Bachelor Thesis

Naturvård och artmångfald
Conservation and Diversity 180hp

Investigating fin whale (*Balaenoptera physalus*) sightings in Skjálfandi Bay, Iceland, and potential migratory movements through photo-identification

Biology 15hp
Húsavík/Halmstad 2023
Hanna Lundström

HÖGSKOLAN
I HALMSTAD

Abstract

In studies of migration and life-history of many large whales, photo-identification has proven a very powerful tool. Unfortunately, photo-identification is not as established and common when it comes to the second largest animal on earth, the fin whale *(Balaenoptera physalus)*. Despite the massive size of the creatures many things remain unknown about them, such as migration patterns, the geographical and temporal locations of wintering and individual seasonal range. This study aimed to investigate when fin whales normally visit Skjálfandi Bay, Iceland, and if they migrate between Skjálfandi Bay and Ireland, using photo-identification. The results showed somewhat that the fin whale visits in Skjálfandi Bay were most common in March and April which could be connected to arrival of schooling fish such as capelin *(Mallotus villosus)* early spring, and that visits have not changed noticeably over the years, suggesting that the fin whales will keep coming to Skjálfandi Bay. One possible fin whale match was found between Skjálfandi Bay and Ireland, suggesting but not confirming migration between the two locations. Further investigation is needed to understand fin whale migration patterns. Because of typical fin whale behavior, similar dorsal fins and unreliable weather, the photo-identification system was discussed, and improvements suggested. A more established photo-identification system could include fin whale photo-ID catalogues with pictures from dorsal view *and* from the left and right side. However, the photo-identification methods need further investigating to improve even more and to find the best possible way to identify and photograph fin whales.

Sammanfattning

Foto-identifiering har visat sig vara ett användbart verktyg för att studera migration men även livshistoria hos många stora valar. Tyvärr är fotoidentifiering inte lika etablerat och vanligt när det gäller det näst största djuret vår jord, sillvalen *(Balaenoptera physalus)*. Trots valens massiva storlek finns det en stor kunskapsbrist kring dess migrationsmönster, de geografiska och tidsmässiga platserna för övervintring och individuellt säsongsutbrednings-område bland annat. Denna studie syftade till att undersöka när sillvalarna normalt kommer till Skjálfandi Bay, Island, och om de migrerar mellan Skjálfandi Bay och Irland, med hjälp av foto-identifiering. Resultaten visade delvis att sillvalarna oftast besöker Skjálfandi Bay i mars och april, vilket kan vara kopplat till att stimfiskar såsom lodda *(Mallotus villosus)* kommer dit tidig vår, och att besökssiffrorna inte har ändrats mycket över åren vilket tyder på att sillvalarna kommer fortsätta komma till Skjálfandi Bay. En möjlig matching hittades mellan en identifierad sillval i Skjálfandi Bay och en identifierad sillval i irländska vatten, vilket tyder på men inte bekräftar migration mellan de två platserna. På grund av det typiska sillvalbeteendet och deras liknande ryggfenor samt det opålitliga vädret som en faktor, diskuterades fotoidentifierings-systemet och förbättringar föreslogs. Ett mer etablerat fotoidentifieringssystem hade kunnat inkludera fotoidentifieringskataloger med bilder på sillvalar från ovan sida *och* från båda sidor. Däremot behöver fotoidentifieringsmetoderna vidare undersökning för ytterligare förbättringar och för att hitta det bästa sättet att identifiera och fotografera sillvalar.

Introduction

Fin whales *(Balaenoptera physalus)* are the second largest animal on the planet (IUCN 2022) 6-7 meters long and weighing about 1-2 tons at birth, while fully grown they can be up to 27 meters long, weighing 81 tons (Shirihai & Jarret 2006 page 54). In Icelandic waters they have been estimated to weigh an average of approximately 42 tons, including differences in sexes and ages (Víkingsson et al. 1988, Sigurjónsson et al. 1990), and reach around 22 meters long in the northern hemisphere (Aguilar & García-Vernet 2018). The fin whales are not social creatures except for the temporary bond between the mother and its nursing calf, which ends after weaning (Aguilar & García-Vernet 2018). They swim mostly alone; however, they can be seen swimming separated by age/sex in groups of 2-7 when they just happen to be next to each other (Shirihai & Jarret 2006 page 55, Aguilar & García-Vernet 2018). They are very fast, among the fastest of our great whales with a swimming speed of 5-8 knots for regular cruising, and for short bursts a speed of up to 15 knots. Diving time varies and is usually between 3-10 minutes and can be as deep as 100-200 m (Aguilar & García-Vernet 2018). Between deep dives the whale comes up to breathe, shallowly diving just beneath the surface between breaths, before arching its back without showing the fluke and disappearing into the deep (Aguilar & García-Vernet 2018). Normally the swimming is smooth, but breaching, which is when the whale jumps with at least 40% of its body out of the water and slaps back onto the surface, has occurred on rare occasions when the whale is being harassed (Aguilar & García-Vernet 2018, Würsig & Whitehead 2009). It has been suggested that although the fin whales are not gregarious, they communicate with other whales through sound. These sounds consist of low-frequency grunts and moans (Watkins et al. 2000) and have been found to differ slightly between several Atlantic and Pacific Ocean regions, the Mediterranean Sea, and the Gulf of California. The long-range low-frequency vocalizations (20Hz pulses) are produced by males most likely to attract females during winter breeding season and are characteristic for the fin whales (Aguilar & García-Vernet 2018).

Fin whales are filter feeders like all baleen whales and strain their food from the water through baleen plates (IUCN 2022). Some have speculated that fin whales circle schools of fish to frighten them into denser schools, right mandible which is white (fig. 1) facing inwards (IUCN 2022). To catch their prey, they lunge with open mouths, a method that is called lunge-feeding (Goldbogen et al. 2006). During the summer months, they feed intensively while largely fasting in winter, similar to other balaenopterids (Aguilar & García-Vernet 2018). In the northern hemisphere the preferred prey is normally krill, composed of euphausiid *Meganyctiphanes norvegica* although other species of planktonic crustaceans *(Thysanoessa inermis, Calanus finmarchicus)* and schooling fish such as mackerel *(Scomber scombrus)*, capelin *(Mallotus villosus)*, herring *(Clupea harengus)*, and blue whiting *(Micromesistius poutassou)* are often consumed (Aguilar & García-Vernet 2018, Sigurjónsson & Víkingsson 1997). As many as 96% of fin whales catches in Icelandic waters only contained krill in their stomach, 2.5% contained a mixture of krill and fish, and 1.6% fish only, which is partially agreeing with available quantitative evidence suggesting that fin whales are generalist feeders (Sigurjónsson & Víkingsson 1997).

Fin whales are characterized by their asymmetrical coloration on their head, with a dark slate coloration on the left mandible and a white right mandible. The right mandible also has something called a blaze posterior of the eye, which is a light grey discoloration. In the dorsal area behind the head of the whale, a light V-shaped pigmentation called chevron is present (Agler et al. 1990). The dorsal fin is falcate and located at 75% of the total length of the whale (fig. 1), which is further anterior than where the fin of the blue whale (*B. musculus*), is located but further posterior than that of sei whales *(B. borealis)* and Bryde´s whales *(B. edeni)* for example (Aguilar & García-Vernet 2018). Despite the massive size of the creature, there are many things we do not know about them (Shirihai & Jarret 2006 page 55, Whooley et al. 2010), such as migration patterns, the geographical and temporal locations of wintering, breeding and calving grounds, stock size and structure, individual seasonal range, partitioning, habitat use, and the reproductive histories of individuals (Agler et al. 1990).

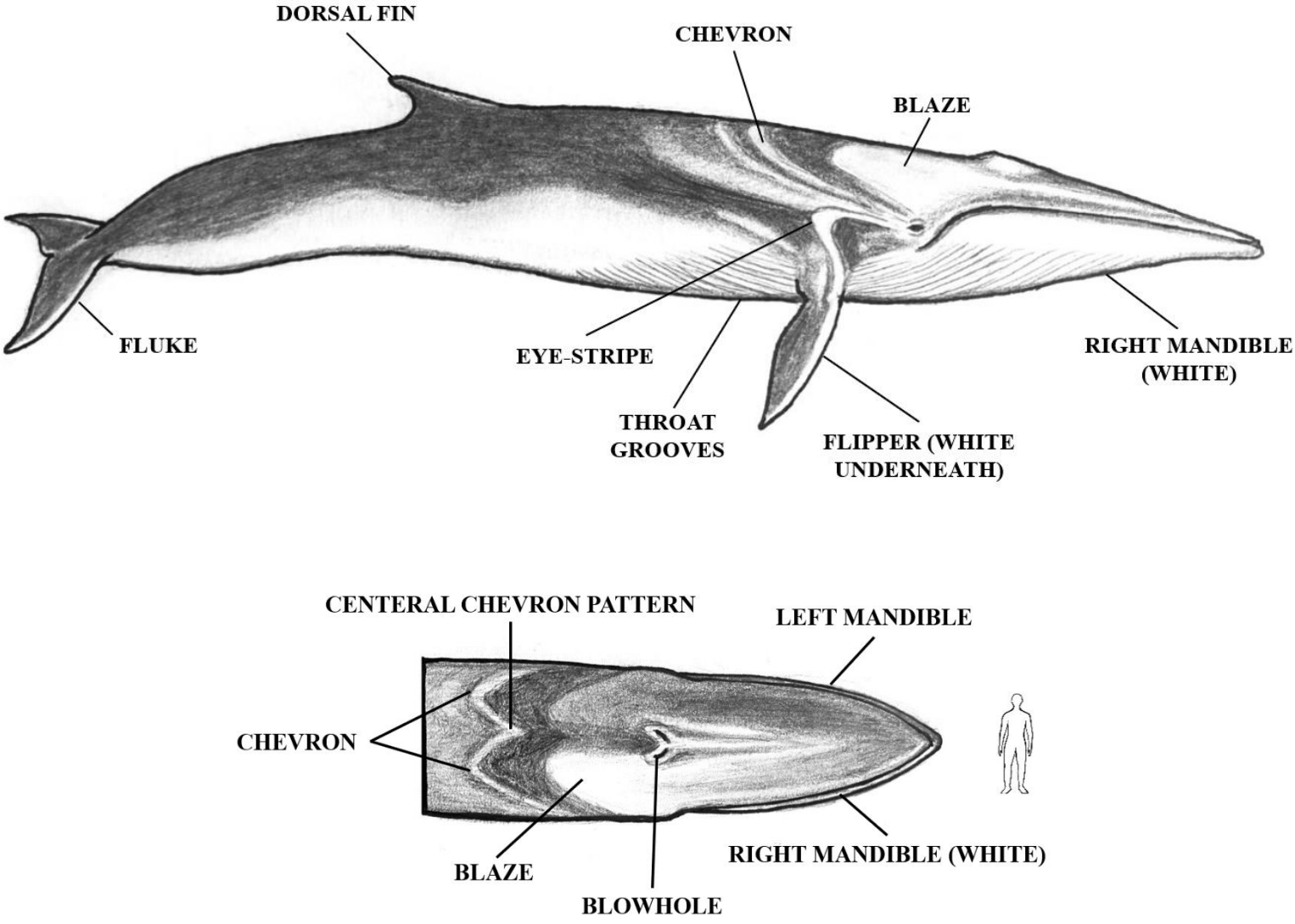


Figure 1. Fin whale illustration from the right side (top image) and the head from dorsal view (bottom image) next to a human silhouette to show size. Illustrated by the author.

Distribution and Populations

The fin whale can be found in deep offshore waters at temperate latitudes and the populations are divided between the north Atlantic, north Pacific and the southern hemisphere (Shirihai & Jarret 2006 page 55). The sum of all fin whales was estimated to between 50 000 - 90 000 animals in 2018 (IUCN 2022). In the north Atlantic they are red listed as vulnerable (VU) (IUCN 2022, WWF 2023), and not much is known about the status of whales in other waters (WWF 2023). They commonly occur from Iceland and Norway down south to the Iberian Peninsula in the Atlantic, and from Baffin Bay located west of Greenland down south to Gulf of Mexico and Florida the west Atlantic (Reid et al. 2003). Populations of fin whales present in the Mediterranean Sea, which is connected to the Atlantic in the west (Atlantic Ocean map 2023), share some heterogeneity in the mtDNA with the parts of the north Atlantic populations suggesting that populations between the different seas were recently diverged and furthermore that some limited gene flow might occur between populations close to each other (Bérubé et al. 2003). Still, the Mediterranean population shows some degree of genetic isolation from the north Atlantic population (Bérubé et al. 2003, Shirihai & Jarret 2006 page 54).

Migration

Fin whales engage in seasonal migrations and their feeding is highly seasonal as well. The first to initiate migration are usually the pregnant females. Quick to follow are the resting females and the adult males. Last to follow are the juveniles and the lactating females (Aguilar & García-Vernet 2018). In the southern hemisphere they show a seasonal pattern of migration, from north to south, feeding in high latitudes in the summer and breeding and fasting in low latitudes in the winter. It has been suggested that fin whales in the northern hemisphere migrate similarly in a latitudinal movement but in many areas the pattern is not completely clear/apparent. In the north Atlantic, no definite wintering grounds are known. However, several summer grounds in medium to high latitudes have been identified, some of them found in Icelandic waters (Aguilar & García-Vernet 2018). This could be due to shorter latitudinal migrations caused by the influence of the Gulf stream, making higher latitudes fit for stay during winter. Another possible explanation could be that individuals who concentrate near the coast often disperse into open waters after the feeding season ends and are therefore more difficult to follow and detect in the winter (Aguilar & García-Vernet 2018). In addition, the swimming speed of the whales can be a contributing factor to the lack of knowledge present today regarding fin whale migration routes and migratory movements (Shirihai & Jarret 2006 page 55, Whooley et al. 2010).

Photo-identification (Photo-ID)

In studies of migration and even life-history of many large whales, photo-identification has proven a very powerful tool (Agler et al. 1990) and is, for example, widely used for identifying humpback whales (*Megaptera novaeangliae*) (Cheeseman et al. 2022). Unfortunately, photo-identification can be tricky and is not as established and common when it comes to fin whales which is why it is still being done manually and not through a computer algorithm, which is often the case with humpback whales. Computer assisted fin whale dorsal fin recognition is currently under development (Húsavík Research Centre, pers. comm.). Photographs of the shape of the dorsal fin, scar patterns, pigmentation, and possible marks such as the chevron- and blaze patterns are used to identify individuals (Agler et al. 1990, Aguilar & García-Vernet

2018). However, you must be very lucky to spot a fin whale, and if you catch one in a photo, you are even luckier. This is due to various reasons, such as their general offshore distribution and the speed of these fast-moving whales, making them difficult to approach (Whooley et al. 2010). Despite this, successful attempts of photo-identification have been made. For example, off the south coast of Ireland where they managed to successfully photograph and categorize their whales for their catalogue using digital cameras from boats and the classification template presented by Agler et al. 1990 (Whooley et al. 2010). In addition to photo-identification using digital cameras from boats, it has also been done differently using drones for many cetaceans (Durban et al. 2015, Degollada et al. 2023, Hartman et al. 2020) but similar studies for fin whales are lacking. This is relatively new method (Degollada et al. 2023) and was not used in this study.

Fin whales in Iceland and Skjálfandi Bay

In Icelandic and adjacent waters, fin whales are one of the largest food consumers after minke whales and are often sighted from May to August (Sigurjónsson et al. 1990). The spring and summer months bring an increase in phytoplankton, increasing abundance of crustacea (e.g., krill) and fish, resulting in a buffet for the baleen whales (Sigurjónsson et al. 1990). Skjálfandi Bay (fig.2) off Húsavík, the "whale-capital of Iceland", is located in the northeast of Iceland, and is a feeding ground for a lot of cetacean species like the fin whale. Normally fin whale sightings in Skjálfandi Bay are suggested to be most common in March by whale watching guides and workers at the Research Centre, although they have occurred in every season. Possibly this bay is a popular destination for fin whales during their annual migrations due to the bay´s sheltered and calm waters which provide a comfortable and safe environment for the fin whales, which have been spotted more commonly in areas of relatively low wind speed and high surface temperature, often associated with calmer seas (Hvidfeldt et al. 2012), as well as the increase of food in the spring (Sigurjónsson et al. 1990). Sightings of fin whales have occurred in Skjálfandi Bay since at least 2014. The first records show sigthings of a hybrid, half fin whale, and half blue whale, from 2014 and then sightings of fin whales from 2015 to present date. A photo- ID catalogue for fin whales in Skjálfandi Bay has been compiled by Marijn Goes, Charla Basran and Alessandra Vancore for the University of Iceland's Húsavík Research Centre (HCR). The catalogue will be referenced as the SB photo-ID catalogue in this report and includes the best photos of the dorsal fin from each side, possible marks, or the lack thereof and the sighting history of each individual.

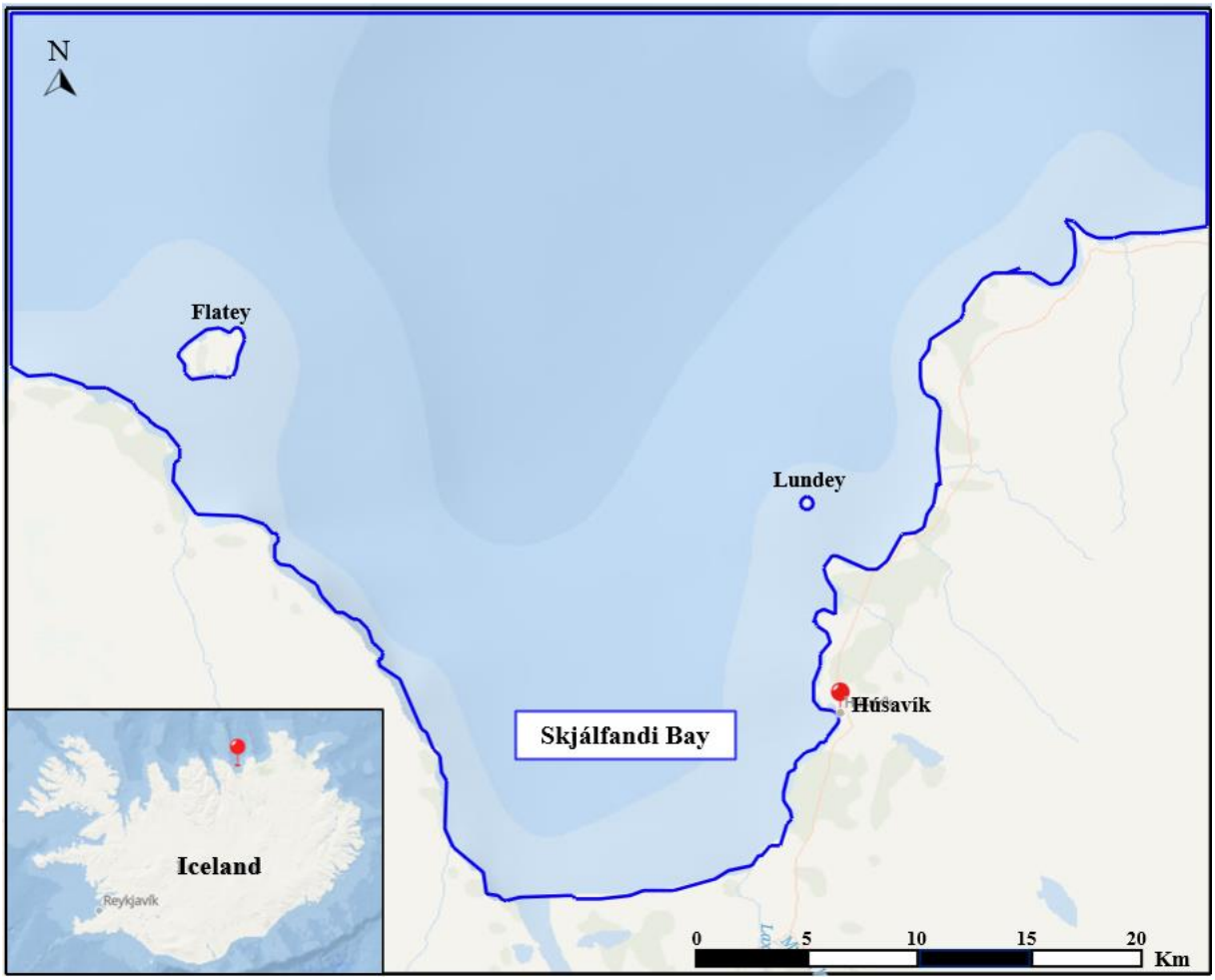


Figure 2. Map of Skjálfandi Bay, Húsavik. Húsavik city is marked with a red pin and two Islands in the bay are circled. Small map of Iceland in the left corner, Skjálfandi Bay is marked with a red pin. Created in ArcGIS online 2023.

Irish whale and dolphin group (IWDG) fin whale research

The Irish Whale and Dolphin Group (IWDG) was founded in 1990. The group were to be an all-Ireland sighting and stranding scheme as well as actively campaigning for the declaration of Irish waters as a whale and dolphin sanctuary. It is a registered charity with funding from a range of sources. In west Cork, fin whales were once the most commonly spotted baleen whale, but 10 years ago the numbers of fin whale visits flatlined and later even decreased (Irish Whale and Dolphin Group 2023). At the same time as fin whale visits declined, the humpback whales started coming in larger numbers, directing the attention to themselves. The photo-ID efforts from the IWDG were focused on the humpback whales until Pádraig Whooley, sightings officer at the IWDG, was asked why the fin whales did not have a photo-ID catalogue, just like the humpback whales. In that moment Whooley decided to make one (Irish Whale and Dolphin Group 2023). Today, this catalogue consists of 53 individual fin whales from all around Ireland and will be referenced as the IWDG photo-ID catalogue in this report. Whooley hopes that the catalogue will help unravel mysteries about the fin whales, such as the location of breeding grounds, that has for some reason eluded whale researchers for now (Irish Whale and Dolphin Group 2023).

Aim

The aim of this study was to investigate fin whale sightings in Skjálfandi Bay, northeast Iceland, to find out when fin whales normally visit Skjálfandi bay and why. Furthermore, the aim was to investigate potential fin whale migration between Skjálfandi Bay and in inshore waters off the Irish coast using photo-identification catalogues from Skjálfandi Bay and the IWDG, hopefully discovering matches, and therefore migration patterns within the north Atlantic Ocean. This could lead to further knowledge regarding fin whale migration routes and future population estimations as well as a more developed and established system for photo-identification of fin whales.

Materials and methods

Checking and updating the SB photo-ID catalogue

Data for the SB photo-ID catalogue and other projects were collected by the author and other interns at the University of Iceland´s HRC by joining whale watching tours, during March and April 2023. The University of Iceland has an agreement with the whale watching companies, North Sailing and Gentle Giants, which enables interns at HRC to join tours for free whenever there is space to conduct research. The SpotterPro app by Conserve.io on ipads was used to collect information on the boat about the time, conditions, sightings, behavior of any whales sighted and to track the route. As the boat left the port the data collection began by pressing "start trip" and when the boat arrived back, it ended by pressing "end trip". When whales were spotted, "start sighting" was pressed and a pin was dropped in the location of the sighting and behavior from a list within the app were chosen manually according to what the whale was doing. When the whale was left or lost, "end sighting" was pressed. Weather conditions such as Beaufort scale, glare, wind speed, wind direction, visibility and cloud cover were put into the app every 30 minutes. To collect photographs, digital cameras (Canon EOS 5D/Canon EOS 7D with a 100-400mm lens) were used. After every boat tour, the collected data was checked and uploaded to the cloud and the photos taken were examined by interns. For each tour, a folder was created on the 2023 hard drive and in that folder, photos were sorted into separate folders for individuals and species as well as best photos of each individual. If there were fin whale sightings, these photos were matched to previously seen whales in the SB photo-ID catalogue and if there was a match, sightings were added to the sighting history of that previously seen whale in the catalogue. If there were no matches and the photos were of good quality, these were cropped and added to the catalogue as new whales, given names and numbers and the fins were coded using a template (Appendix 1). To update the SB photo-ID catalogue, the hard drives from previous years were searched in addition to the new data collection. Missed photos of fin whales, fit for identification were to be put into the catalogue. The hard drives were also checked to see if the best photos of each individual were in the catalogue already. The fins of each individual in the catalogue were also checked to see if they were coded correctly according to the previously mentioned template (Appendix 1).

Investigating fin whale sightings in Skjálfandi Bay using R

Fin whale sightings per time spent searching for whales was calculated as Sightings Per Unit Effort (SPUE) with minutes as the unit, for the months of the whale watching season (March to

November) and the seasons (spring, summer, fall) for the years 2015 to 2022 from data provided by the University of Iceland´s HRC and compiled into an excel sheet. The excel sheet was converted into a csv file (comma-separated values, saves data in a table structured format) and imported into R version 4.3.0 (R Core Team 2023) where a Kruskal-Wallis test was performed to investigate if SPUE differed between months, seasons, and years. This was done to understand when the fin whale normally visits Skjálfandi Bay and if it has changed over the years. The years were tested again, 3 times, grouped into three periods (First test: period 1 = 2015, 2016, period 2 = 2017, 2018, 2019, period 3 = 2020, 2021, 2022. Second test: period 1 = 2015, 2016, 2017, period 2 = 2018, 2019, period 3 = 2020, 2021, 2022. Third test: period 1 = 2015, 2016, 2017, period 2 = 2018, 2019, 2020, period 3 = 2021, 2022.). If the Kruskal Wallis test showed significance, a Dunn test was performed to find out which months, seasons, years, or periods were different from each other.

Comparing the IWDG and the SB photo- ID catalogues

The IWDG photo-ID catalogue currently consisting of 53 fin whales and the SB photo-ID catalogue currently consisting of 27 fin whales were compared to each other. For each individual in the IWDG catalogue, a match was searched for in the SB catalogue visually using the photos of the dorsal fin from the left side as well as any photos of clear marks on individuals. If photos of the dorsal fin from the left side were not available, matches were searched for using photos of the dorsal fin from the right side when the fin was distinctive enough. However, matches were only made if photos of the dorsal fin from the same side were available for both individuals i.e., left side with left side *or* right side with right side.

Results

Updated SB photo-ID catalogue

The catalogue was updated with better and missed photos of whales from the hard drives. Due to low quality photos unfit for identification, 4 of the whales were removed completely from the catalogue (Appendix 2). Since the intern period that transpired between March and April, 4 new whales were added to the catalogue. One of them (Halma) had only photos of questionable quality but was decided to be included in the catalogue for now. The updated photo-ID catalogue consists of 27 individual fin whales and 1 hybrid. Identified new sights and resights from 2015 to 2022 are shown in fig.1. Whales added in 2023 are not in the bar chart, since the season is not complete yet, nor the hybrid due to the possibility of different behavior and migration patterns than that of the fin whale, and the hybrid´s extremely distinctive dorsal fin, making it easy to identify in photographs. Identified sightings have been 42 from 2015 to 2023, excluding the hybrid. With the hybrid sightings included, from 2014, it adds up to 55 during these 10 years. In the year 2021, 10 new whales were added to the catalogue and three previously seen whales were resighted (fig. 3).

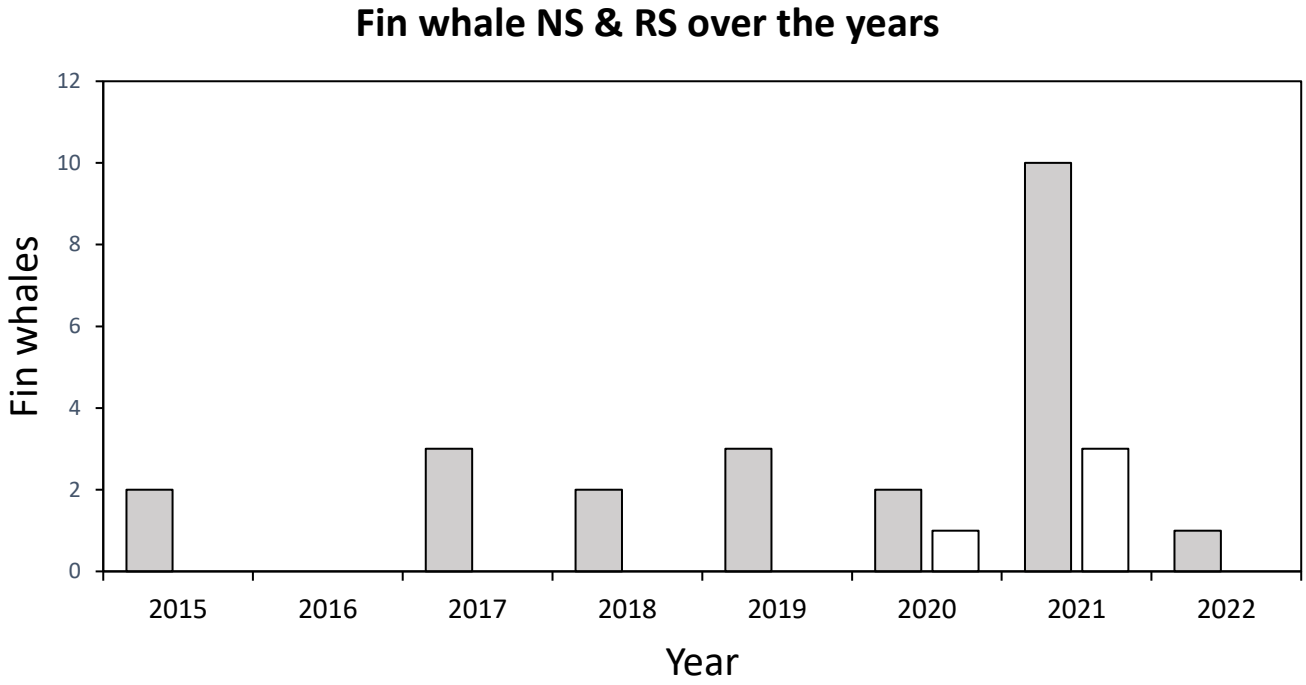


Figure 3. Bar chart of the number of photo-identified fin whales from each year since the data collection started, 2015 – 2022. Number of identified whales are shown on the y-axis, the grey bars represent new sights (NS), the white bars represent resights (RS) and the years are shown in chronological order on the x-axis.

Fin whale visits in Skjálfandi Bay

The total number of fin whales seen in Skjálfandi bay from the years 2015 – 2022 was 88. SPUE differed between months (Kruskal-Wallis test, H = 28.097, P = 0.0004562). The Dunn test showed that SPUE was significantly higher in March than in May, July, August, and November but not than the rest of the months (table. 1 & fig. 4). None of the other months showed a significant difference between each other (table. 1 & fig. 4). SPUE differed between seasons (H = 6.6938, P = 0.03519). The Dunn test showed that SPUE was significantly higher during spring than during summer but not during fall (table. 2). SPUE did not differ significantly between summer and fall (table. 2). SPUE did not differ significantly between years (P > 0.05) or between periods (P > 0.05).

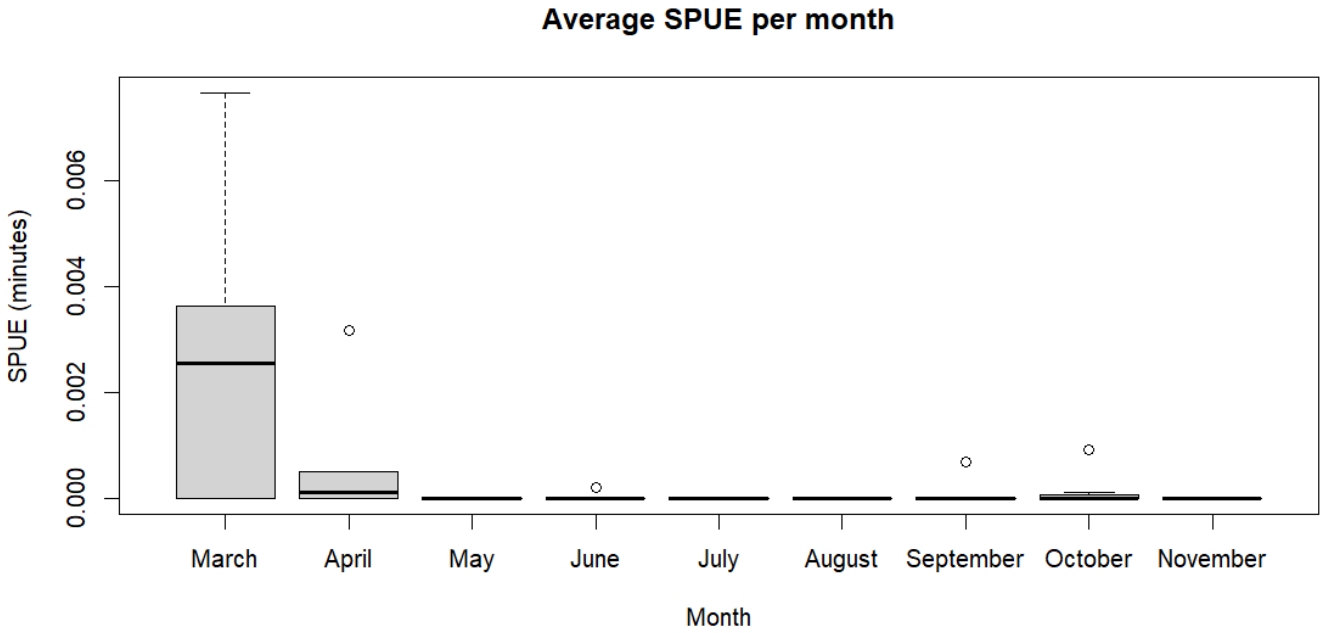


Figure 4. Boxplot of average Sightings Per Unit Effort (SPUE, unites U = minutes) on the y-axis, for months (March – November) on the x-axis. Data from 2014 – 2022. Boxes represent standard deviation and dots represent single extreme values.

Month	SPUE
March**	0.0027263
April	0.0005463
May*	0
June	0.0000252
July*	0
August*	0
September	0.0000856
October	0.0001300
November*	0

Table 1. Average Sightings Per Unit Effort (SPUE, unites U = minutes) for each month from 2015-2022. The month with the highest average SPUE is marked with ** and months with significantly lower SPUE than March are marked with *.

Season	SPUE
Spring**	0.0006038
Summer*	0.0000068
Fall	0.0001416

Table 2. Average Sightings Per Unit Effort (SPUE, unites U = minutes) for each season from 2015-2022. The season with the highest average SPUE is marked with ** and the season which had significantly lower SPUE than spring is marked with *.

Matches

One possible match was found between the IWDG photo-ID catalogue and the SB photo-ID catalogue. The fin whale Layla, from SB is shown in the top photo in both fig. 5 and fig. 6, and the fin whale 005, from the IWDG is shown in the bottom photo of fig. 5 and fig. 6. This is a possible match due to the similar shape and size of dorsal fin and notch. The dorsal fin for both Layla and 005 are characterized as 4 with a distinctive score of 1 (Appendix 1). The match is not confirmed as shape of Layla's fin seems to be slightly more curved and pointed at the end. No other matches were found, meaning that of the 53 identified whales from the IWDG, 52 have not been seen and identified in Skjálfandi Bay.

Figure 5. Two pictures of the dorsal fin from the left side that match. The top one is of Layla from SB and the bottom one is 005 from the IWDG.

Figure 6. Two pictures of the dorsal fin from the left side that match. The top one is of Layla from SB and the bottom one is 005 from the IWDG.

Discussion

Fin whales visits in Skjálfandi Bay

The statistical tests showed a higher SPUE for the month of March than for May, July, August, and November but not the other months. This means that more fin whales were spotted in relation to time spent searching for them in March than half of the other months investigated. However, an argument could be made that more fin whales were seen in March compared to

time searching for them than any other month except for maybe April, which is a close runner up (fig. 4) since even if the statistical test showed no difference between SPUE for March and the other half of the months and between SPUE for April and any other month, both March and April stood out in the boxplot (fig. 4). No fin whales have ever been spotted in May, July, August, and November and SPUE was very low for June, September, and October (fig. 4). Because there are very few fin whale sightings in Skjálfandi Bay, only 88 since 2015, to begin with the sample sizes were small and therefore the statistical test was probably not able to detect all the differences accurately.

In addition, the data used for the calculations might not reflect reality accurately. Many things that might have affected the results were observed during the internship in HRC. For example, March and April are very tricky months when it comes to whale watching and whale research due to the unstable weather and therefore bad conditions and high waves that often occur. This causes boats to not to go out during several days of the two months and poor visibility makes it almost impossible to spot any whales the days where boats do go out. During these bad conditions, it can be especially difficult to spot fin whales because as previously mentioned they move very fast and can be diving long distances under water, making good visibility crucial for spotting big blows, locating the fin whales, and following them. Even the high waves and visibility in combination with the freezing cold can cause the photo-collection in case of sighting, unsuccessful in regard of identification. Using SPUE is a way to make up for having, for example, more good weather days to search for whales in the summer than in the spring. Still, this does not account for the amount of bad weather days trips are made in March and April. On days with bad weather, spotting whales will be less likely and therefore the trip effort should be removed from these days, but this could cause trip effort, during which whales were spotted, to be removed as whales are sometimes spotted despite bad conditions. Imagine there are 20 fin whales in the bay in March, but due to bad conditions, 15 of these will be missed. In September on the other hand, there might be only 4 fin whales in the bay, but none are missed. Even if trip effort, minutes spent searching for whales that is, might be higher in September, SPUE will not differ as much between the months as it should, if conditions were as good when the boat went out in March as it was in September. The statistical test also showed that more whales were seen compared to the time searching for them in spring than summer but there was no significant difference for this between spring and fall nor summer and fall meaning that the only thing that could be said with certainty is that fin whales are more likely to be spotted during spring than during summer in Skjálfandi Bay. Here the same explanation for why SPUE for spring and fall did not differ significantly from each other could be applied as for the months. Why the fin whales come to Skjálfandi Bay mostly during early and mid-spring to feed is probably because fish such as the capelin spawns in winter/early spring, and migrates to Skjálfandi Bay, among other places, during spring to feed themselves (Olafsdottir & Rose 2012). During spring there is an increase of phytoplankton and therefore planktonic crustaceans and schooling fish, which are the preferred prey of fin whales, in coastal waters in the north like Skjálfandi Bay (Olafsdottir & Rose 2012, Sigurjónsson et al. 1990, Aguilar & García-Vernet 2018, Sigurjónsson & Víkingsson 1997). This means that Skjálfandi Bay make an excellent feeding ground for fin whales during March and April.

For SPUE between the years and periods, the statistical test showed no difference, which means that the number of fin whale visits in Skjálfandi Bay have not changed noticeably over the years which is a very positive result. According to this, the fin whales will continue to come to Skjálfandi Bay to feed in the future. Although, another interesting discovery is that the year after the outbreak of covid-19, 2021, 10 new fin whales were added to the SB photo-ID catalogue and three previously seen whales were resighted which have been the most new whales and resights in a year so far (fig. 3). One possible explanation could be that they were lucky this year with the conditions and were very successful with photographing the whales. Another explanation could be that there was in fact more fin whale visits in the bay this year than the other years even if the statistical test did not show this meaning that the visits might have changed only slightly and not dramatically. Still, this suggests that fin whale visits might be affected by boats and the decrease of boat activity that came with the pandemic caused more whales to come into the bay. This is further confirmed by the fact that the numbers of new sights and resights went down again the following year. To understand this, the numbers of sightings would have to be investigated further as well as the boat activity for the years 2019, 2020, 2021 and 2022.

Possible migration patterns

Since there was only one possible match between the photo-ID catalogue, it is both possible that there is migration between Skjálfandi Bay and Ireland as well as that there is not. One possible match is not enough to prove a migration pattern. However, it is enough to encourage further investigation of the subject. To understand how whales migrate, the photo-ID method has proven very successful before (Agler et al. 1990). Matches of humpback whales have previously been found between Iceland and Ireland, using photo-identification, proving migration for this species between Icelandic and Irish waters (Irish Whale and Dolphin Group 2023). This means that migration between Iceland and Ireland is possible and even probable for other baleen whales too, such as the fin whale. The identification system for humpback whales is however different and these whales are more abundant than fin whales in both Irish and Icelandic waters (Irish Whale and Dolphin Group 2023, Cheeseman et al. 2022, Darling et al. 2022) which might make them easier to research than fin whales, which are especially tricky to find, photograph and identify (Whooley et al. 2010). The most likely scenario is that the fin whales identified in each location do not migrate between the locations and that the possible match of Layla and 005 is that of two different individuals with a strong resemblance to each other. Still, it could be argued that some whales migrate between these locations and that the match of Layla and 005 could be accurate, meaning that they are in fact the same whale. To begin with, the dorsal fin of Layla and 005 were both categorized as a 4 with a distinctive score of 1 (Appendix 1). Furthermore, there is some glare, sunlight reflecting onto the dorsal fin, present on the photograph of 005 (fig. 5, fig. 6), which can throw of the naked eye while examining. With this knowledge it is possible to look beyond the glare, and therefore see that the dorsal fin from the left side of both Layla and 005 have the same angle and shape of the leading and trailing edge as well as a similar notch in the trailing edge in the same size and position (fig. 5, fig. 6). The slight observed difference could be explained by the different angles the photographs of Layla and 005 were taken.

The photo-ID method

Identification using digital cameras proved to be very difficult when it comes to fin whales in this study which is probably why the system is not as established and common for this species yet. During data collection on boats in March and April, interns struggled to get photographs of the dorsal fin that were focused and good enough to add to the catalogue. As previously mentioned, weather conditions can be a big factor in collecting data for photo-identification. This is a huge challenge when it comes to researching fin whales in Skjálfandi Bay, since they are already tricky with good conditions (Whooley et al. 2010). If the waves are too high, the researcher holding the camera will rock violently from side to side with the boat and the camera will not be steady enough to capture good photos of the whale. Visibility, cloud cover and precipitation will also cause the photographs to be of poor quality. Even how skilled the researcher is with a camera will be of importance, and since most researchers collecting data for the catalogues in Skjálfandi Bay are interns, no previous experience with digital cameras or photographing are required. As the hard drives were searched while checking and updating the SB photo-ID catalogue, the majority of the photos from previous years were not focused or good enough for identification as well, which suggests that interns using digital cameras on commercial whale watching boats might not be the best approach for identifying fin whales in Skjálfandi Bay. It is however, a very successful method for identifying other whales with a different behavior and photo-identification system such as the humpback whale (Cheeseman et al. 2022, Darling et al. 2022).

Even though the method might be flawed, conducting research for free on board of commercial whale watching boats is very beneficial for both the whale watching companies and the research centers. The companies get to use the fact that they have researchers aboard while selling tours and researchers offer help with things on the boat as well as answer questions from the tourists about the whales. This makes the whale watching more educational which can be really good for conservation and could help mitigate threats such as endangerment and whaling. In addition, researchers, tourists and guides all work together to spot whales which is very beneficial for all parts involved. Digital cameras are easy to bring on a boat full of tourists where researchers are required to be mindful and take little space. They are also very efficient when it comes to this type of data collection as several whales might appear in different locations at the same time or they might only appear for a short time. In these situations, the subject can quickly be changed to photograph all the animals and with several cameras, this is even easier. On the other hand, another difficult task using digital cameras and photographing the sides of the fin whales for identification is that the dorsal fins often are very similar to each other. At the same time, the same dorsal fin can look completely different from different angles that might make us miss a lot of resights as well as matches between fin whales spotted in different locations. This means that the whales that possess dorsal fins with strange shape or size, distinctive marks, or distinctive notches, are the ones that are most easily identified (Appendix 1), which is further supported by the fact that most whales in the SB photo-ID catalogue and the IWDG photo-ID catalogue have very distinctive dorsal fins. The difficulty with similar fins and different angles could cause the ones that do not stand out to be seen once and not recognized as the same whale again. In addition to this, distinctive marks are not always seen due to the lack of light, causing the whale to appear dark and mono-colored. If the match found between Skjálfandi Bay and

Ireland are in fact accurate, this method has proven to work to some extent, meaning that even though the method is lacking in the collection department it is successful in comparing the whales that are put into the catalogue. Although, the possible match is just that, a possible one, and the method therefore still not as good as it could be.

An alternative to using photographs of dorsal fins for identification could be the rather new method of using photographs from dorsal view, showing the chevron patterns, blaze patterns, and marks on the individuals (Dellogada et al. 2023). These photographs would have to be taken from above using some type of aircraft such as drones. This method has recently shown a higher success rate of identification (almost 80%) than photo-identification using photographs of dorsal fins (usually around 65%). In addition, it has been suggested that central chevron patterns and blaze patterns do not alter over time, which dorsal fins do sometimes, and therefore identification from dorsal view is a more reliable way of identifying fin whales (Dellogada et al. 2023). But for this method, lack of light could be an even bigger problem as no patterns or marks would be visible and all whales would look the same from dorsal view, according to observations made in field, except for their size which is not used for identification as it is not constant nor unique to one individual. Data collection success would also most likely be affected by other weather conditions. The best way to go would be a combination of the two methods. This would result in a photo-ID catalogue with pictures from both dorsal view and from the sides of each individual, making identification easier and more accurate. Complications could however occur if photographing is not successful using one of the methods, i.e., no good photographs available from either dorsal view *or* from the sides. Another method for collecting data about individual fin whales could be tracking devices such as satellite tags (Jiménez López et al. 2019, Lydersen et al. 2020, Silva et al. 2013). This method seems far more intrusive than drones or data collection from boats as you have to insert the device that might be around 20 centimeters long and 2 centimeters thick, under the skin of the whale into the blubber. The tags would however show almost exactly where the whale goes and could therefore confirm possible migration patterns (Jiménez López et al. 2019, Lydersen et al. 2020). The question here would be, how much interference and interaction with the animals is justified in the name of science, and how would the whales be affected? To even begin to answer this, all photo-identification methods and alternatives need further investigation.

Conclusions

In conclusion, even though the fin whales visits in Skjálfandi Bay are not limited to one month or season according to the statistical tests, the boxplot and table of sightings per unit effort for the different months confirms that March and April are the months which fin whales mostly visit. In addition, the data used for the calculations might not reflect reality accurately due to factors such as weather conditions and small sample sizes. During the last decade, fin whale visits in Skjálfandi Bay have not changed noticeably between the years and so, fin whales will most likely continue to come here to feed.

Not enough fin whale matches were found, using photo-identification, between Skjálfandi bay and Ireland to confirm migration between the two locations. Further investigation is needed to understand fin whale migration patterns.

Furthermore, photo-identification, though the system has its faults, is the future of marine mammal research. A more established photo-identification system could include fin whale photo-ID catalogues with pictures from dorsal view *and* from the left and right side. However, the photo-identification methods need further investigating to improve even more and to find the best possible way to identify and photograph fin whales. This will lead to more reliable and certain discoveries about these mysterious creatures using photo-identification as well as a more successful and established identification system for fin whales, among others.

Acknowledgements

I want to thank my two supervisors, Göran Sahlén and Charla Jean Basran, for giving me their time, advice, and extensive guidance in conducting this study and writing this report.

I want to thank Charla Jean Basran additionally, and Hùsavik Research Centre, for giving me the opportunity to come to Húsavik and have the experience of a lifetime.

I also want to thank my examiner, Ulf Ottosson, for taking time to review and correct my report.

Last but not least, I want to thank Liese Messing, Anna Chiarini, Luana Millecamps, Laura Monterde and Maria Glarou for making my stay in Húsavik beyond amazing. I miss you all.

References

Agler, B., Beard, J., Bowman, R., Corbet, H., Frohock, S., Hawvermale, M., Katona, S., Sadove, S., Seipt, I. (1990) Fin Whale (Balaenoptera physalus) Photographic Identification: Methodology and Preliminary Results from the Western North Atlantic. Report - International Whaling Commission. Issue: 12. Pages: 349-356.

Aguilar, A., García-Vernet, R. (2018). Encyclopedia of Marine Mammals || Fin Whale. 3rd ed.; Würsig, B., Thewissen, J.G.M., Kovacs, K.M., Eds.; Academic Press: London, UK Pages: 368–371.

Atlantic Ocean Map Explore all seas of Atlantic Ocean. (Interactive picture) Mediterranean Sea Map Extracted: 2023-03-07.

Bérubé, M., Aguilar, A., Dendanto, D., Larsen, F., Notarbartolo di sciara, G., Sears, R., Sigurjónsson, J., Urban-R, J., Palsbøll, J. (2003) Population genetic structure of North Atlantic, Mediterranean Sea and Sea of Cortez fin whales, Balaenoptera physalus (Linnaeus 1758): analysis of mitochondrial and nuclear loci. Molecular Ecology. Issue: 7. Pages: 585–599.

Cheeseman, T., Southland, K., Park, J., Olio, M., Flynn, K., Calambokidis, J., Jones, L., Garrigue, C., Frisch Jordán, A., Howard, A., Reade, W., Neilson, J., Gabriele, C., Clapham, P. (2022) Advanced image recognition: a fully automated, high-accuracy photo-identification matching system for humpback whales. Mammalian Biology. Volume: 102. Pages: 915-929.

Darling, J., Audley, K., Cheeseman, T., Goodwin, B., Lyman, E., Urbán, R. (2022) Humpback whales *(Megaptera novaeangliae)* attend both Mexico and Hawaii breeding grounds in the same winter: mixing in the northeast Pacific. Biology Letters. Volume: 18. Issue: 2.

Degollada, E., Amigó, N., O´Callaghan, S., Varola, M., Ruggero, K., Tort, B. (2023) A Novel Technique for Photo-Identification of the Fin Whale, Balaenoptera physalus, as Determined by Drone Aerial Images. Drones, Special Issue: Advances of Drones in Wildlife Research. Volume: 7. Issue: 3.

Durban, J., Fearnbach, H., Barrett-Lennard, L., Perryman, W., Leroi, D. (2015) Photogrammetry of killer whales using a small hexacopter launched at sea. Unmanned Vehicles. Issue: 3. Pages: 131-135.

Goldbogen, J., Calambokidis, J., Shadwick, R., Oleson, R., McDonald, M., Hildebrand, J. (2006) Kinematics of foraging dives and lunge-feeding in fin whales. The Journal of Experimental Biology. Issue: 209. Pages: 1231-1244.

Hartman, K., van der Harst, P., Vilela, R. (2020) Continuous Focal Group Follows Operated by a Drone Enable Analysis of the Relation Between Sociality and Position in a Group of Male Risso's Dolphins (Grampus griseus). Frontiers in Marine Science. Volume: 7.

Hvidtfeldt, C. B., Desportes, G., Bech, N. I., & Nabe-Nielsen, J. (2012). Spatial and temporal patterns in fin whale (Balaenoptera physalus) habitat use in the Davis Strait. Journal of Cetacean Research and Management Issue: 12. Pages: 305-314.

IUCN (2022) Balaenoptera physalus Extracted: 2023-04-05.

Jiménez López M., Palacios D., Jaramillo Legorreta, A., Urbán, R., Mate, B. (2019) Fin whale movements in the Gulf of California, Mexico, from satellite telemetry. PLOS ONE. Volume: 14. Issue:1

Lydersen, C., Vacquié-Garcia, J, Heide-Jørgensen, M. P., Øien, N., Guinet, C., Kovacs, K. (2020) Autumn movements of fin whales (Balaenoptera physalus) from Svalbard, Norway, revealed by satellite tracking. Scientific Reports. Volume: 10. Issue: 1

Olafsdottis, A., Rose, G. (2012) Influences of temperature, bathymetry and fronts on spawning migration routes of Icelandic capelin (*Mallotus villosus*). Fisheries Oceanography. Volume: 21. Issue: 2-3. Pages: 182-198.

R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/.

Reid, J., Evans. P., Northridge, S. (2003) Atlas of cetacean distribution in north-west European waters. Peterborough: Joint Nature Conservation Committee. Page: 20.

Sigurjónsson, J., & Gunnlaugsson, T. (1990). Summer distribution and abundance of cetaceans in Icelandic and adjacent waters based on surveys conducted in 1986 and 1987. Report - International Whaling Commission. Issue: 40. Pages: 305-332.

Sigurjónsson, J., Víkingsson, G. (1997) Seasonal Abundance of and Estimated Food Consumption by Cetaceans in Icelandic and Adjacent Waters. Journal of Northwest Atlantic Fishery Science. Volume: 22. Pages: 271-287.

Shirihai, H. & Jarret, B. (2006) Whales, dolphins, and seals. A field guide to the marine mammals of the world. Pages: 52-55. Pages(tot): 384.

Silva, M., Prieto, R., Jonsen, I., Baumgartner, M., Santos, R. (2013) North Atlantic blue and fin whales suspend their spring migration to forage in middle latitudes: building up energy reserves for the journey? PLOS ONE. Volume: 8. Issue: 10

Víkingsson, G., Sigusjónsson, J., Gunnlaugsson, TH. (1988) On the relationship between weight. length and girth dimensions in fin and sei whales caught off Iceland. Report - International Whaling Commission. Issue: 38: 323-326.

Watkins, W., Daher, M., Reppucci, G., George, J., Martin, D., DiMarzio, N., and Gannon, D. (2000) Seasonality and distribution of whale calls in the North Pacific. Oceanography. Issue: 13. Pages: 62–67.

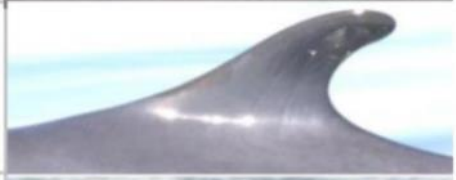
Whooley, P., Berrow, S., Barnes, C. (2010) Photo-identification of fin whales *(Balaenoptera physalus L.)* off the south coast of Ireland. Marine Biodiversity Records, page 1 of 7. Marine Biological Association of the United Kingdom. Volume: 4. E:8. Page: 1-7.

WWF (2023) Fin Whale | Species | WWF Extracted: 2021-04-05.

Würsig, B., & Whitehead, H. (2009). Aerial behavior. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), Encyclopedia of marine mammals. Academic Press. 2nd Edition. Pages: 5-11.

Appendix 1

Appendix 1 depicts a template used for coding the dorsal fin of the fin whale. Example pictures are shown to the right, description to the middle and the number of the fin category to the left.

FinCat	Description	Example
1	Disfigured, significant portions of the fin missing, or fin obviously bent or distorted	
2	One or more notches in both the leading AND trailing edges	
3	One or more notches in the leading edge only	
4	One or more notches in the trailing edge only	
5	Fin distinctly triangular in shape, with minimal concavity in trailing edge. Insertion of trailing edge at or posterior to fin tip.	
6	Fin tip distinctly broad and rounded in shape	
7	Fin tip distinctly narrow and pointed in shape	
8	Ambiguous fin shape, can't be easily classified	

Distinctiveness scores (Dist. Left/Right):

Distinctiveness scores to reflect the number of scars and/or marks on the body or fin of the fin whale:

1. No obvious scars or marks
2. Few obvious scars or marks
3. Many obvious scars or marks

Score the distinctiveness on both the left- and right sight of the dorsal, if photos are available

Please note that:

Only left-side dorsals are used for identifying and matching the fin whales, unless the right sight dorsal has some really distinctiveness scars that could be seen from both sides.

Appendix 2

The 4 individuals that were removed from the catalogue due to bad quality photos unfit for identification. No resights in Skjálfandi Bay or matches to whales seen in other areas could be identified or made using these photos.

Fin whale ID code: Bp10 Fin whale ID name: Demeter	Species code : Bp Fin Cat.: 5 Dist. Left: 2 Dist. Right:	Fin whale ID code: Bp09 Fin whale ID name: Arsinoe	Species code : Bp Fin Cat.: 4 Dist. Left: 2 Dist. Right:	Fin whale ID code: Fin whale ID name: Nemo	Species code : Bp Fin Cat.: 6 Dist. Left: 1 Dist. Right: 1	Fin whale ID code: Fin whale ID name: Nalu	Species code : Bp Fin Cat.: 6 Dist. Left: 1 Dist. Right: