Are seismic surveys responsible for cetacean strandings? An unusual mortality of adult Humpback Whales in Abrolhos Bank, Northeastern coast of Brazil.

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Abstract
Humpback whales (*Megaptera novaeangliae*) aggregate at Abrolhos Bank, Bahia and Espírito Santo States, during spring-winter season for breeding and calving. The Instituto Baleia Jubarte/Humpback Whale Institute – Brazil maintains a permanent marine mammal rescue program along the coast adjacent to the Abrolhos Bank, aiming to register the strandings of humpback whales and to identify their probable cause of death. Since 2001 aerial surveys were also undertaken in order to evaluate the population size and distribution along the Bahia and Espirito Santo States coasts. During the 2002 breeding season, 3D seismic surveys were conducted in the Southern portion of the area, licensed by the Brazilian Environmental Agency/IBAMA. These surveys were coincident with an unusual increase in the strandings rate of adult humpback whales in this region. Some change was observed in the distribution of humpbacks, comparatively to 2001 and 2003 aerial survey data. In 2003, due to uncertainties regarding the relationship between these seismic activities and strandings, using the precautionary principle IBAMA agreed to incorporate in its recent guidelines for licensing the oil activities the prohibition of seismic surveys during the whale breeding season, from July to November. IBAMA is currently discussing and establishing rules and procedures for seismic surveys off the Brazilian coast, including the prohibition of these activities during the reproductive season in important areas for cetaceans as Abrolhos Bank.

Key words: humpback whales, seismic surveys, breeding ground, strandings

Introduction

Anthropogenic noise in the marine environment

Noise pollution in the oceans is an increasing problem, with impacts which are difficult to evaluate. According to Perry (1999), there is a lack of understanding of the short- and long-term consequences of this exposure to noise, due to insufficient research and to difficulties involved in judging noise effects in isolation from other threats.

Many studies have showed that cetaceans can avoid or leave an area because of noise (Richardson and Würsing 1995; Ketten 1998; McCauley *et al.* 2000; Simmonds *et al.* 2003).

Noise can cause temporary or permanent reduction of auditive sensibility (Fair *et al.* 2000). Some studies suggest that anthropogenic noise may increase the bycatch of cetaceans, collision with vessels and mass strandings, probably as a result of auditive system damage or dissimulation of important acoustic signals (Perry, 1999).

Stress in the marine mammals due to noise may cause the disruption of some activities, like resting, feeding and social interactions (Fair, *et al.* 2000). According to Perry (1999), short and long-term disruption of feeding and breeding behaviors because of noise pollution can threaten a whole cetacean population. When an animal is exposed to stress, he suffers a variety of neurochemical and hormonal changes which decreases its immune system. It makes the organism more vulnerable to many pathogenic agents like virus and bacteria. Events of mass mortality recorded in the 80's and 90's, have been associated to stress agents that cause the decreasing of immunity of marine mammals (Fair *et al.* 2000).

Evidence of disturbance from seismic surveys

In the past few years, an increase in seismic surveys worldwide, including Brazil, has been observed. During these activities, high intensity/low frequency sounds are emitted towards the Earth´s crust, reflecting in the geological layers (Simmonds, *et al.* 2003).

During seismic surveys, a single airgun usually produces sounds of 215-230 dB re 1 ?Pa-m and of 10-300 Hz (McCauley 1994, Greene *at al.*1995 *apud* Simmonds, *et al.* 2003). Although most energy is produced in low frequencies, a significant amount of such energy can be produced over 22 kHz (Gordon and Moscrop 1996 *apud* Simmonds, *et al.* 2003). Airgun sounds can propagate miles of kilometers. Studies developed in the North Atlantic Ocean recorded airgun sounds from Northeastern Brazil (Nieukirk *et al.* 2004).

Available data suggest that all marine mammals are potentially susceptible to the impact of sound sources with frequencies of 500 Hz or more. Mysticetes are particularly vulnerable. Regardless of frequency, sound levels that can cause acoustic damage vary according to the species, and constitute a complex interaction of many factors, as for example, time of exposure, characteristics and spectra of the source signal, and relation between the received sound versus the intensity of auditive threshold.

In odontocetes, seismic survey disturbances were described by Goold (1996), who monitored common dolphins *(Delphinus delphis*) in the Southern Irish Sea, and observed an avoidance reaction to seismic surveys in the monitored area (1-2km from the survey vessel). Mate *et al.* (1994) observed sperm whales in the Gulf of Mexico, and demonstrated that sperm whales were displaced 60km away from an area where seismic surveys were taking place.

In a series of studies using a 4000-cubic-inch-airgun array, 10% of gray whales showed avoidance to broad-band levels of 164dB re1µPa, 50% showed an avoidance reaction at 170dB re1µPa, and 90% at 180dB re1µPa (Weller *et al.* 2001).

In another study, McDonald *et al.* (1995) *apud* Perry (1999) acoustically tracked a blue whale while an airgun operation was being carried out, producing a pulse at 215dB re1µPa-m (10-60Hz band). The whale started its call sequence when the airgun vessel was 15km away, and approached the ship in a range of 10km (where it was subject to an estimated received level of 143dB re1µPa). After some silent time, the whale started a new call series and moved diagonally away from the vessel.

In Australia, humpback whales avoided a vessel during seismic surveys at least 3 km away; the sound for this distance was 157 to 164 dB re 1 ?Pa. Mother-calf pairs reacted to even longer distances (McCauley *et al.* 2000). Gray (*Eschrictius robustus*) and bowhead whales (*Balaena mysticetus*) also avoided seismic vessels when the sounds produced were of 150-180 dB re 1 ?Pa (Richardson *et al* 1995).

The case study

In the Southwestern Atlantic Ocean, humpback whales (*Megaptera novaeangliae*) aggregate at Abrolhos Bank (16°40´- 19°30´S and 37°25´- 39°45´W), Bahia and Espírito Santo States, for breeding and calving during spring-winter season (IBAMA/FUNATURA 1991; Engel 1996; Martins *et al.* 2001). Besides its importance to humpback whales, Abrolhos Bank is considered a hotspot area in Brazilian waters (Ministério do Meio Ambiente/Brasil, 2002). Other cetacean species like *Eubalaena australis*, *Sotalia guianensis* and *Steno bredanensis* are also frequent and use the bank as a breeding ground or as part of their home range.

During the 2002 humpback whale breeding season, 3D seismic surveys were conducted in the Southern portion of this area, under permit 242/02 of the Brazilian Environmental Agency - IBAMA. The Instituto Baleia Jubarte/Humpback Whale Institute – Brazil that maintains a permanent marine mammal rescue program in the Abrolhos Bank adjacent coast, aiming at recording strandings of humpback whales and at identifying their probable cause of death, recorded an unusual number of adult strands at this same season.

Here we present the strandings data, the areas where the seismic was done and an overview of the IBAMA efforts to establish guidelines for the seismic activities in the Brazilian coast.

Methods

Strandings Monitoring

Systematic surveys of *Megaptera novaeangliae* strandings were rare in Brazil. Siciliano (1997) conducted a review of humpback whale strandings along the Brazilian coast from 1975 to 1995, obtaining 37 records, which correspond to 31% of the strandings of mysticetes in this period. Pizzorno *et al.* (1998) found 8 new records in Rio de Janeiro State for the period of 1981 to1997. Many single reports or surveys refer to this

species (Siciliano, 1987; Dorneles *et al.*, 1994; Souza, 1996; Lima e Queiroz, 1996; Azevedo *et al*, 1996; Santos, 2000; Wallauer e Flores, 2000; Costa *et al.* 2002; Danilewicz *et al*, 2002; Estima *et al*, 2002).
The humpback whale strandings databank was compiled using both data collected by Instituto Baleia Jubarte/Humpback Whale Institute – Brazil and information from literature and other researches done along the coast. The *causa mortis* was determined according to the carcass conservation conditions.
Whenever possible, age was determined according to the total length of the animal. Whales measuring less than 8m were considered lactant calves (Nishiwaki, 1959; Rice 1963, apud Wiley *et al.*, 1994); newly independent were animals between 8 and 9.9m (Katona *et al*, 1983, apud Wiley et al. 1994). Males between 9.9m and 11.6m and females between 9.9 and 12m were considered sexually immature, but not newly independent. Males with more than 11.6m and females with more than 12m were considered sexually mature (Nishiwaki, 1959; Rice 1963, apud Wiley *et al.* 1994).

Results And Discussion

Strandings monitoring
Eight adult humpback whale strandings, corresponding to 26,7% of the total adult stranding reports between 1975 and 2003, were observed during the 2002 breeding season. Among these eight adult strandings, seven happened in Bahia or Espirito Santo States, and one in Rio de Janeiro´s Northeastern coast (table 1, in bold). Past strandings used to be mainly of calves (not longer than 8m) or immature animals, corroborating a study undertaken in the USA (Wiley et al. 1995) where, in thirty-seven stranded humpback whales, the biggest animal was 11.7m long.
Although no detailed necropsies could be done in the animals stranded during the 2002 season, there was no clear evidence of entanglements, the most common causes of whale strandings in the region, or collision with vessels. The analysis of strandings data must take into consideration the increased field effort that Instituto Baleia Jubarte has made since 1992, and the probable growth of the population.

Seismic surveys an Regulamentation Process
Seismic surveys were conducted during the 2002 humpback whale breeding season, between July and September for part of the blocks named BM-ES-3 and BM-ES-5, and from October 17 to December 19 in the block BM-ES-7 (figure 1), under permit 242/02 of the Brazilian Environmental Agency – IBAMA.
In 2003, Abrolhos Bank was the target of one of the biggest public awareness campaigns for the conservation of the Brazilian marine environment. Conservation International-Brazil, Instituto Baleia Jubarte/Humpback Whale Institute-Brazil, and other non-governmental organizations, actively pursued this campaign and supported IBAMA with scientific data to convince the Brazilian Government to exclude this area from an auction of blocks for oil exploration and exploitation.
After that, IBAMA adopted a more restrictive posture regarding the environmental licencing process. Uncertainties referring to the impacts in marine mammals caused by the seismic data survey operations, led the Centro de Mamíferos Aquáticos/Aquatic Mammal Center – IBAMA and the Escritório de Licenciamento de Petróleo e Nuclear/Oil and Nuclear Licensing Office – IBAMA to suggest the adoption of mitigation measures that were added to biota monitoring projects nedded to obtain environmental permits for seismic surveys. For the auction in 2004, IBAMA was able to exclude almost all of the Abrolhos Bank due to humpback whale occurrence and, in other shallow waters, due to the ocurrence of manatees *(Trichechus manatus)* and Southern Right whales (*Eubalaena australis*). For the few blocks that were maintained in the Southern portion of the Abrolhos Bank, a temporary exclusion, from July to November, will be applied.
Mitigation measures followed the precautionary principle and the Brazilian Aquatic Mammals Action Plan, aiming to control and verify the possible impacts of seismic operations in the marine biota, and to provide additional information for species conservation.
Some of the adopted procedures are standardized for seismic operations worldwide, such as the *soft-start* (progressive increasing of the airgun shots, in order to avoid marine animals near the area of these activities).
According to guidelines recently established by IBAMA, marine mammal sightings have been done onboard seismic vessels by marine mammal specialists, covering a 180^{o} focal angle, in order to stop the airgun shots every time these animals are seen less than 500m away. This monitoring is also an important tool to generate data about the occurrence of species.
Additional requirements for licensing such operations have been determined in more thoroughly surveyed areas regarding the occurrence, status and habitat use of marine mammals, as follows: (i) Monitoring of the beaches adjacent to the seismic survey areas, twice a day, aiming to rescue, as soon as possible, stranded

animals and/or carcasses. This monitoring must be done by a veterinarian able to determine the cause of death, and licensed to collect and transport biological material according to IBAMA Edict nº 332; (ii) studies of the acoustic decaying in that place and time; (iii) information campaign aimed at the local communities; (iv) establishment of seasonally restricted zones, as for example the adoption of a long exclusion zone for seismic surveys in reproductive humpback whale ground between Barra do Riacho, Espirito Santo State (19º50.4´S, 40º4.8´W) and Mangue Seco, Bahia State (11º29.4´S, 37º23.4´W) below 500m deep from July to November.
Acoustic monitoring is also being considered in federal regulations as an efficient tool to identify marine mammal presence in seismic survey zones, since the sighting of them is sometimes difficult due to bad environmental conditions.

Conclusions

Although the relationship between the seismic survey operation period and the observed increasing in the adult strandings rate could not be cientifically comprovated, we strongly believe that the appropriate management response must be the prohibition of seismic surveys during the humpback whale breeding season, from July to November. Also, some change was observed in the distribution of humpbacks, comparatively to 2001 and 2003 aerial survey data (Martins et al. SC/56/SH6) which could be related to the seismic surveys done in the area**.** But this information must be carefully analyzed considering that other environmental or anthropogenic factors may also be significant for the same period of time. The humpback whale population is considered as vulnerable to extinction (IBAMA 2001) and has in the Abrolhos Bank its most important breeding ground in the Southwestern Atlantic Ocean.
Considering that the disruption of breeding and calving activities in preferred areas is a biologically significant event that could have major negative effects, both on individual whales and the population as a whole, the same guidelines would be also important to other known cetacean breeding grounds, such as for Southern Right Whales in Santa Catarina State.
According to Perry (1999) there is an immediate need for systematic research regarding the effects of anthropogenic noise on cetaceans worldwide. The establishment of hearing thresholds and response thresholds to low frequency anthropogenic noise should be a priority, along with studies of the long term impacts of behavioural disturbance, auditory damage and masking of acoustic signals. Cumulative effects with other environmental threats, such as pollution and global climate change, must also be considered in assessing the impact of noise.
Some countries like Australia, UK and USA have recently established guidelines for oil exploration/exploitation, including seismic operations. Brazil is at the moment taking a precautionary approach to the issuing of permits according to the abovementioned requirements, analysing the available scientific data about the subject and developing the appropriate guidelines to harmonize oil-related activities with the long-term survival of cetaceans and the ecosystem as a whole.
The creation of a data bank compiling different seismic survey data in relation to acoustics and cetaceans would be also very useful to widen the knowledge regarding this subject, contributing to improve the oil exploration/exploitation licensing process in Brazil and elsewhere. Furthermore, it could be useful for the International Whaling Commission to explore ways of encouraging and supporting the development of adequate guidelines to regulate seismic activities potentially detrimental to cetaceans and their environment.

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Table 1. Registers of strandings of adult humpback whales from 1964 to 2003 in the Brazilian coast (Instituto Baleia Jubarte data bank by diverse authors).

Ano	Adults	Total Registros
1964		01
1975	01	01
1977		01
1980		01
1981		01
1984		01
1985		01
1986		02
1987	01	06
1988		02
1989	02	02
1990		03
1991	01	02
1992	01	06
1993	01	10
1994	02	4
1995	02	10
1996	01	06
1997	02	13
1998		06
1999	01	13
2000	02	09
2001	02	14
2002	08	20
2003	03	20
Total	**30**	**155**

Table 2. Humpback whale strandings in 2002

Register	**Date**	**Place**	**Sex**	**Total lenght**	**Age**
05C0212/120	14 março	Bertioga - SP	F	7	Calf
05C0212/121	04 abril	Capão da Canoa - RS	F	7,27	Calf
05C0211/122	**06 junho**	**Caravelas - BA**	**M**	**13,7**	**Adulto**
05C0211/123	**10 junho**	**Mucuri - BA**	**M**	**14**	**Adulto**
05C0210/124	04 julho	Ilha de Itaparica - BA	Ind	6	Calf
05C0211/125	06 agosto	Imbassai - BA	M	4,3	Calf
05C0211/126	**17 agosto**	**Porto Seguro - BA**	**M**	**13,35**	**Adult**
05C0210/127	22 agosto	Praia Grande - ES	Ind	-	Ind
05C0210/128	23 agosto	Prado - BA	Ind	4*	Calf
05C0210/129	**28 agosto**	**Buzios - RJ**	**Ind**	**12,5**	**Adult**
05C0211/130	28 agosto	São Mateus - ES	M	5	Calf
05C0210/131	29 agosto	Coroa Vermelha - BA	Ind	-	Ind
05C0212/132	**20 setembro**	**Barra do Sahy- ES**	**F**	**15,05**	**Adult**
05C0210/133	18 setembro	Itaúnas - ES	Ind	4,6	Calf
05C0210/134	**27 setembro**	**Mucuri - BA**	**Ind**	**14,75**	**Adult**
05C0210/135	30 setembro	Touros - RN	Ind	4,5	Calf
05C0210/136	**03 outubro**	**Barra do Riacho - ES**	**Ind**	**16,5**	**Adult**
05C0211/137	**29 outubro**	**Sítio do Conde - BA**	**M**	**15**	**Adult**
05C0210/138	12 novembro	Abrolhos - BA	Ind	-	Ind
05C0210/139	16 novembro	Ilha Queimada Grande - SP	Ind	-	Ind

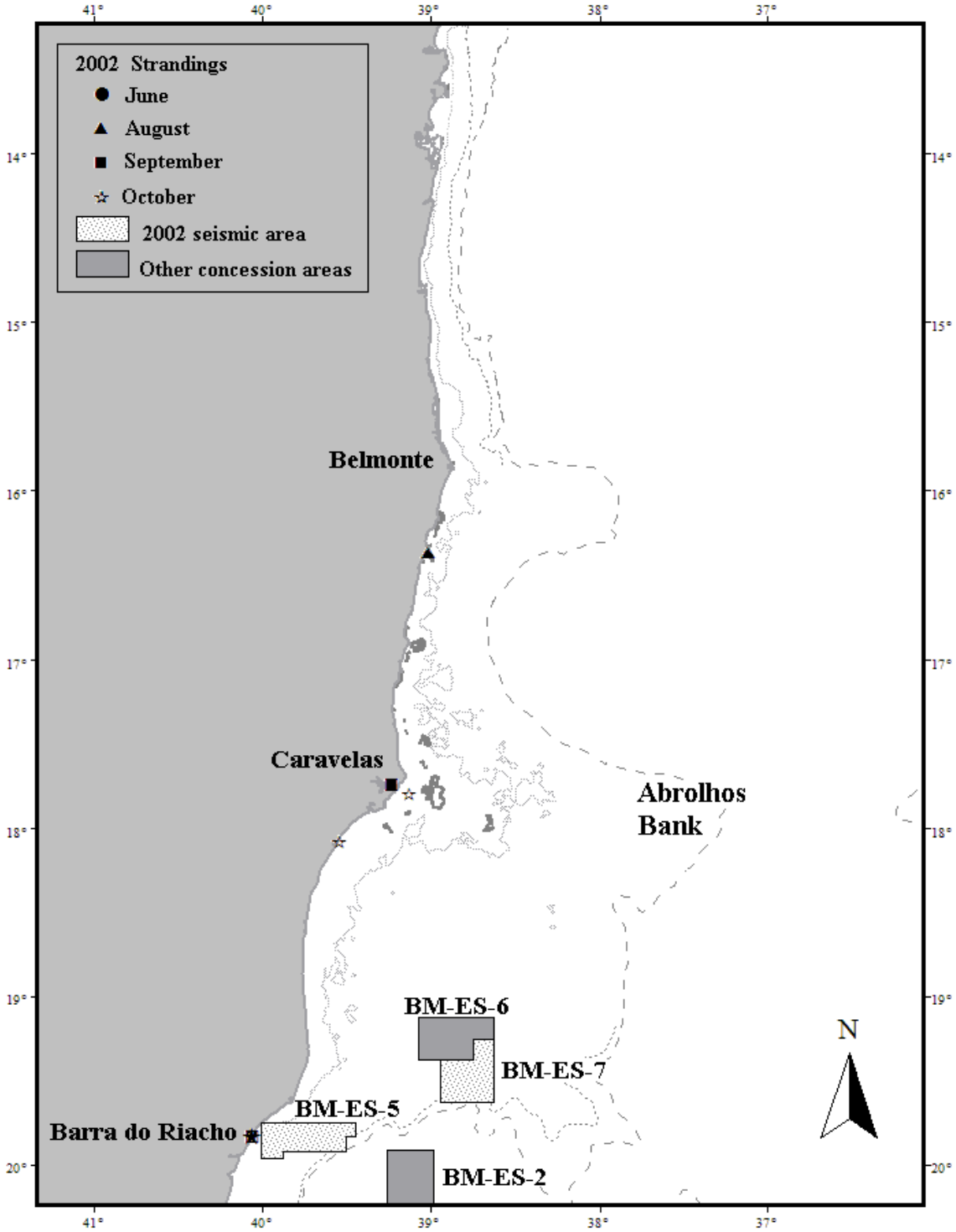

Figure 1. Areas destinated to oil na gas explotaition (Blocks BM-ES-5, BM-ES-6, BM-ES-7, BM-ES-2) and 2002 strandings registered by Instituto Baleia Jubarte.