Western Hazel Grouse *Tetrastes bonasia rhenana* in Luxembourg: Understanding its demise and restoration measures required

Markus Handschuh, Markgrafenstr. 20, D-79211 Denzlingen, Germany.
Email: markus.handschuh@gmx.de

Zusammenfassung: **Das Westliche Haselhuhn *Tetrastes bonasia rhenana* in Luxemburg: Kontext seines Niedergangs und notwendige Schutzmaßnahmen**
Eine im März-April 2018 durchgeführte intensive Suche nach dem Westlichen Haselhuhn *Tetrastes bonasia rhenana* in Luxemburg war erfolglos. Das Verschwinden des Taxons in Luxemburg wird anhand einer Literaturübersicht zur Biologie und den Lebensraumansprüchen des Haselhuhns in einen ökologischen Kontext gestellt. Angesichts derzeitiger Lebensraumdefizite (Flächen mit geeignetem Habitat zumeist zu klein und zu isoliert als Resultat einer ungünstigen Forstwirtschaft) und sehr hoher Dichten an Huftieren (Rothirsch, Wildschwein) und Raubsäugern haben mögliche letzte Einzelvögel ohne rasche und weitreichende Schutzmaßnahmen keine Überlebenschance. Die Schaffung optimierter Lebensräume zum Erhalt des Westlichen Haselhuhns über mögliche letzte Einzelvögel oder für eine zukünftige Wiederansiedlung sowie weitere Schutzmaßnahmen werden vorgeschlagen.

Résumé : **La sous-espèce rhenana de la Gélinotte des bois *Tetrastes bonasia* au Luxembourg: contexte de sa régression et mesures de protection.**
Le résultat de la recherche ciblée de *Tetrastes bonasia rhenana* en mars-avril 2018 au Luxembourg a été négatif. Le contexte écologique de la régression de cette sous-espèce au Luxembourg est analysé sur base d'un résumé des publications traitant de sa biologie et de ses exigences d'habitat. Compte-tenu des déficiences en matière d'habitat (parcelles résiduelles avec habitat adéquat trop exiguës et trop islolées suite à une exploitation forestière inadéquate) et densités très élévées d'ongulés (cervidés et sanglier) et de mammifères prédateurs, d'éventuels individus restants n'auront pas de chance de survie sans mesures de protection rapides et adéquates. Des approches sont évoquées afin de favoriser le maintien des deriers individus, voire de faciliter une réintroduction future, ainsi que d'autres mesures de protection.

Abstract: An intensive search for Western Hazel Grouse *Tetrastes bonasia rhenana* in Luxembourg in March-April 2018 was unsuccessful. Through a literature review on the ecology and habitat requirement of Hazel Grouse, the demise of the taxon in Luxemburg is contextualized. In the face of current habitat deficiencies (patches of suitable habitat mostly too small and too isolated due to widespread forest management practices that are detrimental for Hazel Grouse) and very high densities of ungulates and mammalian predators, possible last individuals of Western Hazel Grouse persisting in the country have no chance to survive without rapid and major intervention. Suggestions of measures to support possible last individuals or to facilitate future reintroduction and of further conservation measures are made.

The Western subspecies *rhenana* of Hazel Grouse *Tetrastes bonasia*, hereafter referred to as Western Hazel Grouse *Tetrastes bonasia rhenana* following Schreiber et al. (2015), is a valid taxon. It differs from all other subspecies of Hazel Grouse worldwide concerning morphological traits (Bauer 1960, Glutz v. Blotzheim et al. 1973/1994, Bergmann et al. 1996, Schreiber in press), genetics (Nowak et al. 2012) and with regards to habitat selection (Glutz v. Blotzheim et al. 1973/1994, Bergmann et al. 1996, Schreiber et al. 2015).

In the frame of an international expert meeting in Bad Dürkheim, Germany, in December 2017, a revision of the latest status information on Western Hazel Grouse revealed that the taxon has become extremely rare in its entire global range in France, Belgium, Luxembourg and Germany, and faces imminent global extinction (Pfeffer in press for the Vosges, Dronneau in press for northern France, Paquet in press for Belgium, Felten & Bastian in press and Handschuh 2018b for Luxembourg, Dietzen & Handschuh in press for Germany).

In March-April 2018, a subsequent search for the taxon in Luxembourg revealed no evidence for its continued presence which lead to the conclusion that the bird is probably extinct in Luxembourg (Handschuh 2018a).
Here, these findings are put into a wider context, to better understand why *T. b. rhenana* has largely disappeared throughout its range, including Luxembourg.

The following is a summary of Pynnönen (1954), Eiberle (1974), Wiesner et al. (1977), Müller (1978), Zbinden (1979), Asch and Müller (1989), Swenson (1991a, 1991b, 1993a, 1993b, 1995a, 1995b), Swenson and Angelstam (1993), Lieser et al. (1993), Swenson et al. (1994), Lieser (1994), Klaus (1995), Kämpfer-Lauenstein (1995), Bergmann et al. (1996), Åberg et al. (1995, 2000, 2003), Sachot et al. (2003), Montadert and Léonard (2003, 2006, 2007, 2011b), Klaus and Bergmann (2004), Jansson et al. (2004), Mulhauser (2003), Montadert (2005), Mathys et al. (2006), Scherzinger (2007), Mulhauser and Zimmermann (2008, 2014), Müller et al. (2009), Schäublin and Bollmann (2011), Kajtoch et al. (2012), Sitzia et al. (2013), Klaus and Ludwig (2015), Ludwig and Klaus (2016), Rechsteiner (2016), Matysek et al. (2018), Guillet (2018), Kortmann et al. (2018), Montadert and Klaus (in press), Montadert (pers. comm.) and Lieser (pers. comm.), and specifically concerning *T. b. rhenana* of Glutz v. Blotzheim et al. (1973/1994), Lieser (1990) and Handschuh (2004, 2015).

Hazel Grouse is a specialised inhabitant of the scrub and low tree layer of closed forests. It is an indicator species for forests rich in biodiversity and of high ecological value. The species inhabits preferably young stages of forest succession with a pronounced scrub and field layer. During summer, Hazel Grouse spend most of their time on the ground and feed in the field layer. During winter, the birds mostly live in trees and feed on buds and catkins of soft woods. Hazel Grouse inhabits a narrow ecological niche; large tracts of forest alone are not enough for the species to persist. The species is short-lived (life expectancy: few years), extremely sedentary and a poor disperser. The following are key parameters for a forest to be suitable for Hazel Grouse:

1. Well-developed understorey that provides good year-round horizontal and vertical cover up to 7 m above ground and in particular in the first 2 m above ground. In coniferous forests, cover is generated mainly by low vital conifer branches and in broadleaved forests mainly by high stem density.
2. Winter food mainly catkins and buds of various soft woods, occurring in close proximity (i.e. within few metres and ideally in direct contact) to cover provided by conifers; these are mainly Spruce and Fir, in some areas also Douglas Fir *Pseudotsuga menziesii*; Pine *Pinus sp.* is unfavourable and only suitable in connection with other conifers and Larch *Larix sp*. is mostly unsuitable in Western Europe due to its lack of leaves in winter. As a specialty, for *T. b. rhenana* winter food can also occur inside very dense pure deciduous stands without any conifers.
3. High quality nutrition for hens in cover during the pre-egg-laying period, i.e. mainly easily digestible field layer vegetation rich in protein.

4. Small sunny forest gaps with a well-developed field layer providing cover and food for brood-rearing and / or stands of translucent deciduous tree species that allow the development of a rich field layer under the canopy (e. g. in dense pioneer regeneration forest or in coppice woodland).
5. Spatial aspects: a) Hazel Grouse territories often consist of a matrix of (seasonally) suitable and unsuitable habitat patches. In Western Europe, territory size of Hazel Grouse is mostly 10-40 ha (min. 5 ha and max. 100 ha), depending, to varying degrees, on the number, size and quality of habitat patches available, population density, the status of the birds (single males tend to have the largest territories) and also on the method of calculating home range size (e. g. minimum convex polygons vs. sum of used grid cells). b) Within their annual home range, Hazel Grouse are able to cover distances of up to c. 1.5 km. c) Habitat patches that as a whole are suitable to set up at least one home range, i.e. basically territories themselves must not be further away from one another than c. 2 km in closed, but unsuitable forest (in Sweden; no data in Western Europe, but according to Scherzinger (2007), a benchmark is 1.5 km). d) Hazel Grouse cannot populate isolated forest fragments that are smaller than c. 30-40 ha (i.e. roughly the size of a territory) *or* that are separated by more than c. 100-200 m of open land (clearcuttings, farmland) from neighbouring forest fragments.

It is important to appreciate that all of these key parameters must be fulfilled in a forest to allow Hazel Grouse to survive; even if only one of the prerequisites is lacking or breaks away (e. g. key parameter 1, cover, due to strong thinning and systematic removal of low vital branches in young forest stands, or key parameter 2, winter food, due to the systematic removal of winter food trees, or if suitable habitat patches are too small and / or too far from one another and thus spatial aspects are not fulfilled), then the entire forest becomes unsuitable for Hazel Grouse.

In Western Europe, good quality habitat is characterised by a fine-grained mosaic of different vertical and horizontal forest structures that both provide good cover and permit light to reach the forest floor. They thus allow the growth of a field layer providing food during the summer and the regeneration of light demanding tree species that are important as winter food (Montadert & Klaus in press; see Fig. 1).

According to Montadert (pers. comm.), based on his long-term experience with Hazel Grouse in the French Alps and in the French Jura (e. g. Montadert 2005), the “ideal situation” in Western Europe seems to be a winter home range with continuous secure cover and good accessibility of winter food in a minimum area of 5 ha, and better 10-20 ha. The habitat conditions for brood rearing (gaps and deciduous stands with a field layer) may not be fulfilled in the winter territory (and vice versa) and thus brood rearing may often take place in an area of at least 20 ha (and better up to 40 ha) outside of the winter home range. Hazel Grouse is quite flexible in terms of food plants, particularly during summer (Zbinden 1979, Lieser 1994, Potapov & Sale 2013, Montadert & Klaus in press, Montadert pers. comm.; also see overviews over food plants in Bergmann et al. 1996 and in Handschuh 2004; specifically for *T. b. rhenana*: Lieser 1986 in Lieser 1990), while it is highly inflexible regarding cover generated by vegetation structure. Cover even has priority over food in the sense that the species does not use food resources away from good cover, even if they are plentiful (Swenson 1991a, 1995a). Therefore, and because the species occurs in a large variety of habitat types (see overview in Bergmann et al. 1996), Hazel Grouse is a “structure specialist” rather than a “habitat specialist” (Montadert & Klaus in press, Klaus pers. comm.). This means that forest age and plant species composition are rather unimportant, as long as Hazel Grouse is able to safely access its above-listed key resources.

In this regard, different forest types can be equally suitable for Hazel Grouse (Glutz v. Blotzheim et al. 1973, 1994, Bergmann et al. 1996, Montadert 2005, Scherzinger 2007, pers. obs.):
- Multi-layered, old growth forest with gaps, holes and small openings
- Open wood pasture or old forest grazed by cattle that results in an open, but still vertically and horizontally diverse structure

- Large, uniform, dense, single-layered young natural regeneration forests after clearcutting, wind throw, insect calamities or fire, or in the form of man-made coppice woodland or forest succession on former open areas such as pastures, farmland and quarries

To the untrained human eye, those forest types may appear totally different to one another, their structure in terms of food and cover for Hazel Grouse, however, is very similar.

In Europe, in general the availability of winter food trees in close proximity to conifers seems to be the most important limiting factor for Hazel Grouse (Swenson 1991a, 1993b, 1995a, Lieser 1994, Bergmann et al. 1996). The cover provided by conifers is crucial for winter survival (including survival of first year birds when they have settled down after autumn dispersal; winter survival also determines the abundance of breeding pairs in the following spring) when due to a lack of foliage, Hazel Grouse is highly vulnerable to Goshawk *Accipiter gentilis*, the main avian predator throughout its range (e. g. Swenson 1991a, 1993a, Bergmann et al. 1996, Montadert & Léonard 2003, Mulhauser 2003, Montadert 2005, Scherzinger 2007, Montadert & Léonard 2011b, Montadert & Klaus in press).

Although the highest Hazel Grouse densities have been recorded in extensive, dense tracts of young regeneration forest (see overview in Bergmann et al. 1996), the species is not a "pioneer species" because, e. g., it lacks the long-range dispersal ability typical for pioneer species. Rather, the natural habitat of Hazel Grouse seems (but is not proven) to be very old forest, parts and patches of which may be in the decay and regeneration phase at any time, resulting in a small-scale matrix of habitat patches that are suitable or unsuitable for the species. In such a forest landscape, Hazel Grouse is able to set up territories at all locations where patches of suitable habitat are large enough and close enough to one another (also see below) so that in their sum, they are sufficient to fulfil the species' requirements. Such long-term stable conditions allowed Hazel Grouse to evolve to be sedentary and develop only poor dispersal abilities, despite being reliant on elements of early stages of forest succession (Swenson 1991a, 1991b, 1993b, 1995a, 1995b, Bergmann et al. 1996, Montadert 2005, Scherzinger 2007). This is opposed to true pioneer species that are able to disperse over large distances, crossing large areas of unsuitable habitat, and rapidly find and populate new, short-term habitat and move on when the habitat becomes unsuitable.

As a specialty, Western Hazel Grouse is the only subspecies of Hazel Grouse that has evolved in and has originally been restricted to purely deciduous forests (except for some small parts of its original range with natural high-altitude mixed montane forests, e. g. in the Vosges Mountains in France) and under Atlantic climate conditions (Schreiber et al. 2015). The habitat requirements of *T. b. rhenana* have long been fulfilled particularly well in man-made deciduous coppice woodland which used to be widespread throughout Western Europe: It was the traditional main habitat type of Western Hazel Grouse, especially throughout the Rhenish Massif, including Luxembourg (Glutz v. Blotzheim et al. 1973/1994, Faber 1987, Ledant 1990, Ledant & Devillers 1991, Lieser 1990, Moes 1991, Bergmann et al. 1996).

In Luxembourg, the main coppice type inhabited by Western Hazel Grouse used to be Oak *Quercus sp*. coppice, the so-called Lohhecken. The woodland was cut every 15-30 years to obtain bark for leather tanning and the timber was used mainly as firewood. These stands were most suitable for Hazel Grouse at ages of about 10 to about 20 years after cutting (e. g. Faber 1987, Aarbechtsgrupp Beschhong 1997, Schmidt & Heidt 1997, Felten & Biver 2009).

Hazel Grouse is a strict forest bird and all studies on the species' habitat selection stress the crucial importance of cover (Swenson 1991a, Lieser 1994, Bergmann et al. 1996, Montadert 2005, Klaus & Ludwig 2015, Scherzinger 2007, Guillet 2018). Due to the high predation pressure by numerous mammalian and avian predators that this small forest grouse is permanently exposed to (e. g. Glutz v. Blotzheim et al. 1973/1994, Swenson 1991a, 1993b, Bergmann et al. 1996, Montadert & Léonard 2003, Montadert 2005, Scherzinger 2007), it is wary of areas and spots that do not fulfil its vital need for security and cover, both on the forest stand (Fig. 1) and microhabitat level (Fig. 2).

The need for cover goes so far that, e. g., Hazel Grouse will regularly use a particular spot in cover for resting while it will not use another spot only a couple of metres away that looks identical except that it is surrounded by slightly less vegetation resulting in a little less overall cover. Even single small saplings or branches of small trees can make a difference in whether Hazel Grouse uses a spot for resting or not, as indicated by the presence of droppings (Fig. 2). Hazel Grouse will also meticulously avoid using or crossing dangerous forest patches and dangerous parts of its territory with little cover whenever possible and even make significant detours in cover to reach certain spots, in particular when suitable and less dangerous forest patches are nearby (Swenson 1991a, Scherzinger 2007; Lieser pers. comm.; pers. obs. in various Hazel Grouse areas).There may be occasions when Hazel Grouse is forced to cross unsuitable forest patches with little cover or other dangerous terrain, e. g. during the dispersion period of juveniles in autumn (Montadert & Léonard 2006, Montadert & Klaus 2011). However, these are rare events and thus, an accidental observation of a bird untypically leaving good cover is unlikely. In Western Hazel Grouse, given the taxon's current rarity throughout its range, an observation in untypical habitat outside of good cover is even more improbable.

Male Hazel Grouse in an aggressive mood that are irritated by a surveyor using the lure whistle may also move into or cross untypical habitat, but such occasions are rare, too, and they are not accidental (pers. obs.).

Habitat deficiencies as a crucial problem for *T. b. rhenana* in Luxembourg

In the standard Luxembourgish forest, there have long been and still are active mechanisms that lead to the loss of one or more of the key parameters for a forest to be suitable for Hazel Grouse. This currently renders a very high proportion of the Luxembourgish forest unsuitable for *T. b. rhenana*. Habitat deficiencies are outlined in the following.

1. Loss of coppice woodland

There is unanimous agreement that the single most important reason for the decline of Western Hazel Grouse populations throughout the taxon's global range, including Luxembourg, is the widespread loss of coppice woodland (e. g. Glutz v. Blotzheim 1973/1994, Faber 1987, Ledant 1990, Ledant & Devillers 1991, Lieser 1990, Moes 1991, Bergmann et al. 1996, Dietzen 2015, Helfrich-Hau 2014). This loss is mainly due to abandonment of active coppice management and subsequent growth of the stands into age classes structurally unsuitable for Western Hazel Grouse. Also, on a large scale, coppice woodland has been transformed into conifer plantations or high forests that are unsuitable for Western Hazel Grouse. Ageing and transformation leads to transparent stands lacking horizontal and vertical cover (key parameter 1) and with few to no winter food trees (key parameter 2) and with no or only a poorly developed field layer (key parameters 3 and 4) and thus such forest stands are unsuitable for Hazel Grouse.

Grown-through former coppice woodland that is now transparent medium-aged deciduous forest is a common picture in Luxembourg and photos of such forest stands can be found in various reports (e. g. Aarbechtsgrupp Beschhong 1997, Johnston 2016, Pfeffer 2017).

The decline of Western Hazel Grouse in Luxembourg due to the loss of actively managed coppice woodland has been reported repeatedly and by basically every single author writing about conservation of the taxon in Luxembourg in recent decades: Already 30 years ago by Faber (1987) and subsequently by, e. g., Ledant (1990, 1991), Moes (1991), Aarbechtsgrupp Beschhong (1997), Schmidt and Heidt (1997), Felten and Biver (2009), Johnston (2016), Felten and Bastian (in press). All of the authors considered it crucial to reverse the negative habitat trend in order to conserve Western Hazel Grouse in Luxembourg.

However, despite alarm calls for decades and judging from their stage of development, large areas of former coppice woodland in Luxembourg seem to have become unsuitable for Western Hazel Grouse only in the past 20 years. Especially on poor soils or in extreme expositions where the (oak) forest grows slower and tends to develop dwarf or cripple structures, until very recent-

ly there would have been the opportunity to conserve and maintain Western Hazel Grouse habitat without much effort.

2. Forest management practices detrimental to Western Hazel Grouse

Apart from the widespread transformation of coppice woodlands into conifer plantations and high forest, there are also other forestry practices that are problematic for Hazel Grouse.

As almost everywhere in the global range of Western Hazel Grouse, intensively managed single-species conifer plantations are a common picture in Luxembourg, too. Such stands are unsuitable for Hazel Grouse due to the lack of winter food trees (key parameter 2) and a field layer (key parameters 3 and 4). At older stages or after strong thinning and pruning, such stands also lack cover (key parameter 1).

However, if young conifer plantations contain at least 10 % deciduous soft woods, they can be suitable Hazel Grouse winter habitat; if they also contain gaps with a field layer, they are also suitable in summer (Lieser 1994, Klaus & Ludwig 2015). Structurally and species-rich young mixed forest stands can even be prime Hazel Grouse habitat (Asch & Müller 1989, Bergmann et al. 1996). These forest types also exist in Luxembourg. However, such potentially longer-term suitable forest stands are almost always devalued for Western Hazel Grouse at an early stage. In particular, strong thinning, mostly combined with the removal of soft woods and pruning, i.e. removal of low vital conifer branches, results in horizontally and vertically transparent stands: Thus, potential Hazel Grouse habitat is destroyed from one day to another. Such practice even renders the forest stand almost irrecoverably unsuitable for Hazel Grouse (Fig. 3 & 4).

Another alarmingly common practice in Luxembourgish forests are harvester-made industrial-scale clear-cuttings that completely alter large swathes of forest habitat from one day to another and cause local forest fragmentation (Fig. 5); both is detrimental to Hazel Grouse (key parameters 5 a-d). The government must intervene regarding this seriously detrimental development and limit the maximum permitted size of clear-cuttings (under consideration of species that may be reliant on clear felling habitat).

In theory, on former clear-cuttings, new Western Hazel Grouse habitat in the form of rich young forest stands could develop rapidly. However, such areas are mostly not left to regenerate naturally, or replanted with deciduous trees or as mixed stands with wide spacing. Instead they are densely replanted with conifers only, even close to the edges of forest tracks and streams. Subsequently, such stands are intensively managed, i.e. thinned, pruned and soft woods that may have managed to come up are removed.

3. Spatial aspects

For Hazel Grouse in general, spatial aspects of habitat availability have been discussed above. For Western Hazel Grouse in particular, there are only few data published.

Schmidt and Heidt (1997) state four different theoretical average territory sizes of Western Hazel Grouse, based on unpublished data and calculated from estimated “cruising radii” determined by the “activities of the male Hazel Grouse” in the German part of the Rhenish Massif in the border triangle of North Rhine-Westphalia, Hesse and Rhineland-Palatinate. They mention c. 28 ha and then 25 ha for basalt soils and c. 78 ha and then 71.4 ha for Devonian underground. However, these figures should probably be treated with caution because the authors do not mention the underlying sample size and how exactly the “cruising radii” were determined; also, it remains unclear which of the different figures actually is the average territory size. Furthermore, in intensively managed forests in Western Europe, Hazel Grouse occurrence and density has little to do with geology, but rather with forest management (pers. obs.).

In the Moselle Valley in the Rhenish Massif in Rhineland-Palatinate, Germany, Lieser (1986 in Lieser 1990 and in Dietzen 2015) found two Western Hazel Grouse territories in coppice habitat to size 12-15 ha, mainly based on locations where indirect signs of the birds were found.

In the Southern Vosges in France (Départements Haut-Rhin and Haute-Saône), the core areas of three home ranges in good quality habitat in coppice woodland and in young regeneration forests were about 5-10 ha; this was determined by locations where indirect signs were found frequently and few incidences when the birds were seen or heard (Handschuh 2004). Several neighbouring core areas with frequent records in high quality Hazel bush forest and other young coppice habitats were about the same size (pers. obs.). The coppice woodlands have been abandoned in the meantime and today, there is not a single territory left in this area that 20 years ago was densely populated by Western Hazel Grouse (Pfeffer pers. comm.).

In the Rhenish Massif in Hesse, Germany, Popp, cited in Glutz v. Blotzheim et al. (1973/1994), found that a pair of *T. b. rhenana* required an area of 40 ha (10-80 ha); however, there is no mention of the sample size, habitat types and how home range size was determined.

Since none of the figures mentioned above are based on telemetry data of tagged birds, they may not be very accurate. Home range sizes determined by telemetry are usually larger than those based on indirect signs and on occasional direct observations.

For example, in *T. b. rupestris* ("Eastern Central European Hazel Grouse") in the Black Forest, Asch and Müller (1989) and Asch (pers. comm.) assumed minimum territory sizes of 2-5 ha in optimal habitat in coppice woodland and forest succession of former pastures, based mainly on locations where indirect signs were found frequently. However, based on data from radio tagged individuals in similar habitats in the Black Forest, Lieser (1994) found monthly home range sizes of 5-7 ha and yearly home range sizes of around 30 ha (sum of 0.25 ha areas used by the birds, respectively).

So, in summary, it seems that 10-15 ha of high-quality habitat per pair of *T. b. rhenana*, in which the birds find fulfilled all of their seasonal requirements (key parameters 1-4), is probably a good benchmark.

Apart from individual habitat patch and territory size, the isolation of habitat patches and territories, even within closed (but unsuitable) forest, is also an important spatial parameter for the survival of Hazel Grouse. Since the species is extremely sedentary and a poor disperser, there is a high risk of population kernels becoming isolated and subsequently, in this short-lived species that faces a permanent high predation risk, disappearing very rapidly (Swenson 1991b, 1995a, Lieser 1994, Bergmann et al. 1996, Jansson et al. 2004, Montadert & Léonard 2003, 2006, 2011b, Scherzinger 2007, Mulhauser & Zimmermann 2008, 2014).

On the level of the individual territory, in Eastern Central European Hazel Grouse in the Black Forest, Lieser (1994) found that c. 30 ha of suitable habitat imbedded and spread out over up to 80 ha of more or less unsuitable, for Hazel Grouse crossable standard forest is sufficient for a pair to set up a territory. Lieser's radio-tagged birds covered maximum distances between two locations within their home range of 1-1.5 km. However, these findings must be considered with caution because at the time of Lieser's study, the Hazel Grouse population in the Black Forest had already declined dramatically and some ten years later Hazel Grouse was extinct in the Black Forest (Asch & Müller 1989, Lieser et al. 1993, Klaus & Bergmann 2004, Asch 2007).

On the next higher level, i.e. with regards to different, neighbouring territories, there have been studies in Sweden on the nominate form of Hazel Grouse *T. b. bonasia*. There, in closed forests, the distribution and number of Hazel Grouse occurrences in fragments of suitable habitat were affected by the size of the respective habitat fragment and by its distance to the nearest neighbouring habitat fragment (Åberg et al. 1995, 2000). Based on these and own studies, Swenson (1995a) states that, within closed forest, the distance between suitable habitat patches of c. 40 ha in size, which is the average Hazel Grouse territory size in that area, should not be more than 2 km.

Although for Western Hazel Grouse there have been no dedicated studies on these issues, it is safe to assume that this taxon does not function differently from other European populations of Hazel Grouse. This assumption is further supported by the study of Nowak et al. (2012) that, based on samples mainly taken from museum skins, revealed genetic differences in Western Hazel Grouse populations on the regional scale, even within the German part of the Rhenish Massif, as well as by detailed taxonomic analyses of museums skins by A. Schreiber (pers. comm.) that revealed fine-scale local plumage differences.

There are no current figures on the exact extent and proportion of potentially suitable Western Hazel Grouse habitat in Luxembourg. However, even lacking an exact quantification, it is obvious that individual habitat patches in Luxembourg are mostly too small and too isolated for Western Hazel Grouse to be able to set up territories.

Without a doubt, this is also true on the next higher level, i.e. with regards to territories themselves not being isolated: Most of the patches with suitable or very good habitat found during the recent search for Western Hazel Grouse in Luxembourg (Handschuh 2018b) were very small (< 1 ha) or up to a couple of ha at most and those patches were mostly widely spaced. Hardly any site with 5-10 ha of contiguous, more or less good quality potential Western Hazel Grouse habitat was found. Only three, widely separated areas contained 10-15 ha of contiguous, potentially very good habitat: A forest succession on former pasture near Bockholtz (c. 10 ha) and two largely naturally forested former clear-cuttings near Grümmelscheid and Mecher (c. 15 ha each). Remarkably, after the survey it came to light that the latter two areas are owned by natur&ëmwelt Fondation Hëllef fir d'Natur.

In order to determine the current exact extent and proportion of potentially suitable Western Hazel Grouse habitat in Luxembourg, a detailed study is required. However, this may be complicated due to the lack of good reference data: Precise and reliable old figures may not be available and there are currently no inhabited reference sites within the country.

4. Aspects of population biology connected to habitat availability

As outlined above, Hazel Grouse has particular habitat requirements that, without habitat management, are only met during certain phases of the natural forest succession and therefore only temporarily in any given area. Also, the species is sedentary and a poor disperser. Furthermore, being a small forest grouse, it faces a permanent high predation risk. For these reasons, population kernels can easily become isolated and then disappear rapidly.

Therefore, it is important to note that Hazel Grouse is not a species that is able to cling on for years or decades at low density, and that the chance of isolated pairs or single individuals occurring and persisting any appreciable length of time is extremely low. The basis for Hazel Grouse to survive in the long term is to be embedded in a strong population on the supra-regional level. This buffers larger scale "natural" population fluctuations (Bergmann et al. 1996) as well as local population declines due to:

- (temporarily) low habitat quality or availability (e. g. when a forest reaches a less suitable age class)
- temporary high adult mortality as a result of temporarily low rodent abundance and thus little other prey for generalist predators
- chance events such as poor weather during the brood-rearing period; if things go particularly badly, then there may even be poor weather for several years in a row.

In a strong, supra-regional Hazel Grouse population, population fluctuations can be compensated for and territories that may have become vacant may be refilled.

However, in Western Hazel Grouse, regional or supra-regional strong populations are not present anywhere in the taxon's range anymore, including Luxembourg (Pfeffer in press for the Vosges, Dronneau in press for northern France, Paquet in press for Belgium, Felten & Bastian in press and Handschuh 2018b for Luxembourg, Dietzen & Handschuh in press for Germany). This

is also the main reason why, without the rapid start of a conservation breeding programme, global extinction of Western Hazel Grouse is virtually inevitable.

To conclude on habitat deficiencies in Luxembourg: Despite decades of repeated calls for measures to be taken to maintain and improve Western Hazel Grouse habitats in the country, obviously none or hardly any concrete measures have been taken. The current absence of *T. b. rhenana* may be explained by anthropogenic habitat deficiencies alone.

Further problems for *T. b. rhenana* in Luxembourg
In addition to the habitat deficiencies due to detrimental forestry practices outlined above, there are also further obvious problems for Western Hazel Grouse in Luxembourg (Johnston 2016, Handschuh 2018b):

1. Very high density of herbivores, in particular Red Deer *Cervus elaphus*, that put immense browsing pressure on the last remaining small pockets of potential Western Hazel Grouse habitat, including the few patches of actively managed coppice woodland that still exist. Excessive browsing reduces general cover (key parameter 1) and the growth of winter food trees (key parameter 2) as well as summer food and cover (key parameters 3 and 4) (also see Lieser 1990, 1994, Bergmann et al. 1996, Handschuh 2015, 2017, Pfeffer 2017).
2. Very high density of Wild Boar *Sus scrofa* that may prey on Hazel Grouse eggs and small chicks (Glutz v. Blotzheim et al. 1973, 1994, Bergmann et al. 1996). Wild Boar is abundant in Luxembourg and signs of its presence are omnipresent in all forests visited. The species prefers dense young forest stands for daytime resting and Handschuh (2018b) saw it frequently, including sounders of a dozen and more individuals. Often, potentially suitable pockets of Western Hazel Grouse habitat are crisscrossed with tracks, rooting sites and daytime beds of Wild Boar. In extreme cases, the boars locally almost completely remove the field layer in potential Hazel Grouse habitats. Also, there are cases where Wild Boars are artificially attracted to and held in potential Hazel Grouse habitats by the operation of feeding stations, even when no raised hide is present and with legal amounts of bait possibly being exceeded.
3. As indicated by the presence of faeces, dens and tracks, very high density of small and medium sized mammalian predators that may prey on all life stages of Western Hazel Grouse, mainly Red Fox *Vulpes vulpes*, Raccoon *Procyon lotor*, Martens *Martes sp*. and Badger *Meles meles*. In particular, Red Fox and Pine Marten *Martes martes* are known main predators of Hazel Grouse (Glutz v. Blotzheim et al. 1973, 1994, Swenson 1991a, Bergmann et al. 1996, Montadert & Léonard 2003, Mulhauser 2003, Montadert 2005). Raccoon is a known predator of the ecologically similar north American Ruffed Grouse *Bonasa umbellus* (e. g. Smith et al. 2015). However, Ruffed Grouse has co-evolved with this predator while in the Western Hazel Grouse range Raccoon is an introduced alien invasive species with potentially great impact. Not least for this reason it must be managed Europe-wide (European Union 2017)

All of these further problems are present in all potential Western Hazel Grouse habitats in Luxembourg and many potential high-quality habitat patches are literally overrun by Deer, Boar and mammalian predators (Handschuh 2018b). Which species of mammalian predators are involved and if there are temporal or spatial variations in densities of Deer, Boar and mammalian predators in potential Hazel Grouse habitats may be investigated in the frame of a detailed study, as long as this does not divert critical time and resources from the most important and statutory issue which is to restore Hazel Grouse.

Measures to restore Hazel Grouse in Luxembourg

Through the Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds, member states are legally bound to conserve and restore Hazel Grouse populations.

Throughout the global range of Western Hazel Grouse, respective measures are extremely urgent. In Luxembourg, the measures outlined in the following are promising.

Development of a Hazel Grouse model area

Handschuh (2018b) found that a c. 2,000 ha area roughly encircled by the polygon Neidhausen-Munshausen-Siebenaler-Pintsch-Lellingen-Hosingen-Neidhausen stood out from the rest of his survey area regarding the proportion of currently still suitable Western Hazel Grouse habitat present and the potential for future habitat development and connection.

This area would be predestined to develop a Hazel Grouse model area that single Western Hazel Grouse, if still present, may find and re-colonise, or, in the likely case that the taxon has already vanished from Luxembourg, as area to be developed and managed for future reintroduction of Hazel Grouse.

A detailed management plan would be required, targeted at the vigorous and binding development of contiguous top quality Hazel Grouse habitat, including habitat creation and management as well as restoration, improvement and maintenance of habitat connectivity. This could be achieved through a combination of, e. g., binding recommendations regarding forest management, targeted land purchase and subsequent management, wood pasture, and dedicated mammalian predator and ungulate management using passive and active means (e. g. fencing, targeted removal). The management plan for the model area should also include a scientifically sound monitoring and evaluation scheme of all management aspects. The role and importance of generalist and specialist mammalian predators and the interconnection between predators and habitat quality has repeatedly been discussed and current agreement amongst European (Hazel) Grouse experts seems to be that mammalian predators are very to extremely important and that on the European scale, the increase of generalist predators in recent decades may be a more important driver of the decline of forest grouse populations than aspects of habitat quality (pers. obs.).

In the longer term, the area should also be widened or further nearby areas be developed, in order to achieve conditions suitable for a Hazel Grouse population that is sufficiently large and dense to be self-sustainingly viable in the long term.

Regarding the minimum population size and minimum area required for the long-term survival of European forest grouse populations, in the past various more or less well-founded figures have been suggested, but currently there is no reliable estimate (Montadert pers. comm., Storch pers. comm.). However, it is well known that forest grouse populations are directly linked to the proportion of suitable habitat. Equally well known are the general spatial requirements of Hazel Grouse (key parameters 5 a-d) which are modest, and the very high densities that the species can reach in top quality habitat. Furthermore, experience from the Black Forest and elsewhere shows that minor general habitat improvements sprinkled over large areas, or bits and pieces of more special habitat measures done here and there are futile for Hazel Grouse. So, all of the basics are known and it is time to act.

Further recommended measures and activities

Most importantly, a country-wide, well-planned massive education campaign on forestry practice beneficial for Western Hazel Grouse should be carried out. Various detailed recommendations and brochures already exist (e. g. Asch & Müller 1989, Lieser et al. 1993, Lieser 1994, Bergmann et al. 1996, BAFU 2001, Montadert & Léonard 2007, Scherzinger 2007; specifically for *T. b. rhenana*: Lieser 1990, Handschuh 2004), also for Luxembourg (Faber 1987; ten years later: Aarbechtsgrupp Beschhong 1997; ten years later: Felten & Biver 2009; ten years later: unsuccessful EU LIFE project application, Felten pers. comm.). These may be updated once again and adapted to the current situation in Luxembourg. In the course of such a campaign, potential Western Hazel Grouse observers (e. g. forest owners, foresters, hunters, birdwatchers) should also be informed about how to find and confirm *T. b. rhenana* in the field.

The term “massive campaign” is used because so far, nowhere in the global range of Western Hazel Grouse have conservation measures been implemented with the necessary vigour and on the required scale, and this is the single most important reason why the taxon is now on the very edge of global extinction. And this, although forest management for Western Hazel Grouse is extremely simple and with appropriate forest management practices, Hazel Grouse in general can almost “be bred” and its population be kept at high levels (pers. obs.). Perhaps in the Grand Duchy of Luxembourg it can finally be demonstrated that effective conservation of the globally threatened *T. b. rhenana* is indeed possible. This is peanuts in comparison to the incredible amounts of money generated and to the attention paid to other issues within the extremely wealthy and highly developed European Union.

It may also be useful to revive a working group on Western Hazel Grouse in Luxembourg, to plan and discuss ways to seriously address these issues and push them forward. However, everyone involved must appreciate that working groups and meetings do not save Hazel Grouse unless they result in rapid concrete action in the forest (Asch 2007, Lieser 2003, 2015, 2018).

When planning and implementing conservation measures to re-open the countryside in possible or former Western Hazel Grouse areas, the potential (also future) negative impact on the globally threatened Western Hazel Grouse and the potential benefits for other, probably less threatened taxa should be weighed up against one another. Western Hazel Grouse benefits from species-rich succession and mosaics where pastures and forest are not clearly separated. Where such measures are indispensable, edges between open spaces and scrub and between long and short vegetation should always be kept gradual and winding and should never be made straight and abrupt. Furthermore, Hazel Grouse food trees should be kept and supported as seed bearers.

On a concluding note, metal fences used to protect forest stands against herbivores are potential death-traps for grouse (Asch & Müller 1989, Lieser & Roth 2001). In Luxembourgish forests, metal fences are a regular occurrence, also in potential Western Hazel Grouse habitat. Where fencing is indispensable, metal fences must be replaced with wooden fencing.

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Figure 1: Aspect of a year-round Hazel Grouse territory (here "Alpine Hazel Grouse" *T. b. styriaca*): Uneven, multi-layered, horizontally and vertically strongly structured forest stand with tight interconnection between food and cover in summer (small-scale mosaic of variably tall, dense and translucent tree and shrub species; rich ground vegetation with European Blueberry *Vaccinium myrtillus* and herbs providing food and cover while still being penetrable for Hazel Grouse; conifers with vital low branches; small, sunny forest gaps) as well as in winter (direct contact between winter food trees, here mainly Rowan *Sorbus aucuparia*, and live conifer branches that provide cover). French Jura, July 2018.

Figure 2: Hazel Grouse (here "Alpine Hazel Grouse" *T. b. styriaca*) is extremely reliant and focussed on cover, even on the very small-scale microhabitat level. The mossy tree stump on the left in the circle, surrounded by few spruce and fir saplings that provide a little extra cover, was used regularly for resting in the course of a winter, while the tree stump next to it on the right, lacking such saplings, was never used, as indicated by the presence or absence of droppings and feathers, respectively. Swiss Jura, April 2018.

Figure 3: Strong thinning of young forest stands with removal of soft woods and low vital conifer branches immediately leads to horizontally and vertically transparent stands with no winter food. This common practice in Luxembourgish forests destroys potential Western Hazel Grouse habitats from one day to the other and renders the forest stand almost irrecoverably unsuitable for Hazel Grouse, also at older stages.

Figure 4: Systematic removal of soft woods and low live conifer branches immediately totally devalues Hazel Grouse winter habitat and renders the forest stand almost irrecoverably unsuitable for the species.

Figure 5: Large-scale clear-cuttings made with harvesters completely alter forest habitats from one day to the other and cause local forest fragmentation. Both is detrimental to Hazel Grouse.