Whale2Sea & Norwegian Orca Survey

Photo-identification and seasonal occurrence of long-finned pilot whales (*Globicephala melas*) off Vesterålen, northern Norway.

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1. Executive summary

Long-finned pilot whales are members of the Delphinidae family, that can be found throughout the North Atlantic, yet it is an understudied species. This thesis used data collected between 2008 and 2023, to investigating the feasibility of using photo-identification to study long-finned pilot whales (*Globicephala melas*) in the Vesterålen archipelago in northern Norway, as well as checking if they have a seasonal occurrence and site fidelity.

The study used a dataset of 16,494 photographs collected during 37 encounters from research and whale-watching platforms. The photo-identification process involved assessing the quality and angle of dorsal fin images, selecting suitable photographs, cropping them, and cataloguing them for individual identification. Permanent markings such as notches, saddle patches, protrusions, and scars were analysed to differentiate individuals.

The results revealed significant insights into the reliability of photo-identification for long-term study of long-finned pilot whales found in the study area. A total of 178 individuals were identified in the permanent catalogue, with an additional 163 individuals in the temporary catalogue. The mark rate, measuring the proportion of identifiable individuals among encounters, averaged at 62.4%. This mark rate was found to be consistent with other pilot whale studies, although caution is advised when interpreting the results due to variations in mark rate calculation methods and potential biases in comparisons.

The study identified a year-round presence with seasonal patterns of occurrence, with higher encounter counts observed in June and July, nonetheless this might be associated with the higher effort during the summer months. Daily and monthly re-sighting patterns highlighted the regularity of pilot whale presence in the study area. Notch markings were the most abundant and consistent mark type, followed by saddle patches, piece protruding, and scars. These distinctive markings played a crucial role in individual identification and were valuable for long-term monitoring purposes.

The research demonstrated the feasibility of photo-identification as a method for studying long-finned pilot whales in this area. It provided valuable insights into their seasonal occurrence, and potential site fidelity. The findings emphasized the importance of considering photo quality, angle, and distinctive markings in the identification process.

While acknowledging the limitations of opportunistic data collection from whale-watching platforms, the study highlighted the valuable information it can provide.

Overall, the findings demonstrate the effectiveness of photo-identification as a monitoring tool and highlight the need for standardized mark rate assessment methods and accurate estimation of group size to enhance the reliability of future studies.

2. Abstract

Long-finned pilot whales are an understudied species of the Delphinidae family, that can be found throughout the North Atlantic. This thesis used data collected between 2008 and 2023, to investigating the feasibility of using photo-identification to study long-finned pilot whales (*Globicephala melas*) in the Vesterålen archipelago in northern Norway, as well as checking if they have a seasonal occurrence and site fidelity. A total of 16,494 images were captured during 37 encounters, resulting in the identification of 178 individuals in the permanent catalogue and 163 individuals in the temporary catalogue. Daily and monthly re-sighting patterns were observed, highlighting their regular occurrence in the study area. The mark rate, which measures the proportion of identifiable individuals among encounters, averaged at 62.4%. Comparison with other studies revealed similar mark rates among different pilot whale groups. However, caution is advised in interpreting the results due to variations in mark rate calculation methods and potential biases in comparisons. Notch markings were the most abundant and consistent mark type, followed by saddle patch, piece protruding, and white scar. Seasonal occurrence analysis showed higher encounter counts in June and July. Overall, the findings demonstrate the usefulness of photo-identification for long-term monitoring of the long-finned pilot whales in Vesterålen and highlight the need for standardized mark rate assessment methods and accurate estimation of group size.

3. Introduction

3.1 Pilot whales

Pilot whales are members of the Delphinidae family, specifically the subfamily Globicephalinae. They are the second largest members of the dolphin family, second only to killer whales. There are two recognized species of pilot whales: the long-finned pilot whale (*Globicephala melas*; Traill, 1809) and the short-finned pilot whale (*Globicephala macrorhynchus*; Gray, 1846) (Olson, 2009). The long-finned pilot whale is further divided into two subspecies: *Globicephala melas melas*, found in the North Atlantic, and *Globicephala melas edwardii*, found in the Southern Hemisphere. These two subspecies have distinct anti-tropical distributions and can be found in sub-tropical, temperate, and sub-Antarctic waters (Davies, 1960), yet they are most commonly found in the North Atlantic and North Pacific (Olson, 2009). Pilot whales can travel in groups of up to several hundred individuals and often form pairs or small pods that travel together. These animals are known for their distinctive bulbous melon-shaped head and black coloration, and they can reach lengths of up to seven meters and weigh up to 3,600 kg (IWC, 2023).

According to the North Atlantic Marine Mammal Commission (NAMMCO), long-finned pilot whales can be found throughout the North Atlantic in a variety of habitats, from coastal to open water, and are most frequently observed in the North-Eastern Atlantic, which includes the areas near Iceland, the Faroe Islands, Norway, Greenland, and Newfoundland. However, their distribution can vary depending on the season and the availability of prey (Pike et al., 2019; Selbmann et al., 2022). The population of the North Atlantic is now estimated at 778,000 individuals (NAMMCO, 2021). In Norway, distribution data on pilot whales have been collected through various sources, including historical whaling records, incidental sightings, and dedicated sighting surveys. The Institute of Marine Research in Bergen has been compiling these data since 1967. Nonetheless, more information is required to properly study its distribution in this area (Abend & Smith, 1999).

The main food source for long-finned pilot whales is squid, although they also eat various fish species like cod, herring, and mackerel. Prey species consumed may vary depending on location and the time of year (NAMMCO, 2021).

Pilot whales are a social and vocally active species, they communicate through a complex system of clicks, whistles, and pulsed calls (Vester, 2017). They have also been known to use these vocalizations to coordinate group activities such as foraging, traveling, and mating (Olson, 2009).

Vester et al. (2017), discusses the vocal repertoire and social structure of long-finned pilot whales in Northern Norway. They describe the matrilineal groups of long-finned pilot whales as long-lasting social units consisting of closely related individuals who are all descended from a common female ancestor. These groups are typically composed of several adult females, their offspring, and sometimes a few adult males. Such matrilineal structure in pilot whales (for both short- and long-finned species), has been previously observed in other regions such as Nova Scotia (Augusto et al. 2017), in Madeira (Alves et al. 2013) and in the Strait of Gibraltar (De Stephanis et al. 2008).

Some cetacean species such as the killer whale acquire permanent, highly distinctive natural scars throughout their lives, allowing for individual recognition from high resolution photographs. However, pilot whales are more challenging to photo-identify as the number of permanently marked individuals appears low (Auger-Méthé & Whitehead, 2007). This likely explains why few long-term photo-identification studies have been conducted on this species to date. This study analysed photo-identification images of pilot whales collected from whale watching and research platforms in Arctic Norway in order to investigate patterns of site fidelity and associations between individuals.

3.2 Photo identification

Photo-identification is a well-established method in cetacean research (Hammond et al., 1990). This technique is based on photographs taken of permanent markings such as nicks, scars, and pigmentation patterns. Temporary markings (such as scars which might heal) can be used within or between encounters on a shorter time scale (Hammond et al., 1990; MacLeod, 1998). Long-term photo-identification studies address research questions related to individuals' movement patterns, social structure, reproductive parameters, survival rates and population size. In pilot whales, photo-identification proved useful giving different outcomes, such as habitat use, abundance estimates or social structure (McComb-Turbitt et al., 2021; De Stephanis et al., 2008; Ottensmeyer and Whitehead, 2003; Auger-Méthé & Whitehead, 2007; Selbmann et al., 2022; Pike et al., 2019).

However, the technique has some limitations; for example, number of identifiable individuals in whale populations varies, making it possible to identify just part of its members, as is the case with the Cuvier's beaked whale (Rosso et al., 2011). In a photo-identification project conducted on long-finned pilot whales off eastern coast of Canada, only 33% of the population was estimated to be identifiable (Auger-Méthé & Whitehead, 2007). Furthermore, this technique must be used with caution when determining sex in pilot whales, since only mature adult males can be identified from their dorsal fin that is much larger, rounded, and has a thicker leading edge (NAMMCO, 2021). In using photo identification as a technique it is also important to pay attention to the fact that the number of permanent markings in an individual is likely to increase over time (Auger-Méthé & Whitehead, 2007).

In Iceland, Pike et al. (2019) used photo-identification to compare the seasonal occurrence of long-finned pilot whales in two different areas. They found that the whales were more abundant in the southeast during summer, while in the winter months the distribution of the species shifted to the northwest. Furthermore, this study showed that the species was more likely to be sighted when squid was present.

In 2022, Selbmann et al. conducted a photo-identification study of long-finned pilot whales off the Faroe Islands. They found that the species was present in all months of the year, though sightings were more common during summer and autumn. Additionally, the study revealed a high degree of site fidelity of the whales, as some individuals were present in the area year-round.

In northern Norway, Vester (2017) used photo-identification to study the occurrence of long-finned pilot whales in the region. They found that the species was present in all seasons, but the highest sighting rate was recorded in autumn. Furthermore, their study revealed a high degree of site fidelity for the whales, with some individuals being sighted for up to 9 consecutive years.

Site fidelity is the behavioural predisposition of animals to return to a previously inhabited place (Switzer, 1993). As movement patterns on a larger scale can be effectively established through re-sighting of individuals in the area, photo-ID studies are frequently used to evaluate the site fidelity of cetaceans (Würsig & Jefferson, 1974). Stronger site fidelity is thought to be a sign of a resident individual or group, but it might also be the result of an animal or population returning to a location repeatedly, which could have a seasonal component (Hartman et al., 2008). This can be studied in pilot whales' population also using photo identification, as Servidio et al. (2019), did to study the site fidelity and movement patterns of short-finned pilot whales in the Canary Islands. Meyer (2020) also saw some seasonal site fidelity patterns in New Zealand, as well as Vester (2017) in Northern Norway.

Although valuable, data collected from whale-watching boats are opportunistic in nature and thus, spatially biased, and more difficult to analyse than data from standardized surveys (Hupman et al., 2015; IWC, 2017). However, as McComb-Turbitt et al. (2021) demonstrated, information gathered from whale watching can be used to understand spatiotemporal changes in species distribution, behaviour and to guide regional management of the marine wildlife tourism sector.

3.3 Study aims

The main aim of this research project was to use photo-identification images taken of long-finned pilot whales on opportunistic and research platforms off Vesterålen since 2008 in order to investigate:

- Seasonal occurrence.
- Potential site fidelity.
- The feasibility of using photo-id to study this species in the region.

4. Material & Methods

4.1 Study area

Long-finned pilot whale photographs used in this study were collected from both research and whale-watching boats, in coastal waters of the Vesterålen archipelago. There were three main locations Andenes and Andfjord, that are located in the northern Norwegian island of Andøya, and Stø that is located in the island of Langøya. The study area can be seen in the map shown in figure 1.

The Gulf Stream warms the seas of the European Arctic, preventing ice from forming at high latitudes. Additionally, the mixing of the water column vertically caused by the interaction of the warm water with the colder, denser Arctic water may bring nutrients from the deeper water to the top, therefore, enhancing the marine ecology (Belkin & Cornillon, 2007). Due to this, the northeast Atlantic region has numerous big fish stocks, including herring (*Clupea harengus*), mackerel (*Scomber scombrus*), cod (*Gadus morhua*), and capelin (*Mallotus villosus*) (Trenkel et al., 2014). Deep fjords and the continental shelf drop-off also favour deep sea species, such as squid. These fish and squid species are consumed by whales and dolphins, which are present across the northeast Atlantic (Skern-Mauritzen et al., 2022; Bjørke, 2001).

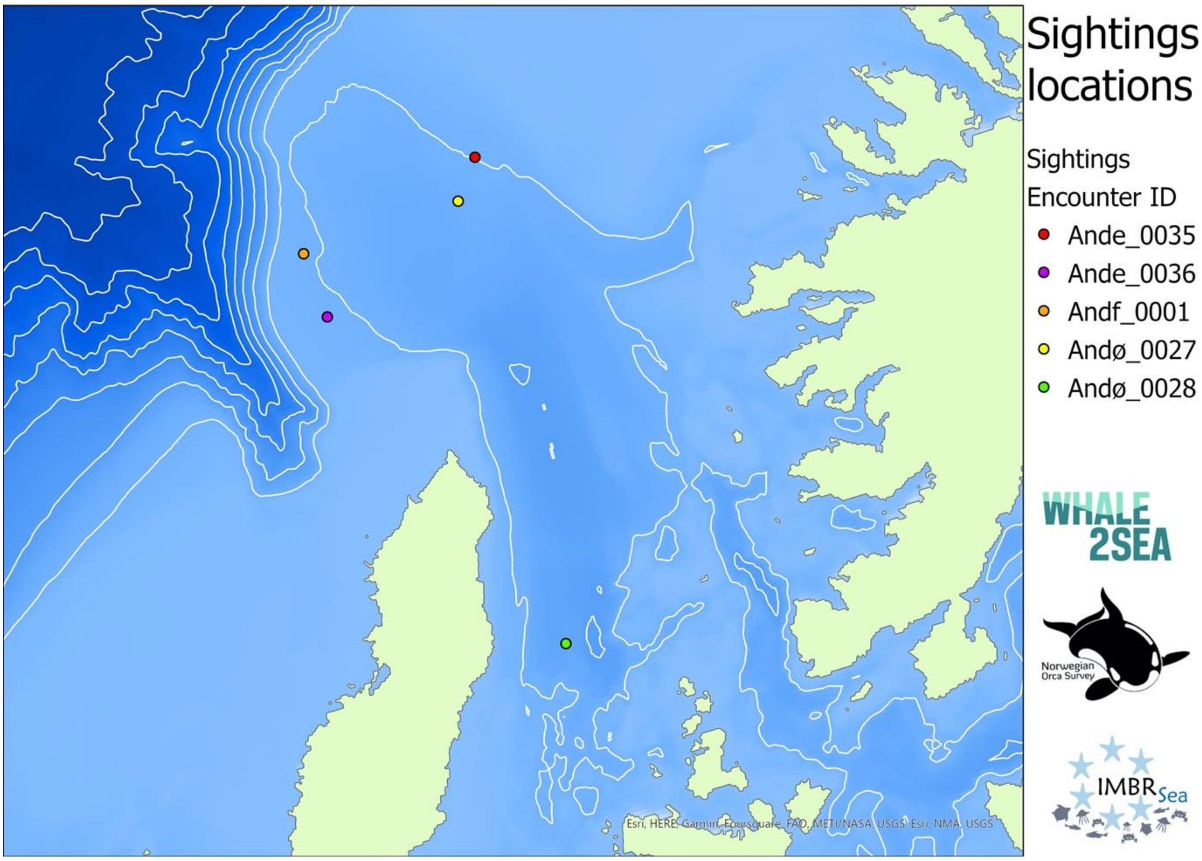


Figure 1. Study area with the sighting's locations for the Ande_0035, Ande_0036, Andf_0001, Andø_0027 and Andø_0028 encounters.

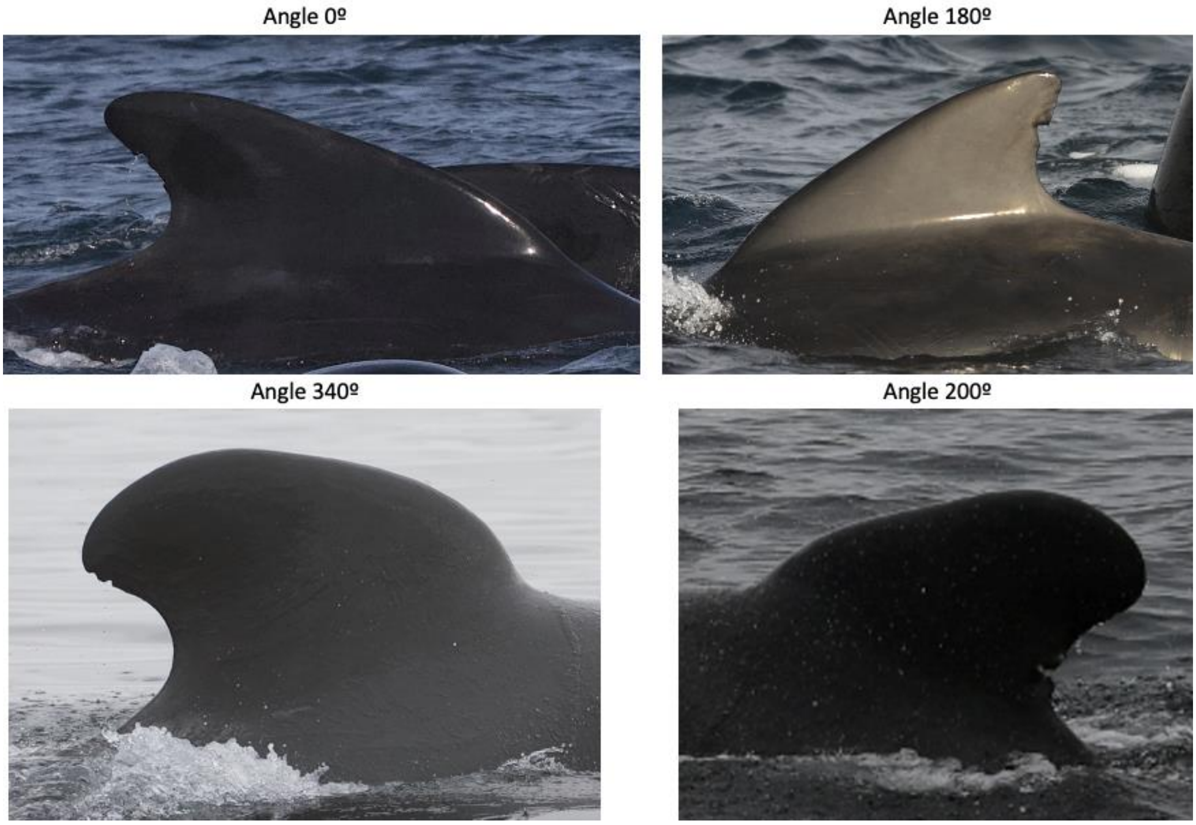
4.2 Data collection

Whale2Sea (whale watching platform) and the Norwegian Orca Survey (research platform) provided the 16,494 photographs used for photo-identification of long-finned pilot whales in this study. Photographs were taken between 2008 and 2023. Individuals were photographed regardless of their size, behaviour, distinctiveness, or distance to the photographer.

4.3 Photo-identification

All images were visualised in the Discovery software (Gailey G. & Karczmarski L., 2012). Each photograph was examined to assure the presence of a dorsal fin of a pilot whale. If the dorsal fin was visible, the quality and angle of the image were assessed in order to further select only best quality images to be retained for analysis. A good angle image was one that captured the right or left side of the individual from a perfectly perpendicular angle relative to the photographer and facing either side, as images from both sides were used for identification purposes.

A 0º angle was assigned to images of the right side of an individual when it was perfectly perpendicular to the photographer and facing that side, while an angle of 180º was assigned to images of the left side under the same conditions. Images that were captured at angles greater than 20º or less than 340º for the right side, or greater than 200º or less than 160º for the left side, were considered to have a suboptimal angle and were therefore excluded from the identification process. An example for some angles can be seen in figure 2.



Angle 0º

Angle 180º

Angle 340º

Angle 200º

Figure 2. Different individuals with their corresponding image grade for angle.

Images that showed a dorsal fin with a good quality and that had a good angle were selected and cropped to the fin for further identification and cataloguing purposes. This facilitated the process of later comparing images, also zooming in the fin helped to better see the identifiable marks of each individual. If necessary, the fin picture was edited, using the Discovery software, to increase the brightness when the image was too dark.

During the following stage of the photo-identification process, only the cropped dorsal fin images were used. By removing the images with no fins, bad quality and bad angle, the number of images available for identification was significantly reduced, resulting in a more efficient identification process. This approach ensured that only the best quality images were used, reducing the risk of false positive (or mismatch).

Following Ottensmeyer and Whitehead's method (2003), each photograph also received a quality grade (Q) on a scale of 1 to 5 (poor to excellent), based on focus, size of the fin relative to the frame, exposure, and the proportion of the fin that is visible in the image frame. Mark points (MP) were also assigned to each photo from 1 to 5 (no marks to highly marked), such as no nicks or internal corners of huge notches. An additional Scratches (S) grade was given to each fin in this study, also on a scale of 1 to 5 (no scratches to completely covered in scratches), to assess whether the individual gained or lost scratches over the sightings and to see if they could be used for photo-id. As Ottensmeyer and Whitehead's method explain, in order to improve the precision of matches and the ability to identify specific individuals, only photographs with a score of Q≥3 showing a dorsal fin score of MP≥3 should be used for the analyses. Non the less since there was a small data set, images with lower quality than three and mark points also lower than three were also used for this studies analysis.

Each distinct individual was given a unique ID code and was added to a catalogue of individuals who could be accurately identified. As individuals were found, they were named/catalogued. The catalogue was divided into permanently identifiable individuals and temporarily identifiable individuals. This was separated due to the lack of marks (MP 1) of some individuals that made it very complicated to accurately match that individual if it was re-sighted, since dorsal fins without any nicks look very similar. Therefore, to avoid the incorrect matching of individuals, all images that contained fins without marks were given a temporary ID.

Unidentifiable individuals who lacked distinctive features for reliable long-term identification (temporary IDs) were distinguished from one another for every encounter using temporary skin marks (such body scars, tooth rakes, etc.) from images of all qualities. The proportion of identifiable individuals within the group known as the mark rate was estimated using the data on the number of identified and unidentified individuals in an encounter. Nonetheless, as previously mentioned it is incredibly hard to recognize the individuals without marks so, there is a possibility that some different individuals were considered as the same or that the same individual was considered to be two different ones. An example of a permanent versus a temporary id can be seen in figure 3.

ID0104 (Q= 4; MP= 2; S=2)

TID0104 (Q= 3; MP= 1; S=1)

Figure 3. Different individuals from the permanent and temporary catalogue with their corresponding image grade for quality (Q), mark points (MP) and scratches (S).

As there was no existing long-finned pilot whale catalogue for the area where the images were collected, all individuals received a new catalogue number, ID…. for the permanent ids or TID…. for the temporary ids, with the following number that is free in the catalogue (for example ID0105).

Before assigning a new id to the fin image, this one was compared with the already existing catalogued fins. Taking into account that the nicks are persistent overtime, these were used to compare with the other individuals, if the same nicks were observed and the shape of the fin also matched, then it was considered to be a re-sighting. Meaning that it is the same individual that has been seen again, in those cases, that fin image was saved with the same id as the matching fin. An example of a re-sighting of one individual seven years apart can be seen in figure 4.

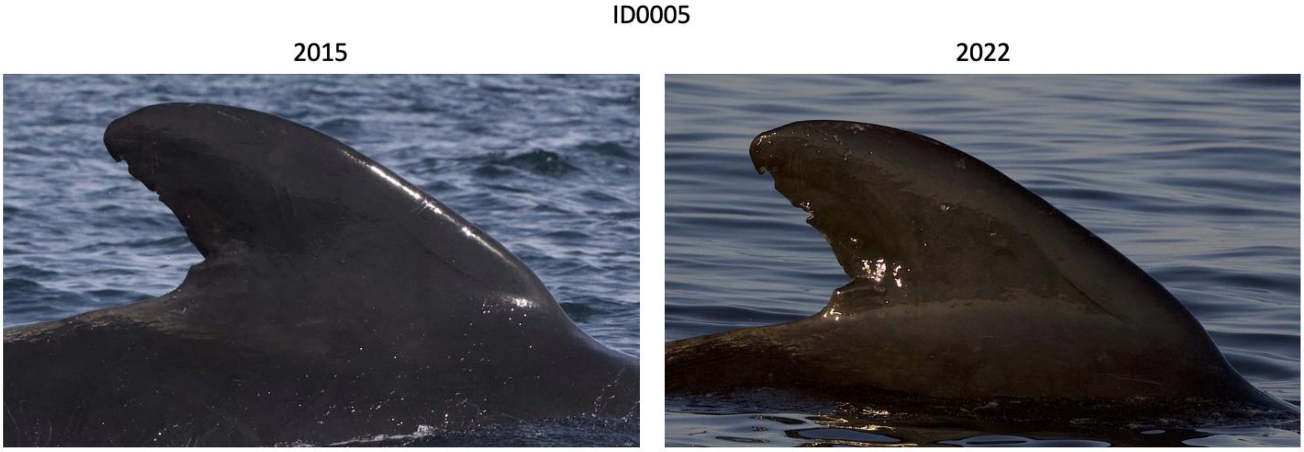


Figure 4. Re-sighting of ID0005 with a seven-year gap between images.

Upon identification of an individual, multiple fields were filled out in a database listing individuals' sighting history. Each encounter also received an ID that consisted of the first letters of the location and the number of the encounter (for example Ande_0010). The three main locations were named as Andenes "Ande", Andfjord "Andf" and Stø "Stø". Details of the encounters were recorded, including date, encounter ID, location, latitude, longitude, platform in which the images were collected (opportunistic or research boat), photographer, and group size estimation. Nonetheless, the group size only started to be noted after 2021 and only on the whale watching boats were the guide that was recording the data made an estimate, therefore it could be biased. Additionally, more information of each image was recorded, such as the quality (Q), the mark points (MP), the angle, as previously described, the visibility of the entire fin, considering that part of the fin may be covered by the water or by other individuals. If possible, the sex of the individual was also recorded, although it should be noted that determining the sex of the individual from the fin alone is not always feasible (Augusto et al., 2013). However, mature adult males typically have a larger dorsal fin, thus, it was recorded when the individual was a male.

4.4 Data analysis

4.4.1 Usefulness of photo-identification

4.4.1.1 Mark rate

For the feasibility of photo identification, the mark rate was estimated for each encounter modifying the below equation, from Ottensmeyer and Whitehead (2003):

$$\frac{\text{Number of good quality fin images } (\mathrm{Q} \geq 3) \text{of well} - \text{marked individuals } (\mathrm{MP} \geq 3)}{\text{Number of good quality fin images } (\mathrm{Q} \geq 3) \text{ of all individuals}}$$

Taking into account that pictures with a lower quality were also used in this study, instead the mark rate was assessed by the following equation:

$$\frac{\text{Number of permanent IDs}}{\text{Number of total IDs (permanent IDs} + \text{temporary IDs)}}$$

Were permanent IDs are considered to be the well-marked individuals and the total number of permanent and temporary ids photographs was equal to the estimated pilot whale group size. This estimate is based on the assumption that, on average, just as many photographs of well-marked individuals were taken as those with no marks, making it possible to estimate the group size by summing the two different identification groups.

4.4.1.2 Quality two image assessment

Additionally, as previously mentioned, photos with a quality rating of less than three were utilised in this study; consequently, a study was conducted to determine whether or not this had an impact on the photo identification process. To analyse this the mark type number was used, by estimating the proportion of each mark type for all images, only images with a quality of three or higher and only images with a quality of 2 or lower.

The viability of using quality two or lower images was then evaluated using a Fisher's exact test. By determining whether the observed proportion of quality 2 or lower photographs in each mark type significantly differed from the observed proportion of quality 3 or higher images.

4.4.1.3 Mark type gain/loss

The number of each mark types for all resighted individuals' images was noted. The mark types used are the same ones as Auger-Méthé & Whitehead, 2007, described in their study. These being, notch, piece protruding, fetal folds, postorbital eye blaze, saddle patch, parallel linear scrape, single linear scrape, tooth rake, black spot, noncircular light patch, white scar, scratch patch, small white dot, and squid mark. An example of each mark can be seen in figure

5, except for fetal folds and postorbital eye blaze since none of these mark types were seen in this study.

For each type of marking, a number was given to an individual for their initial sighting, as well as for subsequent observations made after a minimum interval of one month. These assigned numbers were then compared to determine the change in the number of marks gained or lost during that period.

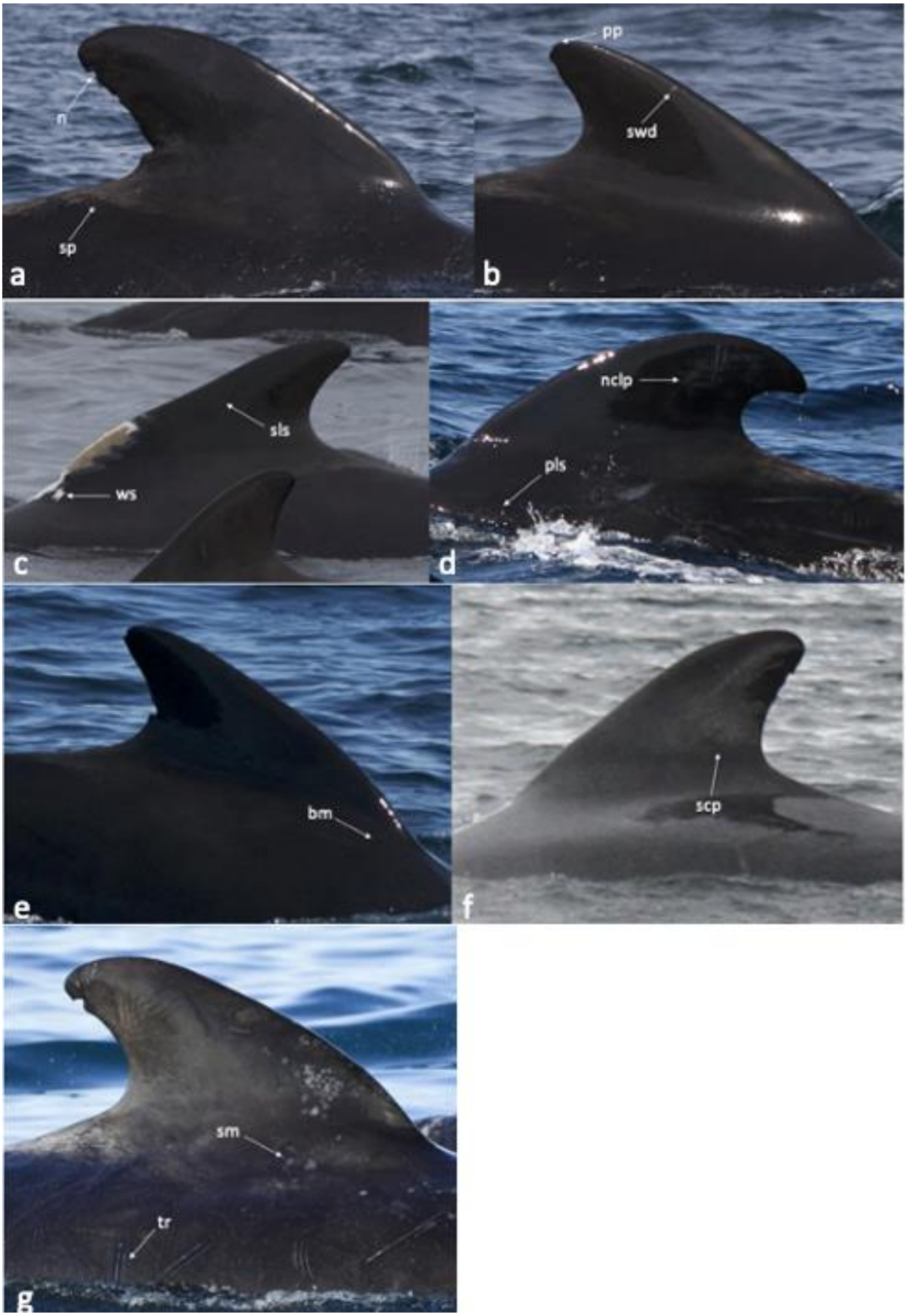


Figure 5. The mark types: (a) sp—saddle patch, n—notch; (b) pp—protruding piece, swd—small white dot; (c) sls—small linear scrape, ws—white scar; poeb—postorbital eye blaze; (d) nclp—noncircular light patch, pls—parallel linear scrape; (e) bm—black mark; (f) scp—scratch patch; (g) tr—tooth rakes, sm— squid marks.

4.4.2 Seasonal occurrence

To study the seasonal occurrence a Poisson regression model was used to check whether there was a correlation between the months and the number of encounters.

4.4.3 Mapping

For the mapping of the few encounters with coordinates, the software ArcGis Pro 2.9 was used, using the bathymetry grid data from the General Bathymetric Chart of the Oceans (GEBCO).

All analyses were done using the RStudio software and p-values were considered significant if $p < 0.05$.

4.4.4 Ethic statement

Generally speaking, no authorization is required to conduct non-invasive marine animal research around the Norwegian coast.

5. Results

5.1 Photo-identification

A total of 16,494 images were taken during 37 encounters between 2008 and 2023, in the months of January, February, June, July and August. From those images, 178 reliably marked individuals were registered in the permanent catalogue and 163 individuals with a mark point of 1 were registered in the temporary catalogue. The re-sightings were separated into daily with 94 re-sightings and monthly with 57 re-sightings. A daily resighting was considered to be when an individual was observed during two different days that could be consecutive. On the other hand, the monthly re-sightings were individuals that were seen again with at least a month in-between the two different encounters. These results can be seen in table 1 and figure 6, broken down by years and months.

Table 1. Total number of images processed by year, with the number of identification and re-sightings.

Years	Encounter days	Images processed	Permanent identifications	Temporary identifications	Daily re-sightings	Monthly re-sightings
2008	1	19	1	0	0	0
2014	9	5,484	63	34	16	5
2015	3	2,615	24	24	24	10
2016	4	738	25	20	18	11
2017	1	982	8	4	2	2
2018	2	272	8	16	2	2
2019	7	1,598	16	11	13	9

2020	4	1,874	13	26	9	9
2021	3	1,937	6	14	9	8
2022	2	710	10	11	1	1
2023	1	265	6	3	0	0
Total	**37**	**16,494**	**178**	**163**	**94**	**57**

In figure 6 it can be better visualised the daily re-sightings compared to the new individuals (permanent IDs), broken down by months.

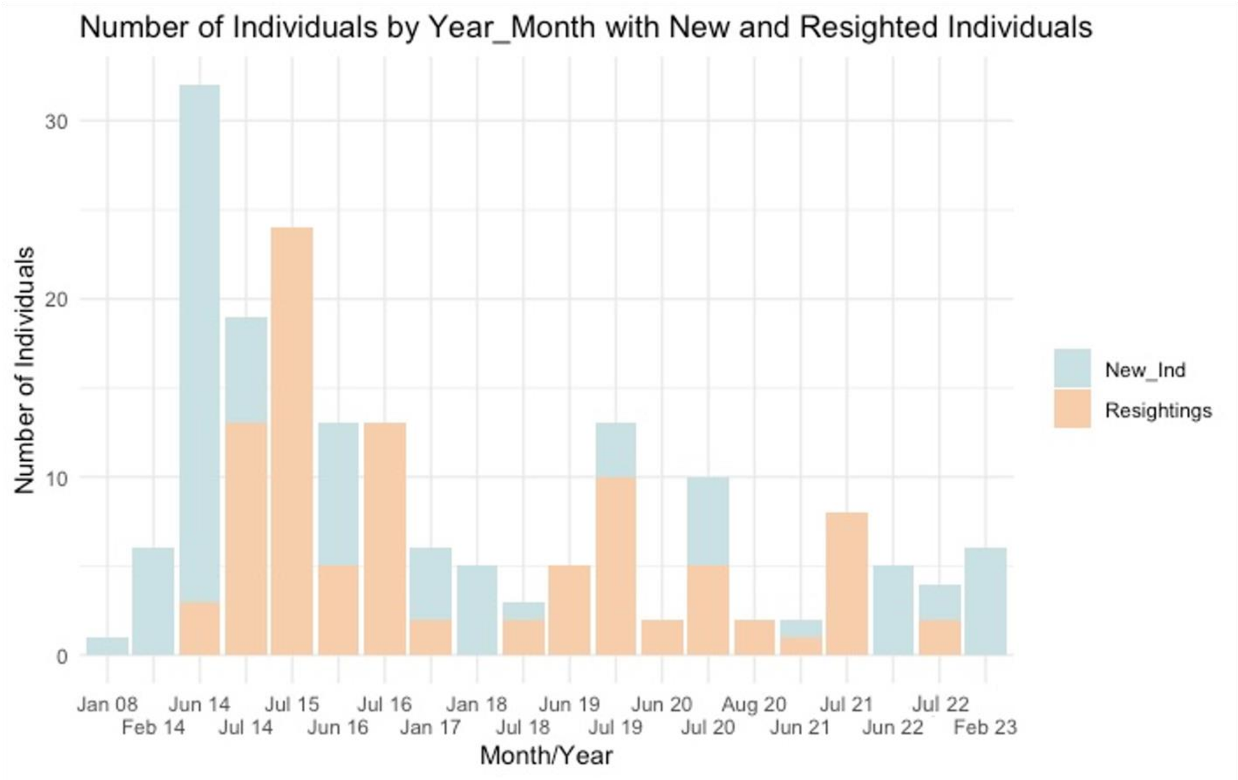


Figure 6. Total number of new and resighted individuals (permanent IDs only) photo-identified per month between 2008 and 2023.

As a whole, the proportion of newly identified individuals increased as seen in the discovery curve (figure 7), were the total number of identifications per year continued on an increasing trend throughout the study period.

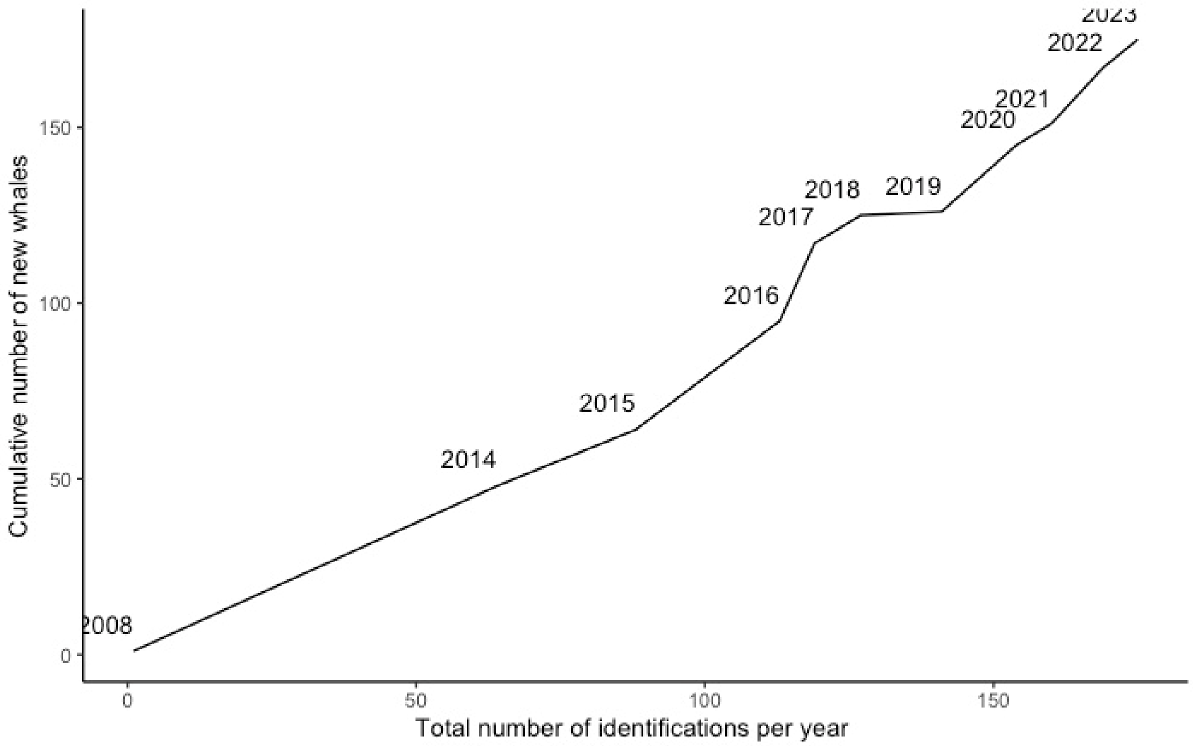


Figure 7. Cumulative number of new permanently marked individuals' photo-identified relative to total number of identifications per year.

5.1.1 Mark rate

The proportion of identifiable individuals varied between encounters, going from 0% to 100% ($\bar{x}$ = 62.4, SE = 3.4, n = 37).

Table 2. Pilot whale encounters used for assessing the proportion of individuals bearing reliable markings.

Date	**Encounter ID**	**Number of Permanent IDs**	**Number of Temporary IDs**	**Total IDs**	**Mark rate (%)**
18/1/08	Ande_0030	1	0	1	100
12/2/14	Andf_0001	6	4	10	60
3/6/14	Andf_0002	4	0	4	100
5/6/14	Ande_0032	12	4	16	75
8/6/14	Ande_0033	9	5	14	64.2857
10/6/14	Ande_0034	10	3	13	76.9230
1/7/14	Andf_0003	15	6	21	71.4285
1/7/14	Ande_0031	13	4	17	76.4705
9/7/14	Andf_0004	7	4	11	63.6363
13/7/14	Andf_0005	4	5	9	44.4444
11/7/15	Andf_0006	13	9	22	59.0909
18/7/15	Andf_0007	18	16	34	52.9411
19/7/15	Andf_0008	16	15	31	51.6129
13/6/16	Ande_0009	3	2	5	60

28/6/16	Ande_0010	15	7	22	68.1818
2/7/16	Stø_0012	17	10	27	62.9629
22/7/16	Ande_0011	8	2	10	80
24/1/17	Ande_0037	8	4	12	66.6666
31/1/18	Andf_0013	5	9	14	35.7142
25/7/18	Andf_0014	5	7	12	41.6666
7/6/19	Ande_0015	0	2	2	0
8/6/19	Ande_0016	3	2	5	60
11/6/19	Ande_0017	2	0	2	100
12/6/19	Ande_0018	2	1	3	66.6666
2/7/19	Ande_0019	6	0	6	100
2/7/19	Ande_0020	8	3	11	72.7272
25/7/19	Ande_0021	9	3	12	75
1/6/20	Andf_0022	4	9	13	30.7692
28/7/20	Ande_0023	6	9	15	40
28/7/20	Ande_0024	8	3	11	72.7272
1/8/20	Ande_0025	4	5	9	44.4444
23/6/21	Andø_0026	3	2	5	60
3/7/21	Andø_0027	6	7	13	46.153
14/7/21	Andø_0028	6	5	11	54.5454
28/6/22	Ande_0036	5	2	7	71.4285
1/7/22	Ande_0029	6	9	15	40
22/2/23	Ande_0035	5	3	8	62.5
Mean		**7.35**	**4.89**	**12.24**	**62.3780**

5.1.2 Quality two image assessment

The total number of each mark type for all resighted individuals can be seen in table 3, as well as the proportion of images that contained that type of mark. The proportions are separated into all images (Prop. all), only images with a quality of 3 or higher (Prop. Q3) and only images with a quality of 2 or lower (Prop. Q2). The p-value for the Fisher's test can also be seen for the mark types that had a big enough sample size.

The most abundant type was the notch with 198 notches in total and with a very high proportion (0.95), this mark type also showed a significant p-value (<0.05). The only other type of mark with a significant p-value was the single linear scrape.

Table 3. Number of each mark type for all re-sighted individuals and the proportion of pictures containing each type for all images (Prop. All), images with a quality of 3 of higher (Prop. Q3) and images with a quality of 2 or lower (Prop. Q2).

Mark type	n	Prop. all	Prop. Q3	Prop. Q2	Fisher's test *P* value
Black spot	5	0.0227	0.0113	0.0113	
Fetal folds	0	0	0	0	
Noncircular light patch	52	0.3068	0.2045	0.1022	0.3712
Notch	198	0.9545	0.5681	0.3863	8.5803 e-21
Parallel linear scrape	12	0.0795	0.0795	0	
Piece protruding	10	0.1136	0.1022	0.0113	
Postorbital eye blaze	0	0	0	0	
Saddle patch	35	0.3977	0.2613	0.1363	0.3087
Scratch patch	2	0.0227	0.0113	0.0113	
Single linear scrape	184	0.4431	0.2386	0.2045	4.390 e-5
Small white dot	135	0.2954	0.2045	0.0909	0.1227
Squid mark	36	0.0340	0.0113	0.0227	
Tooth rake	64	0.28409	0.1590	0.1250	0.1336
White scar	4	0.02272	0	0.0227	

5.1.3 Mark gain/loss

The number of marks for the re-sighted individuals gained or lost during the different encounters is noted down in table 4. The notch seems to be the most stable mark type followed by the piece protruding, saddle patch and white scar.

Table 4. Number of marks gained and lost for each mark type for all re-sighted individuals.

Mark type	n	Gain	Loss
Black spot	5	5	0
Fetal folds	0	0	0
Noncircular light patch	52	24	16
Notch	198	3	1
Parallel linear scrape	12	3	6
Piece protruding	10	0	1
Postorbital eye blaze	0	0	0
Saddle patch	35	4	5
Scratch patch	2	1	1
Single linear scrape	184	85	37
Small white dot	135	49	28

Squid mark	36	28	0
Tooth rake	64	29	17
White scar	4	0	0

5.2 Seasonal occurrence

A time plot was created to better visualise the number of encounters per month (figure 8). Then the Poisson regression model showed a significant effect of month on the count of encounters (X^2= 9.983, df = 3, p-value = 0.019). Specifically, the number of encounters was significantly higher in June (SE = 0.084, z = 2.91, p-value = 0.009) and July (SE = 0.079, z = 3.03, p-value = 0.004).

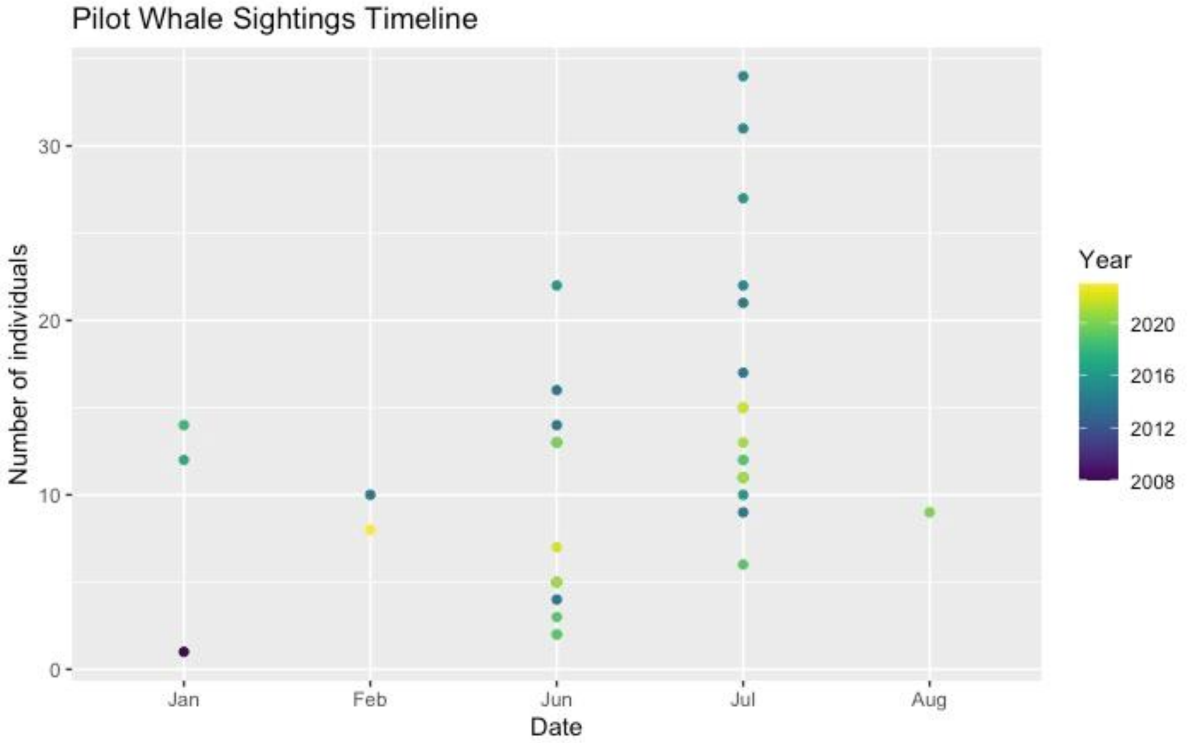


Figure 8. Time plot for the number of encounters per month, broken down by years.

5.3 Mapping

The five encounters that had the coordinates of the sighting were mapped using the ArcGIS Pro software (figure 1). The corresponding dates per encounter are as follows, Ande_0035 the 22/02/23, Ande_0036 the 28/06/22, Andf_0001 the 12/2/14, Andø_0027 the 3/7/21 and Andø_0028 the 14/7/21.

6. Discussion

6.1 Usefulness of photo-identification

The findings of this study shed important light on the long-finned pilot whale photo-identification and mark rate in the Vesterålen region of Norway. A total of 16,494 photos were taken over the course of 37 encounters between 2008 and 2023, and as a result, 178 marked individuals were identified in the permanent catalogue and 163 individuals in the temporary catalogue. The discovery curve shows a consistent increase in the number of identifications per year, indicating that there are still individuals to be identified within the area.

6.1.1 Mark rate

In this investigation, the average mark rate, which measures the percentage of marked whales among encounters, was observed to be 62.4%. A comparison with other studies conducted in different locations, was performed using a two-sample t-test (Table 5). The p-value revealed no significant difference in mark rates within different groups (p-value = 0.076). It is necessary to keep in mind that the two-sample test relies on the assumption that the means of the other studies are normally distributed. However, this presumption could not be true, which could result in inaccurate deductions. Furthermore, no standardized method of calculation was applied to determine the mark rates of the different groups examined here which could bias the results of direct comparisons.

Table 5. Mark rate comparison with different studies.

Location	Mark rate (%)	Species	Reference
Vesterålen, Norway (this study)	62.4	Long-finned pilot whale	
Cape Breton, Nova Scotia	51.0	Long-finned pilot whale	Augusto et al., 2017
Strait of Gibraltar	36.4	Long-finned pilot whale	Verborgh et al., 2009
Madeira	52.2	Short-finned pilot whale	Alves et al., 2013
New Zealand	13.0	Long-finned pilot whale	Meyer, 2020

Nonetheless, these results imply that the mark rates seen in the group studied are within the range seen in other pilot whale groups, demonstrating a pattern that is constant across different geographic regions. However, it is important to note that the mark rates reported in the literature vary a little between studies, suggesting possible small variations in markings or demographic characteristics between regions.

The high mark rate found in our investigation suggests the possibility of long-term monitoring and successful photo-identification of the long-finned pilot whale groups in the Vesterålen area. Although these results should be interpreted with caution, since in this study the group number for each encounter was assumed to be the sum of temporary and permanent individuals for each encounter. There are some encounters that have a mark rate of 0% or of 100% this is an indicator that the use of the group number estimated like we did in this study is probably inaccurate. This would be more reliable if the group size is estimated directly during the encounter as the other studies had done, since maybe there is a low amount of number of pictures taken but it does not mean there was a low number of individuals.

Therefore, to properly compare the mark rates among various studies it is really important to standardise how to perform the mark rate assessment, as well as to collect the data of group size in the same way other studies made.

6.1.2 Quality two image assessment

In the mark type analysis, evaluating image quality is key since it has a direct impact on the precision of mark type identification and, consequently, on the photo identification. In this study, the analysis of the proportions of various mark types found in photos with good quality compared with the lower quality images indicated correlations.

Among the identified mark types that had a low p-value, there was the notch and then the single linear scrape. These means that the pictures with a quality lower than two had a significantly lower number of these mark types than the ones with higher quality. Indicating that some marks could be missed when analysing images with lower quality and would have a negative effect in the photo identification process.

Additionally, mark types including the saddle patch and noncircular light patch had lower proportions in images with a quality grade of two or lower, suggesting that these mark types are harder to observe in low quality images.

Therefore, using poorer quality photos should be done with precaution or only using images with a quality mark of at least three for the analysis as previously stated in other studies (Ottensmeyer and Whitehead, 2003). The chance of introducing bias, misclassification, or incorrect interpretation of mark types can be reduced by doing so.

6.1.3 Mark gain/loss

In this study, we analysed the stability of different mark types and looked at the mark gain/loss for re-sighted individuals in long-finned pilot whales. In comparison to other mark types, the findings showed that notches and saddle patches displayed better levels of stability over time. Protruding pieces and white scars were also stable but were seen in a lower percentage of the groups. These results are consistent with those of Auger-Méthé and Whitehead's (2007) investigation, which discovered that the same mark types did not exhibit significant losses between sightings.

However, it is crucial to take into account a few elements that could affect the endurance and recognizability of these marks. For instance, Bigg (1982) studied killer whales and discovered that notches on developing fins could widen and perhaps become shallower with time. Similar to Auger-Méthé and Whitehead's (2007) work, one minor notch in our analysis appeared to have vanished or stopped being noticeable. It is important to note that the loss of the single notch found in our study occurred in a blurry picture and a with a tiny notch, which may have reduced the notch's visibility.

The results of this study indicated saddle patches had persistence, with just five cases of loss identified between sightings, similar to Auger-Méthé and Whitehead's (2007) study. These lost marks might be explained by the worse picture quality of the photographs taken during successive encounters, which might have made it more difficult to properly recognise saddle patches. Although these marks were only visible in 40% of the images that were analysed, Bloch et al. (1993) showed that their number tend to increase with age and body length. This occurrence may be explained by the calves' and juveniles' light skin tones, which might make it difficult to see the mark when it is there. Likewise, using photographs of poorer resolution makes it much more difficult to see saddle patches, as could also be seen in the lower percentage of saddle patches in images with low quality, when doing the quality image assessment.

Several mark types in this study had smaller sample sizes, including black spots and scratch patches, or some that were not even observed like fetal folds and postorbital eye blazes. Due to the statistical limitations, it is important to use caution when assessing the stability of their proportions. It's interesting to note that these mark kinds were also identified as having small sample sizes in the study by Auger-Méthé and Whitehead (2007), suggesting a possible difficulty in determining their reliability across studies.

It is important to note that, in contrast to Auger-Méthé and Whitehead's (2007) study, which only included individuals with 3MP, our analysis included individuals with lower mark points. This discrepancy might affect how statistical analyses of mark proportions are conducted, especially for mark types with smaller sample sizes, therefore, to make a proper comparison between studies only fins with a mark point of three or higher should be used.

6.2 Seasonal occurrence

In total between the years of our study 97 individuals were resighted during different days and 57 during different months. These daily and monthly re-sightings of marked individuals indicate the presence of the same individual on separate days and in different months, highlighting their regular occurrence in the study area.

A significant correlation between the number of pilot whale encounters and the month was found, with greater encounter rates in June and July. This suggests a possible seasonal trend in the occurrence of long-finned pilot whales with a preference for the summer period (June and July). However, it is important to note that the study was based on opportunistic data which may be biased by the heterogeneity of the effort throughout the year, with an increased number of whale-watching trips during summer. Nonetheless, similar results were observed in Vester (2017) study, performed in a nearby region of Northern Norway. The future studies should include a more systematic sampling approach in order to demonstrate that there is a yearly presence with a high seasonal occurrence throughout the summer months in the Vesterålen region.

The results of other research offer more information about the seasonal presence and behaviour of pilot whales in various areas. Studies carried out off the coast of Nova Scotia, for instance, have revealed that long-finned pilot whales exhibit low year-round site fidelity but some seasonal site fidelity, with individuals occasionally spotted during the warmer months (Ottensmeyer and Whitehead, 2003). Some individuals in the Strait of Gibraltar display a high degree of seasonal residence, showing up during the warmer months of the year both within and between years (Verborgh et al., 2009).

Moreover, Servidio et al. (2019) noted seasonal variations in group size of short-finned pilot whales in the Canary Islands, with summer and autumn groups being bigger than spring groups. Certain subgroups were composed of resident individuals showing strong evidence of site fidelity with a specific island, while some other subgroups were more transients. Both types of groups seem to gather to mate between June and October (De Stephanis et al., 2008). Meyer (2020) noted an increase in pilot whale sightings in the shallow coastal waters of New Zealand during the austral summer, which may be related to increased food availability driving this species' seasonal inshore movements.

Therefore, taking into account the information from other studies a number of variables, including prey availability, oceanographic conditions, and migratory patterns, may have an impact on the seasonal patterns, and therefore should be kept in mind. Therefore, future studies that incorporate environmental variables and long-term monitoring would be able to better understand the factors that influence these variations in occurrence.

6.3 Limitations

Despite the useful information that this study has provided, there are a number of limitations that need to be noted. First, opportunistic observations were used to obtain the data, which may have introduced biases and had limits in terms of sampling effort and geographic coverage. As a result, there could have been spatial and temporal biases in the data because some areas or periods were underrepresented, for example the winter months or areas that were further away from the coast.

Future research may profit from using a systematic and standardised survey design, such as transects, to solve this issue. These could guarantee a more representative sampling effort across the study region and would reduce any potential biases caused by opportunistic data collection.

Nonetheless, the use of opportunistic data is very important, especially in this area where little is known about the species. To improve the data collected from these platforms, it would be of importance to note the estimate of group size during an encounter, reducing the chance of miscalculation performed when calculating it with the number of permanent and temporary ids. For a more detailed understanding of the distribution and habitat use of long-finned pilot whales, recording the coordinates during encounters would be useful.

7. Conclusion

In conclusion, this study provides significant insights into the feasibility of photo-identification on long-finned pilot whales found in the waters off Vesterålen. The mark rate found in this study is within the range recorded in other groups of pilot whales, indicating a consistent pattern across several geographical areas. Nonetheless, when comparing mark rates between studies, caution should be taken to avoid biases caused by differences in marking analysis procedures and data gathering methods.

The analysis of mark types and their stability over time revealed that notches and saddle patches exhibited best levels of persistence. When doing photo-identification, it is crucial to consider several variables such as picture quality; poor quality photographs might lead to missing or wrongly identified markings.

The results of this study also demonstrate that photo-identification is as a useful technique for studying long-finned pilot whales in the area. The use of photo-identification allowed identification of a large number of marked individuals, with some being reidentified over time, on different months and years.

The study also revealed that pilot whales had a year-round presence with a higher seasonal occurrence during the summer months in the Vesterålen region, having greater encounter rates during June and July. Opportunistic data may be extremely valuable, but the results are biased, therefore, this information should be interpreted with caution and there would be a need of further studies to properly prove these findings.

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