Long-term acoustic monitoring of baleen whales in the Southern and Indian Sanctuaries

Introduction & Background

The intensive whaling in the 20th century dramatically reduced the baleen whale populations to near extinction. In the Southern Hemisphere, for example, more than 99% of the blue whale populations were hunted prior to the creation of the first whale sanctuaries by the International Whaling Commission in 1974 (Clapham & Baker, 2001). Since gaining complete legal protection from commercial whaling, several baleen whale populations have remained at low levels (Branch & Butterworth 2001a) and their recovery is uncertain (Branch et al. 2007; 2008). Baleen whales are now on the red list of the International Union for Conservation of Nature (IUCN, www.iucnredlist.org) and some of them are listed as 'Endangered Critical Status' like the Antarctic blue whale and others are 'data deficient' because basic status information is lacking in many cases, and knowledge regarding distribution, abundance or specific habitat preferences is most of the time absent.

Monitoring cetaceans to predict the precise status and recovery of populations is difficult. This is particularly the case for baleen whales because they are often found in low densities well offshore and occupy hostile environments during part of their life history (e.g. Polar Regions). Moreover, the lack of information about the current occurrence and distribution of baleen whale underscores the difficulty to study these species using traditional visual surveys. In the Southern Ocean, since the end of legal whaling, only occasional visual surveys have been conducted, and small numbers of animals have been sighted (Branch & Butterworth 2001a, Thiele et al. 2004). Studying large, free-ranging marine mammals such as blue whales is very a challenging task because they are hard to find, and almost impossible to follow at sea over long periods of time.

In the Southern and Indian Oceans, only during austral summer, cetacean visual surveys have been conducted every year since 1978 along the routes of the research vessel *R/V Marion-Dufresne* between La Reunion Island and the French sub-Antarctic Islands (i.e. Amsterdam, St Paul, Crozet and Kerguelen) (Thiebot & Weimerskirch submitted). Weather and sea conditions combined with the scarcity of individuals do not allow to obtain reliable estimates of baleen whale population numbers with traditional (visual) methods (CEBC-CNRS, unpublished data). Moreover, boat-based visual surveys cannot be conducted through a whole year cycle and represent considerable and expensive logistical constraints for very low sighting rates. In this context we need to use other tools to study whale populations.

Passive acoustic monitoring

Today, it is possible to take advantage of the recent developments in computer technology to use a relatively novel and relevant method to study whale populations: **passive acoustic observation**. Baleen whales such as blue whales are known to produce intense, low frequency, species specific calls (McDonald et al. 2006) that can be detected at distances of several tens of kilometers (Stafford et al. 2007) and much farther (hundreds of kilometers, Clark 1995) with acoustic sensors named hydrophones. By making continuous acoustic recordings, it is possible to obtain long-term records of calling animals over large regions in order to assess the species' presence, timing of migrations, peak periods of relative abundance, seasonality, and distribution patterns over large spatial scales (Nieukirk *et al.* 2004, Stafford *et al.* 2007).

The use of passive acoustic data has become an important means of studying baleen whales in all oceans of the world (Mellinger et al. 2007) especially because these methods can be used at night and year round, in poor weather and in remote locations that are difficult to access by more traditional means. In joint visual-acoustic surveys, acoustic monitoring has detected one to ten times as many cetacean groups as visual monitoring (Širovic *et al.* 2004, Rankin *et al.* 2005). Furthermore, the trends of number of calls detected with long term acoustic monitoring could be correlated with the number of individuals. In this case, acoustic long term monitoring could be useful to assess the health of these

different populations of baleen whales. This non-lethal and non-intrusive method has been used to infer occurrence, distribution and migration of blue whales in the west Antarctic Peninsula region (Širovic et al. 2004, Mellinger et al. 2007), low latitudes in the Indian and eastern Pacific (Stafford et al. 2004) and around the Antarctic continent (Rankin *et al*. 2005, McKay *et al.* 2005**,** *Širovic et al.* 2008).

Passive acoustic survey methods have the additional advantage of easily discerning subspecies or subpopulations of baleen whales by using the difference in call characteristics among subspecies (McDonald et al. 2006, Stafford et al. 2001). For example, in the southern hemisphere there are at least 2 distinct blue whale subspecies (Rice 1998): *B. m. intermedia* (the Antarctic or true blue whale) of the Southern Ocean and *B. m. brevicauda* (the pygmy blue whale) found in the Indian Ocean and South Pacific Ocean. These subspecies present very subtle morphologic differences on the shape of the head, tail and blowhole (Ichihara 1961) that are hard to identify and distinguish visually at a distance. However acoustic monitoring makes distinguishing amongst them very simple: call characteristics of blue whale subspecies are very different in term of frequency, time and pattern (Fig. 1). Moreover, pygmy blue whale presents possibly 3 acoustic populations with very distinct calls: 'Madagascar type' call, 'Australian type' call and Northern Indian 'Sri Lanka' type call (McDonald et al. 2006).

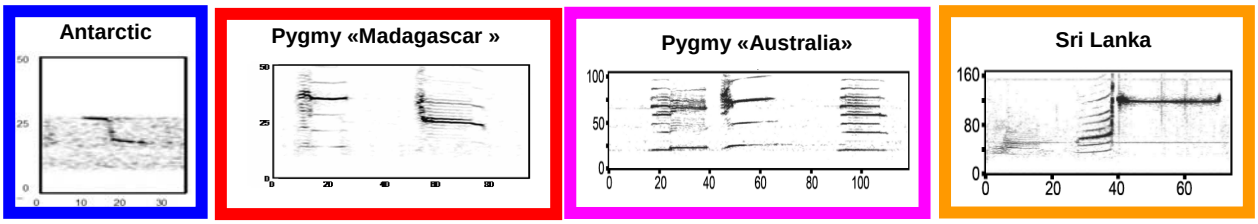

Fig. 1: Time frequency representation (spectrograms) of calls of different blue whale subspecies in Southern and Indian Oceans (Samaran, 2008)

Previous studies in South-western Indian Ocean

This method seems to be particular relevant to study baleen whale populations but no acoustic studies were conducted in the Southern Ocean south of the Indian Ocean or in the Indian Ocean, important areas where different blue whale subspecies co-exist (Branch *et al*. 2007).

Passive acoustic monitoring was successfully tested in 2003-2004 near the Crozet Islands (French Southern and Antarctic Lands – Fig. 2 green star) in the Southern Indian Ocean in the framework of collaboration between the Commissariat à l'Énergie Atomique (CEA) and the CEBC-CNRS, with support of the French Ministry of the Environment (Samaran 2008). A year-long acoustic data set recorded from a permanent hydro-acoustic station (now out of order) of the International Monitoring System (IMS) deployed for the Comprehensive nuclear-Test-Ban Treaty (CTBT) has been analysed to provide the annual cycle of occurrence of baleen whale in this area by using species specific calls.

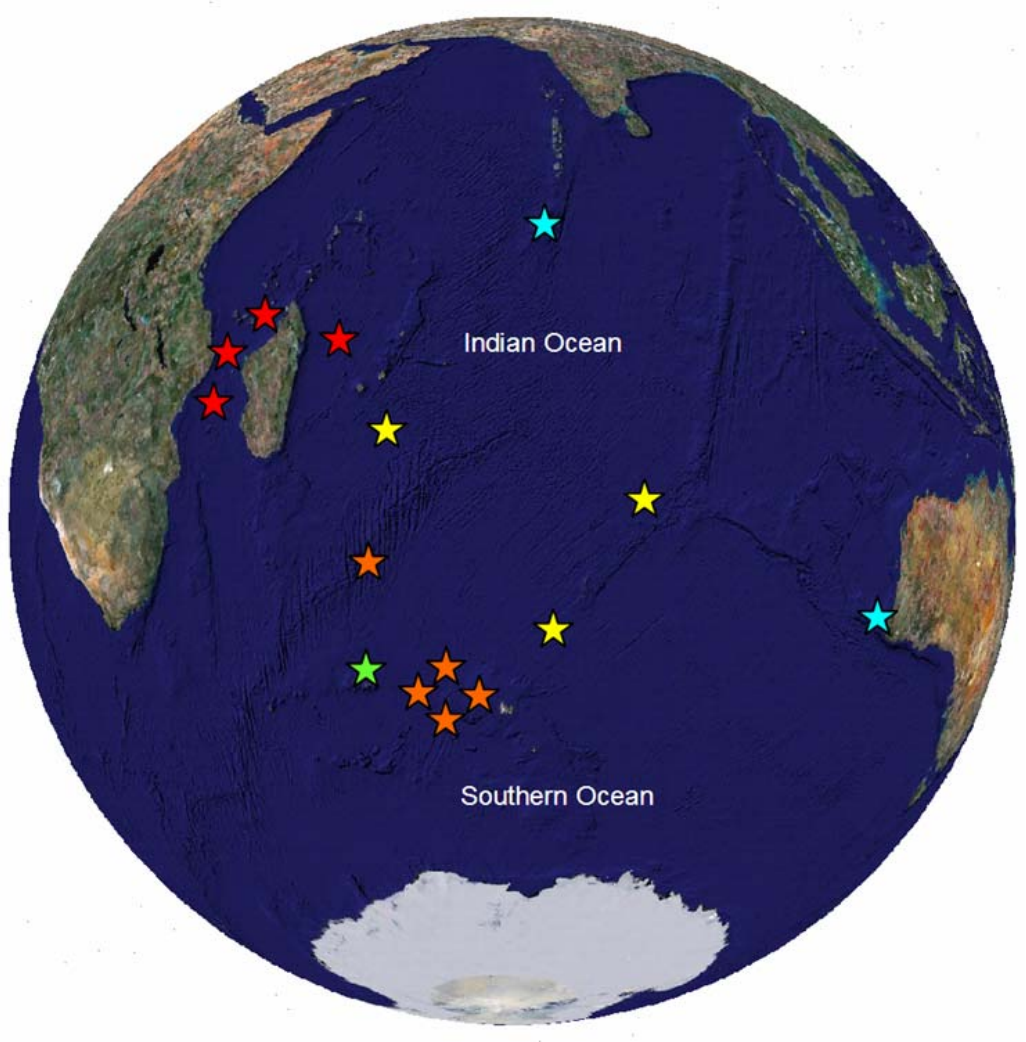

Fig. 2: Locations of autonomous hydrophones that collected baleen whale acoustic data. Yellow stars: hydrophones array for seismic monitoring set by the laboratory 'Domaines Océaniques' of CNRS/University of Brest in collaboration with the NOAA/Oregon State (data collected from 10/2006 to 01/2008). Blue stars: hydrophones from the International Monitoring System of CTBTO (data collected from 2003 up to now). Green star: hydrophones from the International Monitoring System of CTBTO (data collected from 05/2003 to 04/2004 and analyzed in Samaran PhD dissertation). Orange stars: hydrophones array for seismic monitoring set by the laboratory 'Domaines Océaniques' of CNRS/University of Brest (mooring planned for the end of 2009 for 2 years). Res stars: hydrophones array for Passive Acoustic Monitoring of cetaceans around Eparses Islands (data collected from 05/2009 to 05/2010)

The configuration of the instruments has permitted to record the low frequency calls of the blue and the fin whales but was too low to record sounds from the humpback whale, the minke whale and toothed whales such as the sperm or the killer whale. However, acoustic data analysis revealed that 5 species / subspecies or subpopulations of endangered baleen whales are present in the south-western Indian Ocean with a strong seasonal occurrence (Fig.3).

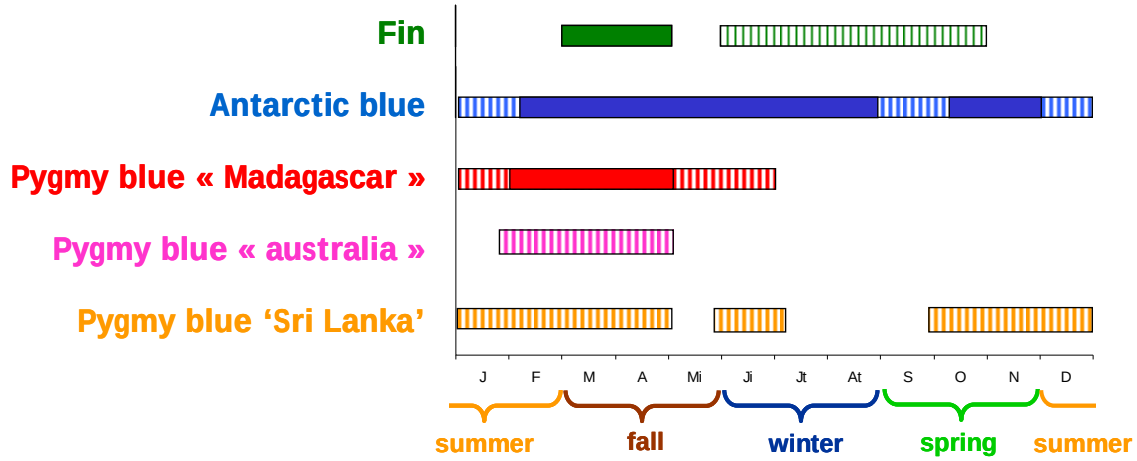

Fig. 3: Baleen whale calls detected at Crozet: Seasonal occurrence. Hatched areas represent few calls detection (Samaran, 2008).

Fin whale calls were detected occasionally and only during austral fall-winter. Antarctic blue whale calls are very abundant and occurred year round with peak calling during fall and winter. Calls of pygmy blue whales 'Madagascar type' are detected only during summer and fall period in association with specific high frequency calls associated with feeding activities. Calls of pygmy blue whales 'Australian type' and 'Sri Lanka type' are detected occasionally only during summer and fall period. The year-round occurrence of blue whale subspecies differed but they were sympatric part of the year especially during summer and fall. These results suggest that this sub-Antarctic area is an important feeding ground for blue whales (Samaran 2008). In this area, water masses form a complex and dynamic system that is thought to maintain a high biological productivity especially during the austral summer, which influences marine mammal foraging (Pollard *et al*. 2007). This first investigation raises new questions about the classic theory of blue whale migration patterns and the current seasonal distribution of baleen whale especially blue whale subspecies at larger scales beyond just the Crozet Archipelago.

Existing data and further works

This original approach represents the first French contribution on baleen whale research in this specific area which covers the two main whale sanctuaries created by the International Whaling Commission. The next step of this work is to analyse other long term data sets initially collected for detecting bioacoustic, seismic or military activity at different sites in the Southern Indian Ocean in order to obtain a complete annual picture of occurrence, seasonality, distribution and movements of baleen whales over a much broader area.

The data sets to be analysed for this further work come from three sources: the "Laboratory of Domaines Océaniques - LDO' of CNRS - University of Brest (UBO), the International Data Center (IDC) of the Comprehensive Test Ban Treaty Organization (CTBTO) and the Agence des Aires Marines Protégées (AMPP) via the CEBC-CNRS and the LDO-CNRS-UBO. One year-round of acoustic records in 2007-2008 (Deflo-Hydro project LDO-CNRS-UBO – Fig. 2 yellow stars) has already been collected and will be completed by another year-round of acoustic records in 2009-2010 (OHA-SIS-BIO project: Observatory of HydroAcousticity from SISmicity and Biodiversty in the Indian Ocean LDO-CNRS-UBO and CEBC-CNRS). The project plans to moor 5 to 8 autonomous hydrophones for at least 2 years in the southern Indian Ocean (Fig. 2 yellow and orange stars) with a specific configuration to localize calling whales. Acoustic data sets recorded by the two other permanent hydroacoustic stations of the CTBTO are currently available to be analysed. These stations are located near the Diego Garcia atoll in the central Indian Ocean and near Cape Leeuwin off the southwest coast of Australia (Fig. 2 blue stars). These hydroacoustic stations have been collecting data

since 2003. Four hydrophones were moored in april-may 2009 in the western part of the Indian Ocean near Eparses Islands to recorded baleen whale sounds during one year (Passive Acoustic Monitoring of cetaceans around Eparses Islands project AAMP and LDO-CNRS-UBO and CEBC-CNRS Fig. 2 red stars).

Long term acoustic monitoring from opportunistic structures such as hydroacoustic seismic experiments or the IMS provides unique data sets to obtain crucial information on baleen whales that is currently lacking despite their critically endangered status. This project intends to compare baleen whale seasonal occurrence in different parts of Southern and Indian oceans (both latitudinally and longitudinally) over mid-and long-terms. Results will give some important outcomes for the conservation of these baleen whale species and the protection of their critical habitat. This research project is motivated by the interest of the International Whaling Commission for additional information about regional blue whale stocks needed for future management recommendations.

This project will be implemented through a multidisciplinary scientific approach built upon collaboration with several scientists from different institutions with complementary expertise: the Centre d'Etudes Biologiques de Chizé - CNRS (Marine predators Team), the University of Paris Sud (NAMC Lab-Bioacoustic Team), the University of Brest (Domaines Océaniques Laboratory) and the University of Washington (Applied Physic Laboratory – Ocean Acoustics Team). Data will be provided by the International Data Center of CTBTO in the framework of a new global scientific endeavour to carry out scientific studies and assessments to assess the capability of CTBTO systems. Financial and logistical supports is provided by the IPEV (Institut Polaire Français), the Terres Australes et Antarctiques Françaises, the AAMP (Agence des Aires Marines Protégées), the INSU, the French government (MEEDDAT) and the Total Foundation for the biodiversity.

Bibliography

Branch, T.A. & 46 authors. 2007a. Past and present distribution, densities and movements of blue whales in the Southern Hemisphere and northern Indian Ocean. Mam. Rev., 37(2), 116-75.

Branch T.A. 2008. Abundance of Antarctic blue whales south of 60°S from three complete circumpolar sets of surveys. JCRM, 9(3), 253–262.

Branch T.A. & Butterworth D.S. 2001a. Southern Hemisphere minke whales: standardised abundance estimates from the 1978/79–1997/98 IDCR/SOWER surveys. Journal of Cetacean Research and Management 3, 143–174.

Clapham P.J. & Baker C.S. 2001. How many whales were killed in the Southern Hemisphere in the 20th century? Paper SC/53/O14 presented to IWC Scientific Committee, 3pp. (Available from IWC, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK, secretariat@iwcoffice.org).

Clark C.W. 1995. Matters arising out of the discussion of blue whales. Report of the International Whaling Commission 45, 210-212.

Ichihara T. 1961. Blue whales in the waters around Kerguelen Island. Norsk Hvalfangst- Tidende 50, 1– 20.

McDonald M.A., Mesnick S.L. & Hildebrand J.A. 2006. Biogeographic characterization of blue whale song worldwide: using song to identify populations. JCRM. 8, 55–65.

Mckay S., Širovic´ A. & Thiele D. 2005. Preliminary results of blue whale (Balaenoptera musculus) call detections in Eastern Antarctica. Paper SC/57/SH4 presented to the IWC Scientific Committee (Available from IWC, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK, secretariat@iwcoffice.org).

Mellinger D.K., Stafford K.M., Moore S.E., Dziak R.P. & Matsumoto H. 2007. An overview of fixed passive acoustic observation methods for cetaceans. Oceanography 20(4):36-45.

Nieukirk, S.L., Stafford, K.M., Mellinger, D.K., & Fox, C.G. 2004. Low-frequency whale sounds recorded from the mid-Atlantic Ocean. Journal of the Acoustical Society of America, 115(4), 1832–1843.

Pollard, R.T., Venables, H.J., Read, J.F. & Allen, J.T. 2007. Large-escale circulation around the Crozet Plateau controls an annual phytoplankton in the Crozet Basin. Deep Sea Research Part II, 54, 1915-1929.

Rankin S., Ljungblad D., Clark C. & Kato H. 2005. Vocalisations of Antarctic blue whales, Balaenoptera musculus intermedia, recorded during the 2001/2002 and 2002/2003 IWC/SOWER circumpolar cruises, Area V, Antarctica. Journal of Cetacean Research and Management 7, 13–20.

Rice, D.W. 1998. Marine Mammals of the World: Systematics and Distribution, edited by K.S. Lawrence. Allen Press Inc.

Samaran F. Adam O., Motsch J.-F. & C. Guinet, 2008 : Definition of the Antarctic and Pygmy Blue whale call templates. Application to fast automatic detection. Canadian Acoustic, 36, 93-102.

Širovic´ A., Hildebrand J.A., Wiggins S.M., McDonald M.A., Moore S.E. & Thiele D. 2004. Seasonality of blue and fin whale calls and the influence of sea ice in the Western Antarctic Peninsula. DSR II, 51, 2327–2344.

Širovic´ A., Hildebrand J.A., Wiggins S.M. & Thiele D. 2009. Blue and fin whale acoustic presence around Antarctica during 2003 and 2004. Mar. Mam. Sc., 25 (1), 125-136.

Stafford K.M., Nieukirk S.L. & Fox C.G. 2001. Geographic and seasonal variation of blue whale calls in the North Pacific. JCRM, 3, 65–76

Thiebot J.-B.and Weimerskirch H. submitted. Contrasted associations between seabirds and marine mammals across four biomes of the southern Indian Ocean.

Thiele D., Chester E.T., Moore S.E., Širovic A., Hildebrand J.A. & Friedlaender A. 2004. Seasonal variability in whale encounters in the Western Antarctic Peninsula. Deep-Sea
Research II 51, 2311-2325.