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Modelling the habitat suitability of cetaceans: Example of the sperm whale in the northwestern Mediterranean Sea

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ABSTRACT

Cetaceans are mobile and spend long periods underwater. Because of this, modelling their habitat could be subject to a serious problem of false absence. Furthermore, extensive surveys at sea are time and money consuming, and presence–absence data are difficult to apply. This study compares the ability of two presence–absence and two presence-only habitat modelling methods and uses the example of the sperm whale (*Physeter macrocephalus*) in the northwestern Mediterranean Sea. The data consist of summer visual and acoustical detections of sperm whales, compiled between 1998 and 2005. Habitat maps were computed using topographical and hydrological eco-geographical variables. Four methods were compared: principal component analysis (PCA), ecological niche factor analysis (ENFA), generalized linear model (GLM) and multivariate adaptive regression splines (MARS). The evaluation of the models was achieved by calculating the receiver operating characteristic (ROC) of the models and their respective area under the curve (AUC). Presence–absence methods (GLM, AUC = 0.70, and MARS, AUC = 0.79) presented better AUC than presence-only methods (PCA, AUC = 0.58, and ENFA, AUC = 0.66), but this difference was not statistically significant, except between the MARS and the PCA models. The four models showed an influence of both topographical and hydrological factors, but the resulting habitat suitability maps differed. The core habitat on the continental slope was well highlighted by the four models, while GLM and MARS maps also showed a suitable habitat in the offshore waters. Presence–absence methods are therefore recommended for modelling the habitat suitability of cetaceans, as they seem more accurate to highlight complex habitat. However, the use of presence-only techniques, in particular ENFA, could be very useful for a first model of the habitat range or when important surveys at sea are not possible.

1. Introduction

Habitat modelling increases the knowledge about the spatial distribution of a species and its relationship with environmental variables. Such information is of great interest for theoretical studies on ecological niches or for practical purposes such as defining and managing protected areas. Habitat modelling can, moreover, be used to predict the impact of climate changes on species spatial distribution. In recent years, such conservation and management considerations have gained in ecological importance. At the same time, computational capabilities have considerably improved, leading to an increase in the number of habitat modelling techniques, using various

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statistical methods such as multiple regression or multi-factorial analyses.

The most used habitat modelling techniques (such as generalized linear models, GLMs) are based on presence–absence data (Guisan and Zimmermann, 2001; Redfern et al., 2006). 'True' absence data (when animals are actually absent) are not easy to collect for mobile or inconspicuous species. For example, Kelly (2000) cited in Hirzel et al. (2002) estimated that 34 visits to a site are needed to confirm the absence of a snake (*Coronella austriaca*). 'False' absence data, when animals are present but not detected, can significantly bias the analysis. As several cetacean species are able to spend long periods underwater and are very discreet at the surface, modelling their habitat with presence–absence methods may be subject to such biases, if absence data are not carefully considered. Moreover, collection of cetacean distribution data requires long and expensive surveys at sea.

This shortcoming can be avoided using presence-only methods such as principal component analysis (PCA) or ecological niche factor analysis (ENFA) (Hirzel et al., 2002). Because of the use of presence-only data, such methods tend to overestimate the area of suitable habitat. Indeed, presence-only methods seem to predict the potential distribution (fundamental niche), whereas presence–absence methods could reflect the present distribution (realized niche) of the species (Brotons et al., 2004; Zaniewski et al., 2002). Even though presence-only methods have limitations, they could be very useful for a first approach of habitat modelling for cetaceans.

The sperm whale (*Physeter macrocephalus*) is one of the eight common cetacean species inhabiting the north-western Mediterranean Sea (NWMS, Fig. 1) (Duguy, 1991). In this area, sperm whales are exposed to anthropogenic disturbances such as noise and ship collisions (with ferries or high-speed boats), net entanglement and pollution (Aguilar et al., 2002; Di Natale and Notarbartolo di Sciara, 1994; Notarbartolo di Sciara and Gordon, 1997). With the creation of a marine protected area, the International Sanctuary for Marine Mammals, it was interesting to model the critical habitat of the sperm whale within the framework of management and conservation.

In the NWMS, the average patterns of the sperm whale typical deep dive are 45 min for the underwater feeding period and 9 min for the surface resting period (Aguilar et al., 2002; Drouot et al., 2004). Because the whales feed throughout the day/night cycle (Drouot et al., 2004; Watwood et al., 2006) and spend around 15% of the time at the surface, the use of only visual detection does not well represent their spatial distribution. We compensate for this lack by the use of passive acoustic detection along the survey track. Indeed, the sperm whale emits regular clicks during its feeding dives. These clicks are produced 80% of the time of the dive, allowing detection of individuals from several kilometres away when they are underwater (Watwood et al., 2006) and the use of both presence-only and presence–absence modelling methods. We therefore compared four methods to model the habitat suitability (HS) of the sperm whale: two well-established methods, PCA and GLM, and two more recent methods, ENFA and multivariate adaptive regression splines (MARS). We will discuss the statistical accuracy and the ecological meaning of the resulting models, in order to show the advantages and disadvantages of each technique for the habitat modelling of cetaceans.

2. Material and methods

2.1. Sampling surveys

From 1998 to 2005, summer surveys were conducted on a motor-sailing boat at a speed of 6 knots. In addition, during summer 2001, a motor boat was used for surveys at a speed of 11–12 knots (Fig. 1a) (Gannier, 2006). The survey track was designed as random zigzags from the upper slope to nearby pelagic waters, and crossings from France mainland to Corsica or to Balearic Islands

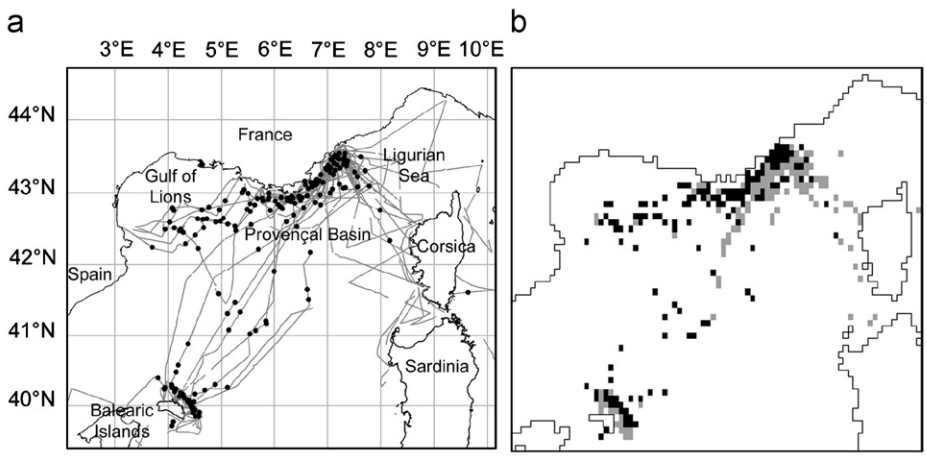

Fig. 1. Survey tracks (grey line) realized from 1998 to 2005 in the northwestern Mediterranean Sea and location of the observation sequences (black dots) of sperm whales (*Physeter macrocephalus*) (a); presence cells (black) and absence cells with a minimum of 5 km of survey effort (grey) of the sperm whale (b).