

Radio Telemetry studies of Dispersal and Survival in juvenile White-tailed Sea Eagles *Haliaeetus albicilla* in Norway

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INTRODUCTION

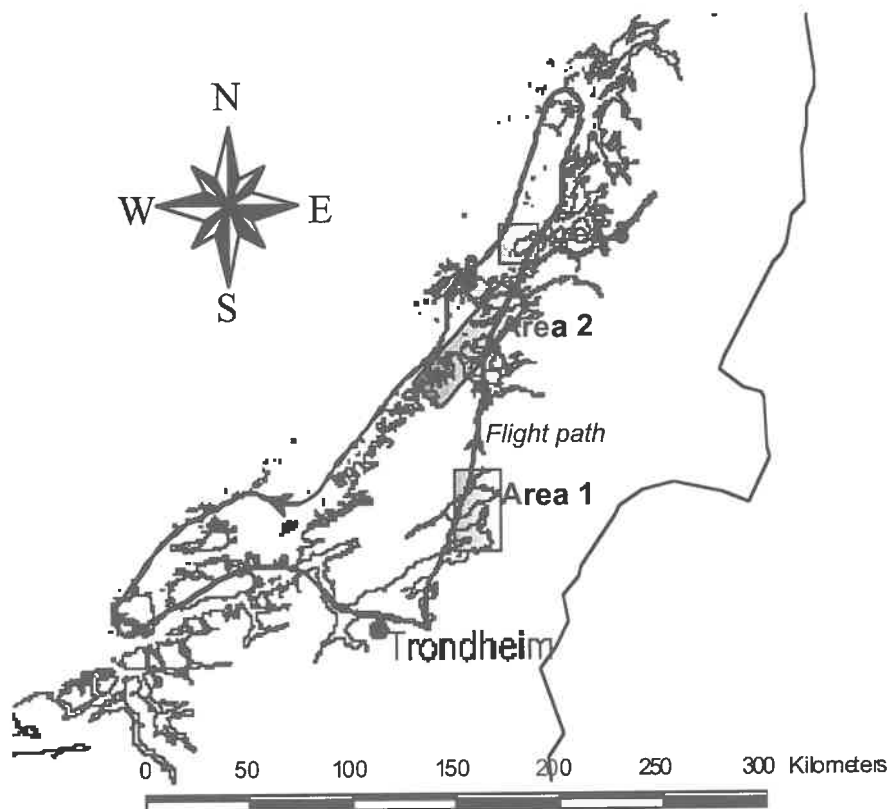
Norway holds approximately half of the current European population of the White-tailed Sea Eagle *Haliaeetus albicilla* (Folkestad, 1997). After having been persecuted for decades, this large long-lived raptor was eventually protected in 1968. Since then it has increased and expanded its range. Little is known, however, about the details of juvenile dispersal and mortality of this species, as ringing recoveries only give crude information on movements. The advent of long-life radio tags has provided more continuous data on movements and a rapid method of estimating survival for rare species, which generally provide too few ring recoveries for reliable survival estimates (Kenward, 1993).

METHODS

Study area

We studied dispersal of juvenile White-tailed Sea Eagles on the coast of Central Norway during 1989-97. The study area was located in the province of North Trøndelag, central Norway 64°-65°N (Fig. 1). Area 1 is located in the inner part of Trondheimsfjorden, a sheltered fjord where the landscape is dominated by forestry (mainly spruce forest) and agriculture (dairy and cereal farms). Area 2 is a coastal area indented with shorter fjords, richly interspersed with small islands. There is some coastal fishing and salmon farming, with small scale forestry and agriculture (dairy farms). The hills are covered with Scots pine and some birch up to an elevation of *ca.* 300 m. Area 3 is an island set off from the mainland, with small-scale agriculture and a growing fish-farming industry. The island is quite barren, especially toward the west, with some birch and mixed deciduous forest in more sheltered sites. The areas 1-3 form a gradient from sheltered inland to exposed outer coast.

Figure 1. The study area in central Norway, 63°-66°N, showing where the fledgling White-tailed Sea Eagles were tagged (Areas 1-3) and the general flight paths regularly travelled by fixed-wing aircraft to track their movements.



Sexing of nestlings

Nests were generally visited only once, but ten eaglets were measured 2-3 times at different intervals during the nest period to estimate growth rates. At our visits at nests, measurements (mm) of culmen length, bill height, tarsus width (at the thinnest point), tarsus breadth (at the same point perpendicularly to the first) were taken with a slide calliper to the nearest 0.1 mm (Bortolotti, 1984c). The wing length (straight flattened chord) was measured with an inch rule to the nearest mm. The tail length was measured by inserting a ruler between the central rectrices. The mass of the birds were taken with a 10 kg Pesola spring balance to the nearest 100 g. The filling of the crop of the nestlings was recorded, and the weight of the content was subtracted as follows: full crop = 300 g, more than half full crop = 200 g, less than half full crop = 100 g, empty crop = 0 g (Helander, 1981). The sex of the eaglets was assigned subjectively based on appearance, behaviour and biometrics. In the cases of twins, the relative size of birds facilitated the sexing. When the mass of an eaglet was more than 6.0 kg, it was assumed to be female. Two males and two females later had their sex verified by post mortem gonad inspection.

Radio tracking

Forty-one eaglets were radio-tagged with 75 g VHF transmitters from Biotrack Ltd, Wareham, UK using back-packs attached with a 1.25 cm wide teflon ribbon in a Y-type attachment and a loose

fit (a least three fingers between the transmitter and the back of the nestling). This method has proven non-harmful to Bald Eagles *Haliaeetus leucocephalus* (Buehler *et al.*, 1995). The batteries of the tags from 1989-90 lasted approximately two years, while the tags used in 1991-1993 lasted five years and more. The backpack design has been extensively tested on Common Buzzards *Buteo buteo* without evidence of adverse impacts on behaviour or survival (Kenward & Walls, 1994). Only one of our birds (a presumed male) that was later recovered alive, showed slight signs of wear and also had some pressure sores on its back. Examination of the tagging-data showed that this was the smallest and probably the youngest bird we tagged. Three others that were examined post mortem showed no such adverse external effects. Radio-tracking was done from land, boat and air. After the birds had left their natal area in autumn, they were tracked from a fixed-wing single-engined aircraft, if possible once a month. The flights were normally of five to six hours, covering a total linear distance of up to 800 km. The signals were detected at a distance of 100 km and more, but usually less, depending on the terrain. Flying altitude was typically 1000-1500 m, at a cruising speed of 100 mph. A total of 943 fixes were collected during the course of study.

The statistical testing was performed using SPSSPC ver 8.0 software.

Table 1. Tracking of 41 fledgling White-tailed Sea Eagles radio-tagged to study movements and dispersal from the nest in central Norway 1989-93.

Year	No. of birds tagged	Status of signal and bird								
		Signal lost 1 st year, no further contact	Signal lost 2 nd year, no further contact	Signal lost 3 rd year, no further contact	Signal lost 4 th year, no further contact	Found dead <4 years	Signal lost >4 th year, no further contact	Alive >4 years, active signal	Controlled alive >4y, signal lost	Found dead >4y, signal lost
1989	5		3						1	1
1990	7		2	4		1				
1991	10	1		1	3	1	1	1	1	1
1992	12	1		2	1		5	3		
1993	7		1		1	1		4		
Total	41	2	6	7	5	3	6	8	2	2

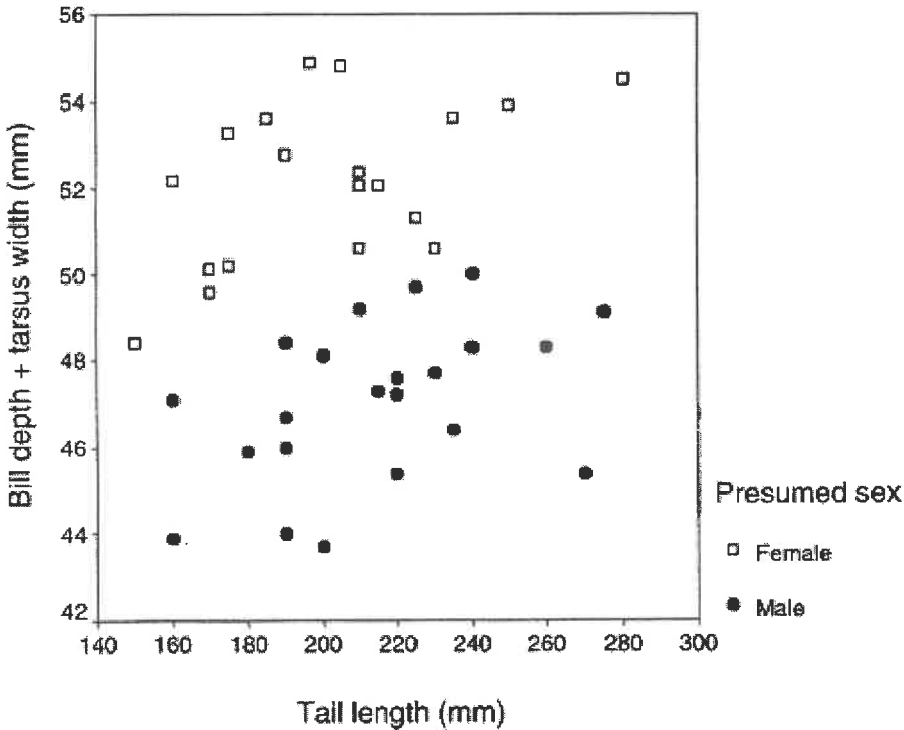
RESULTS

Measurements and sexing

Linear growth of flight feathers between the 24th and the 72th day after hatching has been demonstrated for Bald Eagle (Bortolotti, 1984b), who also found that the rectrices emerged at the age of 25-30 days (estimated from Figure 4 in Bortolotti, 1984a). We found the growth rate of the central tail-feathers to be on the average 5.6 mm/day, with only a slight difference between sexes: 5.5 mm/day for presumed males, and 5.7 for females. The birth date was estimated for each bird using the length of the central rectrices and a growth rate of 5.6 mm/day, and 30 days for their first emergence. A discriminant analysis was performed as a check on our sex-classification, using presumed sex as grouping variable and the different body measurements as independents. On the basis of our biometric data, the analysis divided the birds into two groups that conformed exactly with our subjective classification into males and females. The canonical correlation functions indicated that 49% of total variability between groups could be explained by tarsus width, 17% by bill depth, while 1.6% was explained by tarsus depth. No other measurement explained more than 1% of the total variability. Figure 2 shows the relation between presumed sex, tarsus width + bill depth and tail length. One would, of course, need a larger sample of fledglings of known sex to establish a reliable sexing formula. Bill depth vs. foot pad length have been used to discriminate between the sexes

(Bortolotti, 1984a). We found it difficult to use foot-pad, as the eaglets usually had considerable tension in their talons, making it difficult to obtain a good straight measurement. Helander (1981) suggested using tarsus width to separate the sexes, as he found little overlap between the (presumed) sexes in his material.

Figure 2. The relation between bill depth+tarsus width vs. tail length in 41 nestlings of White-tailed Sea Eagles in Norway. The birds were sexed on physical appearance, measurements and behaviour in the nest.



Dispersal age

For reasons connected with lack of personnel and logistics, the exact departure date was difficult to detect with certainty. A bird was considered dispersed when it was observed more than 4 km away from the nest, with no subsequent return that season. The date of dispersal was calculated as the mean of the last date present and the first date away. Two (5%) of the birds (one male, one female) did not leave during their first year of life. The estimated median age at time of permanent departure from the natal area was 161 ($n = 23$, $SD = 61$) days for males (median date 1 Oct), and 181 ($n = 18$, $SD = 67$) for females (median date 22 Oct); the difference was not significant (Mann-Whitney U test, $Z = -1.03$, $p = 0.31$, two-tailed). Excluding the birds that did not disperse during the first year, the median values were 160 ($n = 22$, $SD = 45$) days for males, and 180 ($n = 17$, $SD = 30$) for females; the difference was not significant (Mann-Whitney U test, $Z = -1.02$, $p = 0.31$, two-tailed). There was a tendency for birds tagged in the inner areas to disperse earlier than birds from the outer areas. Juveniles from Area 1 had a median age of departure of 141 days, while the ages for Areas 2 and 3 were 164 and 185 days, respectively. However, the differences were barely statistically significant (Spearman corr., $r_s = 0.29$, $p = 0.06$, two-tailed).

Patterns and directions of dispersal

Figures 3 a-d show the distances from nest with age of four juveniles, showing different patterns of dispersal. Male 153 (Fig. 3a) moved 100 km south in its first winter, then returned to its natal area during the next spring. The following autumn and winter he moved up to 200 km SW, with a subsequent return to his natal area in the spring the year after at the age of two years. The same pattern repeated in his third year of life. Male 351 (Fig. 3b) stayed close to the natal site the first whole winter: the longest excursions recorded were less than 10 km. He did not leave the natal area before his second autumn, and never went beyond 60 km. In contrast to most other birds, he moved north and east of his natal site. In his third year, he returned close to his birth-place in the spring, followed by a northerly movement next autumn. Female 271 (Fig. 3b) dispersed more than 180 km SW in her first winter, with a slight return movement next spring. This pattern repeated the following year, but she was never recorded closer than 80 km from her natal site. She was later found weak but alive in a snow-drift at the age of 5 years, and she was rehabilitated and later released. Female 473 (Fig 3d) exhibited a very regular alternating pattern between being 200 km away during winter and *ca.* 40 km from the nest in summer, but the second winter she stayed NE of her natal site, all other winters SW. Most recordings of all the birds were made in a SW direction relative to the nest during winter. 57.5% of all the initial movements (first fix after departure date) were in the south-west direction of the nest, and 27.5% were to the north-east. Only 2.5% were to the south-east, which was a movement inland.

Figure 3 a-d. The dispersal and distance from nest in relation to age of two male and two female radio-tagged juveniles of White-tailed Sea Eagle, showing different movement patterns. The broken line indicates 4 km from the nest.

Figure 3a.

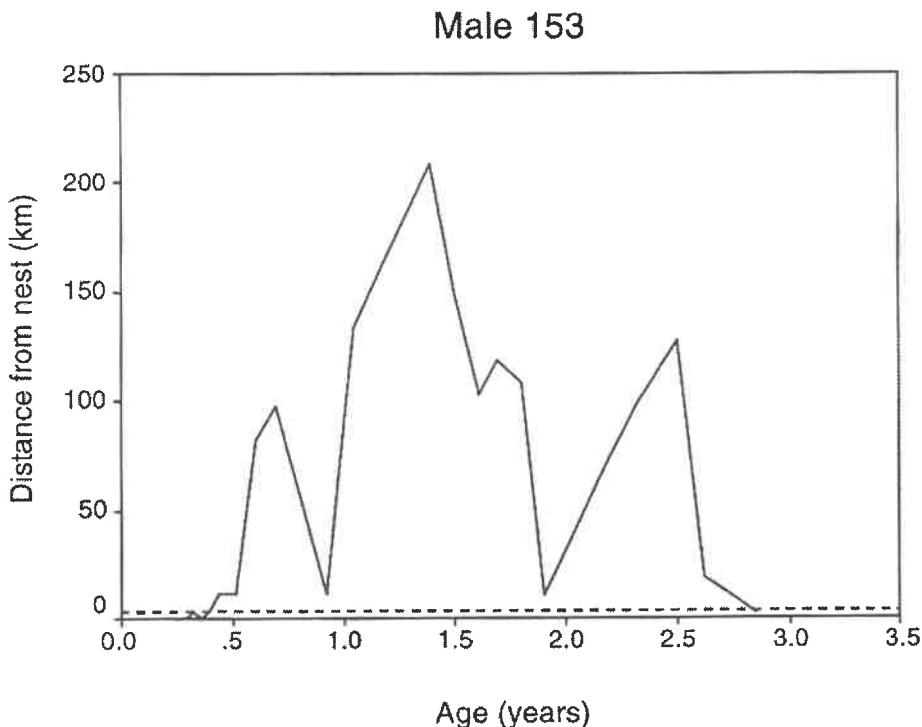


Figure 3b.

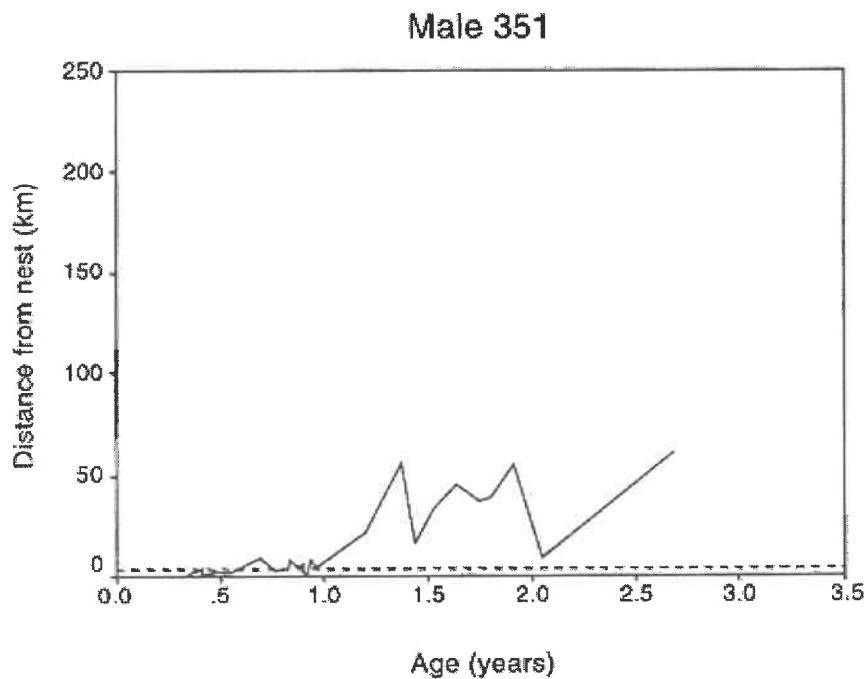


Figure 3c.

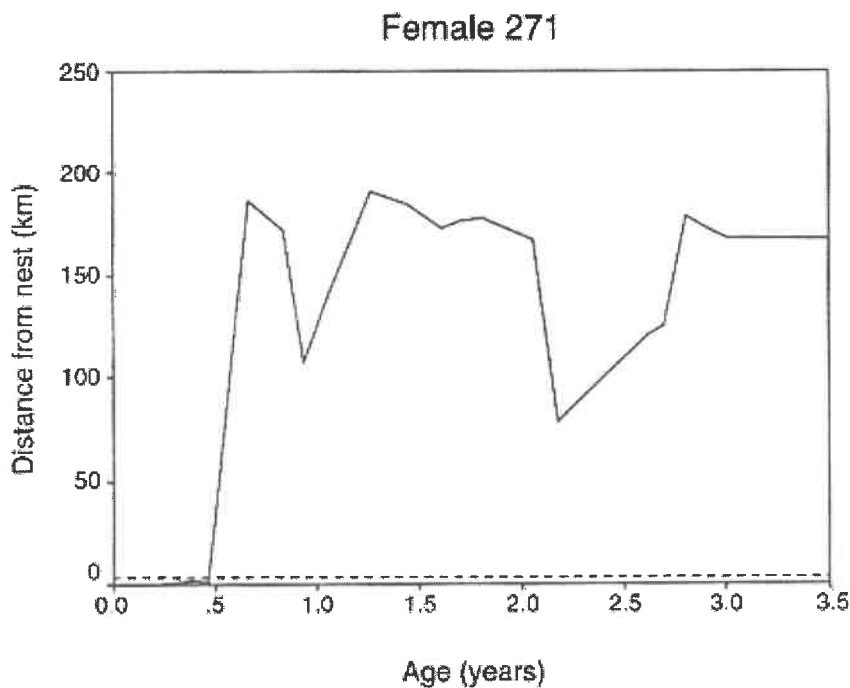
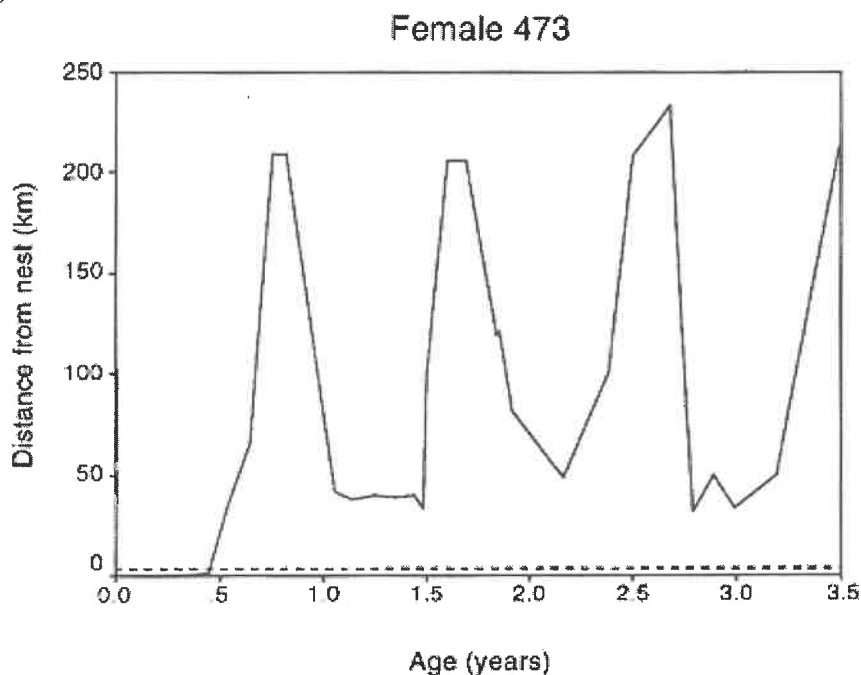


Figure 3d.



Effects of sex and natal area

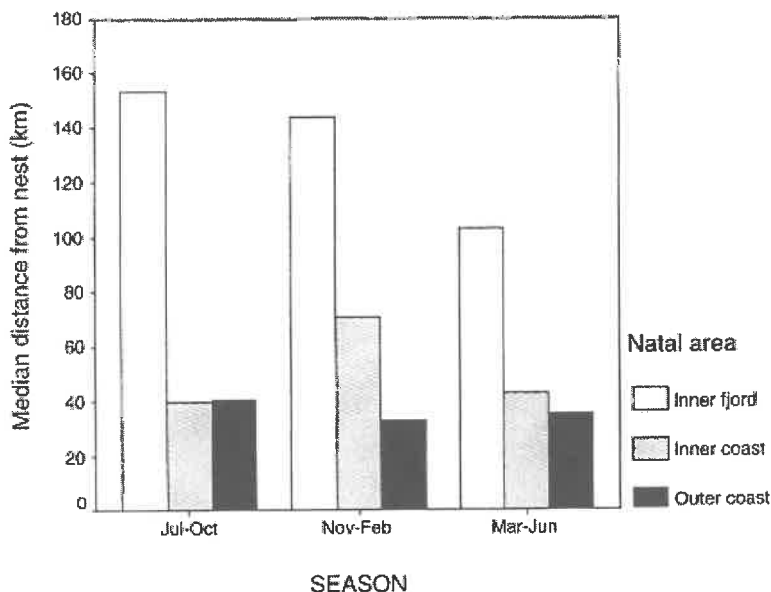
Birds from Area 1 stayed further away from the nest in their second and third year than birds from Area 2 and 3, while birds from Area 2 stayed further away from the nest during November-February than birds from Area 3 in their second and third year (Figure 4). Females were observed further away from their natal site than males in winter. This tendency was strong during the second and the third winter, when the median distance from the nest was 44 km for males during November-February (50 fixes), while it was 121 km for females (49 fixes). An ANOVA on $\log_{10}$ -transformed distances from the natal site (the dependent variable) was performed, using presumed sex, natal area, and brood size as independents. (Table 2). Among these variables, only sex and natal area had significant effect on the distance from natal site, and only in July-February. In the spring/early summer, there were no significant differences.

Table 2. The effect of presumed sex, natal area, brood size, year of study and birth year on distance from nest at different seasons in the second and third year of life. The significance of the differences was tested using general factorial ANOVA on $\log_{10}$ -transformed distances.

Season	Jul-Oct	Nov-Feb	Mar-Jun
Presumed sex	**	**	N.S.
Natal area	*	**	N.S.
Brood size	N.S.	N.S.	N.S.
Year	N.S.	N.S.	N.S.
Birth year	N.S.	N.S.	N.S.
Year*Natal area	N.S.	N.S.	N.S.

* $p < 0.05$, ** $p < 0.01$, N.S. = not significant.

Figure 4. Distance from nest in relation to natal area in the second and third year of life of radio-tagged juvenile White-tailed Sea Eagles in Central Norway.



Survival

As seen from Table 1, the tracking records of the different cohorts were different. The performance of the tags mounted in 1989 and 1990 was poorer than in subsequent years, when an improved transmitter design was available. It was therefore necessary to treat the 1989-90 and 1991-93 cohorts separately, having estimated battery lives of approximately 2 vs. 5 years. All the birds from 1989-90 survived the first twelve months, but after that signal loss makes the survival estimates unreliable. Two of the birds whose signals were lost during their second year, were later proven to have obtained adult plumage. Loss of signal before 24 months without further recovery happened to only three of the 29 birds from the 1991-93 cohorts. A Kaplan Meier survival analysis estimated the maximum survival of these cohorts to be 94% (based on only recorded deaths), and the minimum survival 86% (assuming loss of signals is death). The true figure will lie somewhere between these extremes. The effect of the transmitters must be small, in view of the overall high survival rate found.

DISCUSSION

The age of independence found in our birds was slightly higher than found in the Spanish Imperial Eagle *Aquila heliaca adalberti* (123-145 days after hatch) (Alonso *et al.*, 1987). They also found that the time of independence was determined by parental "meanness", i.e. the young wanted more parental investment than the adults were inclined to give (Trivers, 1974). As the White-tailed Sea Eagle is able to and may attempt to breed each year, it may be adaptive to switch the investment effort from its offspring to its own body resources at a certain point of time in the autumn. However, Kenward *et al.*, (1993) showed with experimental feeding and parent removal in Northern Goshawks *Accipiter gentilis* that although dispersal was brought forward slightly by inadequate feeding, it was ultimately a maturation process. Dispersal may normally be a maturation process in Sea Eagles too. Other eagle species may have different strategies, i.e. the Crowned Eagle *Stephanoaetus coronatus* in East Africa, in which the parents continue to feed young for up to a year after hatching, the normal breeding frequency of this species being every second year (Brown, 1966).

The general SW direction found in the present data is against the prevailing winds in the autumn, contrary to what was found in dispersing juvenile Spanish Imperial Eagles (Ferrer, 1993). One reason for this may be that many species of birds suitable as prey for the White-tailed Sea Eagles (e.g. cormorants, geese, gulls) migrate SW along the coastline at this time of the year. This may be a triggering factor for the initial dispersal flights. The coastline runs in a general SW-NE direction, and it may also be advantageous to move south for slightly better climatic conditions in winter. However, within the distances we covered, (ca. 300 km linearly) there will be only small differences in general climate. Perhaps there are elements of chance involved in the decision whether to travel up or down the coast, but inland travels seem to be avoided.

Juveniles that moved more than 250 km in any direction from the nest would remain undetected, due to limitations of the flying routes. Two individuals were later found dead at distances in north- and easterly directions beyond those normally covered by the tracking-flights. Ringing-data have revealed that juvenile Sea Eagles may travel long distances, in some cases several hundred kilometres (Love, 1983). However, on most tracking flights the majority of the birds were present, indicating that most birds kept within the surveyed area most of the time.

The tendency for female juveniles to disperse further than males is also demonstrated in many other species of birds of prey, e.g. the European Sparrowhawk *Accipiter nisus* (Newton, 1986). If this is accompanied by a tendency for the males to settle closer to the natal site one may speculate on the possible adaptive significance. The male may have an advantage in an area where he is well known. It may therefore be adaptive for the female to behave differently, in order to avoid inbreeding. Under these circumstances there are, of course, chances that young males may pair up with their mothers if the father dies. Why females disperse further than males, and not *vice versa* is not easy to answer. Female biased dispersal seems to be a general pattern among birds (Clarke *et al.*, 1997). Greenwood (1980) explained male-biased philopatry in birds (which are, by and large, monogamous and territorial) by the greater need for males to establish territory (defend resources) and settle in familiar surroundings. Dobson (1982) argued similarly but also pointed out that in monogamous species the competition for mates should be more nearly equal between the sexes and, hence, that both sexes should disperse in equal proportions. Female White-tailed Sea Eagles may defend their territories vigorously, and can engage in violent female-female territorial fights (Einvik, 1989). Also male-male territorial fights are reported (Love, 1983). Birds in juvenile plumage (dark bill, dark-edges rectrices) seem to be tolerated in territories of breeding adults (Willgohs 1961, own obs.), as also has been recorded in Common Buzzards (Walls & Kenward, 1998). Among Swedish Northern Goshawks, it is the males that travel furthest, possibly because of differences in food supply, probably connected to the large size dimorphism between the sexes in this species (Kenward *et al.*, 1993).

Nest site fidelity of marked individuals is demonstrated in Bald Eagles (Gerrard *et al.*, 1992) as in this study. The very slow rate of geographical expansion of the White-tailed Sea Eagle since it was protected in 1968 in Norway may have to do with the tendency of immature birds of this species to return to their natal territories, presumably in search of vacant breeding territories.

The difference observed in moving distance between birds from the inner fjord area and the coastal areas may be explained by the need of the birds from the fjord to move to the outer coastal areas in winter to improve their foraging situation. We believe that the coastal archipelagos, with their extensive shallow areas created by the numerous islands and skerries, provide better fishing opportunities than the rather steeply shelving fjords. The coast has more local fishery, resulting in more available offal, and it also has more wintering birds suitable as prey, such as cormorants and large gulls. These factors may also be responsible for the earlier dispersal of the birds from the fjord.

Our results, indicating annual survival rates in the first two years of life at 90-95%, are remarkably high. They contrast strongly to with reports from Amchitka Island, Alaska in 1972 for Bald Eagles, where the estimated mortality in the juvenile stages up to adulthood was 90%, based on the numerical relationships between brown and mottled (juvenile) and adult-coloured birds (Sherrod *et al.*, 1977). Their calculations were made under the assumption of no immigration or emigration, which may not hold. In a study of released juveniles translocated from Norway to Scotland, Green *et al.* (1996) estimated an annual survival rate at 73% prior to settlement (normally at 4-7 years), and 94% thereafter.

The precision of their estimates was probably reduced as the birds were not radio-tagged, making individual identification in the field more difficult. Survival of large eagles in their first year of life has shown to be high in other studies using radio-tags. Buchler *et al.* (1991) found 100% survival in the first year of Bald Eagles in Maryland, USA. Our findings support the view that radio tagging is able to give better (and usually higher) survival estimates for medium-sized and large philopatric raptors (Kenward, 1993). The annual survival estimates of first-year Common Buzzards in Britain were 43-49% using ringing records, while in a study using radio-tags with back-pack mounts it was 73% (Kenward & Walls, 1994).

The study has provided details of the juvenile-life stage of White-tailed Sea Eagles that would have been very difficult to obtain using traditional methods. Ecological and life-history parameters of the type shown in this study are essential when it comes to constructing population models, predicting population growth, and assessing conservation and management.

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