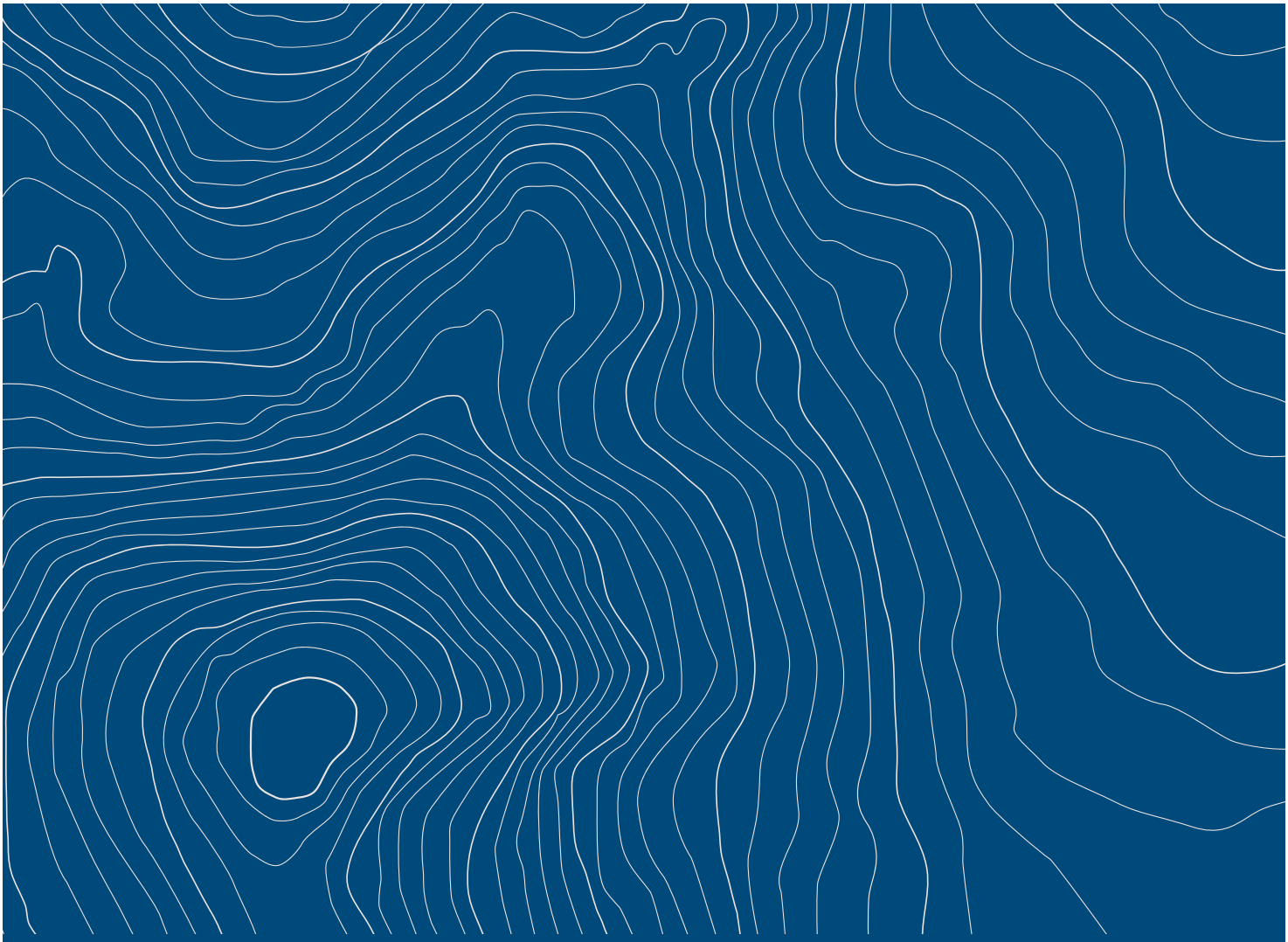

Dublin Array
Generation for generations

EIAR Volume 4: Offshore Infrastructure Technical Appendices Appendix 4.3.5-2 Dublin Array OWF Marine Mammal Abundance Estimates

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Dublin Array OWF Marine Mammal Abundance Estimates 2019-2021

M Chudzinska, L Burt, CREEM, University of St Andrews

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3	xx/07/2021	Sent to SMRU Consulting	MC	

Summary

Information was required on the seasonal occurrence, distribution, density and abundance of marine mammals off the eastern coast of Ireland, close to Dublin. Shipboard surveys took place every month from June 2019 to January 2020, May to September 2020, December 2020 to January 2021 and March to April 2021. The ship travelled along pre-determined tracklines and trained observers searched for marine mammals, recording the species, group size and other relevant information on animals they detected. A total of 2,751 km were covered on survey effort during 17 monthly surveys. The most frequently detected species was harbour porpoise (213 individuals in 135 groups), followed by minke whales (51 individuals in 50 groups).

Line transect distance sampling methods (Buckland *et al.* 2001) were used to estimate harbour porpoise and minke whale abundance. Two analyses were reported for harbour porpoise, one including only survey effort and the other including Beaufort sea state as a covariate. The average harbour porpoise abundance over all surveys was 55 individuals (95% CI 32 - 94). The average minke whale abundance was 4 individuals (95% CI 3 - 7).

Distance sampling methods rely on certain assumptions being valid, in particular, certain detection on the transect centreline; if this assumption is not valid, then estimates will under-estimate the true abundance. This may particularly affect harbour porpoise estimates but may also affect estimates for minke whales. No corrections have been applied to the estimates presented here for uncertain detection on the trackline.The abundance and density estimates presented in this report are, therefore, relative and not absolute.

Introduction

To collect data in order to estimate marine mammal seasonal density and abundance in a region off the eastern coast of Ireland, close to Dublin, a series of shipboard surveys were undertaken. Shipboard surveys took place every month from June 2019 to January 2020, May to September 2020, December 2020 to January 2021 and March to April 2021. Line transect distance sampling methods (Buckland *et al.* 2001) were used; the ship travelled along pre-determined transects, or tracklines, and trained observers searched for animals, recording relevant information when an animal, or group of animals, was detected. In this report, data from all surveys are combined to estimate monthly density and abundance for harbour porpoise (HP; *Phocoena phocoena*) and minke whales (MW; *Balaenoptera acutorostrata*) using distance sampling analysis methods (Buckland *et al.* 2001).

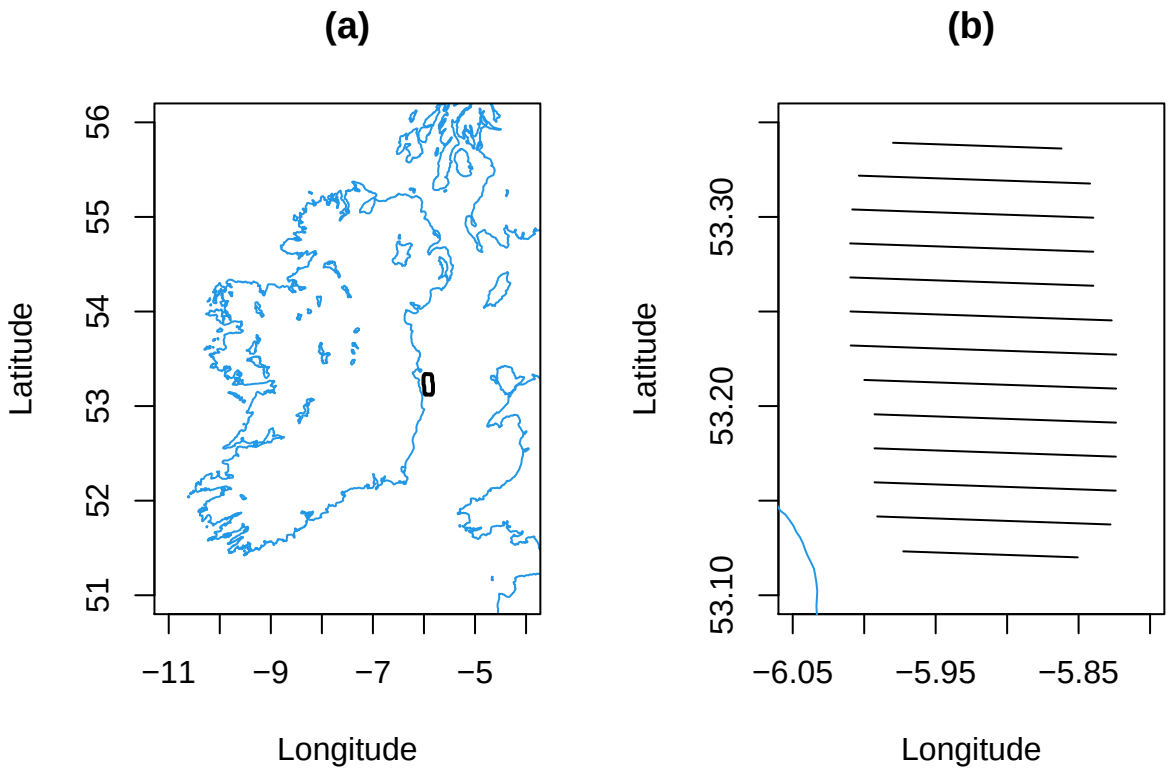
Survey methods

Survey design

The study region (Figure 1a) was approximately 266 km^2. Thirteen parallel transects were located with a random start point in the study region. Transects were oriented east-to-west approximately 2 km apart (Figure 1b) and in total were between 142 - 160 km in length.

Surveys took place each month from June 2019 to January 2020, May to September 2020, December 2020 to January 2021 and March to April 2021. The transects were covered in each survey either in one day or in two consecutive days. In March and April 2021, a full survey, covering all trancects, took place twice during each month.

Figure 1. a) Location of the survey region and b) designed transects.



Search protocol

Observers travelled on board a ship; there were two observers and a data recorder. For each detection, the observers recorded the angle to the detection relative to north, heading of the marine mammal, distance (or reticles) to the animal, species, group size as well as other information. Environmental conditions were also recorded several times along each transect (e.g., Beaufort sea state, visibility).

Statistical methods

Line transect distance sampling (DS) analysis methods (Buckland *et al.* 2001) were used to estimate individual density (D) as follows:

$$\hat{D} = \frac{n}{2wL\hat{p}}\hat{E}[s]$$

and abundance (N) as

$$\hat{N} = \hat{D}.A$$

where

- w is the truncation distance of perpendicular distances,
- n is the number of groups (a group can be one or more animals) detected within w. Only detections recorded as 'primary sightings' were included.
- L is total survey effort,
- $\hat{p}$ is the estimated average probability of detection within distance w of the trackline,
- $\hat{E}[s]$ is the estimated population mean group size,
- A is the area of the study region.

Details of the components of the density estimator are given below.

Survey effort

Survey effort was calculated from the start and end locations of the effort when observers were searching.

The detection of HP becomes increasingly difficult in sea states greater than 2. Therefore, analyses of survey effort and sightings are typically only conducted when Beaufort sea state is recorded as 2 or less. However, results are presented in the current report for HP detected during survey effort where Beaufort Sea state was 3 or less. This is due to relatively small number of detections, especially in early surveys, as well as one survey (2021-03-04), when all detections were in Beaufort sea state = 3. For MW, survey effort and sightings were included for all Beaufort sea state recorded (see Results).

We only took into account sightings which were assigned as 'primary sightings' in the database.

Perpendicular distance and condition calculation

The perpendicular distances of detections to the trackline, x, were required to estimate the probability of detection. These were calculated using the sighting angle, θ, and radial distance, r:

$$x = r.sin\theta$$

The sighting angles (angle between the heading of the ship and the animal) were calculated from the difference between the bearing of the ship and the bearing to the animal. The bearings of the animals were recorded in degrees relative to north. The bearings of the ship for sections of survey effort were either available (as degrees relative to north) in the supplied data, or calculated from the ship location at the start and end of the survey effort. The latter method applied to majority of sightings.

Any conversions from reticle measurements to distances were provided prior to the analysis undertaken for the analysis in this report.

Sea state was assigned at the start, end and at several points along each transect.To assign Beaufort sea state used in the final analysis, we calculated mean value recorded for each transect.

Probability of detection

Two critical assumption of DS methods are that all groups on the transect centre line (i.e., at zero perpendicular distance) are detected with certainty and that distance measurements are exact. Given these assumptions, the distribution of perpendicular distances are used to model how the probability of detection decreases with increasing distance from the trackline.

The probability of detection, p, was estimated from a detection function model fitted to the observed distribution of perpendicular distances using the exact distances for whales. Perpendicular distances were truncated, where required, to avoid a long tail in the detection function. Two forms of the detection function were considered: a hazard rate and a half normal. Cosine adjustment terms were included (to a maximum of 5).

Two sets of models were fitted for HP: model including survey effort only for sightings in Beaufort scale ≤ 3; and models including survey effort and the effect of Beaufort sea state for sightings in Beaufort scale ≤ 3. In the latter set, the effect of Beaufort sea state was incorporated into the detection function model by setting the scale parameter in the model to be an exponential function of the covariates (Marques and Buckland 2004). Thus, the covariates could affect the rate at which detection probability decreases as a function of distance, but not the shape of the detection function. Adjustment terms were not included in this case. To ensure sufficient sample sizes in each level of Beaufort sea state, levels were combined to create three levels: 0-1, 2 and 3. For MW, one set of models was fitted: model including survey effort only for sightings in Beaufort scale ≤ 4.

The form that resulted in the smallest Akaike Information Criterion (AIC) was selected (see Buckland *et al.* 2001 for details of detection function models and model selection methods). If models had comparable AICs, comparison of goodness of fit was the main criteria for the final model choice.

Density and abundance

Detections and survey effort were pooled within each survey to obtain encounter rates ($\frac{n}{L}$), and hence obtain estimates of density and abundance, by survey. Average estimates overall surveys (weighted by survey effort) were also obtained.

Analyses were performed in R (R Core Team, 2019) using the Distance library (Miller *et al.* 2019).

Results

Survey effort and number of detections

Seventeen monthly surveys were conducted, contributing to a total of 2,751 km of survey effort. A summary of the monthly surveys is given in Table 1. Locations of survey effort and sightings are shown in Appendix A.

Overall, harbour porpoise were the most frequently detected species (both in terms of detected groups and number of individuals) and were detected during all 2019-2021 surveys except October 2019. In total, 135 groups of HP (213 individuals) were detected; generally the number of groups detected each survey was small ($\leq$ 10 groups), however, in November 2019, March 2021 and April 2021, 26, 15 and 34 groups, respectively, were detected. For modelling detection function, only detections in Beafort state ≤ 3 were taken into account resulting in the analysis based on 125 sightings of 202 individuals (before truncation). Majority of these sightings (117 out of 125) occured, however, in Beaufort scale ≤ 2.

Fifty groups of minke whales (all singletons except one group of two individuals) were detected in total but only seen on six surveys: June 2019, May 2020, July 2020 and March-April (three surveys) 2021. The majority of these were detected in May 2020 (25 groups) and April 2021 (21 groups). For modelling detection function, only detections in Beafort state ≤ 4 were taken into account, however all 50 sightings of MW occured at Beaufort scale ≤ 2.

The other species detected included 4 groups of bottlenose dolphins (12 individuals), 12 groups of common dolphins (123 individuals) and 22 grey seals (all singletons) (Table 1).

Table 1. Summary of data by survey; survey effort (L, km) and number of groups of harbour porpoise (HP), minke whales (MW), bottlenose dolphins (BD), common dolphins (CD), unidentified dolphins (UD) and grey seals (GS) detected on survey effort (no truncation). Effort and sightings are reported for all recorded Beaufort sea states ≤ 4.

Survey	Effort	HP	MW	BD	CD	UD	GS
2019-06	143	3	1	4	3	0	3
2019-07	140.7	1	0	0	0	0	1
2019-08	156.1	2	0	0	0	1	0
2019-09	145.3	3	0	0	0	0	0
2019-10	142.4	0	0	0	1	0	0
2019-11	159.5	26	0	0	0	0	5
2019-12	143	1	0	0	0	1	2
2020-01	150.6	8	0	0	0	0	1
2020-05	143.2	5	25	0	0	0	1
2020-06	141.5	3	0	0	0	0	0
2020-07	142.4	3	2	0	1	0	0
2020-08	141.6	4	0	0	0	0	0
2020-09	141.8	9	0	0	0	0	1
2020-12	144.4	2	0	0	0	0	0
2021-01	142.6	3	0	0	0	0	0
2021-03-04	143.9	3	0	0	0	0	0
2021-03-20	143.6	15	1	0	0	0	1
2021-04-14	143.4	34	10	0	7	0	6
2021-04-26	141.9	10	11	0	0	0	1
Total	2751	135	50	4	12	2	22

Probability of detection

There were only sufficient sightings to fit detection functions for HP and MW.

The maximum perpendicular distance for HP was 2,208 m, however, to avoid a long tail in the detection function, a truncation of 500 m was used. The maximum distance for MW was 3,000 m; a truncation distance of 1,000 m was used.

For HP, on the basis of lower AIC, goodness of fit and visual inspection of the fitted functions, a hazard rate function with Beaufort state as a covariate was selected. As all MW detections were made in Beaufort ≤ 2, Beaufort was not included as a covariate in the detection function for this species. The AICs were similar for half-normal and hazard-rate detection functions, however, hazard-rate detection function showed better goodness of fit (Table 2).

Table 2. AIC values for the detection functions fitted to HP detected in Beaufort sea state ≤ 3 (HP) and MW (NA indicates not applicable).

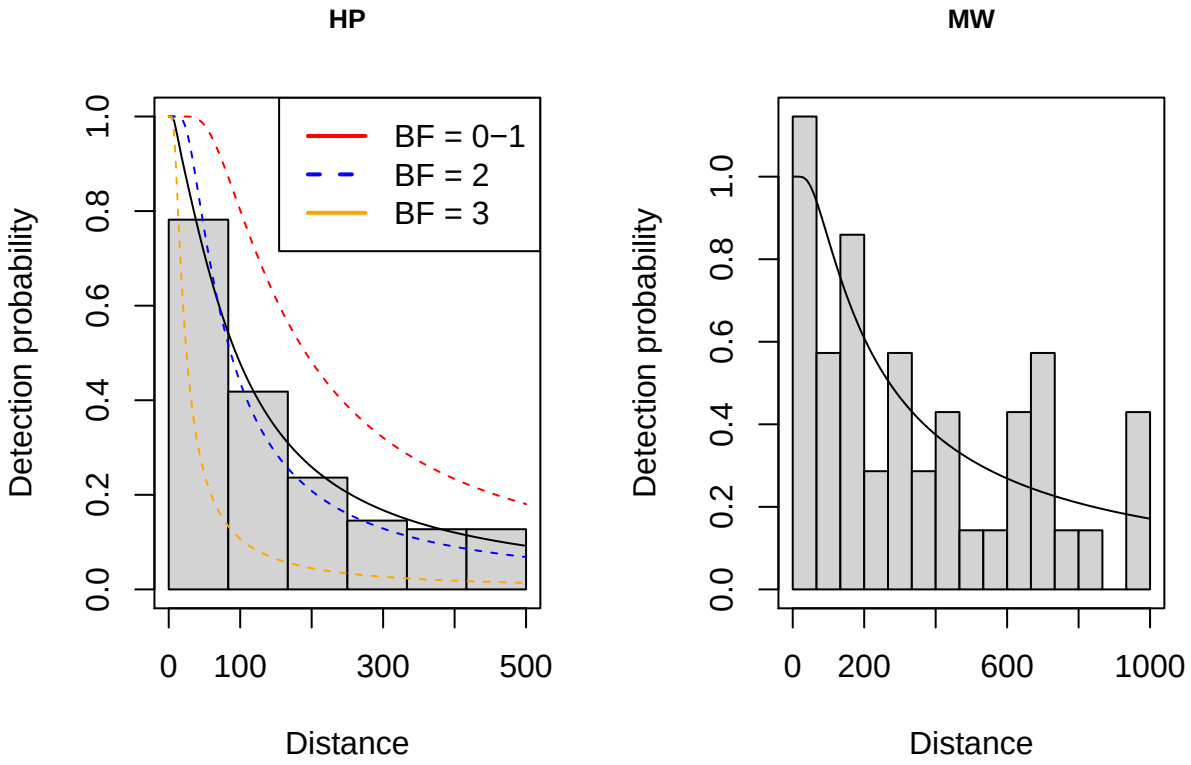
Type	Covariate	HP	MW
Half-normal	None	1209	587.8
Hazard rate	None	1208	587.1
Half-normal	Beaufort	1217	NA
Hazard rate	Beaufort	1205	NA

The selected detection functions are shown in Figure 2 and the estimated probability of detections are given in Table 3.

Table 3. Truncation distance (w, metres), number of detected groups within the truncation distance (n) and estimated probability of detection (p) and coefficient of variation (p.CV) for HP and MW.

Species	w	n	p	p.CV
HP	500	101	0.3061	0.2553
MW	1000	43	0.4106	0.3637

Figure 2. Average estimated detection function (black line) overlaid onto the scaled perpendicular distance (metres) distributions. The lines in colour indicate estimated function for each level of Beaufort.



Density and abundance

Estimates for each survey survey were obtained using encounter rates for each survey and applying the detection probabilities described above.

The density and abundance estimates for HP are shown in Table 4 and Figures 3 and 4. The largest abundance estimates are for November 2019 (155 individuals), September 2020 (243 individuals) and early April 2021 (140 individuals) where 23, 7 and 17 groups were detected respectively (within the truncation distance). The average abundance, over all the surveys, was 55 animals (95% CI 32 - 95), and the average density 0.21 animal/km^2.

Table 4. Summary of results for HP : survey effort (km), number of groups within truncation distance (n), encounter rate (ER, groups/km) and coefficient of variation (ER.CV), individual density (D, animals/km^2) and coefficient of variation (D.CV), individual abundance (N) and lower (LCL) and upper (UCL) limits of the 95% confidence interval for N.

Survey	Effort	n	ER	ER.CV	D	D.CV	N	LCL	UCL
2019-06	135	3	0.02223	0.5258	0.126	0.7715	33.52	8.243	136.3
2019-07	106.5	1	0.009389	0	0.03345	0.2926	8.897	5.037	15.72
2019-08	93.5	1	0.0107	0	0.04377	0.2291	11.64	7.431	18.24
2019-09	145.3	3	0.02064	0.5235	0.1158	0.5871	30.8	9.712	97.68
2019-10	89.22	0	0	0	0	0	0	0	0
2019-11	159.5	23	0.1442	0.2634	0.5824	0.3529	154.9	76.35	314.3
2019-12	113	1	0.008847	0	0.0181	0.2291	4.815	3.073	7.544
2020-01	150.6	8	0.0531	0.4716	0.2044	0.4964	54.38	20.72	142.7
2020-05	143.2	5	0.03492	0.468	0.1032	0.4899	27.46	10.42	72.37
2020-06	120.7	3	0.02486	0.7035	0.1181	0.8103	31.41	6.956	141.8
2020-07	121.2	3	0.02476	0	0.1051	0.2534	27.95	17.04	45.86
2020-08	123.5	2	0.0162	0.6765	0.1089	0.9419	28.96	5.633	148.9
2020-09	65.87	7	0.1063	0	0.9123	0.6018	242.7	80.5	731.5
2020-12	61.19	0	0	0	0	0	0	0	0
2021-01	101.2	2	0.01976	0	0.0704	0.2926	18.73	10.6	33.08
2021-03-04	54.16	1	0.01846	0	0.1824	0.7215	48.52	13.43	175.4
2021-03-20	143.6	11	0.07662	0.443	0.3442	0.6298	91.56	26.97	310.8
2021-04-14	143.4	17	0.1186	0.2933	0.5243	0.4361	139.5	58.62	331.9
2021-04-26	141.9	10	0.07046	0.2439	0.2478	0.4433	65.92	27.36	158.8
Total	2213	101	0.04565	0	0.2076	0.2787	55.22	32.15	94.84

The density and abundance estimates for MW is shown in Table 5.The largest abundance estimates are for May 2020 (50 individuals) and late April 2021 (22 individuals). The average abundance, over all the surveys (including those where MW were not detected), was 4 animals (95% CI 3 - 7).The average density was estimated to be 0.02 animal/km^2.

Table 5. Summary of results for MW: see Table 4 for explanation of column headings.

Survey	Effort	n	ER	ER.CV	D	D.CV	N	LCL	UCL
2019-06	143	1	0.006994	1.003	0.008518	1.067	2.266	0.3545	14.48
2019-07	140.7	0	0	0	0	0	0	0	0
2019-08	156.1	0	0	0	0	0	0	0	0
2019-09	145.3	0	0	0	0	0	0	0	0
2019-10	142.4	0	0	0	0	0	0	0	0
2019-11	159.5	0	0	0	0	0	0	0	0
2019-12	143	0	0	0	0	0	0	0	0
2020-01	150.6	0	0	0	0	0	0	0	0
2020-05	143.2	22	0.1536	0.2662	0.1871	0.4507	49.77	20.97	118.1
2020-06	141.5	0	0	0	0	0	0	0	0
2020-07	142.4	1	0.007022	0.9928	0.008551	1.057	2.275	0.3603	14.36
2020-08	141.6	0	0	0	0	0	0	0	0
2020-09	141.8	0	0	0	0	0	0	0	0
2020-12	144.4	0	0	0	0	0	0	0	0
2021-01	142.6	0	0	0	0	0	0	0	0
2021-03-04	143.9	0	0	0	0	0	0	0	0
2021-03-20	143.6	1	0.006965	0.9926	0.008482	1.057	2.256	0.3575	14.24
2021-04-14	143.4	8	0.0558	0.4621	0.06795	0.5881	18.08	5.922	55.17
2021-04-26	141.9	10	0.07046	0.285	0.08581	0.4621	22.83	9.419	55.32
Total	2751	43	0.01563	0.2323	0.01581	0.262	4.207	2.516	7.033

Discussion

Abundance estimates by survey and overall have been reported for HP and MW. Minke whales were detected on only six surveys with the vast majority of detection taking place during the May 2020 and April 2021 surveys which may indicate a seasonal presence. Porpoises were present in the area for most of the survey months with peak in abundance happening in November 2019, September 2020 and April 2021. The large estimates for September 2020 were despite relatively low number of sightings (7, Table 4). This was due to a very high encounter rate as a consequence of a small amount of search effort in Beaufort sea states 3 or less (66 km).

Distance sampling relies on certain detection on the track centreline and if this assumption is not valid, then the estimated abundance will under-estimate true abundance; this may affect estimates of HP and MW albeit to differing degrees. Given the difficulty of detecting HP, an analysis was performed which included survey effort in Beaufort sea state 3 or less. To account for differences between sea states, especially detection in sea state 3 in comparison to sea state ≤ 2 (see Burt 2020 and Appendix B), Beaufort sea state was included as a covariate in the detection function for HP.

Figure 3. HP abundance estimates from June 2019 to April 2021. Note that the y-axis limit is restricted. The grey dashed lines divide different years.

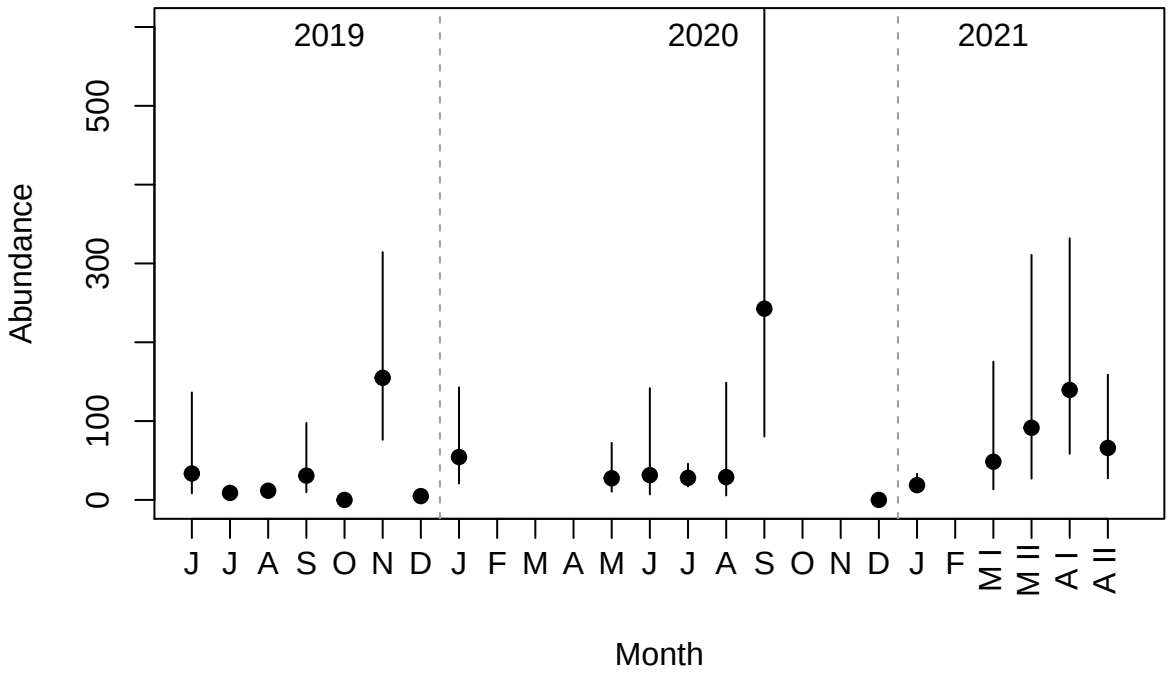
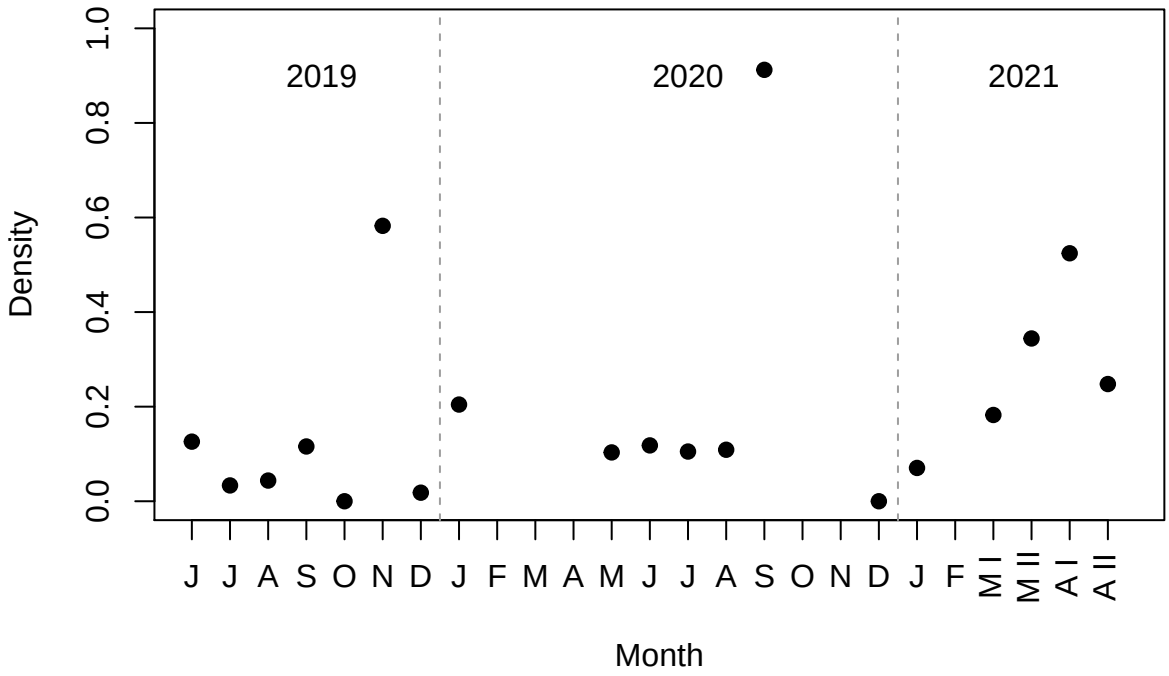


Figure 4. HP density (animals/km^2) estimates from June 2019 to April 2021. The grey dashed lines divide different years.



Another key assumption of distance sampling methods is that perpendicular distances are exact and measured without error. Systematic bias in the measurements can result in over, or under, estimating the detection probability. Sighting angles were obtained from the difference between the bearing of the ship and the bearing of the detected group. Ship bearings for the May 2020 to April 2021 surveys were calculated from the location of vessel at the start and end of survey effort; in some cases this was a substantial distance and so small changes in heading will not be accounted for. Some sighting angles from the earlier set of surveys were greater than 90^o and detections may have been behind the observer. These detections were included in the analyses but may indicate a lower detection on the centreline. Confirmation from the observers that detections beyond abeam were recorded would provide some confidence that these angles were correct.

Errors in the locations have been corrected but some errors may still be present (see Appendix A). If the survey effort is reduced (e.g. to corrections), the encounter rate, and hence, abundance will increase.

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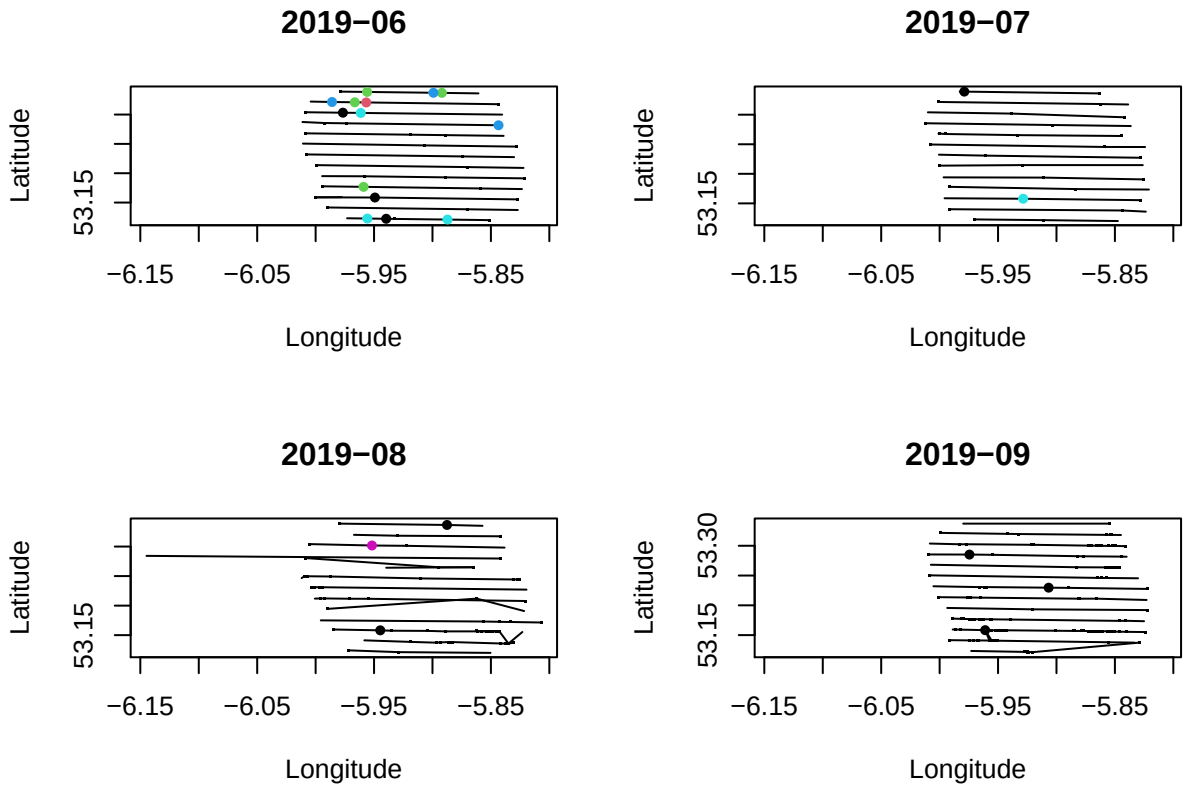
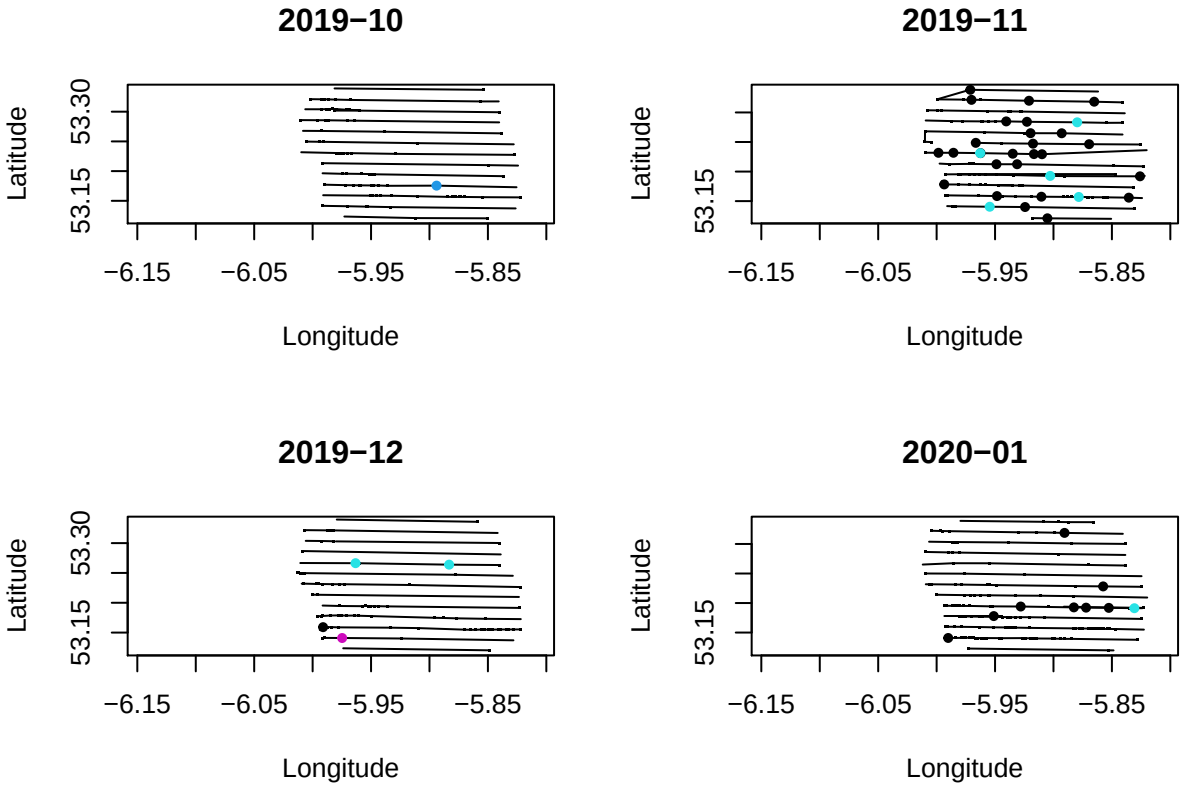
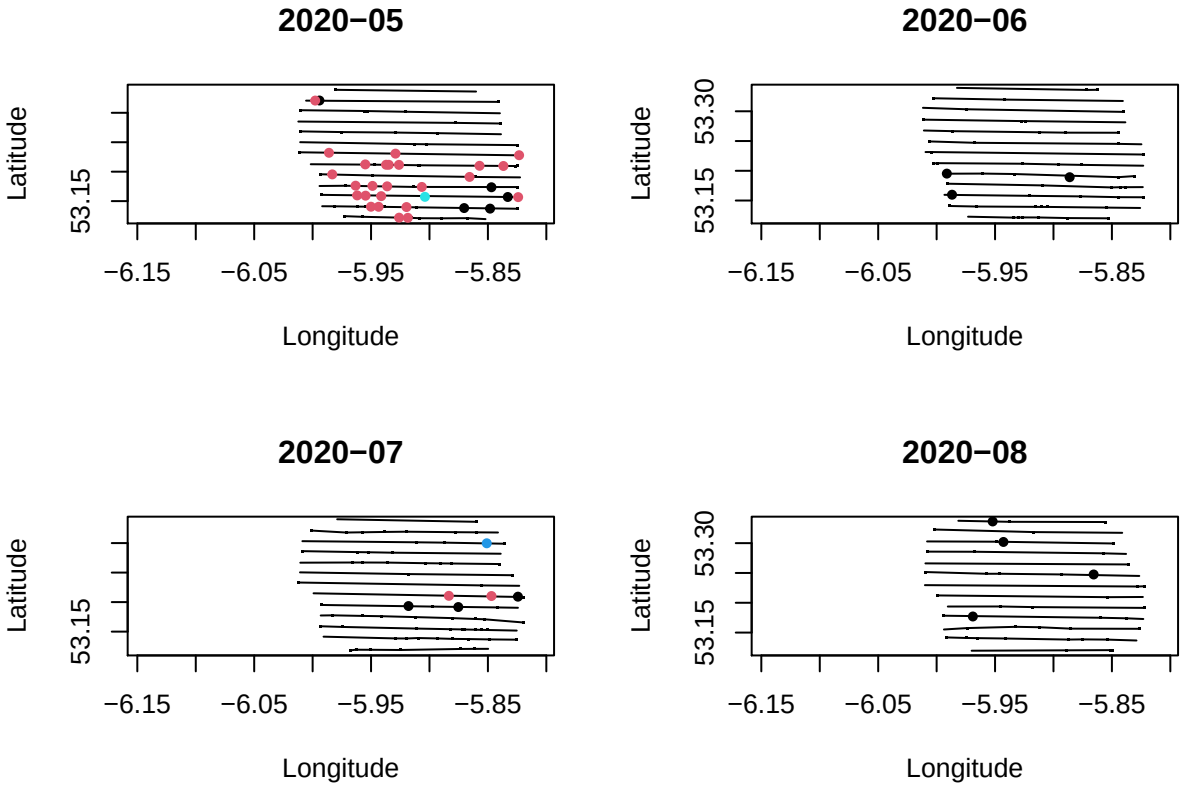
Appendix A: Locations of realised survey effort and sightings

Figure A1. Realised survey effort by survey and sightings of harbour porpoise (black), minke whale (red), bottlenose dolphin (green), common dolphin (blue), unidentified dolphin (pink) and grey seal (cyan).




2019−10
Latitude
53.15
53.30
−6.15
−6.05
−5.95
−5.85
Longitude
2019−11
Latitude
53.15
−6.15
−6.05
−5.95
−5.85
Longitude
2019−12
Latitude
53.15
53.30
−6.15
−6.05
−5.95
−5.85
Longitude
2020−01
Latitude
53.15
−6.15
−6.05
−5.95
−5.85
Longitude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2020−06
2020−07
2020−08
Latitude
Longitude
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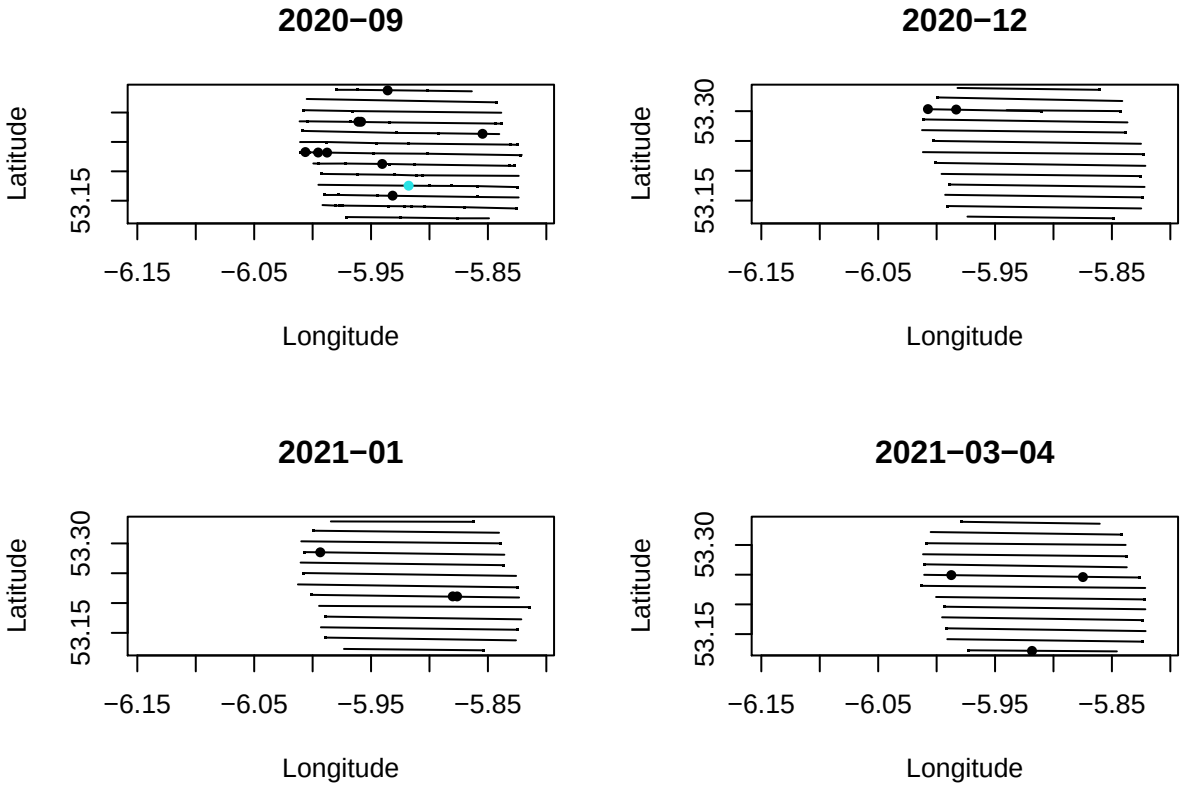
53.30
−6.15
−6.05
−5.95
−5.85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Longitude
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−6.15
−6.05
−5.95
−5.85
Longitude
2021−01
Latitude
53.30
53.15
−6.15
−6.05
−5.95
−5.85
Longitude
2021−03−04
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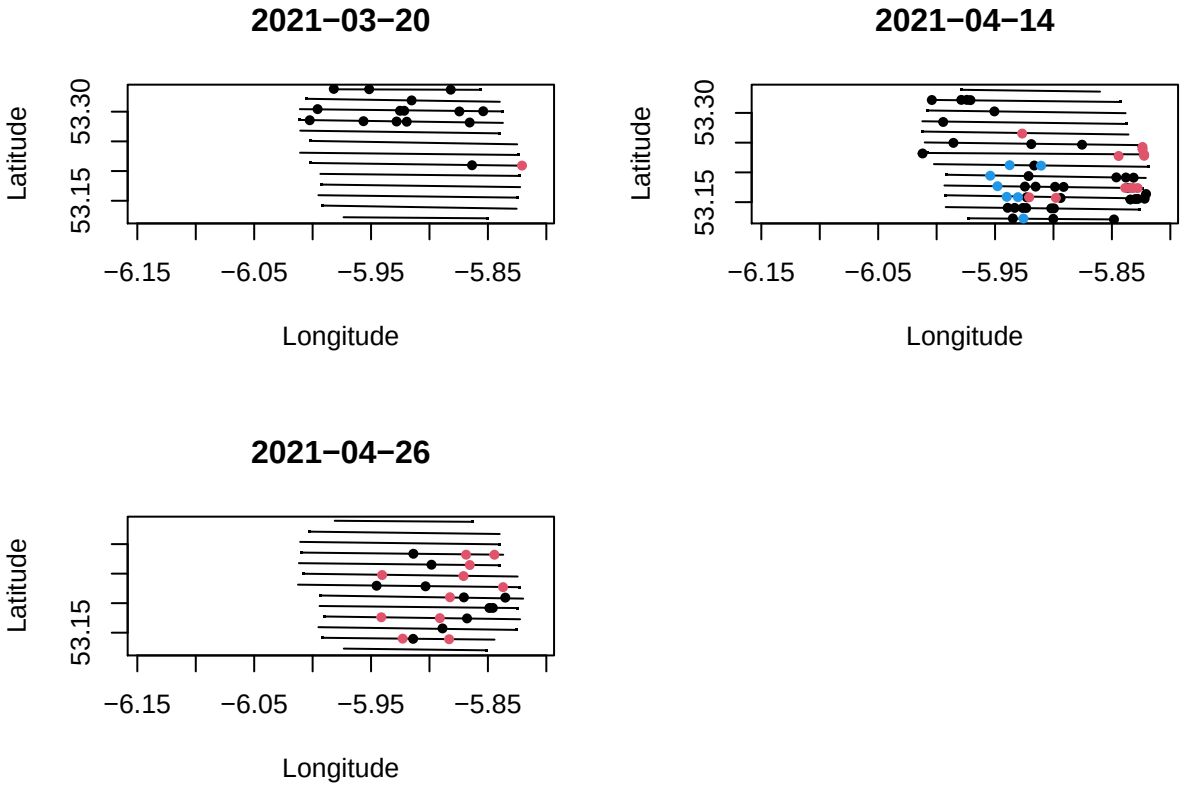
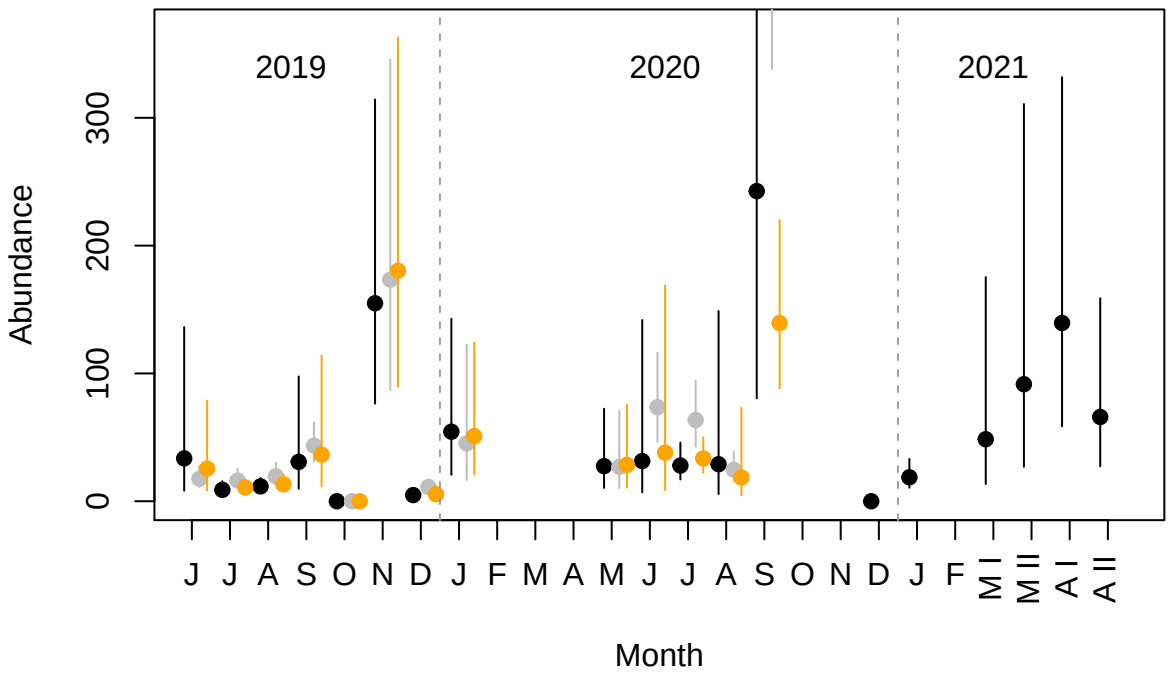
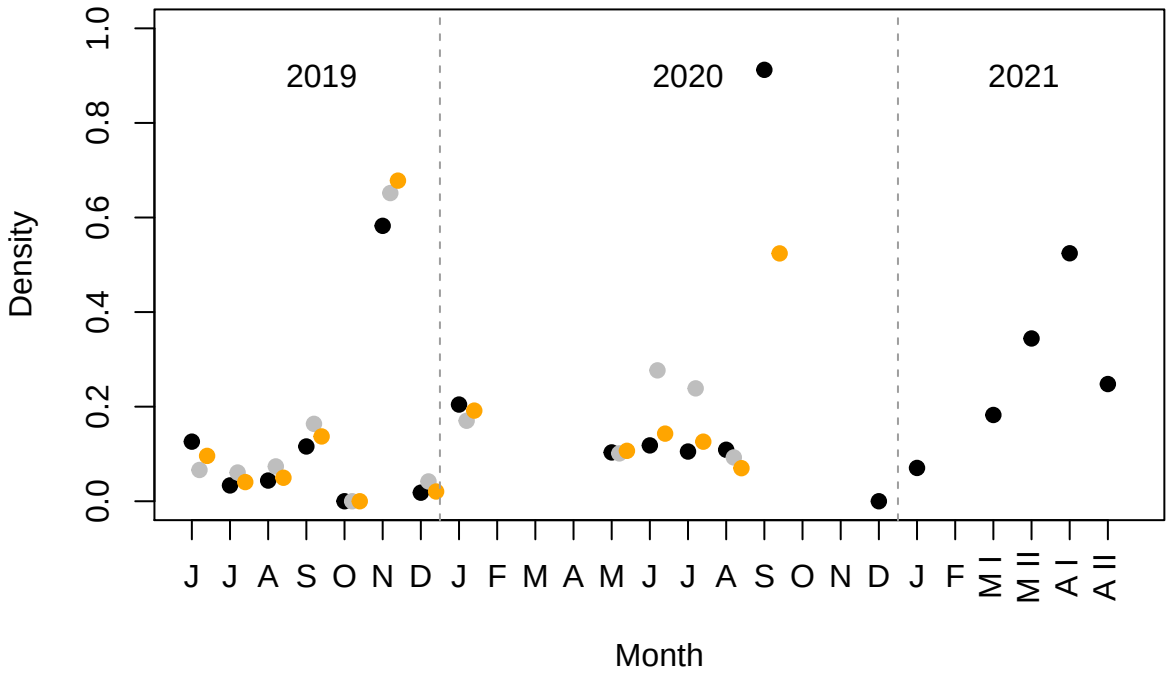


Appendix B: Comparison of abundance and density estimates with estimates from Burt (2020)

Figure B1. HP abundance and density (animals/km^2) estimates for all 2019-2021 surveys (black), and for BF ≤ 2 (grey) and BF ≤ 3 (orange) from Burt (2020). Note that the y-axis limit is restricted. The grey dashed lines divide different years.


2019
2020
2021
Abundance
0
100
200
300
J J A S O N D J F M A M J J A S O N D J F M I M II A I A II
Month


Density
0.0
0.2
0.4
0.6
0.8
1.0
2019
2020
2021
J J A S O N D J F M A M J J A S O N D J F M I M II A I A II
Month