AUTOMATED DETECTION OF WHITE WHALE (*DELPHINAPTERUS LEUCAS*) VOCALIZATIONS IN ST. LAWRENCE ESTUARY AND OCCURRENCE PATTERN

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1 INTRODUCTION

White whales (*Delphinapterus leucas*) are odontocete cetaceans that have a circumpolar distribution. The size of the St. Lawrence estuary population is currently estimated to 600-1000 animals and has been classed as threatened by COSEWIC[1] since 2004 (MPO, 2005). Detailed behavioural and habitat information on this white whale population is needed for improving their protection.

Conventional behavioural observations are usually made by visual observations from ships, airplanes or land observatories. The performance of these visual methods depends on many factors such as weather conditions, water transparency and ambient light intensity (Costa, 1993). Recent advances in passive acoustical monitoring techniques are being used for studying behaviour and habitat of vocalizing marine mammals. Such an approach can be used for monitoring several individuals in continue over long periods, independently of weather and light conditions, and without disturbing marine mammal's behaviour or affecting their environmental conditions (Erbe, 2000).

White whales are well known for their high degree of acoustic activity. Beluga's repertoire can be divided into three main categories : whistles, pulsed tones and clicks (Sjare and Smith, 1986; Faucher, 1988). All white whale vocalizations are very variable in time and frequency, and it is difficult to stereotype each of them for automatic detection.

Here, an automated method using a sequence of signal processing algorithms was developed to detect white whale calls, except clicks, under the loud shipping noise of the St. Lawrence estuary.

2 METHOD

Continuous recordings were collected from 5 to 11 September 2003 using a coastal hydrophone at a depth of 130 m in front of Cap-de-bon-Désir in Saguenay—St. Lawrence Marine Park (Québec, Canada). Records were bandpassed in the 0.5-5 kHz band, where the majority of the white whale's calls are emitted. White whales were simultaneously observed in daytime from a Belvedere at the study site.

Shipping noise was first removed using an adaptive spectral subtraction algorithm (Martin, 1994), which uses minimum statistics to identify the noise spectrum before subtracting it from the recordings. The remaining masking periods, due to close ships, were identified and considered as missing values in further processing. Then a threshold was applied to transform the spectrogram into a binary image on which residual noise was cleaned using two specific image filters. Each positive pixel of this final binary image was considered as a detection of a white whale's vocalization. The false detection rate was statistically estimated from visual validation of 3 % of the total recording period.

A vocalization rate index for each 30 minutes was estimated by the ratio (%) of detections over the total number of pixels on the binary image. Autocorrelation of the occurrence pattern, presence of circadian rhythms, and cross-correlations with wind speed, tide level and current velocity during the same period were analysed.

Finally, the main frequency band used by white whales on these recordings was determined.

3 RESULTS

The false detection rate due to residual noise was estimated to 7 ± 4%. The vocalizations occurred during a short period (~ 1 s) and more than 80% of the silent periods lasted less than 10 s. The frequency band of the vocalizations was relatively stable over the seven days of sampling, but the vocalization rate was variable from day to day (Fig. 1). Call detections was higher on 5 and 11 September. The main frequency band used by white whales in these recordings was between 1.1 to 3.5 kHz.

Autocorrelation did not show any periodicity in the occurrence pattern. Daytime and nighttime calling during this short period did not show differences supporting any clear circadian rhythm. Low significant cross-correlations ($r = -0.2$, delay = 0.5 h) were computed between vocalization rate and wind speed, indicating that more detections occurred 0.5 hour after a low wind period. Low significant cross-correlations ($r < 0.3$) were also computed with tide level and along-channel current velocities, indicating that detection calls seemed to be higher 2.5-3.5 hours after high tide at the study site.

[1] COSEWIC : Committee on the Status of Endangered Wildlife in Canada

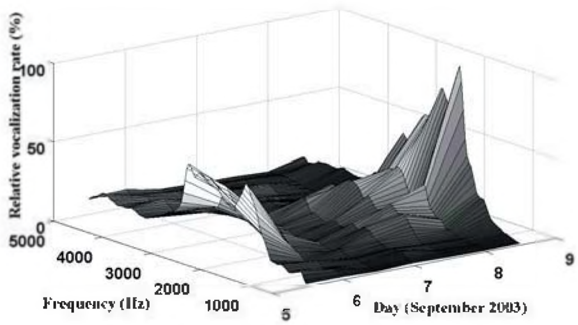

Fig. 1. White whale relative vocalization rate by frequency band [0,5-5] kHz from 5 to 11 September 2003; 0 = 2003-09-05 00 :00 :00 (HAE).

4 DISCUSSION

4.1 Automatic detection method

An automated detection method of white whale vocalizations was developed and tested on a 7-day sampling period. It allowed analysing their occurrence pattern over a continuous time-series for the first time.

This method can detect all the diverse white whale whistles and pulsed tones emerging in the signal after noise filtration. The detection was not based on stereotyped calls, which would be difficult for the loquacious beluga. Detections were associated to white whale calls because they largely dominate in this environment, from manually analyzed recordings and the land-based observations during the sampling period in the study area.

The performance of the method under the loud shipping noise of this environment was computed by the false detection rate estimated at 7 ± 4 %. The vocalization rate intensity of these false detections was however very low compared to that of the detected calls. Therefore the false detections did not strongly influence the call occurrence pattern.

This automated detection method could be worthwhile for analyzing long recordings using an objective and systematic approach, which would be difficult to do manually by an observer. On the other hand, a lot of parameters used in this method were manually adjusted according to regional noise context. It would be interesting to have them automatically adjusted for recordings from other environments.

4.2 Occurrence pattern

Although circadian rhythms in vocal behaviours have been shown for many marine mammals species (Au *et al.*, 2000; Stafford *et al.*, 2005, Ichikawa *et al.*, 2006), no apparent circadian rhythm was observed in this white whale call occurrence pattern.

The meaning of the low significant cross-correlation computed between the vocalizations rate and wind speed is unclear. White whales could have been less abundant in the area during strong wind periods, or they could then have been silent.

Significant cross-correlations between vocalization rate and tide level or current velocities indicated that high level of detection occurred a few hours after the flood upwelling period at the study site (Lavoie *et al.*, 2000). This observation could be due to the presence of concentrated capelin preys at this moment (Simard *et al.,* 2002). However, the correlation coefficients were low and white whale vocal detections were slightly influenced by these factors. A longer recording period and more investigation of the complex dynamics in this area of the St. Lawrence estuary are needed to understand the meaning of all these correlations.

4.3 Dominant frequency band

The main frequency band used by white whales in these recordings was slightly lower than that estimated by Lesage *et al.* (1999) about 65 km upstream (2.6-4.4 kHz). This could result from the sex segregation of the beluga in the Estuary during summer, whereas juveniles and adult white whales (females) are observed upstream, while males are found in our recording region (Michaud, 1993).

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