INTEGRATED PASSIVE ACOUSTIC APPROACH TO EVIDENCE MAJOR SPERM WHALE FEEDING GROUND IN THE FRENCH MEDITERRANEAN SEA.

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INTRODUCTION

Sperm whale dive includes a descent phase (where the whale descends almost vertically from the surface to the foraging depth), a foraging phase (where the whale undertakes horizontal movement at the foraging depth in search for food) and an ascending phase (where the whale returns to the surface) (Gordon, 1987; Watkins *et al*., 2002; Zimmer *et al.,* 2003). During the first and second phases of the dive they produce almost continuously regular clicks, which are used for echolocation. These long sequences of clicks are inter-spaced with "creaks", which are thought to be rapid echolocation pulses produced by sperm whales investigating prey at close range (Mullins *et al*., 1988, Goold, 1999). Sperm whale clicks are made up of a number of regularly spaced sound pulses and the spacing between these pulses, the inter-pulse interval (IPI), has been demonstrated to be a function of the body length (Gordon, 1991; Goold and Jones, 1995).

The north-western Mediterranean Sea shows higher abundance of sperm whales in summer than most other regions of the Mediterranean (Gannier *et al.,* 2002). The objective of this study was to use passive acoustic techniques to describe the dive cycle of sperm whales inhabiting this area, to quantify their foraging activity, and to gain insight into the spatial requirements of the species in terms of habitat use.

MATERIAL AND METHODS

Dedicated sperm whale surveys were performed during the summer field seasons from 2001-2003 in the western Mediterranean Sea. When sperm whales were sighted, the position and timing of the surfacing and fluking-up were noted, the number of blows were counted and continuous recordings was carried out. During their dive, sperm whales were tracked acoustically, through a towed dual hydrophone, using *Rainbow Click* software. Visual data were were used to calculate:

- The surface and dive periods,
- The number of blows per surface period,
- Distance travelled between two successive fluke up.

Post-analysis of the recordings allowed to calculate for each individual dive:

- The number of creaks heard,
- Δt_{creak} : the time interval between the fluke-up and the first creak of the dive,
- The inter-pulse interval (IPI), from the click waveform display (*CED Spike 2* and *Cool Edit* software)

The average IPI was then used to estimate the whale body length according to Gordon's (1991) equation:

Body length $= 4.833 + 1.453\ IPI - 0.001\ IPI^2$

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RESULTS AND DISCUSSION

During the study, 20 sperm whales were observed for at least one dive cycle. From the click IPI measurements, the whales were estimated to be **between 11.8 and 13.8m long** (Table 1), and were probably **sub-adult and adult males** (Rice, 1989).

During the surveys, 51 complete dive cycles were monitored (Table 1). On average, the whales perform **dives of 46 min** (SD=5.5) followed by period of **9 min at the surface**, where the whales take an average of 42 breaths (SD=7.1) (Figure 1). Over a dive cycle, the sperm whales **travel an average horizontal distance of 1.3 NM** (SD=0.3). It could extrapolated that in this area, sperm whale foraging activity extends over an horizontal range of 35NM per day (24h). When followed over several dive cycles, the distance travelled from one cycle to the next appeared to be very consistent. On the 7 occasions where individual sperm whales were followed over 3 or more dives cycles the whales never returned twice to the same area but seemed to follow an approximately steady heading, **essentially along the bathymetry contours** (Figure 2).

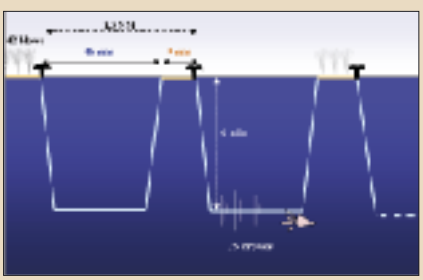

Figure 1. Scheme representing the main results on sperm whale dive patterns.

Sperm whales produced an average of **25.4 creaks per dive** (Table 1). Assuming that a creak represents the successful capture of at least one squid, this average would correspond to at least **750 squids eaten per whale per day**.

Among the dives, the time of occurrence of the first creak (Δt_{creak}) was relatively consistent (Table 1). **Creaks were emitted at 6.6 minutes after the whale fluked-up** (Figure 1) and this time interval showed little variation (SD=0.8). Considering a descending speed of between 75 and 120m/min (Gordon, 1987; Mullins *et al.,* 1988; Papastavrou *et al.,* 1989; Watkins *et al*., 2002 and Madsen *et al.*, 2002), this would imply, **a foraging depth of around 500 and 800m**. This result would be consistent with the midwater habitat of squid species known to be part of the sperm whale diet in the Mediterranean Sea, such *Histioteuthis bonnellii* and *Histioteuthis reversa* (Roberts, 2003).

The whale body size (estimated from IPI) appeared to have a significant influence on both, the number of creaks per dive and the dive time at which the first creak of the dive occurred, suggesting that larger whales may increase their prey intake and forage in deeper water layers than smaller whales.

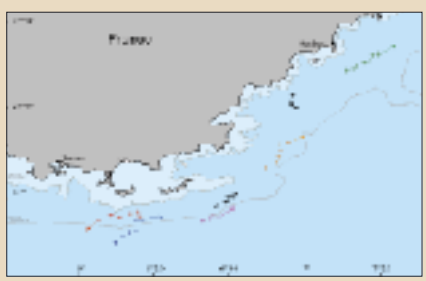

Figure 2. Map showing the position of the fluke-ups (+) during successive dives of 7 sperm whales followed over 3 or more dive cycles off the coast of Provence (France).

Table 1. Descriptive statistics of sperm whale dive cycles observed in the western Mediterranean Sea during 2001-2003 surveys.

CONCLUSION

The study evidence the capacity of passive, non-invasive, acoustic techniques in addressing issues of major conservation interest such as habitat use and foraging activity. The study demonstrated that the waters off Provence (France) represent an important foraging area for sperm whales and particularly male individuals. The passive tracking of individual whales underwater allowed to describe precisely the species dive patterns and to give insight on the species habitat use in this area. Acoustic recordings provide precious information on the species feeding rate and foraging depth, suggesting that the area sustain important population of mid-water cephalopod species, at least in summer. Further surveys are encouraged to investigate the residency and movement patterns of individual sperm whales in the northern Mediterranean Sea over longer period of time.

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