The effects of local habitat quality and farming intensity on insect occurrence in intensive agricultural land

The effectiveness of increasing local habitat quality to support insect occurrence

Michiel Eijkelkamp, S3228754
9 December 2020
Conservation Ecology Group, GELIFES
Supervisor: R. H. G. Klaassen

Images front page, top left: common carder bee
Photographer: Frans
Source: Flickr (2008)

Images front page, top right: cinnabar
Own picture

Images front page, bottom left: common bluetail
Photographer: J. Exel
Source: personal communication, October 29, 2020

Images front page, bottom right: peacock
Photographer: J. Exel
Source: personal communication, October 29, 2020

Abstract

Worldwide, biodiversity is in decline. This also includes insects. Agricultural intensification is often reported as an important cause. Within intensive agricultural landscapes, semi-natural habitats are important for insects. But, the relative importance of the quality of these habitats and the farming intensity of the surroundings, remains unknown. We, therefore, studied the effect of local habitat quality of road verges and ditches on insect occurrence and the effect of farming intensity on local habitat quality and directly on insect occurrence (bumblebees, butterflies, day-flying moths, damselflies and dragonflies).

We studied 83 road verges and ditches in the southeast of Drenthe, the Netherlands, and the southwest of Lower Saxony, Germany. In these semi-natural habitats we counted insects. In addition, we monitored several indicators of local habitat quality, like flowering plant occurrence, and several indicators of farming intensity in the surroundings, like the crop types on the surrounding fields. We analyzed the correlations between local habitat quality, farming intensity and insect occurrence to reveal possible relationships.

We found that insect occurrence was positively affected by local habitat quality. Bumblebee and butterfly occurrence correlated, for example, with flowering plant abundance and damselfly and dragonfly occurrence with the clearness of the water. Farming intensity had no major effect, neither on insect occurrence nor on local habitat quality. From this we conclude that increasing the quality of semi-natural habitats can be an effective measure to support insect occurrence in intensive agricultural landscapes, which could contribute to the recovery of insect populations.

Index

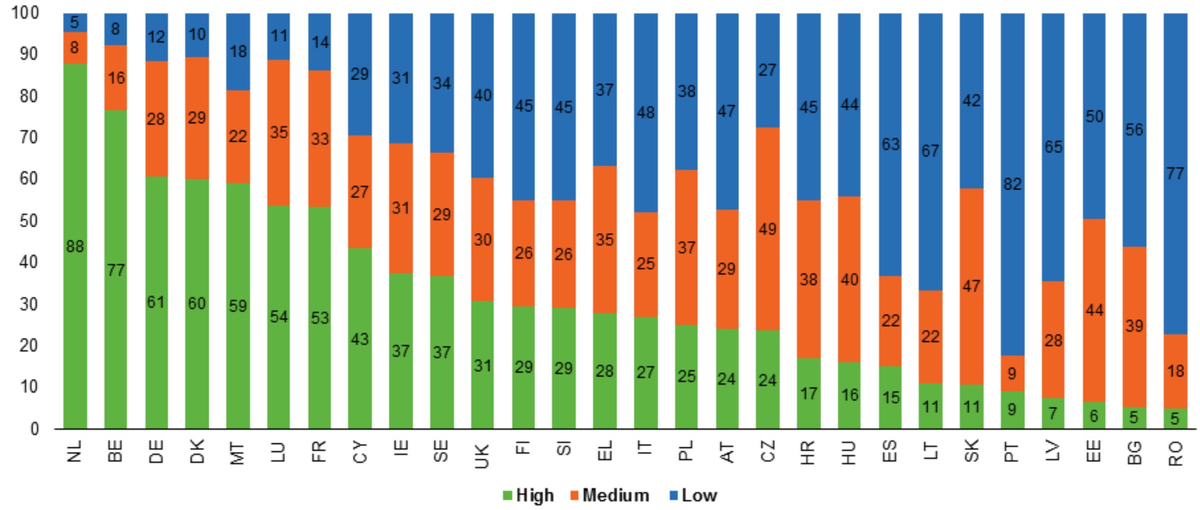
Introduction

Worldwide biodiversity is in decline. Between 1990 and 2014 populations have decreased by 60% (WWF, 2018). The most important causes for biodiversity decline are overexploitation and agriculture, according to the WWF (2018). In 2002 world leaders agreed on the importance of a significant decrease in the rate of biodiversity loss in 2010, as documented in the Convention on Biological Diversity. An evaluation of this goal in 2010 showed that biodiversity loss had continued at the same rate and that pressures on biodiversity, like nitrogen pollution and overexploitation, had further increased between 2002 and 2010. This means that biodiversity loss is still continuing and more effective measures are necessary to stop biodiversity loss (Butchart et al., 2010).

The main focus of studies on biodiversity loss has long been on vertebrate species, but recently more attention is paid to invertebrates, including insects. Wagner (2020) reviewed population trends of insects. His main conclusion was that insects are declining at an alarming rate, equal to or even faster than for plants and vertebrates. Rates of 1-2% loss per year have been reported for multiple insect groups and locations. A steep decline in insect abundance was also found by Hallmann et al. (2017) who studied flying insect biomass with malaise traps in 63 nature reserves in Germany. They concluded that total biomass of flying insects declined with more than 75% in 27 years.

Intensification of agriculture is one of the main causes of the decline of insects, according to many publications of insect decline in northern and western Europe (Wagner, 2020). For butterflies and pollinators, agricultural intensification is often mentioned as the primary cause of their decline (Wagner, 2020). In addition, 94% of the nature reserves studied by Hallmann et al. (2017) were enclosed by agricultural fields and Hallmann et al. (2017) present agricultural intensification as a likely cause of the decline in flying insect biomass.

Within Europe, the Netherlands is the country with the most intensified agricultural system (Eurostat, 2019). Figure 1 shows that 88% of the agricultural area in the Netherlands has a high level of input per unit of production, which is a higher proportion than in all other European countries. Interestingly, biodiversity slightly increased in the Netherlands over the period 1990-2014 (van Strien et al., 2016). Biodiversity in farmland areas, however, decreased steadily and this decrease is still continuing. The overall increase in biodiversity is largely explained by an increase in freshwater biodiversity, as a result of improved freshwater quality and expansion of wetland areas. Although this is a positive development, which proves that biodiversity can be restored, the ongoing decline of biodiversity in farmland is still alarming. Van Strien et al. (2016) state that this decline is probably caused by the very intensive agricultural system in the Netherlands.



Source: DG Agriculture and Rural Development, European Commission

Figure 1: The percentage of agricultural area in different European countries with a high, medium or low input per unit of production, in 2013 (Eurostat, 2019).

If we look at the population trends of insects in the Netherlands, many species are declining, but not all species. Kleijn et al. (2018) state that almost all scientists agree that insects as a group are declining in the Netherlands and the highly intensive agricultural practices in the Netherlands are an important cause for this decline. It is, however, not possible to determine a trend for insects as a whole, because standardized data is lacking for many insect families (Kleijn et al., 2018). Trends are only available for specific groups of insects. In their analysis of overall biodiversity van Strien et al. (2016) included two groups of insects: butterflies and dragonflies. Butterflies decreased by more than 50% independent of habitat (van Strien et al., 2016). Van Strien et al. (2019) confirmed that butterflies declined in the Netherlands. For their analysis van Strien et al. (2019) used random unstructured opportunistic observations by volunteers and professionals collected in 1890 to 2017 and they estimated that the total abundance of butterflies in the Netherlands decreased with more than 80%. Dragonflies showed an increase of 47.7% (van Strien et al., 2016). Termaat et al. (2015) also state that dragonflies are an insect group that is doing well in the Netherlands, which they contributed to improved habitat quality. Kleijn et al. (2018) looked at the total number of damselflies and dragonflies that is counted yearly on standardized monitoring routes in the Netherlands. They found no evidence for a decrease or increase. They, however, emphasized that only very few of the standardized monitoring routes were located in agricultural areas. Van Dooren (2019) looked at unstructured opportunistic observations on bees and bumblebees in the Netherlands. Although it appeared to be hard to analyze such unstructured data, his main conclusion was that bees and especially bumblebees had declined in the Netherlands. One of the methods that van Dooren (2019) used to analyze the data, indicated a decline of 19% of bumblebee species richness, between 1945 and 2018.

Because agricultural intensification is an important cause of insect decline, agricultural *extensification* would be a logical solution. Extensification, however, appears to be hard to achieve, because less intensive farming, like organic farming, has a lower yield than conventional more intensive farming (Wilbois & Schmidt, 2019). It is, therefore, interesting to investigate possibilities to increase insect occurrence within intensive agricultural landscapes. Semi-natural habitats, like road verges, field margins and ditches, play an important role for insects in agricultural areas. Tscharntke et al. (2005), for example, showed that the number of flower-visiting bee species increased when the area of semi-natural habitat increased within the agricultural landscape. Also the quality of the habitat appears to be important, as the number of insect species, for example, appears to be higher in semi-natural habitats with a higher flower abundance and diversity (Hoffmann, 2005). On the other hand, biodiversity in semi-natural habitats in intensive agricultural landscapes could be negatively affected by intensive farming in the surroundings (Goulson & Darvill, 2009). This could work in two ways (Figure 2). There could be a direct negative effect of farming, for example pesticide use, on insects or an indirect effect, in which intensive agriculture negatively affects the quality of semi-natural habitats (for example though fertilization or pesticides), which is negative for insects.

The relative importance of the effect of local habitat quality on insect occurrence and of farming intensity on local habitat quality and insect occurrence, remains unknown and this is the main topic of our study. This is important to know, because measures to improve the quality of semi-natural habitats could be a relatively easy way to support insect occurrence in intensive agricultural landscapes, but these measures would be ineffective in case the effect of agriculture, on local habitat quality or directly on insects, is very large (Figure 2).

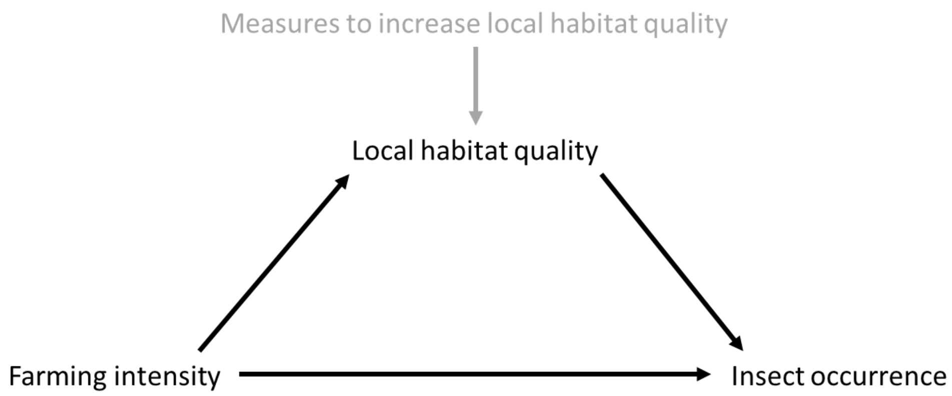


Figure 2: The relationships between farming intensity, local habitat quality of semi-natural habitats and insect occurrence, as investigated in this study. Measures to increase local habitat quality (grey) will not be investigated directly, but by studying the other effects, we can indirectly indicate whether measures to increase local habitat quality would be effective.

Hoffmann (2005) studied biodiversity in road verges and ditches in Drenthe, the Netherlands, including road verges and ditches in agricultural land. He divided the semi-natural habitats in three categories depending on the intensity of the environment: (1) the environment consists of intensive agriculture, (2) the environment consists of extensive agriculture or a combination of natural area and intensive agriculture, (3) the environment consists of natural area. Hoffmann (2005) found that the diversity of flowering plants is higher in road verges and ditches within a natural environment. This is an effect of land use intensity of the surroundings on local habitat quality in semi-natural areas. They also found that some insect groups (wasps and solitary bees) were affected, mostly negative, by land use intensity. Total insect occurrence, as well as different insects groups (for example butterflies, bumblebees and honeybees), were not affected by land use intensity. Besides that, Hoffmann (2005) found that the number of insect species is higher in road verges and ditches with a higher abundance and diversity of flowers. Flower abundance and diversity are measures for local habitat quality, so this indicates that local habitat quality is affecting the number of insect species in road verges and ditches in Drenthe. In general we can conclude from the study of Hoffmann (2005) that both local habitat quality and farming intensity have an effect on insect occurrence, but farming intensity only affects certain groups of insects and not total insect occurrence. We can also conclude that farming intensity affects local habitat quality.

Hoffmann (2005) used very broad categories for land use intensity, which means that there is variation in farming intensity within these categories. A reason for this is that the most intensive category of Hoffmann contains very different crop types and different crop types require highly different levels of fertilizers and pesticides (Wageningen University & Research, n.d.). This variation in farming intensity due to crop type could affect biodiversity. To be able to look at the effect of all variation in farming intensity on biodiversity, this study will look at the effect of farming intensity of the direct environment on insect occurrence and local habitat quality on a continuous scale.

In this study we will look at several insect groups: bumblebees, butterflies, damselflies and dragonflies. ‘Butterflies’ include some species of day-flying moths, because their ecology is similar to the ecology of butterflies (the term butterflies in this study refers to butterflies and these species of day-flying moths). Bumblebees and butterflies are interesting species groups to look at in this study, because these are the species groups that strongly declined due to intensification of agriculture, according to several studies (Wagner, 2020). Damselflies and dragonflies are also interesting, because their populations have been reported to remain stable or even increase (Termaat et al., 2015). Little is known, however, about the abundance of damselflies and dragonflies in agricultural areas. Furthermore, bumblebees, butterflies, damselflies and dragonflies are a good measure for insect occurrence, because they occupy different ecological and functional niches. Bumblebees and butterflies are pollinators and highly dependent on flower occurrence (Goulson & Darvill, 2009; Hoffmann, 2005), while damselflies and dragonflies are predators with a strong link to clean freshwater (Kaunisto et al., 2017; Termaat et al., 2015).

We conducted this study in intensively farmed landscapes in the southeast of the province of Drenthe, the Netherlands, and in the southwest of Lower Saxony, Germany. The main research question of our study was: ‘’How do farming intensity in the direct surroundings and local habitat quality affect the occurrence of bumblebees, butterflies, damselflies and dragonflies in road verges and ditches in intensively farmed agricultural land in the southeast of Drenthe and the southwest of Lower Saxony?’’

Answering this question is important for the conservation of biodiversity, especially insects, in intensive agricultural landscapes. Several conservation measures to increase biodiversity in agricultural land aim at improving local habitat quality, like creating herb rich field margins, planting hedgerows and planting single trees (Visser et al., 2008). The results of our study can be used to assess the effectiveness of these measures in different farming systems. If our study, for example, concludes that insect occurrence is very low in semi-natural habitats surrounded by very intensive farmland, independent of local habitat quality, then it would be ineffective to improve local habitat quality of semi-natural habitats in these agricultural areas without reducing the intensity of farming in the surroundings. In that case it would be more effective to improve the quality of semi-natural habitats in areas with less intensive agriculture. If, on the other hand, the outcome is that the intensity of farming in the surrounding of semi-natural habitats has little effect on insect occurrence, measures to improve the habitat quality of semi-natural habitats would be an easy and effective way to boost insect occurrence in intensive agricultural areas. In addition, this study could conclude that specific local habitat quality characteristics have more effect on insect occurrence than others, so possible something can be said afterwards about which characteristics of local habitat quality can best be improved to increase insect occurrence.

We hypothesize that local habitat quality will be lower when farming intensity in the surroundings is high and we expect that insect occurrence will be higher when local habitat quality is higher. We expect this, because Hoffman (2005) founds these results and our study is similar to the study of Hoffmann. In contrast to the findings of Hoffman (2005) we also expect a direct negative effect of farming intensity on the occurrence of insects, including bumblebees and butterflies, because many studies found that intensive agriculture is a cause of the decline of insects (Hallmann et al., 2017; Kleijn et al., 2018; van Strien et al., 2016; Wagner, 2020; WWF, 2018). In short, we thus expect to find all three effects visualized in Figure 2.

To test the hypotheses and answer the research question we will study standardized transects in road verges and adjacent to ditches in intensively farmed agricultural areas in the southeast of the province of Drenthe, the Netherlands, and the southwest of Lower Saxony, Germany. On these transects we will count bumblebees, butterflies, damselflies and dragonflies and we will quantify several indicators of local habitat quality. In addition, we will quantify several indicators of the intensity of farming in the surrounding of the transects. By correlating the indicators of local habitat quality and farming intensity to insect occurrence in the semi-natural habitats, the relative importance of local habitat quality and farming intensity for insect occurrence will be determined.

Methods

Study area

We conducted this study in intensively farmed agricultural land in the southeast of Drenthe, the Netherlands, and in the southwest of Lower Saxony, Germany. We studied all parameters at 83 locations, 43 in Germany and 40 in the Netherlands. On each location we defined a study route with a length between 170 and 300 meters, although a few routes were shorter because part of the route appeared unsuitable during the fieldwork. We defined two types of study routes: routes for studying bumblebees and butterflies (from now on called ‘bumblebee and butterfly routes’) and routes for studying damselflies and dragonflies (from now on called ‘damselfly and dragonfly routes’). Figure 3 shows the location of the 83 study routes, separately for bumblebee and butterfly routes and damselfly and dragonfly routes.

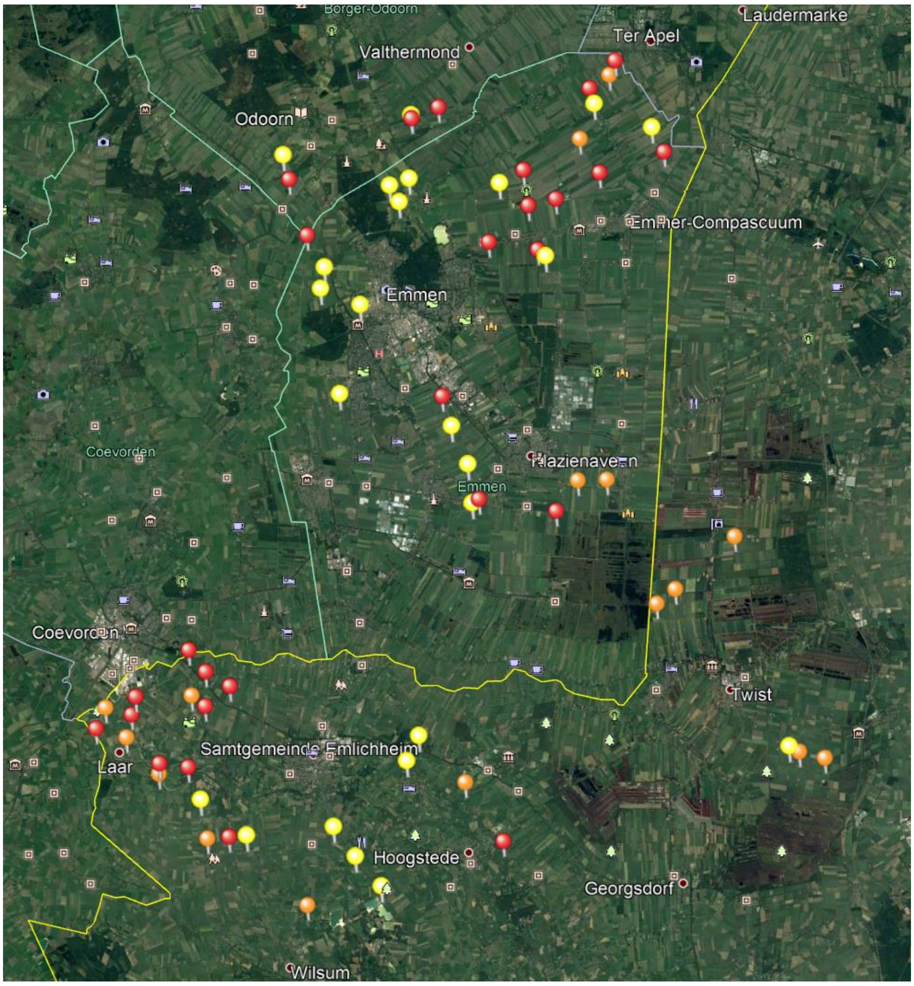


Figure 3: The 83 locations that we studied. The color of the marker indicates the type of study route: yellow=bumblebee and butterfly route, red=damselfly and dragonfly route, orange=both a bumblebee and butterfly route and a damselfly and dragonfly route on exactly the same location.

Most of the bumblebee and butterfly routes were located in road verges next to paved roads, but some were located on or next to unpaved paths between agricultural fields. Damselfly and dragonfly routes were always located adjacent to a water body, which was mostly a ditch, but some routes were located next to a streaming water body. During route selection we maximized variation in the following habitat characteristics: vegetation composition (more diverse or more uniform), width of the road verge or ditch bank, width of the ditch, presence or absence of trees, presence of a ditch or other water body (only on bumblebee and butterfly routes), slope of the ditch bank and aquatic vegetation abundance (the last two only on damselfly and dragonfly routes). Although it was also important to include enough variation in crop types surrounding the study routes, we did not select routes to maximize this variation, because we selected the routes in April when the exact crop types on the fields were not yet fully visible. We made sure, however, that we did not study road verges or ditch banks between two fields of grassland (grassland on one side of a route was allowed). Figure 4 shows two bumblebee and butterfly routes and two damselfly and dragonfly routes that we studied.

Study routes consisted of one or several sections. A section represents a part of a route that is homogeneous in terms of habitat and adjacent agricultural fields. This means that if a study route ran along different agricultural fields, the route was cut into separate sections on the border between two agricultural fields. The same accounted if a study route included different habitat types, for example when a damselfly and dragonfly route was partly adjacent to a small ditch and partly to a substantially wider ditch.

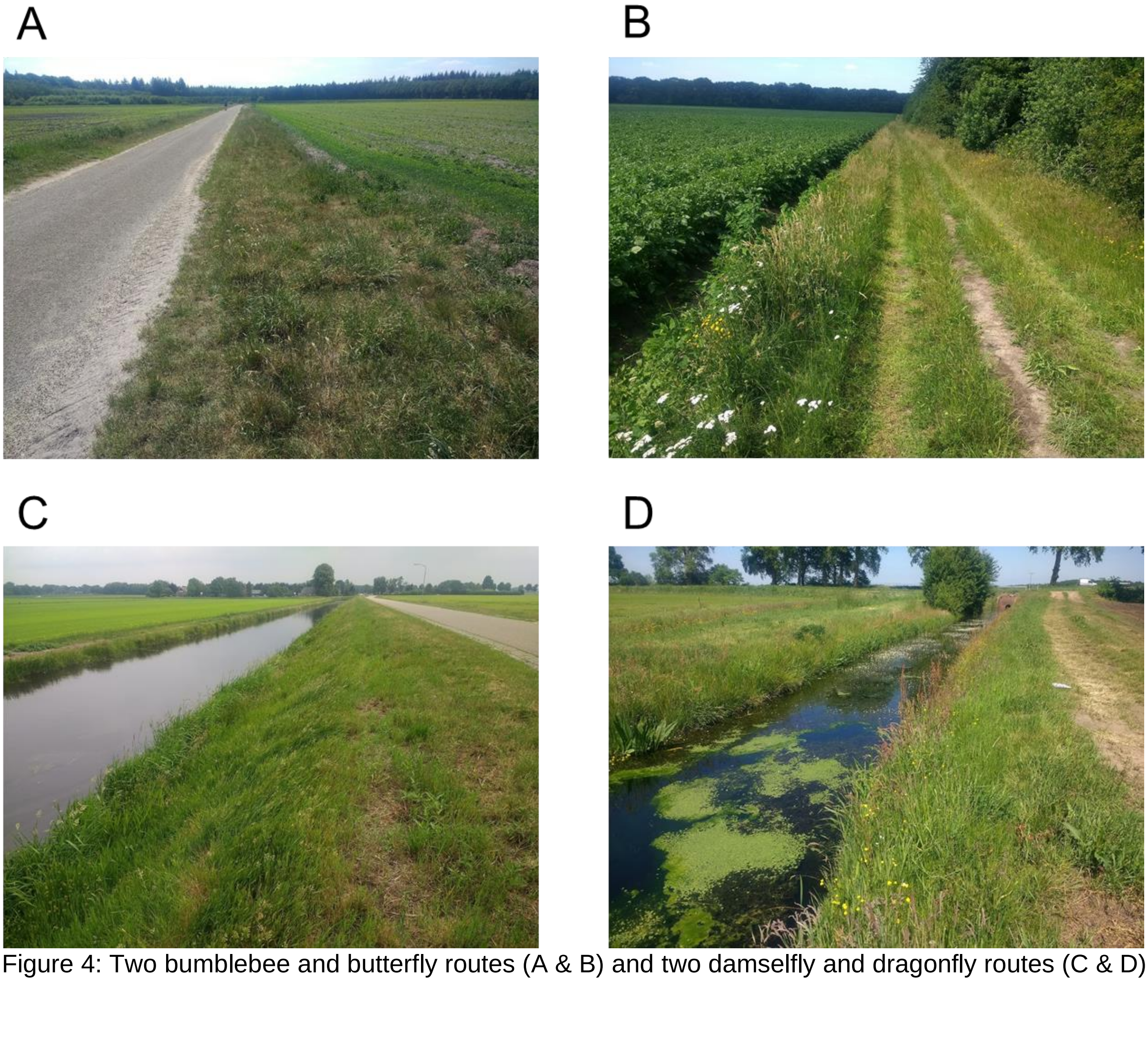


Figure 4: Two bumblebee and butterfly routes (A & B) and two damselfly and dragonfly routes (C & D).

Data collection in the field

We collected data between 23 April 2020 and 20 July 2020. Damselflies and dragonflies appear later in the season than bumblebees and butterflies, so damselfly and dragonfly routes were surveyed from 19 May onwards. Annemarie van Olst surveyed the routes in Germany and Michiel Eijkelkamp surveyed the routes in the Netherlands. The number of routes that could be studied on a particular day depended on the weather (see the explanation under ‘Data collection in the field, Insect occurrence’) and the physical condition of the observer. When an observer finished all routes in the country he or she studied all routes again. Between two repetitions of a route at least a week had passed, but on average routes were studied every three to four weeks. In the end, routes were studied 2-5 times. We changed the order of routes on a day during different repetitions, to prevent that specific routes were always studied on the same time of the day.

On each study route we studied many different parameters. We often studied all parameters successively, but sometimes we studied insect occurrence separately, because insect occurrence could only be monitored within specific times and with good weather (see the explanation under ‘Data collection in the field, Insect occurrence’). Table 1 provides an overview of all studied parameters, including how often they were studied, on what spatial resolution (route, section or agricultural field) and on which type of study routes (on bumblebee and butterfly routes, on damselfly and dragonfly routes or on both). In the paragraphs under Table 1 all studied parameters are further explained.

Table 1: The variables that we studied in the field, including on which routes they were studied, how often and what the smallest spatial unit was.

	Variables	**Studied on**		**How often studied**	**Smallest spatial unit**
		Bumblebee and butterfly routes	**Damselfly and dragonfly routes**		
	Insect occurrence	Yes	Yes	Every repetition	Section
Local habitat quality	Width of road verge	Yes	-	Once	Section
	Width of ditch bank	-	Yes	Once	Section
	Width of ditch	-	Yes	Once	Section
	Steepness of ditch bank on water level	-	Yes	Once	Section
	Flowering plants	Yes	-	Every repetition	Section
	Host plants	Yes	-	Once	Section
	Aquatic vegetation type	-	Yes	Every repetition	Section

	Variables	Studied on		How often studied	Smallest spatial unit
		Bumblebee and butterfly routes	**Damselfly and dragonfly routes**		
Local habitat quality	Clearness	-	Yes	Every repetition	Section
	Riparian vegetation	-	Yes	Every repetition	Section
	Algae	-	Yes	Every repetition	Section
	Aquatic plants indicating nutrient abundance	-	Yes	Once	Section
Farming intensity	Whether or not cultivated	Yes	Yes	Once	Field
	If cultivated: crop type	Yes	Yes	Once	Field
	General steepness of ditch bank	-	Yes	Once	Section
Other variables	Date	Yes	Yes	Every repetition	Route
	End time	Yes	Yes	Every repetition	Route
	Temperature	Yes	Yes	Every repetition	Route
	Cloud cover	Yes	Yes	Every repetition	Route
	Wind force	Yes	Yes	Every repetition	Route
	Length of section	Yes	Yes	Once (digitally)	Section
	Width of studied surface	Yes	Yes	Once	Section
	Number of studied ditch banks	-	Yes	Once	Section

Insect occurrence

We surveyed the occurrence of bumblebees and butterflies according to the protocol by van Swaay et al. (2018) for counting butterflies. This means that we calmly walked a study route and counted all bumblebees and butterflies within predefined distances from us. We only counted with relatively good weather (see van Swaay et al., 2018). This method is very similar to the protocol to specifically count bumblebees of Bumblebee Conservation Trust (2020).

We surveyed the occurrence of damselflies and dragonflies in the same way, except that we counted all damselflies and dragonflies within predefined distances on the ditch bank and the water surface. This is according to the protocol by van Swaay et al. (2018) for counting damselflies and dragonflies.

On a few aspects we deviated from the protocol of van Swaay et al. (2018):

1. According to van Swaay et al. (2018) all observations should be identified to species level. If necessary insects should be caught to be able to identify them. In this study we had too little time to capture insects for identification, which means that some insects were not identified to the species level. This was especially true for 'sister species' which are difficult to distinguish in the field anyway (for example Small White / Green-veined White). During the analysis these data were processed depending on the ratio of observations that was not identified to the species level (see the Analysis section for details).

2. In the identification of insects we only took species into account that could be expected in agricultural landscapes in the southeast of Drenthe, based on their distribution and habitat preferences. We assumed that the species that could be expected in farmland in southwest Lower Saxony were the same as the species that could be expected in southeast Drenthe. Two bumblebee species, brown-banded carder bee and red-shanked carder bee, that could be expected, although with a small chance, appeared too difficult to identify and were disregarded (see Appendix 1). When we in the field encountered an easily identifiable species that was not on the list, we added it.

   Appendix 1 provides the lists of species of bumblebees, butterflies, day-flying moths, damselflies and dragonflies that were taken into account and a more detailed explanation on how we composed the lists.

3. Van Swaay et al. (2018) allows insect monitoring up to a wind force of 5 Beaufort. We decided to restrict this to up to 4 Beaufort, because we had the strong impression in the field that bumblebees, butterflies, damselflies and dragonflies were not very active anymore at higher wind speeds.

4. We only counted insects that were bonded to the local environment on a study route. This means that we did not count insects that flew by.

Local habitat quality

Width of the road verge

We measured the width of the strip of vegetation between the road and the agricultural field or between two agricultural fields (when there was no paved road).

Width of the ditch bank

We measured the width of the strip of vegetation between the ditch and the road or agricultural field.

Width of the water of the ditch

We measured the width of the water of the ditch from a dam or other water crossing structure. In case these were absent and the ditch was wide, we measured the width in Google Earth Pro with the ruler function.

Steepness of the ditch bank on the water level

We estimated the steepness of the ditch bank on the water level using the categories: 0° (horizontal), 0-22.5°, 22.5-45°, 45-67.5°, 67.5-90° and 90° (vertical) (Figure 5). If necessary, we hold a straight stick or our hand parallel to the ditch bank, so we could better estimate the steepness. We used Figure 5 in the field as visualization of the categories.

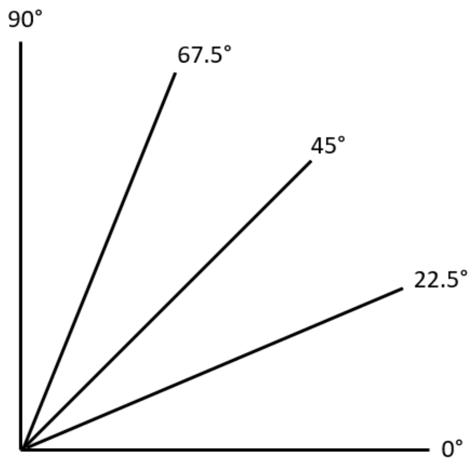


Figure 5: Visualization of the categories of steepness of the ditch bank.

Flowering plants

We counted the number of flowering plants following the protocol by van Swaay et al. (2018). We deviated from this method in the way we counted the category ‘Other flowering plants’. In the first two repetitions, we counted flowering plants in the category ‘Other flowering plants’ when we saw that insects in general made use of the plants at that moment, independent of whether bumblebees and butterflies made use of it. This method appeared to be depending on coincidence, so after the second repetition we made a list of flowering plants from which we expected that bumblebees and butterflies use them and that were not in one of the consisting categories of flowering plants (Table 2). We counted these flowering plants as other flowering plants, independent of whether insects were using the plants at that moment. In addition, we counted flowering plants that were not on this list or in a consisting category as other flowering plants when we saw that bumblebees and butterflies were using them. In this case, we added the species to the list of other flowering plants when we started a new repetition.

Table 2: The flowering plant species that we counted in the category 'Other flowering plants', independent of whether we saw that they were used by insects. The second column gives the repetition in which we first included the flowering plant species in this list.

Flowering plant species	**Repetition**
White nettle (*Lamium album*)	3
Yellow archangel (*Lamium galeobdolon*)	3
Common comfrey (*Symphytum officinale*)	3
Green alkanet (*Pentaglottis sempervirens*)	3
Species of the genus of buttercups (*Ranunculus*)	3
Species of flowering trees	3
Valerian (*Valeriana officinalis*)	4

Host plants

We recorded the presence of host plants of common butterfly species on each section (independent of their abundance) (see Table 3). On each section of a bumblebee and butterfly route we once especially focused on the presence of host plants, when there was abundant vegetation. When we, however, without focusing on it, saw a plant species that was on our host plant species list, we wrote already down that the plant was present on that section.

Table 3: List of host plant species that we took into account in this study (based on De Vlinderstichting (2003) and De Vlinderstichting (n.d. b)).

Host plant species
Species in the family of grasses (*Poaceae*)
Common nettle (*Urtica dioica*)
Annual nettle (*Urtica urens*)
Species of the genus clover (*Trifolium*)
Thistles (polyphyletic group)
Species of the parsley family (*Apiaceae*), except for wild carrot
Wild carrot (*Daucus carota*)
Red sorrel (*Rumex acetosella*)
Common sorrel (*Rumex acetosa*)
Species of the mustards family (*Brassicaceae*)
Garlic mustard (*Alliaria petiolata*)
Cuckoo flower (*Cardamine pratensis*)
Annual honesty (*Lunaria annua*)
Lesser burdock (*Arctium minus*)
Species of the family mallows (*Malvaceae*)
Purple loosestrife (*Lythrum salicaria*)
Common hop (*Humulus lupulus*)
Species of the genus elms (*Ulmus*)
Red currant (*Ribes rubrum*)
Alder buckthorn (*Frangula alnus*)
Common buckthorn (*Rhamnus cathartica*)
Common ivy (*Hedera helix*)
Heather (polyphyletic group)
Common holly (*Ilex aquifolium*)
Butterfly-bush (*Buddleja davidii*)

Aquatic vegetation type

We classified the aquatic vegetation type according to the decision tree in Figure 6.

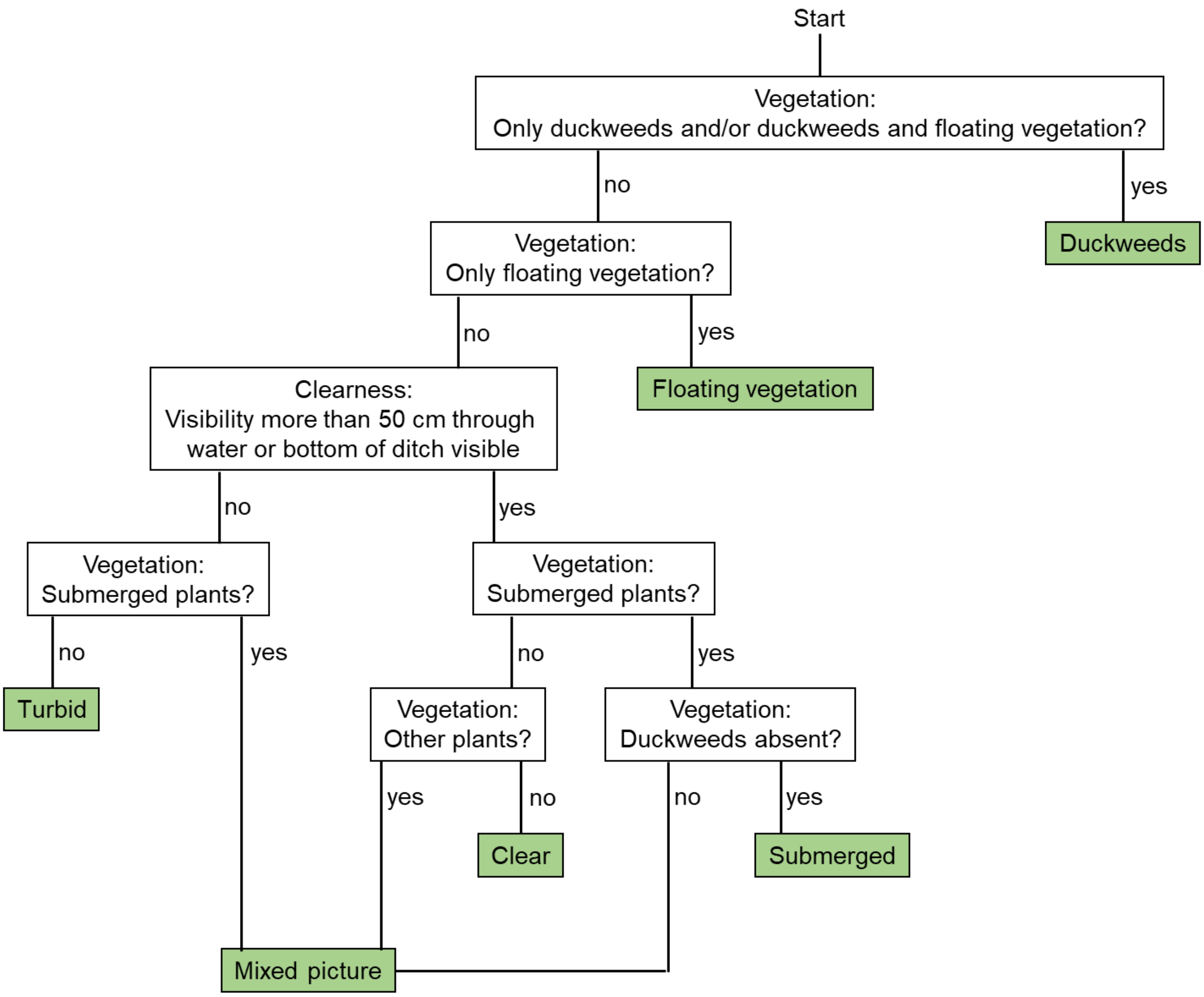


Figure 6: Decision tree that we used to assess the aquatic vegetation type in a ditch (translated from Natuur & Milieu, 2019).

Clearness of the water

We recorded whether the water was clear (transparency larger than 50 cm) or turbid (transparency smaller than 50 cm). We estimated this by looking at submerged plants or by using a stick in case submerged plants were lacking.

Riparian vegetation

We recorded the presence of 5 categories of riparian vegetation types that we expected to be present on part of the sections of damselfly and dragonfly routes but not on all of them (we expected variation between sections). The categories were: bare ground, perennial vegetation, common rush, bulrush/common reed and trees/shrubs.

Algae

We recorded whether algae were present in the water body adjacent to a section.

Aquatic plants indicating nutrient abundance

We recorded the presence of aquatic plants that are indicators of nutrient abundance (Table 4). We only considered plants growing in the water or directly adjacent to it. We once especially focused on these plants, but when we, without focusing on it, saw a plant species that was on our list, we wrote already down that the plant was present on that section.

Table 4: The aquatic plant species that we used as indicators of nutrient abundance (Weeda, 2011).

Aquatic plant species
Water horsetail (*Equisetum fluviatile*)
European bur-reed (*Sparganium emersum*)
Marsh St John's-wort (*Hypericum elodes*)
Floating club rush (*Isolepis fluitans*)
Water violet (*Hottonia palustris*)
Great yellowcress (*Rorippa amphibia*)
Shining pondweed (*Potamogeton lucens*)
Frogbit (*Hydrocharis morsus-ranae*)
Water soldiers (*Stratiotes aloides*)
Arrowhead (*Sagittaria sagittifolia*)
Gibbous duckweed (*Lemna gibba*)
Rigid hornwort (*Ceratophyllum demersum*)
Sea clubrush (*Bolboschoenus maritimus*)
Mare's-tail (*Hippuris vulgaris*)
Sago pondweed (*Stuckenia pectinata*)

Farming intensity

We used two measures to quantify farming intensity: the proportion cultivated land around a section and the environmental pressure caused by fertilizer and pesticide use around a section.

We estimated the use of pesticides and fertilizers in the surroundings of a study route based on the crops around a study route (see the Analysis section for details). This is believed to be a good estimate for pesticide and fertilizer use, because a large part of the variation in pesticide and fertilizer use is caused by the type of crop on a field (Wageningen University & Research, n.d.; W. Sukkel, personal communication, March 17, 2020).

In order to use the described method, we recorded whether fields in the surrounding of a study route were cultivated and if so, what crops were cultivated.

In addition, we used the steepness of the ditch bank as a measure for land use intensity. We estimated the steepness in the same way as described before (for the steepness on the water level), but here we estimated the steepness of the general ditch bank.

Other variables

Date and time

For each survey we noted the date, time of the start of the count and time the count was completed. In the analysis only the end time was used.

Temperature

Temperature at the time the survey was conducted was obtained from nearby weather stations. For study routes in Germany we mostly used the weather station of MeteoGroup in Hoogstede-Kalle, but occasionally no temperature reading from this station was available. In that case, we used information from the weather station of MeteoGroup in Nordhorn. Both weather stations measured the temperature every hour.

For study routes in the Netherlands we used temperature measures from the weather station of KNMI in Hoogeveen. Here temperature was measured every 10 minutes.

Cloud cover

We estimated cloud cover at the onset of insect monitoring following the protocol by van Swaay et al. (2018).

Wind force

We estimated wind force at the onset of insect monitoring following the protocol by van Swaay et al. (2018).

Length of section

We measured the length of each section in Google Earth Pro with the ruler function.

Width of studied surface

For each section we wanted to know the width that we studied to be able to calculate the total studied surface. The studied width was mostly determined afterwards (see the Analysis section for details), but in some uncommon cases it was necessary to wrote it down separately.

Number of studied ditch banks

For ditches wider than 2 meters we only studied one ditch bank for insects and habitat characteristics. For ditches narrower than 2 meters, we surveyed both ditch banks, unless this appeared to be difficult for a specific ditch, then we studied one bank. For each section we noted whether we studied one or two ditch banks

Analysis

All analyses were conducted in R (R Core Team, 2019).

We ran two types of analyses in this study. (1) We analyzed models that contained variables that did not change over the season, like the indicators of farming intensity and some indicators of local habitat quality, at the level of sections. Here the data for the different repetitions was combined. (2) We analyzed models that only contained variables that did change over the season, like insect occurrence and some indicators of local habitat quality, at the level of repetitions.

Calculating the dependent and predicting variables for analysis

Table 5 gives an overview of how the different field measurements were processed for the different analyses. In the text below Table 5 we explain in more detail how the variables for the analyses were created.

Table 5: The variables that we measured in the field, followed by the variables that we created from them for analysis. A plus (+) indicates that the field variable did not need processing before analysis, so the field data was analyzed directly. A minus (-) indicates that the field variable was not included in that type of analysis. Units of the variables for analysis are given between brackets.

	Variables collected in the field	**Variables included in the analysis per repetition**	**Variables included in the analysis per section**
	Insect occurrence	Total number of insects (#) Number of insect species (#) Diversity of insects (no unit)	Total number of insects (maximum) (#) Number of insect species (maximum) (#) Diversity of insects (maximum) (no unit)
Local habitat quality	Width of road verge	Not included in analysis, but used to calculate the studied surface (Are)	Included in analysis (meters) and used to calculate the studied surface (Are)
	Width of ditch bank	Not included in analysis, but used to calculate the studied surface (Are)	Included in analysis (meters) and used to calculate the studied surface (Are)
	Width of ditch	Not included in analysis, but used to calculate the studied surface (Are)	Included in analysis (meters) and used to calculate the studied surface (Are)
	Steepness of ditch bank on water level	-	+ (°, in categories)
	Flowering plants	Total number of flowering plants (# * 100) Number of flowering plant species groups (#)	Total number of flowering plants (maximum) (# * 100) Number of flowering plant species groups (maximum) (#)
	Host plants	-	Number of host plant species (#)
	Aquatic vegetation type	Score for aquatic vegetation quality (no unit)	Score for aquatic vegetation quality (maximum) (no unit)
	Clearness	+ (clear / turbid)	Clearness per section (clear / turbid)
	Riparian vegetation	+ (absence / presence)	Riparian vegetation presence per section (absence / presence)
	Algae	+ (absence / presence)	Algae presence per section (absence / presence)
	Aquatic plants indicating nutrient abundance	-	Nutrient abundance (no unit)

	Variables collected in the field	Variables included in the analysis per repetition	Variables included in the analysis per section
Farming intensity	Whether or not cultivated	-	Proportion cultivated land (no unit)
	If cultivated: crop type	-	Mean environmental pressure per cultivated area (no unit)
	General steepness of ditch bank	-	+ (°, in categories)
Other variables	Date	Julian days (no unit)	-
	End time	Hours after midnight (hours)	-
	Temperature	+ (°C)	-
	Cloud cover	+ (no unit)	-
	Wind force	+ (Beaufort scale)	-
	Length of section	Not included in analysis, but used to calculate the studied surface (Are)	Included in analysis (meters * 100) and used to calculate the studied surface (Are)
	Number of studied ditch banks	+ (#)	+ (#)

Insect occurrence

From the insect occurrence data we calculated three variables: total number of insects, number of insect species and insect diversity. The field data contained observations of insects that could not be identified to species level, like small white / green-veined white. For the calculation of the total number of insects all observations were included. For the calculation of the number of species and the diversity of insects, not all observations were included, because an observation like small white / green-veined white would then be counted as a separate species. We, therefore, defined complexes of species that were not distinguished in the field and we calculated the minimum number of species that was observed during each repetition.

Table 6 provides an overview of the species complexes for which we (sometimes) had problems identifying the exact species. For some species complexes we had identified most of the individuals to the species level, in Germany and the Netherlands. In that case we did not consider the species complex but the individual species in the analyses. Individuals identified to the complex level were discarded, except in case no observations of a species of that complex were made (in that case an observation of an individual identified to the complex level certainly represents an extra species observed during the survey). For other species complexes most individuals were not identified to the species level, in Germany and the Netherlands. In that case all observations were considered at the complex level, including the observations where a species had been identified. For one species complex most individuals were identified to the species level in Germany, but not in the Netherlands. In this case, all observations were considered at the complex level. Observations of unidentified insects (unknown bumblebee, unknown butterfly, unknown damselfly and unknown dragonfly) were removed for the calculation of the number of species and the species diversity.

The measures for insect occurrence that we calculated, are given below. For the analysis at the section level the maximum numbers were taken from the repetitions.

- Total number of insects: The sum of the numbers of all insect species that we observed on a repetition of a section.
- Number of insect species: The number of species that we observed on a repetition of a section.
- Diversity of insects: The Shannon-Wiener index of the observations on a repetition of a section. We used the function diversity() from the package vegan and the function select() from the package dplyr to calculate the Shannon-Wiener index.

Table 6: The species complexes for which we (sometimes) had problems identifying the exact species. The second column shows how we handled the complexes.

Species complex	**Handling**
Common carder bee / tree bumblebee	Most individuals identified to species level, so individual species considered.
Azure damselfly / variable damselfly / common blue damselfly	Most individuals not identified to species level, so species complex considered.
Predefined complex of *Bombus norvegicus* and four-coloured cuckoo bee / predefined complex of gypsy's cuckoo bumblebee and vestal cuckoo bumblebee	Most individuals not identified to species level, so species complex considered.
Common spreadwing / western willow spreadwing	Most individuals identified to species level, so individual species considered.
Hairy hawker / blue emperor	Most individuals identified to species level, so individual species considered.
Small white / green-veined white / large white /orangetip	Most individuals not identified to species level, so species complex considered.
Small copper / small heath	Most individuals identified to species level, so individual species considered.
Brilliant emerald / downy emerald	Most individuals not identified to species level, so species complex considered.
Red-tailed bumblebee / early bumblebee / *Bombus rupestris*	Most individuals identified to species level in Germany, but not in the Netherlands, so species complex considered.
Garden bumblebee / predefined complex of buff-tailed bumblebee, white-tailed bumblebee, northern white-tailed bumblebee and cryptic bumblebee	Most individuals identified to species level, so individual species considered.
Scarce chaser / black-tailed skimmer / broad-bodied chaser	Most individuals identified to species level, so individual species considered.
Vagrant darter / common darter / ruddy darter	Most individuals not identified to species level, so species complex considered.
Small heath / meadow brown / ringlet	Most individuals identified to species level, so individual species considered.

Studied surface

To calculate the surface that was studied on each section, we first determined for each section the width that we studied, using the decision tree in Figure 7.

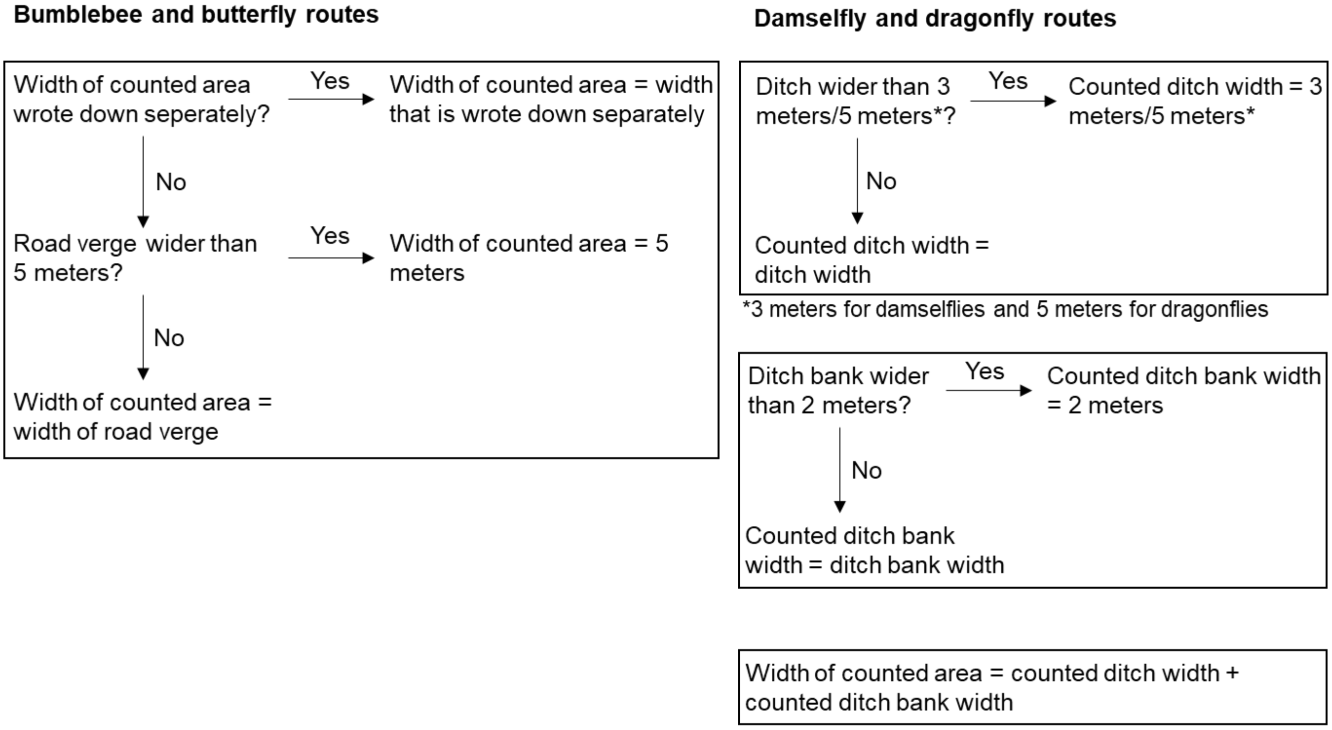


Figure 7: Diagram that shows how we calculated the width of the studied surface.

Then, we calculated the studied surface by multiplying the width of the studied surface with the length of the section. Lastly, we divided the studied surface by 100 to scale this variable to the other variables.

Flowering plants

From the field data we calculated, for each repetition, the total number of flowering plants and the number of species groups of flowering plants. For the analysis at the section level the maximum numbers were taken from the repetitions.

- Total number of flowering plants: Flowering plant abundance was measured in categories, so we estimated a mean number of flowering plants for each category (see Table 7) and summed these means. We divided total number of flowering plants by 100 to scale this variable to the other variables.
- Number of species groups of flowering plants: The number of species groups of flowering plants that we observed on a repetition.

Table 7: The categories used to indicate the abundance of flowering plants in the field and the assigned estimate of the mean number of flowering plants in the abundance categories.

Abundance category, ranges are given between brackets	**Estimate of mean number of flowering plants**
1 (1-10)	5.5
2 (11-50)	30.5
3 (51-500)	275.5
4 (>500)	1000

Host plants

We calculated the number of host plant species per section.

Aquatic vegetation type

Aquatic vegetation type was scored in 6 categories in order of increasing quality, except for category 5 and 6, since category 5 indicated the highest and 6 the second highest quality (Natuur & Milieu, 2019). These numbers were switched to create an aquatic vegetation quality score, which we used directly in the analyses per repetition. For the analyses per section we used the maximum quality score from the repetitions.

Clearness of the water

For the analyses on the level of sections, we considered a water body to have clear water in case on at least one of the repetitions the water had been clear.

Riparian vegetation and algae

For the analyses on the level of sections, we considered a riparian vegetation category or algae to be present in case it had been present on at least one of the repetitions.

Water nutrient abundance

The nutrient abundance in the water body was estimated from the presence of specific aquatic plants. We assigned a score for nutrient abundance to each plant species (Table 8) and then, we calculated the mean nutrient abundance score per section. This mean is a measure for nutrient abundance, ranging from 2 (moderate oligotrophic) to 4 (very eutrophic).

We did not include gibbous duckweed in these calculations, because it appeared that we had not always recognized this species correctly in the field.

Table 8: The plant species that we used to indicate nutrient abundance followed by their nutrient abundance score. Score 2=moderate oligotrophic, score 3=moderate eutrophic, score 4=very eutrophic (Weeda, 2011).

Plant species	**Nutrient abundance score**
Water horsetail	2
European bur-reed	2
Marsh St John's-wort	2
Floating club rush	2
Water violet	2
Great yellowcress	3
Shining pondweed	3
Frogbit	3
Water soldiers	3
Arrowhead	3
Rigid hornwort	4
Sea clubrush	4
Mare's-tail	4
Sago pondweed	4

Farming intensity

We combined our field data on crop types with existing polygons from agricultural fields and grasslands. We obtained the polygons for the agricultural fields in the Netherlands from ‘Basisregistratie Gewaspercelen (BRP)’ (Ministerie van Economische Zaken en Klimaat, 2020). We used three polygons from non-agricultural fields in the Netherlands, which we obtained from Basisregistratie Topografie (BRT) TOPNL' (Kadaster, 2020), because the grass in these garden-like fields was maintained very well, so probably it was also maintained with pesticides and fertilizers. For Germany, we obtained the polygons and direct information on the crops grown in 2020 from the Niedersächsisches Ministerium für Ernährung, Landwirtschaft und Verbraucherschutz (2020).

Subsequently, we calculated two measures for farming intensity:

(1) Proportion cultivated land: We drew a buffer of 50 meter around each section and we intersected this buffer with the field polygons. Then, we summed the area within the 50 meter buffer for all cultivated fields. From this sum we calculated the proportion of cultivated area. Cultivated means here that there is pesticide and fertilizer use.

(2) Mean environmental pressure per cultivated area: First, we calculated the area of the different crops within the 50 meter buffer around each section, by intersecting the buffer with the field polygons. To each crop we assigned an environmental pressure score, which indicates the average pressure of that crop on the environment, based on average pesticide and fertilizer use on that crop (Table 9). We obtained the environmental pressures for common crops, averaged over 2015-2018, from the ‘milieuladder’ (Wageningen University & Research, n.d.). For less common crops that were not listed in this database we used the environmental pressure score of a similar crop. Then, we multiplied the area of a crop within the 50 meter buffer with the environmental pressure of that crop to get

the environmental pressure of a field. We summed these pressures for all fields surrounding a section. Then, we divided this sum by the total cultivated area in the surrounding of a section to get the mean environmental pressure per cultivated area. Lastly, we divided this value by 1000 to scale it to the other variables.

We conducted these spatial analyses in R (R Core Team, 2019). We used the packages rgdal (), raster (), maptools (), gdalUtils () and rgeos ().

Table 9: The crops that we observed and the environmental pressures that we assigned to the crops (averaged over the period 2015-2018). Environmental pressures were obtained from Wageningen University & Research (n.d.). For the crops that were not in this dataset, the last column of this table gives the similar crop from which we used the environmental pressure.

Crop	**Mean environmental pressure (no unit)**	**Similar crop from which we used the environmental pressure**
Common wheat (*Triticum aestivum*)	1892.5	
Barley (*Hordeum vulgare*)	1347.5	
Potato for starch (*Solanum tuberosum*)	5695	
Sugar beet (*Beta vulgaris vulgaris*)	1360	
Onion (*Allium cepa*)	3320	
Grass (*Poaceae*)	132.5	
Maize (*Zea mays*)	925	
Chives (*Allium schoenoprasum*)	3320	Onion
Valerian (*Valeriana officinalis*)	1360	Sugar beet
Cannabis sativa (no English name)	1347.5	Barley
True lily (*Lilium*)	3320	Onion
Rye (*Secale cereale*)	1347.5	Barley
Tagetes (no English name)	1360	Sugar beet
Carrot (*Daucus carota sativus*)	1360	Sugar beet
Common sunflower (*Helianthus annuus*) + goosefoot (*Chenopodium album*)	1360	Sugar beet
Triticale (× *Triticosecale*)	1892.5	Common wheat

Date

We expressed date as the number of days since 22 April 2020. This variable was divided by 10 to scale it to the other variables.

End time

We expressed end time as a decimal number (number of hours after midnight).

Length of section

We divided the variable section length by 100 to scale the variable to the other variables.

Models

For the analyses on the level of sections we used the maximum value of the different repetitions for several variables. As the number of repetitions varied between sections we checked whether this affected the maximum number of insects recorded on a section, the most important variable in this study, as it could be expected that the maximum number of insects was higher for a section that was counted more often. We plotted, therefore, the maximum number of insects per section against the number of repetitions of that section (Figure 8). There was no positive correlation, so we concluded that it was not necessary to compensate for the number of repetitions in the analysis.

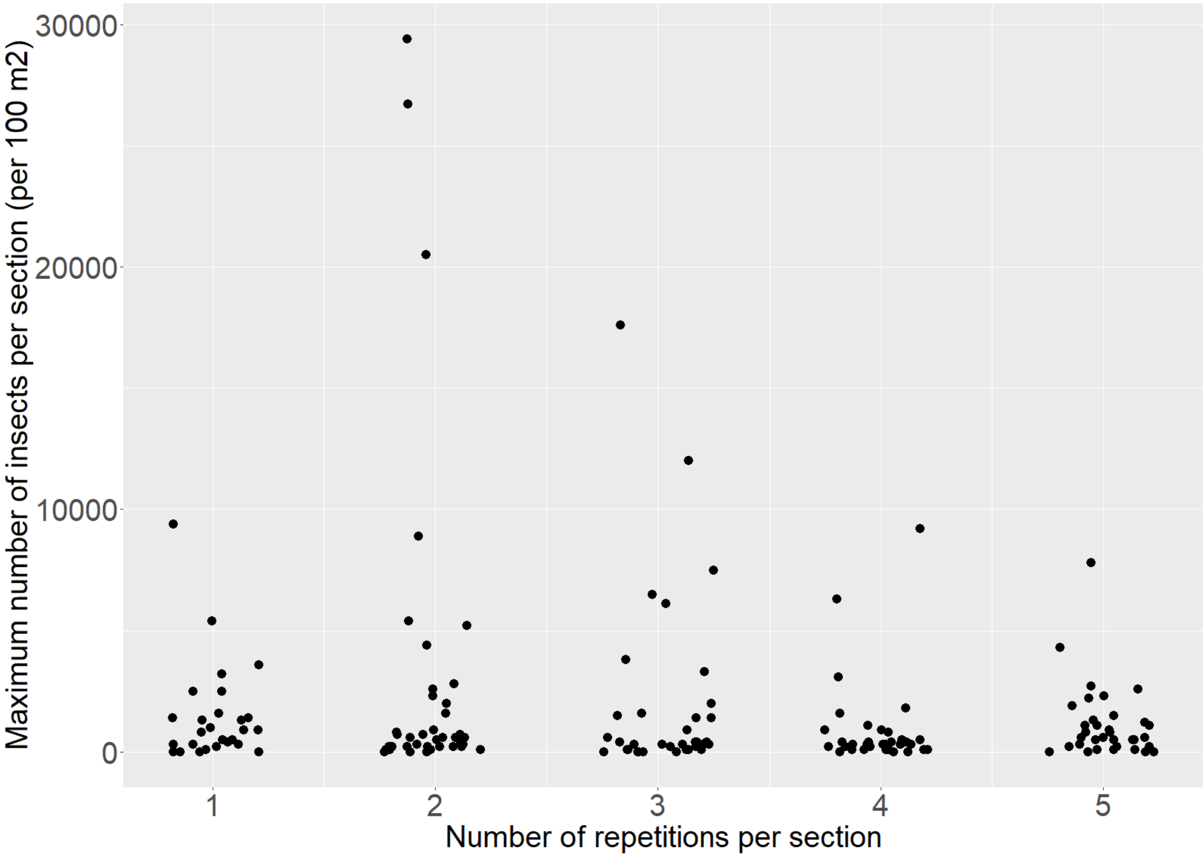


Figure 8: The maximum number of insects per section plotted against the number of repetitions per section. A horizontal jitter is included to visualize the distribution of points.

Table 10 gives an overview of the models that we used in our analyses on the level of repetitions and Table 11 gives an overview of the models that we used in our analyses on the level of sections. We tried to include all ecologically relevant predictors. This was not always possible, because it appeared that we wanted to analyze too many variables compared to relatively few datapoints. Table 10 and 11 provide details on this.

We analyzed continuous response variables with general mixed models and generalized mixed models, with either a poisson or gaussian distribution, depending on the response variable and model fit (see Table 10 and 11). We analyzed binary response variables with generalized mixed models with a binomial distribution. When variables were correlated (correlation coefficient of 0.7 or higher) we dropped the least important or least relevant variable. In some cases models still failed to converge and we were forced to drop more explanatory variables (the least important ones, see Table 10 and 11). This was especially true for interaction terms, which we therefore not included in the models. For the interactions between local habitat quality and farming intensity, interactions we were particularly interested in, we visually inspected whether this interaction would potentially occur, with insect abundance as response. This was not the case, so we did not consider any interactions in the models. In some cases model assumptions were not met completely and we had no possibilities to further improve the model fit, so we accepted these outcomes anyways (see Table 10 and 11). We were not able to check whether the model assumptions of the generalized mixed models with a binomial distribution were met, so we had to accept these outcomes without checking.

We checked (almost) significant model outcomes visually. When effects of variables in which we were not mainly interested, were not confirmed by the plots, we removed the variables from the model. Some plots of variables in which we were interested, indicated that (almost) significant effects were most likely caused by outliers. For these cases we checked whether the model outcomes held when these outliers were removed.

We analyzed all models in R (R Core Team, 2019). For the mixed models we used the function lmer() from the package lme4. Significance of the explanatory variables was obtained with the package lmerTest. For the generalized mixed models we used the function glmer() from the package lme4.

Table 10: The statistical models that we used in our analyses on the level of repetitions, including the variables that we analyzed and the type of model that we used. The column 'Remarks' gives all relevant information on how we came to the final model.

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Bumblebee and butterfly	Total number of insects	Study_route/ section	Date Cloud cover Studied surface Total number of flowering plants Number of flowering plant species groups	Generalized mixed model, family=poisson	The model could not converge with end time, temperature and wind force in it, so we did not include these variables.
Bumblebee and butterfly	Number of insect species	Study_route/ section	Date Temperature Wind force Cloud cover Studied surface Total number of flowering plants Number of flowering plant species groups	Mixed model	The Q-Q plot did not look perfect, but we had no possibilities to further improve the model fit. When we included end time in this model it had a significant effect, but this was not confirmed by plotting. We were not mainly interested in the effect of end time, so we left it out of the model.
Bumblebee and butterfly	Diversity of insects	Study_route/ section	Date Temperature Wind force Cloud cover Studied surface Total number of flowering plants Number of flowering plant species groups	Mixed model	When we included end time in this model it had a significant effect, but this was not confirmed by plotting. We were not mainly interested in the effect of end time, so we left it out of the model.

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Damselfly and dragonfly	Total number of insects	Study_route/ section	Date End time Temperature Wind force Cloud cover Studied surface Number of studied ditch banks Aquatic vegetation Clearness Bare ground Perennial vegetation Common rush Bulrush/common reed Trees/shrubs Algae	Mixed model	

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Damselfly and dragonfly	Number of insect species	Study_route/ section	Date End time Temperature Wind force Cloud cover Studied surface Number of studied ditch banks Aquatic vegetation Clearness Bare ground Perennial vegetation Bulrush/common reed Trees/shrubs Algae	Mixed model	Study_route/section caused the warning message ‘boundary (singular) fit: see ?isSingular’. This random effect was necessary in the model, so we kept it in. Common rush was not included in this model, because the model could not converge with this variable.

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Damselfly and dragonfly	Diversity of insects	Study_route/ section	Date End time Temperature Wind force Cloud cover Studied surface Number of studied ditch banks Aquatic vegetation Clearness Bare ground Perennial vegetation Common rush Bulrush/common reed Trees/shrubs Algae	Mixed model	Study_route/section caused the warning message ‘boundary (singular) fit: see ?isSingular’. This random effect was necessary in the model, so we kept it in.

Table 11: The statistical models that we used in our analyses on the level of sections, including the variables that we analyzed and the type of model that we used. The column 'Remarks' gives all relevant information on how we came to the final model.

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Bumblebee and butterfly	Total number of insects	Study_route	Studied surface Width of road verge Number of host plant species Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	
Bumblebee and butterfly	Number of insect species	Study_route	Studied surface Width of road verge Number of host plant species Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	
Bumblebee and butterfly	Diversity of insects	Study_route	Studied surface Width of road verge Number of host plant species Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	The Q-Q plot did not look perfect, but we had no possibilities to further improve the model fit.

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Damselfly and dragonfly	Total number of insects	Study_route	Studied surface Number of studied ditch banks Nutrient abundance Steepness of ditch bank on water level Width of ditch bank Width of ditch General steepness of ditch bank Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	
Damselfly and dragonfly	Number of insect species	Study_route	Studied surface Number of studied ditch banks Nutrient abundance Steepness of ditch bank on water level Width of ditch bank Width of ditch General steepness of ditch bank Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Damselfly and dragonfly	Diversity of insects	Study_route	Studied surface Number of studied ditch banks Nutrient abundance Steepness of ditch bank on water level Width of ditch bank Width of ditch General steepness of ditch bank Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	
Bumblebee and butterfly	Total number of flowering plants	Study_route	Studied surface Width of road verge Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	
Bumblebee and butterfly	Number of flowering plant species groups	Study_route	Studied surface Width of road verge Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Bumblebee and butterfly	Number of host plant species	Study_route	Studied surface Width of road verge Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	The Q-Q plot did not look perfect, but we had no possibilities to further improve the model fit.
Damselfly and dragonfly	Aquatic vegetation	Study_route	Length of section Width of ditch Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	The Q-Q plot did not look perfect, but we had no possibilities to further improve the model fit.
Damselfly and dragonfly	Clearness	Study_route	Proportion cultivated land Mean environmental pressure per cultivated area	Generalized mixed model, family=binomial	The width of the ditch and the proportion cultivated land were correlated. We left the width of the ditch out of the model.
Damselfly and dragonfly	Bare ground	Study_route	Length of section Number of studied ditch banks Proportion cultivated land Mean environmental pressure per cultivated area	Generalized mixed model, family=binomial	The general steepness of the ditch bank was not included in this model, because the model could not converge with this variable.

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Damselfly and dragonfly	Perennial vegetation	Study_route	Length of section Proportion cultivated land Mean environmental pressure per cultivated area	Generalized mixed model, family=binomial	The model could not converge with the general steepness of the ditch bank and the number of studied ditch banks in it, so we did not include these variables.
Damselfly and dragonfly	Common rush	Study_route	Length of section Number of studied ditch banks Proportion cultivated land Mean environmental pressure per cultivated area	Generalized mixed model, family=binomial	The general steepness of the ditch bank was not included in this model, because the model could not converge with this variable.
Damselfly and dragonfly	Bulrush/ common reed	Study_route	Length of section Number of studied ditch banks Proportion cultivated land Mean environmental pressure per cultivated area	Generalized mixed model, family=binomial	The general steepness of the ditch bank was not included in this model, because the model could not converge with this variable.

Type of study route	Response	Random effect	Fixed effects	Type of model	Remarks
Damselfly and dragonfly	Trees/ shrubs	Study_route	Length of section Number of studied ditch banks Proportion cultivated land Mean environmental pressure per cultivated area	Generalized mixed model, family=binomial	The general steepness of the ditch bank was not included in this model, because the model could not converge with this variable.
Damselfly and dragonfly	Algae	Study_route	Length of section Width of ditch Proportion cultivated land Mean environmental pressure per cultivated area	Generalized mixed model, family=binomial	
Damselfly and dragonfly	Nutrient abundance	Study_route	Width of ditch General steepness of ditch bank Proportion cultivated land Mean environmental pressure per cultivated area	Mixed model	The Q-Q plot did not look perfect, but we had no possibilities to further improve the model fit.

Results

In total we studied 83 sections on 40 bumblebee and butterfly routes during a total of 161 visits (of study routes, consisting of one or several sections). And we studied 90 sections on 43 damselfly and dragonfly routes during 109 visits.

A total number of 4540 insects was observed, which included 337 bumblebees, 556 butterflies, 33 day-flying moths, 3063 damselflies and 551 dragonflies (see also Figure 9).

The average number of insects counted during a survey of a bumblebee and butterfly route section was 2.8 and during a survey of a damselfly and dragonfly route section it was 16.9 (see also Figure 9). The average number of species counted during a survey of a bumblebee and butterfly route section was 1.22 and during a survey of a damselfly and dragonfly route section it was 1.63.

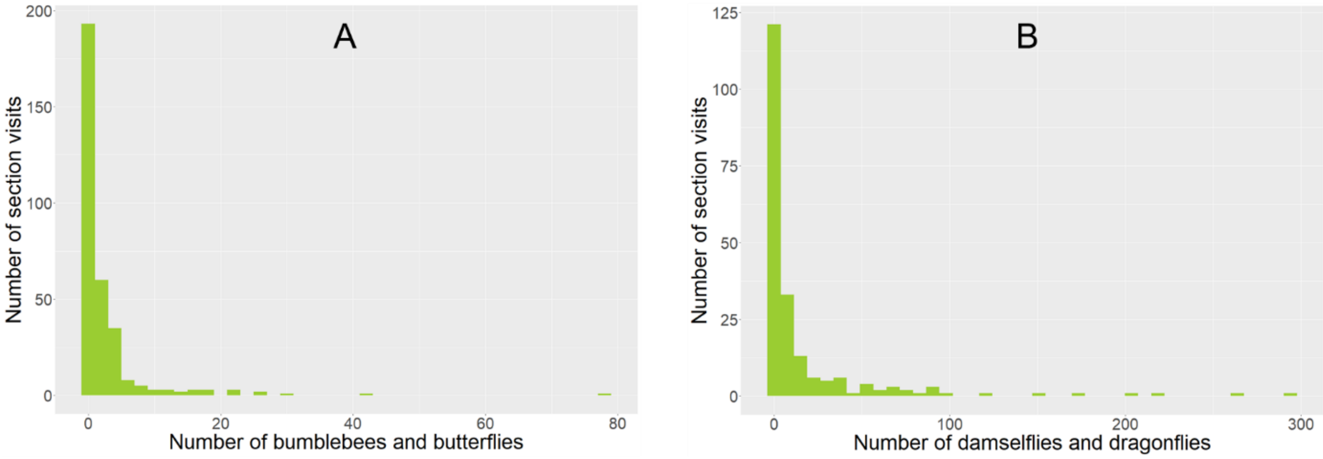


Figure 9: Histograms of the number of bumblebees and butterflies (A) and the number of damselflies and dragonflies (B).

A summary of our processed data, giving the total number of insects, the number of insect species and the diversity of insects per section repetition, can be found in Appendix 2. The outputs of the statistical models and the recognition of important outliers can be found in Appendix 3.

Table 12 provides an overview of the effects of indicators of local habitat quality and farming intensity, the variables in which we are most interested. All (almost) significant effects seemed to have a substantial effect size when we looked at the estimates (Appendix 3) and the ranges of the (almost) significant predictor and the response. Effects that seemed caused by outliers are shown in Table 12, but they are disregarded in the description below and in the discussion.

From Table 12 appears that the occurrence of insects, on both bumblebee and butterfly routes and damselfly and dragonfly routes, was mainly affected by local habitat quality.

Flowering plant occurrence had a dominant effect on bumblebee and butterfly occurrence. Bumblebee and butterfly abundance was positively affected by the total number of flowering plants and the number of flowering plant species groups. Besides that, the number of species and the diversity of bumblebees and butterflies was positively affected by the total number of flowering plants. The number of flowering plant species groups, in turn, appeared to be higher in wider road verges.

Damselfly and dragonfly occurrence was mainly affected by vegetation composition and clearness of the water. Damselfly and dragonfly abundance was higher when the water was clear; the number of damselfly and dragonfly species was positively affected by aquatic vegetation quality and damselfly and dragonfly diversity was higher when bare ground, perennial vegetation and common rush were present along the ditch.

The effect of farming intensity was limited to an almost significant positive effect of the environmental pressure on the number of flowering plant species groups and the number of host plant species.

Table 12: The effects of the indicators of local habitat quality and farming intensity.

	Predictor	**Affected response**	**Effect**	**Significance code**	**Remarks**
Local habitat quality on bumblebee and butterfly routes	Width of road verge	Number of flowering plant species groups	Positive	.	
	Total number of flowering plants	Total number of bumblebees and butterflies	Positive	***	
		Number of bumblebee and butterfly species	Positive	*	
		Diversity of bumblebees and butterflies	Positive	.	
	Number of flowering plant species groups	Total number of bumblebees and butterflies	Positive	***	
	Number of host plant species	-			

Local habitat quality on damselfly and dragonfly routes	Width of ditch bank	Number of damselfly and dragonfly species	Positive	***	Effect caused by outliers (see Appendix 3)
		Diversity of damselflies and dragonflies	Positive	*	Effect caused by outliers (see Appendix 3)
	Width of ditch	Algae	In smaller ditches algae are present more often	*	Effect caused by outliers (see Appendix 3)
	Steepness of ditch bank on water level	-			
	Aquatic vegetation	Number of damselfly and dragonfly species	Positive	.	
	Clearness	Total number of damselflies and dragonflies	More insects if water is clear	*	
	Bare ground	Diversity of damselflies and dragonflies	Higher diversity if bare ground is present	.	
	Perennial vegetation	Diversity of damselflies and dragonflies	Higher diversity if perennial vegetation is present	*	
	Common rush	Diversity of damselflies and dragonflies	Higher diversity if common rush is present	.	
	Bulrush/common reed	-			
	Trees/shrubs	-			
	Algae	-			
	Nutrient abundance	-			

Farming intensity	Proportion cultivated land	Total number of damselflies and dragonflies	Positive	.	Effect caused by outliers (see Appendix 3)
	Environmental pressure per cultivated area	Number of flowering plant species groups	Positive	.	
		Number of host plant species	Positive	.	
	General steepness of ditch bank	-			

Discussion

Insects are globally in decline and intensification of agriculture is seen as one of the main causes. Much is unclear, however, about the driving factors of insect occurrence in agricultural areas. A knowledge gap is, for example, the relative contribution of habitat quality and farming intensity to insect occurrence. In this study we investigated how the occurrence of bumblebees, butterflies, damselflies and dragonflies in intensive agricultural land in the southeast of Drenthe and the southwest of Lower Saxony is affected by local habitat quality and farming intensity. We did this by surveying 40 routes in road verges for bumblebees and butterflies and 43 routes along ditches for damselflies and dragonflies.

Insect occurrence appeared to be (very) low in intensive agricultural land (Figure 9). We counted on average only 2.8 bumblebees and butterflies per section, which is indeed very low compared to Hoffmann (2005) who counted on average 20.3 bumblebees and butterflies per transect, although our sections had a much larger surface than the transects of Hoffmann (2005).

As indicators of local habitat quality of road verges, we looked into the width of the road verge, the number of flowering plants, the number of flowering plant species groups and the number of host plant species. The width of the road verge had an almost significant positive effect on the number of flowering plant species groups, but it did not directly affect insect occurrence. The total number of flowering plants had a significant positive effect on the abundance and number of species of bumblebees and butterflies and an almost significant effect on the diversity of bumblebees and butterflies. In addition, the number of flowering plant species groups had a positive effect on the total number of bumblebees and butterflies. We found no effect of the number of host plant species. These results indicate that flowering plants have a positive effect on bumblebee and butterfly occurrence and that the number of flowering plant species groups could be promoted by wider road verges. These findings correspond to the results of Hoffmann (2005), who found that the number of insect species is higher in road verges and ditches with a higher abundance and diversity of flowering plants.

As indicators of local habitat quality of ditches, we looked into the width of the ditch bank, width of the ditch, steepness of the ditch bank on the water level, nutrient abundance, quality of the aquatic vegetation, clearness of the water, presence of 5 categories of riparian vegetation and presence of algae. The width of the ditch bank had a positive effect on both the number of species and the diversity of damselflies and dragonflies, but as this seemed caused by outliers, we cannot draw reliable conclusions from this. For the width of the ditch we only found a negative effect on algae presence. This correlation seemed also caused by a few outliers and thus it was disregarded. The quality of the aquatic vegetation had an almost significant positive effect on the number of damselfly and dragonfly species, indicating that aquatic vegetation quality could play a role. If the water was clear there were significantly more damselflies and dragonflies, which indicates that clear water is beneficial for damselflies and dragonflies. The presence of bare ground (almost significant), perennial vegetation (significant) and common rush (almost significant) as riparian vegetation had a positive effect on the diversity of damselflies and dragonflies. We found no effect on damselfly and dragonfly occurrence of steepness of the ditch bank on the water level, nutrient abundance, bulrush/common reed and trees/shrubs as riparian vegetation and algae. Thus in general for damselflies and dragonflies, we found that different aspects of local habitat quality play a role, even though effects were not always significant.

As indicators of farming intensity, we looked into the steepness of the general ditch bank, the proportion cultivated land and the environmental pressure of the crops around study routes. First, the general steepness of the ditch bank had no effect on insect occurrence nor on local habitat quality. Secondly, the proportion cultivated land was included in many models, but in most cases it had no effect. It had an almost significant positive effect on the total number of damselflies and dragonflies, but this effect seemed to be caused by outliers. In general, it seems that the proportion of cultivated land has no (major) effect, neither on local habitat quality nor on insect occurrence. Thirdly, environmental pressure (indicator of pesticide and fertilizer use) was also included in many models, but in most models it had no effect. It had an almost significant positive effect on the number of flowering plant species groups and the number of host plant species, in contrast to the negative effect that we expected. This should be further investigated. All in all it seems that the environmental pressure of the crops grown in the vicinity of the routes had no effect, neither on local habitat quality nor on insect occurrence.

In summary, the most important outcomes of this study are (see also Figure 10):

1. Several indicators of local habitat quality have a positive effect on insect occurrence. In general we can conclude that insect occurrence is positively affected by local habitat quality.
2. We found no convincing evidence that farming intensity has a direct effect on insect occurrence.
3. We also found no convincing evidence that farming intensity has an effect on local habitat quality.

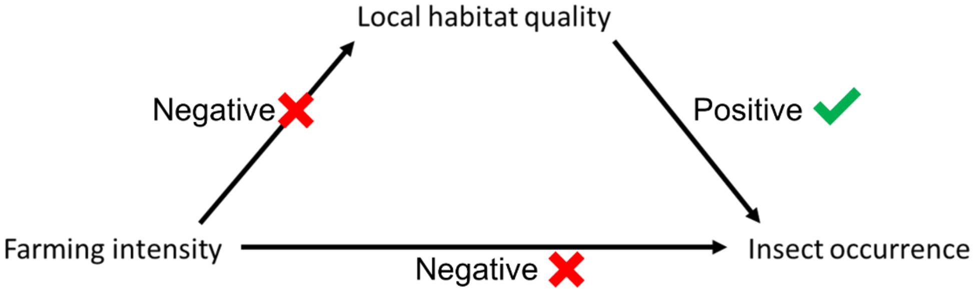


Figure 10: The relationships that we found between farming intensity, local habitat quality of semi-natural habitats and insect occurrence.

Thus, the answer to the main research question of this study is that local habitat quality is positively affecting the occurrence of bumblebees, butterflies, damselflies and dragonflies in road verges and ditches in intensive agricultural areas in the southeast of Drenthe and the southwest of Lower Saxony. In contrast to our expectations, farming intensity was not found to affect local habitat quality nor insect occurrence.

We hypothesized to find an effect of farming intensity on local habitat quality and insect occurrence and we hypothesized that local habitat quality and farming intensity would interact with each other when affecting insect occurrence, but we did not find the effects nor the interaction. This absence of an effect of farming intensity is in contrast to many studies that presented farming intensity as an important cause for biodiversity loss, including insect decline (Hallmann et al., 2017; Kleijn et al., 2018; van Strien et al., 2016; Wagner, 2020; WWF, 2018). We can think of several explanations for the lack of an effect of farming intensity:

(1) Possibly, farming intensity simply has no effect on habitat quality and insect occurrence as fertilizer and pesticide residues do not reach the road verges and ditches. In the Netherlands and in Germany farmers are obliged to realize a buffer zone between an arable field and a water body (Anonymous, 2000; Kuneman et al., 2008). In the field we saw that these buffer zones were sometimes also realized between an arable field and a road verge. These buffer zones are specifically meant to limit the impact of the adjacent farming land on semi-natural areas. Thus, the presence of these buffer zones could explain the absence of an effect of farming intensity. However, we deem this explanation not very likely as the negative impact of intensive agriculture has been reported over much larger spatial scales, in which the impact even ranges into natural areas (Wagner, 2020).

(2) Another possible explanation is that we could not find an effect of farming intensity, because we mainly looked at road verges and ditches in intensive agricultural areas instead of also including road verges and ditches in extensive agricultural areas and in natural areas. Possibly, the effect of intensive farming was the same on all routes that we studied, because on all routes there was substantial fertilizer and pesticide use. This idea is supported by the number of insects that we found being very low.

(3) Another possible reason why we did not find an effect of farming intensity is that we relied on average use of fertilizers and pesticides on specific crop types, instead of obtaining information on true fertilizer and pesticide use. Although we expect that most of the variation in pesticide and fertilizer use is explained by crop type (Wageningen University & Research, n.d.; W. Sukkel, personal communication, March 17, 2020), we cannot rule out that we would have found an effect of farming intensity if we would have used direct pesticide and fertilizer use. In addition, from the study by A. van Olst we know that crop-specific use of fertilizers and pesticides could differ between Germany and the Netherlands, which also pleas for a more direct analysis (A. van Olst, personal communication, December 1, 2020).

It is interesting to compare the outcomes of our study with the study by Hoffmann (2005) as it is very similar to ours. Hoffmann (2005) studied farming intensity on a much coarser scale by comparing road verges surrounded by intensive agricultural areas, extensive agricultural areas or by natural areas. He found a positive effect of local habitat quality on insect occurrence, like we did, but in contrast to our study Hoffmann (2005) did found a negative effect of farming intensity on local habitat quality and an effect (mostly negative) of farming intensity on some insect groups (but notably except bumblebees and butterflies). The reason for this difference could be that Hoffmann (2005) studied the complete range of land use intensity from natural areas to intensive agricultural land, while we focused on intensive agricultural land (explained before). Besides that, it could be that the effect of farming intensity decreased in the period between 2001 (the end of the study of Hoffmann) and 2020 (when we conducted this study), because in 2000 the buffer zones discussed before became obligatory.

Implications for conservation

We concluded that insect occurrence is positively affected by local habitat quality and that farming intensity has no effect, neither on local habitat quality nor on insect occurrence. In addition, we found no evidence for an interaction between local habitat quality and farming intensity. From this follows that conservation measures to increase local habitat quality can be used to increase the occurrence of insects in road verges and ditches in intensive agricultural land and that the effectiveness of these conservation measures will be independent of farming intensity of the surroundings.

From Table 12 appears that most indicators of local habitat quality have an effect on only one aspect of bumblebee and butterfly occurrence, for example only on the diversity. Flowering plant occurrence, however, stands out. The total number of flowering plants has an (almost) significant positive effect on the total number of bumblebees and butterflies, the number of bumblebee and butterfly species and the diversity of bumblebees and butterflies. Furthermore, the number of flowering plant species groups has a significant positive effect on the total number of bumblebees and butterflies. This means that the occurrence of flowering plants is the only indicator which has a positive effect on all aspects of the occurrence of bumblebees and butterflies. This means that, based on this study, conservation efforts should focus on increasing the amount of flowering plants and the number of flowering plant species groups in road verges.

When we, for example, look at the number of flowering plants in road verges in our study area there is much room for improvement (Figure 11). Although the number of flowering plants per m^2 is on a few sections higher than 6, on 79.3% of the sections the number of flowering plants per m^2 is smaller than 2.

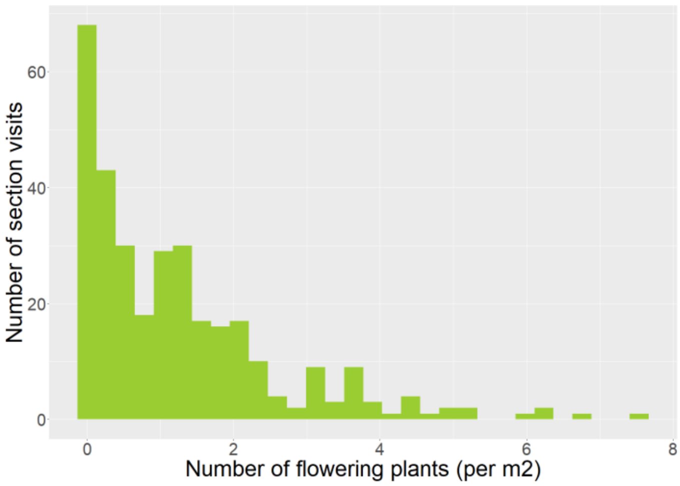


Figure 11: A histogram of the number of flowering plants.

According to Floron & De Vlinderstichting (2018) the richness of flowering plants can be increased by mowing and removing the mowed material (nutrient removal) instead of leaving the material behind. Mowing and removing the material could, therefore, be a good conservation measure to increase the occurrence of bumblebees and butterflies.

From Table 12 there is no indicator of local habitat quality standing out that has an effect on all aspects of the occurrence of damselflies and dragonflies, but different aspects of the vegetation in and around the ditch have a positive effect on different aspects of damselfly and dragonfly occurrence. Aquatic vegetation has an almost significant positive effect on the number of damselfly and dragonfly species and the presence of bare ground (almost significant), perennial vegetation (significant) and common rush (almost significant) leads to a higher diversity of damselflies and dragonflies. So, although not all effects are significant, there is an indication that aquatic vegetation of a higher quality and a more diverse riparian vegetation leads to more damselfly and dragonfly species and a higher diversity of damselflies and dragonflies. In addition, high quality aquatic vegetation goes hand in hand with clearer water (Rijkens et al., 2008) and our study showed that clearer water increases the abundance of damselflies and dragonflies, so high quality aquatic vegetation could indirectly lead to a higher abundance of damselflies and dragonflies. In conclusion, this indicates that improving the quality of the aquatic vegetation, which could lead to clearer water, and increasing the diversity of the riparian vegetation will be positive for all aspects of damselfly and dragonfly occurrence.

When we, for example, look at the clearness of the water in our study area there is much room for improvement (Figure 12). The water appears to be turbid in the water bodies adjacent to 43.9% of our sections.

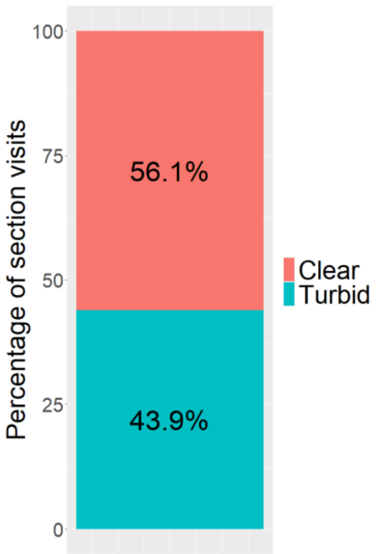


Figure 12: Percent stacked bar chart of clearness of the water.

Several measures could be tried to improve the growth of submerged aquatic plants to increase the quality of the aquatic vegetation, but which measures are most effective depends on the specific situation. Location specific investigations will be necessary to assess which measures will work (Rijkens et al., 2008). Further, not clearing the complete ditch bank, but leaving some vegetation that can develop into perennial vegetation can be an effective measure. Creating bare ground habitats can also be effective.

Shortcomings of the study

One of the potential shortcomings of this study is that this study was conducted by two observers that covered two separate study areas (one in the Netherlands and one in Germany). Because of COVID-19 outbreak measures it was not possible to 'practice' the field work together to make sure that both observers work in exactly the same way. Although methods were discussed extensively online, this could not prevent that some measurements were conducted in a slightly different way. We do not know what the effect of these differences is.

Another problem is that the method to assess the aquatic vegetation (Figure 6) often resulted in the category 'mixed picture', even though the aquatic vegetation in these ditches could look differently. The reasons for this are that mixed picture can be the result of different paths in the decision tree and that the decision tree does not take abundance into account. If there was, for example, a very small amount of submerged plants and duckweeds present, the ditch would be classified as 'mixed picture', although the overall impression of the ditch was for example clear water without much vegetation. We think that this classification method could be improved by dividing the category mixed picture in multiple categories (for example 'turbid & submerged plants', 'clear & other plants' and 'clear & submerged plants & duckweeds'). We also think that abundance should be taken into account, for example by introducing a threshold.

In the third place, it could have been interesting to look at the effect of farming intensity on the level of repetitions instead of on the level of sections. Although farming intensity is constant over the season, most of the responses in the models with farming intensity did change over the season (insect occurrence and part of the indicators of local habitat quality), so analyzing per repetition would have raised the sample size. We do, however, not expect that we would have found an effect of farming intensity by analyzing per repetition, because all our current analyses give a very high p-value for the effect of farming intensity.

Future research

We found that insect occurrence is very low in semi-natural habitats in intensive agricultural land. It would, therefore, be interesting to compare the results of our study with other monitoring results, to examine whether insect occurrence is higher in semi-natural habitats surrounded by less intensively used land, like we expect.

Secondly, this study could be repeated with direct pesticide and fertilizer use as indicator of farming intensity instead of crop types, to further investigate the effect of farming intensity and to investigate whether crop type alone is a good indicator of farming intensity (details given before).

Thirdly, it would be interesting to implement the proposed conservation measures, like mowing and exporting the mowed material, and to monitor whether they have the expected effect on the occurrence of bumblebees, butterflies, damselflies and dragonflies. It would be particularly interesting and relevant to conduct such study in landscapes with different farming intensities.

Conclusions

In this study we looked at the effect of farming intensity and local habitat quality on insect occurrence and at the effect of farming intensity on local habitat quality. Additionally, we indirectly studied the effectiveness of increasing local habitat quality as measure to increase insect occurrence in intensive agricultural land. We conclude that insect occurrence is positively affected by local habitat quality and that farming intensity has no effect, neither on local habitat quality nor on insect occurrence. In addition, there are no indications to believe that the interaction between local habitat quality and farming intensity is of importance. From this follows that increasing local habitat quality, can be an effective measure to increase insect occurrence in intensive agricultural land and the effectiveness of these measures is independent of farming intensity of the surroundings. In addition, there appeared to be much room for improvement of local habitat quality. It is important to realize that there are some weak points in our study, for example that we used crop types as indirect indicator of farming intensity. Nevertheless, our results provide the interesting suggestion that measures to increase local habitat quality can be effective to increase insect occurrence in intensively farmed landscapes.

Intensive agriculture is often mentioned as one of the main causes of insect decline and biodiversity loss in general. The results of this study do not contradict this statement, because we only studied road verges and ditches in intensive agricultural land. Our study does, however, imply that there are possibilities to increase insect occurrence without extensifying the farming system. This does not mean that agricultural extensification is unnecessary, because maybe insect occurrence would increase further when local habitat quality is improved and farming is extensified. Agricultural extensification is, however, an ambitious and long-lasting process, whereas improving the ecological management of road verges and ditches is a relatively easy measure to implement that has a positive effect on insect occurrence. So, although intensive agriculture is one of the main causes of biodiversity loss and agricultural extensification seems the only long term solution, this study suggests that increasing local habitat quality in road verges and ditches in intensive agricultural land can be effective to make a start with the recovery of insect populations.

Reference list

Anonymous. (2000). Staatsblad van het Koninkrijk der Nederlanden [Official Gazette of the Netherlands]. 43.

Bumblebee Conservation Trust. (2020). Welcome to BeeWalk! Retrieved from https://www.bumblebeeconservation.org/wp-content/uploads/2017/07/BeeWalkPack2020.pdf

Butchart, S. H. M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J. P. W., Almond, R. E. A., Baillie, J. E. M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K. E., Carr, G. M., Chanson, J., Chenery, A. M., Csirke, J., Davidson, N. C., Dentener, F., Foster, M., Galli, A., … Watson, R. (2010). Global Biodiversity: Indicators of Recent Declines. *Science, 328*(5982), 1164-1168.

De Vlinderstichting. (2003). Lijst van waardplanten [List of host plants]. Retrieved from https://assets.vlinderstichting.nl/docs/0a2cea8b-cedd-450c-9289-0600632e7591.pdf

De Vlinderstichting. (n.d. a). Alle libellen [All damselflies and dragonflies]. Retrieved from https://www.vlinderstichting.nl/libellen/overzicht-libellen

De Vlinderstichting. (n.d. b). Lijst van waardplanten voor vlinders [List of host plants for butterflies] [Data file]. Groningen: Wankja Ferguson. Retrieved from https://www.vlinderstichting.nl/vlinders/tuinieren-voor-vlinders/planten-voor-rupsen/

De Vlinderstichting. (n.d. c). Alle vlinders [All butterflies]. Retrieved from https://www.vlinderstichting.nl/vlinders/overzicht-vlinders

Eurostat. (7 February 2019). Archive: Agri-environmental indicator - intensification – extensification. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_intensification_-_extensification&oldid=421607

Flickr. (2008). 17719 Akkerhommel [17719 Common carder bee]. Retrieved from https://www.flickr.com/photos/fotoopa_hs/2489530707

Floron & De Vlinderstichting. (2018). Mijn berm bloeit! Hoe bloemrijk zijn onze bermen nog? [My road verge flowers! Hoe rich are our road verges still in flowers?]. *Planten* **8**: 20-21.

Goulson, D. & Darvill, B. (2009). Conservation. In D. Goulson (Ed.), *Bumblebees: Behaviour, Ecology, and Conservation* (pp. 177-217). Oxford, United Kingdom: Oxford University Press.

Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans, W., Müller, A., Sumser, H., Hörren, T., Goulson, D., de Kroon, H. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLoS ONE, 12*(10), e0185809.

Hoffmann, F. (2005). Biodiversity and pollination: Flowering plants and flower-visiting insects in agricultural and semi-natural landscapes (Doctoral dissertation). Retrieved from https://www.rug.nl/research/portal/files/2892458/thesis.pdf

Kadaster. (2020). Dataset: Basisregistratie Topografie (BRT) TOPNL [Dataset: Basic Registration Topography TOPNL] [Data file]. Retrieved from https://www.pdok.nl/geo-services/-/article/basisregistratie-topografie-brt-topnl

Kaunisto, K. M., Roslin, T., Sääksjärvi, I. E., & Vesterinen, E. J. (2017). Pellets of proof: First glimpse of the dietary composition of adult odonates as revealed by metabarcoding of feces. *Ecology and Evolution, 7*(20), 8588-8598.

Kleijn, D., Bink, R. J., ter Braak, C. J. F., van Grunsven, R., Ozinga, W. A., Roessink, I., Scheper, J. A., Schmidt, A. M., Wallis de Vries, M. F., Wegman, R., van der Zee, F. F., & Zeegers, Th. (2018). Achteruitgang insectenpopulaties in Nederland: trends, oorzaken en kennislacunes [Decline of insect populations in the Netherlands: trends, causes and knowledge gaps] (No. 2871). Wageningen, the Netherlands: Wageningen Environmental Research.

Kuneman, G. U., van Herk, J. J., van der Wal, A. J., & Kloen, H. (2008). Buffers voor natuur en water, Europese landbouwsubsidies koppelen aan teeltvrije zones [Buffers for nature and water, Linking European agricultural subsidies to cultivation-free zones]. Utrecht.

Ministerie van Economische Zaken en Klimaat. (2020). Dataset: Basisregistratie Gewaspercelen (BRP) [Dataset: Basic Registration Agricultural Parcels] [Data file]. Retrieved from https://www.pdok.nl/geo-services/-/article/basisregistratie-gewaspercelen-brp-

Natuur & Milieu. (2019). Watermonsters onderzoek, Resultaten van een citizen science project over waterkwaliteit [Water samples research, Results of a citizen science project on water quality]. Utrecht, the Netherlands: Natuur & Milieu.

Niedersächsisches Ministerium für Ernährung, Landwirtschaft und Verbraucherschutz. (2020). LEA-Portal, Landentwicklung und Agrarförderung Niedersachsen [LEA-Portal, Land development and agricultural allowance Lower Saxony]. Retrieved from https://sla.niedersachsen.de/landentwicklung/LEA/

R Core Team (2019). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

Rijkens, B., Claassen, T., Thannhausser-Douwma, M., & Leuven, R. S. E. W. (2008). Waterplanten om van troebel helder water te maken [Aquatic plants to turn turbid water into clear water]. H_2O, **22**: 46-49.

Smit, J. T., Kalkman, V. J., & de Rond, J. (2018). Basisgids hommels [Basic guide bumblebees]. Leiden, the Netherlands: EIS Kenniscentrum Insecten.

Termaat, T., van Grunsven, R. H. A., Plate, C. L., & van Strien, A. J. (2015). Strong recovery of dragonflies in recent decades in The Netherlands. *Freshwater Science, 34*(3), 1094-1104.

Tscharntke, T., Klein, A. M., Kruess, A., Steffan-Dewenter, I., & Thies, C. (2005). Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. *Ecology letters, 8*(8), 857-874.

van Dooren, T. J. M. (2019). Assessing species richness trends: Declines of bees and bumblebees in the Netherlands since 1945. *Ecology and Evolution, 9*(23), 13056-13068.

van Strien, A. J., Meyling, A. W. G., Herder, J. E., Hollander, H., Kalkman, V. J., Poot, M. J. M., Turnhout, S., van der Hoorn, B., van Strien-van Liempth, W. T. F. H., van Swaay, C. A. M., van Turnhout, C. A. M., Verweij, R. J. T., & Oerlemans, N. J. (2016). Modest recovery of biodiversity in a western European country: The Living Planet Index for the Netherlands. *Biological Conservation, 200*, 44-50.

van Strien, A. J., van Swaay, C. A. M., van Strien-van Liempt, W. T. F. H., Poot, M. J. M., & WallisDeVries, M. F. (2019). Over a century of data reveal more than 80% decline in butterflies in the Netherlands. *Biological Conservation, 234*, 116-122.

van Swaay, C. A. M., Bos-Groenendijk, G. I., Deijk, J. R. van, Grunsven, R. H. A. van, Kok, J. M., Huskens, K. & Poot, M. (2018). Handleiding landelijke meetnetten vlinders, libellen en nachtvlinders [Manual national monitoring networks butterflies, damselflies, dragonflies and moths]. Wageningen: De Vlinderstichting.

Visser, A., Leendertse, P. C., den Boer, D. J., & Termorshuizen, A. J. (2008). Gereedschapskist voor biodiversiteit en landbouw: Een definitiestudie [Tool box for biodiversity and agriculture: A definition study]. Culemborg, The Netherlands: CLM Onderzoek en Advies BV en NMI.

Wageningen University & Research. (n.d.). Dutch FADN, agriculture [Data file]. Retrieved from https://www.agrimatie.nl/binternet.aspx?ID=21&bedrijfstype=11

Wagner, D. L. (2020). Insect declines in the Anthropocene. *Annual Review of Entomology, 65*, 457-480.

Weeda, E.J. (2011). Waterplanten als maat voor de biologische kwaliteit van oppervlaktewateren: Biotoets met 15 plantensoorten in de Noardlike Fryske Wâlden [Aquatic plants as measure for biological quality of surface waters: Bioassay test with 15 plant species in the Noardlike Fryske Wâlden]. Wageningen, the Netherlands: Alterra Wageningen UR.

Wilbois, K. P., & Schmidt, J. E. (2019). Reframing the debate surrounding the yield gap between organic and conventional farming. *Agronomy, 9*(2), 82.

WWF. (2018). *Living Planet Report - 2018: Aiming Higher.* Gland, Switzerland: WWF.

Appendices

Appendix 1: Lists of studied species

The lists given below include all species that could be expected in farming land in the southeast of Drenthe, based on their distribution and habitat preferences. These are the species that we took into account during the monitoring. We assumed that these lists were also applicable to farming land in the southwest of Lower Saxony. When we in the field encountered an easily identifiable species that was not on the list, we added it.

Bumblebees

This list of bumblebee species includes all species that were ‘common’ in the Netherlands, according to the Basic Guide Bumblebees (Smit et al., 2018). Some species that were ‘scarce’ according to the Guide were also taken into account, because their habitat preferences and distribution within the Netherlands indicated that these species could be expected in the study area.

Two species, brown-banded carder bee (*Bombus humilis*) and red-shanked carder bee (*Bombus ruderarius*), that could be expected in the study area, although with a small chance, appeared too difficult to identify and were disregarded.

Vincent Kalkman, bumblebee specialist, confirmed that this list of bumblebee species was complete (except for brown-banded carder bee and red-shanked carder bee) (personal communication, March 31, 2020).

Bumblebee species that we took into account during the monitoring:

- Tree bumblebee (*Bombus hypnorum*)
- Common carder bee (*Bombus pascuorum*)
- Early bumblebee (*Bombus pratorum*)
- Red-tailed bumblebee (*Bombus lapidaries*)
- *Bombus campestris* (no English name)
- Complex*
    - Buff-tailed bumblebee (*Bombus terrestris*)
    - White-tailed bumblebee (*Bombus lucorum*)
    - Northern white-tailed bumblebee (*Bombus magnus*)
    - Cryptic bumblebee (*Bombus cryptarum*)
- Garden bumblebee (*Bombus hortorum*)
- Complex*
    - *Bombus norvegicus* (no English name)
    - Four-coloured cuckoo bee (*Bombus sylvestris*)
- *Bombus rupestris* (no English name)
- Complex*
    - Gypsy's cuckoo bumblebee (*Bombus bohemicus*)
    - Vestal cuckoo bumblebee (*Bombus vestalis*)

*Because these species are very similar, we handled them as a complex. In the field we identified these species to the complex level (not to species level).

Butterflies

This list contains all species of butterflies that were observed in or close to southeast Drenthe between 2000 and 2015, except for species that were really not expected in road verges based on their habitat preferences (distributions and habitat preferences were obtained from De Vlinderstichting (n.d. c)) and except for rare species that were not taken into account based on advice from butterfly and moth specialist Ru Bijlsma (personal communication, March 31, 2020). Ru Bijlsma confirmed that this list of butterfly species was complete (personal communication, March 31, 2020).

Butterfly species that we took into account during the monitoring:

Skippers (*Hesperiidae*):
- Large skipper (*Ochlodes faunus*)
- Essex skipper (*Thymelicus lineola*)
- Grizzled skipper (*Pyrgus malvae*)

Swallowtail butterflies (*Papilionidae*):
- Swallowtail (*Papilio machaon*)

Pieridae (no English name):
- Brimstone (*Gonepteryx rhamni*)
- Pale clouded yellow (*Colias hyale*)
- Clouded yellow (*Colias croceus*)
- Large white (*Pieris brassicae*)
- Green-veined white (*Pieris napi*)
- Small white (*Pieris rapae*)
- Orangetip (*Anthocharis cardamines*)

Gossamer-winged butterflies (*Lycaenidae*):
- Holly blue (*Celastrina argiolus*)
- Sooty copper (*Lycaena tityrus*)
- Purple hairstreak (*Neozephyrus quercus*)
- Green hairstreak (*Callophrys rubi*)
- Common blue (*Polyommatus icarus*)
- Small copper (*Lycaena phlaeas*)
- Brown argus (*Aricia agestis*)

Brush-footed butterflies (*Nymphalidae*):
- Red admiral (*Vanessa atalanta*)
- Peacock (*Inachis io*)
- Painted lady (*Vanessa cardui*)
- Comma (*Polygonia* c-*album*)
- Small tortoiseshell (*Aglais urticae*)
- Map butterfly (*Araschnia levana*)
- Wall brown (*Lasiommata megera*)
- Speckled wood (*Pararge aegeria*)
- Meadow brown (*Maniola jurtina*)
- Small heath (*Coenonympha pamphilus*)
- Ringlet (*Aphantopus hyperantus*)
- Hedge brown (*Pyronia tithonus*)

Day-flying moths

This list of day-flying moths is a selection from the list of day-flying moths that De Vlinderstichting takes into account in the monitoring of butterflies (van Swaay et al., 2018). We selected the species that were observed in or close to southeast Drenthe between 2000 and February 2016, except for species that were really not expected in road verges based on their habitat preferences (distributions and habitat preferences were obtained from De Vlinderstichting (n.d. c)) and expect for a rare species that was not taken into account based on advice from butterfly and moth specialist Ru Bijlsma (personal communication, March 31, 2020). Ru Bijlsma confirmed that this list of day-flying moth species was complete (personal communication, March 31, 2020).

Day-flying moth species that we took into account during the monitoring:

- Forester (*Adscita statices*)
- Six-spot burnet (*Zygaena filipendulae*)
- Hummingbird hawk-moth (*Macroglossum stellatarum*)
- Cinnabar (*Tyria jacobaeae*)
- Mother shipton (*Callistege mi*)
- Burnet companion (*Euclidia glyphica*)
- Silver Y (*Autographa gamma*)
- Yellow shell (*Camptogramma bilineata*)
- *Lythria cruentaria* (no English name)

Damselflies and dragonflies

This list contains all species of damselflies and dragonflies that were observed in or close to southeast Drenthe between 2000 and 2015, except for species that were really not expected around ditches in farmland based on their habitat preferences and except for species that were not expected to be present as imago in the study period (distributions, habitat preferences and flight periods were obtained from De Vlinderstichting (n.d. a)).

Damselfly species that we took into account during the monitoring:

Coenagrionidae (No English name):
- Azure damselfly (*Coenagrion puella*)
- Common blue damselfly (*Enallagma cyathigerum*)
- Variable damselfly (*Coenagrion pulchellum*)
- Red-eyed damselfly (*Erythromma najas*)
- Small red-eyed damselfly (*Erythromma viridulum*)
- Common bluetail (*Ischnura elegans*)
- Small bluetail (*Ischnura pumilio*)
- Large red damsel (*Pyrrhosoma nymphula*)

Spread-winged damselflies (*Lestidae*):
- Common spreadwing (*Lestes sponsa*)
- Western willow spreadwing (*Lestes viridis*)

Demoiselles (*Calopterygidae*):
- Banded demoiselle (*Calopteryx splendens*)

White-legged damselflies (*Platycnemididae*):
- Blue featherleg (*Platycnemis pennipes*)

Dragonfly species that we took into account during the monitoring:

Libellulidae (no English name):
- Ruddy darter (Sympetrum sanguineum)
- Common darter (Sympetrum striolatum)
- Vagrant darter (Sympetrum vulgatum)
- Black-tailed skimmer (Orthetrum cancellatum)
- Broad-bodied chaser (Libellula depressa)
- Four-Spotted chaser (Libellula quadrimaculata)
- Banded darter (Sympetrum pedemontanum)
- Scarce chaser (Libellula fulva)
- Broad scarlet (Crocothemis erythraea)
- Black darter (Sympetrum danae)

Aeshnids (*Aeshnidae*):
- Brown hawker (*Aeshna grandis*)
- Hairy hawker (*Brachtron pratense*)
- Blue emperor (*Anax imperator*)
- Migrant hawker (*Aeshna mixta*)
- Green-eyed hawker (*Aeshna isoceles*)
- Blue hawker (*Aeshna cyanea*)
- Green hawker (*Aeshna viridis*)

Emerald dragonflies (*Corduliidae*):
- Brilliant emerald (*Somatochlora metallica*)
- Downy emerald (*Cordulia aenea*)

Appendix 2: Processed data

Table 13: A summary of the processed data, giving the total number of bumblebees and butterflies, the number of bumblebee and butterfly species and the diversity of bumblebees and butterflies per section repetition. DE=Germany, NL=the Netherlands.

route	section	repetition	total number	species	diversity
DE 1 7	1	1	0	0	0.000
DE 1 7	1	2	1	1	0.000
DE 1 7	1	3	3	2	0.637
DE 1 7	1	4	5	3	0.950
DE 1 7	1	5	11	5	1.468
DE 1 7	2	1	0	0	0.000
DE 1 7	2	2	0	0	0.000
DE 1 7	3	1	2	2	0.693
DE 1 7	3	2	0	0	0.000
DE 1 102	1	1	0	0	0.000
DE 1 102	1	2	5	2	0.673
DE 1 102	1	3	0	0	0.000
DE 1 102	1	4	3	2	0.637
DE 1 102	1	5	27	7	1.765
DE 1 102	2	1	0	0	0.000
DE 1 102	2	2	0	0	0.000
DE 1 102	2	3	0	0	0.000
DE 1 102	2	4	1	1	0.000
DE 1 102	2	5	5	5	1.609
DE 1 102	3	1	0	0	0.000
DE 1 102	3	2	0	0	0.000
DE 1 102	3	3	0	0	0.000
DE 1 102	3	4	1	1	0.000
DE 1 102	3	5	5	1	0.000
DE 1 113	1	1	5	2	0.500
DE 1 113	1	2	1	1	0.000
DE 1 113	1	3	3	3	1.099
DE 1 113	1	4	2	2	0.693
DE 1 113	1	5	6	2	0.637
DE 1 113	2	1	0	0	0.000
DE 1 113	2	2	0	0	0.000
DE 1 113	2	3	0	0	0.000
DE 1 113	2	4	0	0	0.000
DE 1 113	2	5	0	0	0.000
DE 2 8	1	1	3	3	1.099
DE 2 8	1	2	0	0	0.000
DE 2 8	1	3	15	4	1.355
DE 2 8	1	4	4	3	1.040
DE 2 8	1	5	2	2	0.693
DE 2 10	1	1	0	0	0.000
DE 2 10	1	2	1	1	0.000
DE 2 10	1	3	1	1	0.000
DE 2 10	1	4	0	0	0.000
DE 2 10	1	5	0	0	0.000
DE 2 10	2	1	2	1	0.000
DE 2 10	2	2	8	3	0.900
DE 2 10	2	3	2	2	0.693
DE 2 10	2	4	3	1	0.000
DE 2 10	2	5	4	2	0.562
DE 2 10	3	1	0	0	0.000
DE 2 10	3	2	2	1	0.000
DE 2 10	3	3	3	1	0.000
DE 2 10	3	4	1	1	0.000
DE 2 10	3	5	3	1	0.000
DE 2 10	4	1	3	2	0.637
DE 2 10	4	2	11	2	0.586
DE 2 10	4	3	5	3	0.950
DE 2 10	4	4	5	2	0.673
DE 2 10	4	5	0	0	0.000
DE 2 33	1	1	2	2	0.693
DE 2 33	1	2	3	2	0.637
DE 2 33	1	3	1	1	0.000
DE 2 33	1	4	5	4	1.332
DE 2 33	1	5	12	8	1.839
DE 2 110	1	1	2	1	0.000
DE 2 110	1	2	1	1	0.000
DE 2 110	1	3	0	0	0.000
DE 2 110	1	4	13	4	1.157
DE 2 110	1	5	5	3	0.950
DE 2 110	2	1	6	1	0.000
DE 2 110	2	2	0	0	0.000
DE 2 110	2	3	1	1	0.000
DE 2 110	2	4	4	1	0.000
DE 2 110	2	5	4	2	0.693
DE 3 18	1	1	0	0	0.000
DE 3 18	1	2	6	1	0.000

route	section	repetition	total number	species	diversity
DE 3 18	1	3	3	3	1.099
DE 3 18	1	4	2	1	0.000
DE 3 18	1	5	43	12	2.269
DE 3 19	1	1	0	0	0.000
DE 3 19	1	2	0	0	0.000
DE 3 19	1	3	0	0	0.000
DE 3 19	1	4	4	2	0.637
DE 3 19	2	1	3	1	0.000
DE 3 19	2	2	3	2	0.637
DE 3 19	2	3	1	1	0.000
DE 3 19	2	4	0	0	0.000
DE 3 22	1	1	2	1	0.000
DE 3 22	1	2	0	0	0.000
DE 3 22	1	3	2	2	0.693
DE 3 22	1	4	1	0	0.000
DE 3 22	1	5	22	8	1.643
DE 3 22	2	1	0	0	0.000
DE 3 22	2	2	0	0	0.000
DE 3 22	2	3	7	2	0.683
DE 3 22	2	4	0	0	0.000
DE 3 22	2	5	23	6	1.166
DE 3 24	1	1	0	0	0.000
DE 3 24	1	2	2	2	0.693
DE 3 24	1	3	5	4	1.386
DE 3 24	1	4	1	1	0.000
DE 3 24	1	5	5	4	1.332
DE 4 35	1	1	0	0	0.000
DE 4 35	1	2	0	0	0.000
DE 4 35	1	3	0	0	0.000
DE 4 35	1	4	0	0	0.000
DE 4 35	2	1	0	0	0.000
DE 4 35	2	2	2	1	0.000
DE 4 35	2	3	0	0	0.000
DE 4 35	2	4	0	0	0.000
DE 4 38	1	1	0	0	0.000
DE 4 38	1	2	0	0	0.000
DE 4 38	1	3	0	0	0.000
DE 4 38	1	4	1	1	0.000
DE 4 38	1	5	6	3	0.868
DE 4 38	2	1	0	0	0.000
DE 4 38	2	2	0	0	0.000
DE 4 38	2	3	0	0	0.000

route	section	repetition	total number	species	diversity
DE 4 38	2	4	0	0	0.000
DE 4 38	2	5	1	1	0.000
DE 4 38	3	1	0	0	0.000
DE 4 38	3	2	0	0	0.000
DE 4 38	3	3	0	0	0.000
DE 4 38	3	4	0	0	0.000
DE 4 38	3	5	2	1	0.000
DE 4 46	1	1	4	4	1.386
DE 4 46	1	2	2	2	0.693
DE 4 46	1	3	5	1	0.000
DE 4 46	1	4	1	1	0.000
DE 4 46	1	5	1	1	0.000
DE 5 82	1	1	0	0	0.000
DE 5 82	1	2	0	0	0.000
DE 5 82	1	3	1	1	0.000
DE 5 82	1	4	1	1	0.000
DE 5 82	1	5	2	2	0.693
DE 5 82	2	1	0	0	0.000
DE 5 82	2	2	0	0	0.000
DE 5 82	2	3	0	0	0.000
DE 5 82	2	4	0	0	0.000
DE 5 82	2	5	0	0	0.000
DE 5 82	3	1	0	0	0.000
DE 5 82	3	2	0	0	0.000
DE 5 82	3	3	0	0	0.000
DE 5 82	3	4	0	0	0.000
DE 5 82	3	5	1	1	0.000
DE 5 82	4	1	0	0	0.000
DE 5 82	4	2	0	0	0.000
DE 5 82	4	3	0	1	0.000
DE 5 82	4	4	0	0	0.000
DE 5 82	4	5	0	0	0.000
DE 5 82	5	1	0	0	0.000
DE 5 82	5	2	0	0	0.000
DE 5 82	5	3	0	0	0.000
DE 5 82	5	4	0	0	0.000
DE 5 82	5	5	0	0	0.000
DE 5 85	1	1	0	0	0.000
DE 5 85	1	2	5	2	0.500
DE 5 85	1	3	1	1	0.000
DE 5 85	1	4	1	1	0.000
DE 5 85	1	5	9	5	1.494

route	section	repetition	total number	species	diversity
DE 5 85	2	1	1	1	0.000
DE 5 85	2	2	2	1	0.000
DE 5 85	2	3	0	0	0.000
DE 5 85	2	4	0	0	0.000
DE 5 85	2	5	0	0	0.000
DE 5 90	1	1	1	1	0.000
DE 5 90	1	2	5	3	1.055
DE 5 90	1	3	2	1	0.000
DE 5 90	1	4	3	4	1.386
DE 5 90	1	5	26	8	1.979
DE 6 62	1	1	0	0	0.000
DE 6 62	1	2	4	2	0.562
DE 6 62	1	3	0	0	0.000
DE 6 62	1	4	2	2	0.693
DE 6 62	1	5	11	3	0.916
DE 6 62	2	1	0	0	0.000
DE 6 62	2	2	0	0	0.000
DE 6 62	2	3	0	0	0.000
DE 6 62	2	4	0	0	0.000
DE 6 62	2	5	8	4	1.321
DE 6 71	1	1	2	3	1.099
DE 6 71	1	2	9	2	0.530
DE 6 71	1	3	6	5	1.550
DE 6 71	1	4	17	3	0.678
DE 6 71	1	5	19	6	1.368
DE 6 77	1	1	0	0	0.000
DE 6 77	1	2	2	2	0.693
DE 6 77	1	3	13	4	1.205
DE 6 77	1	4	78	3	0.601
DE 6 77	1	5	22	7	1.421
NL 1 2	1	1	0	0	0.000
NL 1 2	1	2	0	0	0.000
NL 1 2	1	3	1	1	0.000
NL 1 2	1	4	2	2	0.693
NL 1 2	2	1	0	0	0.000
NL 1 2	2	2	0	0	0.000
NL 1 2	2	3	1	1	0.000
NL 1 2	2	4	3	3	1.099
NL 1 3	1	1	0	0	0.000
NL 1 3	1	2	1	2	0.693
NL 1 3	1	3	2	2	0.598
NL 1 3	1	4	1	1	0.000

route	section	repetition	total number	species	diversity
NL 1 3	2	1	0	0	0.000
NL 1 3	2	2	0	0	0.000
NL 1 3	2	3	1	1	0.000
NL 1 3	2	4	3	2	0.637
NL 1 3	3	1	1	1	0.000
NL 1 3	3	2	1	1	0.000
NL 1 3	3	3	1	1	0.000
NL 1 3	3	4	1	1	0.000
NL 1 5	1	1	0	0	0.000
NL 1 5	1	2	2	2	0.693
NL 1 5	1	3	4	3	1.099
NL 1 5	1	4	2	2	0.693
NL 1 5	2	1	0	0	0.000
NL 1 5	2	2	0	0	0.000
NL 1 5	2	3	0	0	0.000
NL 1 5	2	4	1	0	0.000
NL 1 5	3	1	0	0	0.000
NL 1 5	3	2	1	1	0.000
NL 1 5	3	3	0	0	0.000
NL 1 5	3	4	0	0	0.000
NL 2 2	1	1	0	0	0.000
NL 2 2	1	2	2	1	0.000
NL 2 2	1	3	2	3	0.566
NL 2 2	2	1	0	0	0.000
NL 2 2	2	2	0	0	0.000
NL 2 2	2	3	4	3	0.319
NL 2 4	1	1	0	0	0.000
NL 2 4	1	2	0	0	0.000
NL 2 4	1	3	1	1	0.000
NL 2 4	2	1	0	0	0.000
NL 2 4	2	2	0	0	0.000
NL 2 4	2	3	1	1	0.000
NL 2 4	3	1	0	0	0.000
NL 2 4	3	2	0	0	0.000
NL 2 4	3	3	2	2	0.693
NL 3 2	1	1	0	0	0.000
NL 3 2	1	2	0	0	0.000
NL 3 2	1	3	1	1	0.000
NL 3 2	1	4	0	0	0.000
NL 3 2	2	1	0	0	0.000
NL 3 2	2	2	1	0	0.000
NL 3 2	2	3	0	0	0.000

route	section	repetition	total number	species	diversity
NL 3 2	2	4	0	0	0.000
NL 3 3	1	1	3	2	0.637
NL 3 3	1	2	0	0	0.000
NL 3 3	1	3	1	1	0.000
NL 3 3	1	4	31	8	1.266
NL 3 3	2	1	1	1	0.000
NL 3 3	2	2	3	1	0.000
NL 3 3	2	3	0	0	0.000
NL 3 3	2	4	5	3	0.687
NL 3 4	1	1	2	2	0.693
NL 3 4	1	2	18	2	0.215
NL 3 4	1	3	14	6	1.173
NL 3 4	1	4	18	3	0.778
NL 3 5	1	1	4	2	0.562
NL 3 5	1	2	4	3	1.040
NL 3 5	1	3	2	1	0.000
NL 3 5	1	4	5	2	0.500
NL 3 5	2	1	0	0	0.000
NL 3 5	2	2	0	0	0.000
NL 3 5	2	3	1	1	0.000
NL 3 5	2	4	4	2	0.562
NL 3 5	3	1	3	1	0.000
NL 3 5	3	2	2	1	0.000
NL 3 5	3	3	1	1	0.000
NL 3 5	3	4	0	0	0.000
NL 4 2	1	1	1	1	0.000
NL 4 2	1	2	4	2	0.693
NL 4 2	1	3	3	1	0.000
NL 4 2	1	4	9	4	1.273
NL 4 4	1	1	0	0	0.000
NL 4 4	1	2	0	0	0.000
NL 4 4	1	3	0	0	0.000
NL 4 4	1	4	1	1	0.000
NL 4 4	2	1	0	0	0.000
NL 4 4	2	2	1	1	0.000
NL 4 4	2	3	0	0	0.000
NL 4 4	2	4	4	1	0.000
NL 5 1	1	2	1	1	0.000
NL 5 1	1	3	1	1	0.000
NL 5 1	1	4	3	2	0.693
NL 5 2	1	2	5	3	0.950
NL 5 2	1	3	0	0	0.000
NL 5 2	2	2	2	2	0.693
NL 5 2	2	3	0	0	0.000
NL 5 3	1	2	16	2	0.451
NL 5 3	1	3	0	0	0.000
NL 5 3	1	4	0	0	0.000
NL 5 3	2	2	4	1	0.000
NL 5 3	2	3	0	0	0.000
NL 5 3	2	4	1	1	0.000
NL 5 4	1	2	2	1	0.000
NL 5 4	1	3	1	1	0.000
NL 5 4	2	2	0	0	0.000
NL 5 4	2	3	1	1	0.000
NL 6 5	1	2	3	1	0.000
NL 6 5	1	3	0	0	0.000
NL 6 5	2	2	16	4	1.063
NL 6 5	2	3	4	2	0.693
NL 7 1	1	2	5	2	0.693
NL 7 1	1	3	6	4	1.242
NL 7 1	2	2	0	0	0.000
NL 7 1	2	3	1	1	0.000
NL 7 3	1	2	1	1	0.000
NL 7 3	1	3	4	3	1.040
NL 7 3	1	4	3	1	0.000
NL 8 2	1	2	0	0	0.000
NL 8 2	1	3	0	0	0.000
NL 8 2	2	2	0	0	0.000
NL 8 2	2	3	1	1	0.000
NL 8 2	3	2	2	2	0.693
NL 8 2	3	3	1	1	0.000
NL 8 2	4	2	3	2	0.637
NL 8 2	4	3	2	2	0.693
NL 8 4	1	2	7	3	1.011
NL 8 4	1	3	2	2	0.693
NL 8 4	2	2	2	2	0.693
NL 8 4	2	3	1	1	0.000
NL 8 4	3	2	0	0	0.000
NL 8 4	3	3	0	0	0.000

Table 14: A summary of the processed data, giving the total number of damselflies and dragonflies, the number of damselfly and dragonfly species and the diversity of damselflies and dragonflies per section repetition. DE=Germany, NL=the Netherlands.

route	section	repetition	total number	species	diversity
DE 1 1	1	2	0	0	0.000
DE 1 1	1	3	3	2	0.637
DE 1 1	1	4	1	1	0.000
DE 1 1	1	5	1	1	0.000
DE 1 1	2	2	0	0	0.000
DE 1 1	3	2	0	0	0.000
DE 1 2	1	3	1	1	0.000
DE 1 2	1	4	0	0	0.000
DE 1 2	1	5	3	1	0.000
DE 1 2	2	3	1	1	0.000
DE 1 2	2	4	0	0	0.000
DE 1 2	2	5	0	0	0.000
DE 1 3	1	3	51	5	1.347
DE 1 3	1	4	71	6	1.404
DE 1 3	1	5	75	5	0.552
DE 1 4	1	3	1	1	0.000
DE 1 4	1	4	9	2	0.377
DE 1 4	1	5	0	0	0.000
DE 1 99	1	3	30	6	1.167
DE 1 99	1	4	149	8	1.533
DE 1 99	1	5	176	8	1.476
DE 1 101	1	3	0	0	0.000
DE 1 101	1	4	3	1	0.000
DE 1 101	1	5	0	0	0.000
DE 1 101	2	3	0	0	0.000
DE 1 101	2	4	0	0	0.000
DE 1 101	2	5	0	0	0.000
DE 1 101	3	3	1	1	0.000
DE 1 101	3	4	0	0	0.000
DE 1 101	3	5	0	0	0.000
DE 1 103	1	3	14	3	0.898
DE 1 103	1	4	13	2	0.666
DE 1 103	1	5	4	0	0.000
DE 1 103	2	3	15	2	0.691
DE 1 103	2	4	13	2	0.690
DE 1 103	2	5	3	0	0.000
DE 1 103	3	3	7	2	0.598
DE 1 103	3	4	14	2	0.410
DE 1 103	3	5	1	0	0.000
DE 1 106	1	3	4	1	0.000
DE 1 106	1	4	2	1	0.000
DE 1 106	1	5	1	0	0.000
DE 1 108	1	2	0	0	0.000
DE 1 108	1	3	0	0	0.000
DE 1 108	1	4	1	1	0.000
DE 1 108	1	5	0	0	0.000
DE 1 108	2	2	0	0	0.000
DE 1 108	2	3	0	0	0.000
DE 1 108	2	4	4	2	0.693
DE 1 108	2	5	0	0	0.000
DE 1 114	1	2	0	0	0.000
DE 1 114	1	3	0	0	0.000
DE 1 114	1	4	16	6	1.581
DE 1 114	1	5	2	0	0.000
DE 1 114	2	2	0	0	0.000
DE 1 114	2	3	0	0	0.000
DE 1 114	2	4	8	3	0.736
DE 1 114	2	5	4	2	0.637
DE 2 5	1	3	34	4	1.188
DE 2 5	1	4	65	3	0.656
DE 2 5	1	5	0	0	0.000
DE 2 5	2	3	37	7	1.463
DE 2 5	2	4	32	3	0.567
DE 2 5	2	5	38	4	0.363
DE 2 6	1	3	120	5	1.023
DE 2 6	1	4	83	5	1.170
DE 2 6	1	5	98	5	1.027
DE 2 11	1	3	0	0	0.000
DE 2 11	1	4	0	0	0.000
DE 2 11	1	5	0	0	0.000
DE 2 11	2	3	20	5	1.158
DE 2 11	2	4	0	0	0.000
DE 2 11	2	5	0	0	0.000
DE 2 11	3	3	3	1	0.000
DE 2 11	3	4	0	0	0.000
DE 2 11	3	5	0	0	0.000
DE 2 11	4	3	0	0	0.000
DE 2 11	4	4	3	1	0.000
DE 2 11	4	5	0	0	0.000

route	section	repetition	total number	species	diversity
DE 2 34	1	3	0	0	0.000
DE 2 34	1	4	0	0	0.000
DE 2 34	1	5	0	0	0.000
DE 2 34	2	3	2	1	0.000
DE 2 34	2	4	0	0	0.000
DE 2 34	2	5	0	0	0.000
DE 2 34	3	3	1	1	0.000
DE 2 34	3	4	0	0	0.000
DE 2 34	3	5	0	0	0.000
DE 2 34	4	3	6	4	1.242
DE 2 34	4	4	3	1	0.000
DE 2 34	4	5	0	0	0.000
DE 2 111	1	3	9	2	0.637
DE 2 111	1	4	33	3	0.933
DE 2 111	1	5	5	2	0.673
DE 2 111	2	3	3	0	0.000
DE 2 111	2	4	61	5	0.781
DE 2 111	2	5	0	0	0.000
DE 3 25	1	2	0	0	0.000
DE 3 25	1	3	0	0	0.000
DE 3 25	1	4	0	0	0.000
DE 3 25	1	5	0	0	0.000
DE 4 45	1	2	2	0	0.000
DE 4 45	1	3	1	1	0.000
DE 4 45	1	4	3	1	0.000
DE 4 45	1	5	2	1	0.000
DE 4 50	1	3	0	0	0.000
DE 4 50	1	4	0	0	0.000
DE 4 50	1	5	0	0	0.000
DE 4 50	2	3	0	0	0.000
DE 4 50	2	4	0	0	0.000
DE 4 50	2	5	0	0	0.000
DE 5 84	1	2	0	0	0.000
DE 5 84	1	3	0	0	0.000
DE 5 84	1	4	1	1	0.000
DE 5 84	1	5	0	0	0.000
DE 5 84	2	2	0	0	0.000
DE 5 84	2	3	0	0	0.000
DE 5 84	2	4	0	0	0.000
DE 5 84	2	5	0	0	0.000
DE 5 88	1	2	2	0	0.000
DE 5 88	1	3	0	0	0.000

route	section	repetition	total number	species	diversity
DE 5 88	1	4	1	1	0.000
DE 5 88	1	5	0	0	0.000
DE 6 63	1	2	1	0	0.000
DE 6 63	1	3	0	0	0.000
DE 6 63	1	4	63	5	0.383
DE 6 63	1	5	8	5	1.386
DE 6 63	2	2	0	0	0.000
DE 6 63	2	3	2	1	0.000
DE 6 63	2	4	92	5	0.471
DE 6 63	2	5	1	1	0.000
DE 6 70	1	2	11	3	1.055
DE 6 70	1	3	2	1	0.000
DE 6 70	1	4	6	2	0.451
DE 6 70	1	5	7	3	0.796
DE 6 76	1	2	1	1	0.000
DE 6 76	1	3	4	2	0.562
DE 6 76	1	4	9	2	0.349
DE 6 76	1	5	0	0	0.000
NL 1 1	1	3	10	2	0.611
NL 1 1	1	4	26	4	1.156
NL 1 1	2	3	13	2	0.690
NL 1 1	2	4	20	3	0.999
NL 1 4	1	3	1	1	0.000
NL 1 4	1	4	6	2	0.451
NL 1 4	2	3	1	1	0.000
NL 1 4	2	4	8	1	0.000
NL 2 1	1	3	34	5	1.274
NL 2 1	1	4	205	4	0.824
NL 2 3	1	3	25	3	1.093
NL 2 3	2	3	54	4	1.143
NL 2 5	1	3	3	2	0.637
NL 2 5	2	3	4	2	0.637
NL 2 5	3	3	31	2	0.279
NL 3 1	1	3	89	7	0.932
NL 3 1	1	4	69	6	1.116
NL 3 1	2	3	215	8	1.533
NL 3 1	2	4	267	7	1.267
NL 3 1	3	3	52	6	1.332
NL 3 1	3	4	38	6	1.213
NL 4 1	1	3	1	1	0.000
NL 4 1	1	4	54	3	0.775
NL 4 1	2	3	7	2	0.562

route	section	repetition	total number	species	diversity
NL 4 1	2	4	44	5	1.069
NL 4 3	1	3	0	0	0.000
NL 4 3	1	4	4	2	0.562
NL 4 3	2	3	0	0	0.000
NL 4 3	2	4	6	2	0.451
NL 4 3	3	3	0	0	0.000
NL 4 3	3	4	6	1	0.000
NL 4 3	4	3	0	0	0.000
NL 4 3	4	4	28	1	0.000
NL 4 5	1	3	0	0	0.000
NL 4 5	1	4	9	4	1.311
NL 4 5	2	3	0	0	0.000
NL 4 5	2	4	2	2	0.693
NL 5 5	1	3	14	2	0.662
NL 6 1	1	3	13	2	0.474
NL 6 1	2	3	13	4	0.940
NL 6 1	3	3	9	1	0.000
NL 6 2	1	3	36	5	0.771
NL 6 3	1	3	1	1	0.000
NL 6 3	1	4	1	1	0.000
NL 6 3	2	3	7	2	0.693
NL 6 3	2	4	0	0	0.000
NL 6 4	1	3	8	2	0.693
NL 7 2	1	3	3	2	0.637
NL 7 2	2	3	9	3	0.974

route	section	repetition	total number	species	diversity
NL 7 2	3	3	14	3	0.918
NL 7 4	1	3	294	7	1.041
NL 7 4	1	4	75	2	0.077
NL 7 5	1	3	10	2	0.637
NL 7 5	2	3	1	1	0.000
NL 7 5	3	3	0	0	0.000
NL 7 5	4	3	5	3	1.040
NL 8 1	1	3	23	3	0.576
NL 8 1	1	4	14	3	0.687
NL 8 1	2	3	7	2	0.693
NL 8 1	2	4	0	0	0.000
NL 8 1	3	3	0	0	0.000
NL 8 1	3	4	2	1	0.000
NL 8 3	1	3	0	0	0.000
NL 8 3	2	3	4	2	0.693
NL 8 3	3	3	2	1	0.000
NL 8 3	4	3	3	1	0.000
NL 8 5	1	3	94	7	1.568
NL 8 5	2	3	25	6	1.407
NL 8 5	3	3	16	2	0.679

Appendix 3: Model outputs & recognition of important outliers

Table 15: The output of the model with total number of bumblebees and butterflies as response, analyzed per repetition.

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.9572	0.2878	-6.7996	0.0000 ***
Date	0.2557	0.0145	17.6142	0.0000 ***
Cloud cover	-0.0392	0.0151	-2.6066	0.0091 **
Studied surface	0.0851	0.0344	2.4740	0.0134 *
Number of flowering plant species groups	0.1416	0.0322	4.4033	0.0000 ***
Total number of flowering plants	0.0669	0.0069	9.7518	0.0000 ***

Table 16: The output of the model with number of bumblebee and butterfly species as response, analyzed per repetition.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	-0.0015	0.5933	219.9318	-0.0026	0.9979
Date	0.2775	0.0390	256.3597	7.1219	0.0000 ***
Temperature	-0.0173	0.0283	254.1388	-0.6130	0.5404
Wind force	-0.2084	0.1019	244.0332	-2.0445	0.0420 *
Cloud cover	0.0062	0.0316	224.4665	0.1974	0.8437
Studied surface	0.1180	0.0308	98.1723	3.8361	0.0002 ***
Number of flowering plant species groups	0.0727	0.0640	156.5234	1.1354	0.2580
Total number of flowering plants	0.0331	0.0151	272.9890	2.1869	0.0296 *

Table 17: The output of the model with diversity of bumblebees and butterflies as response, analyzed per repetition.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	-0.0170	0.1670	217.0468	-0.1017	0.9191
Date	0.0638	0.0111	253.6944	5.7613	0.0000 ***
Temperature	-0.0017	0.0080	258.7400	-0.2086	0.8349
Wind force	-0.0775	0.0288	244.5107	-2.6940	0.0075 **
Cloud cover	0.0058	0.0089	235.6787	0.6550	0.5131
Studied surface	0.0396	0.0093	91.3045	4.2571	0.0001 ***
Number of flowering plant species groups	0.0011	0.0180	149.0631	0.0614	0.9512
Total number of flowering plants	0.0080	0.0043	274.4789	1.8501	0.0654 .

Table 18: The output of the model with total number of damselflies and dragonflies as response, analyzed per repetition.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	9.6027	43.5712	104.8746	0.2204	0.8260
Number of studied ditch banks	-17.1248	12.5463	33.5616	-1.3649	0.1814
Date	-0.2942	1.2253	102.0447	-0.2401	0.8108
End time	-0.3239	1.5483	109.9164	-0.2092	0.8347
Temperature	-0.3471	1.1506	113.5636	-0.3017	0.7635
Wind force	-0.8894	2.6196	101.5848	-0.3395	0.7349
Cloud cover	-2.2624	1.0194	110.6171	-2.2193	0.0285 *
Studied surface	5.4356	0.9842	73.4618	5.5229	0.0000 ***
Algae, absent	-6.2852	5.4811	126.5143	-1.1467	0.2537
Trees/shrubs, absent	11.4239	9.6745	130.5671	1.1808	0.2398
Clearness, turbid	-17.5297	6.9052	117.3397	-2.5386	0.0124 *
Bare ground, absent	-0.8328	9.5815	118.8683	-0.0869	0.9309
Bulrush/common reed, absent	-2.5941	6.6526	117.3937	-0.3899	0.6973
Perennial vegetation, absent	10.9585	9.3985	109.5691	1.1660	0.2462
Common rush, absent	3.9793	5.9028	131.6935	0.6741	0.5014
Aquatic vegetation	2.1221	1.4039	116.3627	1.5116	0.1333

Table 19: The output of the model with number of damselfly and dragonfly species as response, analyzed per repetition.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	1.4898	2.0708	127.8978	0.7194	0.4732
Number of studied ditch banks	-1.3044	0.5573	43.5685	-2.3407	0.0239 *
Date	-0.0361	0.0608	145.0774	-0.5939	0.5535
End time	0.0574	0.0762	154.1121	0.7530	0.4526
Temperature	0.0368	0.0557	143.9005	0.6609	0.5098
Wind force	-0.0454	0.1301	151.0071	-0.3487	0.7278
Cloud cover	-0.1674	0.0503	155.6685	-3.3272	0.0011 **
Studied surface	0.1504	0.0391	131.1726	3.8493	0.0002 ***
Algae, absent	0.1099	0.2607	151.3737	0.4214	0.6740
Trees/shrubs, absent	0.6033	0.4615	152.7457	1.3072	0.1931
Clearness, turbid	-0.0363	0.3300	148.4805	-0.1100	0.9125
Bare ground, absent	-0.2544	0.4655	155.7876	-0.5464	0.5856
Bulrush/common reed, absent	-0.3586	0.3143	143.6096	-1.1410	0.2558
Perennial vegetation, absent	-0.4741	0.4568	150.0902	-1.0378	0.3010
Aquatic vegetation	0.1209	0.0675	149.4102	1.7910	0.0753 .

Table 20: The output of the model with diversity of damselflies and dragonflies as response, analyzed per repetition.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.7117	0.5162	115.7243	1.3787	0.1706
Number of studied ditch banks	-0.2570	0.1253	44.7790	-2.0499	0.0463 *
Date	-0.0070	0.0161	151.3992	-0.4348	0.6643
End time	0.0031	0.0199	154.8288	0.1570	0.8754
Temperature	0.0015	0.0141	127.3434	0.1041	0.9172
Wind force	0.0072	0.0343	154.8359	0.2089	0.8348
Cloud cover	-0.0384	0.0130	152.6325	-2.9447	0.0037 **
Studied surface	0.0263	0.0097	114.1533	2.7197	0.0076 **
Algae, absent	0.0178	0.0688	154.6418	0.2583	0.7965
Trees/shrubs, absent	0.1022	0.1176	135.2633	0.8685	0.3866
Clearness, turbid	0.0824	0.0851	135.0369	0.9685	0.3345
Bare ground, absent	-0.1997	0.1193	145.2067	-1.6736	0.0964 .
Bulrush/common reed, absent	-0.0309	0.0847	149.7939	-0.3646	0.7159
Perennial vegetation, absent	-0.2811	0.1209	154.8705	-2.3247	0.0214 *
Common rush, absent	0.1402	0.0728	154.9998	1.9266	0.0559 .
Aquatic vegetation	0.0274	0.0179	154.3219	1.5339	0.1271

Table 21: The output of the model with total number of bumblebees and butterflies as response, analyzed per section.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	4.6979	9.1851	74.5808	0.5115	0.6105
Studied surface	1.0863	0.2585	46.0520	4.2026	0.0001 ***
Width of road verge	-0.5957	0.4410	47.6815	-1.3508	0.1831
Number of host plant species	-0.2766	0.6488	53.1942	-0.4264	0.6715
Proportion cultivated land	3.9146	10.0557	69.1461	0.3893	0.6983
Mean environmental pressure per cultivated area	0.3293	0.9320	66.6048	0.3533	0.7250

Table 22: The output of the model with number of bumblebee and butterfly species as response, analyzed per section.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	-0.6740	1.9294	57.7877	-0.3493	0.7281
Studied surface	0.2695	0.0693	67.8775	3.8907	0.0002 ***
Width of road verge	-0.0617	0.0739	38.4354	-0.8343	0.4093
Number of host plant species	0.1312	0.1595	76.5362	0.8225	0.4134
Proportion cultivated land	2.0153	2.1620	58.0914	0.9321	0.3551
Mean environmental pressure per cultivated area	0.1053	0.2078	68.2230	0.5067	0.6140

Table 23: The output of the model with diversity of bumblebees and butterflies as response, analyzed per section.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.0765	0.4844	30.9299	0.1579	0.8756
Studied surface	0.0769	0.0206	66.7192	3.7297	0.0004 ***
Width of road verge	-0.0151	0.0174	36.9935	-0.8676	0.3912
Number of host plant species	0.0007	0.0447	47.6271	0.0162	0.9871
Proportion cultivated land	0.2932	0.5332	29.8295	0.5500	0.5864
Mean environmental pressure per cultivated area	0.0470	0.0529	38.6353	0.8870	0.3805

Table 24: The output of the model with total number of damselflies and dragonflies as response, analyzed per section.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	114.4730	99.9031	38.1346	1.1458	0.2590
Studied surface	6.0692	1.6646	43.3130	3.6460	0.0007 ***
Number of studied ditch banks	-44.7812	41.8388	23.1124	-1.0703	0.2955
Nutrient abundance	-28.4050	19.3490	46.8734	-1.4680	0.1488
Steepness of ditch bank on water level, 22.5-45°	-53.5736	47.5091	22.3672	-1.1276	0.2714
Steepness of ditch bank on water level, 45-67.5°	-66.0277	42.4641	22.1399	-1.5549	0.1341
Steepness of ditch bank on water level, 67.5-90°	-25.1326	50.7308	21.6775	-0.4954	0.6253
Steepness of ditch bank on water level, 90°	-56.1713	50.3330	21.6937	-1.1160	0.2766
Width of ditch bank	1.3406	1.9945	46.3884	0.6721	0.5048
Width of ditch	0.2404	2.2290	27.7148	0.1078	0.9149
General steepness of ditch bank, 45-67.5°	-10.6856	28.4059	20.9575	-0.3762	0.7106
General steepness of ditch bank, 67.5-90°	-6.8607	80.0306	22.0945	-0.0857	0.9325
Proportion cultivated land	98.1419	54.0243	29.8891	1.8166	0.0793 .
Mean environmental pressure per cultivated area	-2.0255	4.5911	45.6648	-0.4412	0.6612

According to the model the proportion cultivated land had an almost significant positive effect on the total number of damselflies and dragonflies (Table 24). From Figure 13 appeared that the positive effect was probably caused by the outliers at the top right of the graph. This was indeed the case, because the almost significant positive effect disappeared when we analyzed a subset of our data with total number of damselflies and dragonflies being smaller than 150.

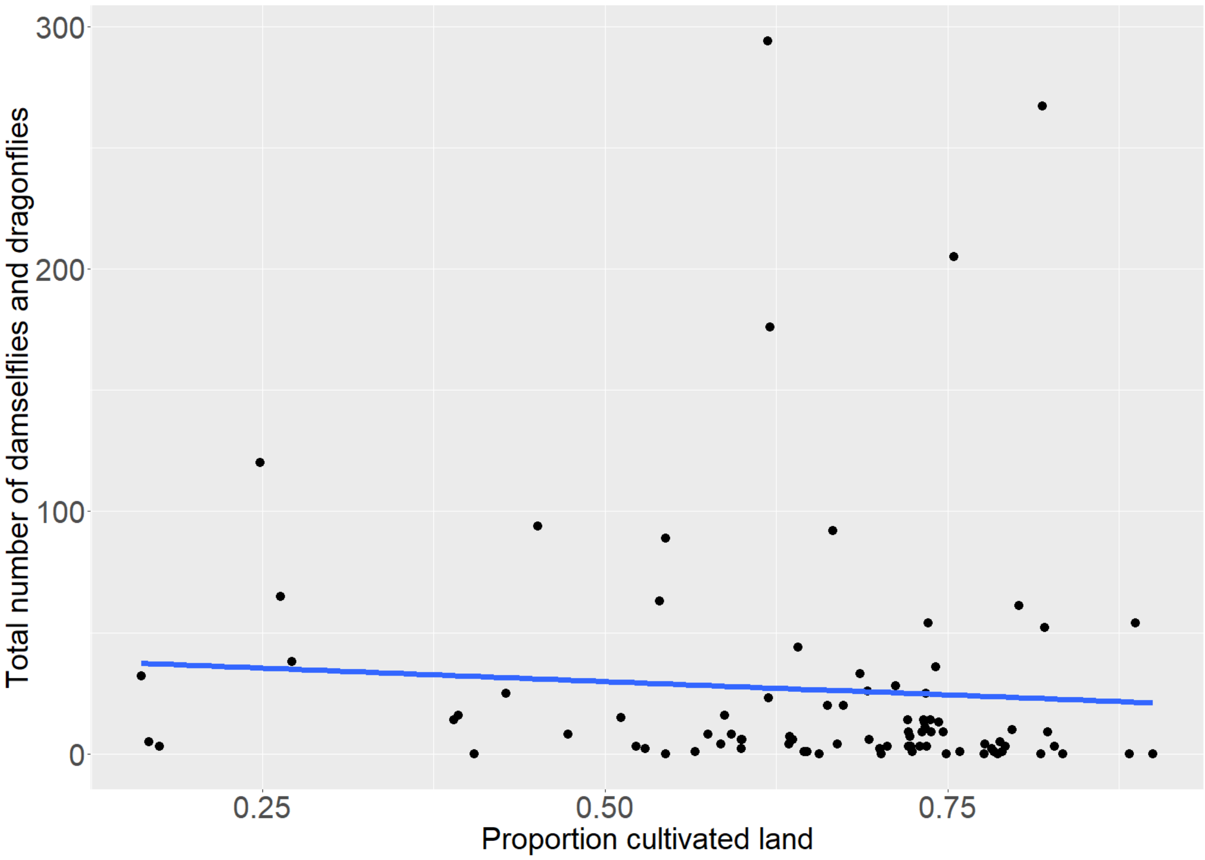


Figure 13: The total number of damselflies and dragonflies plotted against the proportion cultivated land.

Table 25: The output of the model with number of damselfly and dragonfly species as response, analyzed per section.

	Estimate	**Std. Error**	**df**	**t value**	**Pr(>|t|)**
(Intercept)	4.2898	3.2834	35.2852	1.3065	0.1998
Studied surface	0.1627	0.0629	46.2125	2.5885	0.0128 *
Number of studied ditch banks	-1.8931	1.2290	23.0657	-1.5404	0.1371
Nutrient abundance	-0.7556	0.6855	39.4826	-1.1022	0.2771
Steepness of ditch bank on water level, 22.5-45°	-1.3827	1.3897	23.3210	-0.9949	0.3300
Steepness of ditch bank on water level, 45-67.5°	-0.3043	1.2385	22.9627	-0.2457	0.8081
Steepness of ditch bank on water level, 67.5-90°	0.6371	1.4692	21.9520	0.4337	0.6688
Steepness of ditch bank on water level, 90°	0.6307	1.4625	22.7482	0.4312	0.6703
Width of ditch bank	0.2755	0.0721	42.5337	3.8189	0.0004 ***
Width of ditch	0.0135	0.0691	31.1377	0.1952	0.8465
General steepness of ditch bank, 45-67.5°	0.0479	0.8122	20.1512	0.0590	0.9535
General steepness of ditch bank, 67.5-90°	-1.7630	2.3411	23.6768	-0.7531	0.4588
Proportion cultivated land	1.8246	2.3404	35.0722	0.7796	0.4409
Mean environmental pressure per cultivated area	-0.2565	0.1682	43.7295	-1.5251	0.1344

Table 26: The output of the model with diversity of damselflies and dragonflies as response, analyzed per section.

	Estimate	**Std. Error**	**df**	**t value**	**Pr(>|t|)**
(Intercept)	0.4775	0.8287	35.7316	0.5763	0.5681
Studied surface	0.0280	0.0170	38.3822	1.6445	0.1082
Number of studied ditch banks	-0.2327	0.2784	23.7254	-0.8355	0.4118
Nutrient abundance	-0.0938	0.1712	30.0981	-0.5482	0.5876
Steepness of ditch bank on water level, 22.5-45°	0.0077	0.3203	28.5596	0.0239	0.9811
Steepness of ditch bank on water level, 45-67.5°	0.1019	0.2844	28.4448	0.3585	0.7226
Steepness of ditch bank on water level, 67.5-90°	0.3284	0.3319	25.7888	0.9895	0.3316
Steepness of ditch bank on water level, 90°	0.4379	0.3362	28.9399	1.3028	0.2029
Width of ditch bank	0.0394	0.0184	30.5142	2.1388	0.0406 *
Width of ditch	0.0158	0.0173	37.3148	0.9143	0.3664
General steepness of ditch bank, 45-67.5°	0.0169	0.1761	20.3548	0.0961	0.9243
General steepness of ditch bank, 67.5-90°	-0.2409	0.5456	30.5298	-0.4415	0.6619
Proportion cultivated land	0.2297	0.7704	42.5982	0.2981	0.7670
Mean environmental pressure per cultivated area	-0.0116	0.0438	32.6010	-0.2643	0.7932

According to the models the width of the ditch bank had a significant positive effect on the number of damselfly and dragonfly species (Table 25) and on the diversity of damselflies and dragonflies (Table 26). From Figure 14 and 15 appeared that the positive effects on both responses were probably caused by the outliers at the top right of both graphs. This was indeed the case, because both effects did not held when we analyzed a subset of the data with the width of the ditch bank being smaller than 10 meters.

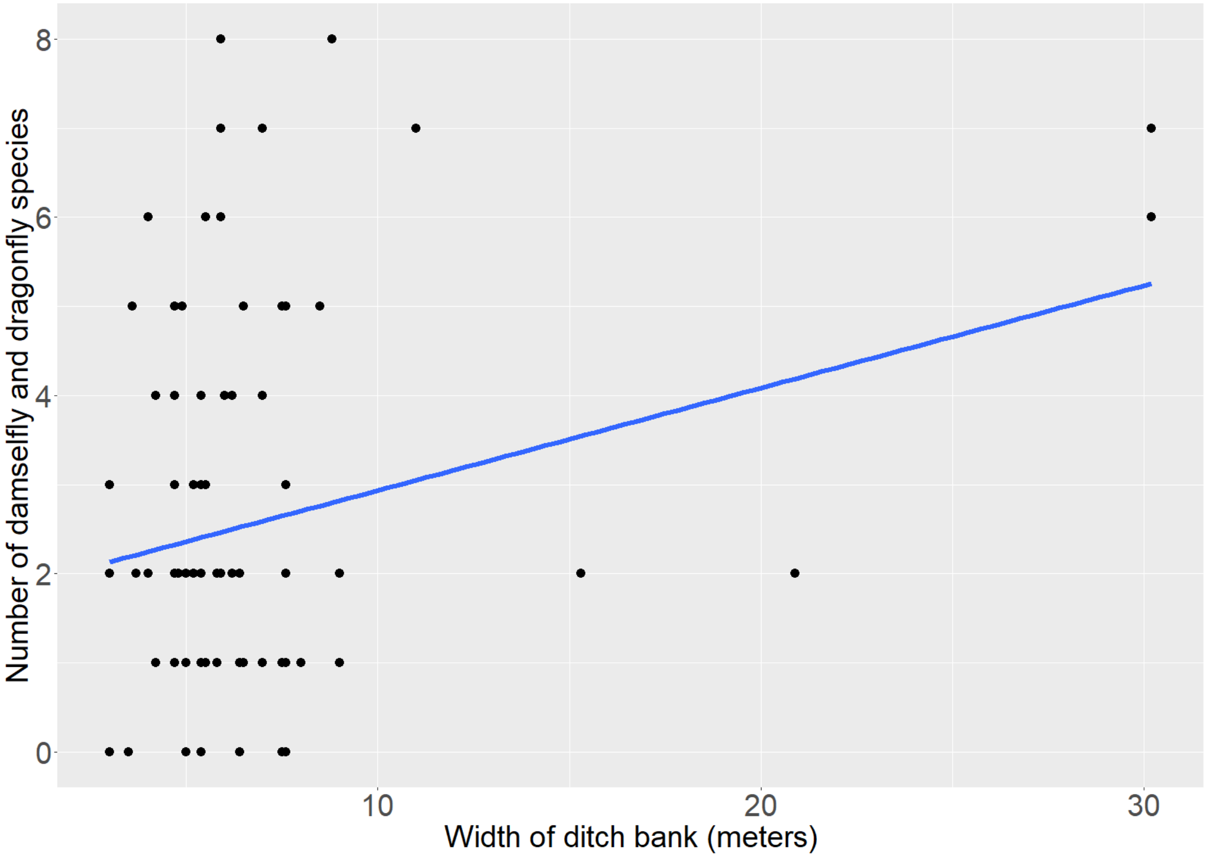


Figure 14: The number of damselfly and dragonfly species plotted against the width of the ditch bank.

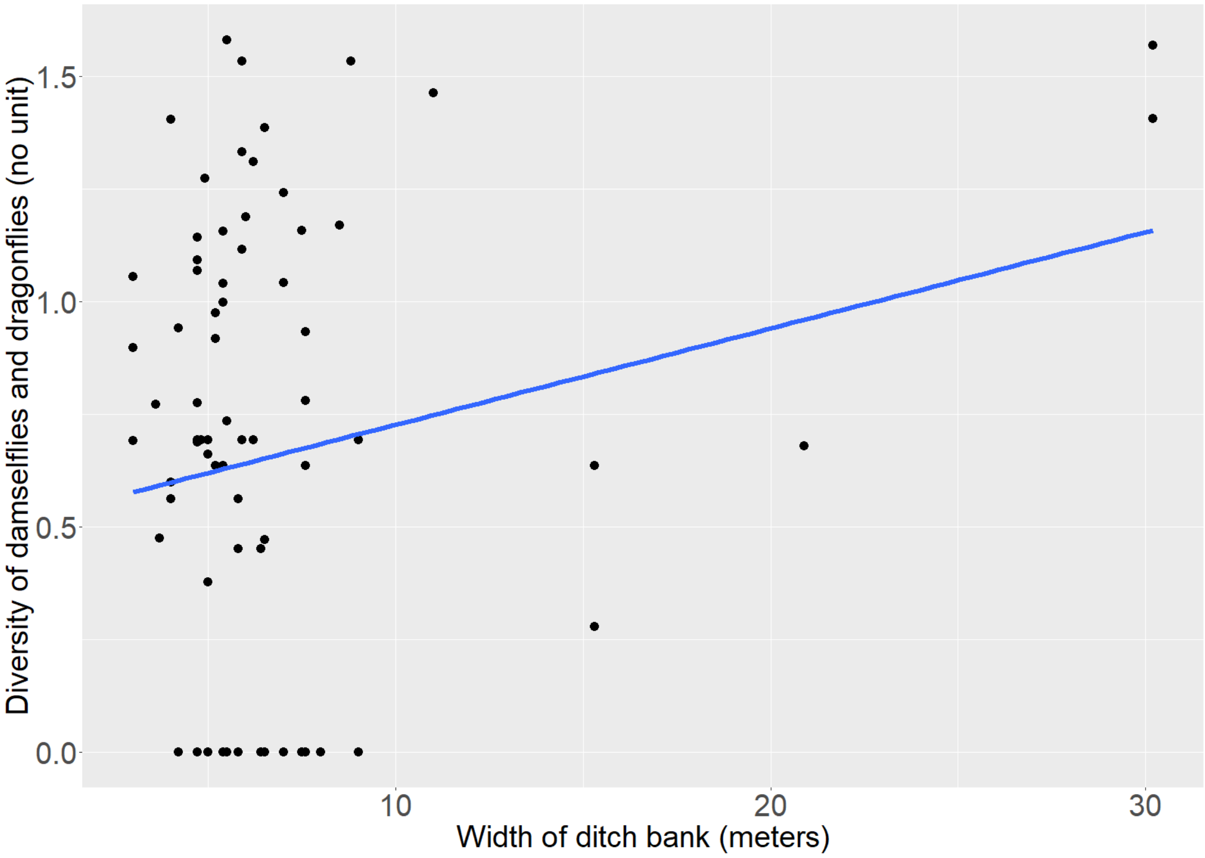


Figure 15: The diversity of damselflies and dragonflies plotted against the width of the ditch bank.

Table 27: The output of the model with total number of flowering plants as response, analyzed per section.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	-4.0815	6.4484	70.0599	-0.6330	0.5288
Studied surface	1.0135	0.2063	58.3901	4.9139	0.0000 ***
Width of road verge	0.2012	0.2702	40.3320	0.7446	0.4608
Proportion cultivated land	11.6882	7.4667	73.6384	1.5654	0.1218
Mean environmental pressure per cultivated area	0.3086	0.6897	77.0510	0.4474	0.6558

Table 28: The output of the model with number of flowering plant species groups as response, analyzed per section.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	2.0590	1.1658	64.2958	1.7661	0.0821 .
Studied surface	0.1613	0.0405	70.9990	3.9825	0.0002 ***
Width of road verge	0.0850	0.0467	47.9090	1.8221	0.0747 .
Proportion cultivated land	0.7277	1.3587	66.4577	0.5356	0.5940
Mean environmental pressure per cultivated area	0.2531	0.1273	72.8616	1.9889	0.0505 .

Table 29: The output of the model with number of host plant species as response, analyzed per section.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	3.3643	1.3319	65.7331	2.5259	0.0140 *
Studied surface	0.1448	0.0458	70.5678	3.1592	0.0023 **
Width of road verge	0.0244	0.0535	48.7391	0.4558	0.6506
Proportion cultivated land	0.3689	1.5514	67.9390	0.2378	0.8127
Mean environmental pressure per cultivated area	0.2806	0.1450	73.6761	1.9349	0.0568 .

Table 30: The output of the model with aquatic vegetation as response, analyzed per section.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.0531	0.7949	77.4921	7.6147	0.0000 ***
Length of section	-0.2600	0.1671	78.9672	-1.5561	0.1237
Width of ditch	0.0023	0.0317	55.9832	0.0730	0.9421
Proportion cultivated land	-0.3386	1.0594	79.9624	-0.3197	0.7501
Mean environmental pressure per cultivated area	-0.0110	0.0915	66.0475	-0.1205	0.9045

Table 31: The output of the model with clearness as response, analyzed per section.

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	12.8649	8.3313	1.5442	0.1225
Proportion cultivated land	-0.2825	11.1732	-0.0253	0.9798
Mean environmental pressure per cultivated area	-0.8297	1.4827	-0.5596	0.5758

Table 32: The output of the model with bare ground as response, analyzed per section.

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-11.4978	12.1070	-0.9497	0.3423
Length of section	1.6686	2.2955	0.7269	0.4673
Number of studied ditch banks	-1.4083	9.2726	-0.1519	0.8793
Proportion cultivated land	-3.5065	11.2490	-0.3117	0.7553
Mean environmental pressure per cultivated area	0.3471	1.1851	0.2929	0.7696

Table 33: The output of the model with perennial vegetation as response, analyzed per section.

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-21.1439	11.7377	-1.8014	0.0716 .
Length of section	9.3926	4.6031	2.0405	0.0413 *
Proportion cultivated land	-12.9238	11.7369	-1.1011	0.2708
Mean environmental pressure per cultivated area	-2.4618	2.7493	-0.8954	0.3706

Table 34: The output of the model with common rush as response, analyzed per section.

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	-0.8457	4.7274	-0.1789	0.8580
Length of section	0.6319	0.8809	0.7174	0.4731
Number of studied ditch banks	2.3336	2.4563	0.9501	0.3421
Proportion cultivated land	1.7172	4.9383	0.3477	0.7280
Mean environmental pressure per cultivated area	-1.0909	0.9651	-1.1304	0.2583

Table 35: The output of the model with bulrush/common reed as response, analyzed per section.

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	12.5748	7.8136	1.6094	0.1075
Length of section	1.1764	0.8915	1.3196	0.1870
Number of studied ditch banks	-3.2954	1.7351	-1.8993	0.0575 .
Proportion cultivated land	-6.0727	6.4428	-0.9426	0.3459
Mean environmental pressure per cultivated area	-0.6330	0.5029	-1.2586	0.2082

Table 36: The output of the model with trees/shrubs as response, analyzed per section.

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	-8.8025	9.9866	-0.8814	0.3781
Length of section	0.9813	1.4840	0.6613	0.5084
Number of studied ditch banks	-2.3593	6.6938	-0.3525	0.7245
Proportion cultivated land	-0.2616	10.7046	-0.0244	0.9805
Mean environmental pressure per cultivated area	-0.0213	0.7965	-0.0267	0.9787

Table 37: The output of the model with algae as response, analyzed per section.

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	14.7773	7.6102	1.9418	0.0522 .
Length of section	1.0644	1.2971	0.8206	0.4119
Width of ditch	-0.7342	0.3115	-2.3571	0.0184 *
Proportion cultivated land	-12.1860	9.4839	-1.2849	0.1988
Mean environmental pressure per cultivated area	1.0442	0.7795	1.3395	0.1804

According to the model algae were present significantly more often in smaller ditches (Table 37). From Figure 16 appeared that this effect was probably caused by the outliers at the bottom right of the graph. This was indeed the case, because the effect disappeared when we analyzed a subset of our data with the width of the ditch being smaller than 15 meters.

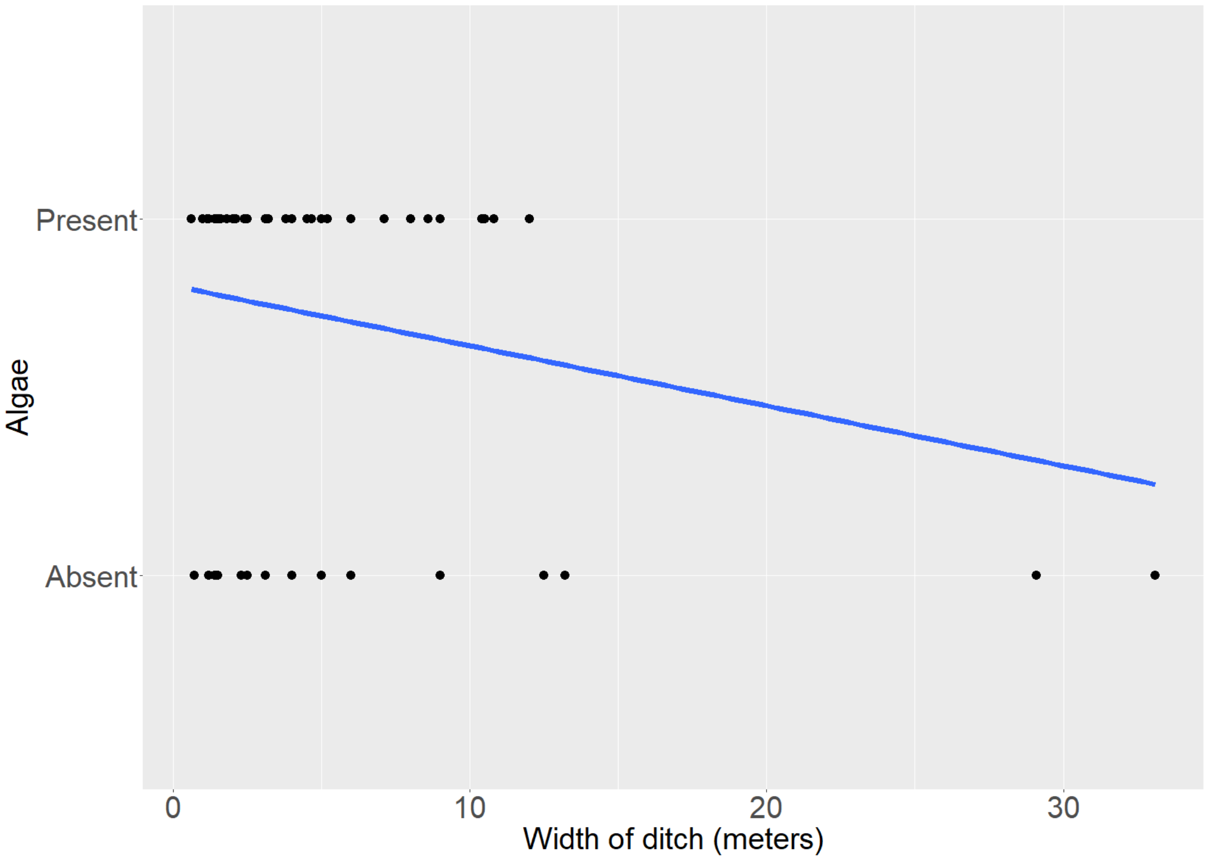


Figure 16: The presence of algae plotted against the width of the ditch.

Table 38: The output of the model with nutrient abundance as response, analyzed per section.

	Estimate	**Std. Error**	**df**	**t value**	**Pr(>|t|)**
(Intercept)	3.1768	0.2821	47.4461	11.2609	0.0000 ***
Width of ditch	-0.0151	0.0118	38.9124	-1.2802	0.2081
General steepness of ditch bank, 45-67.5°	0.0550	0.1625	27.4702	0.3385	0.7376
General steepness of ditch bank, 67.5-90°	-0.1855	0.4577	30.0668	-0.4052	0.6882
Proportion cultivated land	0.0791	0.3404	36.4399	0.2324	0.8175
Mean environmental pressure per cultivated area	-0.0219	0.0300	50.8690	-0.7290	0.4693

Appendix 4: Consulted persons

Name: R. Bijlsma
Function: Committee member of the Vlinderwerkgroep Drenthe, Assen
Consulted on: 31 March 2020

Name: J. Exel
Function: Amateur nature photographer
Consulted on: 29 October 2020

Name: Dr. Ing. V. J. Kalkman
Function: Project manager at Naturalis, Leiden
Consulted on: 31 March 2020

Name: ir. W. Sukkel
Function: Agroecologist at Wageningen University & Research, Wageningen
Consulted on: 17 March 2020

Name: A. van Olst
Function: MSc student Ecology & Conservation at University of Groningen
Consulted on: 1 December 2020