UNIVERSITA' DI BOLOGNA

SCUOLA DI SCIENZE

Corso di laurea magistrale in Biologia Marina

POTENTIAL EFFECT OF MARINE TRAFFIC ON WHITE-BEAKED DOLPHIN (*Lagenorhynchus albirostris*) DISTRIBUTION AND BEHAVIOUR IN FAXAFLÓI BAY, SOUTHWEST ICELAND

Tesi di laurea in Adattamenti degli animali all'ambiente marino

Relatore

Prof.ssa Elena Fabbri

Presentata da

Letizia Zezza

Correlatore

Dott.ssa Marianne H. Rasmussen

III sessione

Anno Accademico 2013/2014

Abstract

Faxaflói bay is a short, wide and shallow bay situated in the southwest of Iceland. Although hosting a rather high level of marine traffic, this area is inhabited by many different species of cetaceans, among which the white-beaked dolphin (*Lagenorhynchus albirostris*), found here all year-round.

This study aimed to evaluate the potential effect of increasing marine traffic on white-beaked dolphins distribution and behaviour, and to determine whether or not a variation in sighting frequencies have occurred throughout years (2008 – 2014). Data on sightings and on behaviour, as well as photographic one, has been collected daily taking advantage of the whale-watching company "*Elding*" operating in the bay. Results have confirmed the importance of this area for white-beaked dolphins, which have shown a certain level of site fidelity. Despite the high level of marine traffic, this dolphin appears to tolerate the presence of boats: no differences in encounter durations and locations over the study years have occurred, even though with increasing number of vessels, an increase in avoidance strategies has been displayed. Furthermore, seasonal differences in probabilities of sightings, with respect to the time of the day, have been found, leading to suggest the existence of a daily cycle of their movements and activities within the bay. This study has also described a major decline in sighting rates throughout years raising concern about white-beaked dolphin conservation status in Icelandic waters. It is therefore highly recommended a new dedicated survey to be conducted in order to document the current population estimate, to better investigate on the energetic costs that chronic exposure to disturbances may cause, and to plan a more suitable conservation strategy for white-beaked dolphin around Iceland.

Útdráttur

Faxaflói er stuttur, breiður og grunnur flói á Suðvesturlandi. Þrátt fyrir fremur mikla skipaumferð halda margar mismunandi tegundir hvala til á svæðinu, þeirra á meðal er hnýðingurinn (*Lagenorhynchus albirostris*), sem þar er að finna allan ársins hring. Rannsókn þessi miðaði að því að meta hugsanleg áhrif aukinnar umferðar skipa á dreifingu og hegðun hnýðingsins og að ákvarða hvort breyting hafi orðið á tíðni hnýðingafunda milli ára (2008 – 2014). Gögnum um fundi og hegðun sem og ljósmyndum hefur verið safnað daglega í samstarfi við hvalaskoðunarfyrirtækið *Eldingu* sem er starfrækt við flóann. Niðurstöður hafa staðfest mikilvægi þessa svæðis fyrir hnýðinga, sem að vissu marki hafa sýnt tryggð við ákveðin svæði. Þrátt fyrir mikla skipaumferð virðist þessi höfrungategund þola viðveru báta; engar breytingar hafa orðið á lengd þess tíma sem hnýðingurinn er sjáanlegur hverju sinni eða staðsetningu funda á því tímabili sem rannsóknin stóð, þó að með auknum fjölda skipa hafi sést aukin forðunarhegðun. Auk þess hefur komið fram árstíðabundinn munur á líkum á fundum, háðum tíma dags, sem bendir til dagsveiflu á hreyfingu þeirra og virkni í flóanum. Rannsókn þessi hefur einnig leitt í ljós mikla lækkun tíðni funda um árabil sem veldur áhyggjum af verndunarstöðu hnýðinga við Íslandsstrendur. Því er eindregið mælst til þess að sérstök rannsókn verði gerð til þess að áætla núverandi stofnstærð, kanna betur áhrif langvarandi truflana á orkubúskap dýranna og til að móta hentugri verndunarstefnu fyrir hnýðinga við Íslandsstrendur.

Riassunto

Faxaflói è una baia situata nella parte sudoccidentale dell'Islanda. Nonostante l'alto traffico marittimo presente, la baia ospita numerose specie di cetaceo tra cui il lagenorinco dal rostro bianco (*Lagenorhynchus albirostris*). Questo odontocete è endemico delle fredde acque del Nord Atlantico e si colloca nelle aree di piattaforma continentale come intorno a Inghilterra, Repubblica d'Irlanda, Olanda, Norvegia, Isole Faroe, a sud della Groenlandia, nello Stretto della Manica e di quello della Danimarca, e lungo le coste dell'Islanda. Il lagenorinco preferisce profondità inferiori ai 120 metri e la sua distribuzione dipende fortemente dalla temperatura dell'acqua: quest'animale è, infatti, raro/assente sopra i 18°C, mentre è ritenuto comune a temperature inferiori ai 13°C. La dieta è molto varia: si assume che questi delfini siano consumatori generici e opportunisti, anche se è noto prediligano merluzzo, merlano, capelano, eglefino, aringa e i pesci della famiglia Ammoditidi (specialmente nella baia di Faxaflói).

Il lagenorinco è generalmente avvistato in gruppi di 3 – 6 individui secondo il comportamento assunto: saranno meno numerosi quando si muovono da un posto a un altro e più numerosi quando invece mangiano o socializzano.

L'Islanda rappresenta una delle quattro unità di gestione proposte per questa specie la cui conservazione, come altri cetacei, è minacciata da numerosi fattori tra cui cambiamenti climatici, degradazione dell'habitat, traffico marittimo, sovrapesca, inquinamento acustico, ecc. Al momento, l'unica stima di abbondanza del lagenorinco nel territorio islandese risale al 2001 e conta circa 31,653 animali. Studi recenti hanno evidenziato un possibile declino negli

avvistamenti di questo delfino nella baia di Faxaflói, in cui è però presente tutto l'anno.

Il presente studio si è posto come obiettivo quello di valutare:

- possibili variazioni negli avvistamenti del lagenorinco nella baia di Faxaflói in diversi anni (2008 – 2014);
- eventuali cambiamenti nella durata degli avvistamenti rispetto agli anni precedenti;
- possibili effetti sul comportamento del lagenorinco causati dall'aumentato traffico marittimo nella baia;
- eventuali cambiamenti nella distribuzione dei delfini all'interno della baia.

Inoltre, considerata l'alta quantità di dati raccolti e a disposizione, molta importanza è stata anche fornita alla compressione degli stessi in modo da ottenerne valide informazioni.

I dati sono stati ottenuti utilizzando le barche da whale-watching della compagnia "*Elding*" che giornalmente compiono tour nella baia di Faxaflói. Le uscite sono state intraprese solo con determinate condizioni metereologiche e marittime, cioè assenza di pioggia e velocità del vento inferiore a 10 m/s. Le osservazioni e gli avvistamenti sono stati il risultato di un lavoro di squadra in quanto sia i membri dell'equipaggio che quelli della ricerca (l'autore e due volontari) erano costantemente focalizzati nell'individuare cetacei. Una volta avvistato un gruppo di animali, i dati riguardanti inizio e fine dell'incontro, specie, data, ora, distanza, numero d'individui, comportamento, insieme ad eventuali commenti, sono stati registrati tramite l'utilizzo dell'applicazione "*Spotter Pro*". Nel mentre, gli animali (in particolare le loro pinne dorsali) sono stati fotografati al fine di identificarli.

I risultati ottenuti hanno confermato l'importanza della baia di Faxaflói per il lagenorinco, il quale ha anche mostrato un certo livello di residenza all'area. Nonostante l'alto livello di traffico marittimo, questo delfino sembra tolleri la presenza delle barche: nessuna differenza è stata, infatti, riscontrata sia nella durata che nella distribuzione geografica degli avvistamenti rispetto al periodo di studio. Tuttavia con un numero maggiore di barche intorno agli animali, è stata registrata una maggior frequenza di strategie elusive adottate. Inoltre, sono state riscontrate delle differenze stagionali nella probabilità di avvistamento rispetto all'ora del giorno, che portano ad ipotizzare l'esistenza di un ciclo giornaliero nei movimenti e nelle attività dei lagenorinco nella baia.

Questo studio ha rilevato un drastico declino nei tassi di avvistamento di lagenorinco negli anni, facendo così aumentare la preoccupazione per la sua conservazione nelle acque islandesi.

Dai risultati ottenuti, appare quindi necessario un nuovo studio focalizzato su questa specie in modo tale da ottenerne un'aggiornata stima di popolazione, da meglio indagare sui costi energetici che un'esposizione cronica ai disturbi antropogenici può causare, e da pianificare una più adatta strategia di conservazione per il lagenorinco dal rostro bianco che abita le acque islandesi.

Table of Contents

1. Introduction

1.1 Marine mammals in Iceland

Marine mammals are the top predators and the larger consumers in Arctic and subarctic ecosystems. For these characteristics, together with a general long life span and the ability to extensively store in their thick fat layer (*blubber*), they are good indicators of mid- and long-term variations in the environment (Reddy *et al*., 2001).

Marine mammals can be divided in three main *Orders*:

- *Carnivora* – Pinnipeds (sea lions, seals and walruses) and Fissipeds (sea otters and polar bears);
- *Cetacea* – Odontoceti (toothed whales as dolphins, porpoises, sperm whales, beaked whales, belugas and narwhals) and Mysticeti (baleen whales, from the biggest blue whales to the smallest pigmy right whales);
- *Sirenia* – Dugongs and Manatees.

Among cetaceans, 12 species are regarded to be regular inhabitants of Icelandic and adjacent waters (Stefánsson *et al*., 1997). Based on the available abundance estimates (Pike *et al*., 2009), the most common species in coastal Icelandic waters are minke whales (*Balaenoptera acutorostrata*), humpback whales (*Megaptera novaeangliae*), dolphins of the genus *Lagenorhynchus*, and harbour porpoises (*Phocoena phocoena*) (Fig. 1).

Fig. 1 Most common species found in coastal Icelandic waters: from the left to the right, minke whale, humpback whale, white-beaked dolphin and harbour porpoise (2014, Faxaflói, Reykjavík)

1.2 Iceland: oceanographic features

Iceland is located on the Greenland-Scotland Ridge, where strong, permanent boundaries are formed between the relatively warm waters of the northeast Atlantic and arctic waters of the Nordic Seas. Because of its location, Icelandic waters are highly sensitive to meteorological changes. Differences in currents circulation and related water influx, in fact, may lead to great temperature and salinity fluctuations, both in space and in time (Stefánsson and Ólafsson, 1991) and consequently, they may affect the timing and intensity of the annual cycles of primary production, together with the distributions, abundances and seasonal cycles of planktonic grazers and their predators (Melle *et al*., 2014).

As shown in Fig. 2, the south coast of Iceland is bathed by relatively warm and saline Atlantic water transported by a branch of the Gulf Stream. As a result of it, Icelandic waters temperature declines gradually in clockwise direction, from southeast towards east Iceland.

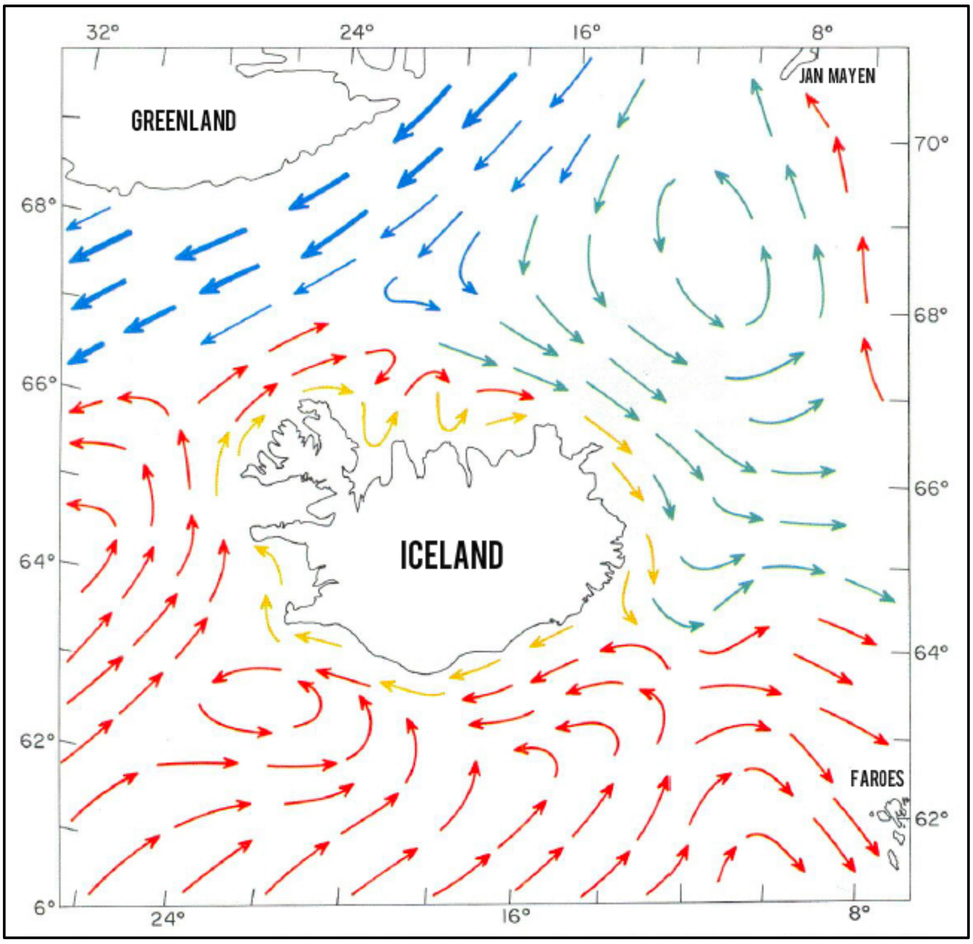


Fig. 2 Ocean currents around Iceland. **Red colour**: relatively warm and saline Atlantic waters; **Blue**: cold and low-salinity polar water; **Green**: Arctic waters; **Yellow**: Icelandic coastal waters. (Stefánsson and Ólafsson, 1991)

1.3 White-beaked dolphin

White-beaked dolphins (*Lagenorhynchus albirostris*) are endemic to the cold temperate water of the northern North Atlantic (Kinze *et al*., 1998; Northridge *et al*., 1997; Reeves *et al*., 1999; Ridgway and Harrison, 1999). This species belongs to the family *Delphinidae* and, together with five other dolphin species, to the genus *Lagenorhynchus* (Fig. 3).

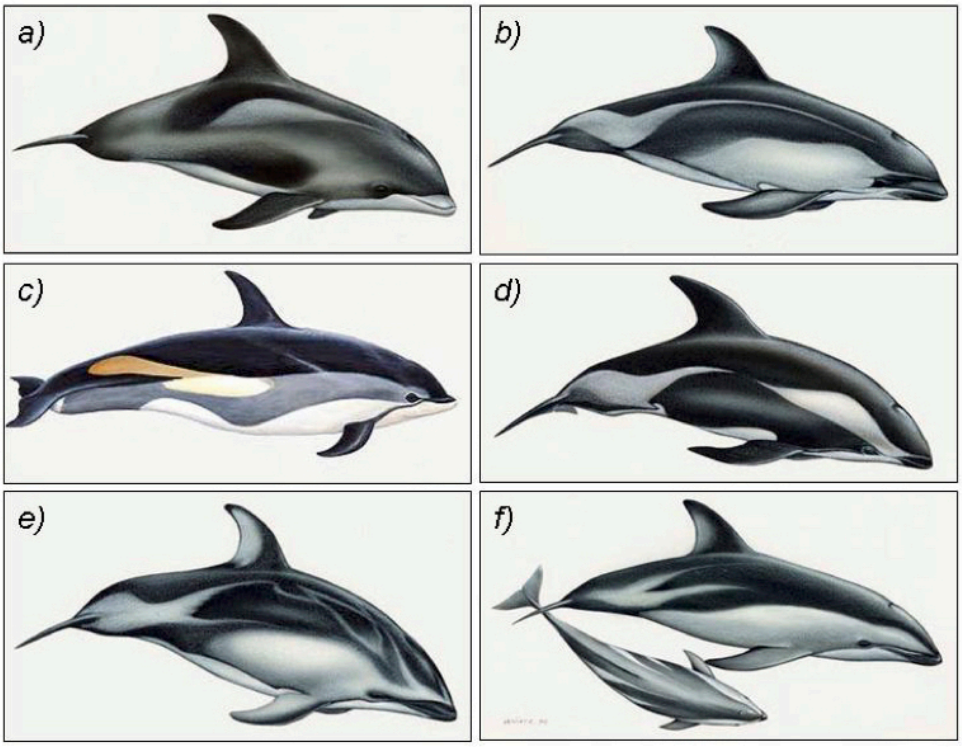


Fig. 3 The genus *Lagenorhynchus*. a): *L.* albirostris (White-beaked dolphin). b): *L. australis* (Peale's dolphin). c): *L. acutus* (Atlantic white-sided dolphin). d): *L. cruciger* (Hourglass dolphin). e): *L. obliquidens* (Pacific white-sided dolphin). f): *L. obscurus* (Dusky dolphin). *Copyright* Wurtz-Artescienz (fig. a, b, d, e, f) and Martin Camm (fig. c)

1.3.1 General characteristics

White-beaked dolphin is the biggest species of the genus *Lagenorhynchus* and has a robust body with a short thick beak that can reach up to 5-8 cm long in adults. Despite its denomination, *i.e. albirostris* ("white rostrum"), not all of them do have a white beak; many of these dolphins present, in fact, a brown/greyish beak and sometimes even a black one (Rasmussen, 1999; Kinze, 2001). The coloration of the body is mainly black and white. The dorsal fin is at mid body, large, often rounded at the peak, strongly curved, and of a dark grey. The flippers, the fluke and the tail stock are generally dark too. As shown in Fig. 4, they also have a lightly pigmented (white/greyish) saddle (*i.e.* the area behind the dorsal fin), which makes them more easily recognisable from the Atlantic white-sided dolphin (*L. acutus*) (Reeves *et al.*, 1999).

Fig. 4 Typical coloration pattern of white-beaked dolphins (06.09.2014, Faxaflói, Reykjavík)

Like in other Odontocetes species, males are generally larger than females, reaching up to three meters in length; however most of white-beaked dolphins are around 2.1 – 2.8 m long (Reid *et al.*, 2003). Fully-grown animals weigh approximately 180 – 275 kg (Rasmussen, 1999) and become mature around 10 years old.

In Iceland, *L. albirostris* reproduces mostly during the summer and, after 11 months of gestation, gives birth somewhere between May and August (Víkingsson and Ólafsdóttir, 2004), which is when waters are warmer and greater supply of nutrition is present. At birth the calves are about 1.2 m in length and weigh around 40 kg (Kinze, 2001).

White-beaked dolphins have a thick layer of blubber, which is vital for their survival in the cool North Atlantic waters; furthermore they depend on energy rich food to balance out the energy spent to keep their body temperature stable (Carwardine and Camm, 1999).

1.3.2 Range and distribution

White-beaked dolphins appear to be located in shelf waters (Northridge *et al.*, 1995), in areas of high bathymetric relief and complexity, such as around the UK, the Republic of Ireland, the English channel coast of France, the Netherlands, Faroe Islands, off southern Greenland, the Denmark Strait, Norway and the seas around Iceland (Fig. 5).

This species is believed to prefer water less than 120 m deep (MacLeod *et al.*, 2007; Weir *et al.*, 2007; Rasmussen *et al.*, 2013), where the most important variable has been demonstrated to be water temperature. In fact, while at temperatures above 18°C they seem to be very rare or absent, white-beaked dolphins are considered common in waters below 13°C. Specifically, their occurrence decreases substantially and it is often even replaced by other species (for example common dolphins, *Delphinus delphis*), in water temperatures greater than 12 – 14°C (MacLeod *et al.*, 2008). Beyond this temperature-based habitat partitioning, white-beaked dolphins seem to favour slope characterized by a predominantly sandy seabed (Cecchetti, 2006; Cooper, 2007; Canning *et al.*, 2008; Weir *et al.*, 2009), leading to the idea that these dolphins prefer particular locations.

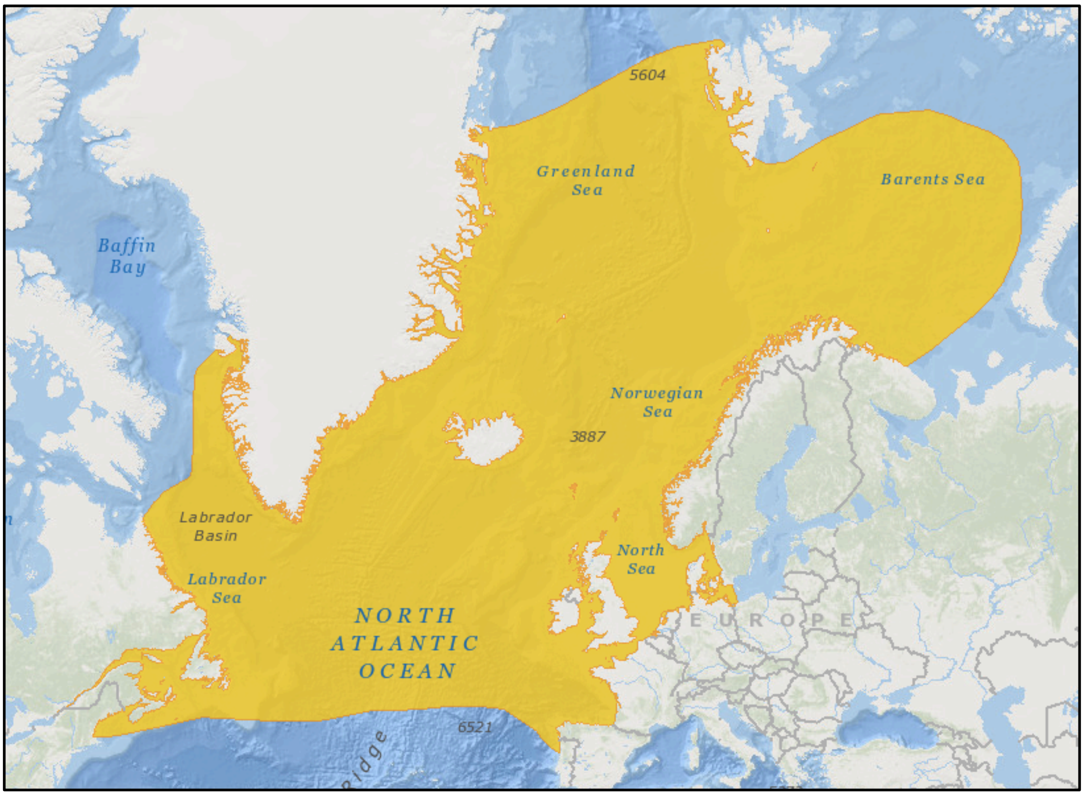


Fig. 5 Hypothetical distribution of white-beaked dolphins based on oceanography. From IUCN (International Union for Conservation of Nature) 2012. *Lagenorhynchus albirostris. The IUCN Red List of Threatened Species*. Version 2014.3 (downloaded on 2014-11-25)

It is not yet known, in fact, why this species is restricted to cooler waters but it's most likely linked to a combination of competition from other species and direct physiological effects, rather than indirect effects related to the distribution of prey (MacLeod, 2013).

However, information on white-beaked dolphins dynamics and habitat use are still limited, but it is known that although they are capable of long-range movements, eastern and western populations are phenotypically distinct (Mikkelsen and Lund, 1994), individuals often show repeated inter-annual site fidelity and no evidence of large-scale migration has been observed.

For example, white-beaked dolphins are found all year-round in Icelandic inshore waters (Magnúsdóttir, 2007; Rasmussen *et al.*, 2013), particularly concentrated in the south western part (Fig. 6).

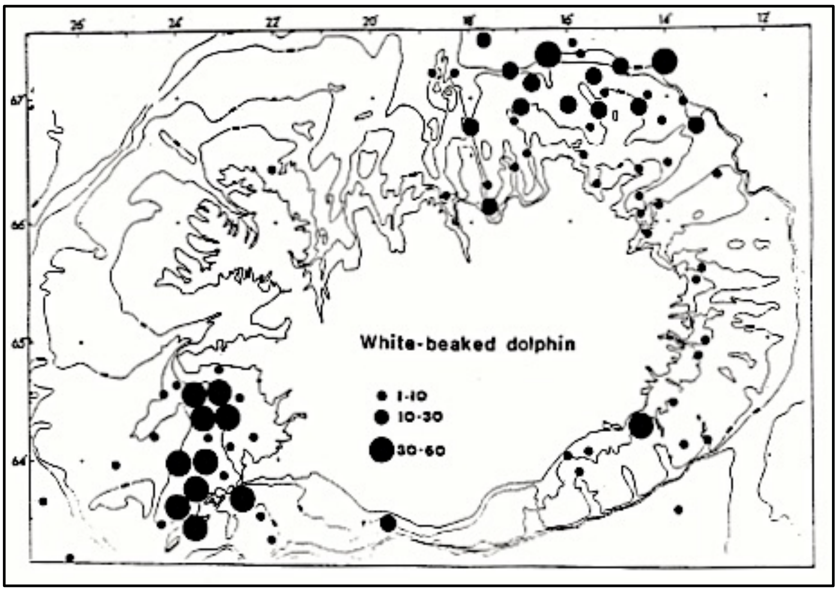


Fig. 6 Occurence of white-beaked dolphins around Iceland (Gunnlaugsson *et al.*, 1988)

Data from one tagged animal revealed a quite large home range area for Icelandic white-beaked dolphins showing that this species spends most of its time travelling (Rasmussen *et al.*, 2013). Their distribution, in fact, seems in this case, to be strongly related to distribution and hotspots of certain prey species.

1.3.3 Diet

From the little available data offered by stranded animals, the white-beaked dolphin is assumed to be a generalist consumer of a wide variety of fish such as cod (*Gadus morhua*), whiting (*Merlangius merlangus*), capelin (*Mallotus villosus*), sand eel (*Ammodytes* spp.), haddock (*Melanogrammus aeglefinus*), hake (*Merluccius merluccius*), herring (*Clupea harengus*), plaice (*Pleuronectes platessa*), flounder (*Platichthys flesus*), mackerel (*Scomber scombrus*), scad (*Trachurus trachurus*) and dab (*Limanda limanda*) (Evans, 1991; Santos *et al.*, 1994; Víkingsson and Ólafsdóttir, 2004). Stomach contents' analysis has also shown that these animals feed occasionally on cephalopods (5%) and that the daily energy consumption is estimated to be around 14,000 – 20,000 Kcal (Sigurjónsson and Víkingsson, 1997; Kinze *et al.*, 1998; Reeves *et al.*, 1999).

Despite this variety of fish, recent studies conducted on stranded white-beaked dolphins on the Dutch coast, have shown a predominance of whiting and cod, without clear changes over time (35 years) or differences between sexes or size-classes of dolphins (Jansen *et al.*, 2010). This high presence of gadoid species has also been reported in those from Icelandic and Scottish waters (Víkingsson and Ólafsdóttir, 2004; Canning *et al.*, 2008).

Although being opportunistic feeders, white-beaked dolphins that inhabit Icelandic waters, particularly Faxaflói bay (southwest), have been documented to feed mostly on sand eels (Rasmussen, 1999; Rasmussen and Miller, 2002; Rasmussen *et al.*, 2013). In addition, according to fishermen, they are also generally sighted in great numbers at the southwest coast of Iceland during the spawning season of the capelin (Magnúsdóttir, 2007).

1.3.4 Social structure: group size, behaviour and communication

White-beaked dolphins are primarily observed in small groups of less than 10 – 20 individuals. Even though pods of up to 50 – 200 animals are not uncommon (Rasmussen, 1999; Reid *et al.*, 2003), group sizes of 3 – 6 individuals comprise the majority of sightings (Hammond *et al.*, 2002; Weir *et al.*, 2007; Canning *et al.*, 2008; Weir *et al.*, 2009; Bertulli, 2010). Noteworthy is that smaller groups were recorded at higher water temperatures (Canning *et al.*, 2008), with significantly greater group size in early summer than in late summer, perhaps indicating a seasonal variation in group size: whether this reflects seasonal changes in prey preferences or a more direct effect of temperature on white-beaked dolphin social behaviour is still unknown (MacLeod, 2013).

Previous studies conducted in Iceland showed a unique tendency in the average group size of these animals: comparison of group sizes in Faxaflói (SW – Iceland) and Skjálfandi (NE – Iceland) (Rasmussen, 1999; Salo, 2004) has revealed that white-beaked dolphins sighted at the northeast coast form generally smaller groups (≅ 12) than dolphins at the southwest coast (≅ 20).

Differences over time have also been noticed: for example, in the same bay, higher average were recorded during 2004 – 2006, with groups frequently counting above 10 individuals (Magnúsdóttir, 2007), whereas 3 – 6 was the average group size identified during whale-watching tours in 2008 – 2009 (Bertulli, 2010).

Furthermore, the group size of this species has been proved to be strongly related to behaviour: a small group size is observed when white-beaked dolphins are travelling (2 – 5 individuals), a larger one when they are feeding

(10 – 15 individuals) and the largest group size is usually linked to dolphins that are socializing or socializing and feeding (30 – 100 individuals) (Rasmussen, 1999).

Regarding the group combination of white-beaked dolphins in Icelandic waters, there seems to be a general segregation by age and sex, where juvenile groups tend to separate from groups of adults and calves (Fig. 7) (Reeves *et al.*, 1999; Víkingsson and Ólafsdóttir, 2004).

Fig. 7 Pod of white-beaked dolphins: in this frame, 2 adults and one calf (right animal) are visible (26.07.2014, Faxaflói, Reykjavík)

Pods of white-beaked dolphins have been observed in mixed herds of Atlantic white-sided dolphins, bottlenose dolphins, common dolphins and Risso's dolphins, or among fin, sei, minke and humpback whales (Reid *et al.*, 2003; Bertulli, 2010).

White-beaked dolphins can show a wide range of different behaviours: for instance at least nine breaching behaviour types have been described in Iceland (Rasmussen, 1999). These animals spend most of their time traveling and a fairly low amount of it feeding (Ramussen, 1999; Bertulli, 2010; Rasmussen *et al.*, 2013), leading to relate this disparity to an increased time required to find food.

The diving behaviour resembles that of other monitored dolphin species, *i.e.* common, Heaviside's, Pantropical spotted and Atlantic spotted dolphin, (Hooker and Baird, 2001): as reported by Rasmussen *et* al. (2013), white-beaked dolphins show, in fact, both V-shaped (*i.e.* dives without a defined bottom, classified as transit and traveling dives) (Otani *et al*., 1998), and U-shaped dives (*i.e.* dives with a flat bottom phase lasting seconds to several minutes, associated with foraging behaviours) (Westgate *et al*., 1995).

Noteworthy is the fact that this species has unique acoustical signatures, making it easily identifiable via passive acoustic monitoring. Thanks to echolocation capabilities, white-beaked dolphins have, in fact, high temporal resolution (Mooney *et al*., 2009). They are acoustically active and produce both whistles and clicks (Rasmussen and Miller, 2002; Rasmussen *et* al., 2002; 2004). Whistles are directional and they may be used for short-range communication (up to 140 m) but also for long-range one, arriving presumably at distances over 10 km (Rasmussen *et al*., 2006). Furthermore, studies conducted in Iceland (Nachtigall *et al*., 2008) have shown that these dolphins have a very similar high frequency sensitivity to harbour porpoises, which are the animals consider to hear the highest frequencies to date (Kastelein *et al*., 2002).

1.3.5 Status and conservation in Icelandic waters

From the 90's to early 2000's, white-beaked dolphins have been protected through many national legislations and international agreements, with the aim of determining and maintaining the species *Favourable Conservation Status* (FCS). Currently, *L. albirostris* is in the *Annex IV* of *EU Habitats Directive*, thereby requiring strict protection; its status is considered *Unfavourable*

(*Appendix II*) within the North and Baltic Seas by the *Convention of Migratory Species* (CMS); consequently, white-beaked dolphins represent a feature of conservation concern within the CMS regional *Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas* (*ASCOBANS*); despite this, the species is globally classified as of *Least Concern – LC* in the *IUCN Red List* (Tetley and Dolman, 2013). In fact, while concern for their conservation has been growing in the last years, especially related to increasing threats, little is still known on white-beaked dolphins' life history, abundance and ecology, to allow a reassessment of their Conservation Status.

Icelandic waters represent one of the four management units proposed for this species (Evans and Teilmann, 2009). The only current estimate of abundance, dated back to 2001, indicates that about 31,653 animals may inhabit Icelandic waters (Pike *et al*., 2009), with an approximately total of a hundred thousands throughout their northeast Atlantic range (Øien, 1996; Hammond *et al*., 2002). Recent studies have shown a declining trend of white-beaked dolphins' sightings off the Reykjanes Peninsula (SW – Iceland) from 100% sightings in July 2000 to only 23% in July 2013 (Rasmussen, 2013). Therefore, new sighting surveys, population estimate and possible conservation strategy have been suggested for white-beaked dolphins around Iceland.

1.4 Threats to white-beaked dolphin conservation

In the last decades, the expansion of human activities at sea and in coastal zone, has made conserving cetaceans an increasing challenge. While limited to rare events may have an impact at individual level with low consequences for the population, actions that cause progressive habitat degradation, influencing the biotic communities at ecosystem level, often have long-term irreversible effects. Consequently, they may cause drastic changes such as the decline, displacement or even extirpation of a certain species population from its critical habitat. Thus, starting from improving available knowledge on species of interest and the habitats they live in, it is fundamental to distinct between impacting factors, short- or long-term effect on the individual, and long-term effect on the population (Notarbartolo di Sciara, 2002).

In this sense, white-beaked dolphins face a high number of potential threats. Like the other cetaceans, in fact, these animals are long-lived vertebrates placed at the highest levels of marine trophic webs, and they have a very low reproductive rate. All these general characteristics, together with their specific ecological needs (e.g. range and distribution), make them extremely vulnerable.

Many studies have now shown how short-term responses to disturbances can have unforeseen consequences for the life history of exposed individuals or for the dynamics of their populations (Coltman *et al*., 2003; Cooke and Schramm, 2007; Lusseau *et al*., 2006; Lusseau and Bejder, 2007; Turvey *et al*., 2007). These consequences can occur at an ecological level (e.g. increased energetic limits to cope with the disturbance that physiologically influence individuals) but also at an evolutionary scale (e.g. selective harvesting can determine the survival of certain individuals with highly heritable traits and thus, influence the genetic make-up of a population) (Coltman *et al*., 2003). Therefore, disturbances become a driving force for the life history and survival of species.

However, it is highly recommended to correctly assess the susceptibility of species to a specific disturbance, so to not wrongly determine conservation priorities (Gill *et al*., 2001): MacLeod (2013), for example, used a combination of demographic and spatial components to describe how a particular threat is likely to affect white-beaked dolphin (Fig. 8):

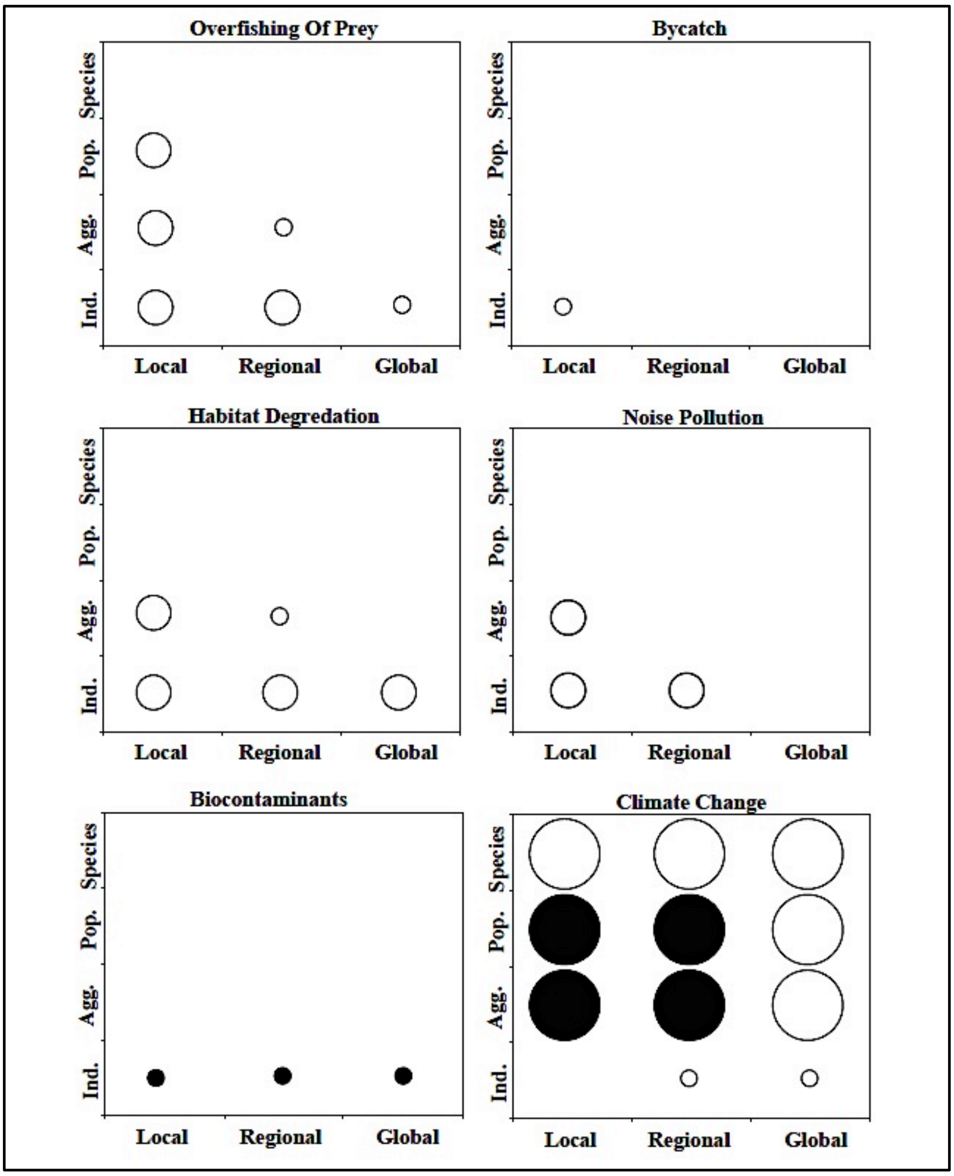


Fig. 8 An assessment and comparison of the combinations of spatial and demographic levels of threats to the white-beaked dolphin in European waters. **Open "Bubbles"**: potential effect; **Closed "Bubbles"**: documented effect. **Size** of the "bubble" indicates the intensity of the threat (high, medium, low). When **no "bubble"** is present, there is currently no known or suspected effect at that particular combination of demographic and spatial levels. **Spatial component (x-axis)**: *Local*: affects a species across the range of up to 100s of km^2; *Regional*: impacts a species across a range between up to 100s to 1000s of km^2; *Global*: impacts a species throughout its range. **Demographic component (y-axis)**: *Ind*: affects the survival of individual animals; *Agg*: affects the persistence of local aggregations of the species; *Pop*: affects the likelihood of extirpation of genetically-distinct or geographically-isolated populations of a species; *Species*: affects the likelihood of extinction of the species as a whole. (MacLeod, 2013)

It's worth of mention that, from a conservation point of view, disturbance is significant only if it affects the population survival or fecundity, leading to a population decline. It is thus important to be cautious in selecting measures of species response to disturbance.

1.4.1 Marine traffic and noise pollution

Anthropological pressure on marine environment is increasing: new industries targeting offshore areas are, in fact, growing alongside traditional activities such as fishing and shipping (Halpern *et al*., 2008). At the same time, human fascination with whales and dolphins have enhanced too, leading to the expansion of marine wildlife tourism (Forestell *et* al., 2007; Constantine and Bejder, 2008; O'Connor *et al*., 2009; Pirotta *et al*., 2015).

These human activities are not homogeneously distributed both in time and in space: for instance ship traffic tends to concentrate in specific periods of the year and along specific routes (Schreier *et al*., 2007). Different species are therefore heterogeneously exposed to human disturbance. The consequent response though, varies depending on the animals' overall ecological landscape (Gill *et al*., 2001; Beale and Monaghan, 2004): e.g. the quality of a foraging area or the condition of an individual and its previous exposure to specific stressors (Pirotta *et al*., 2015). Individuals may also show tolerance to the disturbance and endure even in stressful locations (Sini *et* al., 2005; Bejder *et al*., 2009). Despite this, a chronic exposure can alter their activities, change their residency pattern (Lusseau, 2005) and influence their vital rates (survival and reproduction): for example, if foraging time is reduced, energy intake may be negatively affected, thereby altering reproductive and calving success of the species (Sini *et* al., 2005; Williams *et* al., 2006; Christiansen *et al*., 2013; 2014; New *et al*., 2013; Pirotta *et al*., 2015).

In this context, boat traffic can affect the activity of exposed marine mammals through both physical interactions between the vessel and the animals, and the noise introduced in the environment. A part from the not uncommon episodes of collisions between boats and cetaceans, studies have shown, in fact, that marine traffic affects dolphins' behaviour around vessels: for example increasing dive intervals, direct avoidance of boat vicinity, increasing in speed and variations in vocalization, are all observed responses to this kind of disturbance (Bejder *et* al., 1999; Nowacek *et* al., 2001; Van Parijs and Corkeron, 2001; Hastie *et al*., 2003; Lusseau, 2003a; 2003b; 2004; Sini *et al*., 2005; Williams *et al*., 2011; Pirotta *et al*., 2014).

As already implied before, vessels generate underwater noise including the one created by cavitation (*i.e.* a phenomenon whereby air bubbles form and collapse on the edge of fast-moving propeller blades). Since the fact that the latter is very broadband, it overlaps with the frequency range of many cetaceans' sounds causing the masking of important acoustic signals. If the masking noise increases, active space in which animals are able to detect cues from conspecific will decrease with consequently loss and failure of communication (Jensen *et al*., 2009).

Species that inhabit coastal zones or urbanized areas, such as white-beaked dolphins, are more likely to be affected by the increasing number of commercial boats, but also by the growth of the whale-watching industry that is now present in more than 119 countries (O'Connor *et al*., 2009). Tour boats represent a particular type of marine traffic because they actively approach and congregate around specific cetacean populations. Recently many studies have been focusing on the impact of whale-watching activities on target species (e.g. Constantine *et al*., 2004; Bejder *et* al., 2006; Lusseau and Bejder, 2007; Christiansen *et al*., 2013; 2014; 2015): if on one hand, whale-watching has the enormous potential of educating people while granted them a once-in-a-life-time experience, together with giving the opportunity of collecting precious data for research porpoises, on the other hand the impact of it may have dramatic long-term consequences on cetaceans. It is then necessary and highly recommended an appropriate management of it in order to avoid distress and damage to target species. Common measures include minimum approach distances, maximum speed and the prohibition of chasing the animals, altering their behaviour or separating individuals from pods, limits to noise production and limitations to the number of boats around the animals at the same time (Carlson, 2001; Notarbartolo di Sciara and Birkun, 2002).

1.4.2 Interactions with fisheries

It is known that one of the main threats to marine mammals survival is accidental mortality, which affects approximately 78% of the species (Schipper *et al*., 2008). This high percentage is partly due to fisheries that in some areas can have an extreme negative impact on marine organisms.

Fishery activities may indeed cause mortality or damages through accidental entanglement, e.g. the so-called “*ghost nets*” (*i.e.* fishing gear that has been discarded or lost by fishermen) or the phenomenon named “*bycatch*” (*i.e.* unintentional catch of marine species through active fishing gear, lines or hooks); they may subtract prey through overfishing and/or cause direct mortality deriving from competitive interactions (e.g. the use of cetacean meat as fishing bait or as food) (Notarbartolo di Sciara and Birkun, 2002).

Regarding white-beaked dolphins, they seem to feed primarily on gadoid species that are also some of the main targets of commercial fisheries. At the moment, there is no evidence of an effect occurring on populations, even though it is likely that these dolphins are facing it locally and at individual-level (Fig. 8).

In Faxaflói bay, for example, the harvest on fish species that feed on sand eels, may have had influences on sand eels stock itself, which has been reducing drastically from 2005 (Boganson and Lilliendahl, 2009; Víkingsson *et al*., 2015). This collapse may be linked to the documented decline in sightings percentage of white-beaked dolphins within Faxaflói that are known to feed mostly on them (Rasmussen, 2013). These changes could lead to both short- and long-term adaptations, such as a shift in distribution, or a change in prey species preferences, but also to an increased mortality among the population.

Furthermore, at present, there are not so many evidence of how many white-beaked dolphins are bycaught in fishermen nets (Fig. 8) or of the number of killed dolphins for local consumption (Morizur *et* al., 1999; Rasmussen, 2013).

1.4.3 Climate change

The impact of climate change on marine mammals remains still poorly understood due, in large part, to the lack and difficulty of gaining evidence of it. The effects on the environment, though, are already visible: for instance, oceanic water temperature has been constantly increasing in the last years and it is predicted to keep this trend in the foreseeable future (Levitus *et* al., 2000; Hansen *et al*., 2006; MacLeod, 2009).

As a result of warmer sea temperatures, changes in prey abundance and distribution, together with an enhanced stratification that may cause earlier occurrence of the spring phytoplankton bloom and potential cascading effects through the food chain, are likely expected. In fact, the consequent possible changes in ocean currents and positions of associated fronts, could have profound effects on biological productivity (Stenseth *et al*., 2002; 2004; Walther *et al*., 2002), which in turn would affect top predators like marine mammals (Bjørge, 2001; Würsig *et al*., 2001; Moore and Huntington, 2008; Nicol *et al*., 2008; *IWC workshop* 2009; 2012).

Recently, many studies have been attempting to predict future impacts on marine mammal species (Würsig *et al*., 2001; Learmonth *et al*., 2006; MacLeod, 2009; Simmonds and Eliott, 2009; Evans and Bjørge, 2013). In the 2014 *IWC* meeting (Ashford-Hodges and Simmonds, 2014), the main potential mechanisms through which cetaceans are expected to be impacted, have been summarized as:

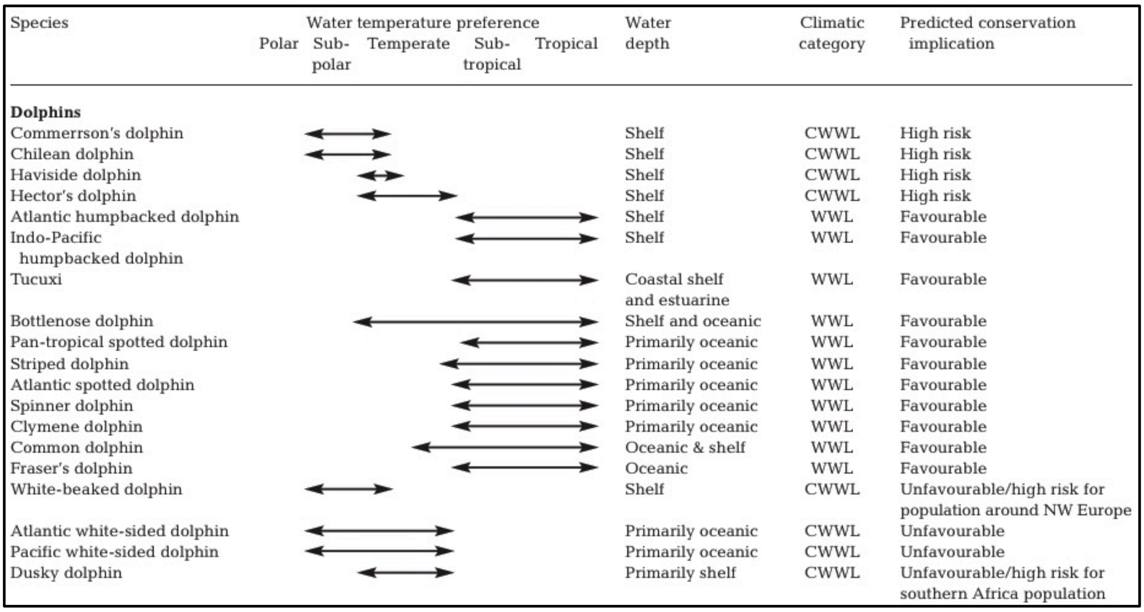
- range changes, driven by thermal tolerance, changes in prey distribution and competitive exclusion;
- increased incidence of disease, reduced immunity, chronic stress through thermoregulation at higher water temperatures;
- loss of habitat in arctic species associated with ice floes;
- loss of habitat in species associated with features specific to a fixed location, e.g. continental shelves, enclosed bays;
- more frequent interaction and competition with humans, increased bycatch or unauthorized hunting by the fishing industry.

At the same time though, many limitations in understanding of possible cetaceans' responses still exist: for example the mechanisms driving current cetaceans distribution are poorly understood (Lambert *et al*., 2014) and it is difficult to discriminate between short-term responses to regional resource variability and the long-term ones as result of climate change.

Anyway, it is expected that the ranges of 88% of cetaceans may be affected by water temperature variation: for 47% of species, these changes are predicted to have unfavourable implications for their conservation, while increasing pressures are foreseen to lead the 21% to a high risk of extinction (MacLeod, 2009).

The most affected species will likely be those that have relatively strict habitat requirements: shelf sea species such as harbour porpoise, white-beaked dolphin and minke whale may come under enhanced pressure with extremely reduced available habitat if they experience range shifts northwards (Evans and Bjørge, 2013).

White-beaked dolphins will likely be, and may already have been, negatively affected by climate change. For example the occurrence of this species in the waters off northwest Scotland has shown a dramatic declined as local water temperatures increased (MacLeod *et al*., 2005).



Species	Water temperature preference: Polar	Sub-polar	Temperate	Sub-tropical	Tropical	Water depth	Climatic category	Predicted conservation implication
Dolphins								
Commerrson's dolphin						Shelf	CWWL	High risk
Chilean dolphin						Shelf	CWWL	High risk
Haviside dolphin						Shelf	CWWL	High risk
Hector's dolphin						Shelf	CWWL	High risk
Atlantic humpbacked dolphin						Shelf	WWL	Favourable
Indo-Pacific humpbacked dolphin						Shelf	WWL	Favourable
Tucuxi						Coastal shelf and estuarine	WWL	Favourable
Bottlenose dolphin						Shelf and oceanic	WWL	Favourable
Pan-tropical spotted dolphin						Primarily oceanic	WWL	Favourable
Striped dolphin						Primarily oceanic	WWL	Favourable
Atlantic spotted dolphin						Primarily oceanic	WWL	Favourable
Spinner dolphin						Primarily oceanic	WWL	Favourable
Clymene dolphin						Primarily oceanic	WWL	Favourable
Common dolphin						Oceanic & shelf	WWL	Favourable
Fraser's dolphin						Oceanic	WWL	Favourable
White-beaked dolphin						Shelf	CWWL	Unfavourable/high risk for population around NW Europe
Atlantic white-sided dolphin						Primarily oceanic	CWWL	Unfavourable
Pacific white-sided dolphin						Primarily oceanic	CWWL	Unfavourable
Dusky dolphin						Primarily shelf	CWWL	Unfavourable/high risk for southern Africa population

Fig. 9 Summary of temperature ranges, water depth preferences, climatic category and predicted conservation status due to changes in species' range resulting from climate change for individual marine cetacean species. **WWL**: warmer water-limited; **CWL**: cooler water-limited; **CWWL**: cooler and warmer water-limited. (MacLeod, 2009)

Given the strong relationship between the occurrence of white-beaked dolphins and water temperature, and the limited availability of suitable alternative habitat further north to move into, climate change must be considered as a highly dangerous threat to their survival (Fig. 8) (*IWC workshop* 2012; MacLeod, 2009; 2013) and therefore, further and deeper studies are vital to correctly assess their population status (Fig. 9) and consequently to plan appropriate conservation strategies.

1.4.4 Others

Together with the previous factors, it is worth to mention that cetaceans and, therefore, white-beaked dolphins are threatened also by habitat degradation and contamination. Degradation of marine environment can be quite difficult to assess but, especially in shelf waters where *L. albirostris* lives, it is likely to be the result from trawl fisheries and pollution from fish farms, oil extraction and coastal development. The effect of such degradation on cetaceans is still poorly understood but it could affect them by causing a change in the composition of local fish communities and/or destroying preferred foraging habitats. In addition, as top predators, these species are likely to accumulate any harmful substances (e.g. heavy metals, PCBs, PAHs) that enter the food chain. When these contaminants reach sufficient levels within the individual, they can potentially cause a reduction in reproductive output and/or an enhanced risk of disease (MacLeod, 2013). Little is still known about the level that may cause negative effects to individuals, but it seems that the overall threat of biocontaminants to the conservation status of white-beaked dolphins is relatively low (Fig. 8).

2. Aims

The purpose of this study is to find out if the increased marine traffic has been influencing white-beaked dolphins in Faxaflói bay (SW – Iceland).

Thus, this study has been focused on:

- possible variations in white-beaked dolphin sightings compared to previous years;
- potential changes in sighting duration over several years (2008 – 2014);
- possible influences on behaviour from increasing number of boats around sighted dolphins;
- potential changes in habitat use of white-beaked dolphins.

Furthermore, due to the large amount of data available, another aim of this study has been to find the more correct method to summarize large datasets to get valuable and complete information.

3. Material and Methods

3.1 Study area – Faxaflói bay

Faxaflói (N64°24 W23°00) is a short, wide and shallow bay situated between the Reykjanes and the Snæfellsnes peninsulas (southwest Iceland) (Fig. 10).

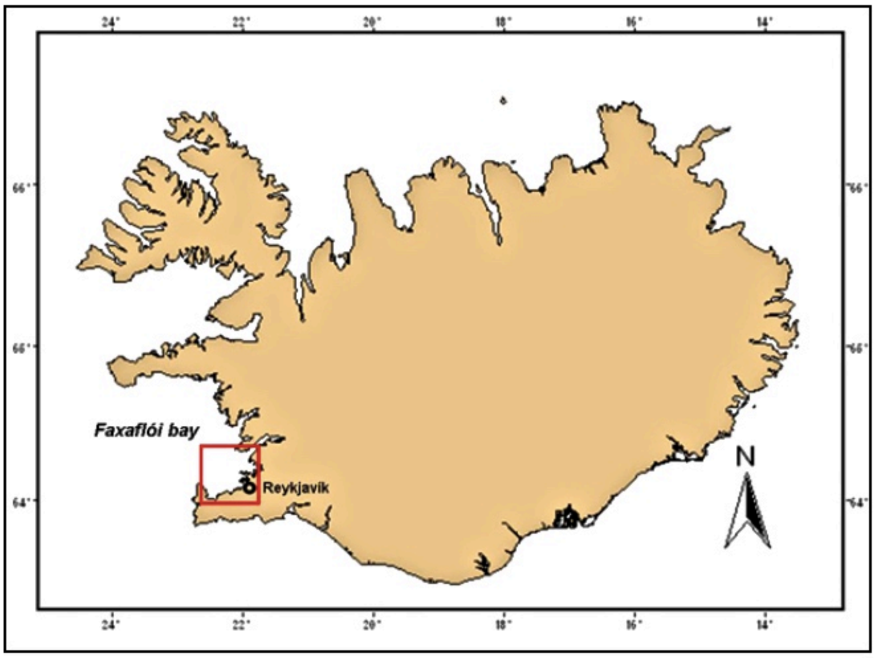


Fig. 10 Map of Iceland: in evidence Faxaflói bay and the study area within it (Bertulli, 2010)

The depth within the bay varies considerably: an average of 50 m characterizes 60% of the total area inside Faxaflói, not excluding though regions less than 20 m deep; depths between 50 to 100 m are found in about 30% of the bay with peaks over 100 m in the region near its mouth, corresponding to 9 – 10% of the total (Stefánsson and Guðmundsson, 1978).

The waters of Faxaflói bay are pretty similar to the Atlantic ones (*i.e.* warm and saline) but they are also a bit diluted by the freshwater coming from land, mainly rivers such as the glacier river of Hvíta in Borgarfjörður.

Due the so-called *upwelling*, this bay is an extremely productive area, rich in prey species and nutrients, which make it a suitable spawning and nursing area as much as hunting ground, for various species of fish (Stefánsson and Guðmundsson, 1978).

For these characteristics, Faxaflói bay is inhabited by many different species of cetaceans, such as minke whale (*Balaenoptera acutorostrata*), white-beaked dolphin (*Lagenorhynchus albirostris*), harbour porpoise (*Phocoena phocoena*), humpback whale (*Megaptera novaeangliae*) and killer whale (*Orcinus orca*).

However, the occurrence of some of these species (*i.e.* minke whale and humpback whale) is variable during the year due to their seasonal migrations to breeding and calving areas (Magnúsdóttir *et al*., 2014; Víkingsson and Heide-Jørgensen, 2014).

For the present research, a restricted area of the bay was surveyed (Fig. 10): the depth within the study area varies from approximately 16 to 60 m, whereas water temperature fluctuates from about 7°C in spring to 13°C during summer months.

3.2 Data collection and analysis

Data collection on white-beaked dolphins was carried out taking advantage of opportunistic platforms. In particular, data were collected everyday, weather permitting, thanks to the whale-watching company "*Elding*" (http://elding.is).

This company performs year-around tours in Faxaflói bay and therefore it provides the opportunity to gather as much information as possible on target species. While in winter (November – early March) one tour per day is scheduled, “*Elding*” offers two trips during spring (late March – May) and autumn months (September – October), and three in summer (June – August). Departing from Reykjavík harbour, tours last approximately three hours each and in summer they cover all day:

- *Hafsúlan* – departing at 9:00, 13:00, 17:00;
- *Elding* – departing at 10:00, 14:00, 20:30.

Fig. 12 Vessels used for whale-watching tours in Faxaflói bay (Reykjavík). On the left: *Hafsúlan*; on the right: *Elding*

The two vessels, *Hafsúlan* and *Elding* (Fig. 12), of respectively 25 and 27 m length, are made available for research surveys, even though the second boat is mainly used as an additional one when the former is not available or to collect extra data. “*Elding*” company has been providing its boats as opportunistic platforms for research since 2004.

During 2014, particularly from April ‘till late September, surveys were designed as follows.

Weather and sea conditions were checked before every tour: fieldwork was carried out preferably when rain was not foreseen and only in wind speeds of less than 20 knots (10 m/s), therefore when the sea state was below 4 on the *Beaufort scale*.

Throughout a whale-watching trip, observation was performed on different levels of the vessel in order to enlarge viewing range and increase sighting probability: the guide of the tour was positioned on the top of the boat (*i.e.* 8 m high for *Hafsúlan* and 7 m for *Elding*), while the research team, formed by two observers (the author and two trained volunteers in turn), was located at the bow of the vessel on the middle deck. In addition, captain, first mate, engineer and deckhands were also helping in scanning the water surface (often using binoculars too), as soon as they were free of their own duties. All crewmembers were constantly in radio contact to inform each other of all sightings and to compare their estimation of the number of animals present at each time. In this way, a sighting was the result of a strong cooperation between all crewmembers and the research team.

It is noteworthy that at least six other whale-watching companies are operating within the same bay, especially in summer season (Rasmussen, 2013): radio contact between companies is usually kept during the entire duration of tours to inform about each other routes and possible sightings.

Beyond direct observation of animals (e.g. dorsal fins when surfacing), helpful cues used to locate cetaceans were blows, splashes in the distance, but also the presence of seabirds feeding rafts: for white-beaked dolphins have been, for example, noticed a strong association especially with species like puffin (*Fratercula arctica*), arctic tern (*Sterna arctica*) (Fig. 13), kittiwake (*Rissa tridactyla*), northern gannet (*Sula bassana*), gull (*Laridae* spp.) and manx shearwater (*Puffinus puffinus*) (Bertulli, 2010).

Fig. 13 White-beaked dolphins surrounded by arctic terns while surfacing (29.05.2014, Faxaflói, Reykjavík)

When an encounter occurred, photographs were taken in order to identify individuals, while sighting data, environmental parameters and effort information were recorded using the app “*Spotter Pro*” (*Copyright Conserve.IO*, Inc. 2014). During 2014, research surveys were conducted from January ‘till late September, but in this study it has been taken into consideration just the April – September interval in order to better compare results with datasets from previous years (2008 – 2013) where winter months were not often available.

3.2.1 *Spotter Pro*

"*Spotter Pro*" is an iOS 'App' created by *Conserve.IO* with the aim to facilitate in-field data capture for conservation management. This application program allows users to record a wide range of information during each survey.

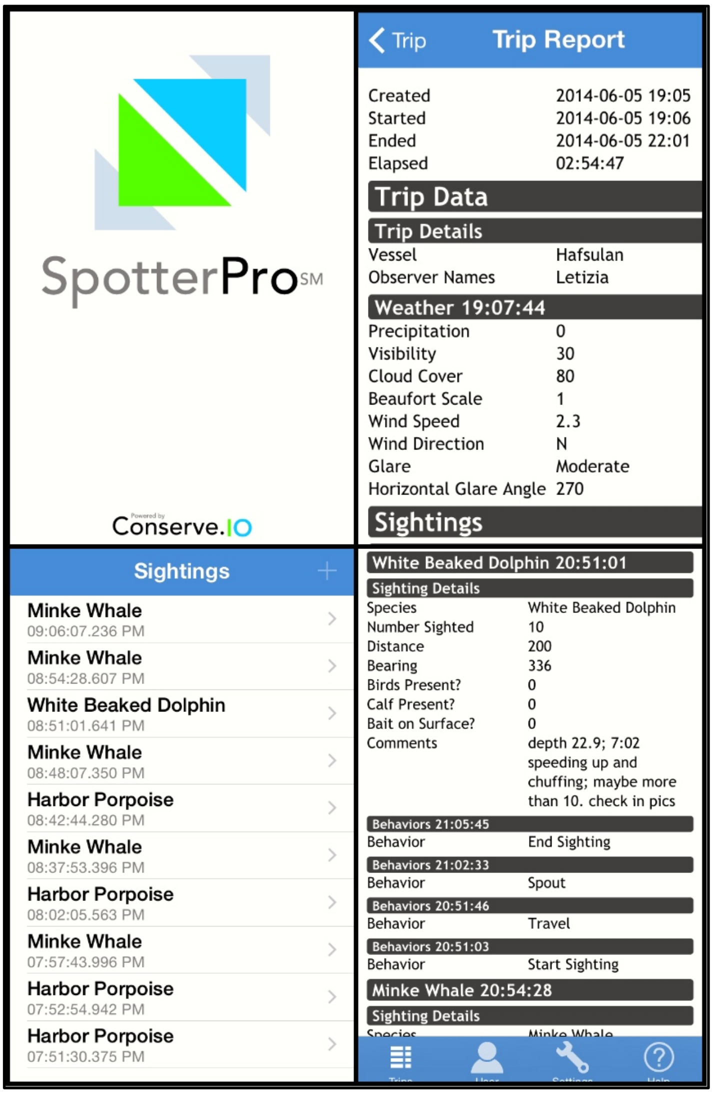


Fig. 14 Example of data collection using "*Spotter Pro*" (*Copyright Conserve.IO*, Inc. 2014)

At first, a "trip" is created and started: trip details such as name of the vessel and of the observer, together with the assessment of environmental conditions, are integrated as shown in Fig. 14.

When animals are spotted, the encounter is recorded as a new sighting including information such as species, date, time, distance, pod size and composition, but also behaviours observed (e.g. feeding; traveling; breaching; lunge; shallow dive). In particular, after a sighting is created, time of start and end of sighting encounter are discriminated respectively as the moment when the boat enters within 500 m from animals and as the moment when either the captain or the observed individuals decide to leave the area. The program gives also the possibility of noting special comments that the observer wishes to specify for each sighting (e.g. pod composition; water temperature; depth).

During the survey, each school spotted, defined as the animals in relatively close spatial proximity (*i.e.* each member within 100 m of any other member) that are involved in similar (often the same) behavioural activities (Parra *et al*., 2006), is recorded as a new sighting.

Furthermore, "*Spotter Pro*" records each location of each sighting and geographically tracks the entire itinerary of the survey.

At the end of each trip, data collected are uploaded on the user "*Spotter server*" by Internet connection: in this way, authorized users will be able to manage them when required.

3.2.2 Effort

To assess the total research survey effort completed in 2014, data regarding starting and ending time of each tour undertaken, were downloaded from "*Spotter Pro*" and organized in an Excel file.

The total survey effort was measured as the time expressed in hours spent per trip. As the survey efforts were not uniform across months and different years (2008 – 2014), comparisons in white-beaked dolphins' sighting pattern were made possible expressing sightings as the number of schools seen per unit effort of search.

Therefore, the sighting rate for white-beaked dolphins was calculated by dividing the total number of schools sighted, with the hours of survey effort completed in the related period.

3.2.3 Photo-ID

Photo-identification is a non-invasive technique that helps obtaining information on wild animal populations and it is commonly used in cetacean studies (Defran *et al.*, 1990; Würsig *et al*., 1990; Evans and Hammond, 2004).

Natural markings and features of the animals, such as dorsal fin shape, nicks or notches on dorsal fin, fluke and body coloration pattern, etc., can be in fact used as distinctive characteristics to recognise not only different species, but also specific individuals (Hammond *et al*., 1990).

In this study, photo-ID has been performed using a digital camera (Nikon D5200) with a 70 – 300 mm zoom lens. Photographs have been taken as perpendicular as possible to the animal's body axis, to capture its dorsal fin, recognised as the best distinctive feature for dolphins photo-identification.

Pictures from each survey have been organised in folders and cropped to facilitate the identification through comparison with pre-existing catalogues (*Copyright* University of Iceland).

Two main aspects have been considered for each photograph: quality of the image (specially related to focus, angle, glare and distance from the subject) and distinctiveness of the identifying features or markings of the animal. Only pictures judged good or excellent have been used to catalogue new individuals.

An example of photo-identification is shown in Fig. 15.

Fig. 15 Fins of white-beaked dolphin *DEM 116_Gaby* (*Copyright* University of Iceland): frame from 20.08.2011 on the left, and from 28.06.2014 on the right (Faxaflói, Reykjavík)

In order to recognise the greater number of catalogued individuals, which may have been spotted during 2014, images of all quality and distinctiveness were submitted to the matching process. In this way dolphins photographed during surveys were divided as “re-sight” (*i.e.* individual successfully matched with the catalogue), “new” (*i.e.* individual not matched with the catalogue but eligible to be added as a new one in it) and “unknown” (*i.e.* match attempted but the individual was not identified, and it is not possible to include it as a new one).

Noteworthy is the fact that while dolphins were previously identified adopting three different categorisations, thus resulting in three catalogues (Bertulli, 2010; *Copyright* University of Iceland), due to the restricted amount of time available for data analysis, just the classification *DEM* (*i.e.* dorsal fin edged marked individuals) has been considered for 2014. This identification criterion has been identified as the most promising one for white-beaked dolphins because mainly based on mark types with low gain and loss rates (Bertulli, 2013).

3.2.4 Marine Traffic

Faxaflói bay hosts a rather high level of boats traffic (Fig. 16): in this area fishing boats, cargo ships, whaling boats, cruise ships, together with many whale-watching vessels, transit daily.

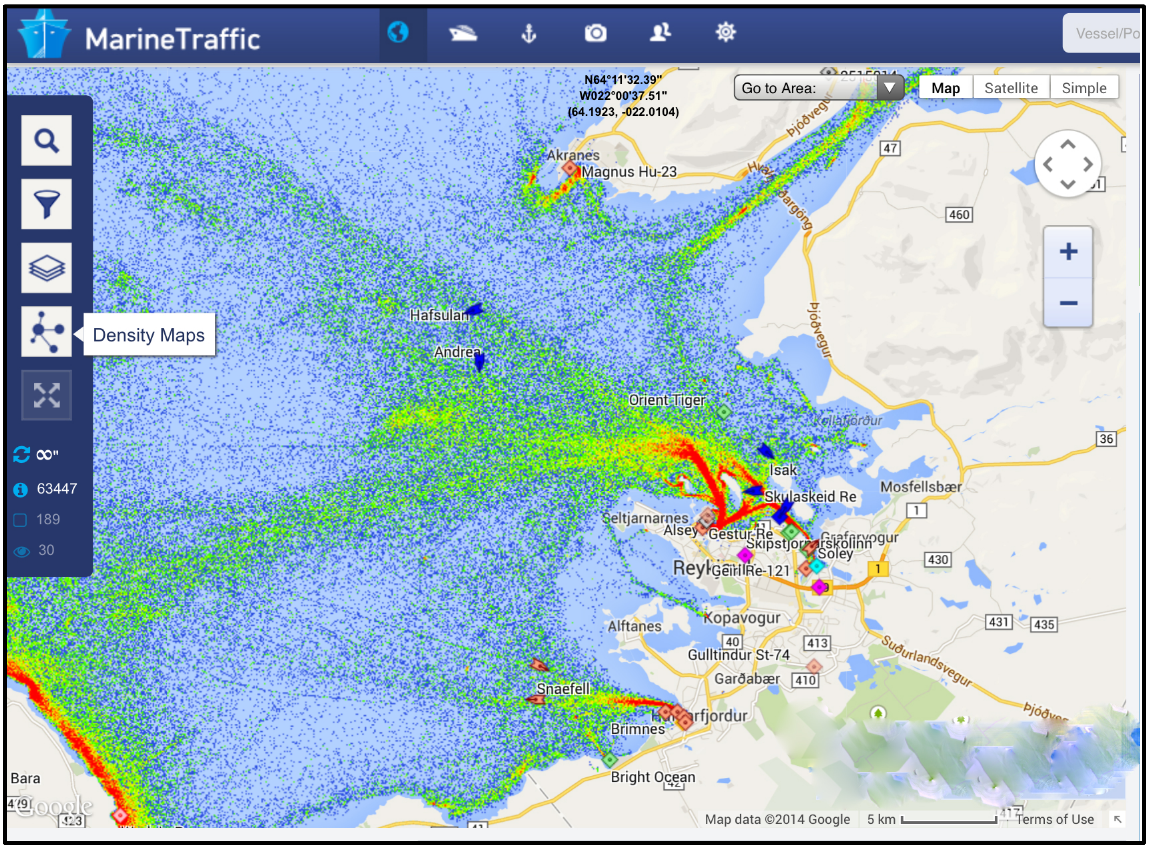


Fig. 16 Density map of boats traffic within Faxaflói bay, Iceland (19.05.14 *Copyright* http://www.marinetraffic.com)

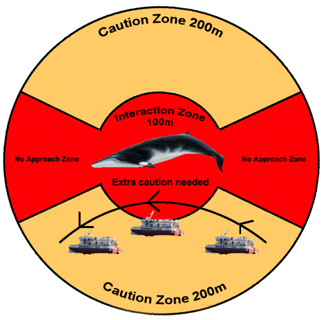
Noteworthy is the fact that the general principles to minimize the risks of adverse impacts of whale-watching on cetaceans agreed by the IWC (*International Whaling Commission*) Scientific Committee in 1996, are followed by most of the whale-watching companies operating in Faxaflói.

This so-called "code of conduct" has been developed as guidelines based on common sense and on existing scientific knowledge. Besides the formerly described common management measures (see paragraph 1.4.1), these principles underline the importance of allowing cetaceans to control the nature and duration of any kind of interaction. Of course a critical aspect of managing whale-watching is the determination of the so-called “carrying capacity” (*i.e.* the amount of whale-watching activities that is sustainable by the population involved over the long-term) because it is strongly related to the behavioural and ecological characteristics of a certain species, to the environmental variables of a specific area and to the peculiarity of the touristic industry which operates within the same place (Notarbartolo di Sciara and Birkun, 2002).

“*Elding*”, in particular, has developed its own guidelines for responsible whale-watching that are respectfully followed by all crewmembers and also used to educate tourists on-board (Fig. 17).

Elding Guidelines for Responsible Whale Watching

These are the guidelines we aim to abide by, however, there are many variables to consider when out at sea, such as the weather, number of whales, prey availability, if there are calves present, animal behavior and so on and so forth. We have to remember that these are wild animals and to enjoy them for the future we need to show them patience and respect. We will try to get you close but how close we get is always on the animals terms as we aim to minimise disturbance.



- No more than 3 vessels in the caution zone.
- Once in the caution zone we maintain a slow cautious speed and any changes in speed should be made gradually.
- Repeated attempts to interact with cetaceans that are showing signs of distress should be avoided.
- Avoid making sudden or excessive noises from both the vessel and the guide on the microphone.
- DO NOT sail through pods of concentrated cetaceans, i.e. do not encourage dolphins to bow-ride.

Potential problems caused by vessel disturbance

- Disruption of behavior (e.g. feeding, migrating).
- Avoidance of important habitats (e.g. feeding areas, resting areas).
- Stress.
- Injury.
- Increased mortality (more deaths).
- Reduced breeding success.

Signs of distress

Distress signals are sometimes very difficult to interpret and differs between species, it is more a feeling you have that the animal is stressed and wants to be left alone. Below are example behaviours that may be linked to vessel disturbance.

- Continuous attempts to move away from the vessel either it be quickly or slowly.
- Regular changes in direction or speed of swimming.
- Hasty dives.
- Changes in breathing pattern.
- Increased times spent diving compared to time spent at the surface.
- Aggressive behaviors such as tail slapping or loud trumpet blows.

Elding adventure at sea

Fig. 17 “*Elding*” guidelines for responsible whale-watching (*Copyright* http://elding.is)

During 2014 research season, the number and type of boats around spotted dolphins was recorded: particular attention was given to the distance discriminating between vessels within and beyond 300 m from the focal group.

In addition, boats movements within the study area were checked using the live map available on "*Marine Traffic*" (http://www.marinetraffic.com).

3.2.5 Behaviour

During surveys, one of the main behavioural states (*i.e.* traveling, milling, socializing and feeding) was assigned to each school of dolphins as soon as they were spotted.

Behavioural activities were classified following standardized criteria (Shane, 1990; Müller *et al*., 1998; Rasmussen, 2004; Bertulli, 2010):

1) TRAVELING: a school swimming consistently in one direction and showing a constant surface pattern.
2) FEEDING: dolphins seen actively chasing fishes close to the water surface or circling a specific area and diving in the same small area; individuals often showing an unpredictable surfacing pattern; birds usually concentrated over the dolphins during the 1-min sample.
3) MILLING: dolphins apparently not involved in any distinctive behaviour, but swimming in close proximity to each other without following a particular direction or undertaking any social activity. This state includes resting.
4) SOCIALIZING: individuals involved in an erratic activity including physical contact at the surface, jumps, leaps, tail slaps, etc., and usually staying long periods at the water surface. In addition, any activity that

incorporates the use of a "foreign object", including vessels, and therefore behaviours like bow riding or wave surfing, were included in this category.

Throughout the observation, behavioural states were continuously recorded in order to investigate white-beaked dolphins' activities during the day, thus improving knowledge and confirming the existing one, and to highlight possible changes potentially linked to human activities. Especially for the latter reason, more attention was paid to any difference among behaviour seen when dolphins were first spotted, after vessels approach and at the end of the sighting when boats were leaving them.

Any sign of avoidance towards boats shown by the school of dolphins was underlined by observers' cautious description of it in the dedicated comments space within "*Spotter pro*": sudden changes in behaviour or in group spacing (e.g. pod splitting into subgroups or the opposite fast close aggregation of them), prolonged dives, multiple and abrupt changes of direction and speed, swimming or "porpoising" away from the vessel, repeated breaching, tail slapping or chuffing (*i.e.* loud exhalations) at surface, were all considered signs of disturbance of the natural behaviour potentially related to vessels presence.

To evaluate potential effects of boats presence, transitions in behavioural states from *pre*- to *post*-approach, signs of avoidance and dolphins' social interaction with vessels, were ranked as a dichotomy (Tab. 1).

Tab. 1 Dichotomy of behavioural response to boat interaction. The variables are ranked as **0** = absence, and **1** = presence

VARIABLE	**RANK**	
Change in behaviour	**0**	**1**
Avoidance	**0**	**1**
Interaction	**0**	**1**

3.3 Data collected in previous years

Databases created during research surveys completed in 2008 – 2013 through whale-watching in Faxaflói, were also used in this study.

Data were collected following similar methods and criteria (e.g. weather and sea conditions; photo-ID; behaviour) to the one used in 2014 (see paragraph 3.2), even though some differences are present, especially due to the not use of "*Spotter Pro*".

Sighting data, environmental parameters and effort data were, in fact, recorded in specific form (datasheet). Observers used a dictaphone to describe sightings, that were then transcribed on Excel spread sheets when back on land. Positions of the encounters were taken using "*Global Positioning System*" (*Garmin GPSmap* 60CSx), when the boat was located within 50 m from the sighted animals. Throughout the survey, environmental conditions were updated every 15 min sample (Bertulli, 2010).

3.4 Statistical analysis

Statistical analysis was applied to evaluate the effects of boat presence on white-beaked dolphin behaviour.

The Chi-square test (χ^2) was chosen as the most suitable test to use because of its characteristics (Siegel, 1956):

- it can be adopted to determine the significance of differences between two independent groups;
- the measurement involved may be as weak as nominal scaling;
- the hypothesis under test is usually that the two groups differ with respect to some characteristic and therefore with respect to the relative frequency with which group members fall in several categories.

4. Results

4.1 Dataset

Data collected through years and transcribed in Excel spread sheets, resulted in an enormous amount of data to deal with. Created for every year of survey, datasets include several pages each, depending, of course, on the organisation of them: for instance, if just the first page of each dataset is taken into consideration, a total of 410,127 cells would be counted.

An example of summarisation of different datasets is presented in Fig. 18 and 19: in the first one, data regarding white-beaked dolphin sightings, time of the tour, duration of the encounter, pod composition, number of boats, distance, behaviours and general comments, have been selected in order to rank (in this case as dichotomy) the different reactions to vessel presence over the study period.

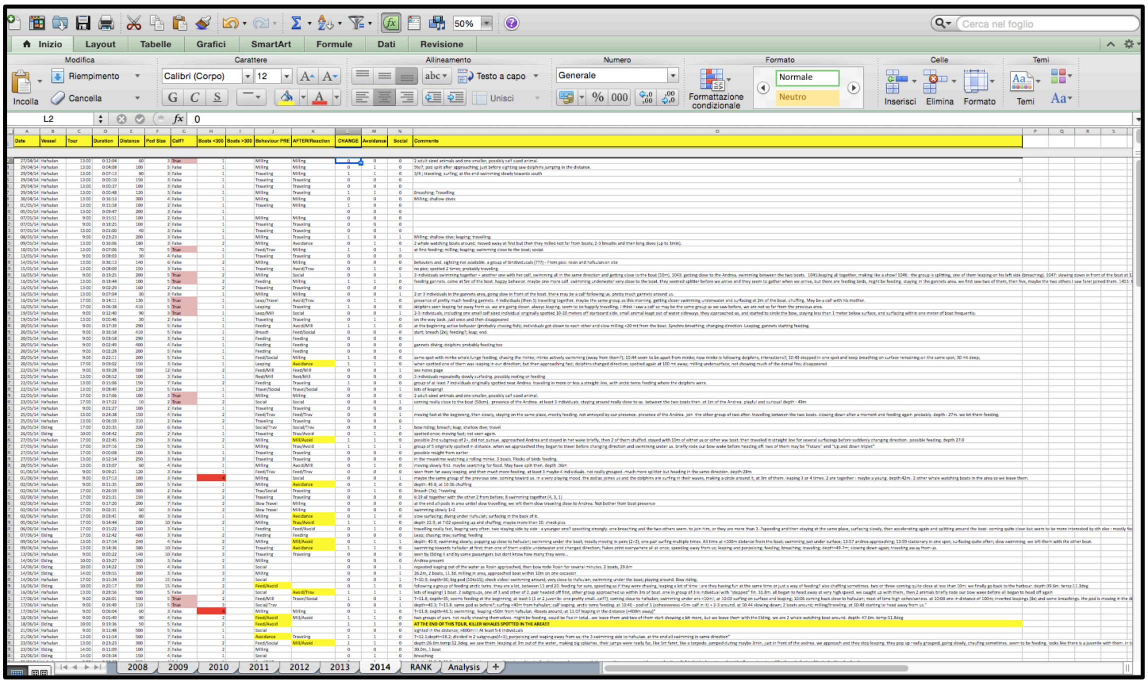
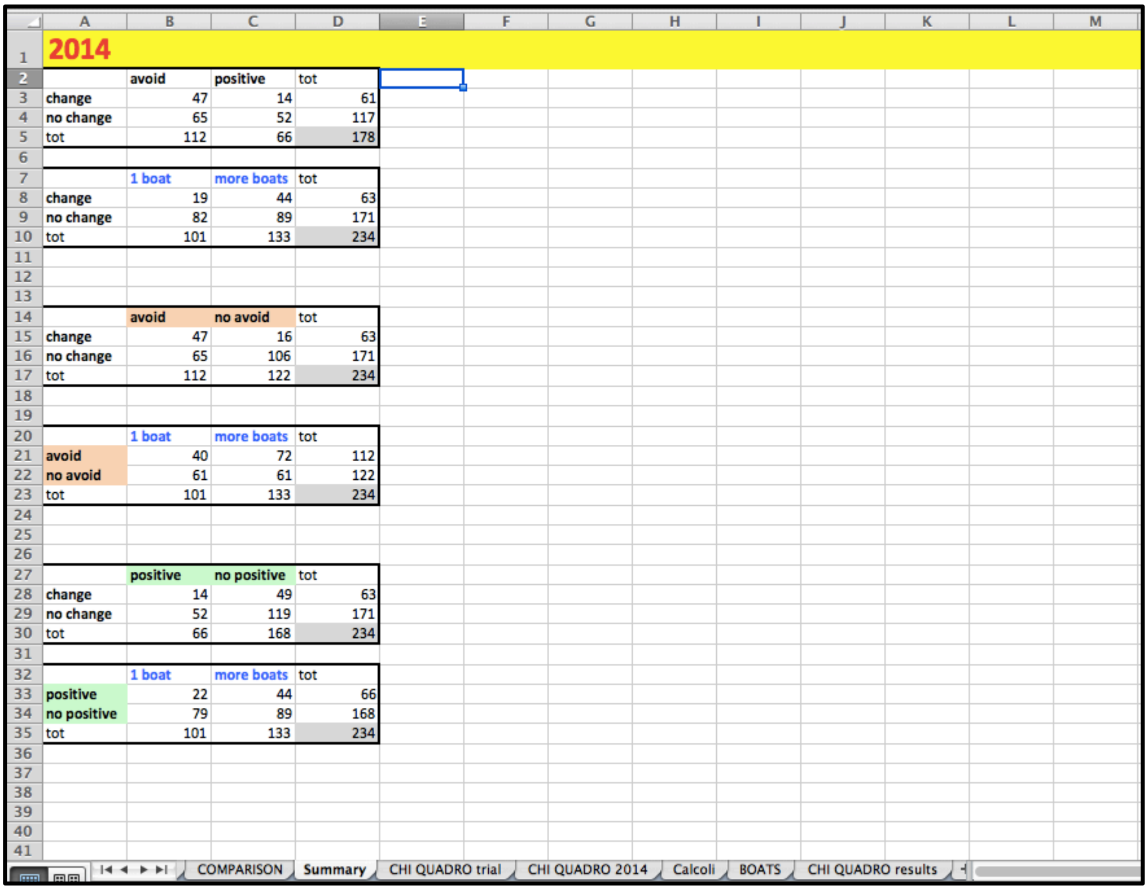


Fig. 18 Example of dataset created in Excel with selected information from the period 2008 – 2014 used for this study

After compressing the data (Fig. 19), the outcomes result way easier to manipulate and way more suitable for further comparisons and analysis.



2014

	avoid	positive	tot
change	47	14	61
no change	65	52	117
tot	112	66	178

	1 boat	more boats	tot
change	19	44	63
no change	82	89	171
tot	101	133	234

	avoid	no avoid	tot
change	47	16	63
no change	65	106	171
tot	112	122	234

	1 boat	more boats	tot
avoid	40	72	112
no avoid	61	61	122
tot	101	133	234

	positive	no positive	tot
change	14	49	63
no change	52	119	171
tot	66	168	234

	1 boat	more boats	tot
positive	22	44	66
no positive	79	89	168
tot	101	133	234

COMPARISON | Summary | CHI QUADRO trial | CHI QUADRO 2014 | Calcoli | BOATS | CHI QUADRO results

Fig. 19 Example of the aspect of a dataset after compression as dichotomy

4.2 Survey analysis

4.2.1 Overall survey effort

During 2014 research season, a total of 1,039 hours of survey effort was completed. This time is referred to the period April – September and it is partitioned within 138 days with 350 trips spread out all months and during all day (Fig. 20), depending on "*Elding*" whale-watching tours schedule (see paragraph 3.2).

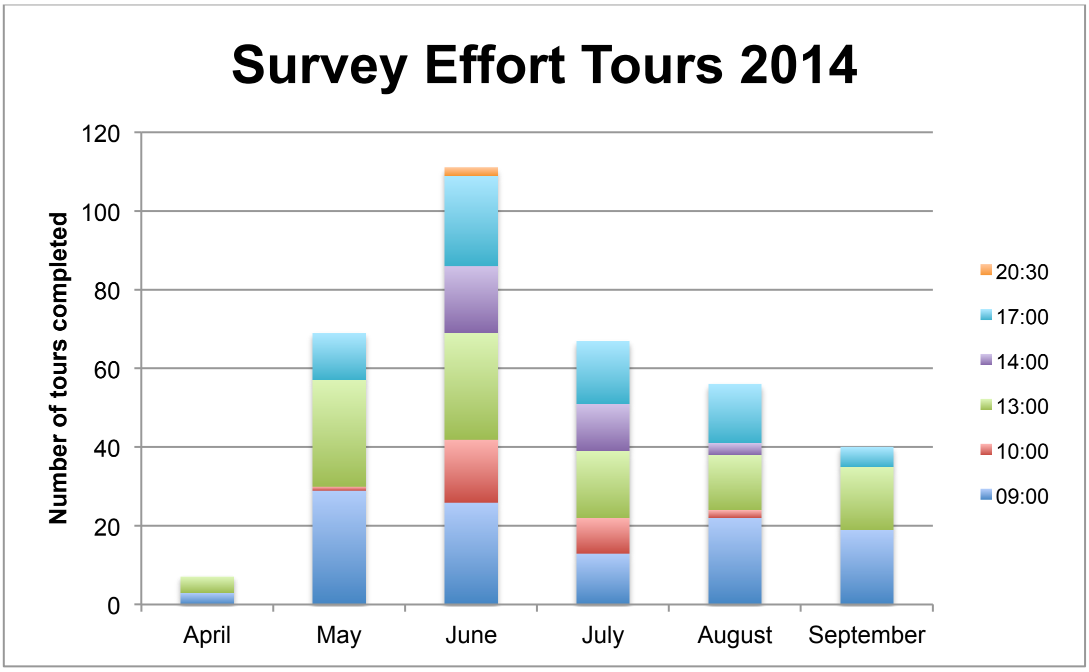


Fig. 20 Partitioning of survey effort tours throughout the day for 2014 (Faxaflói, Reykjavík)

Apart from white-beaked dolphin, the most common sighted cetacean species was the minke whale (*Balaenoptera acutorostrata*), followed by the harbour porpoise (*Phocoena phocoena*). During the season though, sporadic encounters with humpback whales (*Megaptera novaeangliae*) and killer whales (*Orcinus orca*) also occurred.

In the table below (Tab. 2), survey efforts regarding years 2008 – 2014 are presented:

Tab. 2 Survey efforts completed in Faxaflói bay (Reykjavík). Data refer just to the period April – September and include also unsuccessful (*i.e.* without any cetacean sighting) tours: 2008 (18); 2009 (6); 2010 (1); 2012 (9); 2013 (5); and 2014 (9). None of them was reported in 2011

STUDY PERIOD	SURVEY EFFORT (DAYS)	SURVEY EFFORT (TRIPS)	SURVEY EFFORT (HOURS)
2008	93	175	372:59:00
2009	86	170	350:35:00
2010	77	141	259:41:00
2011	86	183	337:04:00
2012	133	246	536:38:00
2013	113	188	385:54:00
2014	138	350	1039:11:41

4.2.2 White-beaked dolphins occurrence

During the time lapse April – September 2014, white-beaked dolphins were encountered in 94 days for 148 tours, counting 444 hours of survey effort. Sightings of dolphins were distributed over all day, depending on whale-watching tours schedule (see paragraph 3.2), through all months considered (Fig. 21).

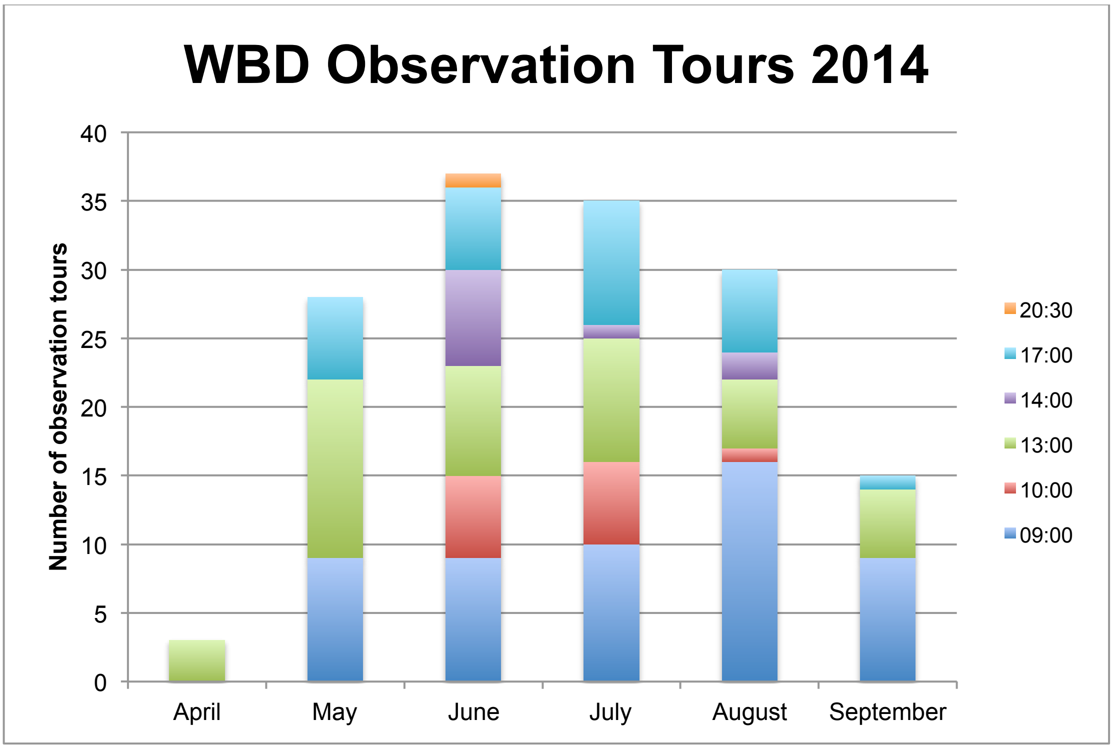


Fig. 21 White-beaked dolphins observation tours during 2014 (Faxaflói, Reykjavík)

Observation days, trips and related effort hours, throughout 2008 – 2014, are shown in Tab. 3.

Tab. 3 White-beaked dolphin observation efforts in Faxaflói bay (Reykjavík). Data refer just to the period April – September

STUDY PERIOD	OBSERVATION (DAYS)	OBSERVATION (TRIPS)	OBSERVATION (HOURS)
2008	61	86	176:10:00
2009	46	61	126:08:00
2010	40	53	97:18:00
2011	45	64	124:41:00
2012	54	64	138:31:00
2013	70	90	187:11:00
2014	94	148	444:09:05

4.2.3 Sighting rate of white-beaked dolphins

The overall sighting rate for white-beaked dolphins was very low, with less than one sighting per hour of survey effort.

Fluctuations through months in different years are expressed as relative frequency (see paragraph 3.2.2) and shown in Fig. 22.

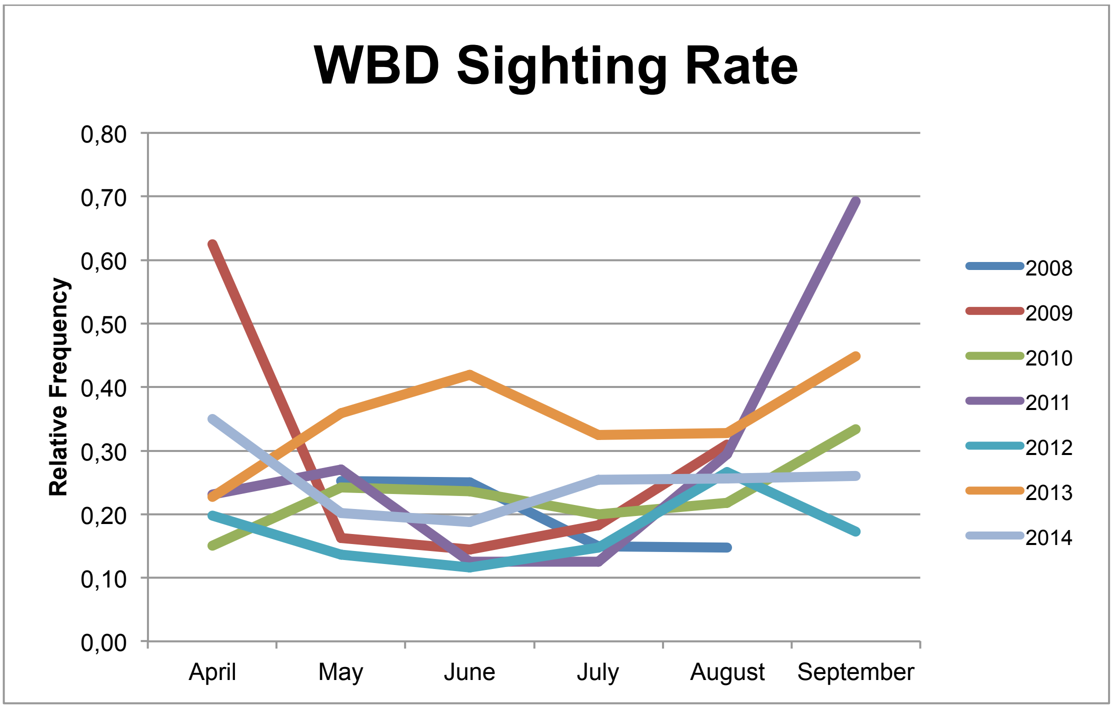


Fig. 22 White-beaked dolphin sighting rate fluctuation through months (Faxaflói, Reykjavík)

Mean sighting rates per year of study are presented in Fig. 23: relative frequencies are, in this case, associated with error bars representing 95% confidence interval.

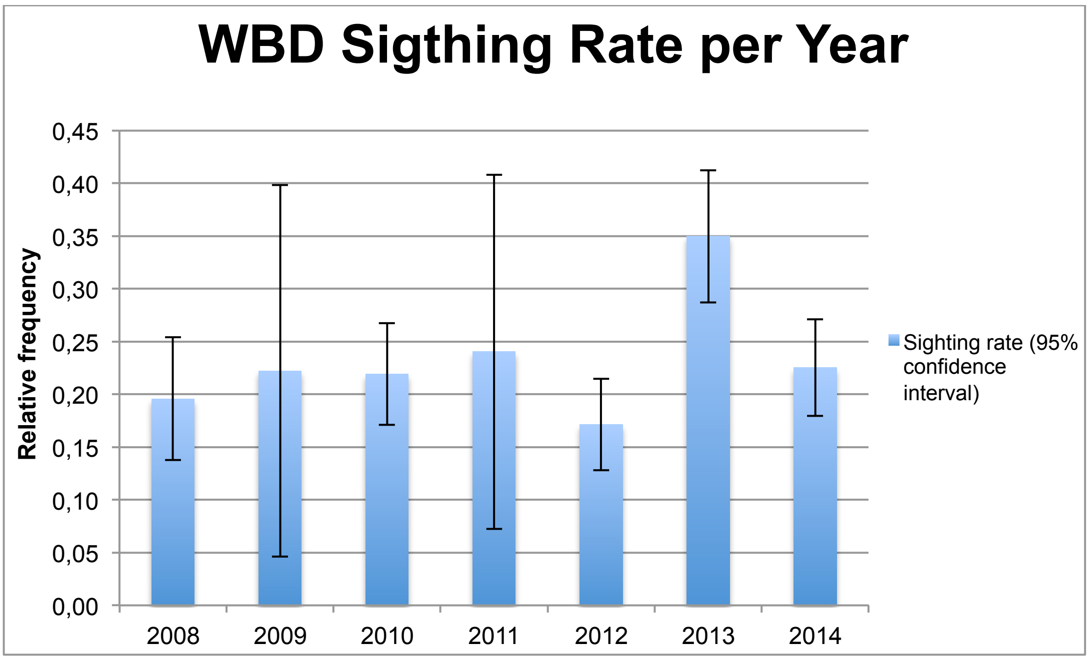


Fig. 23 Mean sighting rate of white-beaked dolphin in Faxaflói bay, Reykjavík

4.2.4 Photo-ID

From the white-beaked dolphin photographs collected during April – September 2014, 8 new individuals were identified and added to the existing catalogue (*Copyright* University of Iceland). A list of re-sighted and new IDs has been included in *Appendix 1*.

The amount of sightings discriminated as the one including new, re-sight and unknown individuals (see paragraph 3.2.3) is presented as percentage in the figure below (Fig. 24).

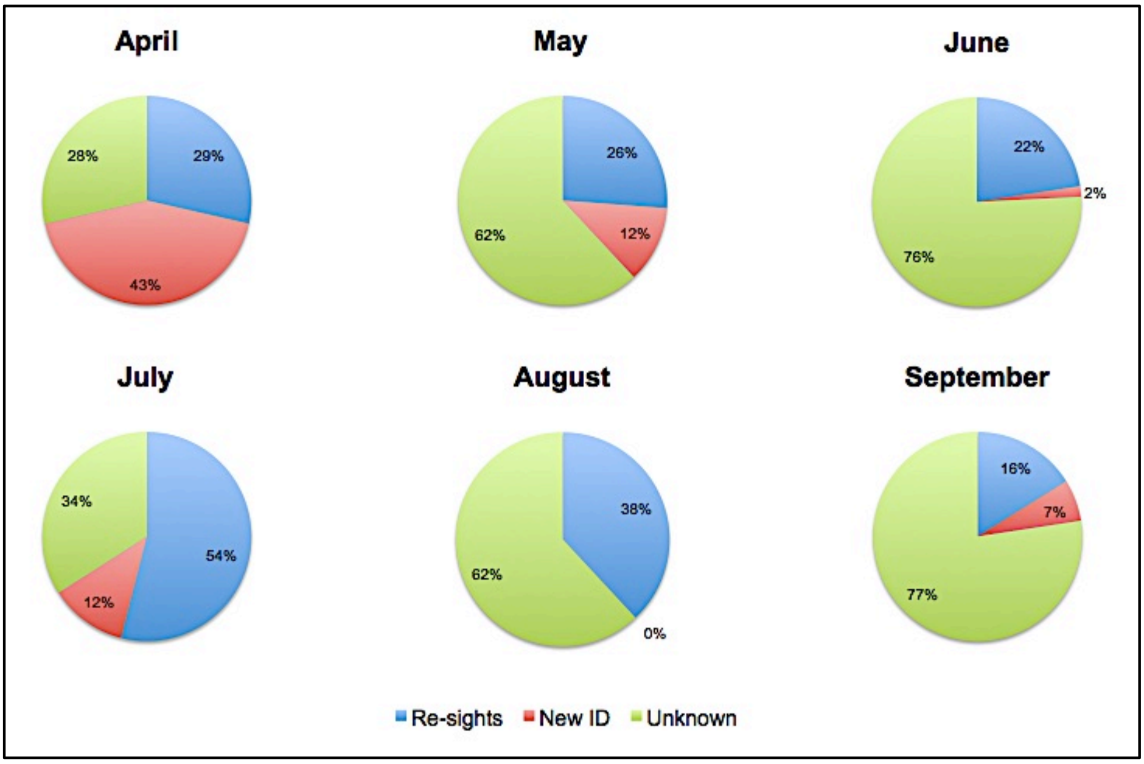


Fig. 24 White-beaked dolphin re-sightings during 2014 research season (Faxaflói, Reykjavík). Percentages represent the number of sightings including **Re-sights** (*i.e.* individual already present in the catalogue), **New ID** (*i.e.* individual added to the catalogue during 2014) and **Unknown** (*i.e.* not identified individuals and/or not eligible to be a New ID)

4.3 Sightings *vs.* Whale-watching

4.3.1 Distribution of sightings

During 2014 surveys, recorded locations of white-beaked dolphin sightings tended to concentrate in one area within Faxaflói bay as shown in the map (Fig. 25):

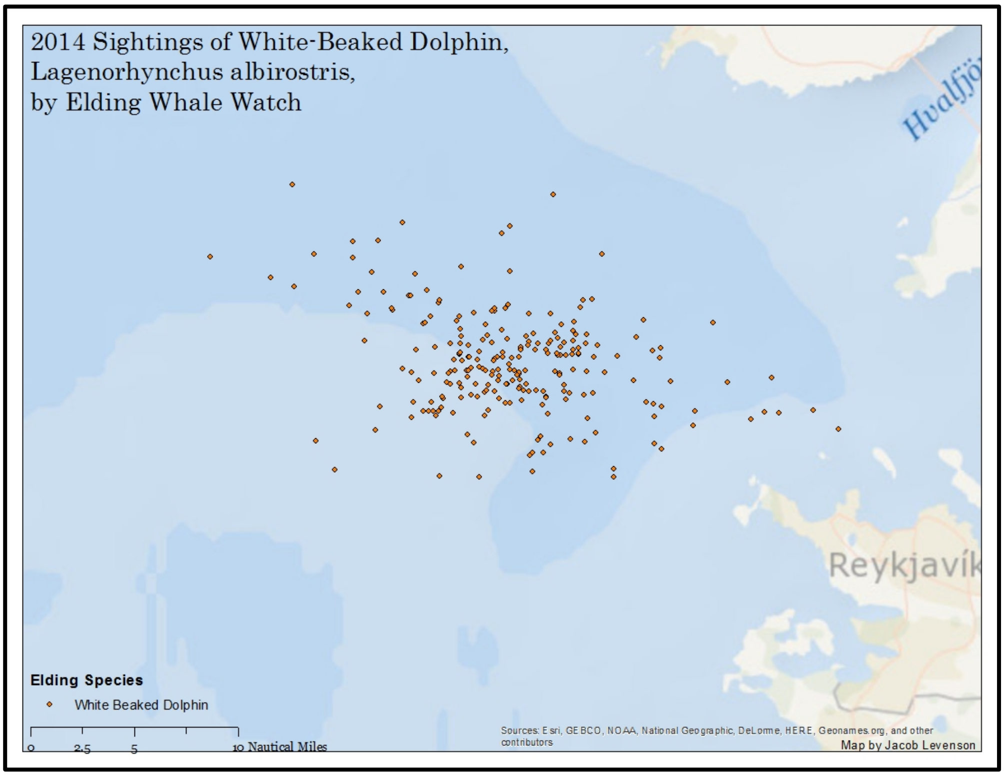


Fig. 25 Distribution of white-beaked dolphin sightings during 2014 (Apr – Sept) within Faxaflói, Reykjavík (by courtesy of Jacob Levenson)

4.3.2 Duration of sightings

Estimates of white-beaked dolphin sightings duration (expressed in min) were inferred for the entire study period (2008 – 2014) using the data collected: mean values are graphically presented in Fig. 26.

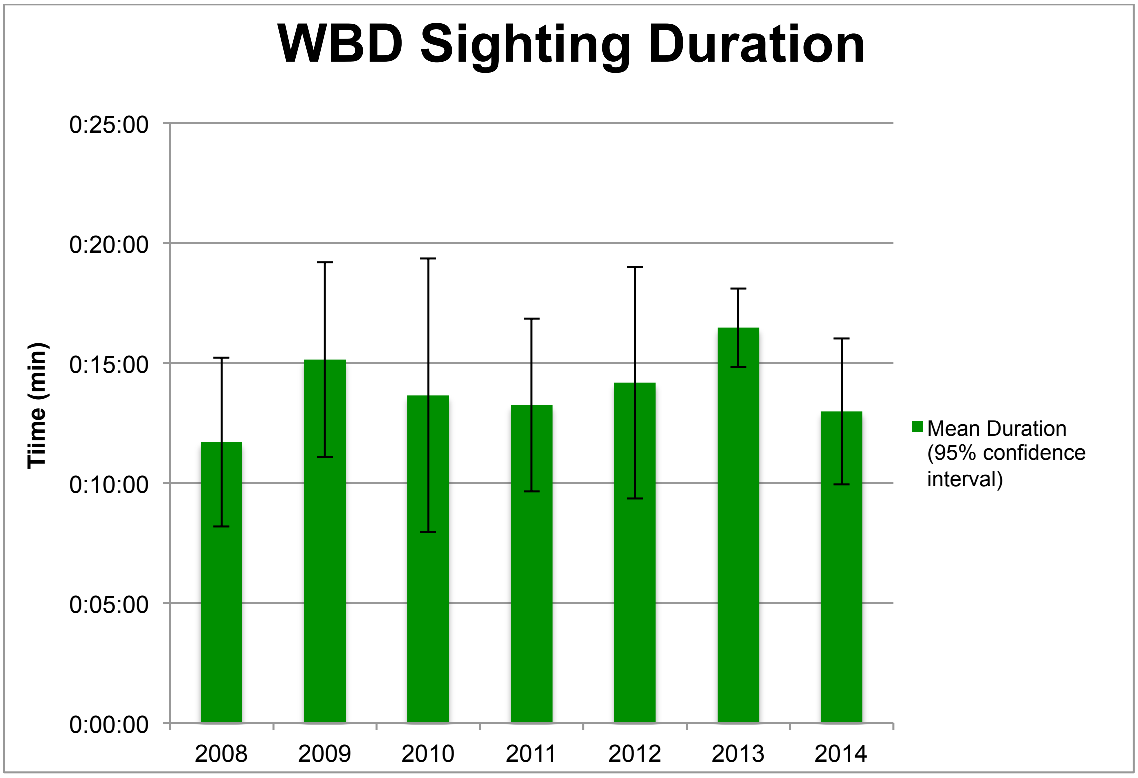


Fig. 26 Mean duration (min) of white-beaked dolphin sightings in Faxaflói, Reykjavík

4.3.3 Whale-watching vessels and distance from focal group

Tour schedule and number of whale-watching boats traveling within the bay varied depending on the month and year of study considered.

Based on 2014 surveys conducting with "*Elding*", an estimate of tour operator vessels present daily in Faxaflói through months was inferred and compared with number of white-beaked dolphin sightings (Fig. 27).

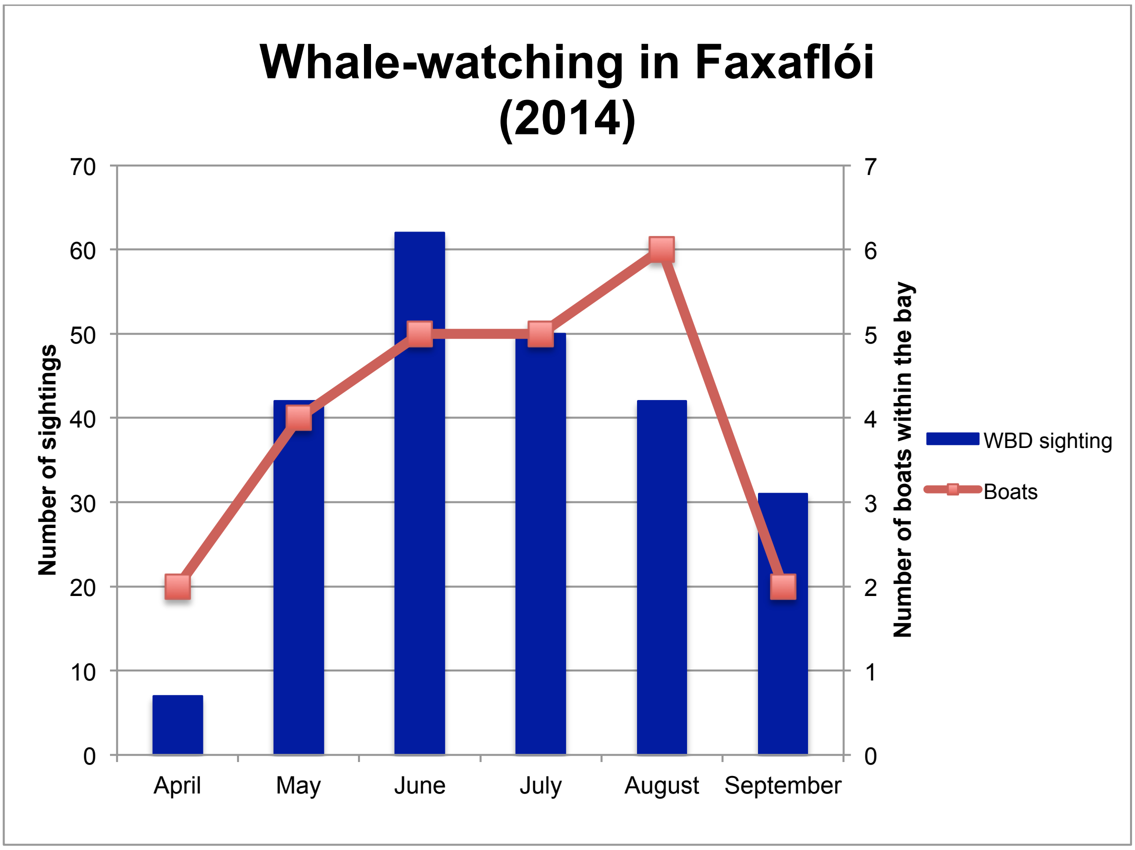


Fig. 27 Whale-watching vessels presence within Faxaflói bay (Reykjavík) during 2014. Tour operators considered with number of boats used in brackets are: "*Elding*" (2); "*Special tours*" (2); "*Sea Safari*" (1); "*Gullfoss*"(1). Sightings refer to the ones collected with "*Elding*" company and thus, are not corrected for survey effort

Despite the number of whale-watching vessels present daily in the bay, the ones around (< 300 m) focal groups of white-beaked dolphin at the same time rarely went over the 3 boats.

Data referring to 2014 were used to estimate monthly means of whale-watching vessels within the sighting area (< 300 m), monthly means of pod size and monthly averages of distance at which dolphins were spotted (Fig. 28).

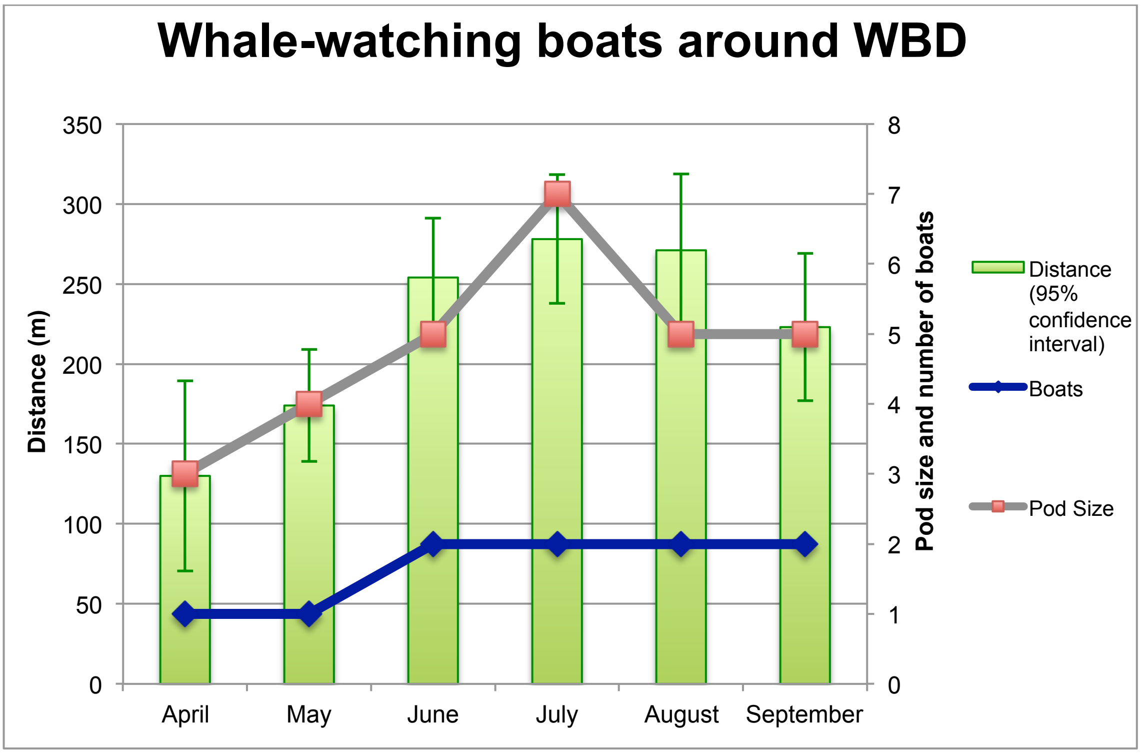


Fig. 28 White-beaked dolphins and whale-watching in Faxaflói, Reykjavík (2014). **Distance** = mean distance per month at which the pod was spotted; **Boats** = average number of boats within 300 m from the focal group; **Pod size** = monthly mean of number of dolphins within the same group.

4.4 Behaviour *vs.* Marine Traffic

4.4.1 Response analysis

White-beaked dolphin reactions to boats presence were first ranked as dichotomy (see paragraph 3.2.5) and then evaluated applying the Chi-square test (χ^2) as explained in paragraph 3.4.

Different comparisons have been taken into consideration:

- presence/absence of a change in the behaviour shown before and after vessels approach *versus* presence/absence of avoidance displayed towards boats;
- presence/absence of a change in behaviour *versus* presence/absence of positive interactions displayed towards vessels;

- presence/absence of a change in behaviour with different number of boats (one and more than one vessel) within the sighting area (< 300 m);
- presence/absence of avoidance towards vessels with different number of boats (one and more than one vessel) within the sighting area (< 300 m);
- presence/absence of positive interactions with different number of boats (one and more than one vessel) within the sighting area (< 300 m).

Due to some lacks in behavioural data (e.g. discrimination between behaviour before and after boat approach), years 2009 and 2013 were not included in this analysis.

Results of the comparisons are included in *Appendix 2*, while the ones of χ^2 test are shown in Tab. 4:

Tab. 4 Chi-square test (χ2) results for the analysis of differences in white-beaked dolphin response to boat presence in different years (numbers in brackets represent the number of encounters considered). Significant values ($p < 0.05$) are marked with a star (*). For each comparison, degrees of freedom (**df**) are noted

CHI-SQUARE test (χ^2)					
STUDY PERIOD	Change/Avoidance (df = 1)	Change/Interaction (df = 1)	Change/Boats (df = 1)	Avoidance/Boats (df = 1)	Interaction/Boats (df = 1)
2008 (72)	0,01	1,97	0	0,47	1,06
2010 (57)	1,71	1,91	0,47	0,22	3,91*
2011 (81)	4,46*	2,30	0,07	1,17	1,49
2012 (92)	8,84*	1,63	6,24*	4,33*	0,38
2014 (234)	24,70*	1,52	5,94*	4,86*	3,62

5. Discussion

5.1 Data mining

Data mining involves the use of different techniques to find a compact description of datasets. The aim of it is to retain the maximum possible information and at the same time, reduce to zero information loss (Chandola and Kumar, 2007).

A first helpful way to compress data is the use of descriptive statistics such as measures of central tendency (*i.e.* mean, median, and mode) and of dispersion (*i.e.* range, variance, and standard deviation), followed by a graphic representation. However, when dealing with "nominal variables", it is not possible to apply them to the data as such: these variables must be first converted in numbers and just after, summarised (e.g. proportions; percentages) (McDonald, 2009).

In this study, the large amount of data available required a tremendous effort in data processing (e.g. Fig. 18 – 19). Decisions on summarising methods need to be carefully taken in order to maintain the representativeness of data collected and to avoid the misunderstanding of results.

5.2 Survey limitations and related issues

Due to the opportunistic nature of the sampling collection, some limitations must be taken into account when reading results. Whale-watching, in fact, offers a great opportunity for cetacean studies but it is also influenced by time limitation, route travelled and, as every project conducted in marine environment, weather and sea conditions. In addition to it, whale-watching tours are not intended to examine systematically cetacean populations: sightings of whales and dolphins are strongly related to those individuals that choose to pass by the whale-watching area and therefore, the individuals spotted are likely to be the one better enduring the presence of vessels.

Noteworthy is that captains' decisions regarding the route to undertake during each trip and the individual/pod to approach, have great impact on data collection: for instance, white-beaked dolphins are not the only (and main) target species of whale-watching tours in Faxaflói, leading often to direct vessels towards whales instead.

Species detectability is also a critical factor and it strongly depends on environmental conditions, such as swell height and glare, but also on the experience that observers have. Nonetheless, the opportunistic nature of the sampling used, influences also photo-identification data since the fact that animals which tend to be identified are those that choose to get closer to the boat, and those with more distinctive features which results easier to recapture (Gill and Fairbainrns, 1995; Magnúsdóttir, 2007; Bertulli, 2010).

Despite the limitations described, data collection occurred in the period considered in this study, were designed to reduce the bias due to heterogeneities in sighting probabilities: for instance, considering that all seasons respected and followed the same environmental criteria (see paragraphs 3.2 and 3.3) to undertake a tour, possible differences as a result of sea state are expected to be negligible.

On account of this, an evident increase in research effort has occurred especially in 2014, where effort hours almost doubled the ones of the second year in place (*i.e.* 2012) if a growing scale is considered (Tab. 2).

5.3 White-beaked dolphin sightings

During the time lapse considered for 2014 (see paragraph 3.2), observations of white-beaked dolphins were distributed throughout all months and day, depending on "*Elding*" schedule (Fig. 21). Despite that, when comparing the partition over the day of total tours completed (Fig. 20) with the one of tours where dolphins were spotted (reported as "n" in the next lines) (Fig. 21), some differences are visible: for the first part of the study period (April – May) schools were encountered more frequently (respectively n = 3, 100% and n = 13, 46%) during the afternoon trips (*i.e.* 13:00 and 14:00), while for the second part (July – September) the situation overturned with dolphins sighted more frequently during morning tours (*i.e.* 9:00 and 10:00) (July: n = 16, 46%; August: n = 17, 57%; September: n= 9, 60%). The month of June showed instead identical encounter frequencies for morning tours and afternoon ones (n = 15, 41%). Frequencies of sightings of white-beaked dolphins during evening tours (*i.e.* 17:00 and 20:30) presented, in general, the lowest values with an average of 19% (mean n = 6) from May until September. The pattern reported could be related to the time of foraging activities: dolphins may be less cautious about vessels presence because focusing on food, while for instance, they may result more elusive, and therefore difficult to spot, while traveling. If this would be the case, August trend would partially agree with what was described in Rasmussen *et al*. (2013) where in the same month, a tagged white-beaked dolphin seemed to feed mainly during the morning hours when the ambient light was low. Noteworthy is that seasonal fluctuations in tide flows, photoperiod, sea temperature, etc., cause changes in recruitment, movement and availability of fish, and, due to the fact that preys represent a strong driven force in cetacean distribution (Friedlaender *et al*., 2006; MacLeod *et al.*, 2007), they influence dolphins behaviour and thus, sightings probabilities.

Despite potential changes in sighting frequencies due to seasonal variations, considering the increase in survey effort occurred in 2014, a consequent increase in successful tours (*i.e.* where white-beaked dolphins are encountered) is expected. In effect, looking at Tab. 3, an extremely higher number of observation hours were recorded in 2014 with respect to previous years. This result, though, must be carefully evaluated: in fact, if the sightings per year are corrected for the related effort hours of survey and thus, the relative frequency of sightings is considered, the situation shown in Tab. 3 changes remarkably.

As shown in Fig. 23, when means of sighting rate per year are contemplated the highest value appears to belong to year 2013 and not to 2014, which actually shows no difference with previous years when way lower survey efforts were completed.

The year 2013 represents also an outlier if fluctuations of sighting rates through months are considered (Fig. 22): while all years describe a similar pattern with lower values around June and lightly higher rates at the beginning and at the end of the study period, the only exception noticed is indeed year 2013 where sighting rate peaks in June, therefore showing an opposite trend with respect to other years.

After a first evaluation, the trend of 2013 described in this study seems to disagree with the one described previously in Faxaflói by Rasmussen (2013): in that study, comparing the sighting rate of white-beaked dolphins in July from 1999 – 2002 with the one from July 2013, the latter was identified as the year when a major decline in white-beaked dolphins encounters has occurred. In order to better investigate this incongruity between the results obtained and the existing one, data from this study were selected, processed following the same method (*i.e.* considering percentages of sightings per trip just in July) as the one used by Rasmussen (2013) and then compared with years 1999 – 2002 (Rasmussen, 2013). Data from 2004 – 2006 (Magnúsdóttir, 2007) were also used to enlarge the information available (Fig. 29).

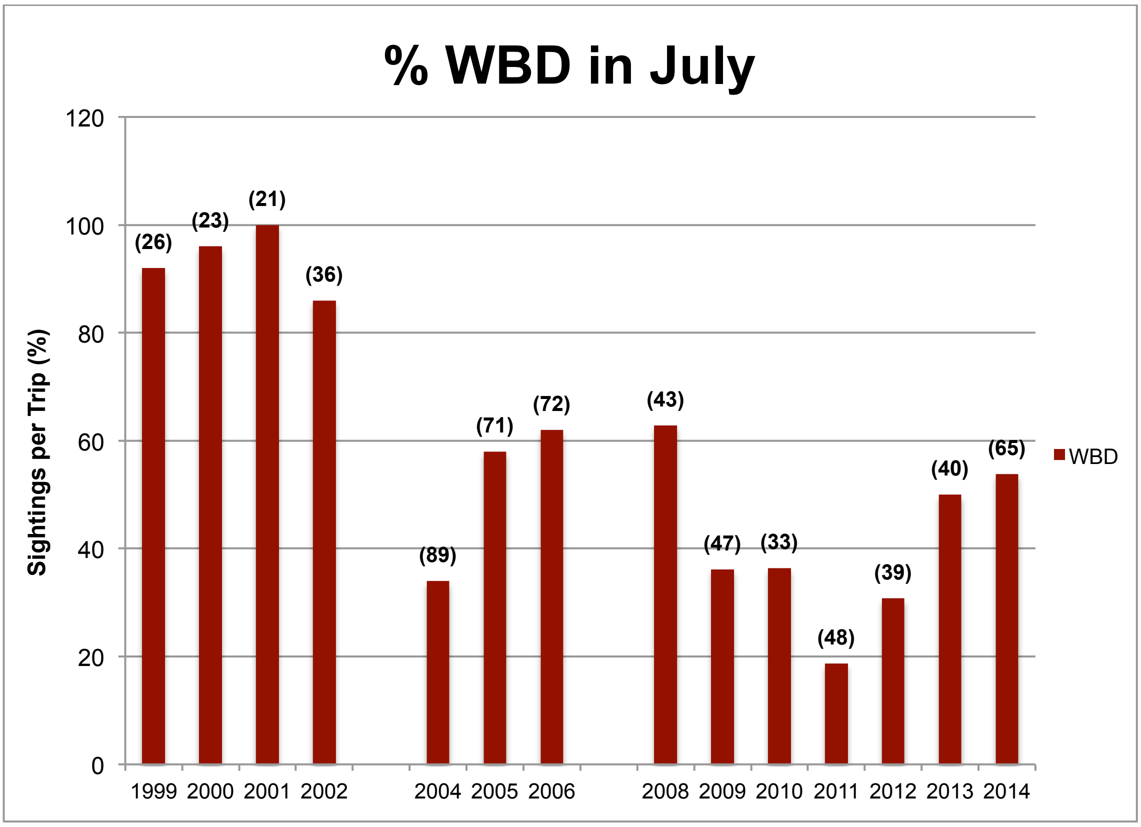


Fig. 29 Changes in sightings percentages (%) of white-beaked dolphins in July from 1999 to 2014 off Faxaflói bay (Iceland). Here **%** represents the number of tours where white-beaked dolphins were spotted in relation to the total number of tours where any cetacean species was sighted. The total number of tours considered **(n)** is indicated on top of each column. Data source: 1999 – 2002 = Rasmussen (2013); 2004 – 2006 = Magnúsdóttir (2007)

This comparison shows and confirms the drastic decline in sighting percentages of white-beaked dolphins in July within Faxaflói: the percentages, in fact, first decrease from the 100% sightings per trip in July 2001 to the 34% in July 2004, then increase until reaching the 63% in July 2008, collapse to the 19% recorded in July 2011, and end increasing until the 54% sightings observed in July 2014.

The percentage from year 2013 confirms therefore to be way lower than the first period considered (1999 – 2002) as the study from Rasmussen (2013) suggested, but the decline in sighting rates appears to have taken place much before, probably dated back to 2003.

Furthermore, during the all time period no evident increase in sighting numbers off the North eastern part of Iceland has been observed, leading to hypothesize that white-beaked dolphins relative abundance around Iceland has declined. Unfortunately, as mentioned in paragraph 1.3.5, the only current estimate of abundance of white-beaked dolphin inhabiting Icelandic waters is dated back to 2001 and counted 31,653 individuals (Pike *et al.*, 2009), thus not allowing an accurate evaluation of the reduction that has potentially occurred.

This negative trend in sighting rate may be related to the many oceanographic and biological changes observed in the bay (Víkingsson *et al*., 2015). White-beaked dolphins in Faxaflói are known to feed mostly on sand eels (see paragraph 1.3.3) and sand eels population has been in decline and was drastically reduced around 2005 for recruitment failure (Bogason and Lilliendahl, 2009). In addition to it, the distribution of several fish species has been changing with, for example, haddock shifting northwards or mackerel becoming a common species in Faxaflói, which did not occurred before 2004 (Rasmussen, 2013). The alterations in the community observed are strongly linked to the increase in temperature and salinity recorded from 1995 in the waters south and west of Iceland (Víkingsson *et al*., 2015). For example, temperature is known to influence sand eel recruitment: warm condition may stimulate the hatching phase and therefore larvae production, but at the same time, natural mortality is typically greater in higher temperature (Lynam *et al*., 2013).

Together with potential variations in prey availability, temperature is considered very important in determining the relative distribution of white-beaked dolphins, whose range might be expected to change and/or reduce in response to the increasing sea temperature resulting from global climate change (MacLeod *et al.*, 2008; MacLeod, 2013).

Other factor to consider is the growing amount of marine traffic in the bay. In the past, Faxaflói was a known mating and breeding area for white-beaked dolphins (Rasmussen, 1999; 2004), but this may have changed in response to increasing disturbances, potentially leading to a partial avoidance of the area in high season.

In summary, marine ecosystems are very dynamic and many variables must be taken into account when studying cetacean species: biological and oceanographic changes, anthropogenic disturbances as well as the other threats that populations face in general (see paragraph 1.4), are all influencing the survival of the species.

When sightings data are analysed, it is therefore highly recommended to carefully evaluate them: as shown in this paragraph, interpretation can be extremely different if data are not accurately treated, and standardized with other studies, prior comparisons. Furthermore, in order to avoid misleading conclusions, it is essential to accurately collect as much data as possible and to use them together with the largest time lapse available to obtain reliable results on populations' trend.

5.4 White-beaked dolphin re-sightings

As in previous studies (Rasmussen and Jacobsen, 2003; Magnúsdóttir, 2007; Bertulli, 2010; 2013), photo-identification confirmed to be a feasible technique for the recognition of this species in the coastal waters of Iceland, contrary to what Weir (2008) has found in the waters around Scotland.

White-beaked dolphins were not just constantly present over the study period examined (2014), but re-sightings were actually recorded every month (Fig. 24). More specifically, some individuals were spotted multiple times throughout the season: for example *DEM 73_Ventiquattro* was encountered once a month from May until August; or *DEM 256_Squared Low* was first seen in May and then twice both in July and August (see *Appendix 1*). These results show the tendency of individuals to return to the same area in more than one occasion and to remain in it over relatively extended period of time, therefore confirming a certain level of site fidelity, as also a study recently completed is describing for white-beaked dolphins sighted until 2010 around Icelandic coastal waters (Bertulli *et al*., 2015 *in press*).

Despite it, a relatively low re-sighting rate occurred if numbers of identified dolphins are compared with the total amount of individuals spotted: this fact may be explained by supposing a relatively large population of dolphins that occur around Icelandic waters, and if it is taken into consideration that this species inhabits specific coastal territories of relatively large scale and travels long distances as Rasmussen *et al.* (2013) study has shown (Fig. 30).

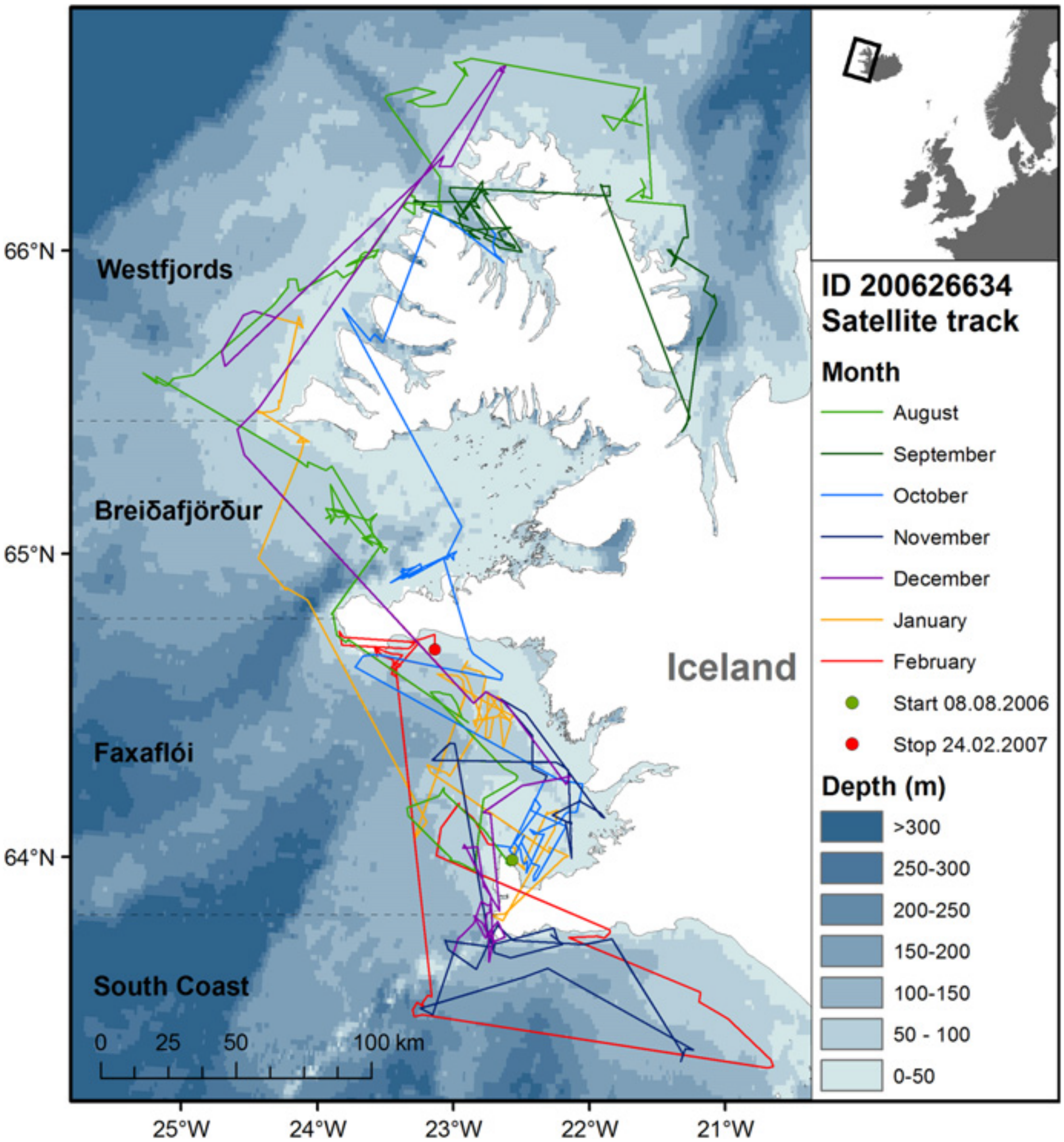


Fig. 30 A small map of Iceland with an enlargement of western Iceland showing the movements of a white-beaked dolphin equipped with a satellite transmitter. Transmissions started on 8 August 2006 (green dot,Garjur harbor) and stopped on 24 February 2007 (red dot). Different colour lines show the distance covered by the tagged animal in different months. The area west and south of Iceland was divided in four parts corresponding to the location: Area1 = The Westfjords, Area 2 = Breiðafjörður, Area3 = Faxaflói, and Area4 = South Coast. An acoustic A-tag was placed on a second dolphin at the green dot. The acoustic tag was recovered approximately 6NM northeast of the lighthouse in Garjur (the star). (Rasmussen *et al.*, 2013)

5.5 White-beaked dolphin and whale-watching

The management of marine populations becomes increasingly difficult when dealing with highly motile animals whose home range and distribution may change over time.

White-beaked dolphins monitored in 2014 confirmed to congregate around the whale-watching area outside Reykjavík harbour. Locations of sightings (Fig. 25), in particular, corresponded to the areas identified as feeding grounds for white-beaked dolphins within Faxaflói (Bertulli, 2010).

However, due to the opportunistic nature of the data collection, any conclusion on distribution of dolphins is limited by the fact that just the whale-watching area was regularly surveyed: even though not a fixed route was followed, tours were not designed to systematically monitor white-beaked dolphins and therefore surveys were not covering the bay in its entirety. Captains were, in fact, usually directing the vessel towards spots where encounters with cetaceans were experienced in the previous days. It is also true, though, that the feeding grounds described by previous studies, are identified by captains as locations with higher probabilities to spot cetaceans (due also to the known higher presence of fish and to their shallower waters), and so they result being more often surveyed. As a consequence of it, a potential increase in avoidance of those areas and therefore, a decline in feeding opportunities may happen, affecting animals' survival rates.

From the data used in this study, no relevant differences have been observed in sighting durations over years (Fig. 26), which in addition to the confirmed locations of sightings, may indicate that the area is of a great importance to the species and/or that, despite the exposure to whale-watching, white-beaked dolphins are habituated to the high levels of boat traffic within those areas.

It is furthermore plausible that disturbances on these animals are being well restrained by the application of the guidelines for responsible whale-watching (see paragraph 3.2.4) that the operating companies in Faxaflói are following. Data from 2014 actually shows that even though many tour vessels were daily surveying, reaching the 6 boats in August (Fig. 27) and improving sighting probabilities, the ones around (< 300 m) focal groups of white-beaked dolphin simultaneously rarely went over the 3 boats (Fig. 28).

For instance, previous studies within Faxaflói have indeed shown that whale-watching disrupts feeding activities of minke whale (Christiansen *et al*., 2013), but at the same time, due to the fact that the estimated time each individual spend with boats is very low, it has been later suggested that the whale-watching industry in its current state is likely not having any long-term negative effects on vital rates of minke whale (Christiansen *et al*., 2015). Similarly white-beaked dolphins may be affected by marine traffic, without being subjected to long-term consequences because of the possible low cumulative exposure of each individual to it and of the potential high tolerance that may characterise them.

Throughout the summer months (June – August) in 2014, together with increasing mean number of whale-watching vessels, an increase in average pod size and in distance at which dolphins were spotted, occurred (Fig. 28). Numbers of individuals per school, also in relation to the time period, appear to be consistent with previous studies (Rasmussen, 1999; Salo, 2004; Bertulli, 2010): it is known that group formation trends among white-beaked dolphins are affected by behaviour with relatively larger ones more often sighted during foraging activities. It is, in effect, plausible that a higher number of individuals result being more efficient when feeding strategies are applied or in the case of the presence of predators. Predation may be indeed responsible for increased group sizes in dolphins (Norris and Dohl, 1979; Norris and Schilt, 1988), however, considering the low numbers of scars inflicted by sharks on identified individuals (Bertulli *et al*., 2012) and the low number of predators observed within the bay, predation pressure appear not to be a major factor in determining pod size. Noteworthy though, is the fact that animals could perceive boats activities as a risk and therefore they could respond through avoidance and other anti-predatory tactics such as increasing pod size and distance from vessels (Lusseau, 2003a; Williams *et al*., 2011; Christiansen *et al*., 2013; Pirotta *et al*., 2015): for example it has been described that, despite showing tolerance towards vessels traffic, bottlenose dolphins inhabiting northeast Scotland perceive boats as a risk, and therefore negatively react to their presence, depending on size, activity and speed of them (Sini *et al*., 2005). Not least to consider is that potentially the increasing trend in pod size and distance with respect to whale-watching vessels during summer months, could be related to calves presence: white-beaked dolphins in Iceland are indeed known to give birth between May and August (Víkingsson and Ólafsdóttir, 2004), possibly explaining the larger groups spotted in summer months and the more careful distance held.

5.6 White-beaked dolphin behavioural response to marine traffic

While long-term effects of disturbances might be hard to identify, short-term ones such as behavioural response to boats presence, are relatively easy to detect. However, when dealing with behavioural data, it is often difficult to control the objectivity and each related interpretation must be carefully evaluated. Reactions of dolphins to vessel activities are, for instance, strongly influenced by a wide range of variables like pod size and composition, boat activity, type of vessel, number of boats, dolphin behaviour, etc.

During the entire study period white-beaked dolphins reactions towards vessels varied considerably. Approaching and following a boat, as well as suspending their activities to start heading away from a vessel, were all relatively common reactions that dolphins performed.

The results of this study have shown that marine traffic affects white-beaked dolphins behaviour, even though in a complex and not very predictable way (see *Appendix 2* and *Tab*. 4).

Across all years considered, cases where dolphins' behaviour did not vary from before to after the approach were the most frequent (e.g. 2011 – change = 15, *versus* no change = 66; 2014 – change = 63, *versus* no change = 171).

The number of boats around focal group (< 300 m) appeared to be a major factor in determining the reactions of dolphins: both in 2012 and 2014 for example, changes in behaviour observed (*i.e.* total 2012 = 24; total 2014 = 63) were recorded more frequently with a higher presence of vessels (*i.e.* 2012 – one boat = 7 cases, *versus* more boats = 17 cases; χ^2 = 6,24; 2014 – one boat = 19 cases, *versus* more boats = 44 cases; χ^2 = 5,94). Furthermore, those changes in behaviours mostly ended in avoidance strategies (e.g. total 2014 = 63 – avoidance = 47 cases, *versus* no avoidance = 16; χ^2 = 24,70).

With respect to positive interactions instead, no significant pattern has been noticed through years: generally though, positive interactions were more frequent when no change in behaviour was observed (e.g. total 2014 = 66 – change = 14 cases, *versus* no change = 52 cases).

Although increasing avoidance episodes has been recorded, these results suggest that white-beaked dolphins tend to tolerate the presence of boats. Short-term interruptions of normal activities, though, could have long-term negative effects on the population: for instance, to avoid boats individuals may increase erratic movement and thus, their energy expenditure, increase respiration and metabolic rates, reduce their time for foraging and resting, push their selves closer to their physiological limits (e.g. longer dives), causing higher level of stress and negative effects on the body condition of individuals, and therefore, threating their survival (Lusseau, 2003a; Sini *et al*., 2005; Meissner *et al*., 2015; Pirotta *et al*., 2015; Christiansen *et al*., 2015).

In addition, the combination of increasing avoidance and growing marine traffic may represent a very critical factor for the species: with more vessels traveling within Faxaflói, noise level is expected to increase extremely. Avoidance strategies often include changes in group spacing (see paragraph 3.2.5) forming for example many subgroups that may potentially head in different directions: considering that boat underwater noise overlaps with the frequency range of cetacean sounds, communication among subgroups and individuals might be compromised. Higher level of vessel noise cause, in fact, a decline in white-beaked dolphins maximum communication distance (Rasmussen *et al*., 2006; Atem *et al.*, 2009; Jensen *et al*., 2009; Rasmussen, 2013). Dolphins are known to live in a fission-fusion society (Leatherwood and Reeves, 1990; Connor *et al*., 2006) where acoustic cues play an important role in mediating social structure (Watwood *et al*., 2005), predator avoidance (Deecke *et al*., 2005), mate choice (Gerhardt and Klump, 1988), mother-calf interactions (Smolker *et al*., 1993), cooperative foraging (Janik, 2000; Meissner *et al*., 2015), and perhaps even cultural learning (Janik, 2005). If communication distance is lowered, it will be more difficult for white-beaked dolphins to engage in any acoustically mediated social interactions, leading to a decline in survival probabilities.

6. Conclusions

Marine traffic is known to affect cetacean populations in different ways and it therefore requires, together with valuable knowledge on target species, a careful management of it in order to minimise potential negative effects on them. Whale-watching, in particular, provides the great opportunity for researchers to collect data on species of interest and on the effect that anthropological disturbances may have on them.

Thanks to the enormous amount of fieldwork completed through years, large valuable datasets have been created and made available for cetacean studies in Faxaflói. Data processing becomes therefore, a critical phase that requires a tremendous amount of time to extrapolate information in order to analyse them. In this study, the selection of the proper method to summarise data has been of a great importance: in particular, the use of dichotomy has provided the possibility to reliably evaluate behavioural response of dolphins to marine traffic, through an extreme simplification of data that, at the same time, has reduced the bias due to personal interpretation.

Despite the limitation due to the opportunistic nature of the sampling collection, the whale-watching platform used in the present work has confirmed to be a great tool to provide baseline information on residency and variations in relative abundance of white-beaked dolphins within Faxaflói. Although hosting a rather high level of boats traffic, the bay represents, in fact, an important and favourable area for this dolphin that has shown a certain level of site fidelity in previous studies and confirmed it in this one. In addition to it, no relevant changes in habitat use have been noticed, with dolphins still congregating around the already identified feeding grounds regardless the increasing number of whale-watching vessels transiting daily across them.

As the results from behavioural response describe, white-beaked dolphins have, in effect, shown the tendency to tolerate the presence of boats. This assumption is also supported by the fact that no differences in encounters duration throughout the study period have occurred. The species appears to cope with the presence of vessels by applying avoidance strategies, even though their reactions result to be very complicated and unpredictable.

For sure, short-term effects on behaviour seem to be strongly related to the number of boats around the focal group, with negative reactions being more frequent when a higher number of vessels is in the area.

Photo-identification analysis for 2014 has confirmed a low re-sighting rate for white-beaked dolphins in Faxaflói and thus, the probable existence of a large population of dolphins with a wide home range inhabiting Iceland.

Seasonal differences in probabilities of sightings of white-beaked dolphins, depending on the time of the day, has been highlighted, leading to assume the possible presence of a daily cycle in their movements and activities.

This study has also shown that, even with increased research effort, no improvement in sighting rate occurred: comparisons with existing data have actually provided evidence of a major decline of sightings of white-beaked dolphins in Faxaflói, probably dated back to 2003.

Little is still known on this species but the negative trend confirmed in this study, together with increasing sea temperatures and the expansion of human activities, raise the urgent necessity to design a new research survey focusing on white-beaked dolphins around Iceland.

Future studies should first of all aim to document the current population estimate in order to develop the most suitable conservation strategy as possible. It is therefore recommended to correctly assess white-beaked dolphins conservation status: for instance, a research vessel could be used to collect data allowing to cover a wider area and to reduce the limitations linked to opportunistic platforms. This dedicated project could fill important knowledge gaps and refine what is known on distribution, habitat use and behaviour of the species. In addition to it, genetic analyses would allow a greater understanding of population structure, eventually confirming the presence of a large population that moves along the coast or quantifying differences between populations around Iceland.

Furthermore, an evaluation of the repeated exposure of white-beaked dolphins to marine traffic is recommended: this study has, in fact, shown their tendency to tolerate vessels presence by frequently applying avoidance strategies, but the energetic cost of this chronic disturbance remains unknown and it could affect individuals' condition and vital rates, and therefore the survival of the species.

References

Ashford-Hodges, N., & Simmonds, M. P. (2014) Climate change and cetaceans: an update. IWC meeting SC/65b/E.

Atem, A. C. G., Rasmussen, M. H., Wahlberg, M., Petersen, H. C., & Miller, L. A. (2009). Changes in click source levels with distance to targets: Studies of free-ranging white-beaked Dolphins (*Lagenorhynchus albirostris*) and captive Harbour Porpoises (*Phocoena Phocoena*). Bioacoustics, 19(1-2), 49-65.

Beale, C. M., & Monaghan, P. (2004). Behavioural responses to human disturbance: a matter of choice?. Animal Behaviour, 68(5), 1065-1069.

Bejder, L., Dawson, S. M., & Harraway, J. A. (1999). Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. Marine Mammal Science, 15(3), 738-750.

Bejder, L., Samuels, A. M. Y., Whitehead, H. A. L., Gales, N., Mann, J., Connor, R., ... & Kruetzen, M. (2006). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology, 20(6), 1791-1798.

Bejder, L., Samuels, A., Whitehead, H., Finn, H., & Allen, S. (2009). Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. Marine Ecology Progress Series 395, 177-185.

Bertulli, C. G. (2010). Minke whale (*Balaenoptera acutorostrata*) and white-beaked dolphin (*Lagenorhynchus albirostris*) feeding behaviour in Faxaflói bay, south-west Iceland. MSc thesis. University of Iceland, Faculty of Biology.

Bertulli, C. G., Cecchetti, A., Van Bressem, M. F., & Van Waerebeek, K. (2012). Skin disorders in common minke whales and white-beaked dolphins off Iceland, a photographic assessment. Skin, 5(2).

Bertulli, C. G. (2013). VIII. Conservation biology of white-beaked dolphins off Iceland. Towards a Conservation Strategy for, 68.

Bertulli, C. G., Tetley, M. J., Magnúsdóttir, E. E., and Rasmussen, M. H. (2015). Observations of movement and site fidelity of white-beaked dolphins (*Lagenorhynchus albirostris*) in Icelandic coastal waters using photo-identification. Journal of Cetacean Research and Management, *in press*.

Bjørge, A. (2001). How persistent are marine mammal habitats in an ocean of variability?. In Marine Mammals. Springer US, 63-91.

Bogason, V., & Lilliendahl, K. (2009). Rannsóknir á sandsíli/An initiation of sand eel monitoring in Iceland. Hafrannsóknir, 145, 36-41.

Canning, S. J., Santos, M. B., Reid, R. J., Evans, P. G., Sabin, R. C., Bailey, N., & Pierce, G. J. (2008). Seasonal distribution of white-beaked dolphins (*Lagenorhynchus albirostris*) in UK waters with new information on diet and habitat use. Journal of the Marine Biological Association of the UK, 88(06), 1159-1166.

Carlson, C. (2001). A Review of Whale Watch Guidelines and Regulations Around the World: Version 2001. *International Whaling Commission*.

Carwardine, M., & Camm, M. (1999). Whales, dolphins and porpoises (Vol. 39). Dorling Kindersley. 240 pp.

Cecchetti, A. (2006). The spatial and temporal distribution of cetaceans within Skjálfandi Bay, North East Iceland. Unpublished master's thesis. University of Wales, Bangor, UK.

Chandola, V., & Kumar, V. (2007). Summarization–compressing data into an informative representation. Knowledge and Information Systems, 12(3), 355-378.

Christiansen, F., Rasmussen, M., & Lusseau, D. (2013). Whale watching disrupts feeding activities of minke whales on a feeding ground. Marine ecology progress series, 478, 239-251.

Christiansen, F., Rasmussen, M. H., & Lusseau, D. (2014). Inferring energy expenditure from respiration rates in minke whales to measure the effects of whale watching boat interactions. Journal of Experimental Marine Biology and Ecology, 459, 96-104.

Christiansen, F., Bertulli, C. G., Rasmussen, M. H., & Lusseau, D. (2015). Estimating cumulative exposure of wildlife to non-lethal disturbance using spatially explicit capture–recapture models. The Journal of Wildlife Management, 79(2), 311-324.

Coltman, D. W., O'Donoghue, P., Jorgenson, J. T., Hogg, J. T., Strobeck, C., & Festa-Bianchet, M. (2003). Undesirable evolutionary consequences of trophy hunting. Nature, 426(6967), 655-658.

Connor, R. C., Smolker, R., & Bejder, L. (2006). Synchrony, social behaviour and alliance affiliation in Indian Ocean bottlenose dolphins, *Tursiops aduncus*. Animal behaviour, 72(6), 1371-1378.

Constantine, R., Brunton, D. H., & Dennis, T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. Biological Conservation, 117(3), 299-307.

Constantine, R., & Bejder, L. (2008). 17 Managing the Whale-and Dolphin-watching Industry: Time for a Paradigm Shift. Marine wildlife and tourism management: Insights from the natural and social sciences, 17, 321-333.

Cooke, S. J., & Schramm, H. L. (2007). Catch-and-release science and its application to conservation and management of recreational fisheries. Fisheries Management and Ecology, 14(2), 73-79.

Cooper, D. (2007). Cetacean Habitat Modelling in Skjálfandi, Eyjafjörður and Öxarfjörður Bays, North East Iceland. Unpublished master's thesis. University of Wales, Bangor, UK.

Deecke, V. B., Ford, J. K., & Slater, P. J. (2005). The vocal behaviour of mammal-eating killer whales: communicating with costly calls. Animal Behaviour, 69(2), 395-405.

Defran, R. H., Shultz, G. M., & Weller, D. W. (1990). A technique for the photographic identification and cataloging of dorsal fins of the bottlenose dolphin (*Tursiops truncatus*). Individual Recognition of Cetaceans: Use of Photo-Identification and Other Techniques to Estimate Population Parameters, Reports of the International Whaling Commission, 53-55.

Evans, P. G. H. (1991). Whales, dolphins and porpoises: order Cetacea. The handbook of British mammals, 299-350.

Evans, P. G., & Hammond, P. S. (2004). Monitoring cetaceans in European waters. Mammal review, 34(1-2), 131-156.

Evans, P. G., & Teilmann, J. (2009). ASCOBANS/HELCOM Small Cetacean Population Structure Workshop. ASCOBANS, Bonn, Germany, 214.

Evans, P.G.H. and Bjørge, A. (2013) Impacts of climate change on marine mammals, MCCIP Science Review 2013, 134-148.

Forestell, P. H., Higham, J., & Lück, M. (2007). Protecting the ocean by regulating whalewatching: The sound of one hand clapping. Marine Wildlife and Tourism Management: Insights from the Natural and Social Sciences. CABI Publishing, Oxfordshire, UK, 272-293.

Friedlaender, A. S., Halpin, P. N., Qian, S. S., Lawson, G. L., Wiebe, P. H., Thiele, D., & Read, A. J. (2006). Whale distribution in relation to prey abundance and oceanographic processes in shelf waters of the Western Antarctic Peninsula. Marine Ecology Progress Series 317: 297-310.

Gerhardt, H. C., & Klump, G. M. (1988). Masking of acoustic signals by the chorus background noise in the green tree frog: a limitation on mate choice. Animal Behaviour, 36(4), 1247-1249.

Gill, A., & Fairbainrns, R. S. (1995). Photo-identification of the minke whale *Balaenoptera acutorostrata* off the Isle of Mull, Scotland. Developments in Marine Biology, 4, 129-132.

Gill, J. A., Norris, K., & Sutherland, W. J. (2001). Why behavioural responses may not reflect the population consequences of human disturbance. Biological Conservation, 97(2), 265-268.

Gunnlaugsson, T., Sigurjónsson, J., & Donovan, G. P. (1988). Aerial survey of cetaceans in the coastal waters off Iceland, June-July 1986. Rep. Int. Whaling Comm, 38, 489-500.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., ... & Watson, R. (2008). A global map of human impact on marine ecosystems. Science, 319(5865), 948-952.

Hammond, P. S., Mizroch, S. A., & Donovan, G. P. (1990). Report of the International Whaling Commission (Special Issue 12). Individual Recognition of Cetaceans: Use of Photo-Identification and Other Techniques to Estimate Population Parameters. *International Whaling Commission*, Cambridge, UK.

Hammond, P. S., Berggren, P., Benke, H., Borchers, D. L., Collet, A., Heide-Jørgensen, M. P., ... & Øien, N. (2002). Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology, 39(2), 361-376.

Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D. W., & Medina-Elizade, M. (2006). Global temperature change. Proceedings of the National Academy of Sciences, 103(39), 14288-14293.

Hastie, G. D., Wilson, B., Tufft, L. H., & Thompson, P. M. (2003). Bottlenose dolphins increase breathing synchrony in response to boat traffic. Marine Mammal Science, 19(1), 74-084.

Hooker, S. K., & Baird, R. W. (2001). Diving and ranging behaviour of odontocetes: a methodological review and critique. Mammal Review, 31(1), 81-105.

International Whaling Commission (2009). Report of the *IWC* workshop on cetaceans and climate change. *Report of the International Whaling Comminssion*, 61(4), 1-31.

International Whaling Commission (2012). Report of the workshop on small cetaceans and climate change. *Report of the International Whaling Comminssion*, 63(1), 319-336.

Janik, V. M. (2000). Food–related bray calls in wild bottlenose dolphins (*Tursiops truncatus*). Proceedings of the Royal Society of London. Series B: Biological Sciences, 267(1446), 923-927.

Janik, V. M. (2005). Underwater acoustic communication networks in marine mammals. Animal communication networks, 390-415.

Jansen, O. E., Leopold, M. F., Meesters, E. H., & Smeenk, C. (2010). Are white-beaked dolphins *Lagenorhynchus albirostris* food specialists? Their diet in the southern North Sea. Journal of the Marine Biological Association of the United Kingdom, 90(08), 1501-1508.

Jensen, F. H., Bejder, L., Wahlberg, M., Aguilar De Soto, N., Johnson, M. P., & Madsen, P. T. (2009). Vessel noise effects on delphinid communication. Marine Ecology Progress Series, 395: 161-175.

Kastelein, R. A., Bunskoek, P., Hagedoorn, M., Au, W. W., & de Haan, D. (2002). Audiogram of a harbor porpoise (*Phocoena phocoena*) measured with narrow-band frequency-modulated signals. The Journal of the Acoustical Society of America, 112(1), 334-344.

Kinze, C. C., Addink, M., Smeenk, C., Hartmann, M. G., Richards, H. W., Sonntag, R. P., & Benke, H. (1998). The White-Beaked Dolphin (*Lagenorhynchus albirostris*) and the Whie-Sided Dolphin (*Lagenorhynchus acutus*) in the North and Baltic Seas: Review of available information. Rep. Int. Whal. Commn., (47), 675-681.

Kinze, C. C. (2001). Marine mammals of the North Atlantic. Princeton University Press. New Jersey. 192 pp.

Lambert, E., Pierce, G. J., Hall, K., Brereton, T., Dunn, T. E., Wall, D., ... & MacLeod, C. D. (2014). Cetacean range and climate in the eastern North Atlantic: future predictions and implications for conservation. Global change biology, 20(6), 1782-1793.

Learmonth, J. A., MacLeod, C. D., Santos, M. B., Pierce, G. J., Crick, H. Q. P., & Robinson, R. A. (2006). Potential effects of climate change on marine mammals. Oceanography and Marine Biology, 44, 431.

Leatherwood, S., & Reeves, R. R. (1990). The Bottlenose Dolphin, Academic Press. San Diego, 653 pp.

Levitus, S., Antonov, J. I., Boyer, T. P., & Stephens, C. (2000). Warming of the world ocean. Science, 287(5461), 2225-2229.

Lusseau, D. (2003a). Effects of tour boats on the behavior of bottlenose dolphins: using Markov chains to model anthropogenic impacts. Conservation Biology, 17(6), 1785-1793.

Lusseau, D. (2003b). Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. Marine ecology. Progress series, 257, 267-274.

Lusseau, D. (2004). The hidden cost of tourism: detecting long-term effects of tourism using behavioral information. Ecology and Society, 9(1), 2.

Lusseau, D. (2005). Residency pattern of bottlenose dolphins *Tursiops* spp. in Milford Sound, New Zealand, is related to boat traffic. Marine Ecology Progress Series, 295, 265-272.

Lusseau, D., Lusseau, S. M., Bejder, L., & Williams, R. (2006, May). An individual-based model to infer the impact of whalewatching on cetacean population dynamics. In *IWC SC/58/WW7 Report to the 58th meeting of the International Whaling Commission Scientific Committee*, St. Kitts and Nevis.

Lusseau, D., & Bejder, L. (2007). The long-term consequences of short-term responses to disturbance experiences from whalewatching impact assessment. International Journal of Comparative Psychology, 20(2).

Lynam, C. P., Halliday, N. C., Höffle, H., Wright, P. J., van Damme, C. J., Edwards, M., & Pitois, S. G. (2013). Spatial patterns and trends in abundance of larval sandeels in the North Sea: 1950–2005. ICES Journal of Marine Science: Journal du Conseil, 70(3), 540-553.

MacLeod, C. D., Bannon, S. M., Pierce, G. J., Schweder, C., Learmonth, J. A., Herman, J. S., & Reid, R. J. (2005). Climate change and the cetacean community of north-west Scotland. Biological Conservation, 124(4), 477-483.

MacLeod, C. D., Weir, C. R., Pierpoint, C., & Harland, E. J. (2007). The habitat preferences of marine mammals west of Scotland (UK). Journal of the Marine Biological Association of the United Kingdom, 87(01), 157-164.

MacLeod, C. D., Weir, C. R., Santos, M. B., & Dunn, T. E. (2008). Temperature-based summer habitat partitioning between white-beaked and common dolphins around the United Kingdom and Republic of Ireland. Journal of the Marine Biological Association of the UK, 88(06), 1193-1198.

MacLeod, C. D. (2009). Global climate change, range changes and potential implications for the conservation of marine cetaceans: a review and synthesis. Endangered Species Research, 7(2), 125-136.

MacLeod, C. D. (2013). IV. White-beaked Dolphins in the Northeast Atlantic: A brief review of their ecology and potential threats to conservation status. Towards a Conservation Strategy for, 26.

Magnúsdóttir, E. E. (2007). Year-round distribution and abundance of white-beaked dolphins (*Lagenorhynchus albirostris*) off the southwest coas of Iceland. Unpublished MSc thesis. University of Iceland, Dept. of Biology.

Magnúsdóttir, E. E., Rasmussen, M. H., Lammers, M. O., & Svavarsson, J. (2014). Humpback whale songs during winter in subarctic waters. Polar Biology, 37(3), 427-433.

McDonald, J. H. (2009). Handbook of biological statistics. Baltimore, MD: Sparky House Publishing. 1, 6-10.

Meissner, A. M., Christiansen, F., Martinez, E., Pawley, M. D., Orams, M. B., & Stockin, K. A. (2015). Behavioural Effects of Tourism on Oceanic Common Dolphins, *Delphinus* sp., in New Zealand: The Effects of Markov Analysis Variations and Current Tour Operator Compliance with Regulations. PloS one, 10(1), 1-23.

Melle, W., Runge, J., Head, E., Plourde, S., Castellani, C., Licandro, P., ... & Chust, G. (2014). The North Atlantic Ocean as habitat for *Calanus finmarchicus*: Environmental factors and life history traits. Progress in Oceanography, 129, 244-284.

Mikkelsen, A. M. H., & Lund, A. (1994). Intraspecific variation in the dolphins *Lagenorhynchus albirostris* and *L. acutus* (Mammalia: *Cetacea*) in metrical and non-metrical skull characters, with remarks on occurrence. Journal of Zoology, 234(2), 289-299.

Mooney, T. A., Nachtigall, P. E., Taylor, K. A., Rasmussen, M. H., & Miller, L. A. (2009). Auditory temporal resolution of a wild white-beaked dolphin (*Lagenorhynchus albirostris*). Journal of Comparative Physiology A, 195(4), 375-384.

Moore, S. E., & Huntington, H. P. (2008). Arctic marine mammals and climate change: impacts and resilience. Ecological Applications, 18(sp2), S157-S165.

Morizur, Y., Berrow, S. D., Tregenza, N. J. C., Couperus, A. S., & Pouvreau, S. (1999). Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic. Fisheries Research, 41(3), 297-307.

Müller, M., Boutière, H., Weaver, A. C. F., & Candelon, N. (1998). Ethogram of the bottlenose dolphin (*Tursiops truncatus*), with special reference to solitary and sociable dolphins. *Vie et Milieu* (France).

Nachtigall, P. E., Mooney, T. A., Taylor, K. A., Miller, L. A., Rasmussen, M. H., Akamatsu, T., ... & Vikingsson, G. A. (2008). Shipboard measurements of the hearing of the white-beaked dolphin *Lagenorhynchus albirostris*. Journal of Experimental Biology, 211(4), 642-647.

New, L. F., Harwood, J., Thomas, L., Donovan, C., Clark, J. S., Hastie, G., ... & Lusseau, D. (2013). Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. Functional Ecology, 27(2), 314-322.

Nicol, S., Worby, A., & Leaper, R. (2008). Changes in the Antarctic sea ice ecosystem: potential effects on krill and baleen whales. Marine and Freshwater Research, 59(5), 361-382.

Norris, K. S., & Dohl, T. P. (1979). The structure and functions of cetacean schools. University of California Center for Coastal Marine Studies.

Norris, K. S., & Schilt, C. R. (1988). Cooperative societies in three-dimensional space: on the origins of aggregations, flocks, and schools, with special reference to dolphins and fish. Ethology and Sociobiology, 9(2), 149-179.

Northridge, S. P., Tasker, M. L., Webb, A., & Williams, J. M. (1995). Distribution and relative abundance of harbour porpoises (*Phocoena phocoena* L.), white-beaked dolphins (*Lagenorhynchus albirostris* Gray), and minke whales (*Balaenoptera acutorostrata* Lacepède) around the British Isles. ICES Journal of Marine Science: Journal du Conseil, 52(1), 55-66.

Northridge, S., Tasker, M., Webb, A., Camphuysen, K., & Leopold, M. (1997). White-beaked *Lagenorhynchus albirostris* and Atlantic white-sided dolphin *L. acutus* distributions in northwest European and US North Atlantic waters. Rep. int. Whal. Commn, 47, 797-805.

Notarbartolo di Sciara, G. (2002). Conservation problems: overview. Cetaceans of the Mediterranean and Black Seas: state of knowledge and conservation strategies. A report to the *ACCOBAMS* Secretariat, Monaco. February 2002. Section 4, 3 p.

Notarbartolo di Sciara, G., Birkun, A. Jr. (2002). Conservation needs and strategies. In: G. Notarbartolo di Sciara (Ed.), Cetaceans of the Mediterranean and Black Seas: state of knowledge and conservation strategies. A report to the *ACCOBAMS* Secretariat, Monaco. February 2002. Section 18, 21 p.

Nowacek, S. M., Wells, R. S., & Solow, A. R. (2001). Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota bay, florida. Marine Mammal Science, 17(4), 673-688.

O'Connor, S., Campbell, R., Cortez, H., & Knowles, T. (2009). Whale Watching Worldwide: tourism numbers, expenditures and expanding economic benefits, a special report from the *International Fund for Animal Welfare*. Yarmouth MA, USA, (Economists at Large), 295pp.

Øien, N. (1996). *Lagenorhynchus* species in Norwegian waters as revealed from incidental observations and recent sighting surveys. *International Whaling Commission*, Scientific Committee Document SC/48/SM15, Cambridge, UK.

Otani, S., Naito, Y., Kawamura, A., Kawasaki, M., Nishiwaki, S., & Kato, A. (1998). Diving behavior and performance of harbor porpoises, *Phocoena phocoena*, in Funka Bay, Hokkaido, Japan. Marine mammal science, 14(2), 209-220.

Parra, G. J., Schick, R., & Corkeron, P. J. (2006). Spatial distribution and environmental correlates of Australian snubfin and Indo-Pacific humpback dolphins. Ecography, 29(3), 396-406.

Pike, D. G., Paxton, C. G., Gunnlaugsson, T., & Víkingsson, G. A. (2009). Trends in the distribution and abundance of cetaceans from aerial surveys in Icelandic coastal waters, 1986-2001. NAMMCO Scientific Publications, 7, 117-142.

Pirotta, E., Thompson, P. M., Cheney, B., Donovan, C. R., & Lusseau, D. (2014). Estimating spatial, temporal and individual variability in dolphin cumulative exposure to boat traffic using spatially explicit capture–recapture methods. Animal Conservation, 18(1), 20-31.

Pirotta, E., Merchant, N. D., Thompson, P. M., Barton, T. R., & Lusseau, D. (2015). Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity. Biological Conservation, 181, 82-89.

Rasmussen, M. H. (1999). Hvidnesens lydproduktion, adfærd samt udbredelse. Unpublished Master thesis. Centre for Sound Communication, Institute of Biology, SDU-Odense, Denmark.

Rasmussen, M. H., & Miller, L. A. (2002). Whistles and clicks from white-beaked dolphins, *Lagenorhynchus albirostris*, recorded in Faxaflói Bay, Iceland. Aquatic Mammals, 28(1), 78-89.

Rasmussen, M. H., Miller, L. A., & Au, W. W. (2002). Source levels of clicks from free-ranging white- beaked dolphins (*Lagenorhynchus albirostris* Gray 1846) recorded in Icelandic waters. The Journal of the Acoustical Society of America, 111(2), 1122-1125.

Rasmussen, M. H. and Jacobsen, T. (2003). Photo-identification of white-beaked dolphins in Icelandic waters. European Research on Cetaceans – 17. Proceedings of the 21st Annual Conference of the European Cetacean Society, Las Palmas, Gran Canaria.

Rasmussen, M. H. (2004). A Study of Communication and Echolocation Sounds Recorded from Free-Ranging White-Beaked Dolphins (*Lagenorhynchus albirostris*) in Icelandic Waters (Unplished Doctoral dissertation, Syddansk Universitet).

Rasmussen, M. H., Wahlberg, M., & Miller, L. A. (2004). Estimated transmission beam pattern of clicks recorded from free-ranging white-beaked dolphins (*Lagenorhynchus albirostris*). The Journal of the Acoustical Society of America, 116(3), 1826-1831.

Rasmussen, M. H., Lammers, M., Beedholm, K., & Miller, L. A. (2006). Source levels and harmonic content of whistles in white-beaked dolphins (*Lagenorhynchus albirostris*). The Journal of the Acoustical Society of America, 120(1), 510-517.

Rasmussen, M. H. (2013). Case Studies: invited submissions from other research activity X. Decreasing sightings rates of Icelandic white-beaked dolphins in the Southwestern part of Iceland–possible threats to the population?. Towards a Conservation Strategy for, 83.

Rasmussen, M. H., Akamatsu, T., Teilmann, J., Vikingsson, G., & Miller, L. A. (2013). Biosonar, diving and movements of two tagged white-beaked dolphin in Icelandic waters. Deep Sea Research Part II: Topical Studies in Oceanography, 88, 97-105.

Reddy, M. L., Dierauf, L. A., & Gulland, F. M. D. (2001). Marine mammals as sentinels of ocean health. CRC Handbook of Marine Mammal Medicine Second Edition. CRC Press, Boca Raton, FL, 3-13.

Reeves, R. R., Smeenk, C., Kinze, C. C., Brownell Jr, R. L., & Lien, J. (1999). White-beaked dolphin (*Lagenorhynchus albirostris*) Gray, 1846. Handbook of marine mammals, 6, 1-30.

Reid, J. B., Evans, P. G., & Northridge, S. P. (2003). Atlas of cetacean distribution in north-west European waters. Joint Nature Conservation Committee.

Ridgway, S. H., & Harrison, R. J. (Eds.). (1999). Handbook of marine mammals: the second book of dolphins and the porpoises. Elsevier. Volume 6.

Salo, K. (2004). Distribution of cetaceans in Icelandic waters (Doctoral dissertation, Syddansk Universitet).

Santos, M. B., Pierce, G. J., Ross, H. M., Reid, R. J., & Wilson, B. (1994). Diets of small cetaceans from the Scottish coast. ICES, COPENHAGEN(DENMARK).

Schipper, J., Chanson, J. S., Chiozza, F., Cox, N. A., Hoffmann, M., Katariya, V., ... & Hammond, P. S. (2008). The status of the world's land and marine mammals: diversity, threat, and knowledge. Science, 322(5899), 225-230.

Schreier, M., Mannstein, H., Eyring, V., & Bovensmann, H. (2007). Global ship track distribution and radiative forcing from 1 year of AATSR data. Geophysical Research Letters, 34(17).

Shane, S. H. (1990). Behavior and ecology of the bottlenose dolphin at Sanibel Island, Florida. *The bottlenose dolphin*. Academic Press, San Diego, CA, 245-265.

Siegel, S. (1956). Nonparametric statistics for the behavioral sciences. International student edition, 6(2), 104-111

Sigurjónsson, J., & Víkingsson, G. A. (1997). Seasonal abundance of and estimated food consumption by cetaceans in Icelandic and adjacent waters. Journal of Northwest Atlantic Fishery Science, 22, 271-287.

Simmonds, M. P., & Eliott, W. J. (2009). Climate change and cetaceans: concerns and recent developments. Journal of the Marine Biological Association of the United Kingdom, 89(01), 203-210.

Sini, M. I., Canning, S. J., Stockin, K. A., & Pierce, G. J. (2005). Bottlenose dolphins around Aberdeen harbour, north-east Scotland: a short study of habitat utilization and the potential effects of boat traffic. Journal of the Marine Biological Association of the United Kingdom, 85(06), 1547-1554.

Smolker, R. A., Mann, J., & Smuts, B. B. (1993). Use of signature whistles during separations and reunions by wild bottlenose dolphin mothers and infants. Behavioral Ecology and Sociobiology, 33(6), 393-402.

Stefánsson, U. and Guðmundsson, G. (1978). The Freshwater regime of Faxaflói, Southwest Iceland, and its relation to meteorological variables. Estuarine and Coastal Marine Science, 6: 535–551.

Stefánsson, U. and Ólafsson, J. (1991). Nutrients and fertility of Icelandic waters. J. Mar. Res. Inst., Reykjavík, 12, 1-56.

Stefánsson, G., Sigurjónsson, J., & Víkingsson, G. A. (1997). On dynamic interactions between some fish resources and cetaceans off Iceland based on a simulation model. J. Northwest Atl. Fish. Sci., 22, 357-370.

Stenseth, N. C., Mysterud, A., Ottersen, G., Hurrell, J. W., Chan, K. S., & Lima, M. (2002). Ecological effects of climate fluctuations. Science, 297(5585), 1292-1296.

Stenseth, N. C., Ottersen, G., & Hurrell, J. W. (2004) Marine ecosystems and climate variation: the North Atlantic: a comparative perspective. Oxford University Press, Oxford.

Tetley, M.J. and Dolman, S.J. (2013). Towards a Conservation Strategy for White-beaked Dolphins in the Northeast Atlantic. Report from the European Cetacean Society's 27th Annual Conference Workshop, The Casa da Baía, Setúbal, Portugal. European Cetacean Society Special Publication Series No. XX, 121pp.

Turvey, S. T., Pitman, R. L., Taylor, B. L., Barlow, J., Akamatsu, T., Barrett, L. A., ... & Wang, D. (2007). First human-caused extinction of a cetacean species?. Biology letters, 3(5), 537-540.

Van Parijs, S. M., & Corkeron, P. J. (2001). Boat traffic affects the acoustic behaviour of Pacific humpback dolphins, *Sousa chinensis*. Journal of the Marine Biological Association of the UK, 81(03), 533-538.

Víkingsson, G. A., & Ólafsdóttir, D. (2004). Hnýðingur (white-beaked dolphin). Íslensk spendýr (Icelandic mammals) Vaka-Helgafell, Reykjavík, 154-157.

Víkingsson, G. A., & Heide-Jørgensen, M. P. (2014). First indications of autumn migration routes and destination of common minke whales tracked by satellite in the North Atlantic during 2001–2011. Marine Mammal Science, 31(1), 376-385.

Víkingsson, G. A., Pike, D. G., Schleimer, A., Valdimarsson, H., Gunnlaugsson, T., Silva, T., ... & Hammond, P. (2015). Distribution, abundance and feeding ecology of rorqual cetaceans in Icelandic waters: have recent environmental changes had an effect. Name: Frontiers in Ecology and Evolution, 3(6).

Walther, G. R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T. J., ... & Bairlein, F. (2002). Ecological responses to recent climate change. Nature, 416(6879), 389-395.

Watwood, S. L., Owen, E. C., Tyack, P. L., & Wells, R. S. (2005). Signature whistle use by temporarily restrained and free-swimming bottlenose dolphins, *Tursiops truncatus*. Animal Behaviour, 69(6), 1373-1386.

Weir, C. R., Stockin, K. A., & Pierce, G. J. (2007). Spatial and temporal trends in the distribution of harbour porpoises, white-beaked dolphins and minke whales off Aberdeenshire (UK), north-western North Sea. Journal of the Marine Biological Association of the United Kingdom, 87(01), 327-338.

Weir, C. R. (2008). Occurrence of the white-beaked dolphin (*Lagenorhynchus albirostris*) and other cetacean species in the Minch, August 2007. Scottish Natural Heritage Commissioned Report No.305 (ROAME No. F05AC701).

Weir, C. R., Macleod, C. D., & Calderan, S. V. (2009). Fine-scale habitat selection by white-beaked and common dolphins in the Minch (Scotland, UK): evidence for interspecific competition or coexistence?. Journal of the Marine Biological Association of the United Kingdom, 89(05), 951-960.

Westgate, A. J., Head, A. J., Berggren, P., Koopman, H. N., & Gaskin, D. E. (1995). Diving behaviour of harbour porpoises, *Phocoena phocoena*. Canadian Journal of Fisheries and Aquatic Sciences, 52(5), 1064-1073.

Williams, R., Lusseau, D., & Hammond, P. S. (2006). Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). Biological Conservation, 133(3), 301-311.

Williams, R., Ashe, E., Sandilands, D., & Lusseau, D. (2011). Stimulus-dependent response to disturbance affecting the activity of killer whales. SC/63/WW5, 1-27.

Würsig, B., & Jefferson, T. A. (1990). Methods of photo-identification for small cetaceans. *Reports of the International Whaling Commission*. Special, (12), 42-43.

Würsig, B., Reeves, R. R., & Ortega-Ortiz, J. G. (2001). Global climate change and marine mammals. In Marine Mammals. Springer US, 589-608.

Appendices

Appendix 1. *Re-sightings and new IDs for 2014 (April – September) in Faxaflói bay, Reykjavík (Copyright University of Iceland). Numbers represent tours where that particular individual has been sighted*

- Re-sightings (within 2014)

ID (re-sights)	April	May	June	July	August	September
DEM47_Dolphin2606a	0	0	0	0	0	**1**
DEM 55_Future	0	**1**	0	0	**2**	0
DEM 62_Funny	0	0	0	0	**2**	0
DEM 73_Ventiquattro	0	**1**	**1**	**1**	**1**	0
DEM 96_Mid Squared	0	0	**2**	**2**	0	0
DEM 108_Double Cheese Bite	0	0	**3**	**2**	0	0
DEM 111_Triangular Dorsal Ridge	0	**2**	0	0	0	0
DEM 116_Gaby	0	0	**1**	**2**	**1**	0
DEM 123_31(Resight sb)	0	0	0	0	**1**	0
DEM 124_32(Resight sb)	**1**	0	0	0	0	0
DEM 128_Cheese Bite	0	**1**	**1**	0	**3**	0
DEM 193_Pulcinella Senza Becco	**1**	0	0	0	0	0
DEM 204_Simil Jump With Ind	0	0	**1**	0	0	0
DEM 213_Bigger Chewy	0	0	0	**4**	**1**	0
DEM 229_Double Sqn Up	0	0	**1**	**3**	**1**	0
DEM 236_Sindri	0	0	0	0	0	**1**
DEM 241_Large Nick	0	**1**	0	**3**	0	**1**
DEM 256_Squared Low	0	**1**	0	**2**	**2**	0
DEM 258_MontGomery	0	**2**	**1**	**3**	0	**1**
DEM 285_Check_114(Resight sb)	0	**1**	**1**	**1**	0	0
DEM 321_Sophie	0	**1**	0	**4**	**2**	**1**
DEM 336_Arrabbiato2	0	0	**2**	0	0	0

- **New IDs**

ID (new)	April	May	June	July	August	September
DEM 340_Ouch (Fresh Wound)	0	0	0	**3**	0	0
DEM 341_Effe	**1**	0	0	0	0	0
DEM 342_Rei	**2**	0	0	0	0	0
DEM 343_Trix	0	**2**	**1**	0	0	0
DEM 344_Penguin	0	**1**	0	**1**	0	0
DEM 346_Mew	0	**1**	0	0	0	0
DEM 347_Esjan	0	**1**	0	0	0	0
DEM348_Marion	0	0	0	**2**	0	**2**

Appendix 2. *Comparisons of white-beaked dolphins behavioural response to marine traffic through years (Faxaflói, Reykjavík). "**p**" values refer to χ^2 test (significant if $p < 0,05$)*

- Change/Avoidance

2008	avoid	no avoid	tot	EXPECTED	avoid	no avoid	tot	p
change	11	9	20	change	10,8	9,2	20	0,930
no change	28	24	52	no change	28,2	23,8	52	
tot	39	33	72	tot	39	33	72	

2010	avoid	no avoid	tot	EXPECTED	avoid	no avoid	tot	p
change	9	2	11	change	7,1	3,9	11	0,191
no change	28	18	46	no change	29,9	16,1	46	
tot	37	20	57	tot	37	20	57	

2011	avoid	no avoid	tot	EXPECTED	avoid	no avoid	tot	p
change	12	3	15	change	8,3	6,7	15	0,035*
no change	33	33	66	no change	36,7	29,3	66	
tot	45	36	81	tot	45	36	81	

2012	avoid	no avoid	tot	EXPECTED	avoid	no avoid	tot	p
change	18	6	24	change	11,7	12,3	24	0,003*
no change	27	41	68	no change	33,3	34,7	68	
tot	45	47	92	tot	45	47	92	

2014	avoid	no avoid	tot	EXPECTED	avoid	no avoid	tot	p
change	47	16	63	change	30,2	32,8	63	6,7E-07*
no change	65	106	171	no change	81,8	89,2	171	
tot	112	122	234	tot	112	122	234	

- **Change/Interaction**

2008	Interact.	no interact.	tot	EXPECTED	Interact.	no interact.	tot	p
change	6	14	20	change	3,9	16,1	20	0,160
no change	8	44	52	no change	10,1	41,9	52	
tot	14	58	72	tot	14	58	72	

2010	Interact.	no interact.	tot	EXPECTED	Interact.	no interact.	tot	p
change	0	11	11	change	1,4	9,6	11	0,167
no change	7	39	46	no change	5,6	40,4	46	
tot	7	50	57	tot	7	50	57	

2011	Interact.	no interact.	tot	EXPECTED	Interact.	no interact.	tot	p
change	0	15	15	change	1,7	13,3	15	0,129
no change	9	57	66	no change	7,3	58,7	66	
tot	9	72	81	tot	9	72	81	

2012	Interact.	no interact.	tot	EXPECTED	Interact.	no interact.	tot	p
change	3	21	24	change	5,2	18,8	24	0,202
no change	17	51	68	no change	14,8	53,2	68	
tot	20	72	92	tot	20	72	92	

2014	Interact.	no interact.	tot	EXPECTED	Interact.	no interact.	tot	p
change	14	49	63	change	17,8	45,2	63	0,217
no change	52	119	171	no change	48,2	122,8	171	
tot	66	168	234	tot	66	168	234	

- Change/Boats

2008	1 boat	more boats	tot		EXPECTED	1 boat	more boats	tot	p
change	15	5	20		change	15	5	20	1
no change	39	13	52		no change	39	13	52	
tot	54	18	72		tot	54	18	72	

2010	1 boat	more boats	tot		EXPECTED	1 boat	more boats	tot	p
change	9	2	11		change	8,1	2,9	11	0,495
no change	33	13	46		no change	33,9	12,1	46	
tot	42	15	57		tot	42	15	57	

2011	1 boat	more boats	tot		EXPECTED	1 boat	more boats	tot	p
change	9	6	15		change	9,4	5,6	15	0,792
no change	42	24	66		no change	41,6	24,4	66	
tot	51	30	81		tot	51	30	81	

2012	1 boat	more boats	tot		EXPECTED	1 boat	more boats	tot	p
change	7	17	24		change	12,3	11,7	24	0,012*
no change	40	28	68		no change	34,7	33,3	68	
tot	47	45	92		tot	47	45	92	

2014	1 boat	more boats	tot		EXPECTED	1 boat	more boats	tot	p
change	19	44	63		change	27,2	35,8	63	0,015*
no change	82	89	171		no change	73,8	97,2	171	
tot	101	133	234		tot	101	133	234	

- Avoidance/Boats

2008	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
avoid	28	11	39	avoid	29,3	9,8	39	0,495
no avoid	26	7	33	no avoid	24,8	8,3	33	
tot	54	18	72	tot	54	18	72	

2010	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
avoid	28	9	37	avoid	27,3	9,7	37	0,642
no avoid	14	6	20	no avoid	14,7	5,3	20	
tot	42	15	57	tot	42	15	57	

2011	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
avoid	26	19	45	avoid	28,3	16,7	45	0,280
no avoid	25	11	36	no avoid	22,7	13,3	36	
tot	51	30	81	tot	51	30	81	

2012	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
avoid	18	27	45	avoid	23,0	22,0	45	0,037*
no avoid	29	18	47	no avoid	24,0	23,0	47	
tot	47	45	92	tot	47	45	92	

2014	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
avoid	40	72	112	avoid	48,3	63,7	112	0,028*
no avoid	61	61	122	no avoid	52,7	69,3	122	
tot	101	133	234	tot	101	133	234	

- **Interaction/Boats**

2008	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
interact.	12	2	14	interact.	10,5	3,5	14	0,302
no interact.	42	16	58	no interact.	43,5	14,5	58	
tot	54	18	72	tot	54	18	72	

2010	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
interact.	3	4	7	interact.	5,2	1,8	7	0,048*
no interact.	39	11	50	no interact.	36,8	13,2	50	
tot	42	15	57	tot	42	15	57	

2011	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
interact.	4	5	9	interact.	5,7	3,3	9	0,222
no interact.	47	25	72	no interact.	45,3	26,7	72	
tot	51	30	81	tot	51	30	81	

2012	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
interact.	9	11	20	interact.	10,2	9,8	20	0,538
no interact.	38	34	72	no interact.	36,8	35,2	72	
tot	47	45	92	tot	47	45	92	

2014	1 boat	more boats	tot	EXPECTED	1 boat	more boats	tot	p
interact.	22	44	66	interact.	28,5	37,5	66	0,057
no interact.	79	89	168	no interact.	72,5	95,5	168	
tot	101	133	234	tot	101	133	234	

Acknowledgements

I would like to thank all people who supported me during my studies and adventures, helping me out and enriching myself.
First of all, thanks to my Family: Mamma, Papà, my brother Paolo and my sister Angela. They have been always there for me to help me going through each obstacle I found on my way. From the beginning my parents gave me the opportunity to choose and follow my dreams. Thanks to them I was able to travel, to gain all the experiences I needed and to meet amazing friends.

Thanks to Dr. Marianne H. Rasmussen, Prof. Elena Fabbri and Prof. Marina Colangelo for the supervision, suggestions and opportunity to develop and work on a project like this one.

Thanks of course to "*Elding*" company that welcomed me with open arms and provided me with every little thing I needed to pursue at the best my project.
Thanks to the University of Iceland, Edda Magnúsdóttir, Caroline Weir and especially Chiara Bertulli (and Marianne again) for letting me use the ID-catalogue they've created and the existing datasets; thanks for the precious collaboration of Jacob Levenson that helped me out both during the season and after. In addition to them, I'd like to thank all the volunteers who worked hard to collect data in the past.
Thanks to the best research partners I could have asked for, Celine and Jonathan: thanks for your help regardless the crazy schedules we went through. Guys, I could have not done anything without you! ..."what?!"

Special thanks to Dominik and Tumi who helped me out with great advices and with the translation of the abstract...you've been awesome!
Nonetheless my sweet floating home *Fífíll* and all the other amazing people I've met in Iceland: Jack, Birkir, Imma, Einar, Linda, Heiður, Elín, Megan, Carine, Baldur, my favourite Captain Jón, Jakob, Vignir, Gulli and all the others…you know who you are! TAKK FYRIR!!!!
How not to mention my university mates: Detta, Simo, Anna, Connie, Giulia, Lori, Annalisa, Davide, Eva, Toni, Marco, Luca, Ago, Francesco, Sergio, Graziana and so many others...you've been my second Family!
GRAZIE REGAZ!!!
Thanks to Ravenna and of course to my beloved "Mela", which together with all the amazing people met, "adopted" me and gave me the possibility to distract myself when I've needed the most.

Thanks to everyone who gave me the opportunity to improve my experiences and knowledge: all the Professors, my "Boss" Daniele, Dr. Michael Krützen, the people I've met in Zürich and "zio" Nicola, and of course Monica and Rita that have been always helpful, patient and available for me.
Thanks then to the people that are always present despite my many travels: Jimmy, Giansi, Jeffi, Cap, Noccio and Drydry.

Finally, I'd like to thank myself too because without my tendency to constantly complicate my life avoiding to choose any possible easy option, I would have never had the opportunity to live these amazing experiences.

***"You just have to trust your own madness"** – [Clive Barker]*