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Collecting data on cetaceans from ferries: a useful method to monitor populations, help modelling and improve knowledge on ship strikes

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Abstract. The collection of data on cetaceans throughout the year on the Toulon-Ajaccio ferry line between 2014 and 2016 enabled the observation of six species (fin whale, striped dolphin, sperm whale, bottlenose dolphin, pilot whale and Risso's dolphin). Indicators have been defined, such as spatial distribution, encounter rate, seasonality and species richness, and compared between the period 2014-16 with the previous period 2011-12. Thus, some species have similar spatial distributions on the Toulon-Ajaccio route between the two periods (striped dolphin and fin whale) while other species have a changed distribution (sperm whale and Risso's dolphin). Species richness is relatively higher in 2014-16 than in 2011-12. Specific richness maxima are observed in deep areas (> 2 000 m depth) with a higher concentration in the northern half of the route. The encounter rates show different trends depending on the species or season, with a slight overall decrease from the first to the second period. The comparison of the encounter rates on the Toulon-Ajaccio ferry line (equivalent to the western border of the Pelagos Sanctuary) and the Civitavecchia-Bonifacio Strait line (the eastern border of the Pelagos Sanctuary) does not show a clear pattern of mass migration of animals, neither at the monthly nor seasonal level. Lastly, observers on board ferries provide a better understanding of ship strike situations between these vessels and large cetaceans and we obtain a rate of 0.006 Near Miss Event (NME) observed for 100 km traveled in observation. The data collected from the network of ferries as observation platforms has many advantages (lower costs, space and time coverage and homogeneity) including validated and improved habitat models and collision risk assessment for sperm whales and fin whales.

Keywords: North-western Mediterranean Sea, Pelagos Sanctuary, cetacean, monitoring, network, indicators, ferry.

Résumé. **Collecter des données sur les cétacés à partir de ferrys : une méthode utile pour le suivi des populations, améliorer les modèles et accroître les connaissances sur les collisions.** La collecte de données sur les cétacés tout au long de l'année sur la ligne de ferry Toulon-Ajaccio, entre 2014 et 2016, a permis l'observation de six espèces (Rorqual commun, Dauphin bleu et blanc, Cachalot, Grand dauphin, Globicéphale noir et Dauphin de Risso). Des indicateurs ont été définis, tels que distribution spatiale, taux de rencontre, saisonnalité et richesse spécifique, et comparés entre la période 2014-16 et la

période précédente 2011-12. Ainsi, certaines espèces présentent des distributions spatiales similaires sur le trajet Toulon-Ajaccio entre les deux périodes (Dauphin bleu et blanc et Rorqual commun), tandis que d'autres espèces ont changé de secteurs (Cachalot et Dauphin de Risso). La richesse spécifique est relativement plus importante en 2014-16 qu'en 2011-12. Le maximum de richesse spécifique est observé au-delà des fonds de 2 000 m avec une concentration plus importante dans la moitié nord du trajet. Les taux de rencontre montrent des tendances différentes selon l'espèce ou la saison considérée, avec néanmoins une légère baisse globale de la première à la seconde période. La comparaison des taux de rencontre sur les lignes de ferry Toulon-Ajaccio (équivalent bordure Ouest du Sanctuaire Pelagos) et ligne Civitavecchia-Bouches-de-Bonifacio (équivalent bordure Est du Sanctuaire Pelagos), ne permet pas de faire apparaitre un schéma clair de migration massive des animaux, mensuel ou saisonnier. Enfin, l'embarquement à bord des ferrys permet une meilleure compréhension des situations de collision (*Near Miss Event* - NME) entre ces navires et les grands cétacés, avec un taux de 0.006 collision évitée pour 100 km parcourus en observation. Les données collectées, à partir du réseau de ferry comme plate-forme d'observation, présentent de nombreux avantages (moindre coût, couverture dans l'espace et le temps, ainsi que leur homogénéité) et ont permis de valider et d'améliorer des modèles d'habitats et de risque de collision pour les Cachalots et les Rorquals communs.

Mots-clés : Méditerranée nord-occidentale, Sanctuaire Pelagos, cétacés, monitoring, réseau de collecte, indicateurs, ferry.

Introduction

The implementation of Marine Protected Areas for marine mammals such as the Pelagos Sanctuary (Moulins *et al.,* 2010; Mangos and André, 2012; Barcelo *et al.,* 2013; Maglio *et al.,* 2015) must be assessed to ensure achievement of its objectives, in particular that of establishing a favourable conservation status for cetacean populations. With this in mind, the monitoring of the populations is a requirement, ideally to be carried out annually on a long-term basis. But covering such vast areas as the Pelagos Sanctuary effectively can be prohibitively expensive. The use of opportunistic platforms such as ferries, with the commitment of shipping companies, makes it possible to carry out scientific monitoring throughout the year and at a lower cost.

Thus, data collection in accordance with 'Fixed Line Transect' (FLT), from the FLT Med Monitoring Network, started in 2007 by Antonella Arcangeli of ISPRA (Istituto per la Protezione e la Ricerca Ambientale, Italy), expanded into a network that has grown up to the 11 lines covered today (Fig.1). *EcoOcéan Institut* is part of the "FLT Med Monitoring Network" since 2011, with responsibility for the Toulon-Ajaccio ferry line and collecting data through most of the year (Arcangeli *et al.,* 2014; Couvat *et al.,* 2014).

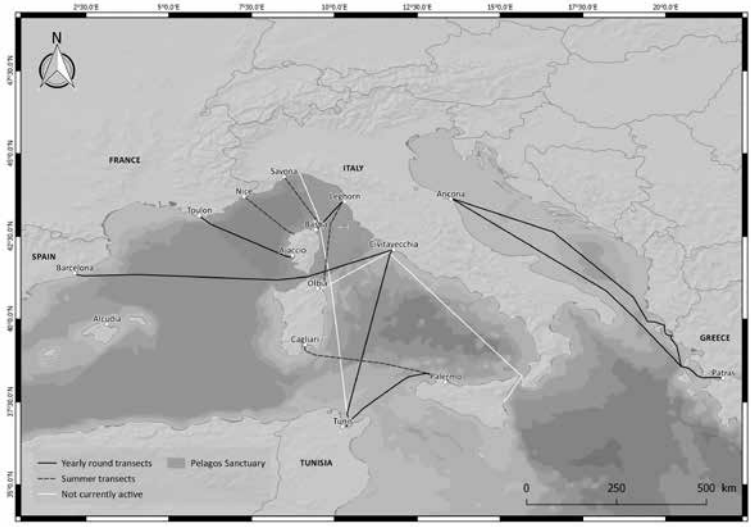

Figure 1. The Fixed Line Transect Med (FLT Med) Network in January 2017: ferry lines with Marine Mammal Observers aboard, applying the same standardised protocols. The results of this study are those from the Toulon-Ajaccio (Provence - Corsica Island) line.

These data serve objectives other than monitoring cetacean populations, they greatly assist: in forming the basis for predictive modelling, validation of model results, supplying testimonies of and avoidance of collisions with marine traffic.

The present study aims to:

- Promote and coordinate research and monitoring, to support management decision-making, by improving knowledge on the monitoring and seasonality of marine mammal populations in the Pelagos Sanctuary area and animal movements at the eastern and western edges of the Sanctuary.
- Provide information on Near Miss Events (NMEs) and limit risks by informing the vessels' crew in real time.

Materials and methods

Collection of data

The data are collected by four Marine Mammal observers (MMOs) on the ferries of the 'Corsica-Sardinia-ferries company', on the crossings from Toulon (Provence) to Ajaccio (Corsica). The sampling frequency is based on two crossings per month from April to October. In the other months, the ferries cross almost only at night, preventing any visual observation. Only three-day crossings are possible during this period, namely 1st November, 24th December and 2nd or 3rd January.

The method applied on ferries is the 'Fixed Line Transect': Fixed transects are predefined individual routes which are regularly sampled. The data are collected according to the 'linear transect' method described by Buckland *et al.* (2001): a rigorous and continuous observation is carried out by three observers scanning with the naked eye 180° forward. The speed of the boat throughout the transects is constant and the route is recorded every minute by a GPS Garmin 72h (date, time, latitude, longitude). Sea and wind conditions should be less than or equal to 3 Beaufort and are noted regularly. For each cetacean sighting, different data are recorded: species, number of individuals, presence of young (and estimated number), behaviour and direction of swim. This method is identical in all respects to that applied during the crossings on this ferry line carried out in 2011-2012 (Arcangeli *et al*., 2012). It is also identical to the one applied on the line Civitavecchia-Barcelona by Accademia del Leviatano who graciously made their data available from Civitavecchia to the Bonifacio Strait (Bouches de Bonifacio) for the comparison of the two transects.

A definition of an avoided collision (by the animal or the boat), called Near Miss Event (NME), within the FLT network has been established: '*A near collision situation is defined when an animal is seen in a 50 m square area located in front of the vessel's bow and the animal shows no net attractive behaviour for the ship's bow, but seems rather unaware of the approaching vessel*'. The presence of large cetaceans detected on the trajectory of the ship is immediately communicated to the bridge crew responsible for navigation. The parameters of distance, behaviour and direction of swimming of the animal are additionally provided so that the officer in charge alters the ships course.

Analysis

The database has been integrated under Qgis 2.4.0 to map the distribution of observation effort and species. The spatial analyses were carried out on a cell grid of resolution of 10 km, a grid already used in many reports of the FLT and allowing the comparison of the data. For each cell, different statistical parameters were calculated:

- prospecting effort d_i (or kilometres prospected in effort condition);
- number of sightings n_i;
- Encounter rate (**ER**), equivalent to $n_i/100d_i$;
- Species richness per crossing.

Results and discussion

Indicators

Eight to ten trips per season were achieved from September 2014 to September 2016, that is 2 044 km for spring, 2 797 for summer, 1 102

for **autumn and 442 in winter. 214 sightings of six species were made: fin whale (*Balaenoptera physalus*) (89 sightings), sperm whale (*Physeter macrocephalus*) (13 sightings), striped dolphin (*Stenella coeruleoalba*) (87 sightings), Risso's dolphin (*Grampus griseus*) (3 sightings), pilot whale (*Globicephala melas*) (1 sighting) and bottlenose dolphin (*Tursiops truncatus*) (3 sightings).**

Species	Spatial distribution		Encounter Rate (No sightings/100 km)		Seasonnality (in terms of ER)				
	Evolution	Localisation	Evolution	values	Evolution per season	Autumn	winter	Spring	Summer
Fin whale		isobath > 2 000 m		0.84 / 1.54		1.0 / 1.5	0.5 / 1.2	0.5 / 1.5	1.5 / 1.6
Striped dolphin		isobath > 2 000 m		1.57 / 1.50		1.8 / 1.3	0.5 / 0.9	2.4 / 1.2	1.6 / 1.9
Pilot whale		Centre		0.01 / 0.01		-	-	-	0.04 / 0.03
Sperm whale		Centre and south / north		0.25 / 0.19		0.2 / 0.3	0.2 / 0.2	0.1 / 0.04	0.4 / 0.2
Risso's dolphin		Centre and south / north		0.01 / 0.04		0.05 / -	-	- / 0.08	- / 0.03

	Spatial distribution		No species		Seasonnality				
	Evolution	Localisation	Evolution	Values	Evolution	Aut	Win	Spri	Sum
Species richness		North half > 2 000 m		3 / 4		3 / 4	3 / 4	3 / 5	4 / 5

Table I. Indicators per species on the ferry line Toulon-Ajaccio between the period 2011-2012 (numbers or letter in orange) and 2014-2016 (numbers or letter in blue). Red means a decrease and green a rise from the first period to the second and grey could be seen as "stable".

The indicators we followed have been calculated for the 2014-2016 period, and compared to the results of the 2011-2012 period (Arcangeli *et al.*, 2012) and are as follow: spatiotemporal distribution, encounter rate per species and species richness (Boudouresque, 2014). The results have been presented in a table as "indicators" (Table I).

Three species show the same pattern of spatial distribution from the period 2011-2012 to 2014-2016: fin whale, striped dolphin and pilot whale. Two species show a different distributional pattern, with a higher occurrence in the centre and southern part of the area in the first period, and a more northerly distribution in the second period: sperm whale and Risso's dolphin. It is interesting to note that over a long period (1989-2012), and on the basis of photo-identification, the Risso's

dolphin was mostly seen in the northern part of the area (Labach *et al.,* 2015). Concerning the Encounter Rate (ER), two species show equal values for the two periods, striped dolphin and pilot whale, two show an increase in the second period compared to the first, fin whale and Risso's dolphin, and sperm whale show a decrease of ER. Finally, per season, we see that fin whale were more frequent each season during the second period (2014-2016), whereas striped dolphin were more frequent in winter and summer but less frequent in autumn and spring. In 2014-2016 the ER of sperm whale was equal in autumn and winter, but less in spring and summer compared to 2011-2012.

Concerning the species richness, the northern part of the line is richest and this happens also for each season. While the number of species (point diversity) was globally higher in the second period (2014-2016).

Comparison of the borders of the Pelagos Sanctuary

The Toulon-Ajaccio line could be linked to the western edge of the Pelagos Sanctuary and the Civitavecchia-Bonifacio Strait line (which continues to Barcelona; Fig.1) to the eastern one. Cuvier's beaked whales (*Ziphius cavirostris*), although present along the Civitavechhia-Bonifacio line (Gannier, 2015), have not been sighted, probably because they spend most of their time underwater (Gannier, 2015). By comparing the indicators (ER) of these two lines on a monthly and seasonal scale, migratory flows of three species (fin whale, striped dolphin, and sperm whale) could be highlighted.

It seems that at the monthly and seasonal levels per year, the variability is too high to indicate migratory movements. Overall on the two lines, the three species show a very different monthly or seasonal pattern and are very different from one ferry line to the other. Migration flows do not appear marked, which could be explained by the fact that either the animals are present more or less permanently in the area, or the animals arrive in the Pelagos Sanctuary in small groups. With this time scale, large population movements can be masked by more local movements and dependent on the variability of ecological conditions.

However, on a seasonal scale comprising all years (2012 to 2015), the encounter rates on the Civitavecchia-Bonifacio Strait line (Fig. 2) show that: i) fin whales and striped dolphins are present year round; ii) sperm whales were never observed in autumn; iii) encounter rates for fin whales are unlike striped dolphins: thus fin whale reaches a maximum rate in the spring (0.71sightings.100 km^{-1}). Conversely, encounter rates of striped dolphins are at a maximum in winter when they reach 1.29 sightings.100 km^{-1}.

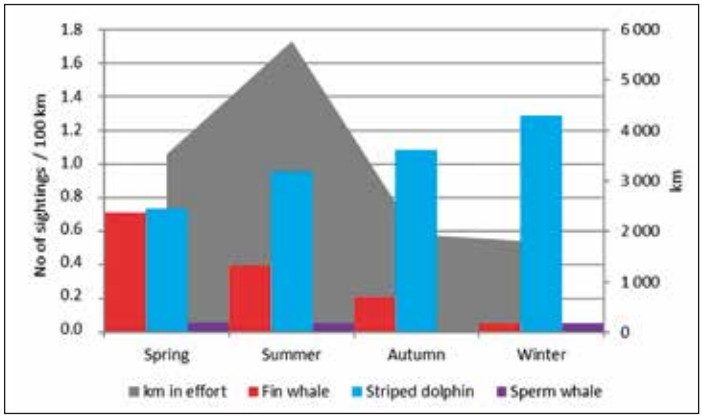

Figure 2. Seasonal encounter rate for three species on the Civitavecchia-Barcelona line, from 2012 to 2015. (data FLT, Accademia del Leviatano/ISPRA).

This discrepancy between these two species could be influenced by their respective position in the food chain. Indeed, the fin whales, being planktonophagous, would arrive earlier than striped dolphins, feeding on the upper links of the food chain, and would pass to their preferential feeding sector further north.

Overall, the seasonal encounter rates between 2011 and 2016 on the Toulon-Ajaccio line (Fig. 3) show that: i) the three species are present all year round; ii) winter is the period of low presence for fin whales and striped dolphins; iii) the peak of occurrence for the striped dolphin (1.66 sightings.100 km^{-1}) is spring whereas it is summer for fin whales (1.47 sightings.100 km^{-1}) and sperm whales (0.35 sightings.100 km^{-1}).

Overall seasonal results for all years combined show spring to autumn rich in animals and a period of lower presence in winter. There is no evidence of mass “departure” or “arrival” of animals, which suggests that we are not bordering an area but that the Pelagos Sanctuary in its western part is a portion of a larger area, corresponding to the whole of the north-western Mediterranean Sea where the cetaceans remain almost all the year.

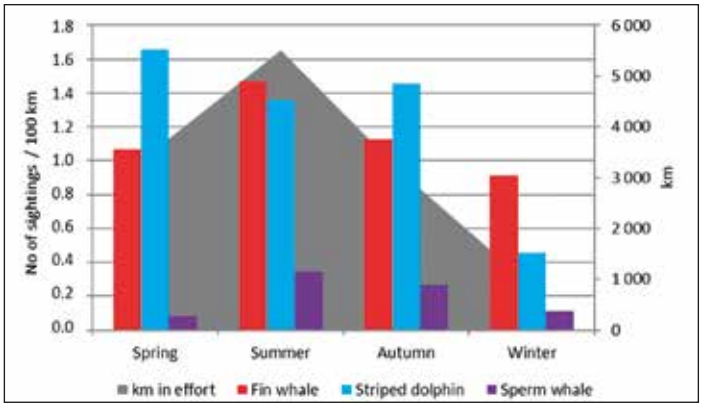

Figure 3. Seasonal encounter rates for three species of cetacean on the Toulon-Ajaccio line (2011 to 2016).

Ship strike

In the course of all trips on the Toulon-Ajaccio line, four cases of NME were witnessed by *EcoOcéan Institut* (Fig. 4.) and were transmitted to the IWC Ship Strike Working Group through the French NGO Souffleurs d'Écume.

These four NMEs were observed between September 2014 and September 2016 between Ajaccio and Toulon (Table II), but none resulted in a collision. They only occurred with fin whales. In all cases, the behaviour of the animal explains why it was not possible to detect them earlier, with the animal emerging from the depths just in front of the ship, or sleeping sub-surface, so as to be not visible from the bridge. In one of the four cases, observers detected the animal a little before and asked the navigation staff to have the course of the ferry altered.

Figure 4. Localisation of the Near Miss Events with fin whale on the Toulon-Ajaccio line from September 2014 to September 2016. © EcoOcean Institut.

Table II. Near Miss Event cases.

Date	Hour	Number of individuals	Situation	Reaction to the vessel
17/04/2015	16:08	1	The whale slept sub-surface, it surfaced about 150 m in front of the ship	The animal positioned parallel to the ship's course.
23/10/2015	13:55	1	The whale surfaced 15 m in front of the vessel	The animal crosses the course of the ferry, plunges again immediately, accelerating to avoid the ferry
10/04/2016	13:51	1	The whale surfaced 50 m ahead of the bow of the boat	The animal blew and dived immediately. It has not been reviewed.
06/06/2016	18:14	1	The whale surfaced just at the bow of the boat	The animal surfaced immediately and emerged just behind the ferry

Table III. summarises our sightings and NME data over the 3 years, and for two biological periods (spring-summer: April to October and winter: November to March). With fin whales, we have witnessed annually 2 cases of NME, except in 2014, when we had a small effort of prospection. The maximum NME rate was reached in 2016 (0.09 NME / 100 km). All NMEs occurred from April to October, and none were observed from November to March.

Table III. Prospecting effort, sightings and NME cases for fin whale on the Toulon-Ajaccio line from 2014 to 2016.

Fin whale		2014	2015	2016
April to October	No. km	402	3 092	2 176
	No. individual	12	81	34
	Relative abundance (Mean No. ind./100 km)	3.0	2.8	1.6
	No. NME	0	2	2
	NME rate (No. NME/100 km)	0	0.06	0.09
November to March	No. km	439	245	-
	No. individual	0	6	-
	Relative abundance (Mean No. ind./100 km)	0	2.45	-
	No. NME	0	0	-
	NME rate (No. NME/100 km)	0	0	-

Usefulness of these data for modelling

All the ferry data collected are pertinent to modelling because of the spatial coverage (all the Sanctuary, all the western basin, etc.), the time coverage (all seasons, all years, etc.) and homogeneity, and because all data are collected according to a common recognised protocol. The data collected from ferries, including the Toulon-Ajaccio line, served to consolidate and validate two models: one model for prediction of fin whale habitat and the second model for collision risk.

The favourable habitat model for fin whales made by Druon (Druon *et al.*, 2012) was constructed with data from the FLT among others. Then in December 2015 a re-calibration of the model was performed, again based on the more recent FLT data, which considered a continuous habitat value based on the size of the chlorophyll front. The observation of large cetaceans from passenger vessels allows, in the long term, economical and efficient sampling both from the point of view of population monitoring and the study of threats. Moreover, the impact of climatic variations on the habitat of large cetaceans can only be followed by large-scale modelling using satellite observations of the ocean surface. Observations of cetaceans from large vessels check the viability over time of the relationships between the species and the environment used in these models. Allowing consideration for any adaptations of species, and a better distinction between climatic and anthropogenic causes of changes in population distribution.

Ship strike high risk areas mapping in the Pelagos Sanctuary (Folegot *et al*., 2015) using the data collected on the Toulon-Ajaccio line have been used to i) validate the AIS data and its process, ii) adapt the formulas for the extrapolated data on the encounters of fin and sperm whales, iii) calibrate the proposed model for the common period in 2014 and 2015. The data collected aboard ferries were therefore critically important in the construction and validation of the different stages of the model.

Conclusion

In order to monitor the evolution of indicators of cetacean populations, the network of ferry lines covered by the FLT Network proves to be a relevant tool, especially since data collection will be continuous (each season, each year) and over the long term. The results by line bring comparative elements in space and time, especially as the network covers various type of cetacean's habitats.

Because of their spatial, temporal, homogeneity, quality and moderate cost of acquisition, FLT data have significant potential for use in modelling work, whether for favourable habitat, risk areas or evolution over the long term (climate change or impact due to anthropogenic activities).

Finally, the records of Near Miss Events is at the forefront of knowledge today in terms of understanding the phenomenon and the reasons for these collisions, quantifying these NMEs based on the real events observed, direct action in real time to limit a collision (course deviation of the vessel) and also potentially testing tools to help limit these collisions.

It appears that it would be relevant for the countries that created the Pelagos Sanctuary (France, Italy and Monaco), to continue and encourage the permanent collection of data from ferries in terms of the collection system / surveillance system under the European Marine Strategy Framework Directive.

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