Cyfoeth Naturiol Cymru
Natural Resources Wales

EIRPHOT: A critical assessment of Wales' grey seal (*Halichoerus grypus*) photo-identification database.

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Mae'r morlo llwyd (*Halichoerus grypus*) wedi'i restru yn Atodiad II o Gyfarwyddeb Cynefinoedd yr UE ac mae'n nodwedd gymhwysol o dair Ardal Cadwraeth Arbennig yng Nghymru. Mae Cyfoeth Naturiol Cymru yn monitro poblogaethau morloi llwyd ledled Cymru ac yn cynnal cronfa ddata o luniau adnabod o'r enw EIRPHOT sy'n cynnwys safleoedd gadael y dŵr o amgylch y Môr Celtaidd a Môr Iwerddon. Nod yr astudiaeth hon oedd asesu, gwirio camgymeriadau, diweddaru ac adrodd ar y gronfa ddata o luniau adnabod.

Roedd yr amcanion fel a ganlyn: 1) asesu, adolygu a phrosesu delweddau o Ynys Dewi a Bae Ceredigion, a'u hychwanegu at gronfa ddata EIRPHOT, 2) gwirio camgymeriadau, diweddaru ac adrodd ar statws y gronfa ddata, 3) defnyddio cronfa ddata EIRPHOT i gynhyrchu hanesion dal ar gyfer morloi llwyd unigol.

Cafodd data Ynys Dewi a Bae Ceredigion eu prosesu a'u cymharu â chronfa ddata EIRPHOT gan ddefnyddio meddalwedd adnabod patrymau â chymorth cyfrifiadur *ExtractCompare*. Cafodd y data presennol o fewn y gronfa ddata eu glanhau ar gyfer camgymeriadau, a chafodd ansawdd y delweddau ar gyfer pob ardal eang ei asesu. Yna, cynhyrchwyd hanesion dal ar gyfer morloi llwyd unigol gan ddefnyddio meddalwedd dal–ail-ddal gofodol benodol. Cafodd adroddiadau penodol i'r safle hefyd eu cynhyrchu i ddarparu cyfranwyr ag ystadegau cryno ac argymhellion data â mwy o ffocws.

Ar ôl cwblhau'r dadansoddiad hwn, roedd cronfa ddata EIRPHOT yn cynnwys data o 17,056 o ddelweddau ar draws 3,273 o achlysuron samplu rhwng 1992 a 2016. Daeth y mwyafrif o ddarnau patrwm blew o gwmpas y pen. Fodd bynnag, ar gyfer rhai lleoliadau roedd mwy o ddarnau pen chwith ac ar gyfer lleoliadau eraill roedd mwy o ddarnau pen de. Gwnaethom felly gynhyrchu hanesion dal ar gyfer unigolion unigryw a oedd wedi'u nodi gan a) darnau pen chwith a b) darnau pen de.

Canfu'r asesiad ansawdd delwedd fod gwahaniaeth sylweddol rhwng ansawdd y ddelwedd ar draws y prif ardaloedd o fewn cronfa ddata EIRPHOT ($p < 0.001$). Daeth y delweddau o ansawdd uchaf o Ynys Sgomer, gyda'r delweddau ansawdd isaf o Fae Ceredigion. Canfu prawf post hoc wahaniaethau sylweddol mewn ansawdd delwedd rhwng ardaloedd Ynys Sgomer – Bae Ceredigion, Ynys Sgomer – Ynysoedd y Moelrhoniaid, Ynys Dewi – Bae Ceredigion a Marloes – Bae Ceredigion. Y prif fater gydag ansawdd oedd ffocws y delweddau, ond roedd metadata hefyd ar goll ar gyfer oedran a rhyw rhai unigolion, a allai fod wedi'i osgoi.

Canfuom mai dim ond unwaith y gwelwyd y mwyafrif o unigolion a gofnodwyd o fewn cronfa ddata EIRPHOT (77% o ddarnau pen chwith a 78% o ddarnau pen de). O'r unigolion a welwyd fwy nag unwaith, cofnodwyd 12-13% ddwywaith, cofnodwyd 5% dair gwaith, cofnodwyd 2% bedair gwaith, cofnodwyd 1% pump

a chwe gwaith, a chofnodwyd <1% saith gwaith neu fwy. Cafodd yr unigolyn gyda'r rhan fwyaf o ailddaliadau ei nodi yn Ynys Sgomer am y tro cyntaf a chafodd ei ail-ddal 12 gwaith mewn lleoliadau o amgylch Ynys Sgomer ac Ynys Dewi. Roedd gan yr un unigolyn yr hanes dal hiraf o fewn cronfa ddata EIRPHOT, a oedd yn ymestyn 23 mlynedd o 1993 i 2016.

Ar gyfer unigolion a welwyd fwy nag unwaith, roedd cysylltiadau (symudiadau awgrymedig) rhwng yr wyth ardal (gan gynnwys "arall"). Ynys Sgomer oedd y mwyaf cysylltiedig, gydag unigolion yn symud rhwng Ynys Sgomer a'r holl ardaloedd eang eraill. Roedd Ynys Môn, Ynys Enlli ac Ynysoedd y Moelrhoniaid wedi'u cysylltu â saith ardal, ac roedd Bae Ceredigion wedi ei gysylltu â chwe ardal. Marloes ac aber Afon Dyfrdwy oedd y lleiaf cysylltiedig, gyda chysylltiadau â dim ond hanner yr ardaloedd eraill.

2. Executive Summary

The grey seal (*Halichoerus grypus*) is listed in Annex II of the EU Habitats Directive and is a qualifying feature of three Special Areas of Conservation in Wales. Natural Resources Wales monitors the grey seal populations around Wales and maintains a photographic identification (photo-ID) database called EIRPHOT which covers seal haul out sites around the Celtic and Irish Seas. The aim of this study was to assess, error check, update and report on the photo-ID database.

The objectives were: 1) to assess, review and process images from Ramsey Island/Ynys Dewi and Cardigan Bay/Bae Ceredigion, and add these to the EIRPHOT database, 2) to error check, update and report on the status of the database, and and 3) to use the EIRPHOT database to produce capture histories for individual grey seals.

Ramsey Island and Cardigan Bay data were processed and compared with the EIRPHOT database using computer-aided pattern recognition software *ExtractCompare*. Existing data within the database were cleaned for errors, and the quality of images for each broad area was assessed. Capture histories were then generated for individual grey seals using Spatially-Explicit-Capture-Recapture software. Site-specific reports were also produced to provide contributors with more focussed summary statistics and data recommendations.

On completion of this analysis, the EIRPHOT database contained data from 17,056 images across 3,273 sampling occasions between 1992 and 2016. The majority of pelage pattern extracts came from the head region. However, for some locations there were more left head extracts and for other locations there were more right head extracts. We therefore generated capture histories for unique individuals that were identified by a) left head extracts, and by b) right head extracts.

The image quality assessment found that there was a significant difference between the image quality across the main areas within the EIRPHOT database ($p < 0.001$). The highest quality images came from Skomer Island/Ynys Sgomer, with the lowest quality images from Cardigan Bay. A post-hoc test found significant differences in image quality between the areas Skomer-Cardigan Bay, Skomer-Skerries, Ramsey-Cardigan Bay and the Marloes-Cardigan Bay. The primary issue with quality was the focus of the images, but there were also metadata missing for the age and sex of some individuals which could have been avoided.

We found that the majority of individuals recorded within the EIRPHOT database were only seen once (77% from left head extracts and 78% from right head extracts). Of the individuals seen more than once, 12-13% were recorded twice, 5% were recorded three times, 2% were recorded four times, 1% were recorded five and six times and <1% were recorded seven times or more. The individual

with the maximum number of recaptures was first identified at Skomer and was recaptured 12 times in locations around Skomer and Ramsey. The same individual had the longest capture history within the EIRPHOT database, which spanned 23 years from 1993 to 2016.

For individuals seen more than once, there were connections (implied movements) among the seven broad areas and to locations outside of these, ie “other”. Skomer was the most connected, with individuals moving between Skomer and all other broad areas. Ramsey, Bardsey Island/Ynys Enlli and the Skerries/Ynysoedd y Moelrhoniaid were connected to seven areas, and Cardigan Bay was connected to six areas. The Marloes and the Dee Estuary were the least connected, with links to only half of the other areas.

3. Introduction

3.1. Grey seal population status

In the northeast Atlantic and Baltic Sea, the grey seal (*Halichoerus grypus*) is listed in Annex II of the EU Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) which requires member states to designate Special Areas of Conservation (SACs) for the species. In Wales, grey seals are a feature of three SACs: Pembrokeshire Marine/Sir Benfro Forol, Cardigan Bay/Bae Ceredigion and Lleyn Peninsula and the Sarns/Pen Llŷn a'r Sarnau. One requirement of the Habitats Directive is to report on the condition of SAC features and for species this typically involves an assessment of abundance, distribution and population health through monitoring a variety of population dynamic parameters eg movements, structure, survival etc. Natural Resources Wales (NRW, formerly the Countryside Council for Wales, CCW) monitors the number of grey seal pups born in these SACs (Stringell *et al.* 2014).

Population censuses indicate that the UK contains approximately 34% of the world's total grey seals and 3% of these are in Wales. Pup production is used to estimate overall population size and the current estimate for the number of grey seals in the UK is 141,000 (SCOS 2017).

3.2. EIRPHOT and grey seal photo ID

Mark-recapture studies (capturing, marking, releasing and recapturing individuals within a population) can be used to study both individual behaviour and population dynamics (Donovan *et al.* 1990). Traditionally this involved the use of invasive, costly methods that had unquantifiable, adverse effects on natural behaviour (Wilson and McMahon 2006). An adaptation to mark-recapture studies is to use photo-identification (photo-ID) of pre-existing, natural markings such as patterning, scarring, colouration, or a combination of the three.

The pelage pattern of female grey seals changes over their lifetime, by a darkening of the pigmentation which increases the contrast between dark and light areas (Vincent *et al.* 2001). The pelage pattern is sufficiently stable from weaning through adulthood to allow for the use of automated photo-ID software to identify individuals (Paterson *et al.* 2013, Hiby and Lovell 1990).

NRW have a continuing photo-ID project on grey seals in waters around Wales and the Irish Sea. This originated with the EU Maritime (Ireland/Wales) INTERREG II program between 1994 and 1999 which examined the movements of seals between Ireland and Wales (Keily *et al.* 2000), hence the name – EIRPHOT. The project used semi-automated pattern recognition software called *ExtractCompare*, originally developed for grey seals at the Sea Mammal Research Unit (SMRU), University of St. Andrews, by one of the authors (Lex

Hiby) and extended as part of a NERC grant awarded to SMRU from 2009 to 2013.

NRW added images to EIRPHOT from the 1992-1995 West Wales grey seal census (Baines *et al.* 1995) and has continued to add data since then. Data have been collected by NRW staff, students and trained volunteers, including those from many collaborating organisations and individuals. To our knowledge, EIRPHOT has become one of the largest databases of its kind in the world, now with over 17,000 photographic images of more than 9,000 grey seals.

A similar but larger database called SMRUPHOT contains 55,473 images of 27,888 grey seals from many UK sites from the 1990s to present, and DUTCHPHOT contains 5,783 images of 2,763 grey seals from Holland and the North Sea sites in recent years. Both of these databases are held at SMRU.

3.3. Aims and objectives

NRW contracted SMRU to assess, error check, update and report on the EIRPHOT database as follows:

Objective 1: Assess, review and process images from the Ramsey and Cardigan Bay 'append' databases (supplied separately) and add these to EIRPHOT before constructing capture histories.

Objective 2: Assess and use the EIRPHOT database as supplied by NRW to produce capture histories for individuals within the database.

Outputs:

- An updated EIRPHOT database;
- Capture history data in the form of summary appendices, Excel spreadsheets and MARK compatible text files;
- A report outlining the data processing undertaken, which data were processed, which data remain unprocessed and the status of the database on completion of the work.

4. Methods

4.1. Study site

The EIRPHOT database contains photo-ID data collected at 280 locations around the British Isles, with a focus on the Irish and Celtic Seas (Figure 1). The majority of the sites are along the Welsh coast and islands (*n* = 246), with other sites in Ireland (*n* = 23), Isle of Man (*n* = 3), England (*n* = 1), Scotland (*n* = 1) and France (*n* = 1). This report focuses on 7 main locations within the Irish and Celtic Seas, as highlighted in Figure 1.

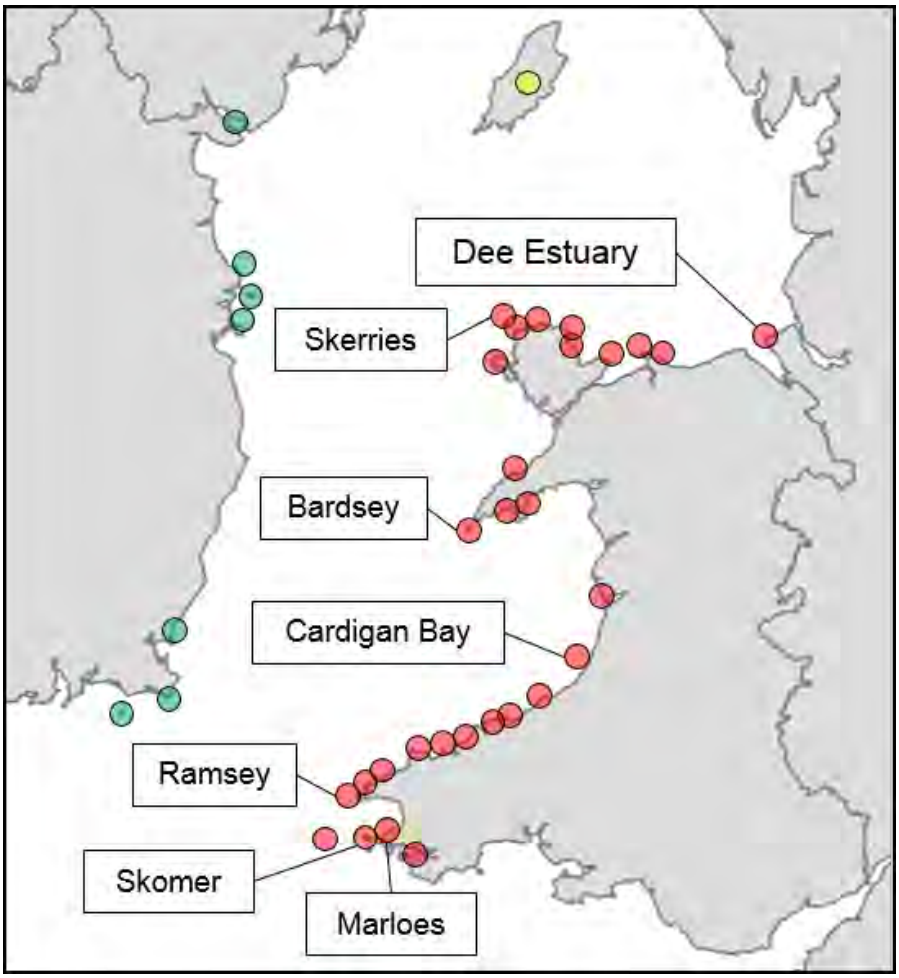

Figure 1. Locations within the EIRPHOT database for the Irish and Celtic Seas, with Welsh sites in red, Irish sites in green and the Isle of Man in yellow. The seven areas of focus in this report are highlighted by text. Skerries/Ynysoedd y Moelrhoniaid, Bardsey/Ynys Enlli, Ramsey/Ynys Dewi and Skomer/Ynys Sgomer are all islands, and Marloes refers to the Marloes Peninsula.

4.2. Data description

4.2.1. Terminology

Throughout this report we use terminology that is consistent with the EIRPHOT database. *Sampling occasions* represent each data collection event on a specific date and at a specific location, *encounters* are the individual seals

recorded at each sampling occasion, *images* are the photographs of seals encountered, *aspects* are the standardised areas of seal pelage and *extracts* are the sampled pelage of which we compared.

4.2.2. EIRPHOT database

The EIRPHOT database uses Microsoft Access to store photo-ID data. The *Sightings* table stores metadata on each sampling occasion including the date and location. This is linked to the *Encounter* table which lists each encounter with a seal, its age, sex, whether it was with a pup, any scars or injuries, and here it is assigned an ID. This table is linked to the *Image* table which records the names of images taken for each encounter. And finally this is linked to the *Cells* table, which lists the details of the pattern extracts that are available from the images. These can be from either side of the animal and from the abdomen, chest, flank, head or neck. Within the *Cells* table is the *AutoMatch* column which determines what stage the extract is in terms of the pattern extraction process.

At the start of this contract (December 2016), the EIRPHOT database was made up of 25,965 extracts, from 16,468 images across 3,095 sampling occasions. Images had been collected around the Welsh coast and Irish Sea between 1992 and 2015, including those from the joint Welsh-Irish INTERREG project from September 1996 to September 1998. There were 1,957 extracts waiting to be extracted and 3,426 extracts waiting to be batch compared and visually confirmed.

4.2.3. Ramsey 'append' database

The first append database was from Ramsey Island - an RSPB Nature Reserve off the coast of St David's peninsula in Pembrokeshire. Grey seal photo-ID images were taken on an opportunistic basis throughout the year by the RSPB warden and were entered into an append version of the EIRPHOT database. SMRU received this append database with 654 extracts waiting to be extracted from 379 images, across 168 sampling occasions in 2015 and 2016.

4.2.4. Cardigan Bay raw data

A second append database was constructed by SMRU from the Cardigan Bay Marine Wildlife Centre (CBMWC) data supplied in January 2017. The collection of data folders supplied by CBMWC contained a total of 12,459 images taken from boats and land between 2004 and 2016, including many non-seal photos and multiple images of a single seal from a single sampling occasion. A subset of these sampling occasions were prioritised (mainly by the number of seals photographed) and entered into an append database. Pelage patterns from

images were then extracted and entered into EIRPHOT to run through the computer-aided pattern recognition process.

4.3. Data preparation

4.3.1. AgeSex

This analysis focussed on adult female grey seals but the EIRPHOT database also contains images of males, juveniles and pups; these extracts were temporarily set aside from the library. The database also contains images from individuals of unknown age and sex; these have been assumed to be adult females and were included for analysis.

4.3.2. Data cleaning

Data were inspected and cleaned where necessary. This included correcting the dates of some sampling occasions, and unmatching images of multiple individuals assigned to the same ID. Some data had to be excluded from analysis due to conflicting metadata. Appendix 2 outlines the changes made in the data cleaning process.

4.4. Data processing

4.4.1. ExtractCompare

Pattern extracts from images entered into EIRPHOT were compared using *ExtractCompare* (EC) software. This process is made up of data input, pattern extraction, batch comparison and visual confirmation. For each stage of this process, extracts are given an AutoMatch value as follows:

- C the extract has been entered and assigned to an image, encounter and sighting,
- E the extract has been entered and is ready to be extracted,
- P the extract has been extracted and is ready to be batch compared,
- V the extract has been batch compared and is ready to be visually confirmed,
- L the extract has been visually confirmed and has been stored in the library.

Extracts can be set aside at any stage of this process and excluded from analysis.

Image data input was completed by NRW before delivery to SMRU. Pattern extraction, batch comparison and visual confirmation were completed by SMRU. Batch comparisons of new extracts with the existing database were performed overnight in EC as comparisons frequently took over six hours to run.

As a result of batch comparison, EC generates highest ranking pairs of extracts which are contenders for matches between the same aspect and side under consideration. These pairs are scored by two algorithms and are ranked from highest to lowest combined score. Potential matches with a combined score exceeding a threshold of 0.75 are then visually confirmed. This is a conservative method which ensures a low false rejection rate but may require a large number of non-matching pairs to be inspected (Hiby *et al.* 2013).

Multibiometric identification can reduce recognition error (Jain 2007). Up to six extracts are possible from a single grey seal; however, these are unlikely to be independent. In our analyses, we used a single aspect from a single side of an animal to reduce the likelihood of producing capture histories for "ghost" individuals (Hiby *et al.* 2013). One way ghost individuals are created is when images from the same individual do not contain the same aspect and side, so cannot be matched and therefore appear to be two separate individuals.

Although some images of males are present in EIRPHOT, male grey seal pelage patterns (at least on the standard aspects used for females) are not distinct enough for successful use of the comparison algorithms within the software (Hiby *et al.* 2013). Males were excluded from further analyses.

4.4.2. Image quality assessment

To investigate whether the quality of images within EIRPHOT are consistent or biased to location, we tested the quality of 30 randomly selected images with head extracts for the main sampling areas: Skomer, Ramsey, Marloes (the Marloes Peninsula), Bardsey, Cardigan Bay, the Dee Estuary and the Skerries. Random numbers were generated using R (R Development Core Team 2008, function *runif*) with the upper limit set to the number of images with head extracts for each location. The images were then ordered by date and those at the position in the database of the random numbers were inspected for image quality.

Images were first checked and given a score for species (*Halichoerus grypus* = 1, *Phocina vitulina* = 0) and sex (Female = 1, Male = 0). The quality of each image was then assessed with a score out of 10 (1 worst, 10 best) for the following criteria: focus, contrast, angle and glare. The mean of these four scores was then calculated. The proportion of the extractable area visible and unobstructed was multiplied by the mean scores, the species and the sex scores, to give an index of overall quality. The proportion of unusable images in the sample of 30 was then calculated and termed the site-specific quality error (SQE).

4.4.3. Capture histories

Capture histories were produced using Spatially Explicit Capture-Recapture (SECR) software developed for NRW by one of the authors (Lex Hiby) and later modified to enable more flexible outputs. Outputs from the present work are Excel spreadsheets where, for a specified aspect, each row represents a uniquely identifiable seal, each column represents a time period during which the individual has been photographed and matched to a previous image, and values in each spreadsheet cell are the location code in which the animal was seen first during that period. Details of the location codes can be found in the second sheet of each capture history spreadsheet, and are consistent with the locations table within EIRPHOT.

Capture history tables were generated to include all sites across all years within the EIRPHOT database after Ramsey Island and Cardigan Bay data were added. These comprised of images associated with 280 locations from 1992 to 2016. Capture histories used a single aspect and side. Unique identities from head extracts were most numerous within the database due to a historical bias towards photographing heads, whereas in more recent years, neck extracts were favoured suggesting capture histories of recent data may benefit from utilising neck extracts. Flank extracts were under-represented within the data as these are often the most difficult to capture, particularly with animals in the water.

Photo surveys were not carried out at the same frequency at different sites and across seasons and years, so the time step for sightings was set to calendar months. Where more frequent surveys were carried out, this had the effect of excluding day to day fluctuations in occurrence. If an individual was seen more than once within a month, only the first location was reported. However, each cell in the capture history spreadsheets was colour coded within Excel to represent the number of times the individual was seen within that time frame.

Capture history spreadsheets were then translated into text files in the format necessary for Program MARK input files. These consist of a list of unique identities, followed by a binary 1/0 pattern of presence/absence at different time periods and a binary group (all individuals were placed in group 1). The time step for presence/absence was set to years.

5. Results and discussion

5.1. EIRPHOT data

With new Ramsey Island and Cardigan Bay data included in EIRPHOT, and after data cleaning, the EIRPHOT database consists of 35,724 extracts, from 17,056 images across 3,273 sampling occasions (Figure 2).

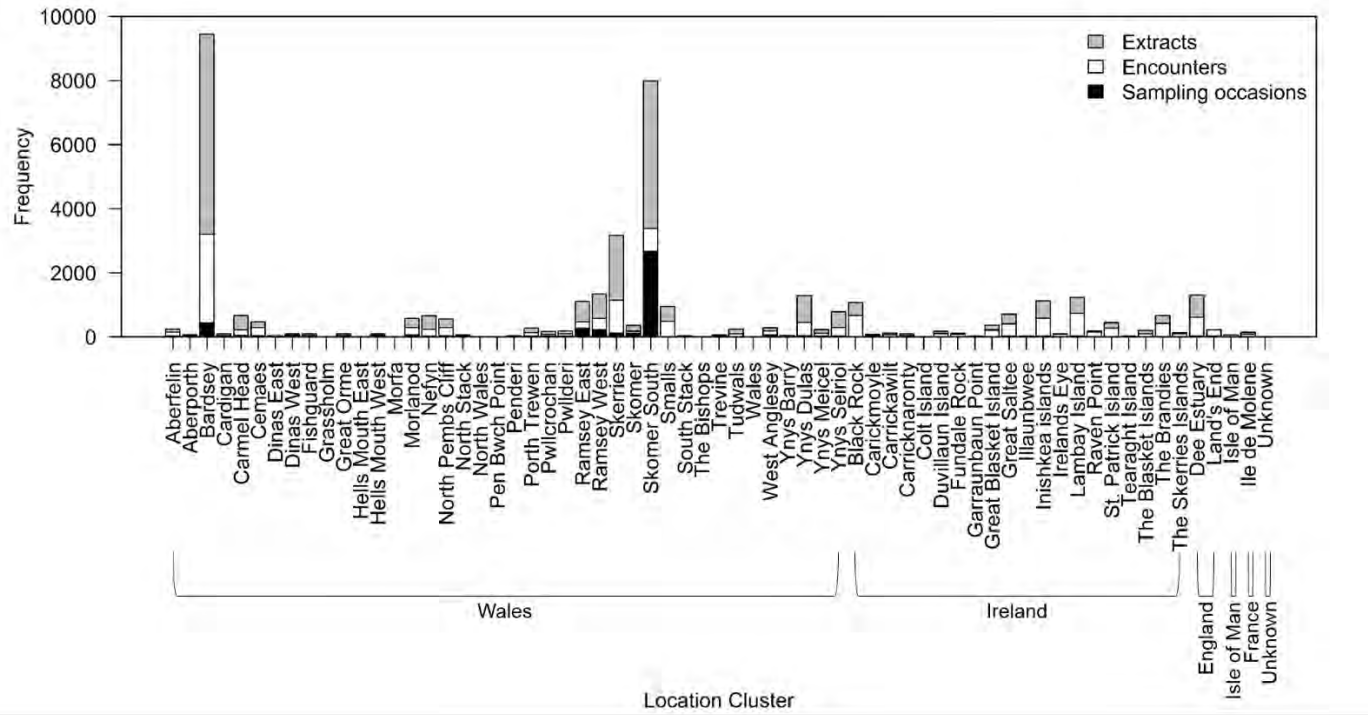

Figure 2. The number of extracts, encounters and sampling occasions within the EIRPHOT database, for each location cluster.

The majority of extracts within the EIRPHOT database are from Bardsey, closely followed by Skomer South and then the Skerries.

Within the EIRPHOT library there were 463 head extracts and 80 neck extracts from images of males, juveniles or pups. These extracts were temporarily set aside from the library for this analysis and have been given the AutoMatch value Lp (Table 1).

Table 1. The number of head and neck extracts assigned to each age/sex category; female (F), male (M), juvenile (J), pup (P), unknown (U) and those left blank. AutoMatch L are extracts within the library and included in analysis, AutoMatch Lp have been temporarily set aside from analysis.

AgeSex	Head extracts	Neck extracts	AutoMatch
F	11,236	2,546	L
M	207	23	Lp
J	2	0	Lp
P	254	57	Lp
U	987	335	L
[blank]	11,326	5	L

There were 987 head extracts and 335 neck extracts from individuals with unknown sex, and 11,326 head extracts and five neck extracts that have been entered into the database with the *AgeSex* data omitted. These extracts have been assumed to have come from images of adult females and were included in the analysis.

Head extracts were more numerous than necks and flanks both overall, and for the seven main areas covered in EIRPHOT (Table 3). The most numerous side in the database was not consistent across the locations, so analysis was performed on both left and right head extracts, and two capture history sets were generated.

Table 2. Summary of the number of unique individuals identified from the same aspect (head/neck/flank) and side (left/right) under consideration for all sites and the seven main areas covered in EIRPHOT. The most numerous extracts for each side are highlighted in grey.

	All sites		Skomer		Ramsey		Marloes		Bardsey		Cardigan Bay		Dee Estuary		Skerries	
	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
Head	2980	2997	598	593	339	349	78	74	736	673	172	169	236	180	294	318
Neck	1063	1082	309	318	287	285	76	70	250	266	13	11	12	13	68	80
Flank	295	298	183	180	118	115	3	3	5	7	5	8	0	0	2	2

5.2. Image quality assessment

For the seven main areas, images from Cardigan Bay had the highest quality error (SQE) with 27% of those inspected too low in quality for semi-automated pattern recognition software. Images from Bardsey, the Dee Estuary and the Skerries all had a SQE of 17% and both Ramsey and Marloes had a SQE of 10%. The highest quality images within this analysis were from Skomer, with only 7% of those inspected too low in quality for EC. Full details of the image quality analysis can be found in Appendix 1, and a summary is shown in Table 4.

Table 3. Summary of image quality assessment, with mean values for species (Sp: *Hg* = 1, *Pv* = 0), sex (F = 1, M = 0), focus, contrast, angle and glare (1-10), visibility (proportion of area), mean score, quality score and site-specific quality error (SQE). Further details in Appendix 1.

Area	Sp.	Sex	Focus	Contrast	Angle	Glare	Visibility	Mean	Score	SQE
Skomer	1.00	1.00	5.97	6.83	7.37	8.43	0.92	7.15	6.68	0.07
Ramsey	1.00	1.00	4.20	5.50	8.00	7.23	0.97	6.23	6.02	0.10
Marloes	1.00	1.00	5.33	6.13	7.70	7.33	0.98	6.63	6.52	0.10
Bardsey	1.00	0.97	4.83	5.60	7.57	5.03	0.98	5.76	5.50	0.17
Cardigan Bay	1.00	0.97	3.17	4.17	7.43	6.47	0.91	5.31	4.71	0.27
Dee Estuary	1.00	1.00	4.40	5.63	7.47	5.90	0.97	5.85	5.67	0.17
Skerries	1.00	0.97	4.53	4.83	6.83	6.50	0.99	5.68	5.39	0.17

There was one location in each of three areas that had a single image of a male with the *AgeSex* column left blank; Bardsey, Cardigan Bay and the Skerries.

The most prominent issue with image quality overall was focus. At times this can be difficult to avoid, especially when working from a boat. However, the effects can be reduced by ensuring the contrast is high, the angle is as close to 90° as possible and there is little glare. Quality control should also be employed during the data input stage to ensure only images with sufficient quality are added to the database.

The proportion of the extractable area visible was high for all locations, and well above the 50% threshold for what EC algorithms can utilise.

A one-way Analysis of Variance (ANOVA) found a significant difference between the mean image quality scores across areas ($F = 5.138$, $df = 6$, $p < 0.001$). A post-hoc Tukey-Honest Significant Difference (HSD) test found significant differences between Skomer-Cardigan Bay ($p < 0.001$), Skomer-Skerries ($p < 0.05$), Ramsey-Cardigan Bay ($p < 0.05$), and Marloes-Cardigan Bay ($p < 0.001$) (Figure 3).

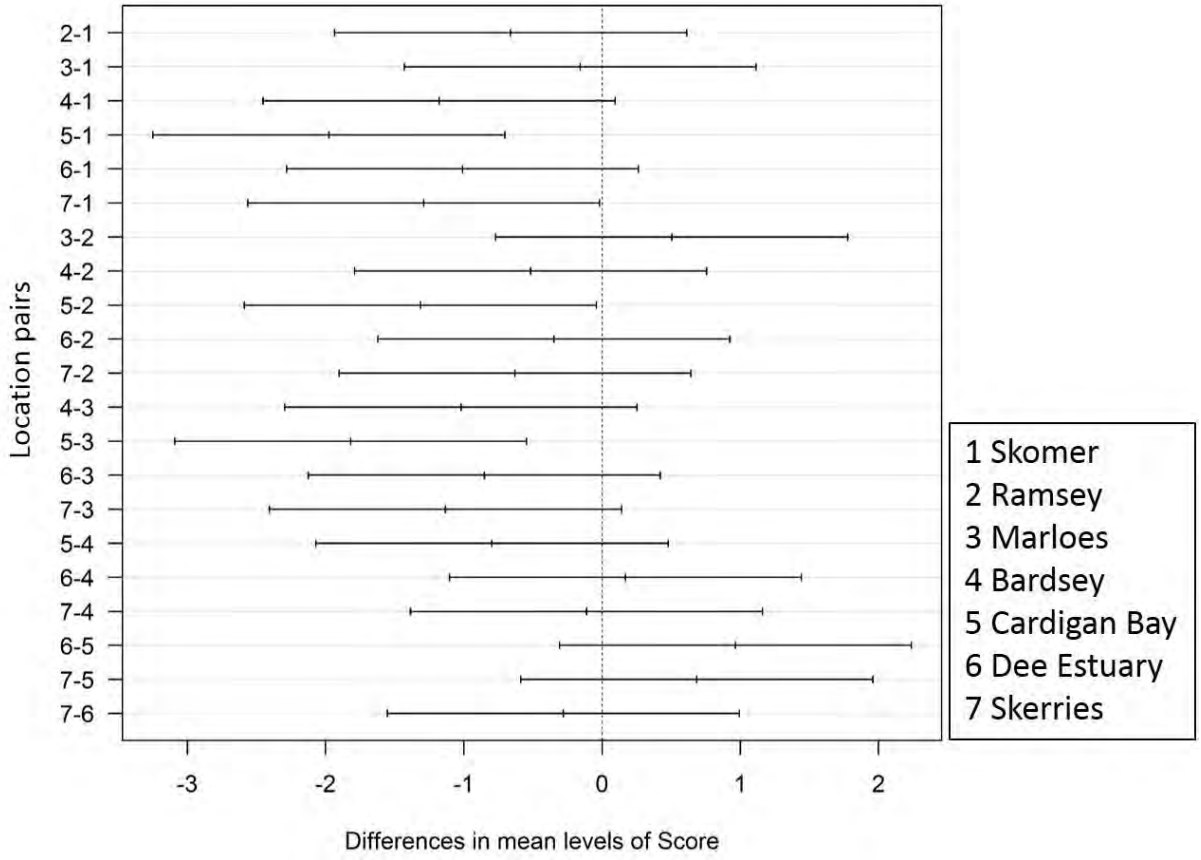

Figure 3. Tukey-HSD 95% confidence levels for image quality scores across the seven main areas within the EIRPHOT database.

5.3. Captures and recaptures

Capture histories were generated from 12,494 left and 13,099 right head extracts. The capture frequency for left and right head extracts are shown in Figure 4.

For both left and right head extracts, the vast majority of unique individuals were only seen once (2,332 and 2,307 individuals respectively). For left head extracts, there were 642 unique individuals seen more than once, and so recaught in the time between 1992 and 2016. For right head extracts, there were 676 unique individuals seen more than once. The highest number of captures was 13, and this single individual was identified by left head extracts.

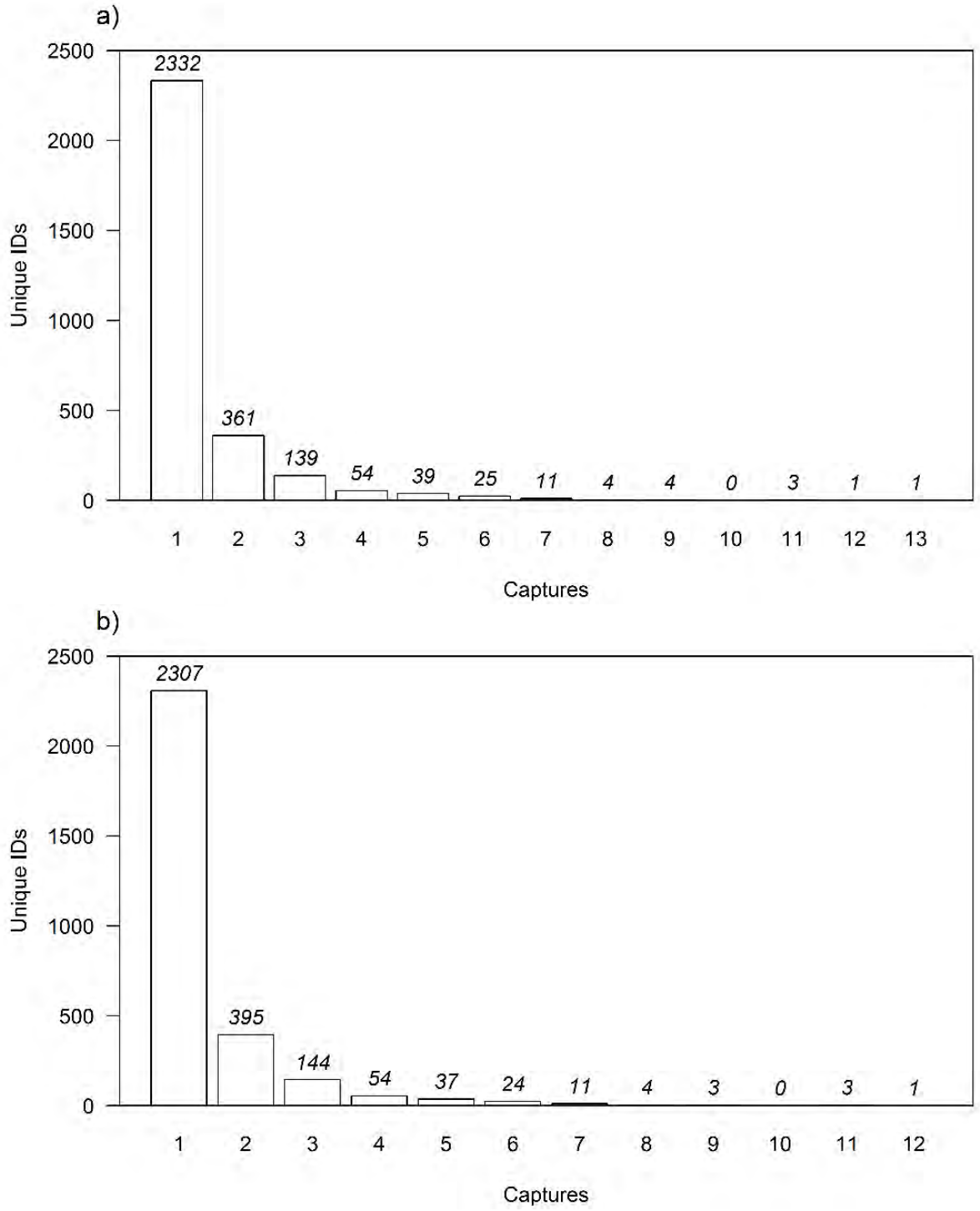

Figure 4. The capture frequency for unique individuals identified by a) left, and b) right head aspects. Captures >1 represent recaptured individuals.

The total number of captures per year are shown in Figure 5. The majority of captures occurred between 2009 and 2012, with early effort showing a smaller peak between 1996 and 1998. For both individuals identified by left and right head extracts, no captures occurred in 2000.

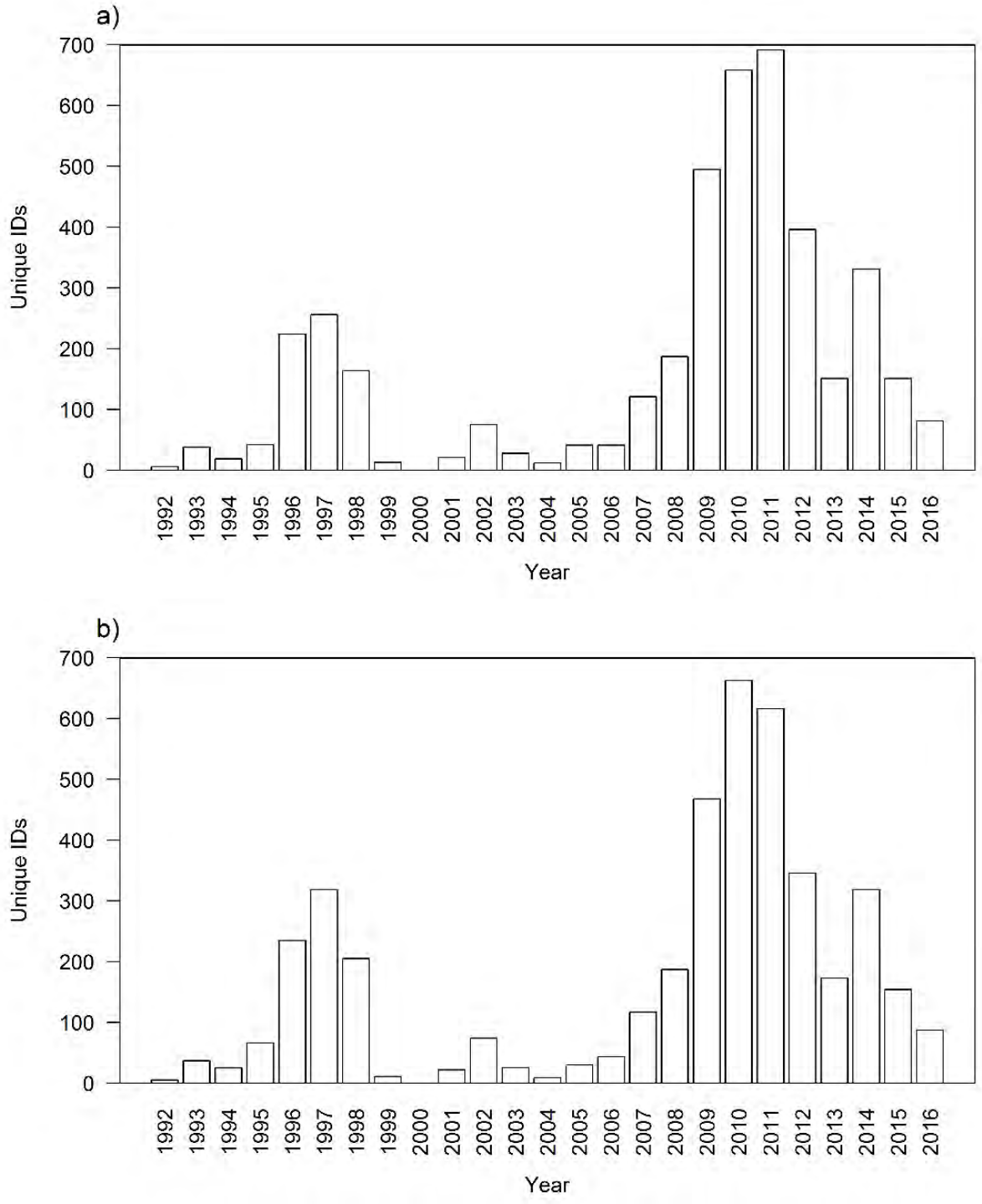

Figure 5. The number of unique individuals captured each year, identified by a) left and b) right head extracts.

5.4. Spatial connectivity

The EIRPHOT database contained 2,974 unique individuals identified from left head extracts between 1992 and 2016. Of these, 2,332 were only seen once (Table 5) with Marloes and Cardigan Bay extracts together contributing only 7% of the data. The database also contained 2,983 unique individuals identified from right head extracts between 1992 and 2016. Of these, 2,307 were only seen

once with Marloes, Cardigan Bay and the Dee Estuary areas contributing least (≤ 7%) to the dataset (Table 6).

Table 5. The number and proportion of unique individuals identified from left head extracts in the EIRPHOT database only seen once between 1992 and 2016 (*n* = 2,332).

Area	Count	Proportion
Skomer	430	0.18
Ramsey	267	0.11
Marloes	53	0.02
Bardsey	545	0.23
Cardigan Bay	124	0.05
Dee Estuary	222	0.10
Skerries	224	0.10
Other	467	0.20

Table 6. The number and proportion of unique individuals identified from right head extracts in the EIRPHOT database only seen once between 1992 and 2016 (*n* = 2,307).

Area	Count	Proportion
Skomer	420	0.18
Ramsey	277	0.12
Marloes	51	0.02
Bardsey	491	0.21
Cardigan Bay	116	0.05
Dee Estuary	165	0.07
Skerries	245	0.11
Other	542	0.23

Of the remaining 642 and 676 individuals (identified from left and right head extracts respectively) seen more than once, the individual with the highest number of recaptures, and the longest capture history, was “SH_057” who was first recorded at J090 (Castle Bay, Skomer) and was recaught 12 times between 1993 and 2016, at locations J090, J100 (Matthew’s Wick, Skomer), J020 (The Wick, Skomer), G020 (Garlic, Ramsey) and G030 (Aber Mawr, Ramsey).

Irrespective of time, the total number of recaptures between each pair of locations in the seven broad areas for individuals identified from left and right head extracts are summarised in Table 7 and Table 9, with the probabilities of recapture summarised in Table 8 and Table 10. For each broad area, the highest probability of recaptures occured in the same area.

The highest probability of inferred movement to Skomer was from Marloes (from both left [p_l] and right [p_r] head extracts = 0.19). The highest probability of inferred movement from Skomer was to Ramsey (both p_l and p_r = 0.08). Skomer was connected with all other broad areas within the EIRPHOT database. However, only single individuals were recorded to have moved from Skomer to the Dee Estuary and to the Skerries, and from Cardigan Bay to Skomer.

The highest probability of movement to Ramsey was from Marloes (p_l = 0.1, p_r = 0.06) and from Skomer (p_l and p_r = 0.08). The highest probability of movement from Ramsey was to Skomer (p_l = 0.11, p_r = 0.08) and to "other" (p_l = 0.05, p_r = 0.08). Ramsey was connected to all other broad areas within the EIRPHOT database excluding the Dee Estuary.

There was little movement between Marloes and other locations within the EIRPHOT database. The highest probability of movement to Marloes was from Skomer (p_l = 0.02, p_r = 0.03) and Ramsey (p_l = 0.02, p_r = 0). The highest probability of movement from Marloes was to Skomer (p_l and p_r = 0.19). There were no recorded individuals that moved between Marloes and Cardigan Bay, the Dee Estuary, the Skerries or locations outside of the seven main areas.

The highest probability of movement to Bardsey was from the Skerries (p_l = 0.13, p_r = 0.11) and from the Dee Estuary (p_l = 0, p_r = 0.13). The highest probability of movement from Bardsey was to the Skerries (p_l and p_r = 0.03) and "other" (p_l = 0.02, p_r = 0.03). Bardsey was connected to all other broad areas within the EIRPHOT database excluding the Dee Estuary; however, only a single individual moved from Bardsey to Marloes.

The highest probability of movement to Cardigan Bay was from "other" (p_l and p_r = 0.03) and from Ramsey (p_l = 0.02, p_r = 0.03). The highest probability of movement from Cardigan Bay was to locations outside the main seven areas (p_l = 0.25, p_r = 0.26). Cardigan Bay was connected to all other broad areas excluding Marloes and the Dee Estuary; however, only a single individual moved from Cardigan Bay to the Skerries.

The Dee Estuary was the least connected out of the broad areas within the EIRPHOT database, with no movement to or from Skomer, Ramsey, Marloes or Cardigan Bay. The highest probability of movement to the Dee Estuary was from the Skerries (p_l = 0.06, p_r = 0.09). There were only two recorded individuals that moved from the Dee Estuary; one was later recorded at Bardsey, and one moved to a location outside of the seven broad areas.

The highest probability of movement to the Skerries was from locations outside the main seven areas (p_l and p_r = 0.04). The highest probability of movement from the Skerries was to Bardsey (p_l = 0.13, p_r = 0.11). The Skerries were connected to all other broad areas within the EIRPHOT database, excluding Marloes. However, only single individuals were recorded to have moved from Skomer, Ramsey and Cardigan Bay to the Skerries.

Table 7. The number of recaptures of unique individuals identified from left head extracts between pairs of locations in the seven broad areas within the EIRPHOT database. Location 1 is the origin and Location 2 is the destination.

		Location 2							
		Skomer	Ramsey	Marloes	Bardsey	Cardigan Bay	Dee Estuary	Skerries	Other
Location 1	Skomer	267	26	7	7	3	1	1	4
	Ramsey	7	51	1	2	1	0	1	3
	Marloes	4	2	15	0	0	0	0	0
	Bardsey	7	5	1	298	0	0	10	8
	Cardigan Bay	0	1	0	4	40	0	1	15
	Dee Estuary	0	0	0	0	0	4	0	1
	Skerries	0	0	0	10	0	5	58	7
	Other	6	3	0	13	11	5	17	328

Table 8. The probability of recaptures of unique individuals identified from left head extracts between pairs of locations in the seven broad areas within the EIRPHOT database. Location 1 is the origin and Location 2 is the destination.

		Location 2							
		Skomer	Ramsey	Marloes	Bardsey	Cardigan Bay	Dee Estuary	Skerries	Other
Location 1	Skomer	0.84	0.08	0.02	0.02	0.01	0	0	0.01
	Ramsey	0.11	0.77	0.02	0.03	0.02	0	0.02	0.05
	Marloes	0.19	0.10	0.71	0	0	0	0	0
	Bardsey	0.02	0.02	0	0.91	0	0	0.03	0.02
	Cardigan Bay	0	0.02	0	0.07	0.66	0	0.02	0.25
	Dee Estuary	0	0	0	0	0	0.80	0	0.20
	Skerries	0	0	0	0.13	0	0.06	0.73	0.09
	Other	0.02	0.01	0	0.03	0.03	0.01	0.04	0.86

Table 9. The number of recaptures of unique individuals identified from right head extracts between pairs of locations in the seven broad areas within the EIRPHOT database. Location 1 is the origin and Location 2 is the destination.

		Location 2							
		Skomer	Ramsey	Marloes	Bardsey	Cardigan Bay	Dee Estuary	Skerries	Other
Location 1	Skomer	262	24	10	6	3	0	1	5
	Ramsey	5	50	0	3	2	0	1	5
	Marloes	3	1	12	0	0	0	0	0
	Bardsey	6	4	1	288	0	0	8	8
	Cardigan Bay	1	1	0	4	39	0	1	16
	Dee Estuary	0	0	0	1	0	6	0	1
	Skerries	0	0	0	9	0	7	59	7
	Other	6	4	0	13	11	2	17	359

Table 10. The probability of recaptures of unique individuals identified from right head extracts between pairs of locations in the seven broad areas within the EIRPHOT database. Location 1 is the origin and Location 2 is the destination.

		Location 2							
		Skomer	Ramsey	Marloes	Bardsey	Cardigan Bay	Dee Estuary	Skerries	Other
Location 1	Skomer	0.84	0.08	0.03	0.02	0.01	0	0	0.02
	Ramsey	0.08	0.76	0	0.05	0.03	0	0.02	0.08
	Marloes	0.19	0.06	0.75	0	0	0	0	0
	Bardsey	0.02	0.01	0	0.91	0	0	0.03	0.03
	Cardigan Bay	0.02	0.02	0	0.06	0.63	0	0.02	0.26
	Dee Estuary	0	0	0	0.13	0	0.75	0	0.13
	Skerries	0	0	0	0.11	0	0.09	0.72	0.09
	Other	0.01	0.01	0	0.03	0.03	0	0.04	0.87

6. Conclusions and recommendations

6.1. Summary of findings

On completion of this analysis, the EIRPHOT database contains 35,724 extracts, from 17,056 images across 3,273 sampling occasions between 1992 and 2016. Almost 30% of these extracts came from individuals identified at Bardsey and just over 20% came from Skomer.

For the main seven areas within the EIRPHOT database, the highest quality images were taken at Skomer and the lowest quality images were taken at Cardigan Bay. The most prominent issue in quality was image focus and the misidentification/non-identification of sex.

The majority of individuals identified within the EIRPHOT database were only seen once. The individual with the highest number of recaptures, and the longest capture history, was “SH_057” who was first recorded at Castle Bay (Skomer) and was recaught 12 times between 1993 and 2016 on Skomer and Ramsey.

Overall, there was a high degree of connectivity among areas across years, with most connection from seals within areas and among seal sites in the region. Skomer was connected with all other broad areas within the EIRPHOT database and Ramsey and Bardsey were connected to all other broad areas excluding the Dee Estuary. This evidence of connectivity supports the findings of Thompson (2011) which demonstrated shorter term (weeks-months) movements and connections of satellite tracked grey seals to sites throughout the Irish and Celtic Seas.

The least connected area within EIRPHOT was the Dee Estuary, although this could be due to less photo-ID effort there. All of the other locations are breeding sites, where seals are likely to be more site faithful within and between seasons (Pomeroy *et al.* 2000); the sites in the Dee estuary area, however, are non-breeding haul-outs (Westcott and Stringell, 2004). It is possible that this area is a transitory ‘rest’ area for seals passing through.

6.2. Recommendations

6.2.1. Duplicate images

The more images of the same individual that are entered into the database, the greater the likelihood of making a match (Hiby *et al.* 2013). However, it was noted that there are duplicates of the same image within EIRPHOT, sometimes with the original and also a cropped version. Exact duplicates slow down the EC process and add nothing to analyses.

6.2.2. *A priori* matches

It was noted that there are instances of multiple images from the same sampling occasion having the same identifying letter within the image name. If these are known to be the same individual *a priori*, they should be entered as the same individual. For example, there was one pair of extracts that were taken on the same day, by the same photographer, and were given the same unique identifier, but had a combined score below the 0.75 threshold. These extracts were visually confirmed as a match. The low combined score is likely due to the poor quality of one of the extracts and highlights that images from the same individual should not be added separately, as EC may falsely reject them resulting in the database containing an inflated number of unique identities.

6.2.3. Multiple photographers

Having more than a single photographer at each sampling occasion may increase the overall coverage but at the cost of slowing down the entire EC process and requiring significant cross-checking. If there are consistently two photographers, twice as much data are input, extracted, compared and visually confirmed.

6.2.4. Fine scale locations

Duplicated images (original and cropped versions) have been added to the database separately and have been assigned slightly different locations. This could be a result of having defined small scale locations with lat/lon coordinates (e.g. EHENSE, EHENS) and broader scale locations with no lat/lon coordinates (e.g. EH, EEMD).

7. Acknowledgements

This work is the product of over two decades of collective effort on grey seal PhotoID across Wales, Ireland and beyond. It has involved the energy, enthusiasm and support of many contributors, collaborators and organisations, most of which offered their time and resources voluntarily. We thank you. This report summarises this work over that time period for key areas around Wales and hopefully represents an important resource for contributors.

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9. Appendices

9.1. Appendix 1 – Image quality assessment

Table A1. Quality assessment of images randomly selected from EIRPHOT that have head extracts in the Skomer library. Species (Sp.) 1 = F, 0 = M. Focus, contrast, angle, glare and mean scored out of 10. Visibility is the proportion of the extract that is visible to be extracted. Score is the mean multiplied by the visibility, species and sex. Images too poor in quality for EC are highlighted in grey; means are shown in the final row.

	runif	Image	Date	Location	Sp.	Sex	Focus	Contrast	Angle	Glare	Visibility	Mean	Score
1	374	97SMALLS\F09WE010	09/08/1997	SMALLS	1	1	4	7	8	10	1	7.25	7.25
2	680	Shoulder_scars\SH-132Lp15	03/09/2009	J140	1	1	8	5	7	4	0.8	6	4.8
3	1510	20121023_SBS\11.C109.SBS (2012-1)p67	23/10/2012	J060	1	1	8	5	8	10	1	7.75	7.75
4	572	Indistinct cows_2008\C062_Rp84	15/09/2008	J040	1	1	9	9	9	8	1	8.75	8.75
5	137	97SMALLS\F02CP026	07/07/1997	SMALLS	1	1	2	4	9	10	1	6.25	6.25
6	1394	20120921_DWB\12.C040.DWB (2012-4)p45	21/09/2012	J050	1	1	8	9	8	9	0.9	8.5	7.65
7	456	97SMALLS\F13WE021	26/09/1997	SMALLS	1	1	3	6	7	10	1	6.5	6.5
8	1287	20111027_CBY\11.C110.CBY (2011-2)p34	27/10/2011	J090	1	1	7	7	8	9	1	7.75	7.75
9	829	Left_side_scars\LS-122Lp46	11/10/2009	J140	1	1	6	8	9	8	1	7.75	7.75
10	402	97SMALLS\F10CP020	09/08/1997	SMALLS	1	1	2	4	6	9	1	5.25	5.25
11	1347	20120829_DWB\12.C008.DWB (2012-1)p65	29/08/2012	J050	1	1	9	8	9	10	1	9	9
12	956	20100907_SSC\10.C007.SSC_2p43	07/09/2010	J030	1	1	5	8	6	8	1	6.75	6.75
13	132	97SMALLS\F02CP017	07/07/1997	SMALLS	1	1	4	8	4	10	1	6.5	6.5
14	308	97SMALLS\F07WE023	21/07/1997	SMALLS	1	1	4	6	1	8	0.2	4.75	0.95
15	1526	20121029_MWK\08.C066.MWK (2012-1)p53	29/10/2012	J100	1	1	7	6	7	10	1	7.5	7.5
16	861	20091023_NHV\09.C107.NHV (2009-1)p55	23/10/2009	J140	1	1	8	9	10	10	1	9.25	9.25
17	2079	14SNHV\0103 14.SC310.NHV.101114	09/11/2014	J140	1	1	5	7	6	7	1	6.25	6.25
18	1666	14SMWK\4145 14.SC306.MWK.130914	13/09/2014	J100	1	1	3	7	7	9	1	6.5	6.5
19	1406	20120926_SSC\10.C054.SSC (2012-3)p43	26/09/2012	J030	1	1	8	6	8	4	1	6.5	6.5
20	1747	14SDWB\5112 14.SC047.DWB.220914	22/09/2014	J050	1	1	6	5	7	10	1	7	7
21	675	Shoulder_scars\SH-134Lp16	01/09/2009	J090	1	1	7	9	8	6	1	7.5	7.5
22	1924	14SSSC\6902 14.SC-NK-139.SSC.151014	14/10/2014	J030	1	1	8	6	7	10	1	7.75	7.75
23	1792	14SCBY\13.SC053.CBY.280913.1	28/09/2014	J090	1	1	5	6	9	9	1	7.25	7.25
24	84	96SMALLS\F01WE021	02/09/1996	SMALLS	1	1	3	7	7	6	0.7	5.75	4.03
25	1296	20111103_MWK\11.C123.MWK (2011-2)p44	03/11/2011	J100	1	1	7	8	7	10	1	8	8
26	845	Indistinct_cows_2009\C108_Rp83	16/10/2009	J050	1	1	4	6	8	6	1	6	6
27	539	Lowerback_scars\LBK-137Lp13	06/09/2008	J140	1	1	7	8	7	8	1	7.5	7.5
28	1254	20111008_AMR\10.C108.AMR (2011-1)p43	08/10/2011	J110	1	1	8	8	9	8	1	8.25	8.25
29	552	Indistinct cows_2008\C040_Lp04	09/09/2008	J090	1	1	7	5	7	7	0	6.5	0
30	1505	20121022_NHV\08.C117.NHV (2012-1)p55	22/10/2012	J140	1	1	7	8	8	10	1	8.25	8.25
					1	1	5.97	6.83	7.37	8.43	0.92	7.15	6.68

Table A2. Quality assessment of images randomly selected from EIRPHOT that have head extracts in the Ramsey library. Species (Sp.) 1 = F, 0 = M. Focus, contrast, angle, glare and mean scored out of 10. Visibility is the proportion of the extract that is visible to be extracted. Score is the mean multiplied by the visibility, species and sex. Images too poor in quality for EC are highlighted in grey; means are shown in the final row.

	runif	Image	Date	Location	Sp.	Sex	Focus	Contrast	Angle	Glare	Visibility	Mean	Score
1	441	13G360\2662_101113	10/11/2013	G360	1	1	1	2	5	7	1	3.75	3.75
2	570	14G030\RC097 right and scar	30/09/2014	G030	1	1	7	7	10	10	1	8.5	8.5
3	898	15G220\IMG_3108 right	04/11/2015	G220	1	1	6	7	8	8	0.9	7.25	6.53
4	113	96G030\F04WE020	10/10/1996	G030	1	1	4	6	9	10	1	7.25	7.25
5	748	15G250\IMG_1650	12/09/2015	G250	1	1	5	8	8	8	1	7.25	7.25
6	91	96G030\F03WE004	10/10/1996	G030	1	1	1	2	6	6	1	3.75	3.75
7	753	15G020\IMG_1753	13/09/2015	G020	1	1	4	5	8	7	1	6	6
8	227	96G320\F02WE029	10/10/1996	G320	1	1	3	5	10	8	0.7	6.5	4.55
9	462	13G360\RC084 301113 a	30/11/2013	G360	1	1	5	4	10	8	1	6.75	6.75
10	427	13G260\RC063 191013 RSN	19/10/2013	G260	1	1	6	6	7	8	1	6.75	6.75
11	703	15G030\IMG_1333 Preg female C	28/08/2015	G030	1	1	4	6	9	3	1	5.5	5.5
12	987	16G220\IMG_7107	30/09/2016	G220	1	1	7	8	7	7	1	7.25	7.25
13	1007	16G030\IMG_7669+II	11/11/2016	G030	1	1	1	4	10	5	1	5	5
14	158	96G200\F01WE035	10/10/1996	G200	1	1	4	5	6	8	0.8	5.75	4.6
15	308	97G260\F03CP027	26/10/1997	G260	1	1	2	1	8	2	1	3.25	3.25
16	648	14G150\IMG_9684	19/11/2014	G150	1	1	7	8	7	10	1	8	8
17	50	96G010\F02WE020	10/10/1996	G010	1	1	4	6	10	6	0.9	6.5	5.85
18	53	96G010\F02WE025	10/10/1996	G010	1	1	3	6	9	7	1	6.25	6.25
19	869	15G030\IMG_2845 +III	23/10/2015	G030	1	1	5	6	9	6	1	6.5	6.5
20	1	96G010\F01WE011	14/09/1996	G010	1	1	4	4	8	10	0.7	6.5	4.55
21	949	16G140\IMG_6734	25/08/2016	G140	1	1	8	9	8	9	1	8.5	8.5
22	141	96G140\F02WE035	10/10/1996	G140	1	1	3	6	6	9	1	6	6
23	297	97G101\F01CP031	26/10/1997	G101	1	1	2	3	6	6	1	4.25	4.25
24	79	96G020\F02WE030	10/10/1996	G020	1	1	2	5	5	7	1	4.75	4.75
25	77	96G020\F02WE025	10/10/1996	G020	1	1	2	4	8	7	1	5.25	5.25
26	499	14G360\3532_270214	27/02/2014	G360	1	1	6	5	10	8	1	7.25	7.25
27	613	14G230\IMG_9300	20/10/2014	G230	1	1	9	8	9	8	1	8.5	8.5
28	1008	16G030\IMG_7671	11/11/2016	G030	1	1	6	7	8	6	1	6.75	6.75
29	627	14G260\IMG_9356	26/10/2014	G260	1	1	4	6	8	5	1	5.75	5.75
30	923	15G270\IMG_0550	02/01/2016	G360	1	1	1	6	8	8	1	5.75	5.75
					1.00	1.00	4.20	5.50	8.00	7.23	0.97	6.23	6.02

Table A3. Quality assessment of images randomly selected from EIRPHOT that have head extracts in the Marloes library. Species (Sp.) 1 = F, 0 = M. Focus, contrast, angle, glare and mean scored out of 10. Visibility is the proportion of the extract that is visible to be extracted. Score is the mean multiplied by the visibility, species and sex. Images too poor in quality for EC are highlighted in grey; means are shown in the final row.

	runif	Image	Date	Location	Sp.	Sex	Focus	Contrast	Angle	Glare	Visibility	Mean	Score
1	108	14I150\1460 JHV Cow2c 010914 KL	01/09/2014	I150	1	1	2	4	8	4	0.9	4.5	4.05
2	103	14I150\JEF Cow 1d 270814 PN	27/08/2014	I150	1	1	8	10	7	9	1	8.5	8.5
3	16	11I150\11.MPC021b.JHV	23/09/2011	I150	1	1	7	8	8	9	1	8	8
4	27	11I160\11.MPC030b.PEB	08/11/2011	I160	1	1	5	4	7	6	1	5.5	5.5
5	109	14I160\1453 PEB Cow1 010914 KL	01/09/2014	I160	1	1	6	7	8	9	1	7.5	7.5
6	128	14I198\1611 RAIN cow1 011014 KL	01/10/2014	I198	1	1	4	5	7	9	1	6.25	6.25
7	32	11I160\11.MPC034.PEB	14/11/2011	I160	1	1	4	4	6	5	1	4.75	4.75
8	69	13I176\13.MPC024.REN	23/09/2013	I176	1	1	4	5	8	9	1	6.5	6.5
9	142	14I160\1650 PEB Cow4 060914 KL	06/10/2014	I160	1	1	8	6	9	10	1	8.25	8.25
10	160	14I130\MHV Cow1b 141114 PN	14/11/2014	I130	1	1	9	9	10	7	1	8.75	8.75
11	40	12I160\12.MPC004.PEB	10/09/2012	I160	1	1	2	3	6	4	1	3.75	3.75
12	82	13I160\13.MPC034.PEB	02/10/2013	I160	1	1	4	4	7	8	1	5.75	5.75
13	117	14I160\1496 PEB Cow1 090914 KL	09/09/2014	I160	1	1	7	5	8	7	1	6.75	6.75
14	157	14I160\1815 PEB Cow3 111114 KL	11/11/2014	I160	1	1	5	7	9	8	1	7.25	7.25
15	143	14I130\1694 MHV Cow1 131014 KL	13/10/2014	I130	1	1	3	4	8	10	1	6.25	6.25
16	30	11I160\11.MPC033.PEB	10/11/2011	I160	1	1	9	10	9	9	1	9.25	9.25
17	37	11I160\11.MPC.sc5d.PEB	17/11/2011	I160	1	1	3	4	7	9	1	5.75	5.75
18	49	13I150\13.MPC001.JHV	29/08/2013	I150	1	1	7	9	7	3	0.6	6.5	3.9
19	100	13I176\13.MPC047.REN	14/11/2011	I160	1	1	4	7	9	5	1	6.25	6.25
20	119	14I160\1500 PEB Cow2 090914 KL	24/10/2013	I176	1	1	5	8	5	9	1	6.75	6.75
21	57	13I196\13.MPC006.3DRb	09/09/2014	I160	1	1	4	5	8	6	1	5.75	5.75
22	168	14I150\1929 JEFCow1 201114 KL	11/09/2013	I196	1	1	4	5	8	7	1	6	6
23	165	14I160\1917 PEBCow1 191114 K	20/11/2014	I150	1	1	6	7	9	9	1	7.75	7.75
24	114	14I160\1471 PEB Cow5b 030914 KL	19/11/2014	I160	1	1	5	8	9	4	1	6.5	6.5
25	135	14I160\1629 PEB Cow3 021014 KL	03/09/2014	I160	1	1	4	5	8	8	1	6.25	6.25
26	120	14I160\1503 PEB Cow3b 090914 KL	02/10/2014	I160	1	1	5	6	8	9	1	7	7
27	169	14I150\1931 JEFCow1 201114 KL	09/09/2014	I160	1	1	7	8	7	9	1	7.75	7.75
28	127	14I160\1572 PEB Cow1b 170914 KL	20/11/2014	I150	1	1	7	6	6	8	1	6.75	6.75
29	98	13I130\13.MPC045.MHV	17/09/2014	I160	1	1	9	7	9	9	1	8.5	8.5
30	85	13I210\13.MPC033c.LCA	02/10/2013	I210	1	1	3	4	6	2	1	3.75	3.75
					1.00	1.00	5.33	6.13	7.70	7.33	0.98	6.63	6.52

Table A4. Quality assessment of images randomly selected from EIRPHOT that have head extracts in the Bardsey library. Species (Sp.) 1 = F, 0 = M. Focus, contrast, angle, glare and mean scored out of 10. Visibility is the proportion of the extract that is visible to be extracted. Score is the mean multiplied by the visibility, species and sex. Images too poor in quality for EC are highlighted in grey; means are shown in the final row.

	runif	Image	Date	Location	Sp.	Sex	Focus	Contrast	Angle	Glare	Visibility	Mean	Score
1	2051	ETB_231110\ZZZZK_7187p83	23/11/2010	ETB	1	1	7	6	6	7	1	6.5	6.5
2	1104	EHEN_260910\ZR_0329p74	26/09/2010	EHEN	1	1	3	3	6	2	1	3.5	3.5
3	2563	EHENS_010711\PP_5649p43	01/07/2011	EHENS	1	1	6	4	8	4	1	5.5	5.5
4	2095	EHENSE_301210\L_7696p72	30/12/2010	EHENSE	1	1	6	5	9	5	1	6.25	6.25
5	579	EHEN_161008\ZI_7287	16/10/2008	EHEN	1	1	7	6	8	4	1	6.25	6.25
6	1448	EHENS_011010\ZH_2335p12	01/10/2010	EHENS	1	1	7	7	9	6	1	7.25	7.25
7	1521	EHENS_021010\T_2941p42	02/10/2010	EHENS	1	1	7	7	6	7	1	6.75	6.75
8	1626	EHENSE_031010\Xa_5874p53	03/10/2010	EHENSE	1	1	8	6	10	4	1	7	7
9	1279	EHENS_290910\ZO_1659p23	29/09/2010	EHENS	1	1	7	7	7	1	1	5.5	5.5
10	734	EHENSE_210909\Q_2131p44	21/09/2009	EHENSE	1	1	8	7	10	8	1	8.25	8.25
11	751	EHENS_220909\J_2340p44	22/09/2009	EHENS	1	1	7	7	7	5	1	6.5	6.5
12	1356	EHENS_300910\ZQ_2086p47	30/09/2010	EHENS	1	1	7	5	5	2	1	4.75	4.75
13	78	CYMRUPHOT 2002 EHEN_1\EHEN_051002_34_RF	05/10/2002	EHEN	1	1	2	7	6	8	1	5.75	5.75
14	2413	EHEN_300511\L_0790p23	30/05/2011	EHEN	1	1	2	1	7	5	1	3.75	3.75
15	652	EPH_171008\L_0310	17/10/2008	EPH	1	1	1	2	8	2	1	3.25	3.25
16	2178	ETB_190111\O_0854p43	19/01/2011	ETB	1	1	1	1	7	6	1	3.75	3.75
17	619	EHEN_171008\M_1	17/10/2008	EHEN	1	0	3	2	10	3	1	4.5	0
18	2419	EHEN_300511\P_5002p43	30/05/2011	EHEN	1	1	2	9	8	3	1	5.5	5.5
19	2682	ETB_280711\ILB_6385p43	28/07/2011	ETB	1	1	3	6	9	8	0.9	6.5	5.85
20	2285	EH_160311_Cropped\ZYE_8828p34	16/03/2011	EH	1	1	4	7	8	4	0.9	5.75	5.175
21	2141	ETB_301210\ZZHa_0732p46	30/12/2010	ETB	1	1	6	9	7	5	1	6.75	6.75
22	2884	EHENS_081111_CL_Cropped\Mo_2998p31	08/11/2011	EHENS	1	1	5	4	8	7	1	6	6
23	2866	ETB_300911_FP_Cropped\K_1221p53	30/09/2011	ETB	1	1	4	7	6	9	0.7	6.5	4.55
24	479	EHEN_131008\O_9144	13/10/2008	EHEN	1	1	4	6	9	2	1	5.25	5.25
25	1112	EHEN_260910\ZX_0357p85	26/09/2010	EHEN	1	1	3	4	6	6	1	4.75	4.75
26	2057	ETB_231110\ZZZZS_7216p61	23/11/2010	ETB	1	1	6	4	5	4	1	4.75	4.75
27	2746	ETB_310811\J_0148p44	31/08/2011	ETB	1	1	5	4	7	3	1	4.75	4.75
28	2451	EHENS_300511\N_0845p43	30/05/2011	EHENS	1	1	7	9	9	8	1	8.25	8.25
29	222	EHEN_131006\M_040	13/10/2006	EHEN	1	1	3	6	8	4	1	5.25	5.25
30	2883	EHENS_081111_CL_Cropped\L_3016p53	08/11/2011	EHENS	1	1	4	10	8	9	1	7.75	7.75
					1.00	0.97	4.83	5.60	7.57	5.03	0.98	5.76	5.50

Table A5. Quality assessment of images randomly selected from EIRPHOT that have head extracts in the Cardigan Bay library. Species (Sp.) 1 = F, 0 = M. Focus, contrast, angle, glare and mean scored out of 10. Visibility is the proportion of the extract that is visible to be extracted. Score is the mean multiplied by the visibility, species and sex. Images too poor in quality for EC are highlighted in grey; means are shown in the final row.

	runif	Image	Date	Location	Sp.	Sex	Focus	Contrast	Angle	Glare	Visibility	Mean	Score
1	172	96C240\F01WE035	24/09/1996	C240	1	1	1	3	8	9	1	5.25	5.25
2	555	97C240\F02CP026	23/09/1997	C240	1	1	1	2	9	7	1	4.75	4.75
3	561	97E120\F04CP001	24/09/1997	E120	1	0	4	5	9	9	1	6.75	0
4	463	97E070\F01CP032	18/09/1997	E070	1	1	4	5	9	8	0.9	6.5	5.85
5	552	97C240\F02CP016	23/09/1997	C240	1	1	5	5	10	8	0.7	7	4.9
6	858	16C040\IMG_9428	02/10/2016	C040	1	1	4	2	7	1	1	3.5	3.5
7	903	16B230\IMG_1685	10/10/2016	B230	1	1	8	6	8	4	1	6.5	6.5
8	600	97C020\F02CP002	22/10/1997	C020	1	1	2	3	8	4	0.9	4.25	3.83
9	339	96C240\F05WE002	15/11/1996	C240	1	1	1	3	9	9	1	5.5	5.5
10	75	96E058\F01WP017	18/09/1996	E058	1	1	3	4	8	9	1	6	6
11	782	15C040\IMG_9723	21/04/2015	C040	1	1	5	3	8	1	0.9	4.25	3.83
12	500	97C040\F02WE001	19/09/1997	C040	1	1	2	4	8	9	1	5.75	5.75
13	191	96D190\F01WE013	02/10/1996	D190	1	1	3	6	6	4	1	4.75	4.75
14	768	15C040\IMG_9354	21/04/2015	C040	1	1	3	6	2	5	0.5	4	2
15	201	96E060\F01WE024	02/10/1996	E060	1	1	3	4	8	6	1	5.25	5.25
16	531	97C240\F03WE012	19/09/1997	C240	1	1	2	5	8	9	1	6	6
17	644	97CEMAES\F01CP008	22/10/1997	CEMAES	1	1	1	3	9	8	1	5.25	5.25
18	439	97E060\F01CP008	18/09/1997	E060	1	1	3	3	1	5	0.2	3	0.6
19	176	96D140\F03WE025	02/10/1996	D140	1	1	4	3	8	4	1	4.75	4.75
20	361	97E116\F02WE010	16/07/1997	E116	1	1	4	6	3	7	0.5	5	2.5
21	769	15C040\IMG_9358	21/04/2015	C040	1	1	6	3	7	4	0.9	5	4.5
22	302	96C020\F02WE003	15/11/1996	C020	1	1	4	4	9	8	1	6.25	6.25
23	653	97C240\F06CP006	23/10/1997	C240	1	1	3	6	8	9	1	6.5	6.5
24	509	97C180\F01WE025	19/09/1997	C180	1	1	1	3	9	6	1	4.75	4.75
25	533	97C240\F03WE018	19/09/1997	C240	1	1	2	5	8	9	1	6	6
26	136	96C225\F01WE027	24/09/1996	C225	1	1	3	3	7	7	1	5	5
27	526	97C230\F02WE007	19/09/1997	C230	1	1	1	5	9	5	1	5	5
28	7	(02)C-060\02L03 C-060 30.9.93	30/09/1993	C060	1	1	7	7	10	6	1	7.5	7.5
29	234	96E120\F03WE007	02/10/1996	E120	1	1	1	2	4	7	0.9	3.5	3.15
30	564	97E120\F04CP007	24/09/1997	E120	1	1	4	6	6	7	1	5.75	5.75
					1.00	0.97	3.17	4.17	7.43	6.47	0.91	5.31	4.71

Table A6. Quality assessment of images randomly selected from EIRPHOT that have head extracts in the Dee Estuary library. Species (Sp.) 1 = F, 0 = M. Focus, contrast, angle, glare and mean scored out of 10. Visibility is the proportion of the extract that is visible to be extracted. Score is the mean multiplied by the visibility, species and sex. Images too poor in quality for EC are highlighted in grey; means are shown in the final row.

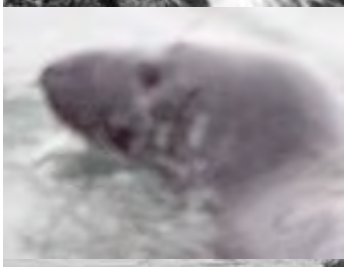
	runif	Image	Date	Location	Sp.	Sex	Focus	Contrast	Angle	Glare	Visibility	Mean	Score
1	362	WHS_210512_CL_Cropped\ZZL_4112p30	21/05/2012	WHS	1	1	3	1	7	3	1	3.5	3.5
2	349	WHS_210512_CL_Cropped\ZV_4062p42	21/05/2012	WHS	1	1	3	2	8	2	1	3.75	3.75
3	188	WHS_Dan_190511\XWC_9725p43	19/05/2011	WHS	1	1	5	6	6	8	1	6.25	6.25
4	276	WHS_Rohan_190511\XTG_2840p64	19/05/2011	WHS	1	1	6	7	9	4	1	6.5	6.5
5	379	WHS_210512_FP_Cropped\L_7684p23	21/05/2012	WHS	1	1	3	5	6	7	1	5.25	5.25
6	136	WHS_Charlie_190511\XZP_559p43	19/05/2011	WHS	1	1	7	7	8	9	1	7.75	7.75
7	427	WHS_210512_FP_Cropped\ZZE_7755p30	21/05/2012	WHS	1	1	4	6	7	4	1	5.25	5.25
8	346	WHS_210512_CL_Cropped\ZR_4062p22	21/05/2012	WHS	1	1	4	2	7	1	1	3.5	3.5
9	213	WHS_Dan_190511\XYN_9571p54	19/05/2011	WHS	1	1	5	5	7	2	1	4.75	4.75
10	154	WHS_Charlie_190511\YZR_357p44	19/05/2011	WHS	1	1	6	7	8	9	1	7.5	7.5
11	56	HN_Dan_190511\YYO_9324p34	19/05/2011	HN	1	1	7	7	9	2	1	6.25	6.25
12	143	WHS_Charlie_190511\XZW_572p33	19/05/2011	WHS	1	1	7	8	8	7	1	7.5	7.5
13	530	WHS_210512_TO_Cropped\ZZP_0349p21	21/05/2012	WHS	1	1	8	9	8	3	1	7	7
14	551	WHS_210512_TO_Cropped\ZZZL_0451p50	21/05/2012	WHS	1	1	1	7	4	7	1	4.75	4.75
15	376	WHS_210512_FP_Cropped\K_7587p43	21/05/2012	WHS	1	1	6	7	8	7	1	7	7
16	487	WHS_210512_TO_Cropped\ZA_0272p55	21/05/2012	WHS	1	1	2	6	7	7	1	5.5	5.5
17	149	WHS_Charlie_190511\YZI_335p44	19/05/2011	WHS	1	1	4	5	8	10	1	6.75	6.75
18	464	WHS_210512_FR_Cropped\ZF_0130p44	21/05/2012	WHS	1	1	2	7	7	7	0.9	5.75	5.18
19	339	WHS_210512_CL_Cropped\ZK_4052p22	21/05/2012	WHS	1	1	2	3	7	3	1	3.75	3.75
20	440	WHS_210512_FP_Cropped\ZZS_7831p53	21/05/2012	WHS	1	1	1	4	7	5	1	4.25	4.25
21	455	WHS_210512_FR_Cropped\V_0066p43	21/05/2012	WHS	1	1	3	6	8	7	0.7	6	4.2
22	431	WHS_210512_FP_Cropped\ZZK_7767p21	21/05/2012	WHS	1	1	2	4	9	10	1	6.25	6.25
23	169	WHS_Dan_190511\XVC_9777p45	19/05/2011	WHS	1	1	7	6	8	10	1	7.75	7.75
24	313	WHS_210512_CL_Cropped\L_3915p21	21/05/2012	WHS	1	1	4	5	8	8	1	6.25	6.25
25	203	WHS_Dan_190511\XWR_9819p55	19/05/2011	WHS	1	1	7	7	8	10	1	8	8
26	350	WHS_210512_CL_Cropped\ZW_4063p64	21/05/2012	WHS	1	1	3	2	7	3	1	3.75	3.75
27	491	WHS_210512_TO_Cropped\ZE_0286p31	21/05/2012	WHS	1	1	3	7	7	3	1	5	5
28	68	HN_Mandy_190511\O_4234p54	19/05/2011	HN	1	1	5	7	8	4	0.8	6	4.8
29	157	WHS_Charlie_190511\YZV_358p55	19/05/2011	WHS	1	1	7	7	8	10	1	8	8
30	88	HN_Mandy_190511\ZF_4415p34	19/05/2011	HN	1	1	5	7	7	5	0.7	6	4.2
					1.00	1.00	4.40	5.63	7.47	5.90	0.97	5.85	5.67

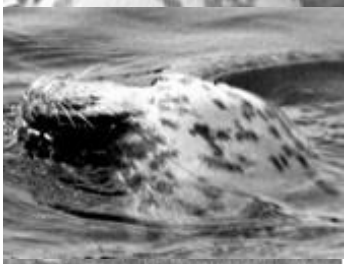
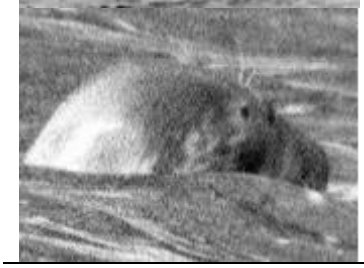
Table A7. Quality assessment of images randomly selected from EIRPHOT that have head extracts in the Skerries library. Species (Sp.) 1 = F, 0 = M. Focus, contrast, angle, glare and mean scored out of 10. Visibility is the proportion of the extract that is visible to be extracted. Score is the mean multiplied by the visibility, species and sex. Images too poor in quality for EC are highlighted in grey; means are shown in the final row.

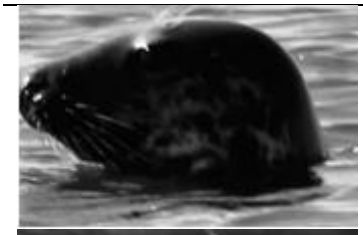
	runif	Image	Date	Location	Sp.	Sex	Focus	Contrast	Angle	Glare	Visibility	Mean	Score
1	180	Skerries 2007\NSYYM_221007_406	22/10/2007	YYM	1	1	3	6	7	8	1	6	6
2	650	YYM_131210_MM\ZE_0114p44	13/12/2010	YYM	1	1	7	3	9	9	1	7	7
3	770	YYM_180311_TO\S_8875p43	18/03/2011	YYM	1	1	2	3	4	5	0.9	3.5	3.15
4	570	YYM_191110_SW\ZB_1921p52	19/11/2010	YYM	1	1	7	6	8	4	1	6.25	6.25
5	194	yym_221007\J_2411	22/10/2007	YYM	1	1	4	4	8	5	1	5.25	5.25
6	554	YYM_191110_SW\L_1848p34	19/11/2010	YYM	1	1	7	8	7	3	1	6.25	6.25
7	984	YYMYA_101012_TO_Cropped\Q0_1221p15	10/10/2012	YYMYA	1	1	4	2	4	8	1	4.5	4.5
8	1033	YYM_180213_TO_Cropped\M_1806p53	18/02/2013	YYM	1	1	3	4	6	7	0.8	5	4
9	277	YYM_051009_SW\Q_0012p33	05/10/2009	YYM	1	1	7	8	8	9	1	8	8
10	9	98SK\F02ED024	06/08/1998	SK	1	1	4	3	7	8	1	5.5	5.5
11	639	YYM_131210_MM\P_9938p35	13/12/2010	YYM	1	1	2	3	8	6	1	4.75	4.75
12	10	98SK\F02ED025	06/08/1998	SK	1	1	4	5	8	9	1	6.5	6.5
13	76	CYMRUPHOT 2002_YYM_3\YYM_150902_24_LF	15/09/2002	YYM	1	1	3	7	7	8	1	6.25	6.25
14	179	Skerries 2007\NSYYM_221007_404	22/10/2007	YYM	1	1	5	4	7	6	1	5.5	5.5
15	220	yym_221007\W_2547	22/10/2007	YYM	1	1	6	8	5	9	1	7	7
16	542	YYM_191110_MM\ZP_6589p63	19/11/2010	YYM	1	1	6	6	8	8	1	7	7
17	1038	YYM_180213_TO_Cropped\R_1723p55	18/02/2013	YYM	1	1	6	2	6	1	1	3.75	3.75
18	154	Skerries 2007\NSYYM_221007_041	22/10/2007	YYM	1	1	7	5	7	8	1	6.75	6.75
19	216	yym_221007\T_2531	22/10/2007	YYM	1	1	1	2	7	3	1	3.25	3.25
20	864	YYM_120812_CL_Cropped\B_5443p31	12/08/2012	YYM	1	0	8	4	6	9	1	6.75	0
21	1045	YYM_180213_TO_Cropped\T_1753p52	18/02/2013	YYM	1	1	5	8	8	4	1	6.25	6.25
22	366	YYMLS_260110\W_9702p34	26/01/2010	YYMLS	1	1	2	7	7	8	1	6	6
23	824	YYM_290712_Cropped\P_4965p45	29/07/2012	YYM	1	1	4	3	5	6	0.9	4.5	4.05
24	625	YYM_131210_CL\ZZN_7406p43	13/12/2010	YYM	1	1	7	8	9	4	1	7	7
25	48	98SK\F06ED029	18/08/1998	SK	1	1	4	3	7	9	1	5.75	5.75
26	829	YYMHC_151112_LH\Q_5074p72	29/07/2012	YYM	1	1	7	7	8	9	1	7.75	7.75
27	459	YYMIE_221010\D_1071p54	22/10/2010	YYMIE	1	1	2	4	8	5	1	4.75	4.75
28	247	YYMYA_221007\ZE_2668p41	22/10/2007	YYMYA	1	1	4	6	3	7	1	5	5
29	944	YYMIW_101012_JV_Cropped\K_7977p45	10/10/2012	YYMIW	1	1	3	4	5	7	1	4.75	4.75
30	501	YYM_191110_CT\Z_1773p54	19/11/2010	YYM	1	1	2	2	8	3	1	3.75	3.75
					1	0.97	4.53	4.83	6.83	6.50	0.99	5.68	5.39

Table A8. All images from the Image Quality Assessment too low in quality for computer-aided pattern recognition software *ExtractCompare*.

Image	Image name	Quality details
	97SMALLS\F07WE023	Bad angle and very little of the extractable area is visible.
	Indistinct cows_2008\C040_Lp04	This underwater shot could be sufficient for a neck extract but the area of the head is not visible.
	13G360\2662_101113	Out of focus and low in contrast.
	96G030\F03WE004	Out of focus and low in contrast.
	97G260\F03CP027	Out of focus, low in contrast and has glare.
	12I160\12.MPC004.PEB	Out of focus, low in contrast and has glare.
	13I150\13.MPC001.JHV	Has glare and little of the extractable area is visible.

	13I210\13.MPC033c.LCA	Out of focus, low in contrast and has glare.
	EHEN_260910\ZR_0329p74	Out of focus, low in contrast and has glare.
	EHEN_300511\L_0790p23	Out of focus and low in contrast.
	EPH_171008\L_0310	Out of focus, low in contrast and has glare.
	ETB_190111\O_0854p43	Out of focus and low in contrast.
	EHEN_171008\M_1	Male but the sex has been left blank.
	97E120\F04CP001	Male but the sex has been left blank.

	16C040\IMG_9428	Low in contrast and has glare.
	97C020\F02CP002	Out of focus, low in contrast and has glare.
	15C040\IMG_9723	Low in contrast and has glare.
	15C040\IMG_9354	Out of focus, at a bad angle and little of the extractable area is visible.
	97E060\F01CP008	Bad angle and little of the extractable area is visible.
	97E116\F02WE010	Bad angle and little of the extractable area is visible.
	96E120\F03WE007	Out of focus and low in contrast.

	WHS_210512_CL_Cropped\ZZL_4112p30	Low in contrast and has glare.
	WHS_210512_CL_Cropped\ZV_4062p42	Low in contrast and has glare.
	WHS_210512_CL_Cropped\ZR_4062p22	Out of focus, low in contrast and has glare.
	WHS_210512_CL_Cropped\ZK_4052p22	Out of focus, low in contrast and has glare.
	WHS_210512_CL_Cropped\ZW_4063p64	Out of focus, low in contrast and has glare.
	YYM_180311_TO\S_8875p43	Out of focus and at a bad angle.
	YYM_180213_TO_Cropped\R_1723p55	Low in contrast and has glare.

	yym_221007\T_2531	Out of focus, low in contrast and has glare.
	YYM_120812_CL_Cropped\B_5443p31	Male but the sex has been left blank.
	YYM_191110_CT\Z_1773p54	Out of focus, low in contrast and has glare.

Table A9. Tukey-HSD results. Significance levels: p < 0.001 = "***", p < 0.01 = "**", p < 0.05 = "*", p < 0.1 ".". Location codes: 1 = Skomer, 2 = Ramsey, 3 = Marloes Peninsula, 4 = Bardsey, 5 = Cardigan Bay, 6 = The Dee Estuary, 7 = Skerries.

Locations	Difference	Lower 95%	Upper 95%	p	Significance
1,2	-0.66	-1.93	0.61	0.71559	
1,3	-0.16	-1.43	1.12	0.99980	
1,4	-1.18	-2.45	0.09	0.08997	.
1,5	-1.98	-3.25	-0.70	0.00014	***
1,6	-1.01	-2.28	0.26	0.22024	
1,7	-1.29	-2.56	-0.02	0.04452	*
2,3	0.50	-0.77	1.78	0.90141	
2,4	-0.52	-1.79	0.76	0.89012	
2,5	-1.31	-2.59	-0.04	0.03818	*
2,6	-0.35	-1.62	0.92	0.98325	
2,7	-0.63	-1.90	0.64	0.76111	
3,4	-1.02	-2.29	0.25	0.20918	
3,5	-1.82	-3.09	-0.54	0.00063	***
3,6	-0.85	-2.13	0.42	0.42195	
3,7	-1.13	-2.41	0.14	0.11660	
4,5	-0.80	-2.07	0.48	0.50627	
4,6	0.17	-1.10	1.44	0.99970	
4,7	-0.11	-1.39	1.16	0.99997	
5,6	0.97	-0.31	2.24	0.26949	
5,7	0.68	-0.59	1.96	0.68159	

9.2. Appendix 2 – Data cleaning and protocol for poor quality images

9.2.1. Data cleaning

There were data assigned to one sampling occasion with the date “22/09/2024”. This has been changed to 22/09/2014 as the location J040/SSHV (South Haven, Skomer South) attached to the extracts was surveyed in 2014, and the original ID given to the individuals in the images were prefixed “Skomer14”.

There were data assigned to one sampling occasion (with 5 encounters) with the date shown as 31/08/2001 but sighting number 1795 has images with the prefix “EOD_310811” and has a sighting number in sequence with sightings in 2011. The date for this sampling occasion was therefore changed to 31/08/2011.

There were 5 pairs of images viewed during the visual confirm stage that have clearly been taken on the same day and at the same time but have been entered with different dates, sometimes with different years. These all concern extracts with the prefix “Indistinct cows” and so we recommend that all these extracts (*n* = 498) are inspected by NRW before they are used in any analysis. These extracts have been set aside and not included in this analysis.

The individual “Ghost“, who was seen at Bardsey, had 12 images matched to its ID, 3 of which were of a different individual. These were updated and recoded back to their original ID “18086”.Details of images taken on the same day at the same time, but given different dates, are shown in the comparison below. A total of 498 extracts with the prefix “Indistinct_cows” have been moved from the library to a new queue with AutoMatch Lc.

Details of images of the same individual that have been taken at the same time, but entered with different dates:

Extracts	Individual	Date
20090901_MWK\09.C013.MWK (2009-2)p45_NK	34602	01/09/2009
Indistinct_cows_2009\C013_Lp05_NK	C013_09	31/08/2009
20090919_MWK\09.C029.MWK (2009-5)p41_NK	34605	19/19/2009
Indistinct_cows_2009\C029_Rp83.RW1_HD	C029_09	09/09/2009
20090924_MWK\09.C042.MWK (2009-5)p46_HD	34606	24/09/2009
Indistinct_cows_2009\C042_Rp66.RW1_HD	C042_09	15/09/2009
20090926_MWK\08.C025.MWK (2009-2)p32_HD	34607	26/09/2009
Indistinct cows_2008\C025_Rp54.RLA_HD	C025_08	02/09/2008
20091023_NHV\09.C107.NHV (2009-3)p64_NK	34761	23/10/2009
Indistinct_cows_2009\C107_Lp16_NK	C107_09	19/10/2009

9.2.2. Technical errors

The following two errors were encountered during the EC process as technical issues with the EIRPHOT database and have been resolved through consulting with Lex Hiby.

i) “no potential matches”

During the visual confirmation stage, some head extracts were generating no potential matches. This is because the extracts waiting to be visually confirmed (AutoMatch V in the cells table) had no corresponding records in the *temp* table. This can only be a result of:

a) Extracts having been assigned insufficiently high matching scores to be stored in the temp table;

b) *temp* table records having been deleted, or;

c) Data with AutoMatch P having been incorrectly updated to V.

It is improbable that this number of extracts have insufficiently high matching scores and it is difficult to accidentally delete *temp* table records so the most likely cause of this issue is that records have been historically, incorrectly updated from AutoMatch P to V. AutoMatch values should only ever be updated to values earlier in the process (i.e. L-V-P-E), to ensure no step in the EC process is skipped.

This issue was resolved by updating the AutoMatch of these extracts from V back to P, and re-running the extracts through the batch comparison stage.

ii) “complibx not working”

During the batch comparison stage, EC gave an error message stating that one of the two algorithms was not working.

The *complib* algorithm splits the extract into four key areas, and if any one of these areas is more than 50% blank, no comparison is made. The closer to 100% blank, the less useful the extract is as the algorithms require some information to use for comparisons. Extracts that are 100% blank are completely useless.

Unfortunately, extracts from heads in the water are the most likely to have more than 50% of any of the core areas blank due to the size of the area and larger variation in angle of view to the aspect.

This issue was resolved by setting aside head extracts with >50% blank (*pcb* in the cells table) from the P and L queues, into new queues; 29 extracts with AutoMatch Px and 738 extracts with AutoMatch Lx. These extracts can remain within these queues as they will not be included in future analyses; they could also be deleted as they are not sufficiently informative to run through the EC software.

9.2.3. Unsuitable images from visual confirmation stage

During visual confirmation of potential matches, EC gives the options to add the new extract to the EIRPHOT library, or to set it aside from future analyses in an

alternative queue. Suitable photo-ID extracts processing at SMRU were given an AutoMatch value of L (in the cells table) and so were added to the EIRPHOT library. Some images were assessed to be unsuitable for computer-aided pattern recognition as they were too low in quality. These were where the image was out of focus, low in contrast, at a bad angle, contained glare, or little of the extractable area was visible.

Extracts from unsuitable images were excluded from the EIRPHOT library. Extracts not added to the library are automatically given an AutoMatch value of R. There were 24 extracts of those viewed that were assessed to be unsuitable and were excluded from further analyses. Details of these can be found in Table A10.

Entering poor quality images into the EIRPHOT library can have a negative effect on future matches. For example, the extract labelled with an asterisk in Table A10 had 685 potential matches with combined scores exceeding the 0.75 threshold, and 79 of these had a perfect score of 1. However, the image is of a head in the water and the extractable area is covered in glare.

9.2.4. Unsuitable images already within the EIRPHOT library

During visual confirmation, some images already within the EIRPHOT library from processing completed at NRW were assessed by SMRU to be unsuitable for computer-aided pattern recognition. We have updated the AutoMatch (from L to Lz) of 6 extracts (see Table A11 for details of these). We have also entered a new entry into the AutoMatch_meanings tables for Lz; “Extracts removed from further analysis by SMRU due to low quality (Jan 2018)”.

Important: it should be noted that the library has not been systematically assessed for these; only the images that have been returned as potentially matching extracts.

It is recommended that when a new AutoMatch queue is created, a corresponding line of data is also entered into the AutoMatch_meanings table. On arrival at SMRU, the EIRPHOT database had 45 extracts in the cells table set aside from the EC process, however it is not obvious why these extracts have been excluded from future analyses (Table A12).

Table A10. Details of unsuitable images (*n* = 24) that were not added to the EIRPHOT library. These extracts have been assigned an AutoMatch value of R and remain within the database but are excluded from future analyses.

Extract	Individual	Date	Location	Details
EHENS_160311_Cropped\ZYF_3064p23_HD	33142	16/03/2011	Bardsey	Extract area not visible
EHENSE_160311_Cropped\ZYM_3108p30_HD	33192	16/03/2011	Bardsey	Moult obstructing pattern
EHENSE_300911_TO_Cropped\P_2627p54_HD*	33236	30/09/2011	Bardsey	Glare obstructing pattern
EMD_160311_TO_Cropped\R_2722p55_HD	33303	16/03/2011	Bardsey	Extract area not visible
EMD_160311_Cropped\T_2750p31_HD	33305	16/03/2011	Bardsey	Male; moulting and no pattern to extract
EMD_160311_Cropped\ZZG_2990p12_HD	33356	16/03/2011	Bardsey	Glare obstructing pattern
WHS_210512_FP_Cropped\ZZQ_7812p25_HD	33626	21/05/2012	Dee Estuary	Glare obstructing pattern
YD_030313_TS_Cropped\M_6992p54_HD	33805	03/03/2013	East Anglesey	Glare obstructing pattern
YYM_180213_FR_Cropped\J_8214p31_HD	34041	18/02/2013	Skerries	Moult obstructing pattern
YYM_180213_FR_Cropped\J_8215p32_HD	34042	18/02/2013	Skerries	Moult obstructing pattern
YYM_180213_TO_Cropped\K_1796p68_HD	34072	18/02/2013	Skerries	Glare obstructing pattern
YYM_180213_TO_Cropped\L_1797p66_HD	34073	18/02/2013	Skerries	Glare and extract area not visible
YYMHC_180213_JV_Cropped\F_4817p44_HD	34163	18/02/2013	Skerries	Moulting and lots of folds
YYMMCE_101012_JV_Cropped\02_7955p54_NK	34240	10/10/2012	Skerries	Pup still covered in lanugo
YYMMCE_101012_JV_Cropped\K_7964p44_HD	34243	10/10/2012	Skerries	Shadow and extract area not visible
YYMYA_101012_JV_Cropped\M_8025p03_NK	34271	10/10/2012	Skerries	Blurry and dark pattern
RH_20131005_CJ_Cropped\Q_0096p43_HD	34343	05/10/2013	North Llyn	Blurry and glare obstructing pattern
RH_20131005_RB_Cropped\B_8687p23_HD	34349	05/10/2013	North Llyn	Blurry, glare and folds
PDE_20131025_RB_Cropped\S_9222p43_HD	34420	25/10/2013	Carmel Head	Extract area not visible
CH_OD_20131015_Cropped\K_3096p21_HD	34306	15/10/2013	Carmel Head	Pup still covered in lanugo
EHENS_300911_FP_Cropped\M_1406p33_NK	33147	30/09/2011	Bardsey	Male; folds and glare obstructing pattern
EHENS_300911_TO_Cropped\L_2646p22_NK	33168	30/09/2011	Bardsey	Male; folds and glare obstructing pattern
ETB_300911_FP_Cropped\L_1333p42_HD	33452	30/09/2011	Bardsey	Male; dark and folds obstructing pattern
ETB_310811_TO_Cropped\U_1880p31_HD	33483	31/08/2011	Bardsey	Male; water and glare obstructing pattern

Table A11. Details of unsuitable images (*n* = 6) that were already in the EIRPHOT library (AutoMatch = L) and have been subsequently removed by SMRU from further analysis (AutoMatch = Lz).

Extract	Individual	Date	Location	Details
AB_20130909_RB_Cropped\K_0024p32_HD	34291	09/09/2013	West Anglesey	Blurry and extract area not visible
AnB_250813_RB_Cropped\J_0423p41_HD	34287	25/08/2013	Angel Bay	Extract area not visible
YD_121008\DSC_0050p23_NK	28744	12/10/2008	East Anglesey	Harbour seal
AB_20130909_CJ_Cropped\L_8375p45_HD	34302	09/09/2013	West Anglesey	Dark and blurry
AB_140812_Cropped\K_6187p33_HD	32984	14/08/2012	West Anglesey	Blurry and glare over extract area

Table A12. Details of extracts set aside from the *ExtractCompare* queue, with no corresponding details in the AutoMatch_meanings table (*n* = 45).

Extract	Individual	Date	Location	AutoMatch
15AB\1abd_CH	15AB_15718	29/09/2015	AB	EX
15AB\1abd_AB	15AB_15718	29/09/2015	AB	EX
ETB_220908\J_7581_FL	18129	22/09/2008	ETB	EX
14SDWB\5168 14.SC028.SBS.240914 in DWB (5,5)_HD	Skomer14_2409_08	24/09/2014	J050	PC
14SDWB\5168 14.SC028.SBS.240914 in DWB (5,5)_NK	Skomer14_2409_08	24/09/2014	J050	PC
14SDWB\5168 14.SC028.SBS.240914 in DWB (5,5)_FL	Skomer14_2409_08	24/09/2014	J050	PC
14SDWB\6953 14.SC-BK-023.DWB.120914 (7,3)_FL	Skomer14_1209_03	12/09/2014	J050	PC
14SDWB\6953 14.SC-BK-023.DWB.120914 (7,3)_HD	Skomer14_1209_03	12/09/2014	J050	PC
14SDWB\6953 14.SC-BK-023.DWB.120914 (7,3)_NK	Skomer14_1209_03	12/09/2014	J050	PC
14SDWB\6966 14.SC-BK-023.DWB.120914 (5,2)_FL	Skomer14_1209_03	12/09/2014	J050	PC
14SDWB\6966 14.SC-BK-023.DWB.120914 (5,2)_HD	Skomer14_1209_03	12/09/2014	J050	PC
14SDWB\6966 14.SC-BK-023.DWB.120914 (5,2)_NK	Skomer14_1209_03	12/09/2014	J050	PC
14SDWB\8368 14.SC-NK-116.DWB.121014 (3,5)_FL	Skomer14_1110_07	11/10/2014	J050	PC
14SDWB\8368 14.SC-NK-116.DWB.121014 (3,5)_HD	Skomer14_1110_07	11/10/2014	J050	PC
14SDWB\8368 14.SC-NK-116.DWB.121014 (3,5)_NK	Skomer14_1110_07	11/10/2014	J050	PC
14SMWK\0541 14.SC208.MWK.121114 (6,3)_FL	Skomer14_1211_03	12/11/2014	J100	PC
14SMWK\0541 14.SC208.MWK.121114 (6,3)_NK	Skomer14_1211_03	12/11/2014	J100	PC
14SMWK\0552 14.SC208.MWK.121114 (7,6)_FL	Skomer14_1211_03	12/11/2014	J100	PC
14SMWK\0552 14.SC208.MWK.121114 (7,6)_NK	Skomer14_1211_03	12/11/2014	J100	PC
14SMWK\5880 14.SC030.MWK.031014 (5,2)_FL	Skomer14_0310_06	03/10/2014	J100	PC
14SMWK\5880 14.SC030.MWK.031014 (5,2)_HD	Skomer14_0310_06	03/10/2014	J100	PC
14SMWK\5880 14.SC030.MWK.031014 (5,2)_NK	Skomer14_0310_06	03/10/2014	J100	PC
14SMWK\6920 14.SC301.MWK.120914 (5,8)_HD	Skomer14_1209_05	12/09/2014	J100	PC
14SMWK\6920 14.SC301.MWK.120914 (5,8)_NK	Skomer14_1209_05	12/09/2014	J100	PC
14SMWK\6920 14.SC301.MWK.120914 (5,8)_FL	Skomer14_1209_05	12/09/2014	J100	PC
14SNHV(S)\5934 14.SC308.NHV(S).031014 (3,3)_FL	Skomer14_0310_01	03/10/2014	J140	PC
14SNHV(S)\5934 14.SC308.NHV(S).031014 (3,3)_HD	Skomer14_0310_01	03/10/2014	J140	PC
14SNHV(S)\5934 14.SC308.NHV(S).031014 (3,3)_NK	Skomer14_0310_01	03/10/2014	J140	PC
14SNHV\7968 14.SC148.NHV.241014 (4,2)_FL	Skomer14_2410_02	24/10/2014	J140	PC
14SNHV\7968 14.SC148.NHV.241014 (4,2)_HD	Skomer14_2410_02	24/10/2014	J140	PC
14SNHV\7968 14.SC148.NHV.241014 (4,2)_NK	Skomer14_2410_02	24/10/2014	J140	PC
14SSHV\1013 14.SP136.SHV.211014 (6,3)_NK	Skomer14_2110_05	21/10/2014	J040	PC
14SSHV\1013 14.SP136.SHV.211014 (6,3)_FL	Skomer14_2110_05	21/10/2014	J040	PC
14SSHV\1013 14.SP136.SHV.211014 (6,3)_HD	Skomer14_2110_05	21/10/2014	J040	PC
14SSHV\7737 14.SC301.SHV.041014 (2,3)_FL	Skomer14_0310_09	03/10/2014	J040	PC
14SSHV\7737 14.SC301.SHV.041014 (2,3)_NK	Skomer14_0310_09	03/10/2014	J040	PC
14SSHV\7737 14.SC302.SHV.041014 (8,5)a_FL	Skomer14_0310_10	03/10/2014	J040	PC
14SSHV\7737 14.SC302.SHV.041014 (8,5)a_HD	Skomer14_0310_10	03/10/2014	J040	PC
14SSHV\7737 14.SC302.SHV.041014 (8,5)a_NK	Skomer14_0310_10	03/10/2014	J040	PC
14SWCK\6842.4 14.SC105.WCK.171014 (3,4)_HD	Skomer14_1710_15	17/10/2014	J020	PC
14SWCK\6842.4 14.SC105.WCK.171014 (3,4)_NK	Skomer14_1710_15	17/10/2014	J020	PC
20100915_MWK\10.C040,MWK_2p44_HD	34623	15/09/2010	J100	PC
20100915_MWK\10.C040,MWK_3p25_HD	34623	15/09/2010	J100	PC
20100915_MWK\10.C040,MWK_3p25_NK	34623	15/09/2010	J100	PC
20100915_MWK\10.C040,MWKp43_HD	34623	15/09/2010	J100	PC

9.3. Appendix 3 – Site-specific summary reports

9.3.1. Skomer

9.3.1.1. Study site

The EIRPHOT database contains photo-ID data collected at 17 locations around Skomer (Figure A1, Table A13).

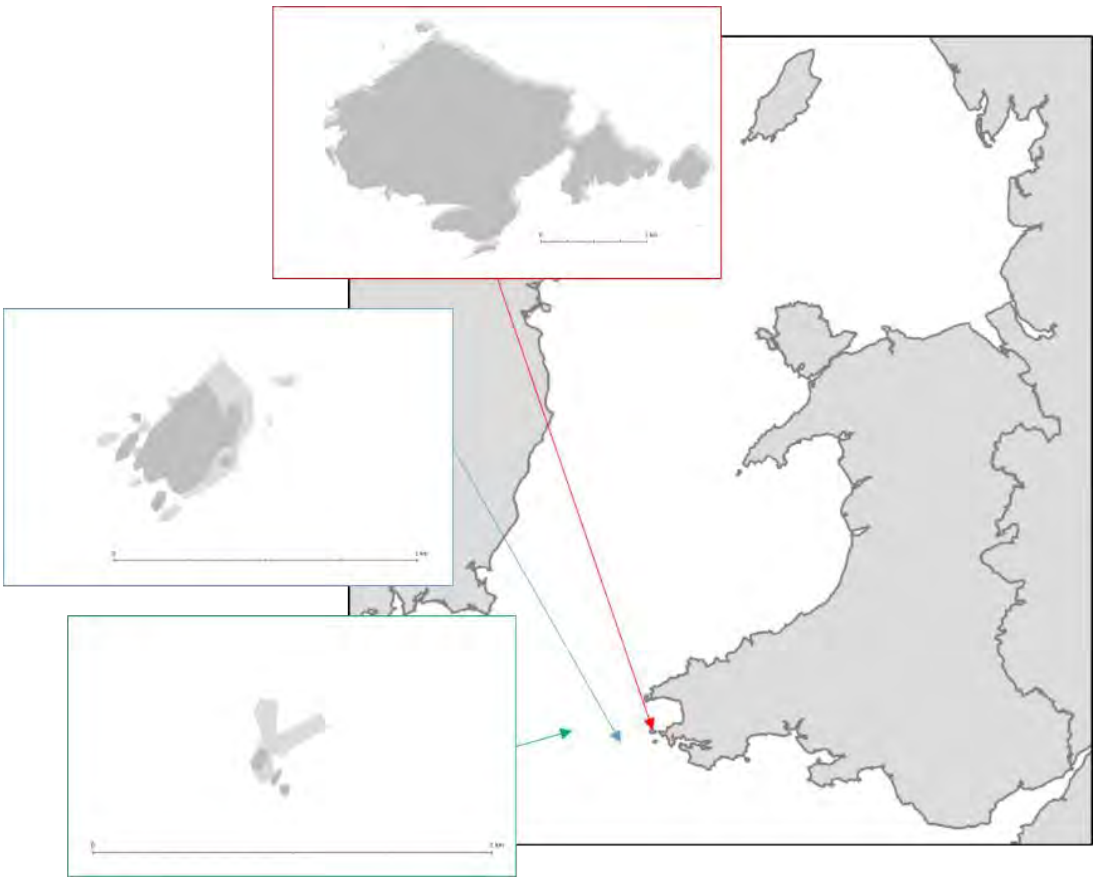


Figure A1. Three locations within the EIRPHOT database grouped into the area of Skomer; with the islands: Skomer in red, Grassholm in blue and the Smalls in green.

Table A13. Location codes for sites within the EIRPHOT database grouped into the area of Skomer.

Code	Description	Cluster	Section
GRASS	Grassholm Island	Grassholm	Skomer
J010	Pigstone Bay	Skomer South	Skomer
J020	The Wick	Skomer South	Skomer
J025	High Cliff Boulders	Skomer South	Skomer
J030	South Stream Cave	Skomer South	Skomer
J040	South Haven	Skomer South	Skomer
J050	Driftwood Bay	Skomer South	Skomer
J060	The Slabs	Skomer South	Skomer
J070	Seal Hole	Skomer South	Skomer
J080	South Castle Beach Cave	Skomer South	Skomer
J090	Castle Bay	Skomer South	Skomer
J100	Matthew's Wick	Skomer South	Skomer
J110	Amy's Reach	Skomer South	Skomer
J140	North Haven	Skomer South	Skomer
SBAS	Skomer South	Skomer South	Skomer
SSCB	South Castle Beach	Skomer South	Skomer
SMALLS	Smalls	Smalls	Skomer

9.3.1.2. Summary of data within EIRPHOT database

On completion of this report, the EIRPHOT database library was made up of 6,830 extracts, from 4,517 images across 2,690 sampling occasions at Skomer between 1992 and 2014 (Figure A2).

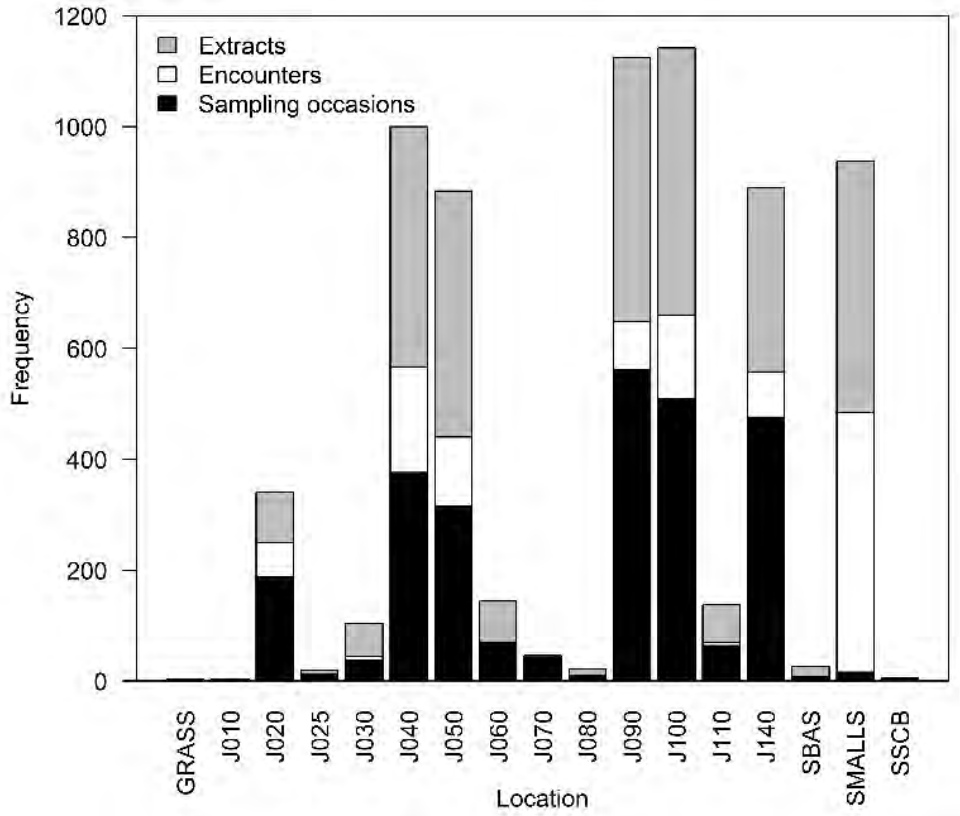


Figure A2. The number of extracts, encounters and sampling occasions within the EIRPHOT database, for each location grouped into the area of Skomer.

The majority of extracts, encounters and sampling occasions were at locations J090 (Castle Bay) and J100 (Matthew's Wick) in the south of Skomer. There were few data from GRASS (Grassholm) and some areas of Skomer including J010 (Pigstone Bay), J025 (High Cliff Boulders), J080 (South Castle Beach Cave), SBAS (Skomer South) and SSCB (South Castle Beach).

9.3.1.3. Captures and recaptures

At Skomer, there were 598 unique individuals identified by left head extracts. Of these, 430 were seen once and 168 individuals were recaught at least one time (Figure A3a). There were also 593 unique individuals identified by right heads extracts. Of these, 420 were seen once and 173 individuals were seen more than once (Figure A3b).

The individual seen at Skomer with the highest number of recaptures was "SH_057" who was first recorded at J090 (Castle Bay, Skomer) in 1992 and was recaught 12 times between 1993 and 2016, at locations J090, J100 (Matthew's Wick, Skomer), J020 (The Wick, Skomer), G020 (Garlic, Ramsey) and G030 (Aber Mawr, Ramsey).

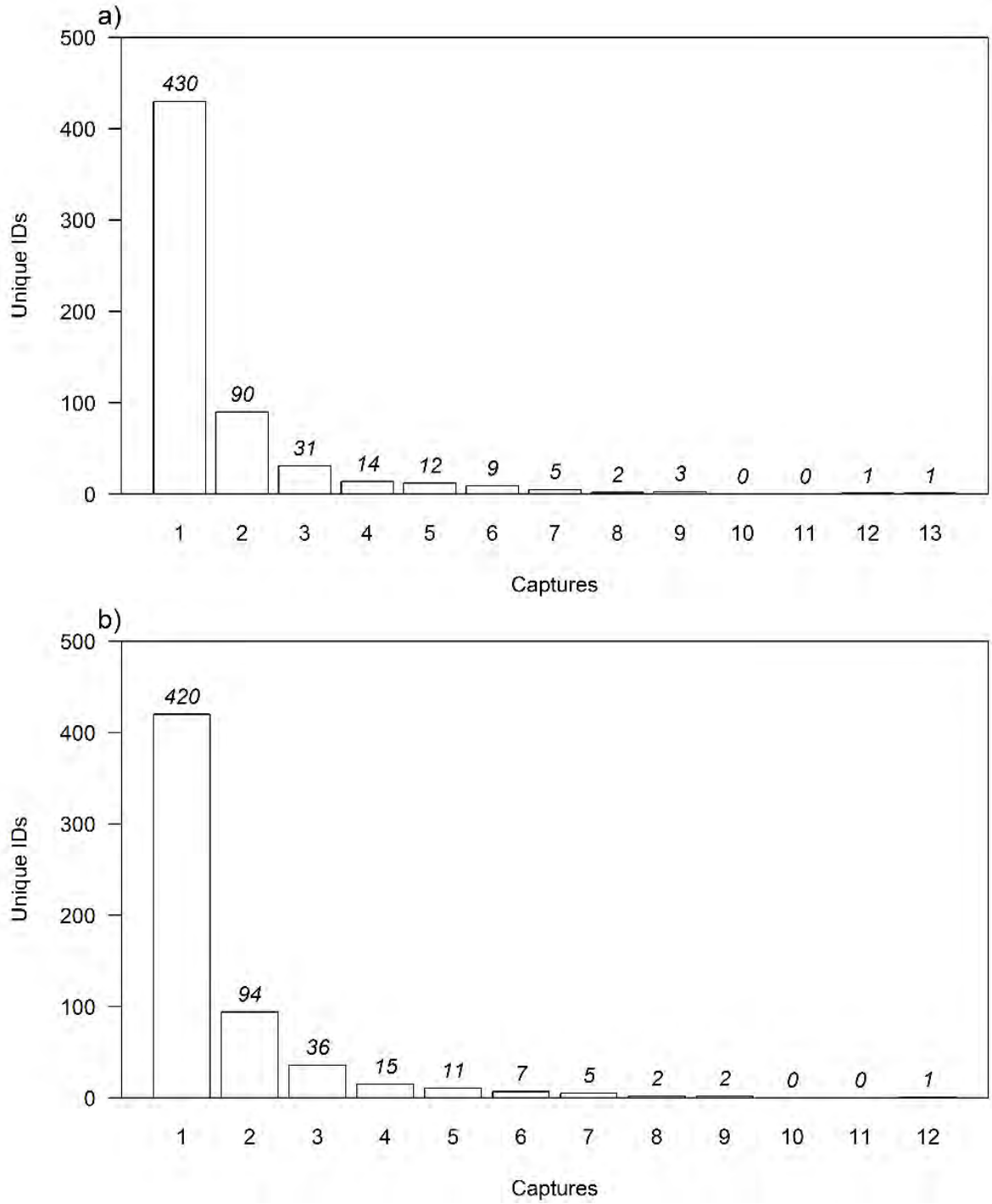


Figure A3. Capture frequency of unique individuals identified by a) left, and b) right head aspects, grouped into the area of Skomer.

The most frequent mean interval between captures in Skomer was one year (Figure A4). The maximum mean interval was 13 years, for individual “C014_09”, who was first caught at CO (Coningmore Rocks, The Brandies, Great Saltee Island, Ireland) in 1996 and subsequently recaught at J090 (Castle Bay, Skomer South) in 2009.

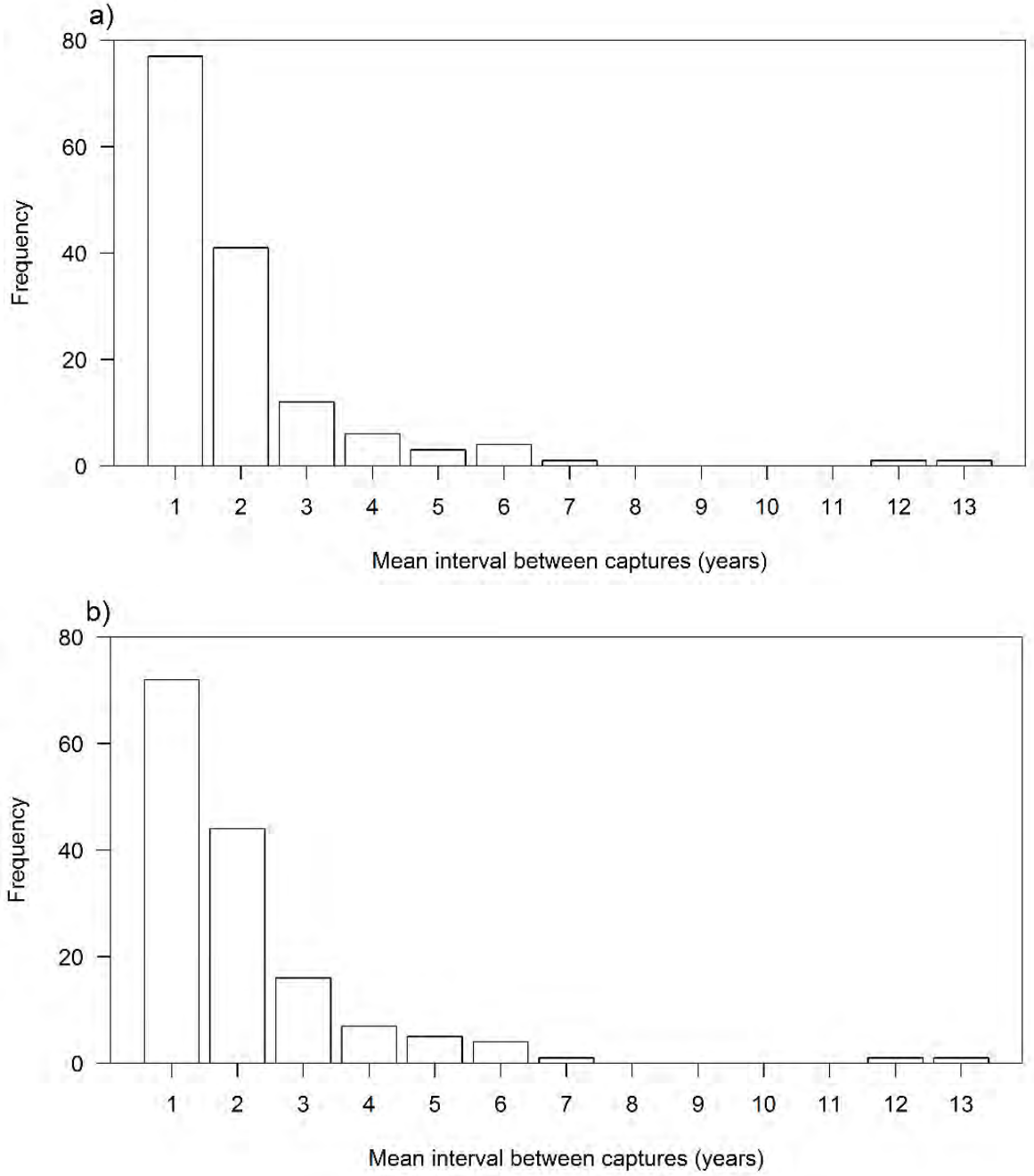


Figure A4. The mean interval between each capture within the capture database for unique individuals identified by a) left and b) right head extracts, grouped into the area of Skomer.

9.3.1.4. Spatial connectivity

The highest probability of recaptures at Skomer were from individuals either seen previously or subsequently at Skomer (Figure A5). Outside of Skomer, these individuals were most likely to be seen at Ramsey, the Marloes and Bardsey. Unique individuals identified by left head extracts within Skomer were connected to every other broad area. However, unique individuals identified by right head extracts within Skomer were not seen previously or subsequently at the Dee Estuary.

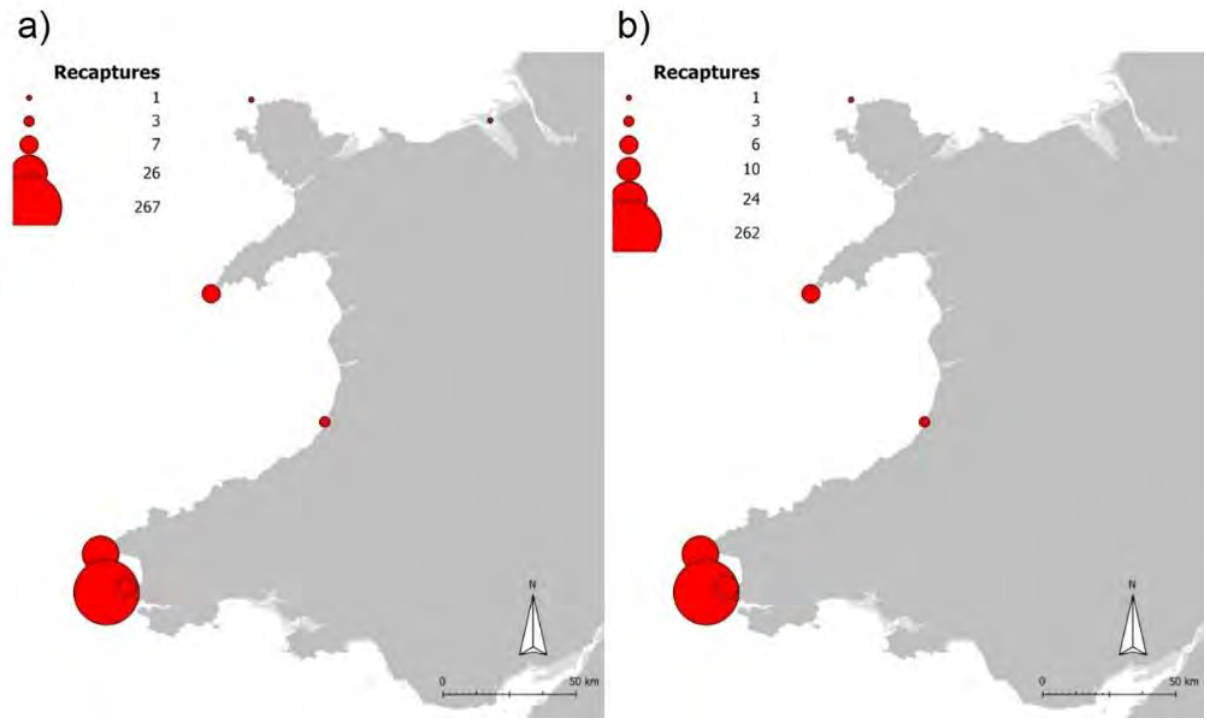


Figure A5. The maximum number of recaptures of unique individuals identified by a) left and b) right head extracts, moving to or from the area of Skomer.

9.3.1.5. Data recommendations

Within the EIRPHOT database, there were 996 extracts from Skomer set aside from the EC process, all with the prefix “Indistinct cows” or “Indistinct_cows”. The sample of these images observed during the data processing at SMRU contained duplicates of the same individuals clearly taken at the same time but assigned different dates. We therefore recommend that these extracts are inspected, with the corresponding paperwork, to resolve the discrepancies in dates.

Within the Skomer extracts, there were 68 from males, 78 from pups and 11 from unknown *AgeSex*. We recommend that these unknown extracts are inspected and their *AgeSex* class confirmed where possible.

There were also 952 extracts from images of individuals with blank *AgeSex* data. For the purpose of this analysis, these extracts were assumed to have been taken from adult females. For future analyses, we recommend that these extracts are inspected and their AgeSex class confirmed where possible.

During this analysis, SMRU encountered a technical error within EC. This resulted in 48 head extracts from Skomer set aside from analysis as they contained >50% blanking of the extractable area. These are currently sitting in the AutoMatch queue Lx, but we recommend that these extracts are deleted from the database, as they do not contain sufficient data to run through EC.

On arrival at SMRU, the EIRPHOT database contained 84 Skomer extracts that had an AutoMatch value of PC. As there was no corresponding explanation in the *AutoMatch_meanings* table, it is not clear why these extracts have been set aside. It

is therefore recommended that these extracts are inspected for reasons why they may have been set aside originally, and that the *AutoMatch_meanings* table is updated.

Within the EIRPHOT locations table, there are 31 locations grouped into the area of Skomer. These all have unique descriptions that distinguish them from one another but only two (Smalls, Grassholm Island) have lat/lon coordinates. We recommend that these data are added so that people working on the database who are unfamiliar with the study site can distinguish between the finer scale locations.

9.3.2. Ramsey

9.3.2.1. Study site

The EIRPHOT database contains photo-ID data collected at 28 locations around Ramsey (Figure A6, Table A14).

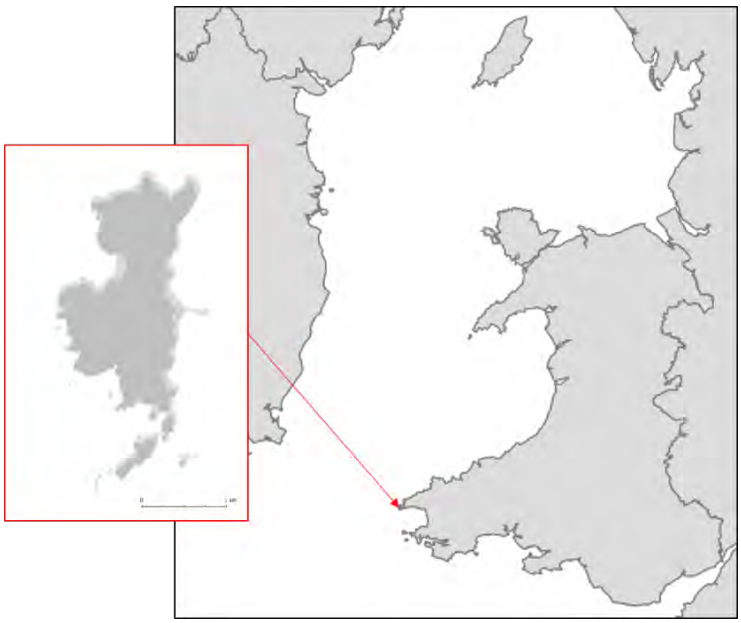


Figure A6. The area of Ramsey in red, which includes Ramsey Island and the Bishops.

Table A14. Location codes for sites within the EIRPHOT database grouped into the area of Ramsey.

Code	Description	Cluster	Section
G010	Ogof Colomenod	Ramsey West	Ramsey
G020	Garlic	Ramsey West	Ramsey
G021	Garlic Spit	Ramsey West	Ramsey
G030	Aber Mawr	Ramsey West	Ramsey
G050	Ogof Tywod	Ramsey West	Ramsey
G101	Ogof Hen Slabs	Ramsey East	Ramsey
G140	Rhod Uchaf	Ramsey East	Ramsey
G150	Capel Spit	Ramsey East	Ramsey
G160	Capel	Ramsey East	Ramsey
G180	Y Llech	Ramsey East	Ramsey
G190	The Waterings	Ramsey East	Ramsey
G200	The Tooth	Ramsey East	Ramsey
G210	The Harbour	Ramsey East	Ramsey
G220	Aber Felin	Ramsey East	Ramsey
G230	Hwrddod	Ramsey East	Ramsey
G240	Shag Cave	Ramsey East	Ramsey
G250	Abermyharan	Ramsey East	Ramsey
G260	Rhossyn	Ramsey East	Ramsey
G270	Foel Fawr (AKA Bachelor Pad)	Ramsey East	Ramsey
G300	Twll y Gwyddel	Ramsey West	Ramsey
G310	Gwelltog	Ramsey West	Ramsey
G320	Ogof Thomas Williams	Ramsey West	Ramsey
G330	Ogof Mynachdy	Ramsey West	Ramsey
G350	Ogof Genau	Ramsey West	Ramsey
G360	Porth Lleuog	Ramsey West	Ramsey
G370	Ogof Lleuog	Ramsey West	Ramsey
G391	Bendro ledges	Ramsey West	Ramsey
NB	NORTH BISHOP	The Bishops	Ramsey

9.3.2.2. Summary of data within EIRPHOT database

On completion of this report, the EIRPHOT database library was made up of 2,225 extracts, from 1,202 images across 483 sampling occasions at Ramsey between 1996 and 2016 (Figure A7).

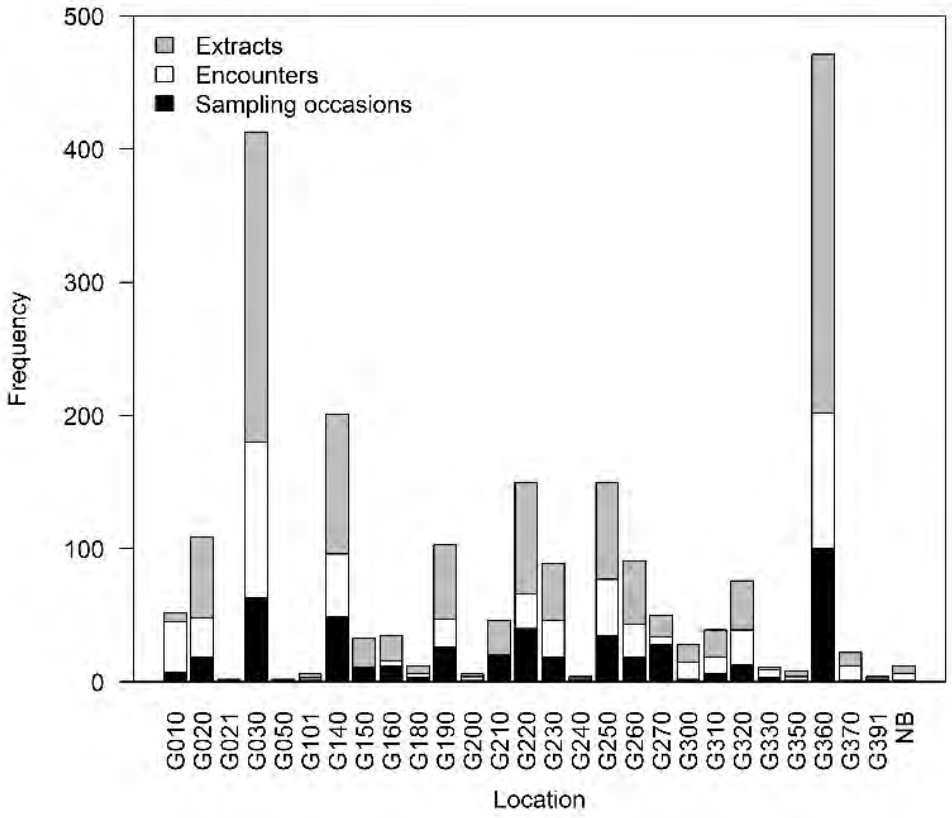


Figure A7. The number of extracts, encounters and sampling occasions within the EIRPHOT database, for each site grouped into the area of Ramsey.

The majority of extracts, encounters and sampling occasions were at locations G360 (Porth Lleuog) and G030 (Aber Mawr) to the west of Ramsey. There were few data from NB (North Bishop) and some areas of Ramsey including G021 (Garlic Spit), G050 (Ogof Tywod), G240 (Shag Cave) and G391 (Bendro ledges).

9.3.2.3. Captures and recaptures

At Ramsey, there were 339 unique individuals identified by left head extracts. Of these, 267 were seen once and 72 individuals were recaught at least one time (Figure A8a). There were also 349 unique individuals identified by right heads extracts. Of these, 277 were seen once and 72 individuals were seen more than once (Figure A8b).

The individual seen at Ramsey with the highest number of recaptures was “SH_057” who was first recorded at J090 (Castle Bay, Skomer) and was recaught 12 times between 1993 and 2016, at locations J090, J100 (Matthew’s Wick, Skomer), J020 (The Wick, Skomer), G020 (Garlic, Ramsey) and G030 (Aber Mawr, Ramsey).

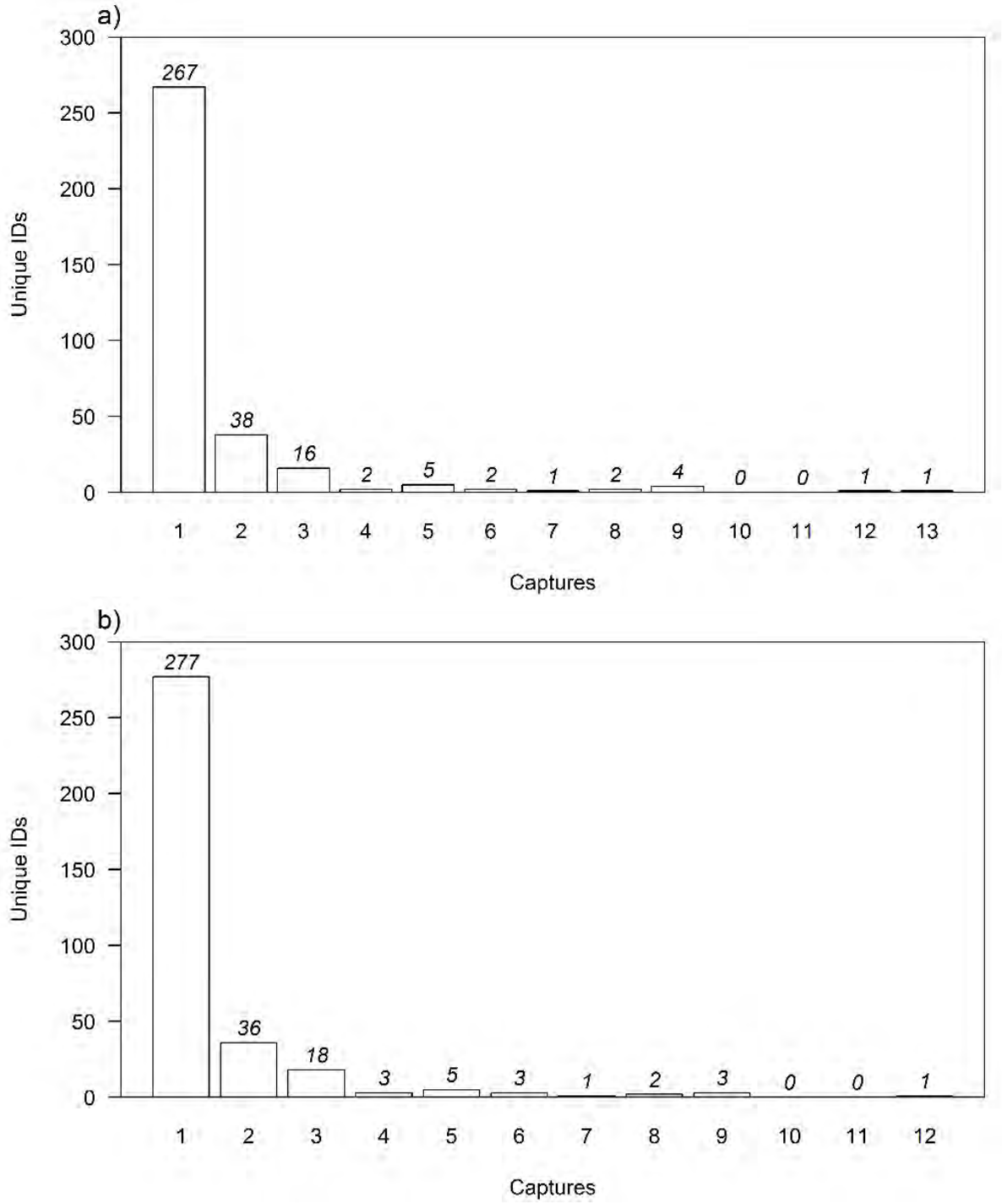


Figure A8. Capture frequency of unique individuals identified by a) left, and b) right head aspects grouped into the area of Ramsey.

The most frequent mean interval between captures in Ramsey was one year (Figure A8). The maximum mean interval was 15 years, for individual “8526”, who was first caught at G020 (Garlic, Ramsey West) in 1996 and subsequently recaught at EHENSE (Bardsey Island) in 2011.

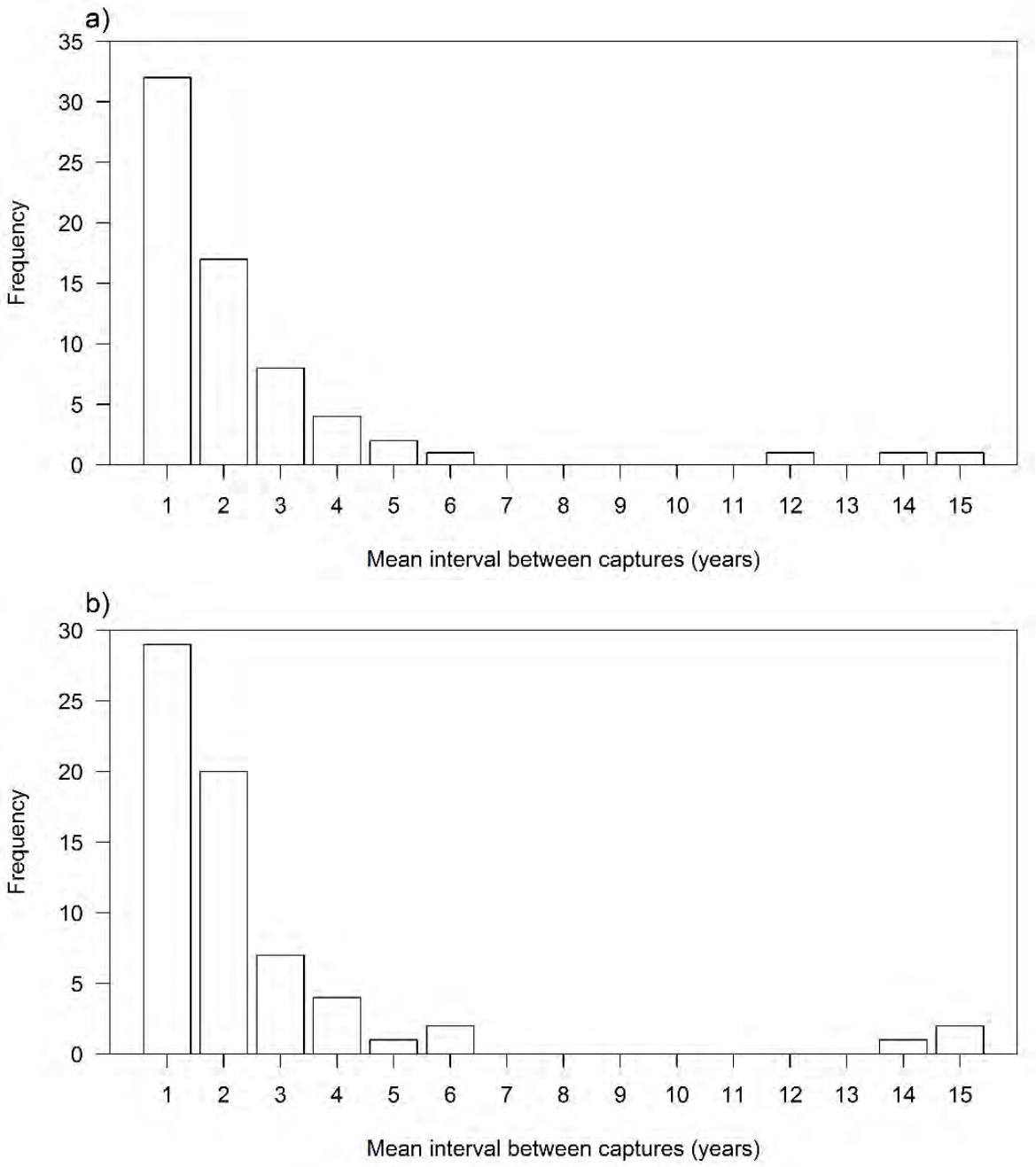


Figure A9. The mean interval between each capture within the capture database for unique individuals identified by a) left and b) right head extracts, grouped into the area of Ramsey.

9.3.2.4. Spatial connectivity

The highest probability of recaptures at Ramsey was for individuals either seen previously or subsequently at Ramsey (Figure A10). Outside of Ramsey, these individuals were most likely to be seen at Skomer, the Marloes and Bardsey. Unique individuals identified by either left or right head extracts within Ramsey were connected to every other broad area, excluding the Dee Estuary.

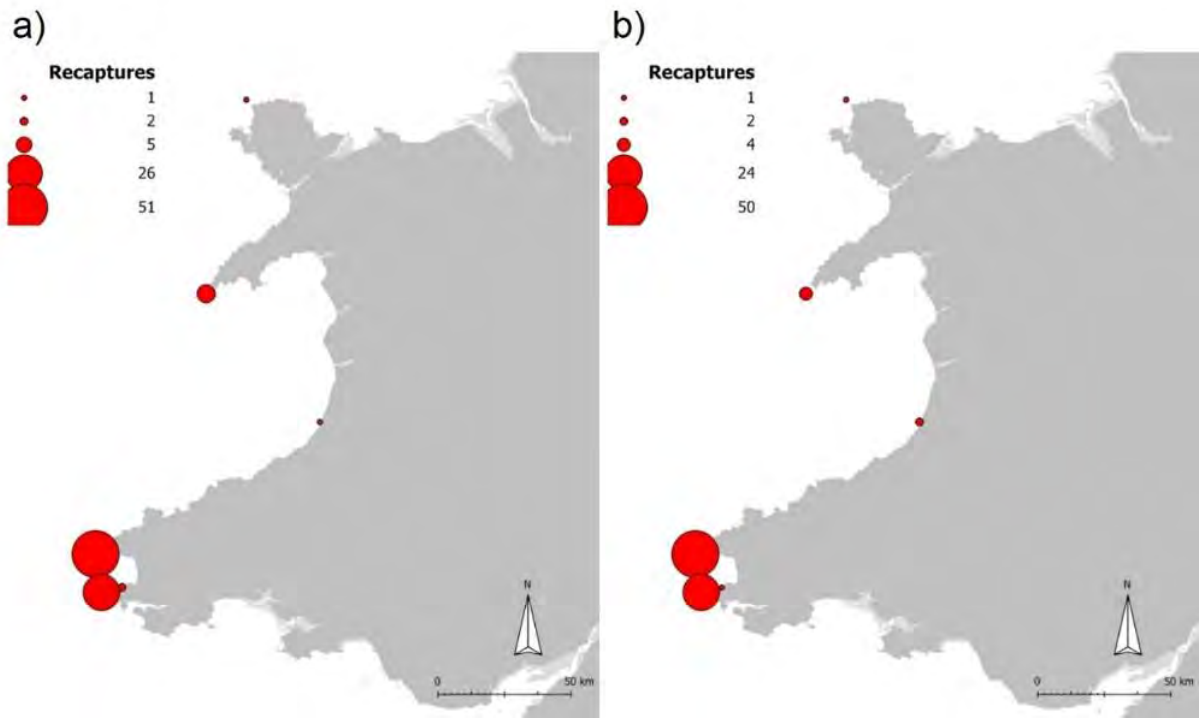


Figure A10. The maximum number of recaptures of unique individuals identified by a) left and b) right head extracts, moving to or from the area of Ramsey.

9.3.2.5. Data recommendations

Within the EIRPHOT database, there were 38 Ramsey extracts from males, 6 from pups and 76 from unknown *AgeSex*. We recommend that these unknown extracts are inspected and their *AgeSex* class confirmed where possible.

There were also 783 extracts from images of individuals with blank *AgeSex* data. For the purpose of this analysis, these extracts were assumed to have been taken from adult females. For future analyses, we recommend that these extracts are inspected and their *AgeSex* class confirmed where possible.

During this analysis, SMRU encountered a technical error within EC. This resulted in 38 head extracts from Ramsey set aside from analysis as they contained >50% blanking of the extractable area. These are currently sitting in the AutoMatch queue Lx, but we recommend that these extracts are deleted from the database, as they do not contain sufficient data to run through EC.

9.3.3. The Marloes

9.3.3.1. Study site

The EIRPHOT database contains photo-ID data collected at 15 locations around the Marloes (Figure A11, Table A15).

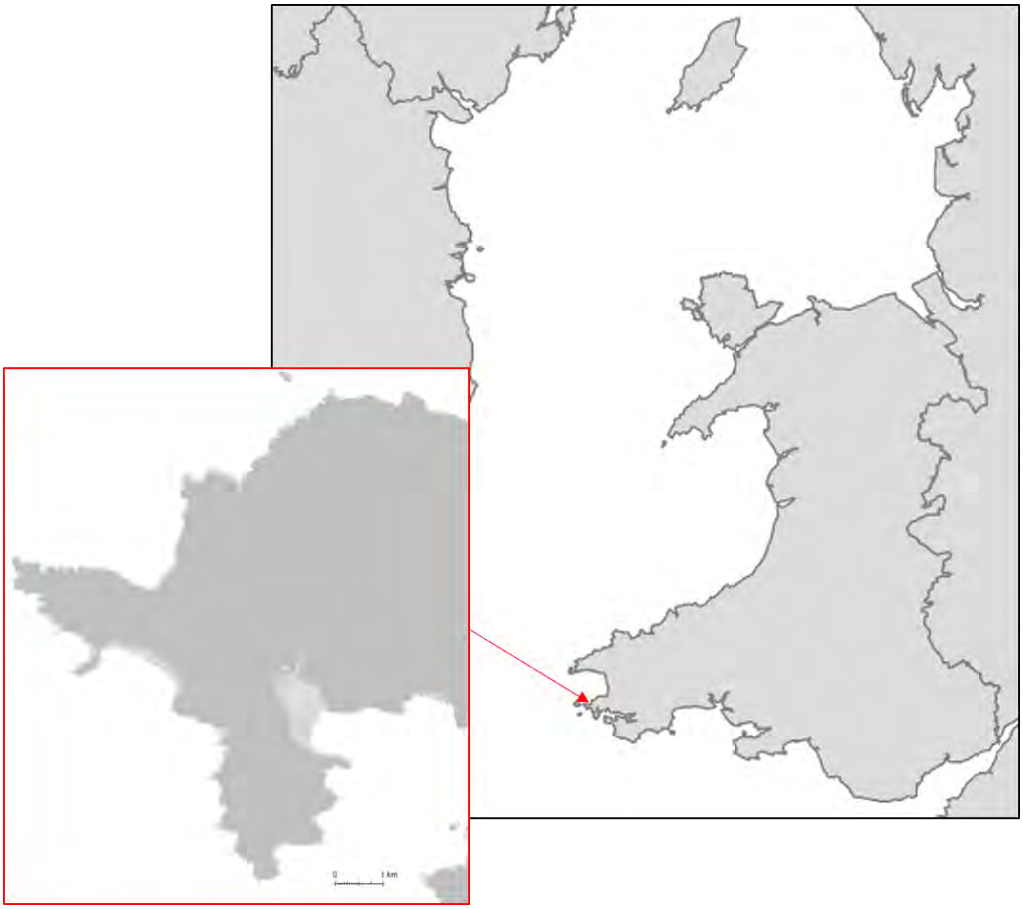


Figure A11. The area of the Marloes in red, which includes Marloes North, Marloes South and St Brides.

Table A15. Location codes for sites within the EIRPHOT database grouped into the area of the Marloes.

Code	Description	Cluster	Section
I150	Jeffery Haven	Skomer	Marloes South
I160	Pebbly Beach	Skomer	Marloes South
I030	Brandy Bay	Skomer	St Brides South
I040	Dutch Gin	Skomer	St Brides South
I060		Skomer	St Brides South
I120		Skomer	Marloes North
I130	Martin's Haven Beach	Skomer	Marloes North
I135	Martin's Haven Cave	Skomer	Marloes North
I140	Wooltack Bay	Skomer	Marloes North
I168	Horseshoe Cave	Skomer	Marloes South
I170	Boulder Beach	Skomer	Marloes South
I176	Renney Slip	Skomer	Marloes South
I195	Three Doors Cave	Skomer	Marloes South
I196	Three Doors Beach	Skomer	Marloes South
I198	Rainy Rock Beach	Skomer	Marloes South
I210	Little Castle Bay	Skomer	Marloes South
I220	Victoria Bay	Skomer	Marloes South
I225	Watery Bay	Skomer	Marloes North

9.3.3.2. Summary of data within EIRPHOT database

On completion of this report, the EIRPHOT database library was made up of 342 extracts, from 203 images across 107 sampling occasions at the Marloes between 2011 and 2014 (Figure A12).

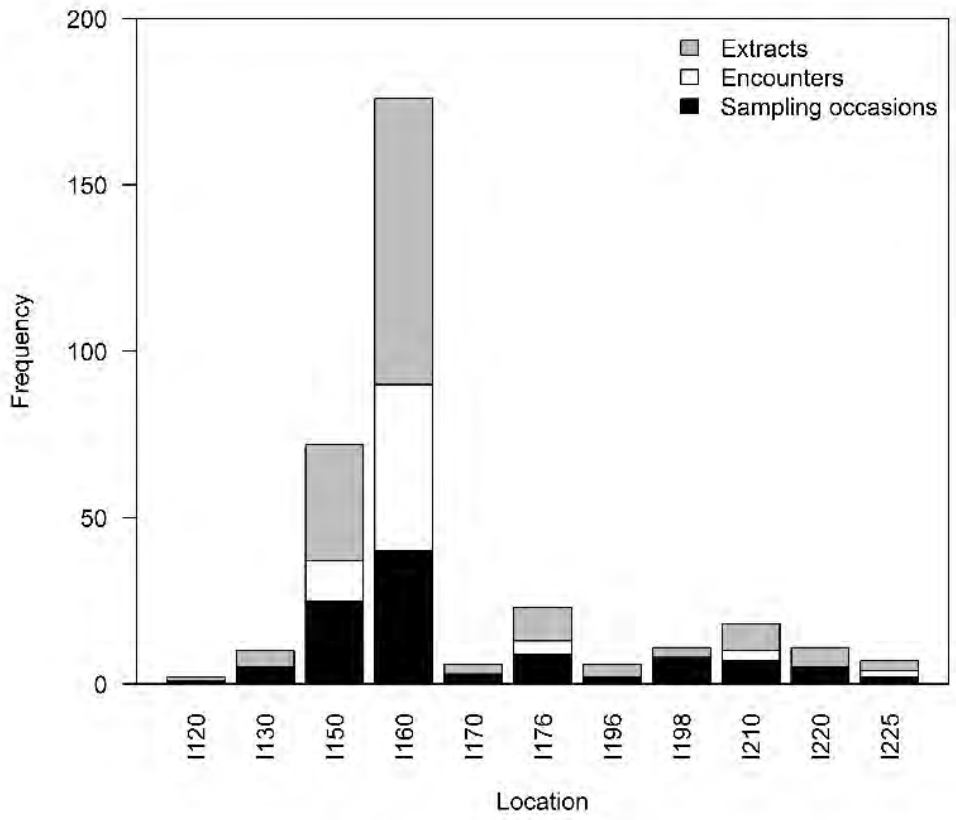


Figure A12. The number of extracts, encounters and sampling occasions within the EIRPHOT database, for each site grouped into the area of the Marloes.

The majority of extracts, encounters and sampling occasions were at locations I160 (Pebbly Beach, Marloes South) and I150 (Jeffery Haven, Marloes South). There were no data from locations I030 (Brandy Bay), I040 (Dutch Gin) or I060, all at St Brides South.

9.3.3.3. Captures and recaptures

At the Marloes, there were 78 unique individuals identified by left head extracts. Of these, 53 were seen once and 25 were seen more than once (Figure A13a). There were also 74 unique individuals identified by right head extracts. Of these, 51 were seen once and 23 were seen more than once (Figure A13b).

The individual seen at the Marloes with the highest number of recaptures was “NK_101” who was first recorded at J050 (Driftwood Bay, Skomer South) in 2008, and was recaught 6 times between 2008 and 2014, at locations J050, J090 (Castle Bay, Skomer South) and I160 (Pebbly Beach, Marloes South).

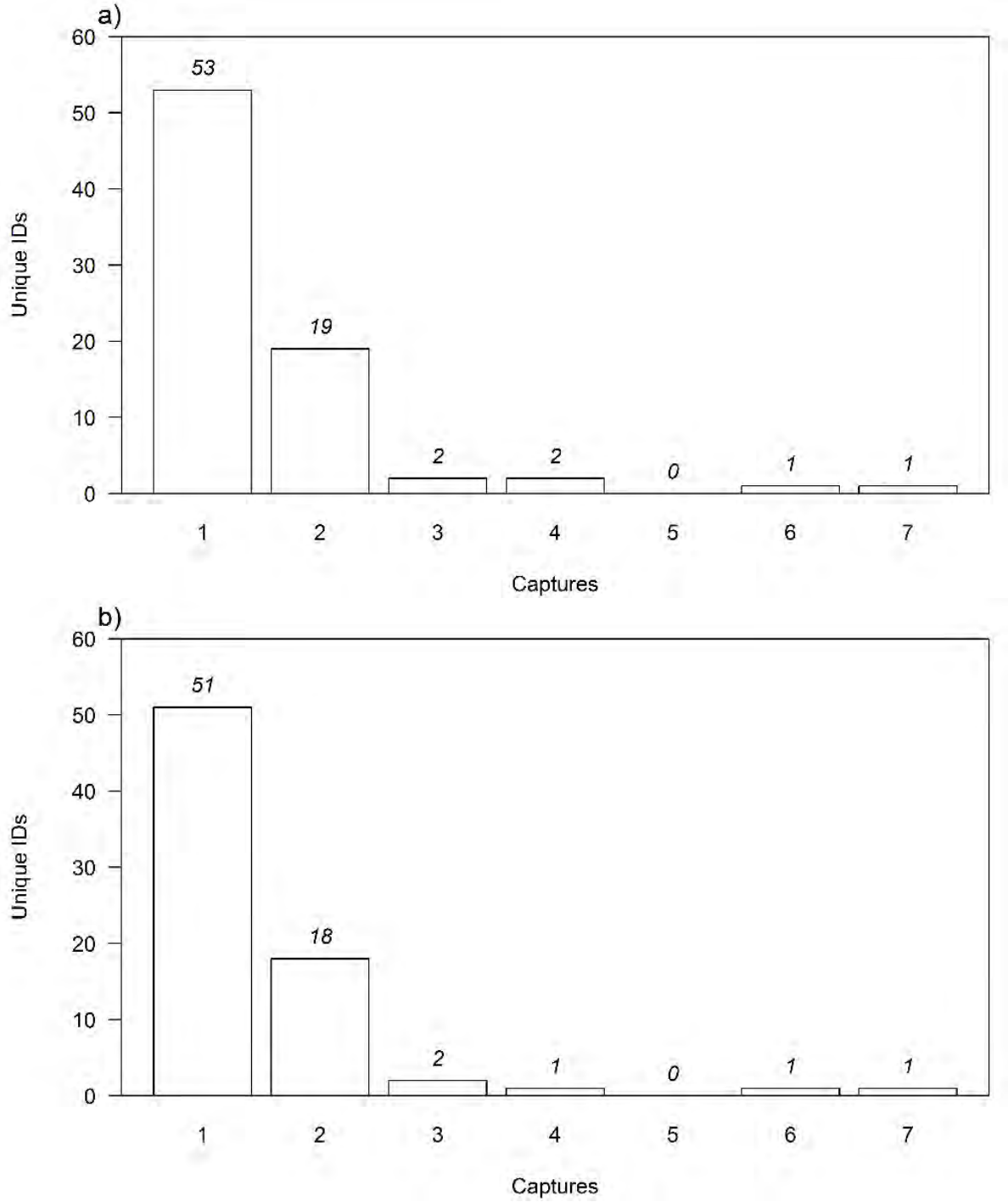


Figure A13. Capture frequency of unique individuals identified by a) left, and b) right head aspects grouped into the area of the Marloes.

The most frequent mean interval between captures in the Marloes was one year (Figure A14). The maximum mean interval was 18 years, for individual “29254”, who was first caught at EHENS (Bardsey) in 1993 and subsequently recaught at I160 (Pebbly Beach, Marloes South) in 2011.

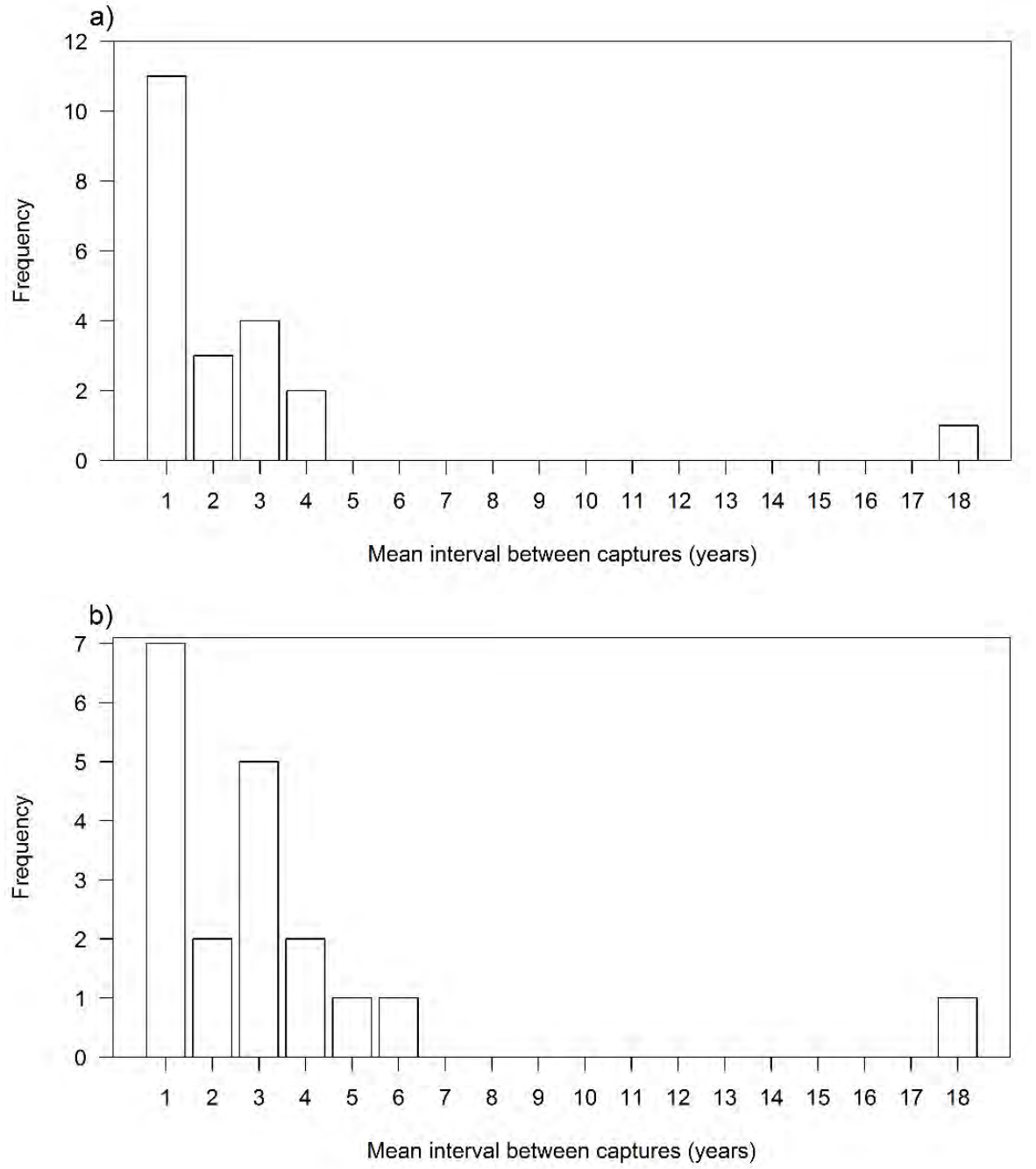


Figure A14. The mean interval between each capture within the capture database for unique individuals identified by a) left and b) right head extracts grouped into the area of the Marloes.

9.3.3.4. Spatial connectivity

The highest probability of recaptures at the Marloes were from individuals either seen previously or subsequently at the Marloes (Figure A15). Outside of the Marloes, these individuals were most likely to be seen at Skomer. Unique individuals identified by either left or right head extracts within the Marloes were connected to every other broad area, excluding Cardigan Bay and the Dee Estuary.

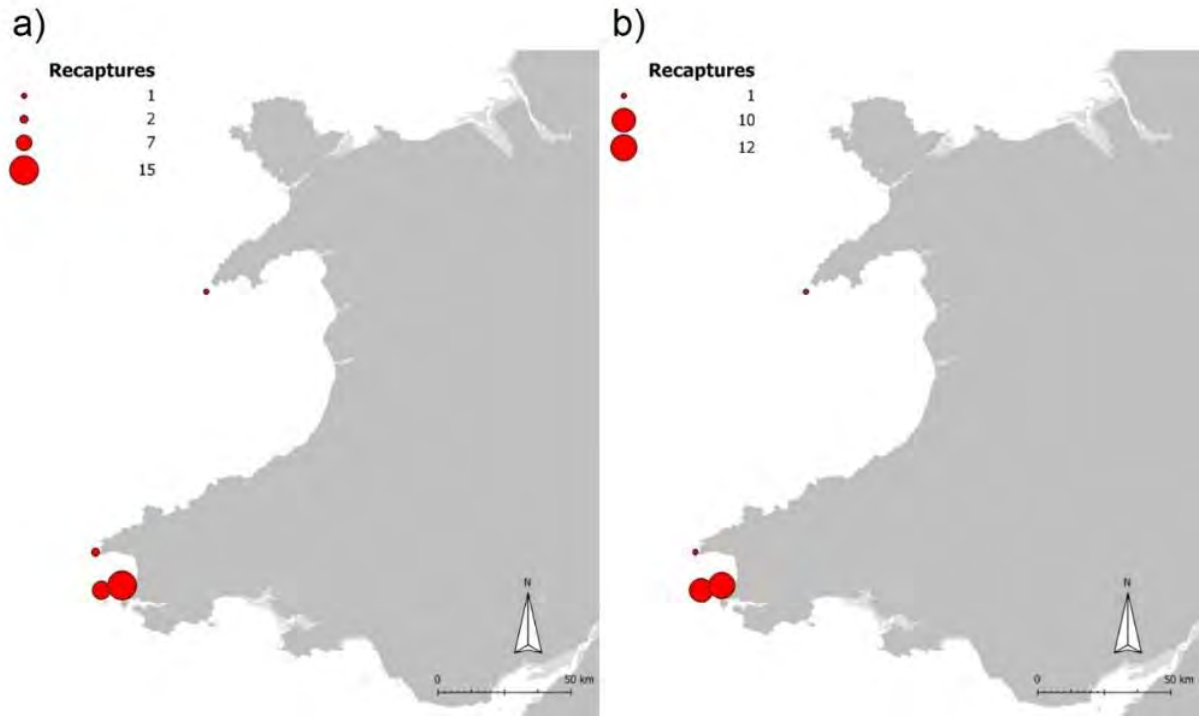


Figure A15. The maximum number of recaptures of unique individuals identified by a) left and b) right head extracts, moving to or from the area of the Marloes.

9.3.3.5. Data recommendations

Within the EIRPHOT database, there were 3 Marloes extracts from males, but no pups or individuals of unknown *AgeSex*. There was also a single extract from an individual with missing *AgeSex* data. We recommend that this unknown extract is inspected and the *AgeSex* class confirmed if possible.

9.3.4. Bardsey

9.3.4.1. Study site

The EIRPHOT database contains photo-ID data collected at 29 locations around Bardsey (Figure A16, Table A16).

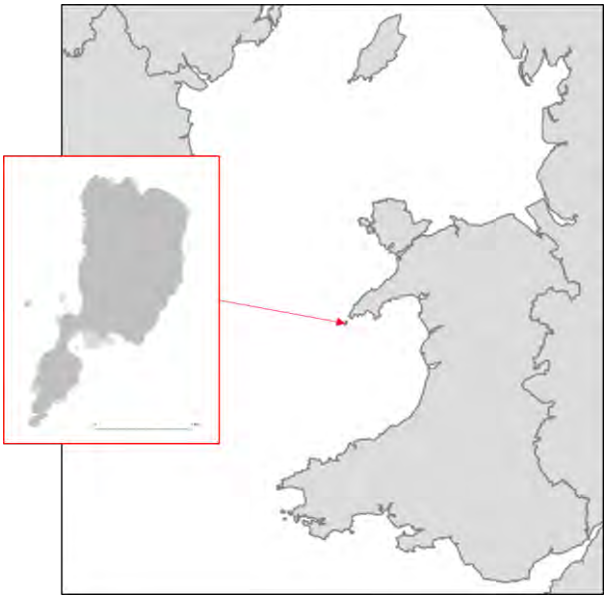


Figure A16. The area of Bardsey in red, which encompasses the island.

Table A16. Location codes for sites within the EIRPHOT database grouped into the area of Bardsey.

Location	Description	Cluster	Section
E	Ynys Enlli / Bardsey	Bardsey	South Llyn
EBN	Ynys Enlli / Bardsey	Bardsey	South Llyn
EBR	Ynys Enlli / Bardsey	Bardsey	South Llyn
EBRN	Ynys Enlli / Bardsey	Bardsey	South Llyn
EBYR	Ynys Enlli / Bardsey	Bardsey	South Llyn
ECH	Ynys Enlli / Bardsey	Bardsey	South Llyn
EEMD	Ynys Enlli / Bardsey	Bardsey	South Llyn
EFCS	Traeth Bach	Bardsey	South Llyn
EH	Ynys Enlli / Bardsey	Bardsey	South Llyn
EHEN	Ynys Enlli / Bardsey	Bardsey	South Llyn
EHENE	Ynys Enlli / Bardsey	Bardsey	South Llyn
EHENN	Ynys Enlli / Bardsey	Bardsey	South Llyn
EHENS	Ynys Enlli / Bardsey	Bardsey	South Llyn
EHENSE	Ynys Enlli / Bardsey	Bardsey	South Llyn
EICS	Traeth Bach	Bardsey	South Llyn
ELCE	Ynys Enlli / Bardsey	Bardsey	South Llyn
EMD	Ynys Enlli / Bardsey	Bardsey	South Llyn
EOD	Ynys Enlli / Bardsey	Bardsey	South Llyn
EOG	Ynys Enlli / Bardsey	Bardsey	South Llyn
EOH	Ynys Enlli / Bardsey	Bardsey	South Llyn
EOL	Ogof Las	Bardsey	South Llyn
EOM	Ynys Enlli / Bardsey	Bardsey	South Llyn
EPH	Ynys Enlli / Bardsey	Bardsey	South Llyn
EPR	Ynys Enlli / Bardsey	Bardsey	South Llyn
ES		Bardsey	South Llyn
ETB	Ynys Enlli / Bardsey	Bardsey	South Llyn
ETF	Ynys Enlli / Bardsey	Bardsey	South Llyn
ETTD	Ynys Enlli / Bardsey	Bardsey	South Llyn
EYG	Ynys Enlli / Bardsey	Bardsey	South Llyn

9.3.4.2. Summary of data within EIRPHOT database

On completion of this report, the EIRPHOT database library was made up of 5,989 extracts, from 4,152 images across 441 sampling occasions at Bardsey between 1993 and 2011 (Figure A17).

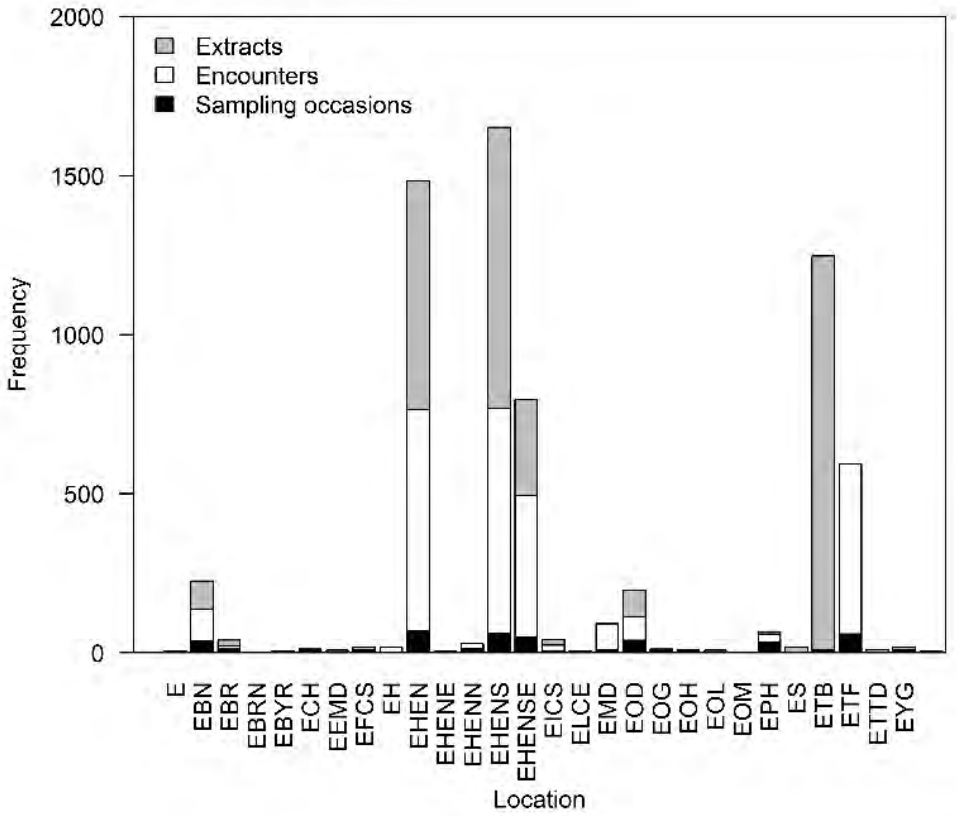


Figure A17. The number of extracts, encounters and sampling occasions within the EIRPHOT database, for each site grouped into the area of Bardsey.

The majority of extracts, encounters and sampling occasions were at locations EHEN, EHENS, EHENSE, ETB and ETF, all locations around Bardsey. There were few data from EFCS and EICS (both Traeth Bach) and EOL (Ogof Las).

9.3.4.3. Captures and recaptures

At Bardsey, there were 736 unique individuals identified by left head extracts. Of these, 545 were seen once and 191 were seen more than once (Figure A18a). There were also 673 unique individuals identified by right head extracts. Of these, 491 were seen once and 182 were seen more than once (Figure A18b).

The individual seen at Bardsey with the highest number of recaptures was “Evilfinger2Giraffe” who was first recorded at R (Rhosgar, Nefyn, North Lyn) in 2002 and was recaught 10 times between 2009 and 2012, at locations AB (Aberffraw, West Anglesey) and EH (Bardsey).

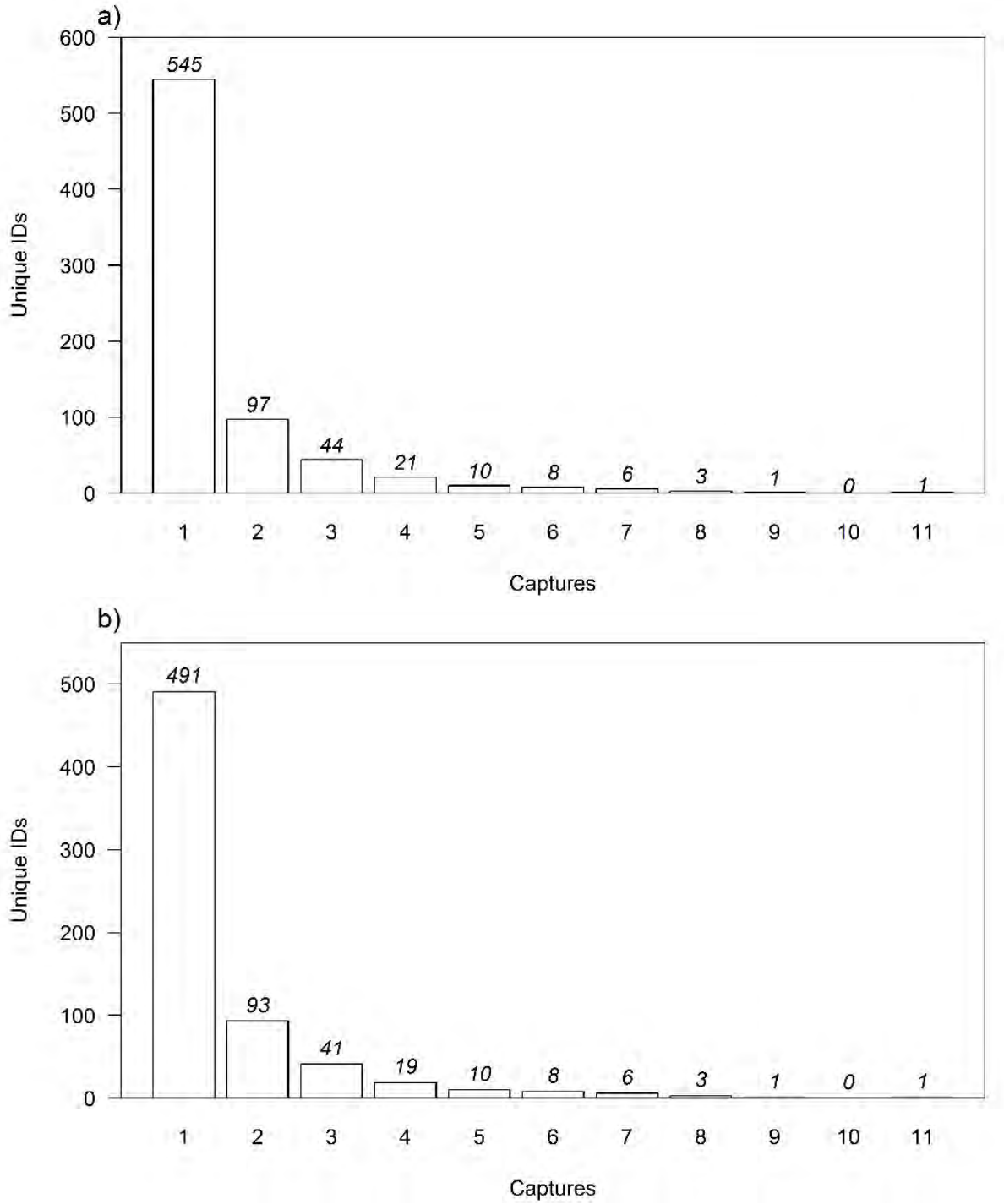


Figure A18. Capture frequency of unique individuals identified by a) left, and b) right head aspects grouped into the area of Bardsey.

The most frequent mean interval between captures in Bardsey was one year (Figure A19). Two individuals shared the maximum mean interval of 18 years; individual “29222”, who was first caught at EHENS (Bardsey) in 1993 and subsequently recaught at EHEN (Bardsey) in 2011, and individual “29254”, who was first caught at EHENS (Bardsey) in 1993 and subsequently recaught at I160 (Pebbly Beach, Marloes South) in 2011.

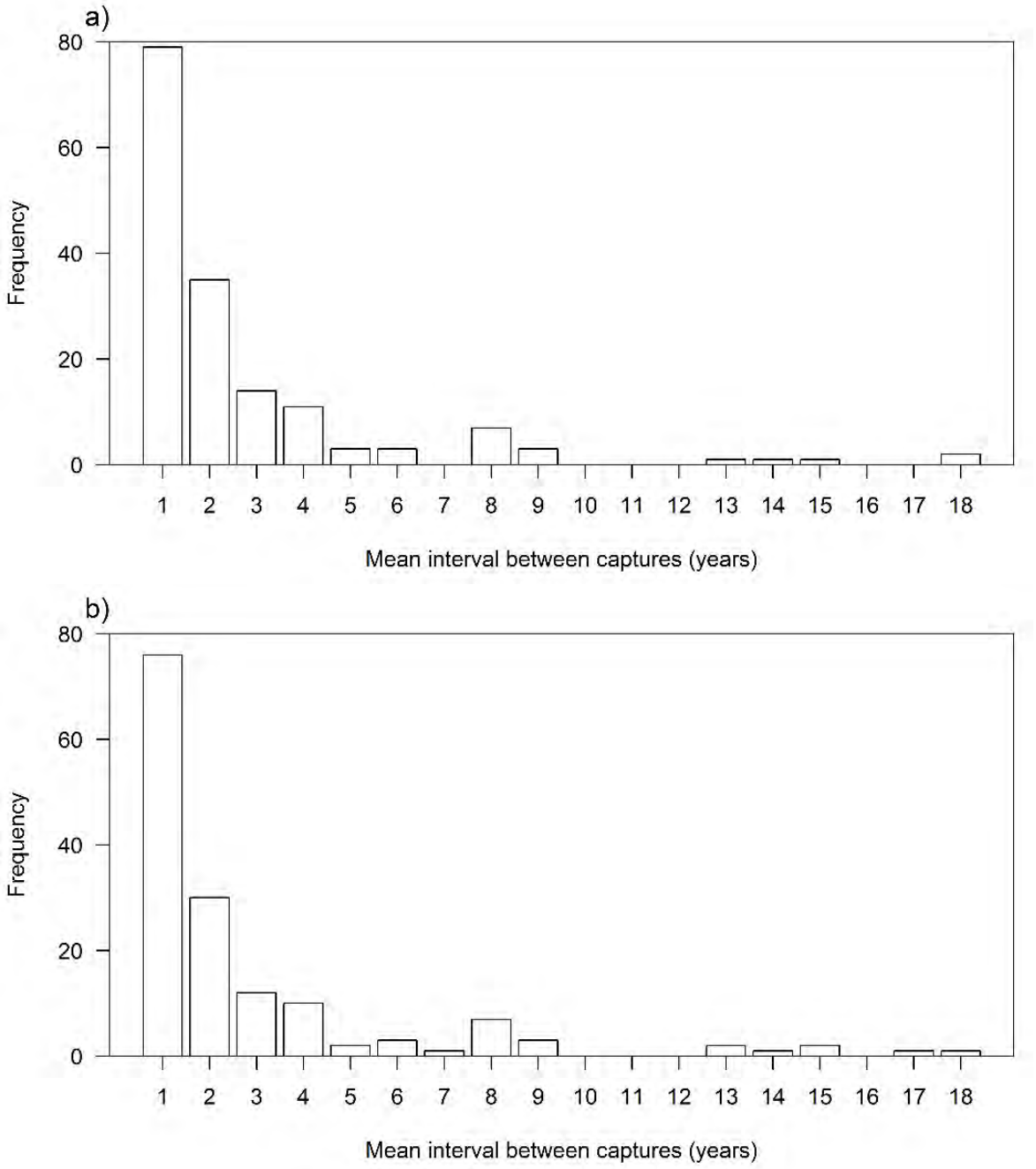


Figure A19. The mean interval between each capture within the capture database for unique individuals identified by a) left and b) right head extracts grouped into the area of Bardsey.

9.3.4.4. Spatial connectivity

The highest probability of recaptures at Bardsey were from individuals either seen previously or subsequently at Bardsey (Figure A20). Outside of Bardsey, these individuals were most likely to be seen at the Skerries, Skomer and Ramsey. Unique individuals identified by right head extracts within Bardsey were connected to every other broad area. However, unique individuals identified by left head extracts within Bardsey were not seen previously or subsequently at the Dee Estuary.

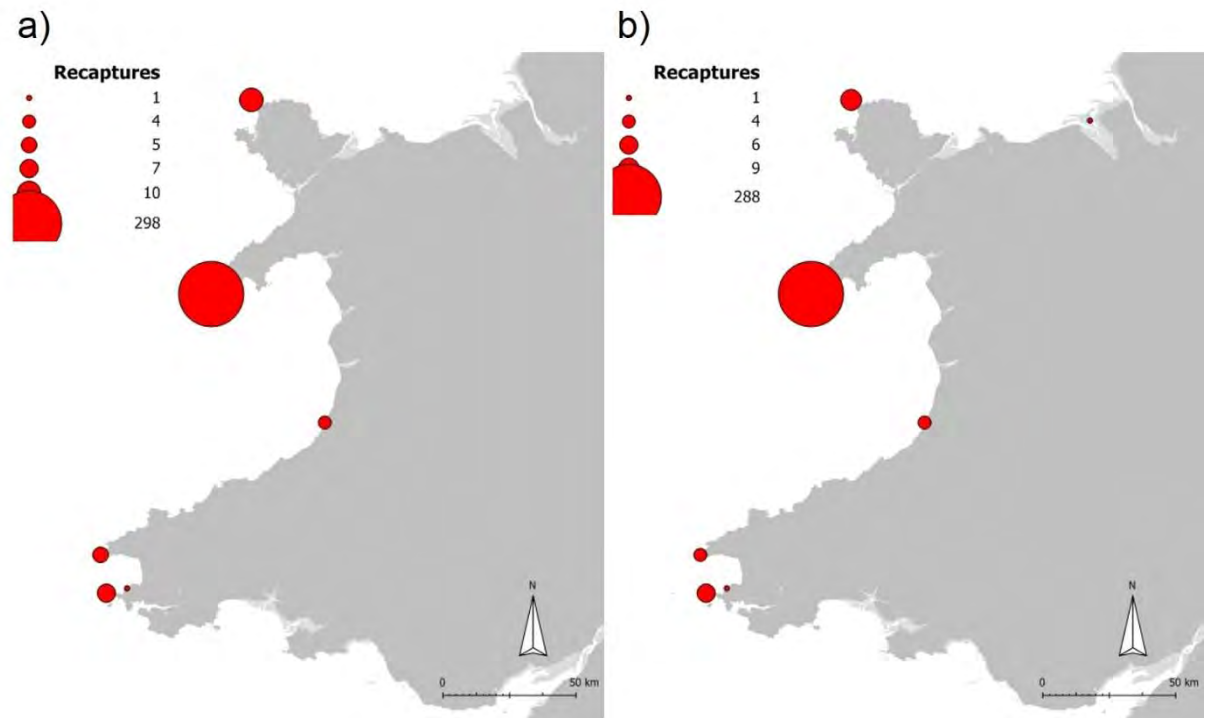


Figure A20. The maximum number of recaptures of unique individuals identified by a) left and b) right head extracts, moving to or from the area of Bardsey.

9.3.4.5. Data recommendations

Within the EIRPHOT database, there were 719 Bardsey extracts from males, 305 from pups and 543 from unknown *AgeSex*. We recommend that these unknown extracts are inspected and their *AgeSex* class confirmed where possible.

There were also 3 extracts from images of individuals with blank *AgeSex* data. For the purpose of this analysis, these extracts were assumed to have been taken from adult females. For future analyses, we recommend that these extracts are inspected and their *AgeSex* class confirmed where possible.

During this analysis, SMRU encountered a technical error within EC. This resulted in 109 head extracts from Bardsey set aside from analysis as they contained >50% blanking of the extractable area. These are currently sitting in the AutoMatch queues Px and Lx, but we recommend that these extracts are deleted from the database, as they do not contain sufficient data to run through EC.

On arrival at SMRU, the EIRPHOT database contained 1 Bardsey extract that had an AutoMatch value of EX. As there was no corresponding explanation in the *AutoMatch_meanings* table, it is not clear why this extract has been set aside. It is therefore recommended that this extract is inspected for reasons why it may have been set aside originally, and that the *AutoMatch_meanings* table is updated.

During the EC process, images from Bardsey were found to have been duplicated and therefore entered into the database more than once. Sometimes the duplicate was just a cropped version of the original image. As these were identified at the visual confirm stage of EC, it is unknown how many duplicates of Bardsey images are in the

database. We therefore recommend that this does not continue to happen in the future, as it slows down the EC process with no added benefit.

However, some of these duplicate images from Bardsey have been entered into the database separately and have been assigned slightly different locations. This could be a result of having defined small scale locations with lat/lon coordinates (e.g. EHENSE, EHENS) and broader scale locations with no lat/lon coordinates (e.g. EH, EEMD). Within the EIRPHOT locations table, there are 29 locations grouped into the area of Bardsey. Six of these do not have lat/lon data and have the same description. We recommend that the locations table in EIRPHOT is updated with only locations that can be distinguished from another, either by lat/lon coordinates or detailed descriptions.

9.3.5. Cardigan Bay

9.3.5.1. Study site

The EIRPHOT database contains photo-ID data collected at 49 locations around Cardigan Bay (Figure A21, Table A17).

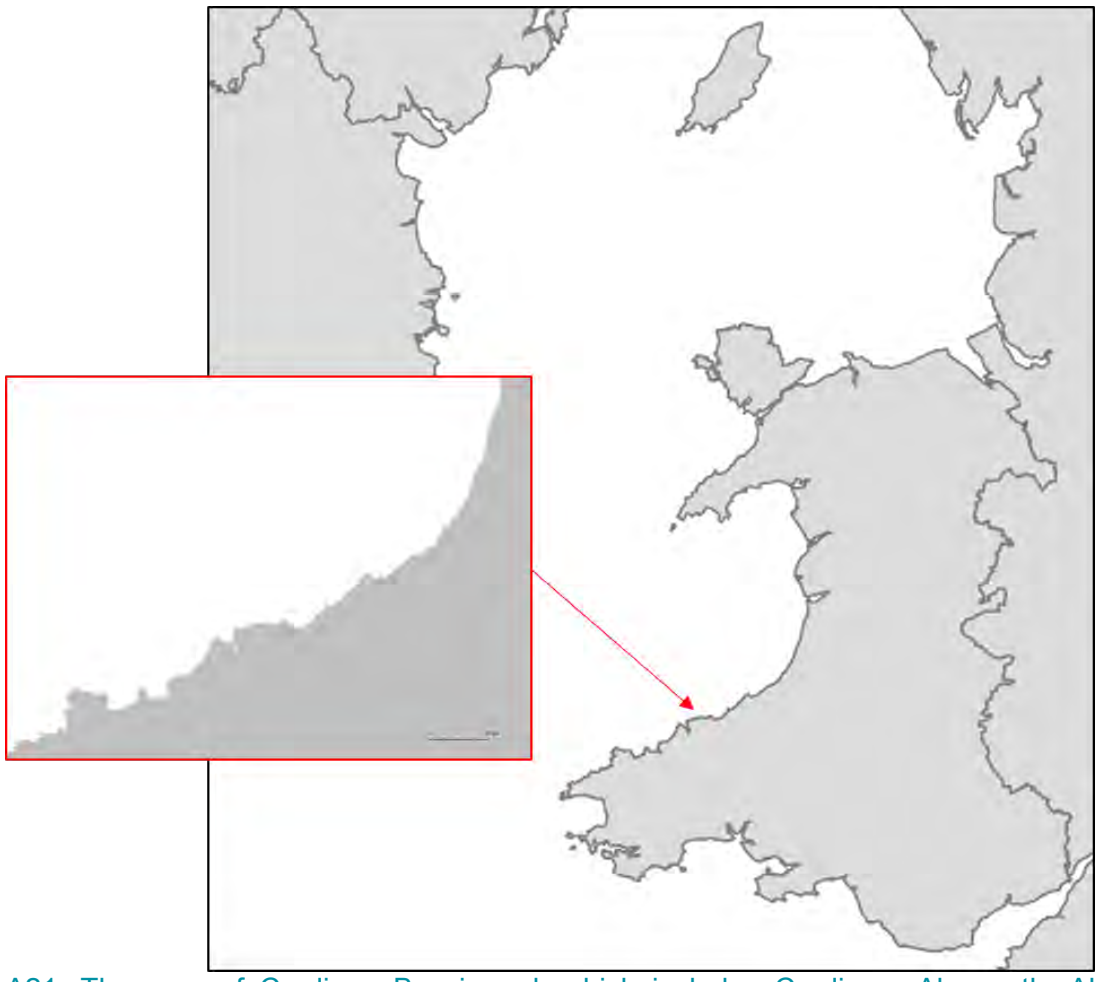


Figure A21. The area of Cardigan Bay in red, which includes Cardigan, Aberporth, Aberfelin, Fishguard, Dinas, North Pembrokeshire cliff and Cemaes.

Table A17. Location codes for sites within the EIRPHOT database grouped into the area of Cardigan Bay.

Code	Description	Cluster	Section
BR		Cardigan	Cardigan Bay
CI		Cardigan	Cardigan Bay
Clyn yr ynys		Cardigan	Cardigan Bay
CT		Cardigan	Cardigan Bay
B230	Pencestyll	Aberporth	Cardigan Bay
E090		Aberfelin	Cardigan Bay
E080		Aberfelin	Cardigan Bay
E074		Aberfelin	Cardigan Bay
E070		Aberfelin	Cardigan Bay
E068		Aberfelin	Cardigan Bay
E069		Aberfelin	Cardigan Bay
E065		Fishguard	Cardigan Bay
E066		Fishguard	Cardigan Bay
E050	Porth Maen	Fishguard	Cardigan Bay
E040		Fishguard	Cardigan Bay
E060		Fishguard	Cardigan Bay
E060B		Fishguard	Cardigan Bay
E058		Fishguard	Cardigan Bay
E108	Aber Degan	Ynys Meicel	Cardigan Bay
E100	Trwyn Llwyd	Ynys Meicel	Cardigan Bay
D190	Aber Careg-y-fran	Dinas West	Cardigan Bay
E116		Ynys Meicel	Cardigan Bay
D180	Aber Pensidan	Dinas West	Cardigan Bay
E120	Pwlluog	Ynys Meicel	Cardigan Bay
D170		Dinas West	Cardigan Bay
D160		Dinas West	Cardigan Bay
D130	Pwll Glas	Dinas East	Cardigan Bay
D156		Dinas West	Cardigan Bay
D157		Dinas West	Cardigan Bay
D140	Stinking Hole	Dinas East	Cardigan Bay
C240		North Pembs Cliff	Cardigan Bay
C230		North Pembs Cliff	Cardigan Bay
C220		North Pembs Cliff	Cardigan Bay
C225		North Pembs Cliff	Cardigan Bay
C227		North Pembs Cliff	Cardigan Bay
C180		North Pembs Cliff	Cardigan Bay
C080	Traeth y Rhedyn	Cemaes	Cardigan Bay
C060		Cemaes	Cardigan Bay
C050		Cemaes	Cardigan Bay
C040	Traeth Godir-coch	Cemaes	Cardigan Bay
C015		Cemaes	Cardigan Bay
C030		Cemaes	Cardigan Bay
C020	Cemaes Cardigan Bay	Cemaes	Cardigan Bay
CEMAES	Cemaes Cardigan Bay	Cemaes	Cardigan Bay
C020		Cemaes	Cardigan Bay
B270		Cardigan	Cardigan Bay
B278		Cardigan	Cardigan Bay
B300		Cardigan	Cardigan Bay
CARDI_B360	Cardigan Isle	Cardigan	Cardigan Bay
PENDER	Wales PENDERI cliffs	Penderi	Cardigan Bay

9.3.5.2. Summary of data within EIRPHOT database

On completion of this report, the EIRPHOT database library was made up of 1,802 extracts, from 1,048 images across 167 sampling occasions at Cardigan Bay between 1993 and 2016 (Figure A22).

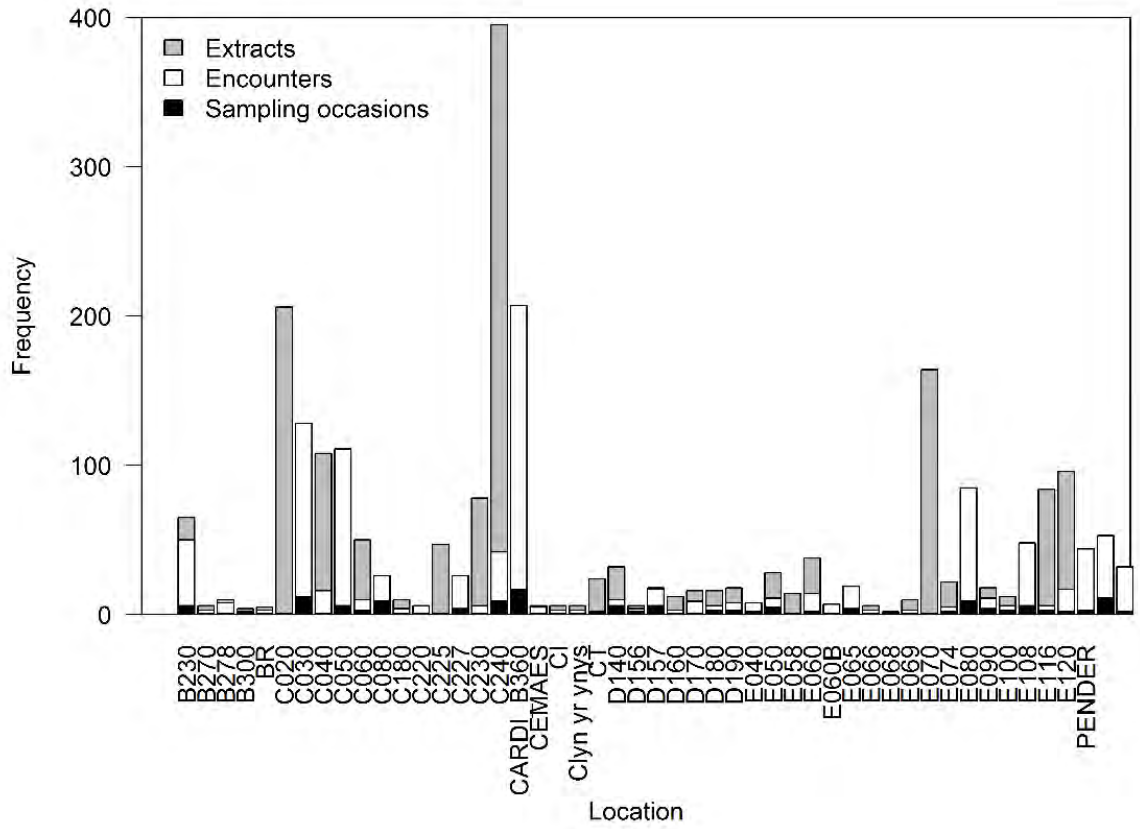


Figure A22. The number of extracts, encounters and sampling occasions within the EIRPHOT database, for each site grouped in Cardigan Bay.

The majority of extracts, encounters and sampling occasions were at locations C240 (North Pembs Cliff), C020 (Cemaes), CARDI_B360 (Cardigan Isle) and E070 (Aberfelin). There were few data from B270, B278, B300 and BR (all Cardigan).

9.3.5.3. Captures and recaptures

At Cardigan Bay, there were 172 unique individuals identified by left head extracts. Of these, 124 were seen once and 48 were seen more than once (Figure A23a). There were also 169 unique individuals identified by right head extracts. Of these, 116 were seen once and 53 were seen more than once (Figure A23b).

The individual seen at Cardigan Bay with the highest number of recaptures was “9374” who was first recorded at D190 (Aber Careg-y-fran, Dinas West, Cardigan Bay) in 1993 and was recaught 6 times between 1994 and 1998, at locations D190, D180 (Aber Pensidan, Dinas West, Cardigan Bay) and LA (Lambay Island, Howth Peninsula, Ireland).

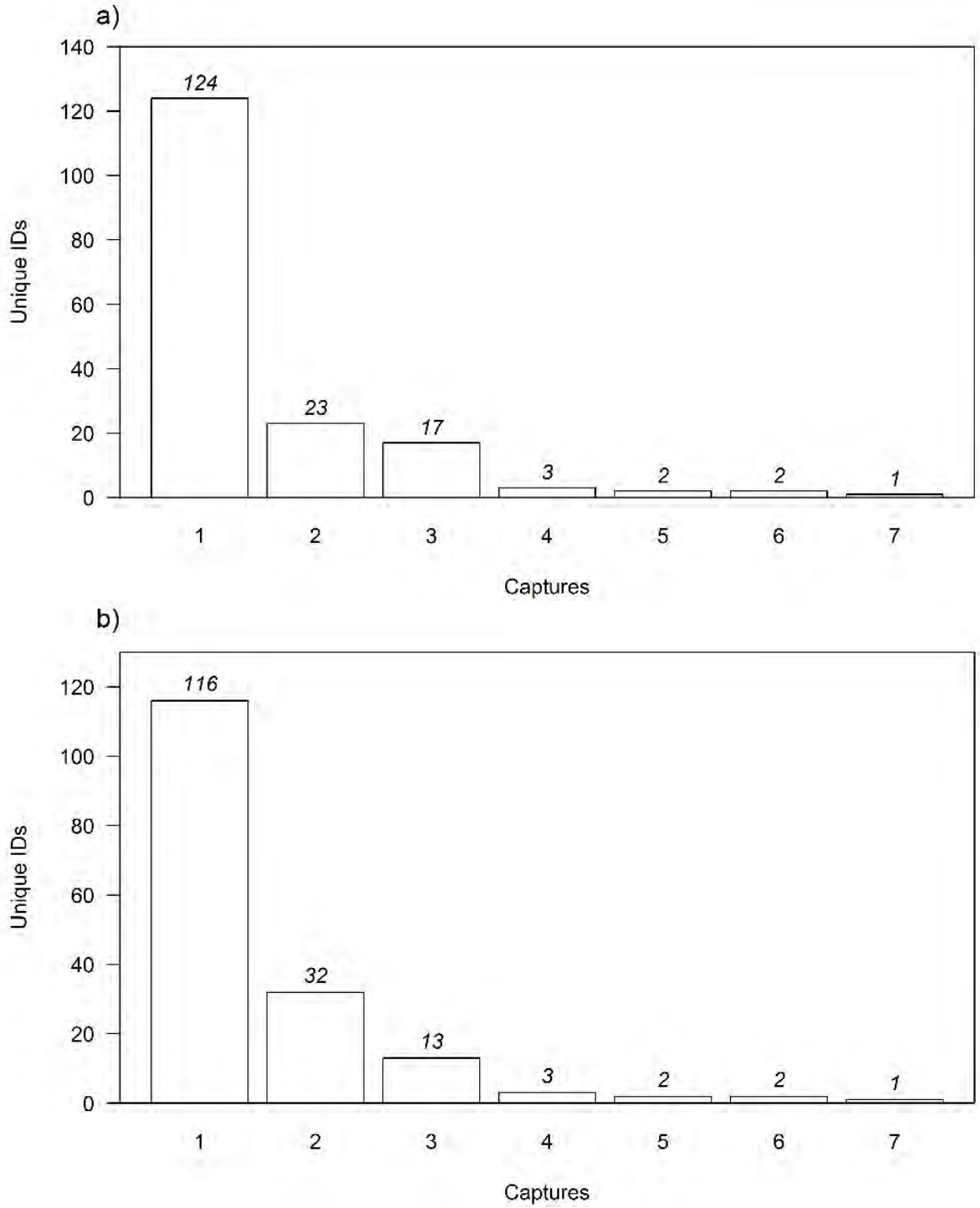


Figure A23. Capture frequency of unique individuals identified by a) left, and b) right head aspects grouped into the area of Cardigan Bay.

The most frequent mean interval between captures in Cardigan Bay was one year (Figure A24). The maximum mean interval was 19 years, for individual “11151”, who was first caught at B230 (Pencestyll, Aberporth, Cardigan Bay) in 1993 and subsequently recaught at the same location in 2012.

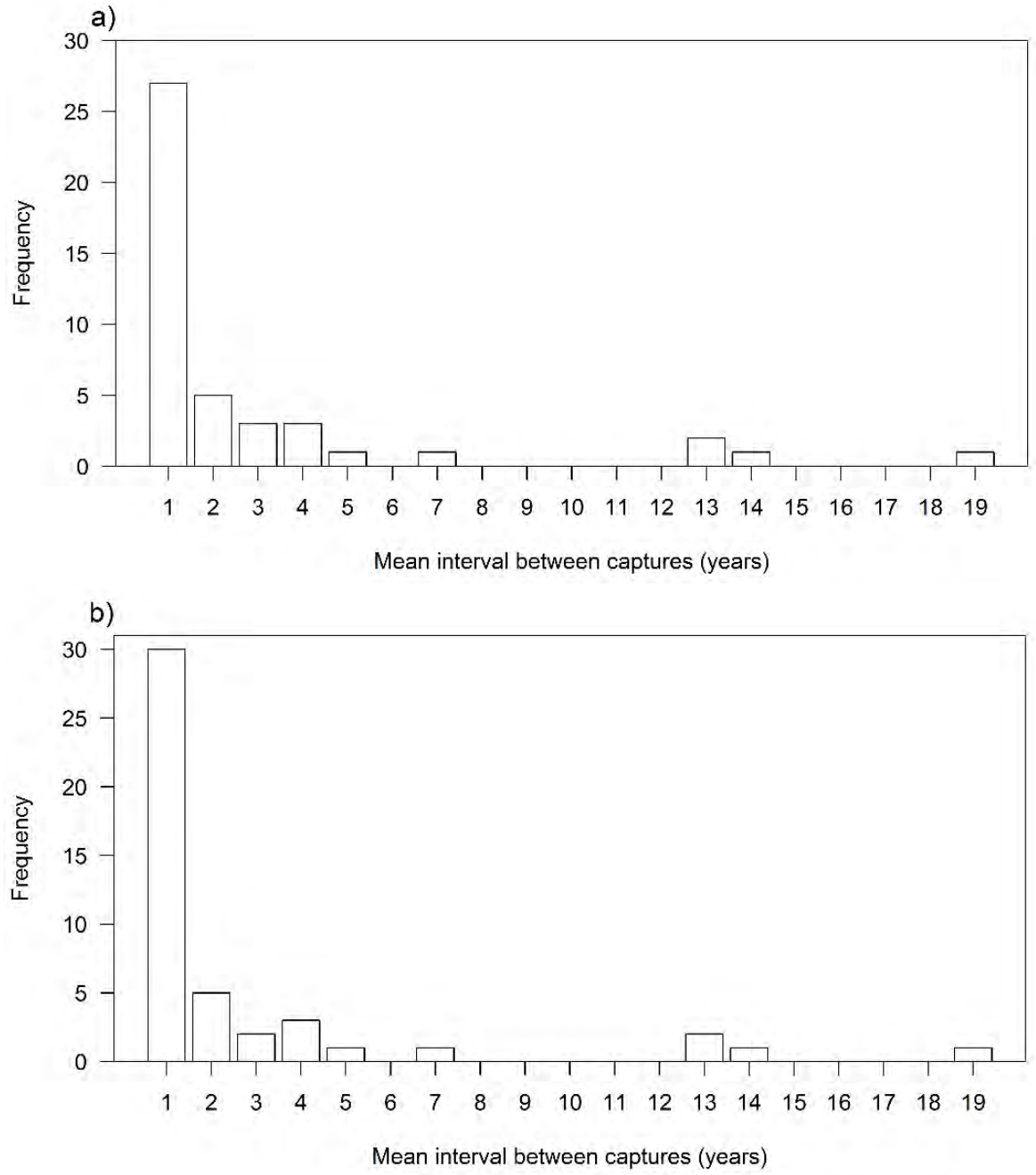


Figure A24. The mean interval between each capture within the capture database for unique individuals identified by a) left and b) right head extracts grouped into the area of Cardigan Bay.

9.3.5.4. Spatial connectivity

The highest probability of recaptures at Cardigan Bay were from individuals either seen previously or subsequently at Cardigan Bay (Figure A25). Outside of Cardigan Bay, these individuals were most likely to be seen at Bardsey and Skomer. Unique individuals identified by either left or right head extracts within Cardigan Bay were connected to every other broad area, excluding the Dee Estuary and the Marloes.

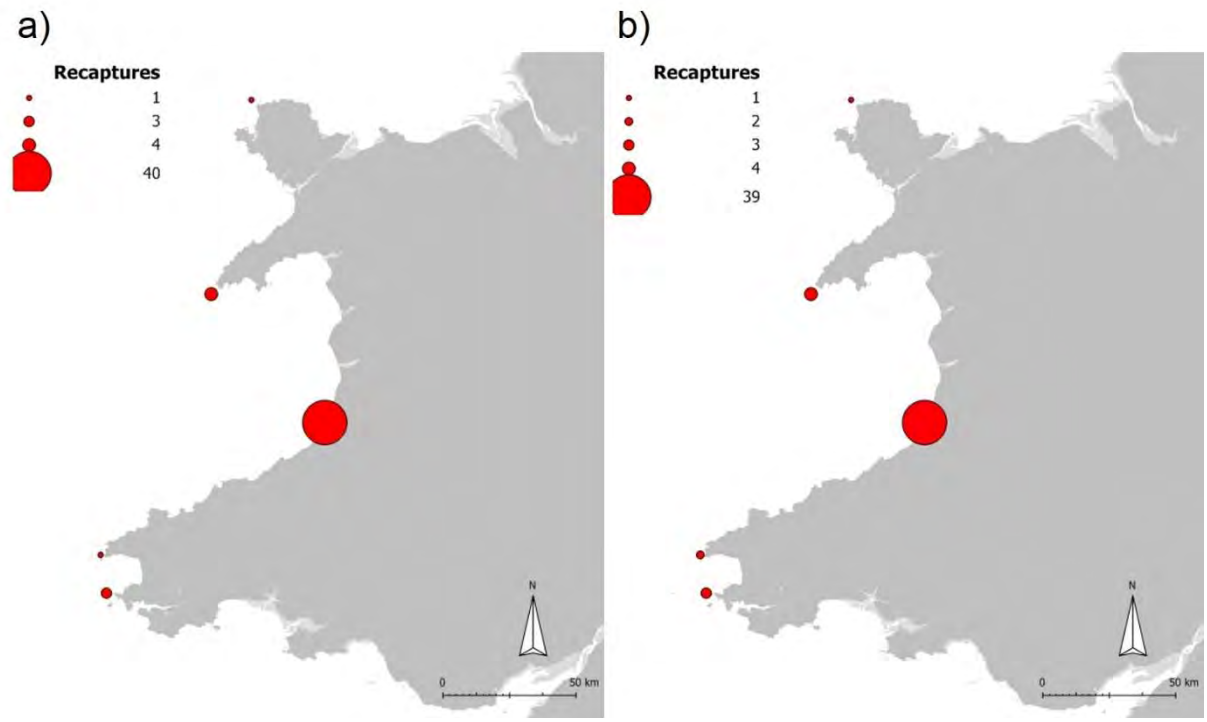


Figure A25. The maximum number of recaptures of unique individuals identified by a) left and b) right head extracts, moving to or from the area of Cardigan Bay.

9.3.5.5. Data recommendations

Within the EIRPHOT database, there were 2 Cardigan Bay extracts from males and 10 from unknown *AgeSex*. We recommend that these unknown extracts are inspected and their *AgeSex* class confirmed where possible.

There were also 1,574 extracts from images of individuals with blank *AgeSex* data. For the purpose of this analysis, these extracts were assumed to have been taken from adult females. For future analyses, we recommend that these extracts are inspected and their *AgeSex* class confirmed where possible.

During this analysis, SMRU encountered a technical error within EC. This resulted in 58 head extracts from Cardigan Bay set aside from analysis as they contained >50% blanking of the extractable area. These are currently sitting in the AutoMatch queues Px and Lx, but we recommend that these extracts are deleted from the database, as they do not contain sufficient data to run through EC.

9.3.6. The Dee Estuary

9.3.6.1. Study site

The EIRPHOT database contains photo-ID data collected at 2 locations around the Dee Estuary (Figure A26, Table A18).

Figure A26. The area of the Dee Estuary in red, which includes the West Hoyle sandbank and Hilbre.

Table A18. Location codes for sites within the EIRPHOT database grouped into the area of the Dee Estuary.

Location	Description	Cluster	Section
HN	Hilbre North	Dee Estuary	Dee Estuary
WHS	West Hoyle Sandbank	Dee Estuary	Dee Estuary

9.3.6.2. Summary of data within EIRPHOT database

On completion of this report, the EIRPHOT database library was made up of 893 extracts, from 667 images across 18 sampling occasions at the Dee Estuary between 2011 and 2012 (Figure A27).

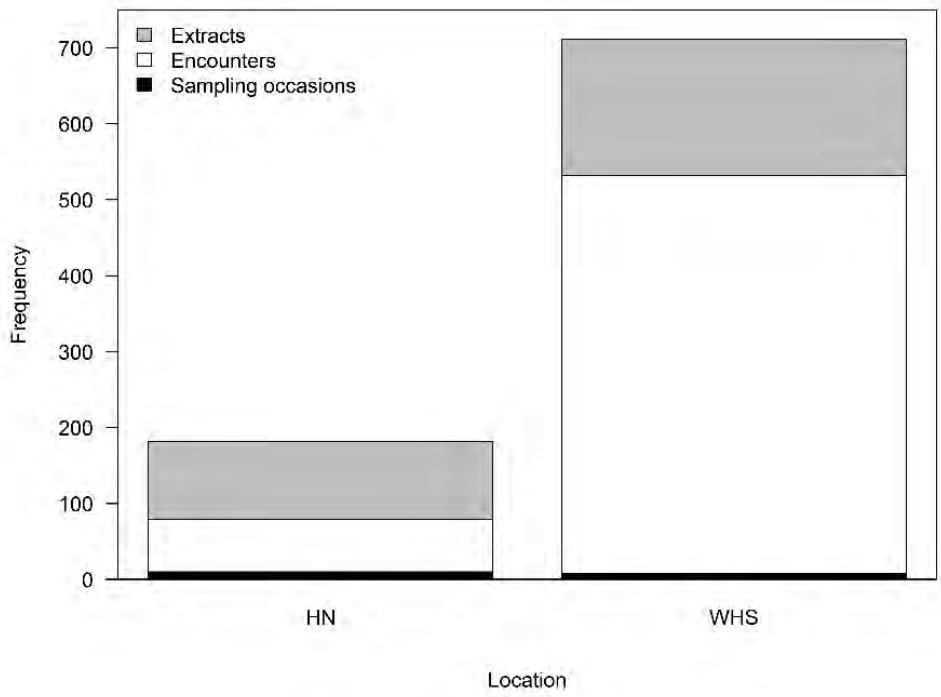


Figure A27. The number of extracts, encounters and sampling occasions within the EIRPHOT database, for each site grouped into the area of the Dee Estuary.

The majority of extracts and encounters were at WHS (West Hoyle Sandbank), but the number of sampling occasions within the Dee Estuary were evenly split between the two locations; West Hoyle Sandbank (WHS) and Hilbre North (HN).

9.3.6.3. Captures and recaptures

At the Dee Estuary, there were 236 unique individuals identified by left head extracts. Of these, 222 were seen once and 14 were seen more than once (Figure A28a). There were also 180 unique individuals identified by right head extracts. Of these, 165 were seen once and 15 were seen more than once (Figure A28b).

The individuals seen at the Dee Estuary with the highest number of recaptures were “10561”, “28673” and “31022”. Individual “10561” was first recorded at LA (Lambay Island, Howth Peninsula, Ireland) in 1997 and was recaught 5 times between 1997 and 2011, at locations LA, YD (Ynys Dulas, East Anglesey) and HN (Hilbre North, Dee Estuary). Individual “28673” was first recorded at YD in 2008 and was recaught 5 times between 2009 and 2012, at locations YD, YYM (The Skerries, North Anglesey), HN and WHS (West Hoyle Sandbank, Dee Estuary). Individual “31022” was first recorded at YYM in 2007 and was recaught 5 times between 2009 and 2012, at locations YD, YYM, WHS and CH (Carmel Head, North Anglesey).

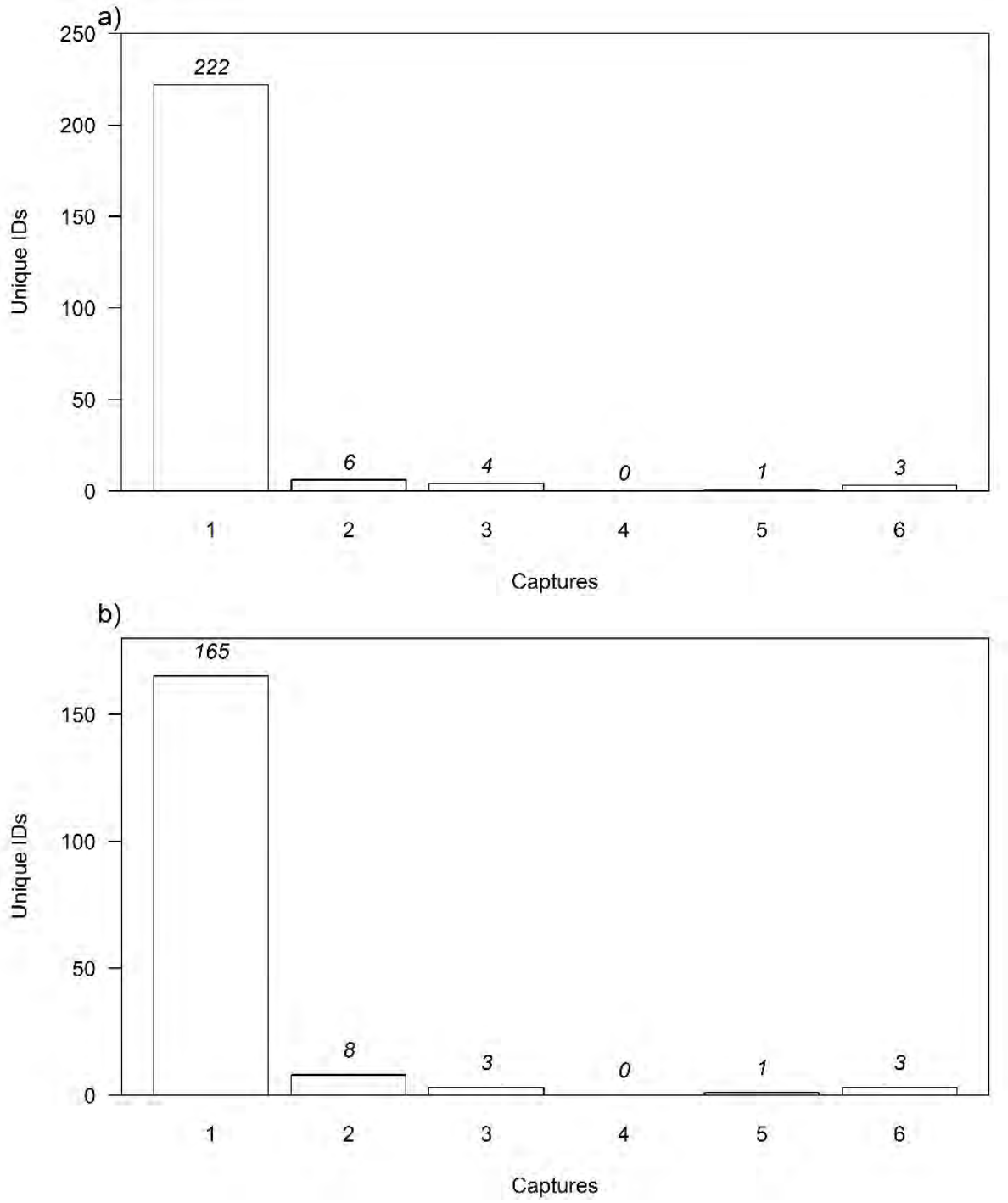


Figure A28. Capture frequency of unique individuals identified by a) left, and b) right head aspects grouped into the area of the Dee Estuary.

The most frequent mean interval between captures in the Dee Estuary was two years for left head extracts (Figure A29a) and one year for right head extracts (Figure A29b). The maximum mean interval was 6 years, for individual “10691”, who was first caught at SP (St Patrick Island, Ireland) in 1998 and subsequently recaught at YYM in 2009 and WHS in 2011.

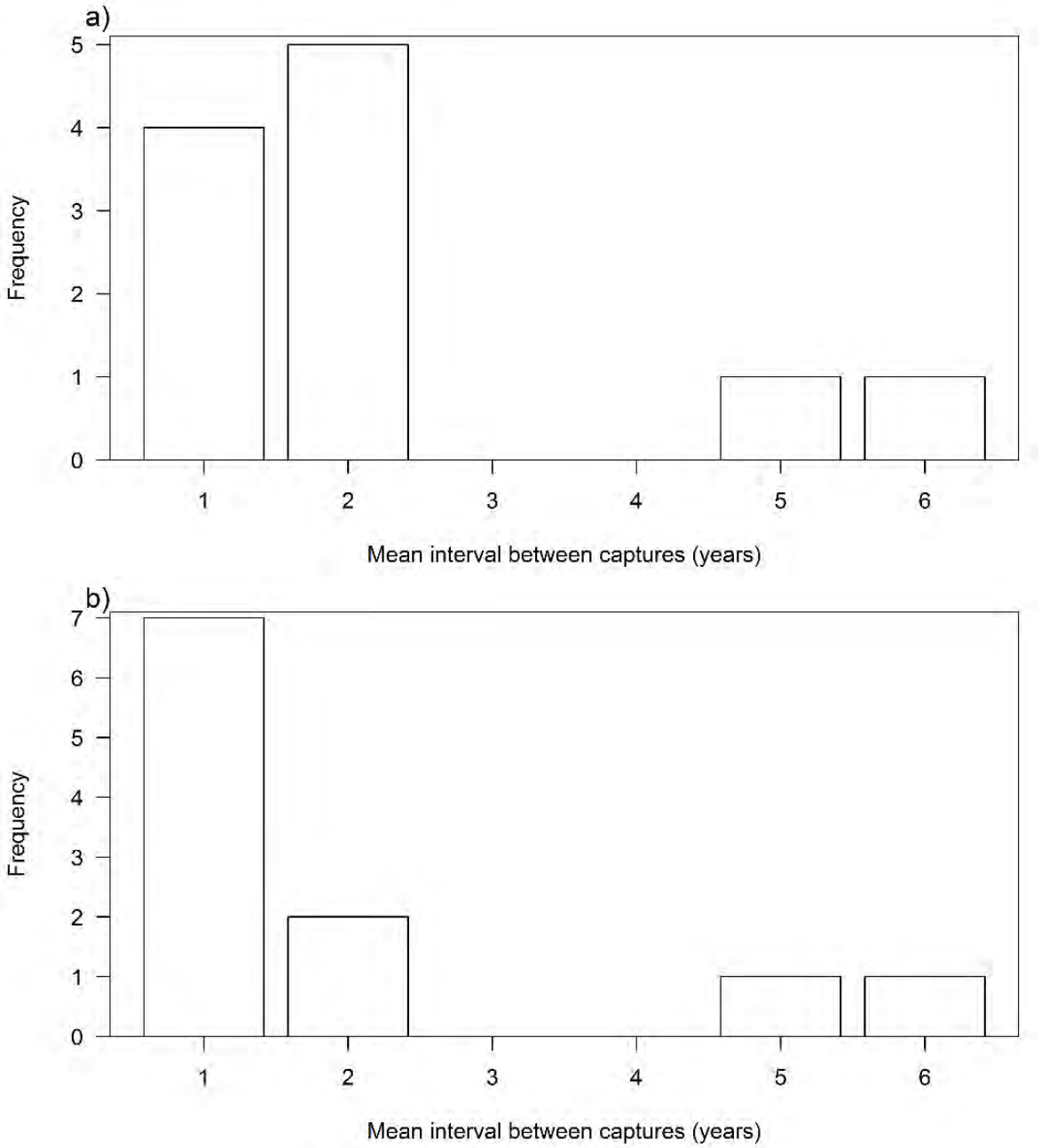


Figure A29. The mean interval between each capture within the capture database for unique individuals identified by a) left and b) right head extracts grouped into the area of the Dee Estuary.

9.3.6.4. Spatial connectivity

The highest probability of recaptures at the Dee Estuary were from individuals either seen previously or subsequently at the Dee Estuary and the Skerries (Figure A30). Unique individuals identified by left head extracts within the Dee Estuary were connected with the Skerries and Skomer. Unique individuals identified by right head extracts within the Dee Estuary were connected with the Skerries and Cardigan Bay.

Figure A30. The maximum number of recaptures of unique individuals identified by a) left and b) right head extracts, moving to or from the area of the Dee Estuary.

9.3.6.5. Data recommendations

Within the EIRPHOT database, there were 50 Dee Estuary extracts from males and 316 from unknown *AgeSex*. We recommend that these unknown extracts are inspected and their *AgeSex* class confirmed where possible.

During this analysis, SMRU encountered a technical error within EC. This resulted in 5 head extracts from the Dee Estuary set aside from analysis as they contained >50% blanking of the extractable area. These are currently sitting in the AutoMatch queue Lx, but we recommend that these extracts are deleted from the database, as they do not contain sufficient data to run through EC.

9.3.7. The Skerries

9.3.7.1. Study site

The EIRPHOT database contains photo-ID data collected at 14 locations around the Skerries (Figure A31, Table A19).

Figure A31. The area of the Skerries in red, which encompasses the island.

Table A19. Location codes for sites within the EIRPHOT database grouped into the area of the Skerries.

Code	Description	Cluster	Section
NSYYM	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYM	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMHC	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMIE	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMIW	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMLS	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMLSI	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMMC	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMMCE	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMMCW	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMW	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMYA	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey
YYMYB	Skerries / Ynysoedd y Moelrhoniaid	Skerries	North Anglesey

9.3.7.2. Summary of data within EIRPHOT database

On completion of this report, the EIRPHOT database library was made up of 1,863 extracts, from 1,417 images across 122 sampling occasions at the Skerries between 2001 and 2013 (Figure A32).

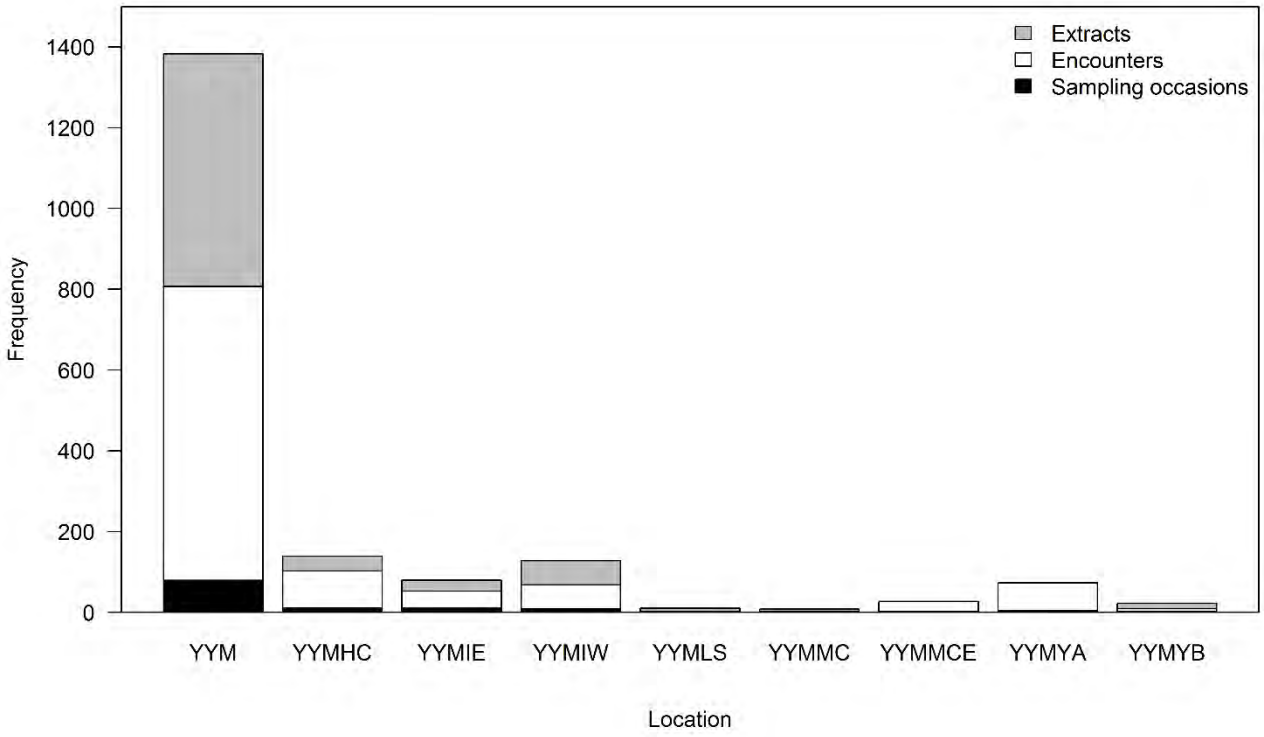


Figure A32. The number of extracts, encounters and sampling occasions within the EIRPHOT database, for each site grouped into the area of the Skerries.

The vast majority of extracts, encounters and sampling occasions were at YYM, which is the only location grouped into the Skerries with lat/lon data. It is unclear from looking at the locations table within EIRPHOT how to define any differences between the other 8 locations as they lack both lat/lon data and unique descriptions.

9.3.7.3. Captures and recaptures

At the Skerries, there were 294 unique individuals identified by left head extracts. Of these, 224 were seen once and 70 were seen more than once (Figure A33a). There were also 318 unique individuals identified by right head extracts. Of these, 246 were seen once and 72 were seen more than once (Figure A33b).

The individual see at the Skerries with the highest number of recaptures was “EarbandCross” who was first recorded at AB (Aberffraw, West Anglesey) in 2009 and was recaught 10 times between 2009 and 2012 at AB and YYM (The Skerries).

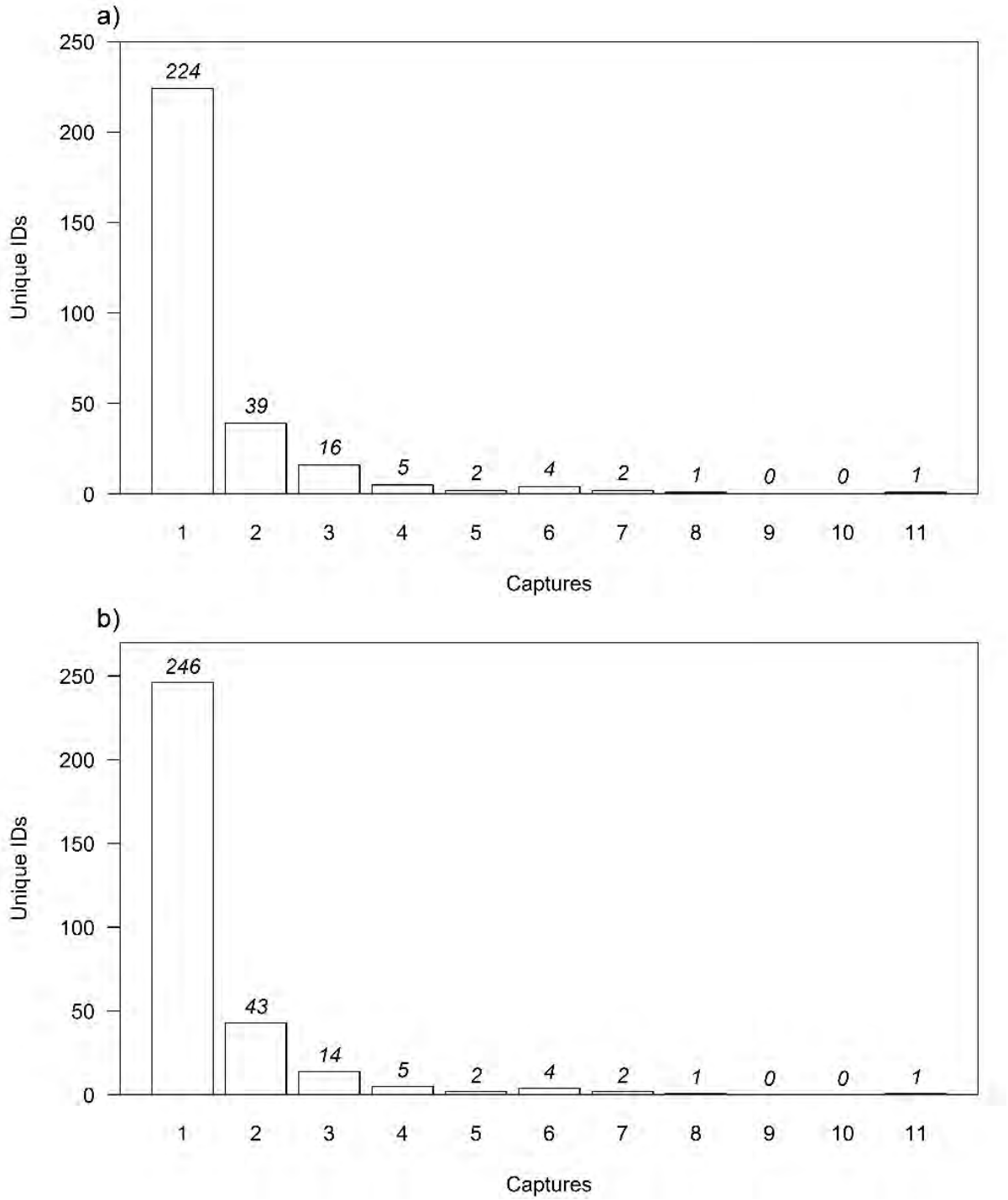


Figure A33. Capture frequency of unique individuals identified by a) left, and b) right head aspects grouped into the area of the Skerries.

The most frequent mean interval between captures in the Skerries was one year (Figure A34). The maximum mean interval was 14 years, for individual “8581”, who was first caught at G140 (Rhod Uchaf, East Ramsey) in 1996 and subsequently recaught at YYM (The Skerries) in 2010.

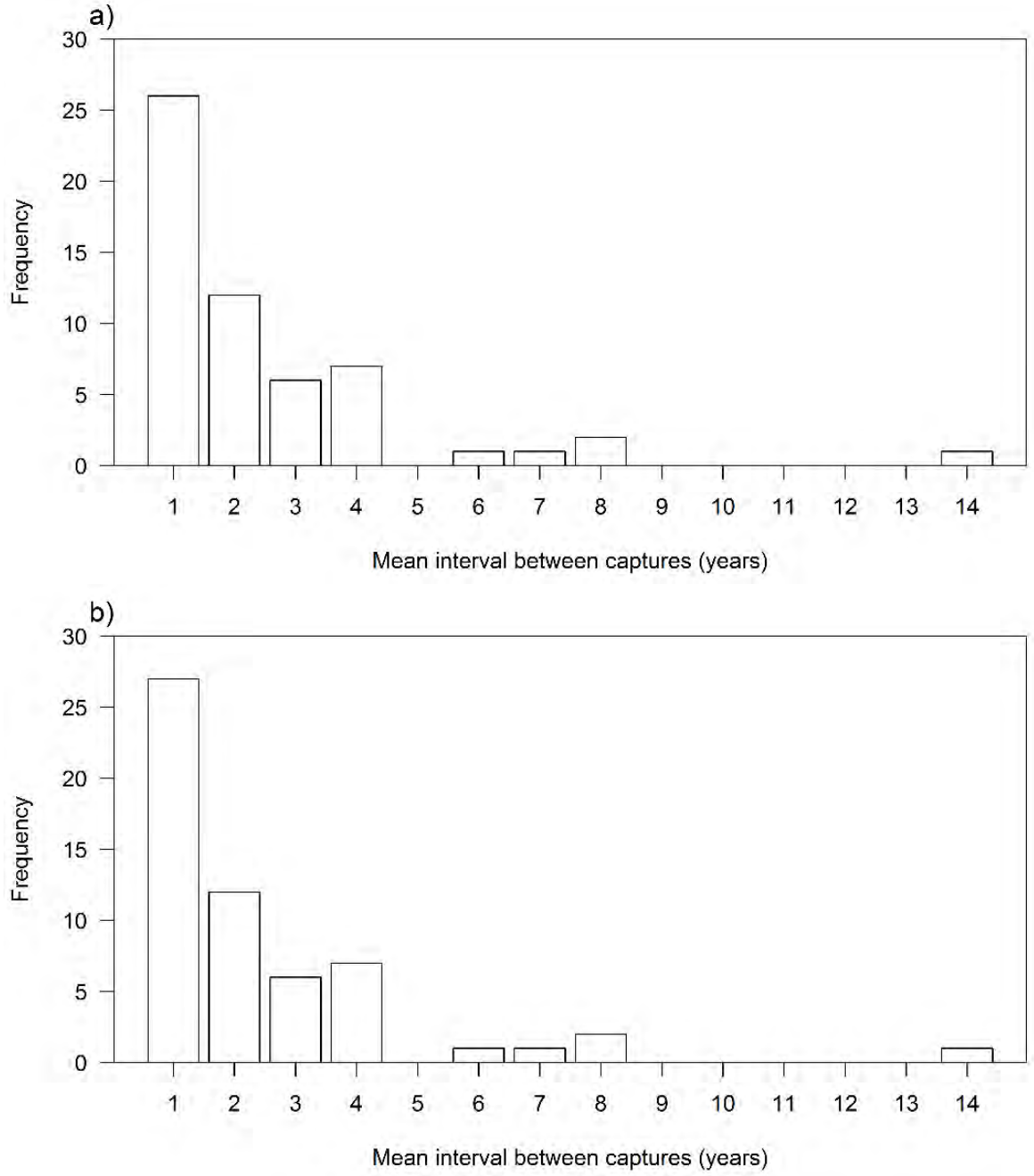


Figure A34. The mean interval between each capture within the capture database for unique individuals identified by a) left and b) right head extracts grouped into the area of the Skerries.

9.3.7.4. Spatial connectivity

The highest probability of recaptures at the Skerries were from individuals either seen previously or subsequently at the Skerries (Figure A35). Outside of the Skerries, these individuals were most likely to be seen at Bardsey and the Dee Estuary. Unique individuals identified by either left or right head extracts within the Skerries were connected to every other broad area, excluding the Marloes.

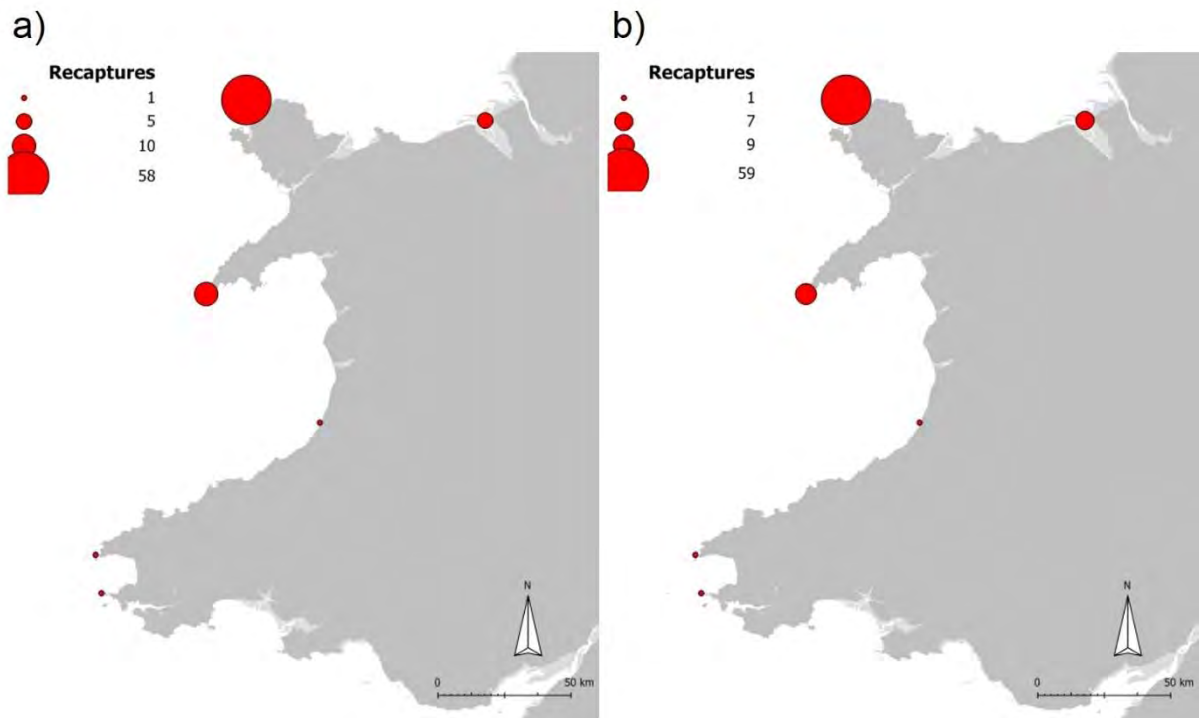


Figure A35. The maximum number of recaptures of unique individuals identified by a) left and b) right head extracts, moving to or from the area of the Skerries.

9.3.7.5. Data recommendations

Within the EIRPHOT database, there were 170 Skerries extracts from males, 112 from pups and 521 from unknown *AgeSex*. We recommend that these unknown extracts are inspected and their *AgeSex* class confirmed where possible.

There were also 120 extracts from images of individuals with blank *AgeSex* data. For the purpose of this analysis, these extracts were assumed to have been taken from adult females. For future analyses, we recommend that these extracts are inspected and their *AgeSex* class confirmed where possible.

During this analysis, SMRU encountered a technical error within EC. This resulted in 55 head extracts from Skomer set aside from analysis as they contained >50% blanking of the extractable area. These are currently sitting in the AutoMatch queues Px and Lx, but we recommend that these extracts are deleted from the database, as they do not contain sufficient data to run through EC.

Within the EIRPHOT locations table, there are 13 locations grouped into the area of the Skerries. These all have the same description and only one (YYM) has lat/lon coordinates. We recommend that lat/lon data and unique descriptors are added so that people working on the database who are unfamiliar with the study site can distinguish between the finer scale locations.

9.4. Appendix 4 – Summary of data added during this report

9.4.1. Ramsey Island data added to the EIRPHOT database.

Date	Location	Sighting
04/01/2015	G260	1
21/01/2015	G360	3
04/03/2015	G360	4
15/03/2015	G360	5
23/03/2015	G360	6
03/04/2015	G270	7
12/05/2015	G330	8
30/07/2015	G140	9
20/08/2015	G030	10
22/08/2015	G250	11
23/08/2015	G190	12
23/08/2015	G140	13
24/08/2015	G360	14
26/08/2015	G250	15
28/08/2015	G030	16
28/08/2015	G150	17
28/08/2015	G140	18
28/08/2015	G140	19
02/09/2015	G360	20
02/09/2015	G260	21
02/09/2015	G230	22
03/09/2015	G190	23
03/09/2015	G140	24
05/09/2015	G250	25
05/09/2015	G360	26
06/09/2015	G210	28
08/09/2015	G360	29
08/09/2015	G250	30
08/09/2015	G230	31
09/09/2015	G030	32
11/09/2015	G140	33
11/09/2015	G020	34
11/09/2015	G250	35
12/09/2015	G220	36
12/09/2015	G360	37
12/09/2015	G210	38
12/09/2015	G250	39
13/09/2015	G020	40
13/09/2015	G030	41
15/09/2015	G190	42
15/09/2015	G140	43
17/09/2015	G160	44
18/09/2015	G140	45
18/09/2015	G190	46
24/09/2015	G030	47
24/09/2015	G250	48
25/09/2015	G220	49
28/09/2015	G140	50
28/09/2015	G030	51
01/10/2015	G020	52
01/10/2015	G140	53
02/10/2015	G220	55
03/10/2015	G360	54
06/10/2015	G220	56
06/10/2015	G210	57
06/10/2015	G250	58
06/10/2015	G220	59
07/10/2015	G210	60
07/10/2015	G220	61
10/10/2015	G030	62
11/10/2015	G030	63
11/10/2015	G220	64
11/10/2015	G160	65
11/10/2015	G190	66
11/10/2015	G020	67
12/10/2015	G360	68
12/10/2015	G250	69
13/10/2015	G210	70
13/10/2015	G220	71
13/10/2015	G140	72
16/10/2015	G030	73
16/10/2015	G160	74
17/10/2015	G030	75
17/10/2015	G150	76
17/10/2015	G220	77
18/10/2015	G360	78
18/10/2015	G250	79
20/10/2015	G030	80
21/10/2015	G030	81
22/10/2015	G220	82
23/10/2015	G140	83
23/10/2015	G030	84
23/10/2015	G360	85
27/10/2015	G230	86
27/10/2015	G250	87
28/10/2015	G360	88
28/10/2015	G260	89
29/10/2015	G030	90
30/10/2015	G020	91
30/10/2015	G190	92
03/11/2015	G230	93

03/11/2015	G320	94
03/11/2015	G190	95
04/11/2015	G220	96
10/11/2015	G160	97
10/11/2015	G220	98
12/11/2015	G150	99
12/11/2015	G140	100
13/11/2015	G220	101
16/11/2015	G210	102
18/11/2015	G220	103
19/11/2015	G020	104
19/11/2015	G230	105
19/11/2015	G250	106
19/11/2015	G360	107
19/11/2015	G360	108
26/11/2015	G220	109
06/12/2015	G320	110
11/12/2015	G020	111
16/12/2015	G360	112
17/12/2015	G360	113
02/01/2016	G360	2
02/01/2016	G360	114
04/01/2016	G260	116
04/01/2016	G260	119
11/01/2016	G360	115
11/01/2016	G360	117
11/01/2016	G360	118
13/02/2016	G360	120
10/07/2016	G140	123
15/07/2016	G010	121
15/07/2016	G140	122
21/07/2016	G140	124
29/07/2016	G140	125
08/08/2016	G140	126
24/08/2016	G190	127
25/08/2016	G020	128
25/08/2016	G030	129
25/08/2016	G140	130
30/08/2016	G360	131
31/08/2016	G030	132
01/09/2016	G030	133
02/09/2016	G260	134
02/09/2016	G310	135
04/09/2016	G030	136
04/09/2016	G230	137
04/09/2016	G320	138
04/09/2016	G320	139
08/09/2016	G360	140
08/09/2016	G230	141
08/09/2016	G030	142
09/09/2016	G210	143
11/09/2016	G190	145
12/09/2016	G220	144
12/09/2016	G210	146
13/09/2016	G210	147
14/09/2016	G230	148
14/09/2016	G250	149
14/09/2016	G360	150
20/09/2016	G160	151
20/09/2016	G360	152
20/09/2016	G190	153
21/09/2016	G030	154
30/09/2016	G220	155
07/10/2016	G360	156
11/10/2016	G230	157
15/10/2016	G230	158
15/10/2016	G250	159
25/10/2016	G320	160
27/10/2016	G220	163
29/10/2016	G030	161
29/10/2016	G140	162
02/11/2016	G190	164
02/11/2016	G180	165
03/11/2016	G230	166
11/11/2016	G030	167
20/11/2016	G260	168
24/11/2016	G030	169

9.4.2. Cardigan Bay data added to the EIRPHOT database.

Date	Location	Sampling Occasion	Number of Encounters	Number of Extracts
21/04/2015	C040	1	56	57
11/09/2015	C020	2	28	36
02/10/2015	PENDER	3	28	28
06/05/2016	C060	4	2	2
07/09/2016	C040	5	25	39
02/10/2016	C040	6	19	22
10/10/2016	B230	7-10	46	63

10. Data Archive Appendix

Data outputs associated with this project are archived on server–based storage at Natural Resources Wales as Project No. 480 and Media No. 1557.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats

[B] EIRPHOT database

[C] Software: ExtractCompare.exe for use with the database

[D] Capture history data in the form of Excel spreadsheets

[E] Capture history data in the form of MARK compatible text files

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue https://libcat.naturalresources.wales (English Version) and https://catllyfr.cyfoethnaturiol.cymru (Welsh Version) by searching 'Dataset Titles'. The metadata is held as record no 122202

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