of ship strikes is still underestimated as strikes are usually unreported, a proportion of dead animals do not reach the coast (due to prevailing winds or predation by sharks), or reach the coast in advanced state of decomposition preventing in depth analysis.

The IWC recognizes the importance of ship strikes to the mortality of large whale species and has named a working group to advance the knowledge on the subject. Besides, repositioning of large ship lanes in consequence of whales' population recovery and overlain with navigation corridors have already begin in different areas. At the Mediterranean Sea, efforts are being made to find a solution to manage ship traffic in relation to the fin whale (*Balaenoptera physalus*) distribution inside the Pelagos Sanctuary where the species concentrate to feed in summer months (Notarbartolo-Di-Sciara et al., 2003; David et al., 2011). The navigation scheme of the port of Massachusetts was modified and a real time monitoring system detects and adverts the presence of right whales to passing ships (Kraus et al., 2005; Clark et al., 2007; Vanderlaan et al., 2008). Repositioning of the navigation corridor that crosses the Abrolhos Bank (mainly the southern portion of the lane within Espirito Santo State) should be evaluated in face of new data on the species habitat use and on reliable information of ship traffic intensity in the area. The later measure is supported not only due to increasing probabilities of ship strike but also due to continued exposure to noise that can have deleterious effects on the population (see discussion below).

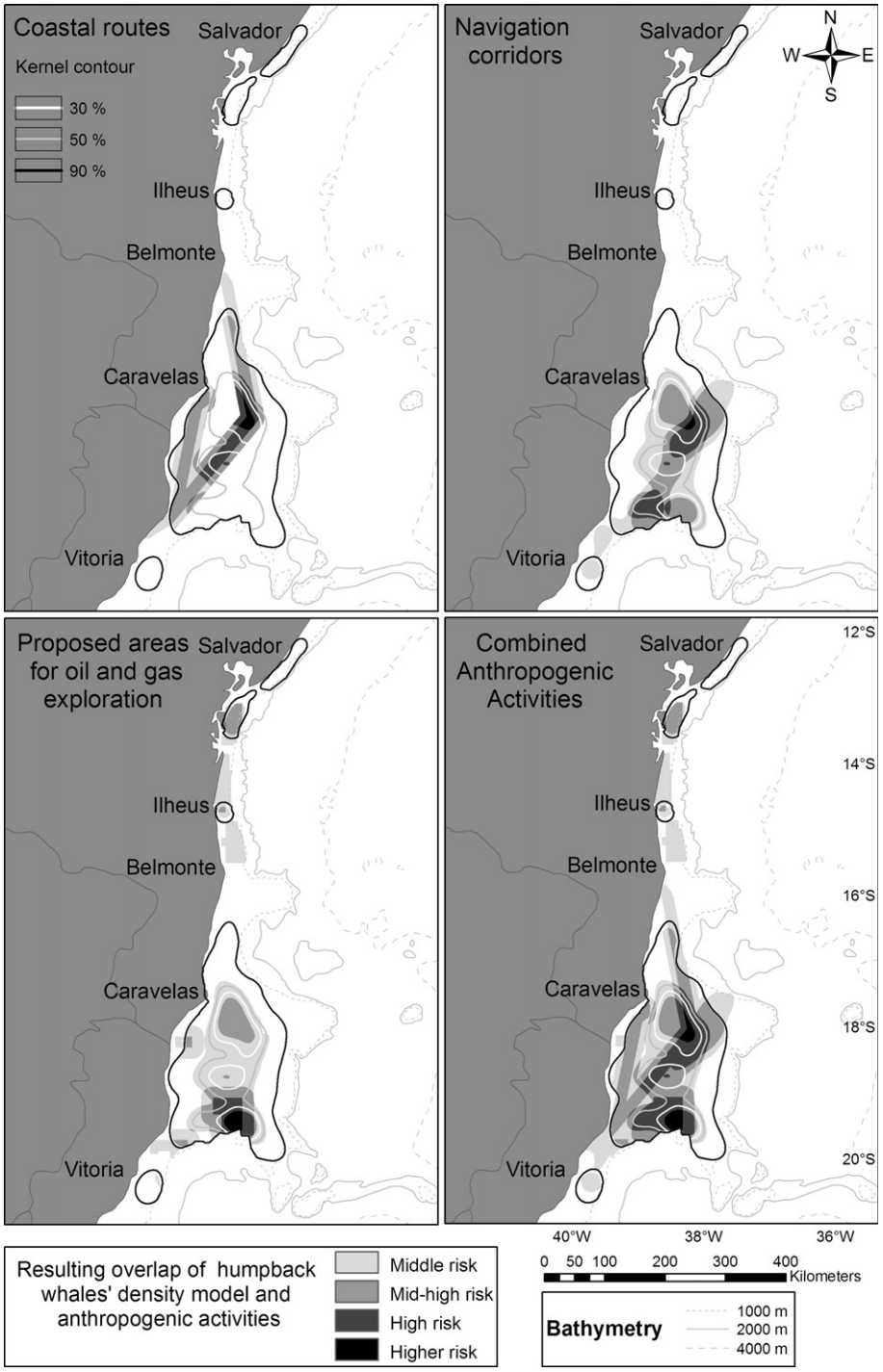

Fig. 2. Resulting map showing the risk areas to the humpback whale conservation at the Eastern Brazilian Coast related to coastal routes, navigation corridors, proposed areas for oil and gas exploration and all combined anthropogenic activities.

In Brazil recreational vessels are regulated under the IBAMA ("Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renovaveis") 117/96 federal act and its modification 024 from 08/02/2002. They regulate the actions that should be taken to prevent the injury of cetacean species and determine the rules that should be observed by vessels engaged in whale/dolphin watching. Whale watching vessel speed is regulated under the act, however, large ships are not considered by the law. Additionally, as a preventive measure we strongly recommend the inclusion of the species' distribution and season of occurrence in the Brazilian Navy Nautical Charts as it might alert ships and vessels crossing the area during their period of occurrence. Long distance sailors visiting the Abrolhos Archipelago during the whales' breeding season were often surprised by the whales density in the area, and stressed the importance of such information on nautical charts (Edson Patricio personal communication). Besides, fine-scale analysis should be conducted in order to verify the necessity of repositioning existent lanes to avoid concentration areas or of implementing speed reduction zones during the reproductive season within the species' core areas.

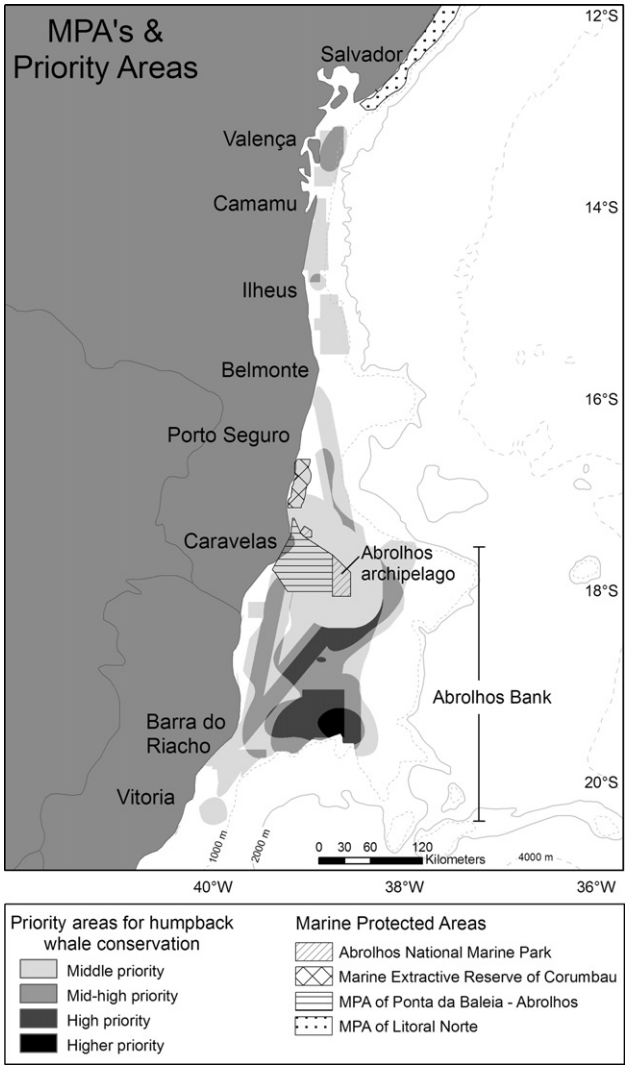

Fig. 3. Resulting map showing the priority areas to the humpback whale conservation at the Eastern Brazilian Coast resulted of the overlay of marine protected areas and risk areas (combined anthropogenic activities).

4.2. Proposed areas for oil and gas exploration

The analysis regarding the proposed areas for oil and gas exploration along the EBC revealed important conflicts in areas where other sources of systematic data on the species is lacking. We verified a total overlap with areas of high density of whales in the southern portion of the Abrolhos Bank. Also, seven exploration blocks (and their 10 nm buffer zone) cover the entire continental shelf south of Salvador up to Belmonte, an area that presents increasing whale density.

The exploration areas that were overlapped with the species distribution were in different stages of the petroleum and gas exploratory process. Some have been focus of seismic surveys, in others perforations were done or were scheduled, and some blocks were already been exploited. All the stages of the petroleum exploration process are associated to activities that introduce noise into the marine environment, acute (seismic surveys) or chronic (exploration platforms). Besides, intense ship traffic is associated to the exploration platforms (tanker and support ships, for example). Seismic is part of the whole process, as it serves to identify the presence of oil and gas and to monitor the petroleum exploration. Additionally, as the environmental licensing process is fragmented, with each stage of the petroleum exploration analysed separately (seismic, perforation and production) as they were not part of the same process, the whole is diluted in relatively less impacting activities.

The high densities of humpback whales observed in the southern portion of the AB indicate that this area is of essential importance to the species. The presence of calves in the area indicated that it is being used also as a calving ground (Instituto Baleia Jubarte unpublished data). The long-term monitoring of the species distribution and habitat use patterns is essential in order to evaluate the impact of the activity to the species recovery. It was observed at the Beaufort Sea that bowhead whales avoid areas of petroleum exploration during their migration (Schick and Urban, 2000) and many studies have shown that cetacean species avoid or abandon acoustic impacted areas (Richardson and Würsig, 1995; McCauley et al., 2000; Simmonds et al., 2003). Two possible consequences of a long-term exposure to a stationary noisy activity established near a marine mammal concentration area may be the habituation or the exclusion of the animals. If the animals fail to habituate, they will be excluded from an important concentration area or will be subject to ongoing stress while in the area, with long-term implications to the individuals and the population (Richardson et al., 1995; Hatch et al., 2008).

In face of the impact of the seismic activities to cetaceans, the Brazilian Humpback Whale Institute (BHWI) has drawn an excluding zone for this activity during the main humpback whale breeding season (July to November) that encompasses the shallow waters (shallowest than 500 m) between 19°50.4′S – 40°4.8′W (Barra do Riacho) and 11°29.4′S – 37°23.4′W (north of Salvador) (Engel et al., 2004). Besides, during the ANP auction of 2003, 183 of 243 predetermined blocks designated to oil and gas exploration in the vicinity of the Abrolhos Bank area were excluded from the selling (Marchioro and Nunes, 2003). The later was in response to a coalition of organizations that were against the auction. It was an important step to the conservation of the Abrolhos Bank ecosystem and it was a great victory of the civil society in favour of the environment. Afterwards, strategic evaluations by the ANP should be conducted previous to allocation of blocks in order to exclude areas of extremely environmental sensibility (Marchioro and Nunes, 2003). However, to date no legal and effective management measures guarantee the protection of this fragile ecosystem.

4.3. Marine Protected Areas

One possible solution to enhance the conservation of this important breeding and calving area is through the establishment of MPAs. The present analysis revealed that the existent MPAs of the Eastern Brazilian Coast are not enough to guarantee the protection of the main concentration areas of humpback whales during their reproductive season. In the coastal area between the South of Salvador city up to the vicinity of Ilheus there are seven coastal MPAs but none of them reaches the marine environment. Since this MPA category does not allow buffer zone definition, they have no jurisdiction on the marine portion, precluding their inclusion in the present analysis and their effectiveness to conserve coastal habitats. Although, besides the presence of whales, this portion of the EBC presents important mangroves and coastal reefs that should be integrated in an ecosystem-based zoning plan.

The Abrolhos National Marine Park (91.300 ha) created in 1983 (Brasil, 2000), guarantee the protection of the species concentration area located in the northern Abrolhos Bank, being the only MPA capable to delegate in their adjacency in the case of activities as oil and gas exploration. A buffer zone was decreed by the Park as a result of an in depth analysis of the possible impacts of oil and

gas accidents at the vicinity of the MPA (Marchioro and Nunes, 2003). However, it was suspended twice due to divergent political interests.

Marine Protected Areas should be representative of the environment to be protected and have to function efficiently, as recognized by the Biodiversity Convention, 21 Agenda and other acts and international diplomas (Prates, 2003). Almost the entire continental platform of the EBC is within coastal and marine priority areas identified by the Brazilian Biodiversity Conservation Plan (Brasil, 2002). It is extremely recommended to create new MPA's to integrate the already existent network of MPAs in order to enhance the ecosystem integrity. In addition, the Brazilian Environmental Minister and the United Nations Educational, Scientific and Cultural Organization (UNESCO) declared the Abrolhos Bank as part of the Atlantic Forest Biodiversity Reserve and Natural World Patrimony Site. Such status would be enough to guarantee the protection of this important ecosystem.

5. Conclusion

In the present work a large database was built and GIS capabilities allowed obtaining a broad view of the humpback whale distribution and density in relation with the main risk factors for its conservation at the Eastern Brazilian Coast. This database should be updated frequently, adding new factors and reanalyzing the ones here presented. The humpback whale was used here as an umbrella species, as the protection of its habitat allow the protection of an important coral reef ecosystem. However, the inclusion of other species in such analysis is of extreme relevance. In addition, at the time the work was conducted no information was available to characterize fisheries activities in the area, an aspect that should be considered in the future. The growing humpback whale population (Ward et al., 2011) and the increasing reports of whale–gear interaction (Zambonim et al., 2009) are of concern not only to the species conservation but also for the fisheries management. The study and management of this species interaction with fisheries, navigation routes, and oil exploration are recommended in the Brazilian Action Plan for Conservation of Aquatic Mammals (ICMBIO, 2011). This study provides an example of how the integration of GIS with knowledge on endangered species ecology and anthropogenic activities can guide management actions that recognize the interaction among different activities and their cumulative impacts on the ecosystem. The present work gives support to an ecosystem-based management and ocean zoning (Halpern et al., 2008) of this portion of the Brazilian coastal zone.

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