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Home-range, movements and use of powerline poles of Eagle-Owls (*Bubo bubo*) at an island population in northern Norway

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A dense island population of Eagle-Owls (*Bubo bubo)* close to the Arctic circle had suffered considerable mortality due to powerlines (electrocution and collision) throughout many decades. A study using GPS transmitter technology was carried out between 2009 and 2014. We studied home-range sizes, dispersal distances, mortality, and proposed mitigation techniques to prevent accidents. We found as expected that juvenile Eagle-Owls had larger home-ranges and moved farther than adults, but both age-groups moved much less than shown elsewhere in Europe. The probable reason for this was thought to be that this population was isolated by the surrounding sea, which might act as a barrier. The GPS data indicated that the poles of the grid were used as perching posts more than expected from a random distribution. This was explained by the lack of high trees and other elevated landscape features on these low islands. As a mitigation effort, we contributed to designing a perching-device for fitting on the poles that would prevent electrocution of the owls. This is now used by several grid-owners in coastal areas with high electrocution risk and is followed up by the National action plan for Eagle-Owl in Norway.

1. Introduction

The Eurasian Eagle-Owl (*Bubo bubo)* is the largest owl species in the world. It is a nocturnal raptor, is highly adaptive and can be found in many different environments, ranging from deserts to forests and arctic tundra (Penteriani & Delgado 2019). In Norway it is mainly distributed from southern Norway up to the Arctic circle in the north. The study took place at the archipelago of Solværøyane in Lurøy municipality, Nordland county, 12°35’ E, 66°22’ N (Fig. 1). The main food of the Eagle-Owl in our study area in Nordland is Water vole (*Arvicola amphibius)*, which has a yearly fluctuation in numbers (Frafjord 2022). In years of low vole numbers, the owls have access to a variety of other food species, as the Eagle-Owl is a versatile hunter and preys on a wide range of vertebrate species, such as small rodents, rats, hares, frogs, seabirds and even fish. Its diet depends on the availability of prey and might differ between locations (Willgohs 1974, Obuch & Bangjord 2016). The archipelago lies close to the Arctic circle, and therefore there is broad daylight during most of the hours during the summer months. The Eagle-Owls here must therefore hunt in light conditions during most of the summer.

The Eagle-Owl population in Norway has declined since the 1900-century (Hagen 1952, Haftorn 1971). The species was protected in 1971 and is classified as an endangered species on the Norwegian Red List for Species (Stokke *et al.* 2021). The number of breeding pairs is now estimated at 451–681 (Øien *et al.* 2014). The Eagle-Owl has historically been severely persecuted in Norway. After it gained its protected status the decline has continued (Fremming 1986, Shimmings & Øien 2015), due to electrocutions, habitat changes, decline of prey stocks, environmental pollutants and disturbance (Frøslie *et al.* 1986, Heggøy & Shimmings 2020). Electrocution has been a major factor for the decline (Bevanger & Overskaug 1998), and is recognized as a major problem for the Eagle-Owl elsewhere in its range (Bevanger 1994, Bevanger 1998, Sergio *et al.* 2004, Fransson *et al.* 2019)

In the current study, we tracked Eagle-Owls using satellite telemetry, focusing on movements and mortality. Over the past 30 years, members

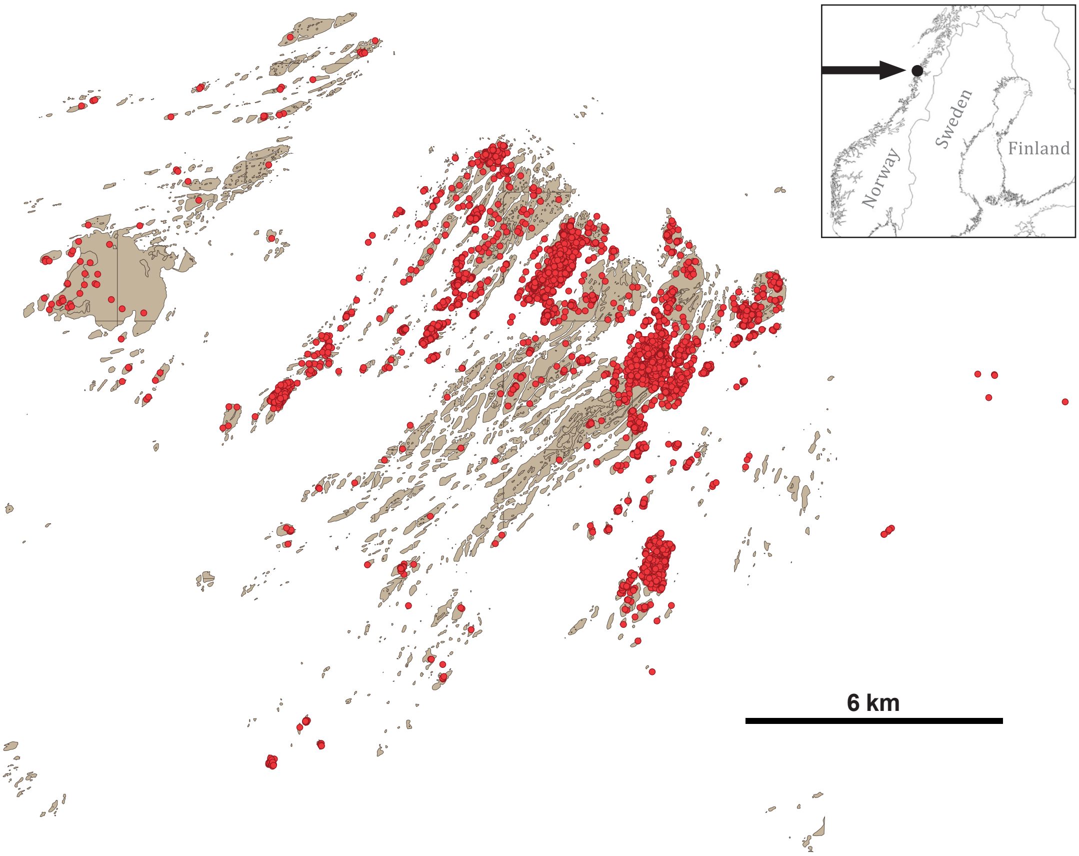

Fig. 1. All GPS positions of all individual Eagle-Owls tagged with GPS transmitters. Location map refers to the southern part of Fennoscandia with the study area of Solværøyane (12°35’ E, 66°22’ N) indicated with an arrow and a black dot.

of the Rana Zoological Society have found 30–40 dead Eagle-Owls in connection with power lines in the study area, of which about 90% of the individuals were probably killed by electrocution, the rest by collisions (Espen Rolv Dahl pers. comm. in Gjershaug *et al.* 2015). Being the densest population of Eagle-Owl in Norway, and because of the high mortality of owls found killed by the distribution grid here, Solværøyane was chosen as a good place to study movements of the owls in relation to the local power-grid. One of the main goals was to investigate the extent to which the Eagle-Owl used power poles as perches during hunting, to study dispersal and home ranges, and to locate dead tagged individuals and note the causes of deaths. To obtain this, we used accurate GPS satellite telemetry tags on the birds. The Norwegian authorities issued a national action plan for Eagle-Owl in 2009 (Direktoratet for naturforvaltning 2009). At the same time, the Norwegian Research Council was funding a research program OPTIPOL, which in part aimed at studying risks of, and potential mitigation methods for Eagle-Owl electrocutions. Our project was a part of this.

2. Material and methods

The study area is a group of low islands called Solværøyane and has a sparse human population. The area consists of a group of 1,841 islands and skerries. The total area is 30.1 km^2. Sheep are grazing the islands, and the vegetation consists mainly of heather, grass and low-growing birches. The shortest distance to the mainland is 14 km. The islands have a population of at most 26 breeding pairs of Eagle-Owls. The islands have 9 km of powerlines, with altogether 138 poles. The project started in 2008, and the tagging went on from 2009 to 2014. To study the movements of the owls, GPS back-pack tags of different designs were employed on both nestlings and adults. The study was carried out under a permission from the Norwegian animal welfare committee (Permits no. 2014/101595 and 2012/54696). The nestlings were tagged when they had just left the nest and were fully feathered, while the adults were caught in claptraps and bownets. In total, 18 nestlings and 5 adults were employed with satellite tags of a back-pack design with harnesses (Buehler *et al.* 1995). As the site is close to the Arctic circle, the light conditions were only adequate to power solar-powered transmitters during the summer season. Therefore, a combination of battery-powered tags (15 of Microwave Telemetry LC 40, (40 g) one on an adult and 14 on juveniles) and solar-powered tags (8 of Microwave Telemetry Argos/GPS 45 g, 4 on adults, 4 on juveniles) were used (Microwave Telemetry, Inc.) (Table 1). The LC 40 gave one position per day (at midnight), while the Argos/GPS 45 was programmed to give a position at 01, 05, 09, 13, 17 and 21 H. The first two adults were fitted with transmitters with harnesses made of Teflon ribbon (PTFE | Bally Ribbon Mills). We soon found out that the adults were able to remove the harnesses, presumably by snipping them off with the beak, so they were lost after a few days and giving very limited data for use. The ribbons were tubular, so we later reinforced them with inserted braided nylon thread, and subsequently reused the dropped transmitter tags. Maps and home-ranges were produced using QGIS (v.3.10 Coruna) and presented as minimum convex polygons (MCP) 100%, using all GPS data from the study period. Statistics and graphs were made using SPSS (v.27, IBM Corporation 2020). We created a smoothed buffer of 200 m distance from the row of poles. From the base-map we did the same, omitting the areas in the sea. The reason why we chose the 200 m buffer distance, was that within this distance the pylons were available as a choice for perching. There are no high trees at Solværøyene, only low bushes, mostly heather and bogs, and no high lookout-points. Then we created a buffer of 20 m radius around each power-pole as a "target area". The GPS transmitters have an expected accuracy of *ca.* +/–18 m (MTI: Choosing a Transmitter, microwavetelemetry.com), and we obtained accurate positions of the pylons by using our own GPS devices. We assumed that positions less than 20 m from the poles probably were of birds using a pole as a perch. Positions further away than 200 m from the gridlines were excluded from the calculations of perching preference, as they were too far away from the poles as perching alternatives. As the islands have very few and low trees, the poles serve as attractive places to perch and look for voles and other prey.

3. Results

Excluding the italicized individuals in Table 1, three adults gave 110–2,413 positions, while 12 juveniles gave 99–1,212 positions, excluding the day of tagging. Fig. 1 shows all the positions for all birds. The number of days from tagging to last signal of juveniles varied between 5 and 428, and of adults from 3 to 1,874. Juveniles with less than 100 days of data were, however, excluded from further calculations. The most short-lived transmitters could partly be explained by early death of juveniles, and of transmitter loss, especially in the adults. Consequently, during the further

Table 1. Home ranges, maximal dispersal distances and position data of the different Eagle-Owls tagged with GPS transmitters (day 0 excluded). For juveniles, individuals giving less than 100 days of data, found or likely dead are excluded from the overall calculations (in italics and marked with an asterisk). N was too small to calculate statistics for adults. Fate: T = transmitter loss, D = dead or likely dead.

Individual	Transmitter type	Sex	MCP 100, km^2	No. of days	No. of pos.	Pos./ day	Max dist. from nest (km)	Fate
Adults								
57268	Argos GPS 45 g	F	14.10	1874	2413	1.3	3.49	
*95335**	*Argos GPS 45 g*	F	0.24	5	97	19.4	0.59	T
95336*	Argos GPS 45 g	F	0.45	*4*	*53*	*17.7*	*0.76*	*T*
107843	LC4 40g	M	2.62	242	478	2.0	1.91	
195335	Argos GPS 45 g	M	0.67	734	110	0.1	1.01	D
Juveniles								
57269	Argos GPS 45 g	M	10.67	382	607	0.8	7.69	D
57270	LC4 40g	F	0.58	188	322	1.7	0.87	
95331	LC4 40g	M	27.47	138	132	1.0	8.13	
*95332**	*LC4 40g*	M	0.20	54	60	0.9	0.38	D
95333*	LC4 40g	*M*	*1.05*	*77*	*75*	*1.0*	*2.94*	
95334	LC4 40g	M	93.78	117	109	0.9	16.70	
*95337**	*Argos GPS 45 g*	*M*	*0.03*	*36*	*33*	*6.6*	*0.27*	*D*
107841	LC4 40g	M	24.09	123	212	1.7	13.13	
107842	LC4 40g	M	40.50	165	323	2.0	10.69	
107844	LC4 40g	M	0.83	112	211	1.9	1.83	
115976	LC4 40g	M	57.19	145	279	1.9	9.68	
115977	LC4 40g	M	31.37	133	259	1.9	7.29	
*115978**	*LC4 40g*	*M*	*0.01*	*21*	*48*	*1.2*	*0.21*	*D*
115979	LC4 40g	M	110.31	125	230	1.8	9.95	
195332	LC4 40g	M	19.87	100	99	1.0	7.68	
195336	Argos GPS 45 g	F	70.04	428	1212	2.8	10.69	
*195337**	*Argos GPS 45 g*	M	0.46	69	380	5.5	1.05	D
215978*	LC4 40g	*M*	*1.27*	*71*	*132*	*1.9*	*1.37*	
Average	Juveniles		37.44	166	307	1.5	8.03	
Minimum	Juveniles		0.58	100	99	0.8	0.87	
Maximum	Juveniles		110.3	428	1212	2.8	16.70	

calculation of home-ranges, the italicized juvenile and adult individuals in Table 1 were omitted. We assumed an individual had died when the last GPS coordinates of the transmitters came from the same place for a period of a few days (n=2).

3.1. Movements

Juveniles. As Fig. 2 shows, little dispersal happened between July 29 (week 30) and September 17 (week 37). From then, there was a gradual increase in movement distances up to October 27 (week 44), from when there was a pronounced increase in movements. Surprisingly, there seems to be a temporary return to the natal area at around November 21 (week 47). This seems to last for only about two weeks, as new movements take place at around December 6 (week 49). Even though the variation is high, these juveniles rarely went further away from their natal site than 5 km (Fig. 2), the maximum distance was 16.7 km.

Much mortality seemed to occur during late autumn or winter, as only three of the juvenile birds gave signals into their second year. The mean date of the last signal during the first year was 12 November, (median 19 Nov, sd=41 d), excluding those with less than 100 days. Three juveniles, born in the moderately high vole year of 2011 (Frafjord 2022), made it into the next calendar year (Ind nr 57269, 57270 and 195336). The last one was born in 2014, a low vole year (Frafjord 2022), and just barely made it into January next year. As most of the transmitters were powered by solar panels, death events were difficult to detect, as the dark winters at this latitude did not provide enough solar power for the transmitters to function properly. A single data point of a juvenile in year three was omitted from Fig. 2. It was from a bird found dead, the exact date of which was impossible to establish.

Adults. As two of the five adults shed their transmitters after a few days, we have usable movement data from only three adults. They did not move far, probably because they were territory-holders, and therefore did not take the risk to leave their territory open for competitors (Fig. 3). One exception was seen in female no. 57268, who took long excursions from her nesting place in the first, second and third autumn, but she was back in March (we lack winter data). The data indicate that she might have bred at a site *ca*. 1 km away from the

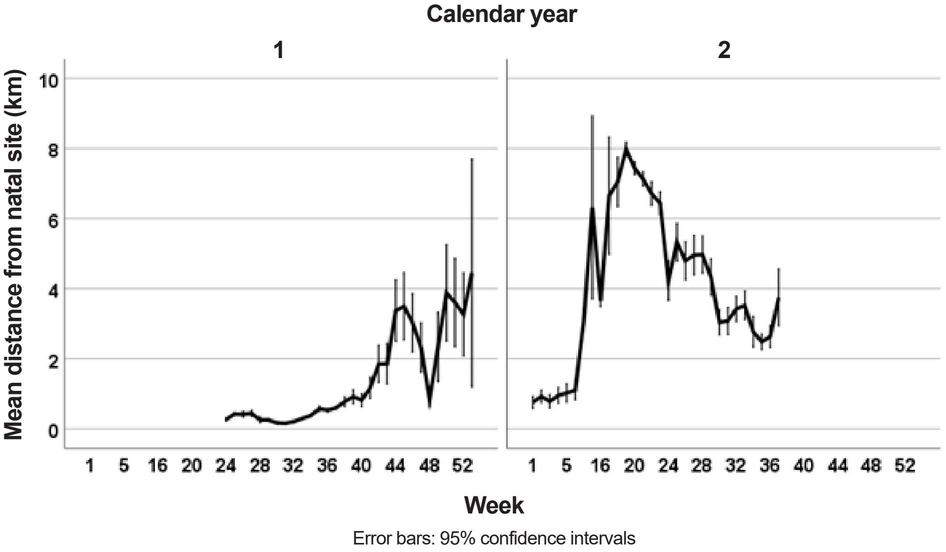

Fig. 2. Movements of juveniles shown as average horizontal distance from nest per bird per week, 95% confidence limits, during their first and second calendar year (n=18 from start, n=12 after Julian day 270).

original site in year three. She was unique in our dataset, as we were able to follow her through six calendar years. She is the only adult represented in the years four, five and six in Fig. 3.

3.2. Home-range

Juveniles. We got little data from many of the juveniles. We don't know the exact reason for this, but early death was probably a main cause. Therefore, we omitted all the juveniles who gave less than 100 days of data before calculating MCPs (minimum convex polygons) for their segment of the population. That left us with 12 birds (Fig. 4). MCP 100 of these juveniles varied from 0.58 to 110.3 km^2, the mean was 27.2 km^2. There may also have been some mortality among the 12 tagged birds that we included in the calculation that we have not been able to record. This could apply to birds no. 107844 and 57270. We did expect the juveniles to roam more than the breeding adults, and this was true in general. Juvenile no. 115979 used an area of 110 km^2, which covers almost the entire archipelago of Solværøyane, almost three times the average for the juveniles. All the tagged juveniles stayed in Solværøyane, none ever visited the mainland or nearby archipelagos.

Adults. The minimum convex polygons of the three remaining adults after exclusion of the two that gave signal for five days and less, varied from 0.67 to 14.1 km^2 (Fig. 5). The average MCP 100 of the three remaining adults were 5.8 km^2. Male no. 195335 was tagged on June 16 in 2009, with signals coming from his tag until July 21 the same year. Then the tag was silent until June 17 in 2010 and sent signals until July 21 in 2010. On July 6 2,011 signals were again received from this tag, and it kept transmitting until permanent silence on July 20 in 2011, more than two years after tagging. Such intermittences during the dark period of the year was also seen in female no. 57268, tagged in 2012 who transmitted signals again in May 2013, March 2014, May 2015, May 2016 and April 2017, each time after winter silence.

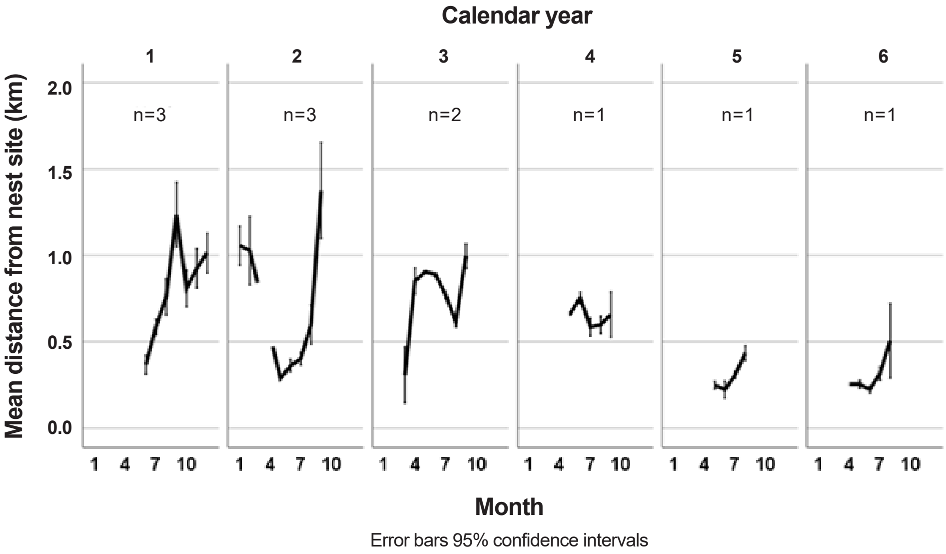

Fig. 3. Mean straight distance (km) between locations and tagging site (nest) by calendar year and month for adult eagle-owls (n = number of individuals). For years 4,5 and 6, only data is from female no. 57268.

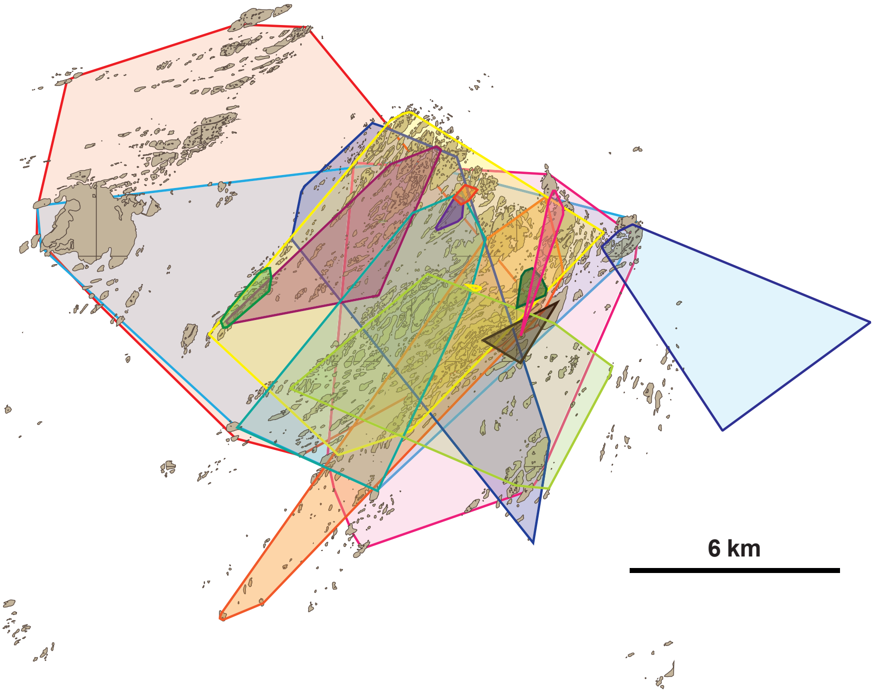

Fig. 4. Home-ranges of all juvenile Eagle-Owls, MCP 100 (n=18). For location reference see Fig. 1.

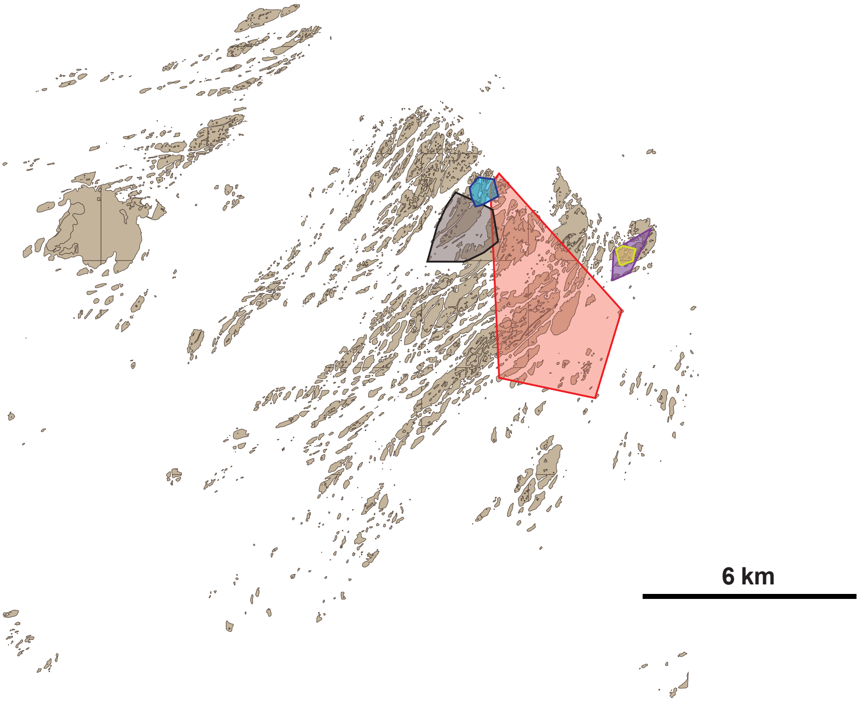

Fig. 5. Home-ranges of all adult Eagle-Owls, MCP 100 (n=5). For location reference see Fig. 1.

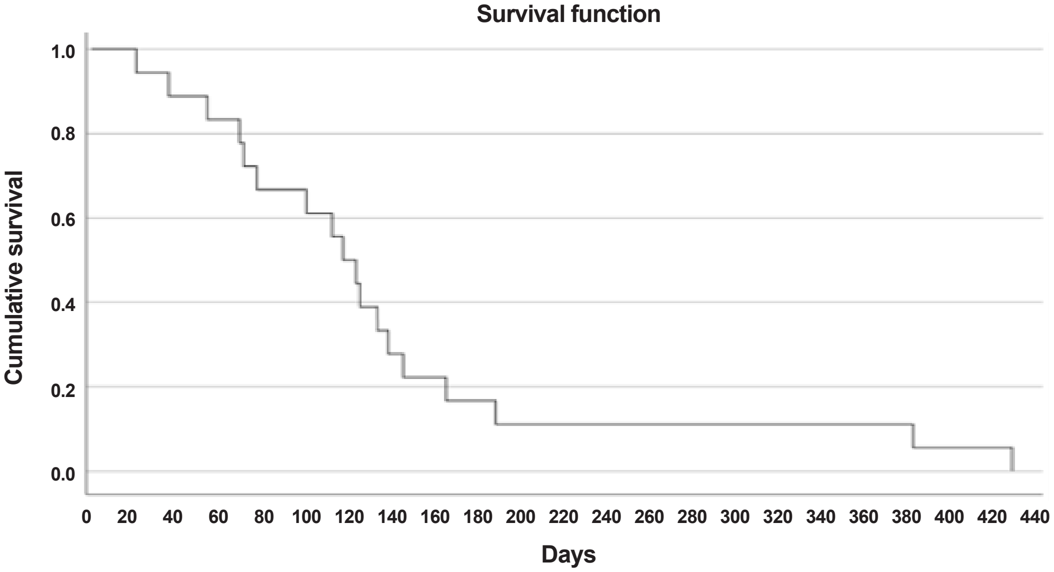

Fig. 6. Estimated survival of juveniles tagged with GPS transmitters (n=18) using the Kaplan-Meier method, in days after deployment. X-axis is days after deployment. Y-axis is fraction surviving (1 = all survived, 0 = all apparently dead).

3.3. Mortality

In only four out of 18 juveniles we were able to observe or define death of birds with a reasonable degree of certainty. A Kaplan-Meier analysis of survival showed that at 100 days, 61% of the juveniles were expected to survive, but only 11% after 200 days (Fig. 6). Birds with missing signals without confirmed death are treated as censored in the analysis. The implied survival rates must be therefore taken with great care, as for most of the juveniles we were not able to confirm death, or to distinguish transmitter failure from death.

3.4. Use of power-poles for perching

In the QGIS analysis, we used only the birds that had an overlapping home-range with the 200 m buffer, and which had 50 or more positions within the buffer. Six juveniles and two adults fulfilled that criterium. Out of 4,792 datapoints of juveniles 635 were from within this buffer, but only 32 out of these were overlapping with the 20 m buffer around poles (5.0% of positions, 4.2% average between birds). Only two adults fulfilled our selection criteria, females 95335 and 57268. (Table 2). The adult female 57268 had far more positions than any other bird. From a total of 2,420 positions, 1,115 were within the 200 m buffer around poles. Out of these, 245 overlapped with the 20 m radius (22.0%). We assumed she was perching in these cases. Perching is the normal hunting preparation method of the Eagle-Owl (Penteriani & Delgado 2019). Using QGIS, we created 1,115 random points within the 200 m buffer. Only 80 of these overlapped with the 20 m radius buffers around the pylons. There was a highly significant difference between the random points and the actual points of female 57268 ($p < 0.001$, Chi-square test) (Fig. 7). If we include female 95335 in the calculation, the average of adults becomes 13.9% of overlapping positions with poles.

One of the practical outcomes of the project was an effort to minimize the number of electrocutions caused by the Eagle-Owls perching on “killer-poles”. A deterrent device was constructed as a suggestion by the team, consisting of an arm fitted onto the crossbar that had an elevated extension to the side, and spikes extending upwards on the full length of the crossbar (Fig. 8). This was to encourage the birds to perch on the elevated extension, thereby

Table 2. The frequency of GPS positions of Eagle-Owls and power-poles within a 20 m radius around a power-pole and within a 200 m buffer around poles. Only birds with more than 50 positions within the buffer zone were included. Averages are the average between individual birds.

Bird no.	No. of GPS positions	No. of GPS positions inside 200 m buffer	No. of overlapping positions with 20 m radius	Fraction of overlapping positions with 20 m radius	Age
57268	2420	1115	245	22.0%	Adult
95335	121	103	6	5.8 %	Adult
Sum Adults	2541	1218	251	Average 13.9 %	Adult
57270	325	126	16	12.7 %	Juvenile
95333	77	56	1	1,8	Juvenile
95334	111	50	1	2.0 %	Juvenile
107841	215	158	11	7.0 %	Juvenile
195332	101	81	0	0 %	Juvenile
195336	1220	164	3	1.8 %	Juvenile
Sum juveniles	2049	635	32	Average 4.2 %	Juvenile
All Eagle Owls	4590	1853	283	Average 6.6 %	All

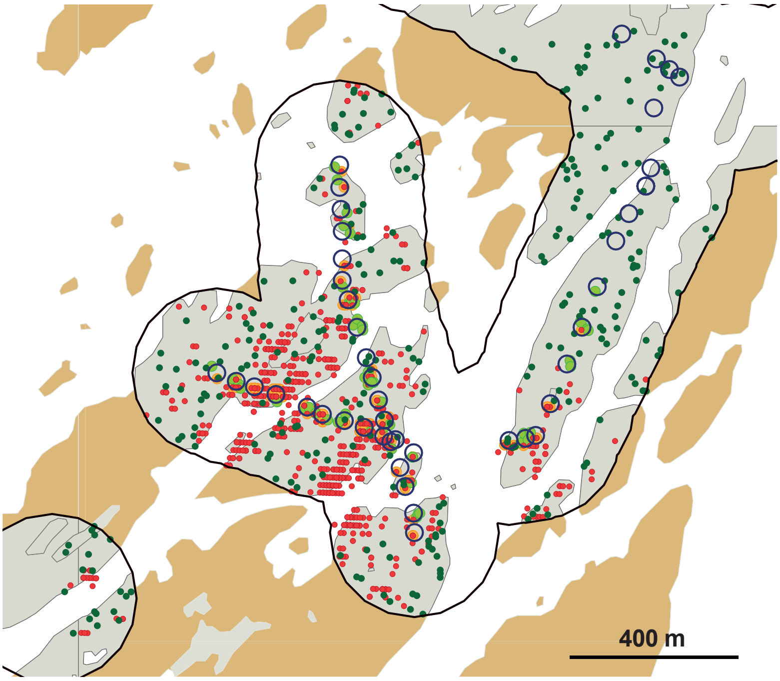

Fig. 7. Section of the map showing overlap between GPS positions of female 57268 (small red circles) and a buffer with radius 200 m around poles (solid line surrounding the area of observations). In cases where female GPS positions overlap with the 20 m radius buffers around poles (large unfilled circles) the GPS positions of female 57268 are highlighted as larger orange circles. Small dark green circles are randomly generated points, and in cases where these random points overlap the 20 m buffers (large open circles) they are highlighted as larger light green circles). All points are restricted within the section of overlap between the home-range of female 57268, the 200 m buffer around pylons and the dry land mass (shown in grey).

escaping from the risk of touching the hot leads. The local power-company has carried out several mitigating measures on the grid at Solværøyene in the period 2012–2014, by fitting a number of poles with deterrent devices as part of the follow-up of the national 'Action plan for the Eagle-Owl'. This deterrent device has later been mass-produced by El-Tjeneste AS (Hubrostøtte Hsaus - El-tjeneste as | Steinkjer) and fitted on power-poles in Eagle-Owl terrain in several areas throughout the coast of Norway.

4. Discussion

The juveniles' movement distances (natal dispersal) were much greater than those of the adults. This was as expected, as the adults were breeders, holding a territory. Juveniles are not expected to set up an own territory as a basis for future breeding close to their parents', partly because the cost of potential inbreeding (Rosenfield & Henny 1992, Szulkin & Sheldon 2008), and partly because lack of vacant space to set up an own territory. The dispersal distance of juveniles normally was between 4 and 8 km from the natal site in our study area, much less compared to what other authors have shown (Olsson 1979, Scherzinger 1987, Saurola 2002, Melling *et al.* 2008, Aebischer *et al.* 2010, Penteriani *et al.* 2012). These authors report juvenile mean dispersal distances between 13 and 72 km. The short distances travelled by the juveniles at Solværøyane is probably best explained by the physical outline of the location. It is a group of islands, separated from the mainland by the open sea, which probably discourages the birds from crossing over. All the tagged juveniles stayed in the Solværøyane archipelago, none ever visited the mainland or nearby archipelagos. It could be done in short intervals through "island hopping", but it was never proven. Also, the normally good supply of suitable prey on these islands, the Water vole, which is not present at most of the neighboring islands, is also a factor discouraging long dispersal distances. The obvious high mortality of juveniles during their first winter could be explained by the relatively low density of Water voles during most of the time of our study (Frafjord 2022). The mortality rates indicated by our data are considerably higher than those reported in Penteriani & Delgado (2019).

The apparent return to the natal site in late autumn after the first natal dispersal of juveniles is puzzling (Fig. 2), but the same has also been observed in Sweden (Olsson 1979). One possibility is that the juveniles check out whether the breeding site of their parents could offer a vacancy and an opportunity to set up their own

Fig. 8. Eagle-Owl perching on a power-pole with deterrent devices fitted. Photo: Karl-Otto Jacobsen.

territory. Another explanation could be that they are hoping to be fed by their parents at or near the place they were raised, or they return to a familiar place when food becomes scarce.

The size of the home-ranges expressed as MCP 100 were small. This may be explained in the same way as for dispersal; this is a very dense island population, and the propensity to leave the island was small. A study of dispersal in the southern part of Norway showed MCPs of 8.9 to 163.5 km^2 of adult Eagle-Owls during the time when they had chicks in their nests, with a mean of 72.3 km^2 (Heggøy *et al.* 2021). Our oldest female, no. 57268, showed a MCP 100 of only 14.1 km^2, combined over all six years, but we don't have any winter data for this bird. Periods of intermittent signal transmission could be caused by back feathers covering the solar panel wholly or partly, resulting in sufficient charge only during mid-summer.

The results indicate a use of power-poles (within the 20 m buffer) as perch in approximately 20% of the time spent within a range of 200 m from a pole (based on female 57268, as the quality of data for her was better than for any other bird).

The same for juveniles was on average 4.2% but as there were only six juveniles that had home-ranges that were included in the calculations, the results must be interpreted with caution. Even though the frequency of apparent use of the power-poles may seem low in juveniles, only one single contact with the leads could be fatal. Many of the GPS points were from the summer, probably before the juveniles started to hunt for themselves and were still fed by their parents.

We have documented that the Eagle-Owls used the deterrent devices after mounting (Fig. 9), which suggests that this may have an important effect of reducing the mortality caused by the electricity grid, especially at locations where high perches are naturally absent. The use of power-poles as perching-places is prone to increase the probability of Eagle-Owls to become electrocuted. High mortality of Eagle-Owls due to electrocution is shown elsewhere, such as in Italy (Rubolini *et al.* 2001), Finland (Valkama & Saurola 2005), Germany (Brauneis & Hormann 2005), France (Nadal & Balluet 2010), Sweden (Olsson 1979), Spain (Molina-Lopez *et al.* 2011), and Norway (Bevanger & Overskaug 1998). In Norway, pole-mounted transformers was identified as the most serious cause of bird electrocutions (Bevanger 1994). Therefore, mitigation measures are highly needed to prevent electrocutions of the Eagle-Owl. The device described here and shown in Fig. 8, seems to be highly promising, and is now fitted at many stretches of the grid in the vicinity of Eagle-Owl breeding-sites. Hopefully, this will lead to reduced mortality of this endangered species at those sites.

Huuhkajien (*Bubo bubo*) elinpiiri, liikkuminen ja voimalinjapylväiden käyttö Pohjois-Norjan saaristossa

Huuhkajien (*Bubo bubo*) tiheä Norjan saaristossa elävä populaatio lähellä napapiiriä on kärsinyt huomattavasta kuolleisuudesta useiden vuosikymmenten ajan voimalinjoista johtuvien sähköiskujen ja törmäyksien vuoksi. Tässä tutkimuksessa tutkimme huuhkajien elinpiirin kokoa, leviämisetäisyyksiä ja kuolleisuutta vuosina 2009–2014 GPS-lähetinteknologian avulla. Yhtenä tutkimuksen tavoitteena oli löytää sopivia toimintatapoja onnettomuuksien ehkäisemiseksi. Havaitsimme odotetusti, että nuorilla pöllöillä oli laajempi elinpiiri ja että ne liikkuivat kauemmas kuin aikuiset. Kuitenkin molemmat ikäryhmät liikkuivat vähemmän kuin muualla Euroopassa, mikä johtunee siitä, että huuhkajapopulaatio on ympäröivän meren eristämä. Keräämämme aineiston GPS-tiedot osoittavat, että voimalinjojen pylväitä käytettiin tähystys- ja lepopaikkoina enemmän kuin satunnaisjakauman perusteella odotettiin, mikä selittyy korkeiden puiden ja muiden paikkojen puutteella alavilla saarilla. Vahinkojen ehkäisemiseksi ehdotamme pylväisiin suunniteltavien alustojen asentamista sähköiskujen saamisen estämiseksi. Alustoja käyttävät jo useat voimalinjarakenteiden omistajat rannikkoalueilla, joilla on havaittu korkea sähköiskuvaara, ja ne on huomioitu myös Norjan kansallisessa huuhkajien toimintasuunnitelmassa.

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