Animal diversity on short-rotation coppices – a review

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Abstract

The animal diversity on short-rotation coppices (SRC) has not yet been investigated adequately. Most research conducted up to now did focus on birds and ground beetles. Their biodiversity, equated with species richness, differs considerably. Diversity of breeding birds is higher in SRC than in agricultural cropland, but generally lower than in forest ecosystems. Diversity of ground beetles is higher in arable fields than in SRC. In general the portion of forest species is lower in SRC than in typical forest habitats but rises with increasing age of stands.

The animal diversity depends on various environmental factors. These include the surrounding landscape, the shape and size of the plantation. For example, small and oblong SRC are more favourable due to the edge effect, for example. Besides these landscape ecological parameters, there are other important factors. Willows contain both a greater diversity and higher abundance in most animal groups than poplars. Some birds even prefer certain clones when selecting a nesting site.

The habitat structures of a SRC change as its age increases and the composition of the biocoenoses also changes as a result.

The biodiversity in SRC is enhanced most significantly by the structural richness within the poplar or willow blocks and in the peripheral areas. As a result, some animal species of conservational value can find a suitable habitat in SRCs. The increasing cultivation of SRCs can lead to a slight increase in biodiversity in cleared agricultural landscapes, but to significant adverse effects in landscapes with high conservational value. Further research is required, especially regarding species-rich invertebrate groups.

Keywords: Woody biomass, biodiversity, birds, ground beetles, environmental impacts, short-rotation coppices

Zusammenfassung

Tierdiversität auf Kurzumtriebsplantagen – eine Übersicht

Es liegen noch keine umfassenden Untersuchungen zur Biodiversität der Tiere auf Kurzumtriebsplantagen (KUP) vor. Am besten untersucht sind die Vögel und die Laufkäfer. Ihre Biodiversität, gemessen als Artenreichtum, ist unterschiedlich ausgeprägt. Während die Brutvögel KUP artenreicher besiedeln als z. B. Äcker, aber hier eine geringere Artenzahl als bspw. in Laubwäldern aufweisen, treten Laufkäfer auf Äckern in höheren Artenzahlen auf. Generell ist der Anteil an Waldarten in den Artenspektren gering, nimmt aber mit zunehmendem Alter der KUP zu. Die Tierartenvielfalt auf einer KUP hängt von verschiedenen Umweltfaktoren ab. Dazu gehört die umgebende Landschaft, die Flächenform und die Flächengröße. So sind zum Beispiel lange rechteckige Anlagen wegen des Randeffektes günstiger als quadratische. Neben diesen landschaftsökologischen Parametern gibt es weitere wichtige Faktoren auf der Bestandesebene. So weisen z.B. Weiden größere Artenzahlen und Individuendichten bei vielen Tiergruppen auf als Pappeln, und manche Vogelarten bevorzugen bestimmte Gehölzklone bei der Nistplatzwahl.

Die Habitatstrukturen einer Kurzumtriebsplantage ändern sich mit zunehmendem Alter und damit einhergehend ändern sich die Zusammensetzungen der Lebensgemeinschaften.

Begleitstrukturen und Strukturreichtum innerhalb der Pappel- oder Weidenblöcke können die Diversität auf KUP am stärksten erhöhen. Durch Begleitstrukturen und junge Offenlandstadien können naturschutzfachlich wertvolle Tierarten im Einzelfall gefördert werden.

In ausgeräumten Landschaften kann der Anbau von KUP eine biodiversitätsbereichernde Wirkung ausüben; in Landschaften mit hohem naturschutzfachlichen Wert kommt es jedoch zu gegenteiligen Effekten.

Es besteht noch Forschungsbedarf, gerade bei den artenreichen wirbellosen Tiergruppen.

Schlüsselwörter: Energieholz, Biodiversität, Vögel, Laufkäfer, Umwelteinflüsse

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1 Introduction

Energy use projections for North America and Europe predict that biomass will be an important source of renewable energy in the coming decades – and short-rotation woody plants will be the prime source of this biomass (Volk et al., 2004; Reeg et al., 2009). Short-rotation coppices (SRC) are production systems for generating wood in short time periods (Murach, 2009; Knust, 2009). For this, hybrids of willows (*Salix*) and poplars (*Populus*) that have been selected on the basis of their growth performance and ability to resist pests are planted in high density on areas of agricultural land (Knust, 2009).

But while technology is rapidly advancing to utilising woody perennials there are a lot of questions concerning environmental impacts of biomass and biofuel production (Firbank, 2007; Johnson et al., 2007; Porder et al., 2009; Rode, 2005). Thus, as more and more short-rotation coppices are planted, the question as to their influence on the biodiversity is also raised (Firbank, 2007; Schmidt & Glaser, 2009).

Nowadays, biodiversity is one of the overriding principles in nature conservation and land use. At the Convention on Biological Diversity in Rio (1992), the contracting states agreed to "protect and enhance biodiversity" within their national borders (Groom et al., 2006; Haughton et al., 2009). There are conflicts between biodiversity conservation and human land use activities, however, particularly in agricultural landscapes (Henle et al., 2008). An important aspect relevant to the future acceptance or rejection of the SRC by the general public will be whether they increase or reduce a landscape's biodiversity. The following is an attempt to summarise the current knowledge concerning animal diversity in SRCs.

2 Animal species diversity

Species are the fundamental units of biodiversity (Prance, 1995) and the number of animal species is the highest of all taxonomic groups (Wilson, 1988; Trevelyan & Pagel, 1995). The vast majority are invertebrates (Wilson, 1988), but the diversity of invertebrates is underestimated and poorly examined. Studies of animal diversity are complex, but surprisingly high numbers of species were discovered when such studies were carried out on agricultural sites. For example, more than 900 insect species have been found in monocultures of cereals which are supposed to represent very species-poor habitats (Potts, 1977 in Schneider, 2006). New insect species continue to be discovered on European agricultural land (as an example see the Sciaridae: Diptera compiled by Menzel & Schulz, 2007). Even less knowledge exists with regard to the diversity of soil animals. The "enigma of soil animal species diversity" cited by Anderson (1975) still applies today.

Vertebrates

In the overall diversity of animals in a SRC, as in other ecosystems, vertebrates make up only a small fraction. Most research has been conducted into the diversity of birds in SRCs. Tangible data and meaningful overviews from Great Britain (Sage & Robertson, 1996; Sage et al., 2006; Anderson et al., 2004), Sweden (Berg, 2002), Germany (Jedicke, 1995; Liesebach & Mulsow, 1995, 2003; Gruß & Schulz, 2008) and the USA (Christian et al., 1997; Christian et al., 1998; Dhondt & Sydenstricker, 2000; Dhondt et al., 2004; Dhondt et al., 2007) already exist on this subject. Londo et al. (2005) dealt with the habitat potential and theoretical avian diversity of willow SRC in the Netherlands.

The cited number of bird species in SRC differs from 8 to 60 species. Different bird species are associated with different age classes of SRC. The abundance of birds in SRC has also been shown to be linked with coppice stem or planting density and with increased weediness (Sage et al., 2006). But the different numbers of species are due to many further factors, such as variety of areal sizes, intensities of management, landscape context and regional species pool. These parameters will be discussed in the following chapters.

Up to now, very little research has been conducted on mammals in SRC. Species observed in SRC plantations in England included 17 mammals (compiled by Rowe et al., 2007) and trapping suggested that SRC provided a more attractive habitat for small mammals than arable land, with older coppices being more attractive, nevertheless it still represents a poorer habitat than hedgerow and scrub land (Coates & Say, 1999, in Rowe et al., 2007). Christian et al. (1997 and 1998) investigated small mammals in poplar SRC in USA. Shrews appear in well-vegetated patches on both young and older poplar plantations (Christian et al., 1998), young poplar plantations tend to be dominated by single rodent species (Christian et al., 1997). However, the composition of bird and small mammal fauna on SRCs varies among study sites and regions. Furthermore larger herbivores such as deer and rabbit can play an important role due to their browsing damage on trees and shrubs (Christian et al., 1998; Rowe et al., 2007; Helbig & Müller, 2008; Schulz et al., 2008a; Helbig & Müller, 2009). Bergstrom & Guillet (2002) suggest that although large herbivores are often supposed to damage SRC plantations, e. g. by barking or browsing, SRC could also be viewed as a resource for deer and hare in terms of the game value of these species. For many larger bird and mammal species, SRC with small area sizes merely represent partial habitats within larger home ranges.

Overall, it becomes clear from the cited works that the bird and mammal communities of SRCs are made up of species typically found in open land and woodland. Christian et al. (1998) did not observe any bird or mammal species on *Populus* plantations that did not occur elsewhere in the region. The most abundant bird species and small mammals on hybrid plantations are habitat generalists. Most of the bird species are regionally abundant, widespread and capable of using a wide variety of breeding habitats (Christian et al., 1998; Gruß & Schulz, 2008; Jedicke, 1995).

Invertebrates

Most studies of animal species diversity in SRCs have dealt mainly with vertebrates and left invertebrates largely neglected. The research was focussed on insects that directly populate poplar and willow plants and trees. Poplars and willows act as host to a large number of insects. This has been known for some time (e.g. FAO 1979), particularly since some insect species can emerge as pests. These include defoliating and boring species of the beetle (Coleoptera) and butterfly (Lepidoptera) orders, but also gallformers and sucking insects of other insect orders, such as sawflies (Hymenoptera: Symphyta), gallmidges (Diptera: Cecidomyiidae) and aphids (Sternorrhyncha: Aphidoidea) (Christersson et al., 1992; Gruppe et al., 1999; Helbig & Müller, 2008). Beetle species belonging to the *Phratora* and *Chrysomela* genera can cause major damage (Coyle et al., 2002; Helbig & Müller, 2008 and 2009). Leaf beetles (Chrysomelidae), which occur in remarkably high numbers in German poplar plantations, include *Chrysomela populi* (Helbig & Müller, 2008; Schulz et al., 2008b) and *Chrysomela tremulae* (Helbig & Müller, 2008).

Due to the overwhelming diversity of invertebrates, investigations have to be limited to individual indicator groups. Up to now, earthworms (Lumbricidae; Makeschin et al., 1989; Makeschin, 1994), web-spinning spiders (Blick & Burger, 2002; Blick et al., 2003) and butterflies (Britt et al., 2007; Haughton et al., 2009) have been investigated in SRCs. In other studies, epigeic arthopods are surveyed on the order and family level (Britt et al., 2007; Liesebach et al., 2000; Schulz et al., 2008b), or guilds such as flower-visiting insects (Reddersen, 2001) or as canopy-invertebrates (Sage & Tucker, 1997). The invertebrate group studied in greatest detail in SRC are ground beetles (Carabidae) (Allegro & Sciaky, 2003; Liesebach & Mecke, 2003; Britt et al., 2007; Schulz et al., 2008b; Lamersdorf et al., 2008). Species numbers ranging from 10 to 43 were discovered on SRC. These numbers are of little significance, however, if they are not related to adjacent habitats and to the various influencing factors. This will be enlighted in the following chapters.

3 Comparison with other forms of land use

Haughton et al. (2009) summarise that compared with cultivated areas of energy crops such as oilseed rape, SRCs have particular advantages as bioenergy sources:

- they are not food crops
- there is no annual cultivation cycle
- they achieve rapid growth with the potential to produce large yields with low fertilizer and pesticide requirements
- there are only a few disturbances in the growing period
- harvesting is carried out in winter and causes therefore less disturbance
- there is a greater richness of spatial structures.

This has an overall positive effect on the biodiversity. Animals that depend heavily on the vertical structure, such as many breeding birds, can benefit from the growth characteristics of SRC. This is particularly the case when SRCs are planted in an agricultural landscape with little structural diversity. Many insect groups benefit from the decreased use of pesticides in SRCs and earthworms e.g. are favoured by the longer soil rest period, for instance (Makeschin, 1989; Makeschin, 1994). Liesebach et al. (2000) demonstrate that a higher diversity of epigeal invertebrates is present in a SRC than in a barley field. Britt et al. (2007) found a greater abundance and diversity of butterflies (Lepidoptera) and a higher number of springtail species (Collembola) in hybrid poplar fields than in agricultural fields. Regarding arachnids, Blick & Burger (2002) and Blick et al. (2003) found more individuals and species of arachnids in German SRCs than on nearby agricultural crop land. Blick et al. (2003) found three times as many species of each of the groups Aranea, Opilionida and Pseudoskorpiones, and a total of 85 species in an SRC, compared with 72 species on the agricultural crop land.

But most research has been conducted on breeding birds and ground beetles (see chapter 2). According to this they will be considered in greater detail in the following.

Birds

Results obtained in the USA, the UK, and Sweden confirm that bird abundance and diversity is generally high in short rotation coppices (Anderson et al., 2004; Berg, 2002; Dhondt & Sydenstricker, 2000; Dhondt et al,. 2007; Sage & Robertson, 1996). Christian et al. (1997) found a greater avian species richness in SRCs in the north of central-western USA (Minnesota, Wisconsin and South Dakota) and more individual breeding birds than on agricultural crop land, but fewer than in woodland. Liesebach & Mulsow (2003) found more birds in a German SRC than in surrounding fields and fewer than in a neighbouring spruce forest. After analysing in depth the numbers of breeding birds in swedish willow SRCs, Berg (2002) came to the conclusion that bird species-richness in the SRCs was high compared with open farmland sites dominated by other crop-fields, but lower than that in forest edge habitats. Thus, SRCs also perform better than other biomass crops and arable crops when species-richness of breeding birds is considered only. Regarding to the habitat potential for endangered species or more specialized birds SRCs are generally of lesser value. In comparison to open grasslands, fallows or even arable lands they offer a considerably lower habitat potential for many avifaunistic elements of open lands – especially for demanding species (Gruß & Schulz, 2009; Rowe et al., 2007; Sage et al., 2006)

Ground beetles

A different picture emerges with regard to the ground beetles (Coleoptera: Carabidae) sampled by pitfall trapping, however. They are species-poorer in some SRCs than on agricultural crop land. Britt et al. (2007) found significantly more ground beetle species in arable fields than in poplars on english sites. Also, fewer species of ground beetle were found in various North German SRCs than on the neighbouring intensively farmed agricultural crop land (Liesebach & Mecke, 2003; Lamersdorf et al., 2008; Brauner & Schulz, 2009).

In the course of the investigations in Northern Germany Brauner & Schulz (2009) detected that particularly during the first years of a SRC species communities of persistent ruderal sites and species of arable weed societies reached in SRCs the greatest shares in species richness and abundances. The fraction of typical forest species rises significantly with increasing age of the stands. Thus, generally those species are only appearing in stands with longer rotation periods (see chapter 4.1).

Besides the age of stands of SRCs the distance to other forest patches might be of crucial importance for the number of occurring ground beetle species. Hence in larger long-term isolated forest patches fewer Carabids typical for forests were found than in smaller and younger forest patches that were less isolated (Gruttke, 1997).

The most in-depth research into ground beetles was conducted by Allegro & Sciaky (2003). They studied ground beetle assemblages for about ten years in different age groups of poplar stands distributed over a vast territory of the Po Valley in Italy. The number of species found in the different poplar stands varied between 10 and 39 without any correlation with factors such as habitat typology or age of the poplar stand (1 year old to 10 years old). But they captured 46 species in a maize-cultivated area (Allegro & Sciaky, 2003). In North-Eastern Germany Brauner & Schulz (2009) recorded the highest number of species in the recently planted or harvested SRCs. These are comparable to the numbers that could be found in the adjacent arable land.

Heterogeneity and spatial structures play a critical habitat role on SRCs. Many intensively managed poplar plantations have little ground vegetation, as a result of chemical or mechanical weed control early in the rotation cycle and of canopy shading later in the rotation (Christian et al., 1998). Others have gaps in the canopy that allow other plant species to grow, differences in canopy height or woody debris (Christian et al., 1998). This has strong influences on animal diversity.

Thus, it cannot be stated generally that SRCs have a positive effect on biodiversity. Instead, one has to differentiate between animal groups, between spatial structures and ecological conditions of SRCs. In addition, the respective landscapes concerned need to be considered and certain influencing factors such as age and form of the area taken into account. The following chapters will reveal how these and other factors can affect the animal diversity of SRCs.

4 Impact of environmental factors

4.1 Impact of age

It is not surprising that animal use changes with SRC age (Christian et al., 1998). Poplar and willow plantations change very quickly due to their rapid increase in height. Thus, the habitat conditions relevant to animals such as spatial structure, structural density, complexity of vegetation, shade and humidity also change. Berg (2002) measured increasing bird species numbers with increasing height of *Salix* plantations. Different bird species are associated with different age classes of SRCs (Sage et al., 2006; Jedicke, 1995; Gruß & Schulz, 2008). According to Christian et al. (1998) and Londo et al. (2005), three phases of an SRC can be identified: open area phase, shrub-like stands and tree-like forms. In the breeding bird studies carried out by Dhondt & Sydenstricker (2000), Berg (2002), Sage et al. (2006) and Gruß & Schulz (2008, 2009), the highest numbers of species and the greatest breeding density were found in the second, shrub-like development phase.

In poplar and willow SRCs of northern Germany the largest numbers of species (15 to 19) and individuals (45 breedingpairs/10 ha) were to be found in the 2 to 5 year-old plots but only 3 to 5 species (3.5 to 19 bp/10 ha) in the open area phase (Gruß & Schulz, 2009)

In the open area phase, after planting or harvesting of the SRC, despite the low number of species, sometimes species with conservational value were found. For example the skylark (*Alauda arvensis*) was observed to breed on recently harvested SRC in Britain (Sage et al., 2006) and in Germany (Gruß & Schulz, 2009).

As the age and growth height of SRCs increase, the avian species communities change and shift from open land species to forest species. This was proven not only for breeding birds (Dhondt et al., 2007; Sage et al., 2006; Gruß & Schulz, 2008), but also for web-spinning spiders (Araneae; Blick & Burger, 2002) and ground beetles (Carabidae; Allegro & Sciaky, 2003; Schulz et al., 2008b; Brauner & Schulz, 2009). Besides the change in species composition, the diversity of animal species declines again.

A short rotation coppice in northern Germany contained a lower number of breeding birds after 13 years' growth than in younger phases (Gruß & Schulz, 2009). Thirteen years is longer than the rotation period of 3 to 4 years common in practice, however and will not occur very often in future SRCs.

Allegro & Sciaky (2003) detected with increasing age of poplar plantations in the italian Po Valley the species spectra of ground beetles shift clearly from communities of the open areas to those of forests. A research in pine afforestations in the lignite open-cast mining area of the Lausitz (Kielhorn, 2004) indicates that numbers of species and abundances of characteristic forest species did not increase until reaching 15 years of stand age. Furthermore, the investigations of Brauner & Schulz (2009) show that only for longer rotation periods an increase of species typical for forests and their initial succession stages was evident. Here ground beetles of the forests occured in a poplar plantation of 8 years with 12 species as being 40 % of the total species amount and with 12 % of the total amount of individuals. However, these species mostly have a broader ecological amplitude.

Sixty-year-old poplar plantations in Poland represent an extreme example. Even in this case the ground beetle species numbers were lower than in the adjacent arable land (Ulrich et al., 2004) and the community contained mainly ubiquitous species with unspecific requirements. There were no habitat specialists not occurring elsewhere in the adjacent rural environments. Ulrich et al. (2004) conclude that poplar plantations neither reach species diversities of at least seminatural forests nor enhance regional species diversity.

4.2 Impact of choice of tree

Different hybrids of poplar species (*Populus* sp.) and willow species (*Salix* sp.) are selected for cultivation in short rotation coppices. Robinia (*Robinia pseudoacacia*) is increasingly used in areas of eastern Germany with low precipitation (Knust, 2009).

There are various reasons why the choice of trees affects the colonization of an SRC by animals. Because their structural richness is generally greater, blocks of willow are home to more breeding birds than blocks of poplar (Dhondt et al., 2007; Gruß & Schulz, 2008). Willow SRCs in England contained more resident and migrant songbird species than poplar SRCs (Sage & Robertson, 1996). Furthermore, the male and female flowers of the willow (*Salix viminalis*) are an important food source for bees, bumblebees and other flower visitors. Overall, willow SRCs contain more invertebrates than poplar SRCs (Sage & Tucker, 1997). As a result, willow SRC offer breeding birds more favourable conditions for nest-building and foraging (Sage et al., 2006).

The potential biodiversity of arthopods that directly populate the individual trees and plants – particularly phytophagous beetles and butterflies – can vary significantly between tree and plant genera. Kennedy & Southwood (1984) only found two species of insects on the *Robinia* genus, which is a neophyte in Europe, but 450 on *Salix.* Willows are known to provide a habitat for more arthropod species than most other trees. Brändle & Brandl (2001) compiled the numbers of insect and acarian species on various trees and plant genera and concluded that, in general, the *Salix* genus displays the greatest potential of animal diversity with 728 species, followed by *Quercus* with 699 species, *Betula* with 499 species and *Populus* with 470 species.

There are other differences within the tree and plant genera. According to Hondong (1994), 34 species of pollen-collecting wild bees populate *Salix caprea* (in southern Germany), of which nine are oligolectic, whereas only 16 species populate *Salix alba*, for example (of which five are oligolectic). In general, Thüring (2007) demonstrated, on the basis of literature reviews, a higher zoodiversity for native autochthonous tree and plant species (e.g. *Salix caprea*) than for allochthonous trees and plants (e.g. *Salix daphnoides*; summarised in Schulz et al., 2008b). On the whole, poplar species were cited as host plants for phytophagous insects less frequently than willow species (Thüring, 2007).

However, these theoretical numbers of species cannot be transferred to the willows and poplars in SRCs even in approximate terms. Much lower numbers of species of phytophagous arthropods are to be anticipated on the densely planted, young short-rotation trees with a lower richness of structure. Up to now, very little has been published on the actual colonization of SRCs by phytophagous insects – aside from the key pests studied by Sage & Tucker (1997) and Helbig & Müller (2009). Studies of the biodiversity of phytophagous insects (Coleoptera, Lepidoptera, Auchenorrhyncha) were carried out in poplar SRCs in northern Germany (Kreinsen, 2008; Kubis, 2008; Schulz et al., 2008). The species richness, which included 51 species of phytophagous beetle (Kreinsen, 2008) and 35 species of leafhoppers (Kubis, 2008), was on the low side. In addition, most species found are not associated with the poplars themselves, but instead are eurytopic or typically inhabit the grass and ground vegetation layer.

4.3 Impact of clone choice

Very few studies have been carried out into the influence of clone choice on colonization by animals. The research papers published by Dhondt & Sydenstricker (2000) and Dhondt et al. (2004) which focus on North American SRC plantations provide an initial point of reference. They report that certain bird species favour certain clones when selecting a nesting site. Dhondt & Sydenstricker (2000) found 41 % of the nests in the poplar clone S365, but only 24 % in the poplar clone NM6. This can obviously vary between bird species. For example, the American Goldfinch (*Carduelis tristis*) favours the poplar clones S25 and SA2, yet eschews NM6 (Dhondt & Sydenstricker, 2000). The American Robin (*Turdus migratorius*) behaves in the exact opposite way and favours NM6. The choice of nesting site appears to be influenced by the branching pattern of the respective clone. To increase the attractiveness for several breeding birds, Dhondt et al. (2004) therefore recommend a mix of different clones when establishing large-scale SRC plantations and not planting clones such as S301, as these are avoided by breeding birds.

Helbig & Müller (2009) also recommend polyclonal plantations, since these could minimize the damage caused by leaf-eating insects. According to Kendall & Wiltshire (1997) and Peacock & Herrick (2000), the defoliators display very diverse, species-specific food preferences, which depend on the chemical ingredients of the plants which differ among the clones.

Very little research has been conducted on the influence of different species or clones on the biodiversity of invertebrates, however. Initial observations have been made of caterpillars of various butterfly species which feed on willow and poplar hybrids in German SRCs. The butterfly species *Cerura vinula* and *Scoliopteryx libatrix* have been discovered on the poplar hybrid Max 5 (*Populus maximowiczii* x *nigra*) and the Eyed Hawk Moth (*Smerinthus ocellatus*) has been spotted on the willow hybrid Tora (*Salix schwerinii x Salix viminalis*) (Schulz et al., 2008b). Only isolated sightings were made of monophageous beetles that rely on Salicaceae, however.

Up to now, two mechanisms of action via which different willow and poplar clones can affect the biodiversity of animals are known about: by way of different structural patterns (e.g. branchings) in the case of breeding birds, and by way of plant ingredients in the case of herbivorous insects. It is also conceivable that foliation and consequently also shade have an effect on colonization by thermophile insects, for instance.

4.4 Impact of plantation size

Christian et al. (1998), Cunningham et al. (2004) and Sage et al. (2006) came to the conclusion that significantly more bird species with a higher concentration of individuals populate the periphery of the SRC and that the most obvious effect of plantation size on biodiversity is the higher proportion of edge habitat in small plantations. On large plantations lower overall bird densities were observed in plantation interiors than on edges (Christian et al., 1998). Sage et al. (2006) summarized that the interior of large SRC plots contained fewer birds than the edge-Zone (< 50 m). This ecotone effect also becomes apparent when other groups of animals are considered (Cunningham et al., 2004). From this it can be derived that under certain conditions, smaller areas of energy wood are more favourable from an animal ecology perspective, as they boast a higher proportion of peripheral areas than large-area SRCs (Londo et al., 2005). For the same reasons, elongated sites would be more preferable in comparison to quadratic sites, for instance.

This statement needs to be qualified for freshly planted and/or freshly harvested areas, however, as well as for SRCs which are highly heterogeneous due to the loss of individual blocks of plants, and which therefore feature a patchwork of trees and shrubs and open areas. Concentrations of breeding pairs in the peripheral areas and/or a decrease in density towards the center of the crop are less conspicuous here (Gruß & Schulz, 2008).

4.5 Impact of location

The biodiversity of an SRC is influenced to a large degree by the surrounding landscape. Berg (2002) emphasised the strong influence of adjacent habitats on bird community composition in the SRCs. He found major differences between bird communities depending on whether the SRC bordered onto woodland or open land, for example (Berg, 2002). In Ontario (USA) more bird species occurred on poplar plantations adjacent to both forest and open habitats than those in uniform settings (Christian et al., 1998).

The conservational significance of the surrounding landscapes also becomes apparent when initial comparisons are drawn between SRCs in western and eastern Germany. Thus, bird species on Brandenburg's Red List, such as the Corn Bunting (*Emberiza calandra*) and Wood Lark (*Lullula arborea*), which are completely absent from west German SRCs, have been spotted in freshly harvested poplar plantations (Gruß & Schulz, 2009). That might be ascribed to the stable populations and source habitats on agricultural land in eastern Germany (Flade et al., 2006).

On the other hand, SRCs are supposed to affect the biodiversity of the surrounding landscape. Planting SRCs has a positive effect on the biodiversity in cleared landscapes, but a negative effect in valuable open countryside (Sage et al., 2006). In general, Berg (2002) and Sage et al. (2006) state that the planting of SRCs in open farmland plains will have positive effects on bird diversity by increasing the structural diversity of the landscape. In England Haughton et al. (2009) demonstrate that the abundance of total butterflies and most butterfly families was significantly greater in field margins surrounding SRC willow than in field margins of arable crop. However, Sage et al. (2006) also recognise possible negative effects and presume that it is highly likely that less widespread species would (also) be displaced by SRC or other energy crops, e.g. on arable land. They cite the rare Montagu's Harrier (*Circus macrourus*) and Corncrakes (*Crex crex*) as examples of affected bird species which are reliant on open country.

4.6 Impact of accompanying structures

In agro-ecosystems, species richness is often correlated with the spatial heterogeneity of the environment (Freemark, 1995; Hendrickx et al., 2007). Structurally rich blocks of trees and heterogeneously composed SRCs increase the diversity and the density of breeding birds (Berg, 2002; Sage et al., 2006; Gruß & Schulz, 2008). In particular, the diversity of vertebrates and invertebrates in SRCs can be greatly increased by accompanying structures in boundary and internal border areas. Marginal farmland habitats such as hedgerows and grass land margins provide valuable wildlife habitats (Anderson et al., 2004; Kühne & Freier, 2001; Röser, 1989). Such accompanying structures can also be represented in SRCs by sunlit interior borders (along the farm tracks between blocks of poplar) and by peripheral hedges, for instance. Few studies have been conducted in this area. Thus, for example, four butterfly species were found in the interior of an 8-year-old poplar plantation in Germany; however, 14 butterfly species were found in a relatively euphotic internal border with a width of around 15 m between two blocks of poplar (Schulz et al., 2008b; Brauner & Schulz, in prep.). In addition, a hedge approximately 3 m wide (which included field maple, hawthorn and other shrubs) at the edge of the SRC was studied. The largest number of ground beetles was discovered here (Sachs, 2007; Schulz et al., 2008a), as well as high densities of breeding birds, butterflies and grasshoppers (Gruß & Schulz, 2009; Brauner & Schulz, in prep.).

5 Recommendations

Up to now, in this review only the absolute numbers of animal species have been considered, without any attention being paid to the actual species concerned. The quality of the species encouraged or discouraged is crucial from a conservational point of view, however. Overall, small numbers of specialists and much larger numbers of generalists have been found in SRCs (see chapter 2). The detected spectra contained mainly eurytopic species which are common in woods, arable lands and ruderal habitats.

The surveys suggest that hybrid poplar or willow plantations are not likely to provide wildlife habitats of major significance, but are likely to contribute to increased biodiversity in many agricultural areas (Britt et al., 2007). Very few Red List species were discovered, however (Anderson et al., 2004; Berg, 2002; Gruß & Schulz, 2008 and 2009; Jedicke, 1995; Sage et al., 2006). Bird species of conservational value were most frequently found in recently planted or harvested SRCs, as some threatened open land breeders are able to find replacement habitats here (see chapter 3).

Like afforestation SRC offer chances and risks to nature conservation and landscape management (Klein, 1997). Overall, the conservational value of SRCs can generally be improved by encouraging habitat diversity. This includes the spontaneous development or establishment of hedges, external and internal boundaries, outer zones and borders – or even gaps within the SRC (Jedicke, 1995; Schulz et al., 2008c; Schmidt & Glaser, 2009).

Sage et al. (2006) state that if biomass crops become more widely grown, it is likely that economies of scale will encourage the planting of large, uniformly managed blocks, harvested at the same time. Under such a scenario, there could be a potential benefit in developing agri-environment options to encourage smaller plantings, the splitting of blocks by rides and hedges, and rotational harvesting in mixed age-class blocks (Sage et al., 2006). Jedicke (1995) proposes that, when planning SRCs, 10 % of the area should be reserved for smaller habitats, such as islands of field wood, stepped wood boundaries and strips of grass. Rowe et al. (2007) summarise that SRCs should be designed with a large edge to interior ratio, a mix of varieties and clones should be used, and willow clones with a range of flowering times. Furthermore, the use of pesticides should be limited (Rowe et al., 2007).

A crucial point, however, is the location of the SRC. Berg (2002) suggested that plantations should be avoided close to habitats of high conservation values, such as wet meadows. Conservationally valuable areas of Germany where SRCs should not be planted also include xerothermal grassland, marsh areas, ground nesting areas and river meadows (Jedicke, 1995; Völkl, 1997). For example the conversion of grassland into short-rotation poplar plantations causes a significant change in the diversity of species, but the cultivation of maize would be more unfavourable (Rösch et al., 2009). Set-asides, where birds and insects that favour fields and meadows can replenish their population, and the negative curtain effect associated with the occurrence of meadow breeders also need to be considered (Jedicke, 1995; Lee & Elsam, 2008). SRC on infields in forest-dominated landscapes will have negative effects, since the mosaic structure (i.e. mixture of open and forested habitats) will disappear, and relatively few forest species are favoured by *Salix* plantations (Berg, 2002).

Some open farmland birds, like sky lark, have been recorded in recently harvested SRC (Sage et al., 2006; Gruß & Schulz, 2009), suggesting that including a range of harvesting cycles in large plantations could reduce negative effects (Sage et al., 2006; Rowe et al,. 2007). Rowe et al. (2007) state nevertheless for English willow SRC, that the rapid growth rate may limit the effectiveness of this method, and a few bird species such as stone curlew (*Burhinus oedicnemus*) are likely to be negatively affected by establishment of SRC regardless of harvest cycle.

For the future, it is crucial that priority areas and restricted areas for SRCs are established on the basis of Gruttke (1997) and Jedicke (1995). Schmidt & Glaser (2009) make valuable suggestions. They have developed a decision algorithm that can be used to select and/or exclude areas that may be suitable for SRC on the basis of various nature conservation criteria.

6 Future research questions

In the future, the various development phases must be defined more precisely when studying biodiversity in SRCs, and their effects compared in greater detail. Christian et al. (1998) have already pointed out that, as plantations of a variety of sizes, ages, intensities of management, and landscape contexts become available, it will be imperative that biodiversity studies continue. This still applies, particularly with regard to the conditions in Central Europe. Regional distinctions and, in particular, the influence of the surrounding landscapes on the diversity of SRCs and the influence of SRCs on the diversity of the surrounding landscapes need to be considered. And the impact of hybridization of poplar and willow clones with autochthonous trees has to be scrutinized (Rotach, 2004; Schmitz et al., 2008).

Not all conclusions drawn with regard to biodiversity in SRCs in other countries are applicable to Germany. The extensive bird studies carried out by Berg (2002) were performed largely in Swedish *Salix* plantations, for instance. However, poplar plantations, which obviously have a lower biodiversity, dominate in Germany (Sage at al., 2006; Gruß & Schulz, 2008). No research whatsoever has been carried out in areas planted with robinia.

Furthermore, the distribution areas, ecological plasticities and population densities of animal species are of course different in Northern Europe than in Central Europe. This is apparent from the relatively extensive bird studies carried out in the past. Game birds, for instance (mainly pheasant and partridge), of which there is a relatively high abundance in British and Swedish SRCs (Berg, 2002; Sage & Robertson, 1996), have not been discovered in any Germany SRC up to now (Jedicke, 1995; Liesebach & Mulsow, 1995; Liesebach & Mulsow, 2003; Gruß & Schulz, 2008; Gruß & Schulz, 2009).

Furthermore, most studies into animal diversity carried out in the past have taken place in pre-commercial short-rotation coppices. But it makes a difference whether small sample areas or large plantations used for commercial purposes are studied. There were often gaps in the overall crop in pre-commercial plantations, due to poplar or willow hybrids of various origins being tested, and due to trees which had died. Such gaps in the canopy allow other plant species to grow and other animal species to settle. Therefore, these gap-habitats can considerably enrich the biodiversity and ultimately reflect structural complexity and abiotic conditions that are not to be expected in future commercial SRCs. Particularly in Germany, commercial SRCs which have been planted recently are considerably larger and more homogeneous than the sample areas.

In the future, large commercial SRC might generate high pest levels. Agroforestry has been assumed to reduce pest outbreaks usually associated with monocultures (Altieri & Nicholls, 2004). It should be investigated how such benefits from biological interactions could be achieved in SRC.

Furthermore, more indicator groups than previously should also be selected. Up to now, only the bird group has been studied in depth. But evidence from well-studied animal and plant taxa in Britain shows that areas rich in species for one group, such as birds, may be depauperate for a different group, such as the butterflies (Trevelyan & Pagel, 1995). Consequently, several indicator groups that complement one another in terms of their ecological properties and habitat requirements need to be studied in the future. These should include members of species-rich invertebrate groups and species groups with little mobility. More research is required to investigate the effect of SRC plantations on either euedaphic or hemiedaphic species of soil invertebrates (Rowe et al., 2007).

Comparisons with traditional coppices could be useful for deriving suggestions for enriching biodiversity in SRCs. Traditional coppices are centers of especially high biodiversity (LANUV, 2007) and it may be the case that the biodiversity in SRCs can be increased by adopting structures and characteristics typical of traditional coppices. For English plots, Sage & Robertson (1996) report that the songbird species using the SRC survey plots were similar to those reported from traditional coppice habitats. There is entirely contradictory information with regard to German plots, however (Jedicke, 1995; LANUV, 2007; Blankenstein, 2007). This is another indication of the different characteristics and environmental effects of woody biomass crops within the various countries of Europe.

In the future, in terms of conservation values, it seems to be worth to put more emphasis on qualitative aspects of SRCs' coenotic composition, its surroundings and the areas where SRCs are supposed to be established, respectively. So far most studies merely consider species-richness as a parameter of a conservation value. But, due to the prospective habitat loss especially for demanding or even endangered species of open lands by establishing SRCs the evaluation of this land use should focus more intensively on such distinguishing faunistic elements and accordingly the habitat potential of SRCs for those species. Target species for future monitoring programmes should then be derived from biocoenotic studies and subsequent nature conservational assessments (Schmidt & Glaser, 2009).

Furthermore, future in-depth research is recommended which deals with the similarities and differences in species composition and abundances that exist between SRCs and forest ecosystems.

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References

Allegro G, Sciaky R (2003) Assessing the potential role of ground beetles (Coleoptera, Carabidae) as bioindicators in poplar stands, with a newly proposed ecological index (FAI). For Ecol Manage 175:275–284

Altieri MA, Nicholls CI (2004) Effects of agroforestry systems on the ecology and management of insect pest populations. In: Geoff G, Wratten SD, Altieri MA (eds) Ecological engineering for pest management : advances in habitat manipulation for arthropods. Ithaca NY : Comstock Publ, 232 p

Anderson GQA, Haskins LR, Nelson SH (2004) The effects of bioenergy crops on farmland birds in the United Kingdom : a review of current knowledge and future predictions. In: Biomass and agriculture : sustainability, markets and policies; OECD workshop, Vienna, 10-13 June 2003. Paris : OECD, pp199-218

Anderson J (1975) The enigma of soil animal species diversity. In: Vanek J (ed) Progress on soil zoology : proceedings of the 5th International Colloquium on Soil Zoology held in Prague September 17 - 22, 1973. Prag : Academia, pp 51-58

Berg A (2002) Breeding birds in short-rotation coppices on farmland in central Sweden : the importance of *Salix* height and adjacent habitats. Agric Ecosyst Environ 90(3):265–276

Bergstrom R, Guillet C (2002) Summer browsing by large herbivores in short-rotation willow plantations. Biomass Bioenergy (23):27–32

Blankenstein G (2007) Die Vögel (Aves) im „Historischen Hauberg Fellinghausen". LANUV-Fachber 1:221-232

Blick T, Weiss I, Burger F (2003) Spinnentiere einer neu angelegten Pappel-Kurzumtriebsfläche (Energiewald) und eines Ackers bei Schwarzenau (Lkr. Kitzingen, Unterfranken, Bayern). Arachnol Mitt 25:1–16

Blick T, Burger F (2002) Wirbellose in Energiewäldern : am Beispiel der Spinnentiere der Kurzumtriebsfläche Wöllershof (Oberpfalz, Bayern). Naturschutz Landschaftsplanung 34(9):276–284

Brändle M, Brandl R (2001) Species richness of insects an mites on trees expanding Southwood. J Anim Ecol 70:491–504

Brauner O, Schulz U (2009) Laufkäfer auf Energieholzplantagen und angrenzenden Vornutzungsflächen (Carabidae: Coleoptera) : Untersuchungen in Sachsen und Brandenburg. [in prep.]

Brauner O, Schulz U (2009) Heuschrecken (Saltatoria) und Tagfalter (Lepidoptera: Rhopalocera & Hesperiidae) auf Energieholzplantagen und angrenzenden Vornutzungsflächen in Brandenburg, Hessen, Niedersachsen und Sachsen. [in prep.]

Britt C, Fowbert J, McMillan SD (2007) The ground flora and invertebrate fauna of hybrid poplar plantations : results of ecological monitoring in the PAMUCEAF project. Asp Appl Biol 82:83–89

Christersson L, Ramstedt M, Forsberg J (1992) Pests, diseases and injuries in intensive short-rotation forestry. In Mitchell C.P. (ed.) Ecophysiology of short rotation-forest crops. Elsevier Science Publisher, London, p. 185-216

Christian DP, Collins PT, Hanowski JM, Niemi GJ (1997) Bird and small mammal use of short-rotation hybrid poplar plantations. J Wildlife Manage 61(1):171–182

Christian DP, Hoffmann W, Hanowski JM, Niemi GJ, Beyea J (1998) Bird and mammal diversity on woody biomass plantations in North America. Biomass Bioenergy 14(4):395–402

Cunningham MD, Bishop JD, McKay HV, Sage RB (2004) ARBRE monitoring ecology of short rotation coppice [online]. Zu finden in <http://www.berr.gov.uk/files/file14870.pdf> [zitiert am 05.08.2009]

Dhondt AA, Sydenstricker KV (2000) Birds breeding in short-rotation woody crops in upstate New York : 1998 – 2000. In Volk TA, Abrahamson LP, Ballard JL (eds) Proceedings of the Short-Rotation Woody Crops Operations Working Group : 3rd Conference ; october 10-13, 2000, Syracuse, NY. Syracuse NY : Faculty of Forestry, pp137–141

Dhondt AA, Wrege PH, Sydenstricker KV, Cerretani J (2004) Clone preference by nesting birds in short-rotation coppice plantations in central and western New York. Biomass Bioenergy 27(5):429–435

Dhondt AA, Andre A, Wrege PH, Cerretani J, Sydenstricker KV (2007) Avian species richness and reproduction in short-rotation coppice habitats in central and western New York. Bird Study 54(1):12–22

FAO - Food and Agriculture Organisation (1979) Poplars and willows in wood production and land use. Rome : FAO, 328 p, FAO forestry series 10

Firbank LG (2007) Assessing the ecological impacts of bioenergy projects. Bioenerg Res 1(1):12-19

Flade M, Plachter H, Schmidt R, Werner A (2006) Nature conservation in agricultural ecosystems : results of the Schorfheide-Chorin Research Project. Wiebelsheim : Quelle & Meyer, 706 p

Freemark K (1995) Assessing effects of agriculture on terrestrial wildlife : developing a hierarchical approach for the US EPA. Landscape Urban Planning 31:99–115

Groom MJ, Meffe GK, Carroll CR (2006) Principles of conservation biology. Sunderland : Sinauer, 793 p

Gruppe A, Fußeder M, Schopf R (1999) Short-rotation plantations of balsam poplar and aspen on former arable land in the Federal Republic of Germany: Defoliating insects and leaf constituents. Forest Ecology and Management 121:113-122

Gruß H, Schulz U (2008) Entwicklung der Brutvogelfauna auf einer Energieholzfläche über den Zeitraum von 13 Jahren. Arch Forstwesen Landschaftsökol 40(2):75–82

Gruß H, Schulz U (2009) Brutvogelfauna auf Kurzumtriebsplantagen in Brandenburg, Hessen und Sachsen – Lebensraumpotential verschiedener Strukturtypen. Naturschutz Landschaftsplanung [in prep.]

Gruttke H (1997) Berücksichtigung tierökologischer Erfordernisse bei der Standortwahl für Aufforstungen in der Agrarlandschaft. SchrR Landschaftspflege Naturschutz (49):123–138

Haughton AJ, Bond AJ, Lovett AA, Dockerty T, Sünnenberg G, Clark SZ, Bohan DA, Sage RB, Mallott MD, Mallott VE, Cunningham MD, Riche AB, Shield IF, Finch JW, Turner MM, Karp A (2009) A novel, integrated approach to assessing social, economic and environmental implications of changing rural land-use : a case study of perennial biomass crops. J Appl Ecol 46:315–322

Helbig C, Müller M (2008) Potenzielle biotische Schadfaktoren in Kurzumtriebsplantagen. Cottbuser Schr Ökosystemgenese Landschaftsentwickl (6):101–116

Helbig C, Müller M (2009) Abiotische und biotische Schadfaktoren in Kurzumtriebsplantagen. In: Reeg T, Bemmann A, Konold W, Murach D, Spiecker H (eds) Anbau und Nutzung von Bäumen auf landwirtschaftlichen Flächen. Weinheim : Wiley-VCH, pp 227-230

Hendrickx F, Maelfait JP, Van Wingerden W, Schweiger O, Speelmans M, Aviron S, Augenstein I, Billeter R, Bailey D, Bukacek R, Burel F, Diekotter T, Dirksen J, Herzog F, Liira J, Roubalova M, Vandomme V, Bugter R (2007) How landscape structure, land-use intensity and habitat diversity affect components of total arthropod diversity in agricultural landscapes. J Appl Ecol 44:340–351

Henle K, Didier A, Clitherow J, Cobb P, Firbank L, Kull T, McCracken D, Moritz RFA, Niemelä J, Rebane M, Wascher D, Watt A, Young J (2008) Identifying and managing the conflicts between agriculture and biodiversity conservation in Europe : a review. Agric Ecosyst Environ 124(1-2):60-71

Hondong H (1994) Gattung *Populus* (Pappeln) : Sektionen, Arten, Standorte, Gesellschaftsanschluss, Gefährdung, Fauna, Epiphyten. Unveröff. Gutachten im Auftrag der Wasserwirtschaftsverwaltung Baden-Württ., Institut für Landespflege Univ. Freiburg

Jedicke E (1995) Naturschutzfachliche Bewertung von Holzfeldern : schnellwachsende Weichhölzer im Kurzumtrieb, untersucht am Beispiel der Avifauna. Mitt NNA (1):109-119

Johnson JMF, Coleman MD, Gesch R, Jaradat A, Mitchell R, Reicosky D, Wilhelm WW (2007) Biomass-bioenergy crops in the United States : a changing paradigm. Americas J Plant Sci Biotechn 1(1):1-28

Kendall D A, Wiltshire C W (1997) An applied study of clonal resistance to willow beetle attack in SRC willows. Report to the Energy Technology Support Unit (Department of Trade and Industry), Biomass Study B/M4/00532/2700, 38 p

Kennedy CEJ, Southwood TRE (1984) The number of species of insects associated with British trees : a reanalysis. J Anim Ecol (53):455–478

Kielhorn K-H (2004) Entwicklung von Laufkäfergemeinschaften auf forstlich rekultivierten Kippenstandorten des Lausitzer Braunkohlereviers – Cottbuser Schriften zu Bodenschutz und Rekultivierung 22:189 p

Klein M (1997) Erstaufforstung – Chancen und Risiken für Naturschutz und Landschaftspflege. SchrR Landschaftspflege Naturschutz (49):167–171

Knust C (2009) Kurzumtriebsplantagen – Stand des Wissens. In: Reeg T, Bemmann A, Konold W, Murach D, Spiecker H (eds) Anbau und Nutzung von Bäumen auf landwirtschaftlichen Flächen. Weinheim : Wiley-VCH, pp 1–9

Kreinsen B (2008) Zoodiversität auf Energieholzflächen : Erfassung der Käferfauna auf Weiden- und Pappelplantagen bei Cahnsdorf (Süd-Brandenburg). Eberswalde : Fachhochschule, 71 p, [Masterarbeit]

Kubis W (2008) Erfassung der Zikaden (Auchennorrhyncha) auf den Kurzumtriebsplantagen Cahnsdorf in Südbrandenburg und Thammenhain in Nordsachsen. Eberswalde : Fachhochschule, 72 p, [Diplomarbeit]

Kühne S, Freier B (2001) Saumbiotope in Deutschland – ihre historische Entwicklung, Beschaffenheit und Typisierung. Mitt Biol Bundesanst Land-Forstwirtsch 387:24-29

Lamersdorf N, Bielefeldt J, Bolte A, Busch G, Dohrenbusch A, Knust C, Kroiher F, Schulz U, Stoll B (2008) Naturverträglichkeit von Agrarholzanpflanzungen – erste Ergebnisse aus dem Projekt NOVALIS. Cottbuser Schr Ökosystemgenese und Landschaftsentwickl 6:19–32

LANUV (2007) Niederwälder in Nordrhein-Westfalen : Beiträge zur Ökologie, Geschichte und Erhaltung. Recklinghausen : Landesamt f Natur Umwelt Verbraucherschutz, 510 p, LANUV-Fachbericht 1

Lee E, Elsam R (2008) Abolition of set-aside in the EU threatens European farmland birds [online]. Zu finden in <http://www.birdlife.org/eu/pdfs/BirdLife_Biofuels_report> [zitiert am 05.08.2009]

Liesebach M, Mulsow H (1995) Zur Bedeutung des Biotops Kurzumtriebsplantage für den Sommervogelbestand. Beitr Forstwirtsch Landschaftsökol 29(1):32–35

Liesebach M, Mulsow H (2003) Der Sommervogelbestand einer Kurzumtriebsplantage, der umgebenen Feldflur und des angrenzenden Fichtenwaldes im Vergleich. Holzzucht 54:27–30

Liesebach M, Mecke R, Rose A (2000) Epigäische Wirbellosenfauna einer Kurzumtriebsplantage im Vergleich zu der eines angrenzenden Gerstenackers und der eines Fichtenwaldes. Holzzucht 53:21–25

Liesebach M, Mecke R (2003) Die Laufkäfer einer Kurzumtriebsplantage, eines Gerstenackers und eines Fichtenwaldes im Vergleich. Holzzucht 54:11–15

Londo M, Dekker J, ter Keurs W (2005) Willow short-rotation coppice for energy and breeding birds : an exploration of potentials in relation to management. Biomass Bioenergy 28:281–293

Makeschin F, Rehfuess KE, Rüsch I, Schörry R (1989) Anbau von Pappeln und Weiden im Kurzumtrieb auf ehemaligem Acker : standörtliche Voraussetzungen, Nährstoffversorgung, Wuchsleistungen und bodenökologische Auswirkungen. Forstwiss Centralbl 108(3):125-143

Makeschin F (1994) Effects of energy forestry on soils. Biomass Bioenergy (6):63–79

Menzel F, Schulz U (2007) Die Trauermücken in Deutschland : ökosystemare Bedeutung, zönologische Koinzidenzen und bioindikatorisches Potential (Diptera: Sciaridae). Beitr Entomol 57(1):9-36

Murach D (2009) Agrarholzanbau: quo vadis : ein Ausblick auf die Zukunft des Agrarholzanbaus. In: Reeg T, Bemmann A, Konold W, Murach D, Spiecker H (eds) Anbau und Nutzung von Bäumen auf landwirtschaftlichen Flächen. Weinheim : Wiley-VCH, pp 227-230

Peacock L, Herrick S (2000) Responses of the willow beetle *Phratora vulgatissima* to genetically and spatially diverse *Salix* plantations. Journal of Applied Ecology 37(5):821-331

Porder S, Bento A, Leip A, Martinelli LA, Samseth J, Simpson T (2009) Quantifying the environmental impacts of biofuel production : knowns and unknowns [online]. Zu finden in <http://cip.cornell.edu/biofuels/files/SCOPE14.pdf> [zitiert am 05.08.2009]

Prance Gt (1995) Biodiversity. In: Nierenberg WA (ed) Encyclopedia of environmental biology : vol IA – E. San Diego : Academic Press, pp 183–193

Reddersen J (2001) SRC-willow (*Salix* viminalis) as a resource for flower-visiting insects. Biomass Bioenergy 20(3):171-179

Reeg T, Bemmann A, Konold W, Murach D, Spicker H (2009) Anbau und Nutzung von Bäumen auf landwirtschaftlichen Flächen. Weinheim : Wiley-VCH, 355 p

Rode M (2005) Energetische Nutzung von Biomasse und Naturschutz. Natur Landsch 80(9/10):403–412

Rotach P (2004) Poplars and biodiversity. In: Koskela J (ed) *Populus* nigra network : report of the seventh (25-27 october 2001, Osijek, Croatia) and eighth (22-24 may 2003, Treppeln, Germany) meetings ; European Forest Genetic Resources Programme. Rome : IPGRI, pp 79-100

Röser B (1989) Saum- und Kleinbiotope : ökologische Funktion, wirtschaftliche Bedeutung und Schutzwürdigkeit in Agrarlandschaften. Landsberg/Lech : ecomed, 258 p

Rösch CJ, Skarka J, Raab K, Stelzer V (2009) Energy production from grassland : assessing the sustainability of different process chains under German conditions. Biomass Bioenergy 33:689–700

Rowe RL, Street NR, Taylor G (2007) Identifying potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK. Renewable Sustainable Energy Rev 13(1):271–290

Sachs D (2007) Erfassung der Laufkäfer (Carabidae) auf der Kurzumtriebsplantage Thammenhain in Nordsachsen und auf der Kurzumtriebsplantage Cahnsdorf in Südbrandenburg. Eberswalde : Fachhochschule, 77 p [Bachelorarbeit]

Sage R, Robertson PA (1996) Factors affecting songbird communities using new short rotation coppice habitats in spring. Bird Study 43(2):201–213

Sage R, Tucker K (1997) Invertebrates in the canopy of willow and poplar short rotation coppices. Asp Appl Biol 49:105-111

Sage R, Cunningham M, Boatman N (2006) Birds in willow short-rotation coppice compared to other arable crops in central England and a review of bird census data from energy crops in the UK. Ibis 148(1):184–197

Schmidt PA, Glaser T (2009) Kurzumtriebsplantagen aus Sicht des Naturschutzes. In: Reeg T, Bemmann A, Konold W, Murach D, Spiecker H (eds) Anbau und Nutzung von Bäumen auf landwirtschaftlichen Flächen. Weinheim : Wiley-VCH, pp 161-170

Schmitz U, Ristow M, May R, Bleeker W (2008) Hybridisierung zwischen Neophyten und heimischen Pflanzenarten in Deutschland. Natur Landsch (83):444–451

Schneider R (2006) Zoocoenoses and indicator species. In: Flade (ed) Nature conservation in agricultural ecosystems : results of the Schorfheide-Chorin Research project. Wiebelsheim : Quelle & Mayer, pp 134-137

Schulz U, Gruß H, Hoffmann V (2008a) Wirbeltiere auf Agrarholzflächen (Säugetiere und Brutvögel) : erste Ergebnisse aus dem Projekt NOVALIS. Cottbuser Schr Ökosystemgenese Landschaftsentwickl (6):167–169

Schulz U, Brauner O, Sachs D, Thüring M (2008b) Insekten an Pappeln und Weiden : erste Ergebnisse aus dem Projekt NOVALIS und Auswertung von Wirtspflanzenangaben. Cottbuser Schr Ökosystemgenese Landschaftsentwickl (6):171–173

Schulz U, Brauner O, Gruß H, Neuenfeldt N (2008c) Vorläufige Aussagen zu Energieholzflächen aus tierökologischer Sicht. Archiv Forstwesen Landschaftsökol 40(2):83–87

Thüring M (2007) Zoodiversität auf Weiden (*Salix* spp.) und Pappeln (*Populus* spp.). Eberswalde : Fachhochschule, 52 p [Bachelorarbeit]

Trevelyan R, Pagel M (1995) Species diversity. In: Nierenberg WA (ed) Encyclopedia of environmental biology : vol III O – Z. San Diego : Academic Press, pp 383–390

Ulrich W, Buszko J, Czarnecki A (2004) The contribution of poplar plantations to regional diversity of ground beetles (Coleoptera: Carabidae) in agricultural landscapes. Ann Zool Fenn 41(3):501-512

Völkl W (1997) Die Bewertung von Erstaufforstungen für den Biotop- und Artenschutz aus tierökologischer Sicht. SchrR Landschaftspflege Naturschutz (49):47–49

Volk TA, Verwijst T, Tharakan PJ, Abrahamson LP, White EH (2004) Growing fuel : a sustainability assessment of willow biomass crops [online]. Zu finden in <http://www.esf.edu/willow/pdf/2004%20esa_sustainability.pdf> [zitiert am 05.08.2009]

Wilson EO (1988) Biodiversity. Washington : National Academic Press, 557 p