Identifying dangerous grounds for fast ferries and fisheries
The model of a permanent passive acoustic sonar system for monitoring Cetacean movements

Torda, G.[1,2] and López Jurado, L. F.[1]

1 Facultad de Ciencias del Mar, Universidad de Las Palmas de Gran Canaria, Campus Universitario de Tafira, 35017, Las Palmas, Spain

2 Institute of Ecology and Botany of the Hungarian Academy of Sciences, Alkotmány u. 2-4., 2163, Vácrátót, Hungary

INTRODUCTION

Fast ferries' routes and fishery grounds are usually designated ignoring distribution of Cetaceans (Cetacea), despite that acoustic pollution in key frequencies causes severe hearing loss (Brill et al. 1997), which reduces the overall fitness of these acoustically sensitive animals. Furthermore, fishery bycatch and collisions with fast ferries are additional factors to natural mortality rate, which can lead to the extinction of whole local populations in species with such low reproduction rate. This is mainly because habitat use of Cetacean species is poorly known due to the difficulties of tracking individuals for longer periods of time, and local hotspots are rarely identified. One of the few non-invasive techniques to track Cetacean individuals underwater takes advantage of the highly vocal nature of most of these species, and the characteristics of the propagation of sound underwater.

AIMS

The aim of this proposal is to establish a non-invasive continuous tracking system by which the movements of underwater vocalizing animals can be followed in a certain area. Data from such a system has direct conservation benefits, as it provides information for land use and management policy and gives real-time Cetacean distribution data for maritime traffic control. At the same time, such data reveals yet unknown features of Cetacean life, as it provides long term information on movement patterns and dynamics, habitat use, distribution and abundance of various Cetacean species of a well defined area. By sound co-operation with other ocean observation initiatives, such a system could become part of the Global Ocean Observing System (GOOS) and ultimately, of the Global Earth Observation System of Systems (GEOSS).

THE PROPOSED PILOT AREA

The area between Tenerife and Gran Canaria (Canary Islands, Spain) is a hotspot for Cetaceans, which hosts a resident population of sperm whales, bottlenose dolphins and other small delphinid species (Carwardine 1995; André 1997; Urquiola 1998), and at the same time, is an important maritime traffic route, crossed by a great variety of vessels, including fast ferries (Figure 1.). There have been several collisions reported between ferries and sperm whales in the past (André 1997), some of which caused the death of not only this endangered animal, but also of humans; the magnitude of unreported collisions with smaller delphinids (which cause no observable harm to the vessels) is unknown. Studies have shown that the members of the resident population of whales in the area also suffer from permanent hearing loss, probably due to man-made acoustic pollution (André 1997).

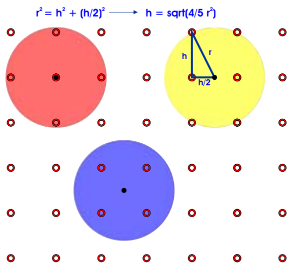

Figure 2. The ideal grid design of the hidrophone system: the distance between the receivers (h) is equal to sqrt(4/5r²), where "r" is the acoustical range of the object species, so that at any given source location the signals are received by at least four hydrophones, which makes 3D localisation possible. Black dot: sound source. Transparent coloured circles: acoustic range.

species / sound type	dB mean	kHz	literature of source levels	approx. mean detection range
Tursiops truncatus whistle	158	9	Janik (2000)	6 km
Tursiops truncatus click	210	115	Au (1993)	2 km
Physeter macrocephalus click	218	8-26	Madsen et al. (2002)	>10 km
Grampus griseus click	220	49	Madsen et al. (2004)	>10 km
Pseudorca crassidens click	220	40	Madsen et al. (2004)	>10 km

Table 1. A figure of approximate detection ranges of some Cetacean sounds: Assuming a general background noise level (NL) of 40 dB (at all frequencies) and a signal-to-noise ratio (SNR) of 40 dB, received levels above 80 dB are detected. Corresponding detection ranges are calculated from the equation of transmission loss $TL = 20\log R + \alpha R$ (where α is a frequency dependant factor) using measured source level data from the indicated literature sources.

THE PASSIVE SONAR MONITORING SYSTEM

The proposed sonar system is built up of an array of hydrophones (Figure 1.), placed at the depth of the acoustic channel in the study area, at cc. 1000 meters, by a grid-design (Figure 2.) corresponding to the vocal characteristics of the species in question and the area's ambient noise level (Table 1.). The hydrophones are anchored to the bottom and are linked with buoys on the surface via low-noise cables, which are equipped with radio transmitters (and preferably photovoltaic panels to supply the system with energy) (Figure 3.). When planted, the location of each hydrophone is measured by GPS. The radio transmitter on the buoy transmits the sounds recorded by the hydrophone connected to it to a land-based computer lab in real-time, where the incoming multi-channel signals are analyzed, recorded and geo-referenced automatically by a computer. Geo-coordinates and depth of the signal source are calculated from the differences of the receipt time at each hydrophone receiving a certain signal (at least 4 hydrophones for a 3D localization) (Figure 4.). Basic vocalization patterns can be identified automatically by a simple neural network, thus allowing for an automated classification of species or higher taxa (e.g. sperm whales, beaked whales, baleen whales, delphinids). An amplitude-triggered recording scheme archives sound-samples on a hard-drive for further analysis, along with geo-coordinate, depth and time data. The real-time display of the system is a 3 dimensional map of the study area, where sound sources are displayed with symbols of taxa, according to the results of the first automatic classification. This display can be immediately used by maritime transport companies to modify their routes (e.g. fast ferries to avoid collision with sperm-whales) (Figure 3).

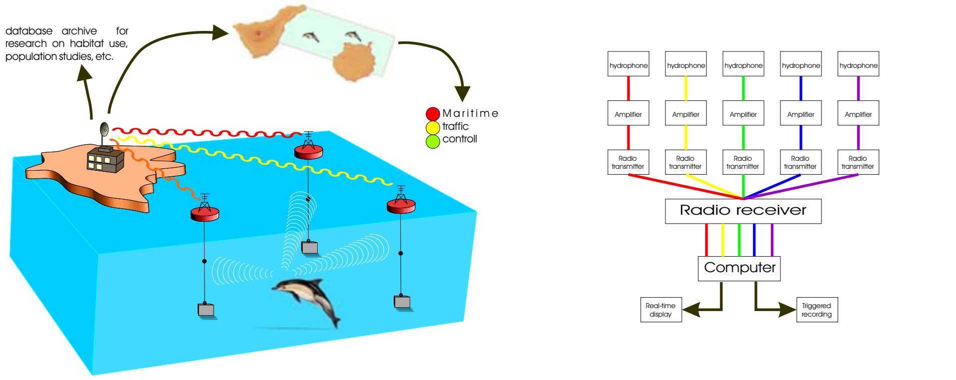

Figure 3. The scheme of the passive acoustic monitoring system: a number of sonobuoys receive underwater acoustic signals, which are converted and transmitted via radio waves to a land-based laboratory along with the individual identifier of the receiver in real-time. Signals are digitalized andon basis of the coordinates of the receivers, the sound source's location is identified. Still in real-time, the signals are run through a neural network, capable of recognising groups corresponding to predetermined taxa/groups. The processed information is displayed on a GIS platform and is sent to maritime traffic controll for further use. The digitalized sounds, and the processed GIS tracklogs are recorded for further analysis.

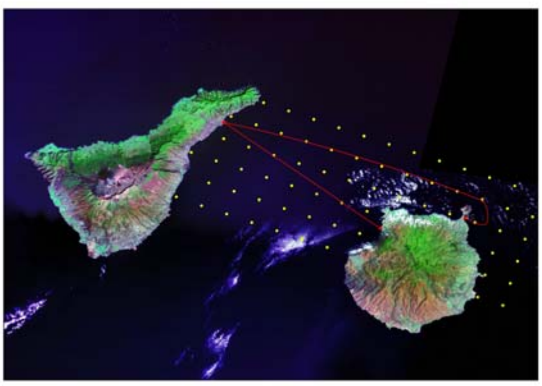

Figure 1. A 10 km grid design to plant hydrophones in the zone with heavy maritime traffic between Tenerife and Gran Canaria for the tracking of Cetaceans with an acoustic range greater than 10 kms. Red line: main traffic routes. Yellow dots: hydrophone locations. Image source: https://zulu.ssc.nasa.gov/mrsid/

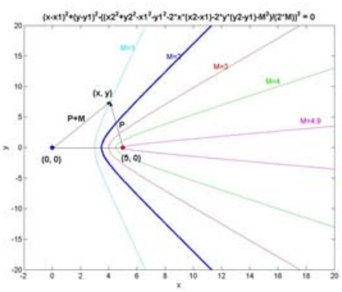

Figure 4. The figure demonstrates how the possible locations of a sound source can be determined by two hydrophones in 2D. Known variables are the coordinates of the hydrophones ($x_1=0, y_1=0$ and $x_2=5, y_2=0$ in this example) and the difference between the distances of the sound source from the hydrophones (M, calculated from the difference of the receipt time of the sound at each hydrophone). Unknown variables are the coordinates of the source (x, y). The equation is:

$$(x-x_1)^2+(y-y_1)^2-\{x_2^2-x_1^2+y_2^2-y_1^2-2x(x_2-x_1)-2y(y_2-y_1)-M^2]/(2M)\}^2=0$$

The solution for various M values is indicated by colour curves. A third hydrophone would cut the curves in one point only, giving an explicit solution in 2 dimensions. For 3D results, four receivers are needed.

REFERENCES

André, M. 1997. Distribución y conservación del cachalote (Physeter macrocephalus) en las Islas Canarias.. Ph.D. Thesis. Universidad de Las Palmas de Gran Canaria.

Arbelo, M., André, M., Degollada, E., Castro, A., Jaber, R., Lorenzo, H. and Sierra, E. 2002. Conclusiones estudio anatomo patológico del varamiento masivo de zifios en Fuerteventura y Lanzarote. 24-27 de Septiembre de 2002. Report of the Faculty of Veterinary Science of the UNiersity of Las Palmas de Gran Canaria.

Au, W. W. L. 1993. The sonar of dolphins. Springer-Verlag, New York. 277 pp.

Brill, R.L., P. W. B. Moore, L. A. Dankiewicz, and D.R. Ketten (1997) Evidence of hearing loss in an Atlantic bottlenose dolphin (Tursiops truncatus). Invited paper, 134th Meeting, Acoustical Society of America.

Carwardine, M. 1995. Whales, dolphins and porpoises. Doeling Kindersley Ltd., London.

Janik, V. M. 2000. Source levels and the estimated active space of bottlenose dolphin (Tursiops truncatus) whistles in the Morray Firth, Scotland. J. Comp. Physiol. A., 186, 673-680.

Madsen, P. T., Kerr, I. and Payne, R. 2004. Echolocation clicks of two free-ranging, oceanic delphinids with different food preferences: false killer whales Pseudorca crassidens and Risso's dolphins Grampus griseus. The Journal of Experimental Biology 207, 1811-1823.

Madsen, P. T., Payne, R., Kristiansen, N. U., Wahlberg, M., Kerr, I. and Møhl, B. 2002. Sperm whale sound production studied with ultrasound time/depth-recording tags. The Journal of Experimental Biology, 205, 18991906

Tregenza, N., Aguilar, N., Carrillo, N., Delgado, I, Díaz, F., Brito, A & V. Martín, 2000. Potencial impact of Fast Ferries on whale populations a simple model with examples from the Canary Islands. 14th Annual Conference of the European Cetacean Society, Cork, Ireland, 2-5 April.

Urquiola, E. 1998. Ballenas y delfines de Canarias: Cetaceos en Tenerife. In: Tenerife y el Mar. (Ed. Excmo.Cabildo Insular de Tenerife). Canarias . Spain

1st European Congress of Conservation Biology, 22-26 August 2006 – Eger, Hungary