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Home range size, Habitat utilisation, Hunting and Time budgets of Lesser Spotted Eagles *Aquila pomarina* with regard to Disturbance and Landscape Fragmentation [1]

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ABSTRACT

The extent of the home range, habitat utilization and time budget of the Lesser Spotted Eagle (LSE) were examined with particular regard to disturbance and landscape fragmentation in North-eastern Germany at the western edge of its range and, for comparison purposes, in Latvia. The results, based on conventional VHF radio-telemetry backed up by visual observation, produced valuable data on home range coverage (which was significantly greater than recorded in earlier studies) and the characteristics and utilization of preferred hunting grounds.

A total of 9 birds in Germany, and 6 birds in Latvia, were studied. The home ranges exploited by successful breeding males in Germany were significantly larger than those in Latvia, averaging 2,711.2 ha compared with a 1,142.7 ha. The maximum/minimum ranges covered in Germany were 3,393.8 ha/2,218.5 ha compared with 1,552 ha/672 ha in Latvia. There was no marked difference between the average daily home range of 347.3 ha and 483.8 ha in Germany (mean 471.9 ha) and between 244.3 ha and 489.3 ha (mean 361.2 ha) in Latvia. There was little difference in the maximum daily home range size in Germany 1,287.5 ha and in Latvia 1,156.0 ha.

All eagles used open countryside considerably more than forested areas for hunting. All of the Latvian and most of the German males showed a clear

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preference for grassland as hunting habitat. In Latvia grassland, where the availability in the home range was correspondingly greater, was used more frequently and for longer periods (39%) of total hunting time (24.5% Germany). The proportion was reversed in hunting over arable land because of the smaller percentage of grassland in Germany where cereal crops or set-asides were preferred for hunting in the vegetation period; hunting over rape and maize crops began generally after the harvest. There was a difference in the proportion of individual hunting methods. Perch hunting dominated among the Latvian birds, the German birds mainly hunted on the wing.

Wide-open and unbroken countryside must be preserved in breeding area concentrations, with potential disturbance factors confined to marginal zones. All forms of infrastructural development (particularly road construction) must be strictly controlled here.

The following disturbance factors must be excluded from an area up to 3 km radius from the nest, the main hunting zone: tourism, all substantial urban development and installations involving substantial habitat change (e.g. wind turbines).

TASKS AND AIMS

It is well known that large bird species in Central Europe threatened with local extinction occupy relatively unbroken, extensive and ecologically intact habitats. The presence of such birds as White-tailed Sea Eagle *Haliaeetus albicilla*, Lesser Spotted Eagle *Aquila pomarina* and Black Stork *Ciconia nigra* is usually an indication of the high ecological value of a region.

Study of the home range size and habitat use (space and time structure) of the Lesser Spotted Eagle (LSE) was carried out within the framework of the following:

1. Determination of the home range and space and time use of territory of selected LSE s in various types of countryside in the state of Mecklenburg-West Pomerania (MWP) in north-eastern Germany.
2. Analysis of characteristics and choice of feeding grounds taking account of countryside utilization.
3. Recording of features that break up the countryside and their relevance to choice of nest site and use of feeding grounds.
4. Comparative studies in a test area in Latvia (core area of the LSE in Europe).
5. Identification of necessary protection measures for the species in the North German Plain.

METHODOLOGY AND PERIOD OF THE STUDY

VHF radio telemetry was used to track the adult birds selected for the study, with the emphasis on the male eagle, as he has the task of providing food for the brooding female and subsequent offspring. In the three-year period 1994-1997 transmitters were fitted to seven male birds and one female in MWP and, for comparison purposes, four males and one female in Latvia. Two males, one each in MWP and Latvia, were fitted with long life transmitters in two subsequent years. The birds were trapped after successful egg laying at the

beginning of May using the Dho-gaza method. The range of the transmitters lay between 5 and 25km dependent on terrain and flight height. The following detailed data were recorded: date, time, location, direction, activity (based on different signals), type of terrain visited, disturbances and interactions, changes in land usage (mowing, harvest etc.) and climatic conditions. The observers, in MWP always a pair due to more extensive LSE territories, relied on a combination of transmitter signals and visual sightings over an unbroken 8-10 hour daylight period once weekly for each bird.

A habitat type and usage analysis within 7.5km of the nest site (3km in Latvia) was carried out by specialists, or by reference to detailed topographic material provided by relevant institutes. The telemetry data were collated and evaluated by computer.

STUDY AREAS

Over 80% of the German LSE breeding population currently occupy territories in MWP in an area of some 6,549 km with a breeding density of 1.77 BP/100km_. The density is not regular and there are four more or less isolated centres of distribution. In these areas the distance between nest sites does not usually exceed 6km and therefore many territories overlap and contact between neighbouring pairs is common. This contact appears to have a social component within a population. The western border of the LSE's normal European range, unchanged since at least the end of the 1960s, runs through the centre of the state of Mecklenburg-West Pomerania.

In Latvia the LSE has a wide distribution throughout the country. Population density varies according to forest type, with a higher density in deciduous and mixed woodland with rich soil. Nests are built in forests of differing sizes over 5.8ha and are usually located within 150 m of the forest edge. A not inconsiderable number of birds nest in the middle of extensive forests. Hunting habitats are as a rule different types of farmland; although those birds which nest deep inside the forest also hunt in rides, tracks and clearings. The LSE avoids larger human settlements but is not disturbed by isolated farms and often breeds within 100–300 m of the latter (and also frequently tracks between villages), hunting on the periphery in old orchards.

RESULTS AND DISCUSSION

Detailed results for individual birds

Descriptions of the precise areas where the study took place, and the results of the evaluations of home range and hunting habitat use of individual birds in both countries, are recorded in great detail in the full German version of this paper, which also contains a full bibliography.

Home range size, distance from nest site and time and space utilization

The values given in the previously available literature on the home range size of the LSE are almost all considerably smaller than those recorded in this study.

Earlier studies (Siewert 1932; Golodushko 1959) that recorded hunting ground size varied from 1km_ to 2-4km_. Gedeon & Stubbe (1991) recorded

territories between 3.2 and 5.2 km_ (mean 3.9 km_) in a study of six breeding pairs. The territory was restricted, however, to the area where regular flight or hunting activity was observed. Abuladze (1966) recorded hunting grounds in Georgia up to 1.5km from the nest. Matthes & Neubauer (1987) observed in MWP that the hunting ground rarely exceeded more than 1km radius from the nest. Zebe (1942), in the Bartsch river lowlands in Silesia, observed LSE hunting in a radius of 2km from the nest. It should be mentioned here that in all cases of eagles studied the hunting and nest territories overlapped, i.e. the bird also hunted directly in the immediate area of the nest. Wendland (1951) confirmed this. Wendland (1959) later stated that the hunting ground can be quite small when the area immediately around the nest site has a rich food supply; and further observed that the birds sometimes fly up to 3km to hunt in fields full of mice. The resulting theoretic home range of 28km_ comes very close to the results of this study, which recorded home range coverage of 21.0–33.9km.

Of interest is the conclusion of Schroot's (1938) study of a LSE pair in the Gnoien (MWP) area, which is still occupied today and was included in this study. In an area easy to observe, where the eagle principally hunted over pasture and meadows but also in woods and cultivated farmland, total home range coverage of approx. 25km_ was estimated. The telemetry study of the male bird in 1994 gave a home range of 22.6km_. The conclusion is that the habitat use here has hardly changed over the years. Of note is that the 1938 study, which like all previously mentioned studies was based solely on visual observations, is the only one where the habitat size is comparable to the results gained using telemetry.

Meyburg (1991) was the first to suggest that LSE territories are probably larger than previously supposed, the author having regularly observed birds hunting up to 4–5km from the nest. He suggested that this distance could be greater; but this could not be established by visual observation alone. His hypothesis is validated by the results of this study, which also served to confirm his experience that the home ranges of pairs from neighbouring territories overlap in most cases, and that a relatively low degree of intra-specific aggressiveness results.

This study, using continuous 8–10 hours observation supported by telemetry, confirms that the true extent of the home range can be achieved only exceptionally by visual observation and under ideal terrain conditions. During the project the eagles could often be traced only via the transmitter signal. They left the nest repeatedly from the opposite side of the woodland to the observer, flying low over meadows and fields for over 1km before soaring to great heights. They returned, or changed direction, sometimes at heights of more than 1000m without coming into sight even briefly. Tracking them was only possible by directional signals and the use of a scope with 25 X or greater magnification. It can be assumed therefore that previous estimates of home range size, based on visual observations only, are as a rule too conservative. This is applicable particularly to the results of Matthes & Neubauer (1987) and Gedeon & Stubbe (1991) based on knowledge of territories and studies carried out in MWP.

The home range of 2–4km, calculated by Golodushko (1959) for territories in the Bialowieza primeval forest, are somewhat similar to the smallest (6.7km) recorded in the study in Latvia. Nevertheless it can be assumed that even in the optimal territories of the Bialowieza a greater home range would have been recorded using telemetry equipment.

As far as the furthest distance flown from the nest is concerned, figures vary between 1.5 km (Abuladze 1996), 2.4km (Golodushko 1959), 3km (Gedeon & Stubbe 1991), 3.55km (Stubbe *et al.* 1991), 4km (Wendland 1932) and 5km (Meyburg 1991). In this study the maximum distance from the nest for the male eagle lay between 4.17 and 15.98km, flown by an unsuccessful breeding male. The furthest distance for a male with young to feed was 10.08km. All maximum flights recorded by telemetry could not have been measured visually, so that previous literature references above must be treated with caution. Only Meyburg (1991) suspected that eagles visited hunting grounds more than 4–5km from the nest.

In Latvia the maximum hunting distance for successful male breeders lay between 2.08–3.54km and for unsuccessful male breeders 2.86–4.84km.

Biotopes and habitat used for hunting

There are many references in the relevant literature to the preferred type of hunting ground. The majority of lowland observations cite grassland as the most favoured. Wendland (1951), in his study on the behaviour of two breeding pairs, reported that they hunted only on meadows in the vicinity of the nest. Baumgart (1980) and Siewert (1932) limited the typical hunting grounds to meadows and ditch edges. Matthes & Neubauer (1977) and Wendland (1959) claimed that the LSEs hunted primarily over permanent grassland but occasionally over tillage. Eagles in the Save water meadows in Croatia were recorded more often over grassland than tillage. The flood meadows were however avoided (Schneider-Jacobi 1996). Observations in a former breeding territory by Rochlitzer (1969) in the mid-Elbe region of Saxony-Anhalt recorded that tillage was hunted over only after the harvest had begun. Only Gedeon & Stubbe (1991) reported a breeding pair in MWP which hunted over cereal crops and a silage field more intensively than over permanent grassland, although the latter was to be found in the vicinity of the nest. Their report discussed the changes in grassland due to drainage measures and the resultant qualitative degradation as a food source. They also observed that the small mammal density was greater on the more frequently hunted over tillage than on grassland.

In terms of the proportional size of grassland and tillage, the eagles in MWP in the present study, with one exception, spent a more than average amount of time hunting over grassland; but almost all birds spent a greater percentage of their hunting time over tillage (corresponding to its greater proportion of the whole area) than over grassland. The difference was particularly marked in the territories with a smaller proportion of grassland. Only one eagle spent more time hunting over grassland than over tillage. This was in the Schlutow territory where the pair studied by Schroot (1938), besides hunting over tillage and in the forest, spent the majority of hunting time over permanent grassland.

In the territories in Latvia grassland was used over-proportionally in relation to its area size and the percentage of hunting time also exceeded time spent over tillage (corresponding to the greater grassland area).

The fact that the eagle hunts in forest biotopes as well as in the open countryside is well documented in the relevant literature on the North German and Polish Plain (former East Prussia) (Siewert 1932; Schroot 1938; Wendland 1959; Ruthenberg 1965; Matthes & Neubauer 1977; Neubauer 1987). In this study, hunting within the forests was observed primarily over marshes and bogs, but also in rides and logged clearings. In Latvia hunting was recorded principally in the latter two areas.

The importance of the forest as a continuous food resource was pointed out by Gedeon & Stubbe (1991). The present study confirms this. Woodland is particularly important as a hunting ground in adverse climatic conditions (rain, extreme heat and storm) and in the early morning before the development of thermals. In terms of habitat management the forest must therefore be allocated equal significance (e.g. structure, curtailment of drainage measures and conservation of small mammals) as grassland.

Hunting ground preference is dependent on the nature of the available land and the associated food sources and densities. Meyburg (1991) also pointed out the relevance of variations in the different distribution ranges of the LSE, a finding confirmed by this study. Variations are found not only in hunting habitat but also in preferred prey. In Greece reptiles (especially the European Grass Snake *Natrix natrix*) are at the top of the menu (Vlachos & Papageorghiou 1996) but are replaced by small mammals in Central and Eastern Europe (Scheller & Meyburg 1995; Haraszthy *et al.* 1996; Bergmanis *et al.* 1999).

The literature contains few references to preferences for particular forms of tillage or managed grassland. A male observed by Gedeon & Stubbe (1991) in MWP was observed mostly on silage and cereal crops. In the Hakel (Saxony-Anhalt) the authors established that fields of root crops and maize were less frequented than cereal crops. The latter also play a greater role as food source in Hungary than other tillage. In this study a preference in MWP for cereal crops, hunted over throughout the breeding season, was also established. Root crops and maize played a minor role and rapeseed was hunted over only after mowing. Set-aside tillage was regularly and extensively hunted over throughout the breeding season.

In Latvia a clear preference was also shown for cereal crops, with root crops again playing a minor role. Set-aside and rough grazing land played a major role for all eagles observed in the study. Mundt & Uhlig (1992, 1996) and Stubbe *et al.* (1996) also confirm the importance of silage as a food source, especially when freshly mown. The preference for freshly mown and tilled areas observed during the present study was also recorded by Rochlitzer (1969), Palásthy & Meyburg (1973) and Mundt & Uhlig (1992, 1996).

This study also confirmed the general view that the LSE does not hunt over open water (Glutz von Blotzheim *et al.* 1989; Brown & Amadon 1989; Meyburg 1994). Birds were observed hunting on foot and from a perch at dew or field ponds (common in north-east Germany), in reed beds and on the edge

of ditches. Here the eagles hunted on foot, even in dense stands of reeds. According to Cramp & Simmons (1980) the eagle hunts on foot only in short vegetation. Hunting at field ponds, often observed in MWP, is not recorded in the literature. Searching for food at ditch edges, boggy areas, water meadows and stream valleys is mentioned however (i.e. Siewert 1932; Wendland 1959; Baumgart 1980; Neubauer 1987; Haraszthy *et al.* 1996).

Matthes & Neubauer (1987) established that the LSE is very sensitive to changes in habitat characteristics caused by intensive or changed land use. The breeding process was always disrupted when affected by wide-scale arterial drainage. They blamed the critical disruption of the species on the drastic decline in prey density on dry meadows; and Neubauer (1991) cited the increasing resettlement within the population as the consequence of habitat impairment.

Meyburg (1991) believed, however, that the eagle was quite insensitive to habitat changes and contraction. He based his opinion on the decline of the species in Germany at the beginning of the 20th century, when the main causes were shooting and egg theft, and habitat change and settlement and fragmentation of the open countryside only began gradually. In fact the LSE, not least because of its mastery of different hunting methods, is very flexible in terms of food source. Changes in its food spectrum caused, for example, by habitat change, can be compensated for to a degree. The precondition is, however, that with a decline in one form of prey, another is available in sufficient density (cf. Wendland 1932; Zebe 1942; Haraszthy *et al.* 1996). Examples from MWP confirm this. According to Scheller *et al.* (2000) the LSE abandoned its breeding areas in the Peene estuary following wide-scale drainage of the low-lying wet grasslands, whilst during the simultaneous drainage of the grassland in the Trebel and Recknitz valleys the breeding pairs here stabilised. In the Peene estuary only grassland was available in acceptable proximity as a substitute hunting ground. In Trebel and Recknitz structurally rich ground moraine plates with tillage were available, which adequately compensated for the loss of grassland. After a number of years of drainage, the mineralization of the peat bog here altered the surface soil structure so that small mammal density noticeably increased and the dominant food source shifted from the once abundantly available amphibians to small mammals. This process also took place in the wet grasslands of the Peene estuary. Over a longer time scale, the eagle was unable, however, to compensate for the initial loss of its food source by changing to other suitable areas and prey.

The countryside restructuring since 1989 in the new federal states (former GDR), which comprise the German distribution range of the LSE, has had a negative effect. The drastic reduction in cattle stocks reduced the requirement for fodder and thus areas of silage. At the same time permanent grassland is being abandoned. The planting of rapeseed is increasing (Stubbe *et al.* 1996). As the study shows, the availability of silage, with its abundance and good accessibility of small mammals, is of great importance where there is little fresh and wet grassland in the vicinity of the nest. Rapeseed areas are unsuitable as a hunting ground. The succession of abandoned permanent grassland does not compensate adequately for the loss of well-used meadows

and pasture. When abandoned, these develop mostly into cabbage thistle *Cirsium oleraceum* wasteland or, due to the profusion of nutrients, to nitrophilous shrub zones. With increasing age and vegetation height, prey becomes increasingly more difficult to find. The declining proportion of grassland and silage in the eagle's potential hunting grounds leads to loss of important feeding areas.

The negative consequences of the loss of grassland were pointed out by Matthes & Neubauer (1977). Volke (1966) accredited the reduction in semi-natural grassland as a possible reason for the decline of the LSE population in Estonia. The threat to hunting habitats through contemporary changes in agricultural methods (intensive farming) is also considered critical for the size of the population in Poland.

Hunting methods and prey

Information on the proportional frequency of the discrete behaviour forms of the LSE is not available in the literature examined. References to the ratio of different hunting methods are however available. In older studies on wet and well-wooded breeding areas in former East Prussia and Brandenburg (Siewert 1932; Wendland 1959), where the eagle hunted almost exclusively on wet meadows and in forest bogs, ground hunting is highlighted as the most common method. In this study the ground hunt in MWP was preferred in only two cases; for the remainder hunting in flight dominated. In Latvia all eagles clearly favoured hunting from a perch. In areas with high prey density, ground and perch hunting were preferred; in areas with lower prey density hunting in flight was more frequent. This is supported by Meyburg (1970), who observed that hunting in flight was the main method used in the dry mountain regions of East Slovakia. On the other hand Mundt & Uhlig (1996) observed that at a gathering of 50–70 birds during the breeding season on freshly mown silage in Welsebruch (Brandenburg), with an abundance of small mammals, ground or perch hunting was preferred and hunting on the wing was infrequent.

Gedeon & Stubbe (1991) recorded more precise figures on the frequency of different hunting methods in studies of four pairs of eagles in MWP and two pairs in the Hakel (Saxony-Anhalt). They investigated the number of hunting instances initiated by visual contact with the prey. In this study however, the time expended on the individual hunting form, hunting duration, was calculated. Differing hunting methods dominate depending on the time of year (vegetation height) and habitat structure. In breeding territories in the wide-ranging tillage areas in the Hakel in June and July, the brood and nestling period, flight hunting (78.6%) dominated. In August, during the post-fledging period, the ground hunt (46.4%) in stubble fields was preferred. The proportion of perch hunting rose from 14.5% in June and July to 35.7% in August. These figures, with a small percentage variation, are confirmed by results for the present study in the Ballin and Hochkamp areas, which have a high proportion of tillage and little grassland. In the predominantly grassland areas in MWP, Gedeon & Stubbe (1991) recorded figures for July and August of 69.5% for the perch hunt compared with flight hunting (19.6%) and ground hunt (9.8%). These latter figures cannot in any way be confirmed by the present study. The

eagles observed by Gedeon & Stubbe (1991) probably also used flight and ground hunting methods more regularly. As, however, birds hunting in flight and on the ground are often not seen when they are in dead ground, observations unsupported by telemetry can be misleading. In addition, the use of telemetry and the longer periods of observation of the present study enabled considerably more instances of hunting behaviour to be recorded than in the 1991 study.

The frequent hovering flight observed by Gedeon & Stubbe (1991) and also (although less often) by Siewert (1932) and Matthes & Neubauer (1977), was not recorded for any of the eagles in this study in either MWP or Latvia.

Hunting in the branches of trees, also recorded by Gedeon & Stubbe (1991), where the eagle crashes into the branches from a height, can however be confirmed. This hunting method is also known from the eagle's wintering areas in Africa. In this way the LSE takes the chicks from the colonies of the Red-billed Quelea *Quelea quelea* (Meyburg 1994).

Only Grimm & Nammert (1978) and Wendland (1934, 1959) mention occasional prey parasitism of the LSE. The birds observed during the study in the Ballin, Hochkamp, Gross Niekoehr and Grieve areas also showed such behaviour, partly with the Common Buzzard *Buteo buteo* and partly with the Red Kite *Milvus milvus*.

Wendland (1959) and Brown & Amadon (1968) also mentioned that the eagles occasionally take carrion, which was observed in Gross Niekoehr and in the Trebel valley.

The prey listed in the literature (Siewert 1932; Wendland 1959; Meyburg 1970; Palásthy & Meyburg 1973; Scheller & Meyburg 1996): small mammals, smaller birds, reptiles, amphibians and insects, also played a major role in the food taken by the eagles observed in this study. In almost all areas the main item of prey was the Common Vole *Microtus arvalis*.

Disturbance factors and countryside fragmentation

To date there has been little discussion on the effect of disturbance factors and countryside fragmentation on the hunting and habitat behaviour of the LSE. Wendland (1959) reported that a pair bred not further than 600m from the edge of a settlement and that a pair in woodland north of Berlin, despite massive disruption of the forest structure, drainage of the water meadows and the construction of an airfield in the favourite hunting ground, did not abandon its breeding territory. The observations covered only a short period however and the territory was later abandoned. In other Brandenburg breeding areas in which Wendland in his time monitored up to 16 LSE pairs, the population is today almost extinct (Scheller & Meyburg 2000). As Neubauer (1991) and C. Scharnweber (pers. comm.) observed, the eagle seldom leaves its breeding territory abruptly as a result of continuous disturbance or habitat change in its hunting grounds. Abandonment of a breeding territory is a process that takes several years and is signalled by unsuccessful breeding and frequent change of nest site. The spontaneous abandonment of a breeding site by a breeding pair near Stavenhagen (Mecklenburg-West Pomerania) was monitored by Scheller in 1996. Only 50m distant from a brooding female eagle a farmer practised

clay pigeon shooting. The pair abandoned the nest site and was not observed at this location again during the breeding season. In 1998 a new nest site was occupied some 4km distant by probably the same pair. In 2000 the old nest site was reoccupied.

There are frequent references in the literature to disturbance in woodland breeding sites by forestry work, as observed during this study in Klein Markow and Hochkamp. Abandonment of old breeding territories as a result of tree clearance, logging or removal of old tree stands is reported by Wendland (1932, 1934), von Dobay (1934), Zebe (1941), Gentz (1975), Matthes & Neubauer (1977), Svehlik & Meyburg (1979), Stubbe & Matthes (1981), Fischer (1983), Neubauer (1987) and Bauer & Berthold (1996). Protection of the immediate nest area, and the preservation of the woodland structure suitable for nest site selection, are therefore of great importance.

Tarred roads intersecting the woodland breeding areas also create recurrent disturbance factors, both from forestry traffic and walkers. Kostrzewa (1988) confirmed that Common Buzzard, Honey Buzzard *Pernis apivorus* and Goshawk *Accipiter gentilis* were affected. Wendland (1932), Meyburg (1973), Svehlik & Meyburg (1979) and Haraszthy *et al.* (1996) mention disturbance of the LSE by birdwatchers, photographers, falconers or other intruders into the woodland. This list does not include disturbances caused by shooting, and theft of eggs or chicks in the breeding areas, which were the main causes of the grave population decline up to the start of the 20th century (Bijleveld 1974; Scheller & Meyburg 1995). Losses due to such disturbance factors in Germany have become very uncommon since the eagle was declared a protected bird in the 1920s. Instead, as a result of the increased volume of leisure and recreational activity, new factors have emerged in the eagle's breeding and hunting territories (e.g. model aircraft flying in the Hochkamp area). The increasing pressure on all raptors from recreational activity is pointed out by Biljefeld (1974), Newton (1979), Bauer & Thielcke (1982), Brüll (1982), Hauff (1996), Stubbe *et al.* (1996), Köhler (1996) and Bauer & Berthold (1996). Such disturbance factors have an additional secondary effect, in that they work to the advantage of less sensitive predators. For example, if the female is disturbed and leaves the nest the chicks become easy prey to the Goshawk or Raven *Corvus corax*.

There are few references to disturbance by different types of aircraft or helicopters. Gentz (1965) established that the breeding female was insensitive to over-flying jets. We were able to demonstrate, by means of a remote-controlled video camera, that the female certainly noticed the aircraft, ducked her head and tried to establish visual contact (Scheller & Meyburg 1996). Mikiara (1990) reported the case of an eagle that attacked a glider by which it felt threatened.

Other raptors react sensitively to aircraft. Schubert (1957) tells of a Golden Eagle *Aquila chrysaetos*, which injured itself in an attack on a military aircraft at a height of 300m over Finland in 1942. The author reports an aerial encounter where a Common Buzzard attacked a glider. As a rule, though, raptors take evasive action when aircraft approach them, as observed by us in the case of migrating Black Kites *Milvus migrans* over Israel. Hauff (1996)

considers planes and helicopters to be disturbance factors for the White-tailed Sea Eagle.

Large-scale human settlement was established as a significant disturbance factor in both MWP and Latvia. In many cases eagles would not even overfly them. Telemetry studies of the Bald Eagle *Haliaeetus leucocephalus* by Buehler *et al.* (1991a, b) and Fraser *et al.* (1996) showed that these birds also avoided built-up areas or areas with human activity. The former doubt whether eagles can adjust at all to human presence; as a result areas used by man are then irreversibly lost as Bald Eagle habitats. LSE breeding close to farms and small villages, as observed in Lithuania by Drobelis (1996), was also recorded in Latvia. where it must, however, be pointed out that, in comparison with German breeding territories, farming is more intensive and the human population density is very low. In the study areas in Latvia the population density over a wide area was only 4–8 per sq.km. The majority of people present in the countryside are involved in farming activity and the number of leisure-seekers is negligible compared with Germany. This is the main reason why hamlets and farms represent relatively minor disturbance factors for the eagles.

In the German breeding areas a broad corridor of disturbance around human settlements must be reckoned with. A greater volume of leisure activity and use of the surrounding countryside for recreation is the result. In addition the countryside is utilized more intensively, based on the settlements, with humans the dominant presence in their immediate vicinity.

In this context it must be mentioned that the opinion is often held that the LSE is no more sensitive than the Common Buzzard to cultural influences (Wendland 1958; Meyburg 1970, 1971). The authors based their findings on an equally intensively utilized countryside but a relatively low disturbance potential (particularly recreational activity). These findings are still valid in Latvia, but no longer applicable to the now more intensively utilized German countryside, including the breeding territories of the LSE. Whereas the Common Buzzard has shown itself adaptable and now also breeds on the outskirts of large settlements and even in parks, the LSE can still only be found breeding, and as a rule hunting, in manifestly disturbance-free areas. This does not however preclude the occasional use of high density and easily accessible feeding grounds in the vicinity of busy main roads and the edges of small villages and isolated farms. Langgemach & Sömmer (1996) highlight the fact that breeding territories in Brandenburg are only to be found in districts with a low human population density of 14-35 per sq.km and only exceptionally of 75 per sq.km.. Typically, habitats not fragmented by roads, motorways or large overhead power lines, are preferred.

Although the Common Buzzard to some extent uses highly fragmented countryside with a high proportion of human settlements and many barriers, its tolerance has limits. In the Wolfsburg district the breeding population declined by 73% from 1946 to 1971 due to increasing urbanisation, and the raptor spectrum was reduced from eight to only two species in the same period (Latzel 1972). Nowadays the Common Buzzard, but never the LSE, can be found breeding in greatly fragmented and densely populated countryside. The

flight distances of the buzzard and the eagle in the German countryside also differ greatly. For the eagle, a flight distance of 150–350m from clearly visible humans in open country has been established. From personal experience it is only 40–100m for the buzzard. Graetz (1994) established values of 30m and 150m. There are therefore very clear differences in the sensitivity of the Common Buzzard and the LSE to disturbance in the heavily utilized countryside.

According to Bauer & Thielcke (1982) habitat destruction is the main threat factor for 12 species of raptor in Germany. Particularly threatening is disturbance through the increasing pressure of leisure and recreation activities. Intensive forestry, farming and water management measures also lead to habitat loss. These factors also present a concrete threat to the survival of the LSE (Bauer & Berthold 1996). Kostrzewa (1988) and Kostrzewa & Speer (1995) also see habitat destruction, including all forms of urbanization, as the main threat factor for raptors. The authors point to the decline in prey species, which inevitably leads to a decline in predators.

Haas (1980) and others refer to the threat to raptors from the increasing construction of overhead power lines in the countryside. This study confirms that the power lines and their steel grid masts present a definite disturbance factor for the LSE in both Latvia and MWP.

The increasing number of wind farms can also have a negative effect on the breeding territory of the eagles. Scheller (1999) not only highlights the direct scare effect that the wind turbines create, leading to permanent loss of feeding grounds; but also warns of the danger of a more widespread alienating effect for the habitat. The decrease in food supply due to loss of hunting grounds, and resettlement as a result of habitat alienation, can lead to destabilization of complete part-populations of the LSE in MWP.

CONCLUSIONS ON NATURE PROTECTION

Home range and distance from nest site

Analysis of the home range of individual eagles takes into account spatial as well as temporal components. For the eagles in MWP, an average radius of 3km from the nest site represented only 78% of the home range, which extended much further. It has been shown earlier that the eagles undertake occasional long-range flights in excess of 3km during the breeding season, leading to an extension of the home range. A study of the time budget makes clear, however, that on average 96% of the eagle's total activity takes place within the 3km radius.

The main prey requirement for these eagles is met within a radius of 3km from the nest, so that this area must be allocated particular emphasis when determining habitat protection measures. These findings were taken up and included in the EU Commission's action plan for preservation of the LSE as the appropriate distance for nest site protection measures (Meyburg *et al*. 2001).

Land area usage and habitat characteristics

In both MWP and Latvia the open countryside was the main hunting ground. In the former this was wet grassland (on lowland bogs), in the latter

particularly grassland on non-porous mineral land. The aim should be therefore to conserve grassland areas within a minimum radius of 3km from the nest. They should be as intensively managed as possible in order to ensure a high prey density and a continuous food source throughout the breeding season.

In territories with a small proportion of grassland, set-aside tillage, cereal fields and silage are increasingly hunted over. In addition the eagles hunt near dew or field ponds and in marshy woodland. Those eagles in territories with a high proportion of grassland also hunt extensively in the latter areas. As woodland, in particular woodland marshes, are hunted in throughout the breeding season, it can be concluded that continuous food resources are available here which can be more intensively exploited when adverse climatic conditions or natural disasters preclude hunting in the open countryside. The conservation of these woodland resources is therefore an important contribution to the eagle's protection. The woodland marshes in particular must be preserved or re-naturalised in order to increase the food supply. The elimination of small mammals (e.g. by setting out of poisoned bait) must be banned in a radius of 3km from the nest site in woodland. On the one hand an important food source would otherwise be destroyed; on the other the risk of eagles being contaminated by consumption of the poisoned mammals will be reduced.

Of arable land, fields with a high density of small mammals and easily accessibility (low vegetation height) were preferred. These were principally cereal crops and silage as well as set-aside. High and densely growing crops such as rapeseed, maize and hemp were unsuitable for hunting during the vegetation phase. Root crops played a minor role due to low prey density. Independent of the type of crop, unmanaged verges and untilled edges, and dew or field ponds amongst the tillage, provided a food source throughout the breeding season. The preservation of a diverse arable land structure, and unmanaged verges, is therefore very important. Wide-scale planting of non-exploitable crops (rapeseed, hemp and maize) in breeding territories with a small proportion of grassland can lead to food shortages for the eagles. It should be considered whether agricultural subsidies should be introduced in order to promote the planting of suitable crops or the provision of set-aside areas.

Hunting behaviour

In Latvia the eagle prefers perch hunting when prey density is high. The large numbers of solitary trees in the Latvian countryside enable the eagles to use this hunting method within the open fields and not only from the woodland edge. This is only possible in few locations in MWP as, even when prey density is high, solitary trees are few and far between. Planting of single or small groups of trees would be of great benefit for the eagle. It should be possible to integrate this into the forthcoming new land area distribution plan.

Disturbance factors and countryside fragmentation

Human disturbances and countryside fragmentation lead to habitat contraction that sooner or later can result in the abandonment of breeding territories. There are several factors to be considered here, which in

combination can aggravate habitat loss. The following land usage measures can prove particularly grave and persistent:

An increase in route density, usually combined with an increase of vehicles per capita, leads to a reduction in prey density (road deaths, isolation effect etc.,) and an increase in disturbance in the breeding and hunting grounds. Direct disturbance caused by roads is a complex phenomenon; but above all an increase in different emissions can be expected (exhaust fumes, soot, dust, noise – c.f. Ellenberg 1981).

Noise in particular can have a severe effect on bird habitats. The tolerance level on busy roads, at which impairment for breeding populations begins, has been experimentally calculated. The values were around 40-60 db for meadow and 30-60 db for woodland birds (Maczey & Boye 1995). Dependent on the surface material this can mean that woodland habitats up to 300m from the road, and open countryside habitats 1000m distant are affected!

In addition to emissions, moving vehicles add a visual disturbance component. More seriously, however, following infrastructural improvement, are the development of previously undisturbed countryside and the increase presence in and recreational use of these areas.

The construction of wind turbines and wind farms in the eagle's hunting grounds can lead to permanent loss of feeding areas. It is feared that the wide-scale habitat alienation effect caused can lead to abandonment of breeding sites, combined with resettlement and destabilization of sub-populations (Scheller 1999)

The increase in intensive farming since 1990, particularly on arable land, leads to a reduction of biotope variety (loss of dew and field ponds, field edges and verges etc.,) and initially straightforward mechanical destruction of animal prey refuges (i.e. Basedow 1987; George 1995). This is intensified by the use of large amounts of increasingly more efficient herbicides that lead to a reduction in species density and variety (Basedow 1989). Changed forms of soil working, particularly deeper ploughing and more frequent tillage lead to a collapse of small mammal populations on arable land (Thormeyer 1978; George 1995). It can be expected that the comprehensively cited reasons for the decline of the Field Hamster *Cricetus cricetus* (e.g. Backbier 1998; Backbier *et al*. 1998; Seluga 1998) will also affect the LSE's main prey, the Common Vole. In particular the following changes in arable land working can lead to a tangible reduction in vole density:

- faster harvesting followed by immediate ploughing,
- contraction of crop cycles and reduction of crop variety (George 1995 refers in particular to the decline in fodder crops)
- use of slurry,
- working of verges and narrowing of field edges, and
- increased use of herbicides.

Since 1990 a number of animal groups with skin respiration (e.g. amphibians) are affected by the increased use of fertilisers (esp. nitrates – Schneeweiss & Schneeweiss 1999) and biocides (c.f. also Blab 1986).

Continuing use and possible further intensification of such methods will increase food shortages. These will be most marked in territories where, due to

the low proportion of grassland, substitute feeding areas are not available. It is therefore essential to conserve all elements of biotope structure in hunting areas, at the same time promoting extensive worked-over or set-aside areas which, in the areas under study, were increasingly used by the eagles. In addition a monitoring of the availability of biotopes on farmland is recommended.

Increase in tourism. The traditional concentrations of tourism in MWP are in its lake district and on the Baltic coast. The LSE does not breed in either of these areas now, or apparently not in significant numbers in the past (Wüstenei 1902). The increase in tourism in MWP in the past few years did not affect the breeding areas. So-called "soft tourism" is now being actively promoted for these comparatively less attractive tourist areas by infrastructural development of large areas of the mainly open countryside for hiking, cycling and horse riding. This form of tourism is a big problem in the breeding areas as it leads to a wide dispersion of visible humans in open spaces, which is the worst imaginable form of disturbance for the birds. Hikers, cyclists and riders are therefore among the most serious disturbance factors, and an uncontrolled tourist use of the countryside can lead to marked contraction of the hunting grounds. It is therefore absolutely essential that future tourist planning channels visitor flow in order to prevent an unacceptable frequency of human presence in the hunting and breeding areas of the LSE (and of other sensitive species)

Intensification of forestry management and hunting. The study showed clearly that woodland, especially around the nest site, plays an important role as a food source. The woodland marshes in the interior and the irregular forest edges are particularly important. The conservation or re-naturalisation of woodland marshes is therefore an important factor in securing the eagles' food resources. Equal attention must also be paid to the retention of irregular forest edges, as the transition zone from woodland to open countryside is one of the richest food source biotopes and is used intensively by eagles in both Latvia and MWP. According to Hampicke *et al.* 1991, the length of forest edge in the former West Germany decreased continuously in length and suffered a corresponding decline in its ecological value due to straightening. As a large number of eagles breed in forests which are privately owned, or which will be privatised in the near future, a tendency towards the methods of forestry management used in West Germany can be expected. As well as the loss of large extents of forest edge due to planned straightening measures, the pressure of market forces is already leading to the exploitation of stands of certain types of old timber. In one year the demand was for oak, which was logged to extinction in one forest area, two years later it was the turn of old birches. This inevitably leads to over-exploitation of older trees and an impoverishment of forest stock. As the eagle prefers large coherent stands of older trees for its nest site, intensive forestry management leads to the loss of breeding sites as well as woodland edges as rich food sources. This has caused increased competition between individual raptor species, and the equally demanding Raven, for nest sites.

A further threat is the general tendency in forestry management to improve supposedly the quality of the forest floor by drainage of woodland marshes. This leads to a decrease in moor frog density; one of the most important food

sources in the woodland interior.where, in addition to the moor frog, the eagle also hunts small mammals. The practice of setting out poison bait for the extermination of small mammals, leading to the accumulation of the poison in the food chain, must be prohibited despite claims that it is harmless. On the one hand the impending loss of hunting grounds in the open countryside makes it all the more important to conserve other hunting areas; on the other, an adverse effect on the eagles through consumption of poisoned mice cannot be ruled out.

The picture would not be complete without a mention of the extreme disturbance which hunting has on the birds. The spontaneous abandonment of a brood and nest site as a result of shooting in the immediate vicinity was described above. As the eagles are hunted, above all in the Mediterranean area during the spring and autumn migration (Baumgart 1991a, b, 1995; Meyburg *et al.* 1993, 1995), it is unlikely that they will adapt to hunting or other shooting activities in their breeding areas.

In summary the requirements for management of the current and potential woodland breeding areas of the eagle (c.f. Langemach *et al.* 2001; Scheller *et al.* 2001) are:

- preservation of the largest possible unbroken stands of old trees,
- preservation and promotion of a highly diverse woodland structure, where a variety of tree species, a phased age structure and a high degree of vertical and horizontal coverage is available,
- preservation of an irregular and extensive woodland edge
- preservation or re-naturalisation of woodland marshes and bogs,
- a ban on hunting in woodland breeding areas during the breeding and nestling periods and
- refraining from small mammal extermination in woodland used for breeding.

RECOMMENDATIONS FOR PROTECTION OF THE LSE IN GERMANY

The following three main areas of habitat protection derive from the size and characteristics of the habitat required by the eagle and the known causes for the abandonment of breeding sites:

1. Protection from direct and indirect human disturbance

The breeding site concentrations must be preserved as large-scale unbroken countryside so that disturbance factors of any kind can be restricted to the margins. If an unfragmented area of sufficient size is secured, buffer zones are created preventing any disturbance of the eagles' breeding territories. It is essential that only a limited degree of infrastructural development be permitted in these zones. Above all clear guidelines on permitted traffic density must be laid down for the development of the road network.

Tourism, which is being developed as an important economic factor in MWP, must be so channelled that it develops outside the breeding area concentrations. Within these areas appropriate restrictions are necessary. For example, activities linked with tourist facilities must not affect the eagle's main hunting ground within a 3km radius of the nest.

Within a minimum radius of 3km from the nest site no new settlements (housing and industrial estates or factories of any kind) should be permitted. In addition the construction of technical facilities that significantly change the normal character of the habitat, i.e. wind turbines, should be banned within this zone.

These guidelines should be anchored in agreed and compulsory procedures at the highest planning level.

2. Security of the food base and food accessibility

The food potential in the open countryside can be guaranteed in the long term by a calculated use or redistribution of the already available EU funds for agricultural improvement. Subsidies already in place for extensive use of permanent grassland in lowland bog areas in MWP, in accordance with nature protection requirements, should be continued and specifically applied in the breeding territory concentrations. In future however the raising of the water table must be made a precondition.

In the scope of farming subsidies on arable land the present practice within breeding area concentrations, in particular for tillage comprising the main hunting ground, should be modified (e.g. the percentage of set-aside, which is very important as a food source, should be increased). Under no circumstances should the wide scale planting of crops that are unusable for the eagles, such as rapeseed, maize, hemp (currently planned) or root crops (sugar beet and potatoes) be permitted in these areas.

Intensive planting of non-usable crops on the wide-ranging arable land in MWP could lead to the loss of extensive feeding areas that can affect significantly the reproduction success. The dominance of non-usable crops in the main hunting grounds must be reduced using available subsidy instruments.

The eagle's mastery of a wide range of hunting methods permits its use of a broad spectrum of biotopes within its hunting grounds. At different times these biotopes supply a different range of prey and provide refuge and breeding sites for prey occurring on tillage and grassland. These important biotopes are primarily those close to the water table such as moor, woodland marsh, reed beds, dew and field ponds, open ditches and boggy areas on arable land. In addition hedges, tree lines, solitary trees, bushes and unmaintained tracks and field verges are important. All current eagle habitats are relatively well structured in this way. A number of these biotopes receive general protection under federal (BNatSchG § 20 c) and state (LNat-SchG M-V) nature protection laws. In addition to this general protection for biotopes important to the eagle, a Programme for the Conservation of Habitat Diversity as a basis for the preservation of food resources is essential. Standards for the optimal state of biotopes covered by general protection measures (e.g. hedges and field ponds) must be set and included in revisions of nature protection legislation for general protection of biotopes and countryside structures.

Although there is at present no known threat from the use of pesticides in breeding areas, the use of chemicals to eliminate or exterminate the Field Mouse should be banned. Restrictions on the use of insecticides are also necessary. Under no circumstances must the use of substances that accumulate

in the food chain and are hard to break down, such as DDT in the past, be permitted.

3. Conservation and development of preferred woodland structures

The LSE breeding sites in MWP are found mainly in wet and undisturbed deciduous or mixed woodland, plentiful in undergrowth and with varied biotopes. The proportion of bogs and marshes in "LSE woodland" is high, with the forest floor consisting largely of heavily swamped or well-watered ground moraines. Woodland marshes and bogs are very important as a food source. Forest management must therefore pay great attention to the maintenance of a high water table level in addition to well-structured stands of timber rich in undergrowth, and with a high proportion of coherent stands of older trees. The past practice of draining areas with a high water table as part of an intensive forest economy must cease in LSE breeding areas. The nest site guidelines for the protection of threatened large bird species (White-tailed Eagle, Osprey *Pandion haliaetus*, LSE and Black Stork) developed and successfully implemented in the former GDR, have now been anchored in the State Nature Protection Law of MWP (100m and 300m radius protection zones). The legal protection must not be tied solely to the occupied nest site but must cover all usable LSE territories, as many pairs move to a new nest site annually due to competition or disturbance. This will ensure that reserves of suitable woodland are available for nest site choice. In addition irregular forest edges, including those immediately bordering meadows or clearings, must be preserved as important perch hunt sites. Relevant protection measures for the forests in the East German LSE breeding areas, which will be affected by the imminent privatisation by the government trustees, must be anchored in law.

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