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Modest recovery of biodiversity in a western European country: The Living Planet Index for the Netherlands

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ABSTRACT

We calculated a Living Planet Index (LPI) for the Netherlands, based on 361 animal species from seven taxonomic groups occurring in terrestrial and freshwater habitats. Our assessment is basically similar to the global LPI, but the latter includes vertebrate species and trends in population abundance only. To achieve inferences on trends in biodiversity more generally, we added two insect groups (butterflies and dragonflies) and added occupancy trends for species for which we had no abundance trends available.

According to the LPI, the state of biodiversity has slightly increased from 1990 to 2014. However, large differences exist between habitat types. We found a considerable increase in freshwater animal populations, probably because of improvement of chemical water quality and rehabilitation of marshland habitats. We found no trend in the LPI for woodland populations. In contrast, populations in farmland and open semi-natural habitats (coastal dunes, heathland and semi-natural grassland) declined, which we attribute to intensive agricultural practices and nitrogen deposition, respectively. The LPI shows that, even in a densely populated western European country, ongoing loss of animal biodiversity is not inevitable and may even be reversed if adequate measures are taken. Our approach enabled us to produce summary statistics beyond the level of species groups to monitor the state of biodiversity in a clear and consistent way.

1. Introduction

To stop the worldwide loss of biodiversity (Butchart et al., 2010), the United Nations formulated the Convention on Biological Diversity (CBD) which entered into force in 1993. On the tenth Conference of the Parties (COP) under the convention in Aichi (Japan) in 2010, the Strategic Plan for Biodiversity 2011–2020 was adopted and targets were updated. One of the main aims of the Aichi Biodiversity Targets is to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity (SCBD, 2014). The EU agreed upon the target to halt the loss of biodiversity by 2020 and to restore biodiversity as far as possible.

Changes in the state of biodiversity need to be evaluated to assess whether these aims are met. Indicators that are most commonly used to track changes in taxonomic biodiversity are based on the geometric mean of relative abundance indices of animal species (Buckland et al., 2011; Butchart et al., 2010; Loh et al., 2005), as for instance the Living Planet Index (SCBD, 2014; WWF, 2014). Such indicators can be easily disaggregated into indices for different taxonomic groups, habitat types or geographical or socioeconomic regions (Loh et al., 2005; WWF, 2014).

The World Wide Fund for Nature (WWF), in collaboration with the Zoological Society of London, publishes a global Living Planet Report

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that presents the global Living Planet Index (LPI) every two years. The global LPI is based on the abundance time series of vertebrate populations (Loh et al., 2005). Parties (countries) under the CBD are obliged to report on the state of biodiversity on a national scale, as they are responsible for the conservation of biodiversity within their borders. However, this requires a sufficient amount of data on species' distribution and abundance. In many countries, such data are scarce.

In the Netherlands, many citizens take part in animal monitoring programmes on a voluntary basis. Through these programmes, large amounts of data have been collected since 1990 following standardised methodologies, enabling the calculation of abundance trends. In addition, 'opportunistic' data are available through the Dutch National Database Flora and Fauna (NDFF), which aims to assemble data from on-line species reporting platforms such as Waarneming.nl and Telmee.nl. Opportunistic data are not collected using standardised field protocols. If properly analysed, preferably with occupancy modelling techniques, such data may also be useful to calculate trends in species, albeit these trends represent changes in distribution (occupancy) as a proxy for abundance trends, rather than genuine abundance trends (Van Strien et al., 2013, 2015; Termaat et al., 2015).

Exploiting these two data sources and following the methodology of the global LPI, we compiled a 'Living Planet Index' for the Netherlands. The global LPI includes vertebrate species and trends in abundance only. To achieve inferences on trends in biodiversity more generally, we added two insect groups: butterflies and dragonflies, as many data are available for these groups as well. Moreover, we included occupancy trends for species for which we had no trends in abundance available.

We first show how the LPI has changed in the Netherlands from 1990 to 2014. To examine how populations changed in different habitat types, we then calculated separate indices for 1) freshwater and marshland, 2) farmland, 3) open semi-natural habitats (coastal dunes, heathland and semi-natural grassland), and 4) woodland. Finally, we discuss the possible causes of these changes.

2. Material and methods

2.1. Species

Seven species groups were included in our study: breeding birds, mammals, reptiles, amphibians, freshwater fishes, butterflies and dragonflies. We had sufficient data to assess the national trends for nearly all native species of breeding birds, reptiles, amphibians, butterflies and dragonflies (see Table 1). Some species, mainly mammals and fishes, were excluded because data were poor or spatial coverage was not representative for the entire country. We also excluded exotic species, i.e., species that colonised the Netherlands with human interference, mainly coming from other continents or through the Rhine-Main-Danube canal. Newly arrived species which reached the Netherlands on their own account were however included, such as Middle spotted woodpecker (*Dendrocopos medius*) and Little egret (*Egretta garzetta*), as were formerly extinct species which have been recently re-introduced in the framework of nature restoration, such as Otter (*Lutra lutra*) and Beaver (*Castor fiber*). All but two new species had been present in the country at least some years prior to our study period.

2.2. Data

We used data from standardised monitoring schemes, organised by national recording societies who coordinate the fieldwork that is done by volunteers. These schemes mainly produce population count data (see Table 1 for details). If for a certain species or species group no adequate population count data were available, we used opportunistic data (Table 1 and Supplementary information). The opportunistic data were primarily extracted from the NDFF, which contains records of many species observed by (amateur) naturalists. Most datasets cover the entire study period, whereas some datasets start later.

Table 1
Datasets used. For each dataset the number of species included is given between brackets. Datasets contain either count data (from standardised monitoring schemes) or occupancy data on 1 × 1 km grid cells (from opportunistic data, except Owl pellet data which are collected in a standardised way). Total number of 1 × 1 km grid cells in the Netherlands amounts to 37,065. NDFF = Dutch National Database Flora and Fauna.

Species group	Number of species (% of all native species)	Dataset	Period covered	Type of data used	Type of trends assessed	Mean no. of monitoring sites or grid cells with records annually
Breeding birds	161 (89%)	Breeding Bird Monitoring Scheme (103)	1990–2014	Counts	Population number	1800
		Rare birds (50)	1990–2014	Counts	Population number	Species specific
		Colony birds (8)	1990–2014	Counts	Population number	Species specific
Mammals	32 (60%)	Breeding Bird Monitoring Scheme (8)	1995–2014	Counts	Population number	400
		Hibernacula counts of bats (8)	1990–2014	Counts	Population number	600
		Summer roost counts of bats (2)	1991/1996–2014	Counts	Population number	50
		Species specific surveys (5)	Species specific	Counts	Population number	Species specific
		Owl pellet data for shrews, mice and voles (11)	1995–2012	Presence	Occupancy	350
Reptiles	7 (100%)	Reptile Monitoring Scheme (7)	1994–2014	Counts	Population number	230
Amphibians	16 (100%)	Amphibian Monitoring Scheme (5)	1997–2014	Counts	Population number	520
		NDFF data (11)	1990–2014	Presence	Occupancy	3010
Frw. fishes	37 (61%)	NDFF data (37)	1990–2014	Presence	Occupancy	2500
Butterflies	51 (94%)	Butterfly Monitoring Scheme (47)	1992–2014	Counts	Population number	450
		Egg surveys of butterflies (3)	Species specific	Counts	Number of eggs	Species specific
		NDFF data (1)	1990–2014	Presence	Occupancy	9000
Dragonflies	57 (81%)	NDFF data (57)	1991–2014	Presence	Occupancy	4800

2.3. Estimating trends per species

For species that are monitored in a standardised way, we estimated annual indices of their abundance; the first year of our study period was taken as the base year (index = 100). We applied TRIM (Pannekoek and Van Strien, 2005), a widely used GLM-Poisson regression program to produce annual indices and linear abundance trends from data collected in many sites (see e.g. Gregory et al., 2005). For species for which we had only opportunistic data, we estimated occupancy trends. Reliable trend estimates can only be produced from opportunistic data if they are adequately analysed, as they suffer from uneven and unknown temporal and spatial variation in field effort of observers (Isaac et al., 2014). A change in observer effort will result in a change in the probability to detect the presence of a species and may lead to spurious signals of change. Occupancy models are being considered as the best tools currently available to avoid this problem while analysing opportunistic data (Kéry et al., 2010; Van Strien et al., 2013; Isaac et al., 2014). Occupancy models separate the estimation of occupancy (the presence of a species in a site) from detection (the observation of a species in that site) when analysing field data and thereby enable correction of any changes in observer efforts over space and time. We used JAGS (Plummer, 2009) to run the occupancy models.

We first quantised observations at a 1 km × 1 km resolution and compiled 'day-lists' from casual observations of all species observed at particular 1 km × 1 km sites on particular dates. We then deduced non-detection (0) records for each study species. All cases in which the species was not on a day-list at a site in a year, were taken as non-detections. Using occupancy models to analyse the detection/non-detection data, we estimated annual occupancy, i.e., the proportion of 1 km × 1 km grid squares occupied by the species. Finally, occupancy estimates were converted into annual indices with first year = 100 and linear occupancy trends were computed (see for details Van Strien et al., 2013).

2.4. Composing indicator values

We aggregated annual species indices by calculating the geometric mean per year. This procedure is widely adopted to create indicators for biodiversity change (e.g. global LPI, Loh et al., 2005; European farmland bird indicator, Gregory et al., 2005; European grassland butterfly indicator, Van Swaay et al., 2015) because of its desirable methodological properties (Buckland et al., 2011; Van Strien et al., 2012). The geometric mean is stable when positive and negative trends, as well as their magnitude, are in balance. If the number of species declining outweighs the number of species increasing at the same rate, the mean goes down, and vice versa. The geometric mean values were converted into annual indices with first year = 100. There were 18 species with index values of zero or close to zero in some years. Such low values may disproportionally affect the geometric mean (Van Strien et al., 2012) and were therefore replaced by 1. For some other species we had missing yearly indices (see Table 1) and these were filled in using a chain index.

Our assessment of a Living Planet Index for the Netherlands is basically similar to the global approach (Loh et al., 2005; WWF, 2014), but a few technical differences exist. First, the global LPI includes only indices that are based on abundance, while we added occupancy indices. Second, we included the uncertainty due to sampling error of species indices into the confidence limits of our LPI, thereby ensuring error propagation (Soldaat et al., in preparation). The global LPI, in contrast, is forced to ignore the uncertainty of species indices due to the nature of the data with which it is compiled. Finally, the global LPI applies a Generalised Additive Model for each species to dampen the annual fluctuations and then calculates the geometric mean. But to take into account the uncertainty of species indices, we preferred to do this the other way around. We first sampled for each species and year a value from the standard error of the indices. We then calculated the geometric mean for each year for all species together. This resampling was repeated 1000 times, thereby producing an annual geometric mean with a confidence interval. Finally, we resampled this mean and confidence interval again and applied LOESS (Locally weighted polynomial regression; Cleveland, 1979) in each sample to produce smoothed indices and confidence intervals for all years, including the base year (Soldaat et al., in preparation). From this we derived the % change between the smoothed index value of the last year and that of the first year. The % change is considered significant when the mean change ±1.96 ∗ standard error does not include 0. All LPI's were computed using R 3.2.3 (R Core Team, 2015).

In addition, we tested whether species considered threatened at the beginning of our study period did worse than non-threatened species (see Thissen et al. (2009) for details about assessing threat status of species in the Netherlands). Therefore we composed LPI's for both species groups.

2.5. Trends per habitat type

We composed LPI's for different habitat types in order to gain more insight into possible causes of the trends. We included only species with a close association with one of the distinguished habitat types, as these are considered most informative. We first distinguished freshwater (including marshland) and terrestrial species. All fish, dragonfly and amphibian species were attributed to freshwater, as well as those breeding bird and mammal species that have a clear preference for marshland and wetland (31 and 5 species respectively) plus one butterfly species, the Large copper (*Lycaena dispar*). With respect to land, we distinguished two semi-natural habitat types (open semi-natural habitat and woodland) and two non-natural habitats (farmland and urban area). Species were regarded as inhabiting semi-natural habitat if their average density in any of the two semi-natural habitats was at least twice their average density in each of the non-natural habitats. A similar rule was used to assign species to either open semi-natural habitat or woodland: if the density in woodland was at least twice the density in each of the open semi-natural habitats, the species was designated as woodland species. To apply these rules, we analysed data on density, if available (birds, butterflies, some mammals); otherwise, we relied on expert opinion.

We adopted a different procedure to select farmland species, as there are no farmland-specific butterflies anymore. Butterflies were once abundant in semi-natural grassland, but are nowadays rare in agricultural areas. We selected all butterfly species with sufficient data in farmland to calculate annual indices (14 species) for the farmland

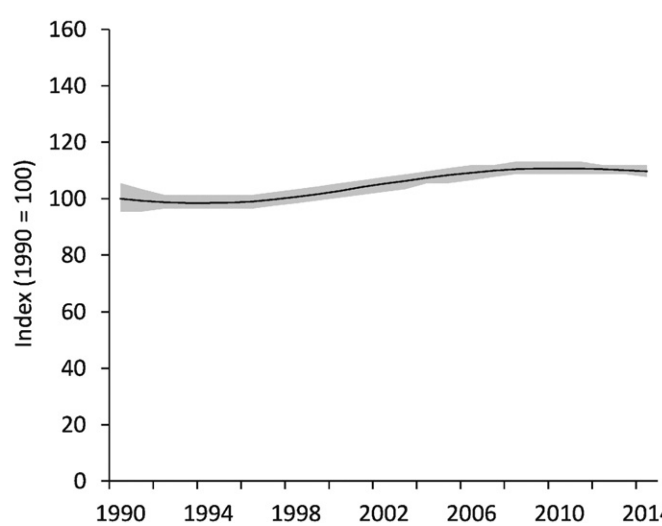

Fig 1. Living Planet Index (±95% confidence intervals) for the Netherlands based on all species (n = 361).

Table 2
Percentage change in Living Planet Index (±standard error) in 1990–2014 per species group. Also the number of newly arrived species is given. The change is considered significant when change ±1.96 ∗ standard error does not include 0.

	No. species involved	No. new species	% change
Vertebrates			
All species	253	17	21.8 ± 2.8[1]
Breeding birds	161	14	18.3 ± 3.1[1]
Mammals	32	2	102.2 ± 14.9[1]
Reptiles	7	0	78.3 ± 31.5[1]
Amphibians	16	0	5.4 ± 3.4
Fishes	37	1	1.0 ± 8.3
Invertebrates			
All species	108	7	-7.2 ± 12.3
Butterflies	51	3	-56.2 ± 9.2[1]
Dragonflies	57	4	47.7 ± 21.8[1]

[1] Significant ($P \le 0.05$).

LPI plus the 27 bird species selected for the national farmland bird indicator (CBS et al., 2015) and seven mammal species which regularly occur in agricultural areas.

For species mainly restricted to one habitat type, e.g. dragonflies to freshwater, we used the national trend. For species occurring in more than one habitat type, we assigned sites to their actual habitat-type and calculated the trend per habitat type.

3. Results

Overall, Dutch animal species populations increased since 1990. The LPI increased from 100 to 110 ($9.7 \pm 3.1\%$; Fig. 1). The increase was also reflected in the number of species with increasing populations (171), which outnumbered declining species (115; chi-square test $P < 0.05$). The newly arrived species ($n = 24$) contributed considerably to the increase in LPI. If these species are excluded, there was even a slight decline ($-11.0 \pm 2.2\%$; $n = 337$). The LPI for vertebrates increased, while the LPI for invertebrates remained unchanged, but the difference in trend between these two LPI's was not significant (Table 2). Results per species group varied widely. Butterflies are the only group in decline. Increases are strongest in mammals, reptiles and dragonflies. The breeding bird fauna has a slightly increasing LPI.

The freshwater LPI increased considerably since 1990 (Fig. 2a; Table 3) and we report more freshwater species increasing than declining (chi-square test $P < 0.05$; Table 3). Like dragonflies (37 up, 7 down), amphibians (10 up, 1 in very strong decline) and mammals (4 up, 0 down), a considerable number of marshland bird species flourished (18 up, 10 down). In freshwater fishes, however, we did not discern a positive balance in trends (12 up, 14 down). If newly arrived species are excluded, the freshwater LPI still increased ($22.8 \pm 6.6\%$; $n = 139$).

In contrast to freshwater animals, the LPI for terrestrial species was stable (Fig. 2b; Table 3) and the number of increasing terrestrial species equaled the number of declining species (Table 3). Without newly arrived species, the terrestrial LPI declined ($-30.8 \pm 1.5\%$; $n = 198$).

A considerable number (55) of the 120 species considered threatened in 1995 had larger population sizes or distribution ranges in 2014 than in 1990 (46%; Table 3). Yet, the LPI for threatened species has declined, because large declines in some species outweigh the smaller increases of other species, even though the latter are in the majority. The decline in LPI for threatened species was due to terrestrial species; the LPI for threatened species in freshwater increased. The LPI for non-threatened species increased both in freshwater and in terrestrial habitats (Table 3).

Trends differed between terrestrial habitat types. Farmland animal populations showed a large and steady decline ($-35.4 \pm 3.3\%$; $n = 48$; Fig. 3). While birds and butterflies on farmland declined ($-36.7 \pm 2.1\%$; $n = 27$ and $-34.1 \pm 9.5\%$; $n = 14$, respectively), the LPI for mammals in farmland was uncertain ($258 \pm 133\%$; $n = 7$). In open semi-natural areas, animal populations also strongly decreased ($-59.7 \pm 1.9\%$; $n = 46$; Fig. 4a), although this seemed to level off in recent years. Again, both bird and butterfly species declined ($-58.2 \pm 2.3\%$; $n = 22$ and $-61.8 \pm 2.7\%$; $n = 18$, respectively), while reptiles ($n = 4$) and mammals ($n = 2$) were stable on average. In contrast, the woodland LPI has not changed ($-0.57 \pm 5.1\%$; $n = 36$; Fig. 4b); birds and butterflies were stable, but mammals increased ($-5.1 \pm 4.2\%$; $n = 26$, $-16.3 \pm 26.6\%$; $n = 6$ and $58.3 \pm 24.3\%$; $n = 4$, respectively).

4. Discussion

4.1. Modest improvement

The global LPI reports a decline of 25% in the period 1990–2010, based on vertebrate trends (WWF, 2014). In contrast to the global picture, we report a modest improvement in the state of biodiversity in the Netherlands since 1990, as measured by the LPI. For a fair comparison, we also calculated the LPI based on vertebrate trends only. This index showed an increase as well (Table 2). The improvement we measured is in line with the slightly increasing LPI found in high-income countries (WWF, 2014). The increase marks a break in the trend of a long-term strong decline in biodiversity in the Netherlands (Van Veen et al., 2008).

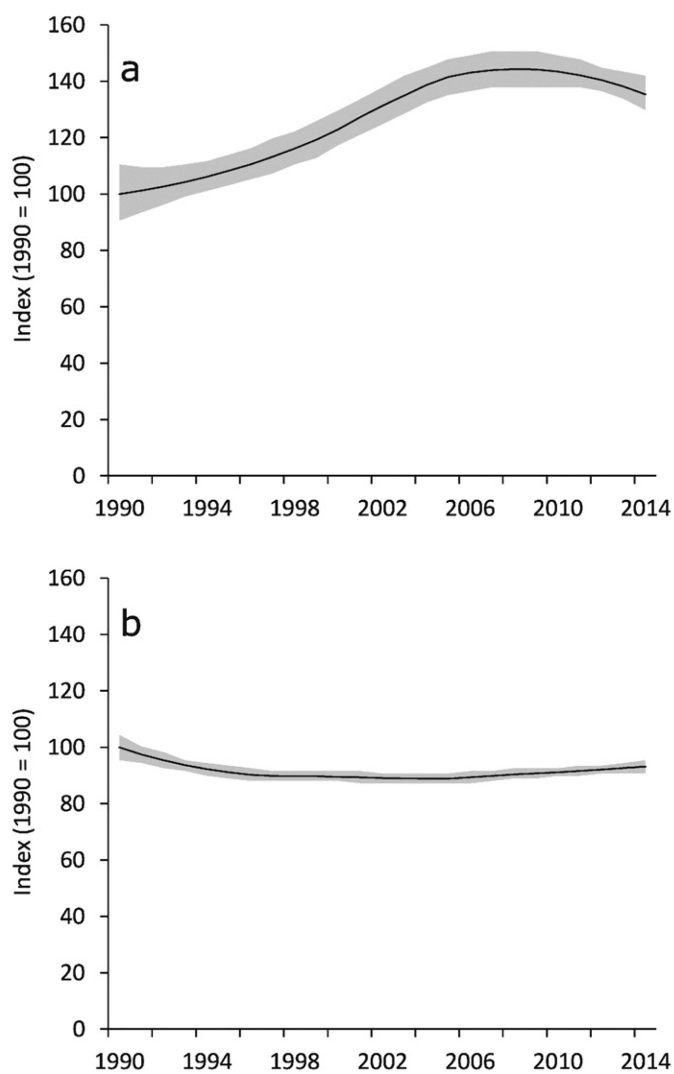

Fig. 2. Living Planet Index (±95% confidence intervals) for (a) freshwater ($n = 147$ species) and (b) terrestrial habitats ($n = 214$ species).

Table 3
Percentage change in Living Planet Index (± standard error) in 1990–2014 for all species and for threatened and non-threatened species separately. Also the number of increasing and declining species is given. Threat status describes the situation in approximately 1995. Newly arrived species were included in this table. The change is considered significant when change ± 1.96 ∗ standard error does not include 0.

	No. species involved	% change	No. species increasing	No. species declining
All-species LPI				
All species	361	9.7 ± 3.1[1]	171	115
Non-threatened	241	28.9 ± 3.7[1]	116	74
Threatened	120	−21.8 ± 5.0[1]	55	41
Freshwater LPI				
All species	147	35.6 ± 7.7[1]	81	32
Non-threatened	95	32.7 ± 8.2[1]	52	22
Threatened	52	41.6 ± 19.6[1]	29	10
Terrestrial LPI				
All species	214	−6.5 ± 2.3[1]	90	83
Non-threatened	146	24.6 ± 3.7[1]	64	52
Threatened	68	−50.0 ± 2.4[1]	26	31

[1] Significant ($P \leq 0.05$).

Populations of many species increased, and in this respect threatened species improved to a similar extent as non-threatened species: 48% (116 of 241) of all non-threatened species increased and 46% (55 of 120) of all threatened species (Table 3). In addition, a considerable number of new species colonised the country (Table 2). Five of them, Otter (*Lutra lutra*), Beaver (*Castor fiber*), two *Phengaris* butterfly species, and the fish species Houting (*Coregonus oxyrinchus*), were successfully re-introduced as part of nature restoration projects. Others extended their geographical range.

The LPI averages species indices geometrically. As a consequence, the appearance of new species has a large effect on the LPI (Van Strien et al., 2012). Yet, the LPI would be biased if newly arrived species were deliberately excluded, because it is equally sensitive to disappearing species, i.e., species whose indices approach zero.

4.2. Possible causes

The improvement of the state of biodiversity in the Netherlands is primarily achieved in freshwater habitats. The increase of freshwater animal populations is not unexpected, given that chemical water quality has improved considerably since 1990 (Van Puijenbroek et al., 2014). In addition, marshland has been restored and the area of wetland has increased substantially (Nienhuis et al., 2002; Van Turnhout et al., 2012). Apparently, both non-threatened and threatened species benefitted equally from these measures (Table 3).

The ongoing decrease of animal species in farmland is not unexpected either. More than 70% of the land is used for agriculture and Dutch farming practices belong to the most intensive of the world (Bos et al., 2013). There is overwhelming evidence of the detrimental consequences for flora and fauna of modern agricultural practices, which include conversion of pastures into arable land, crop monocultures, drainage, early and frequently mowing and large input of inorganic fertilizers (Bos et al., 2013; Donald et al., 2000; Newton, 2004; Gregory et al., 2005). The intensive land use leaves little room for animals, whereas agri-environmental schemes have been insufficient to halt the decline (Breeuwer et al., 2009). This results in an ongoing decrease of Dutch farmland birds (CBS et al., 2015) and grassland butterflies. The heavy use of pesticides (e.g. neonicotinoids; Hallmann et al., 2014) aggravates the situation.

It is alarming that animal populations have on average decreased in open semi-natural habitats. Most of these habitats are nowadays confined to nature reserves in the Netherlands, but apparently, nature management and protection measures are insufficient. The decrease is most probably to be ascribed mainly to the effects of nitrogen deposition from anthropogenic sources (Bobbink et al., 2010; Dise et al., 2011), in combination with the loss of semi-natural ecosystem dynamics. In spite of the recent reduction in nitrogen deposition in the Netherlands (CBS et

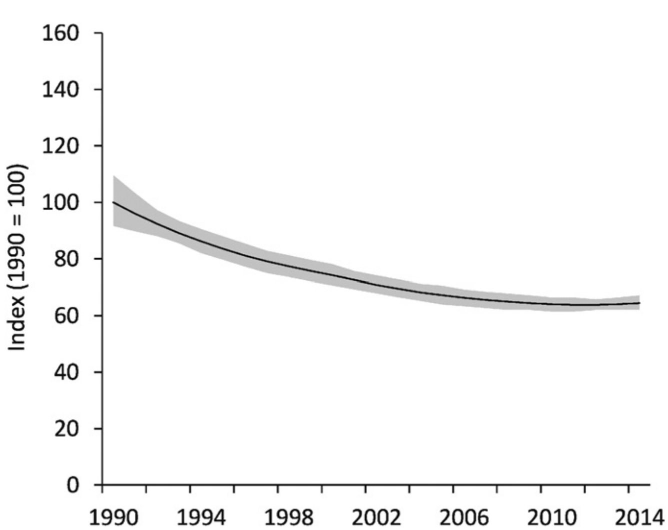

Fig. 3. Living Planet Index (±95% confidence intervals) for farmland (n = 48 species).

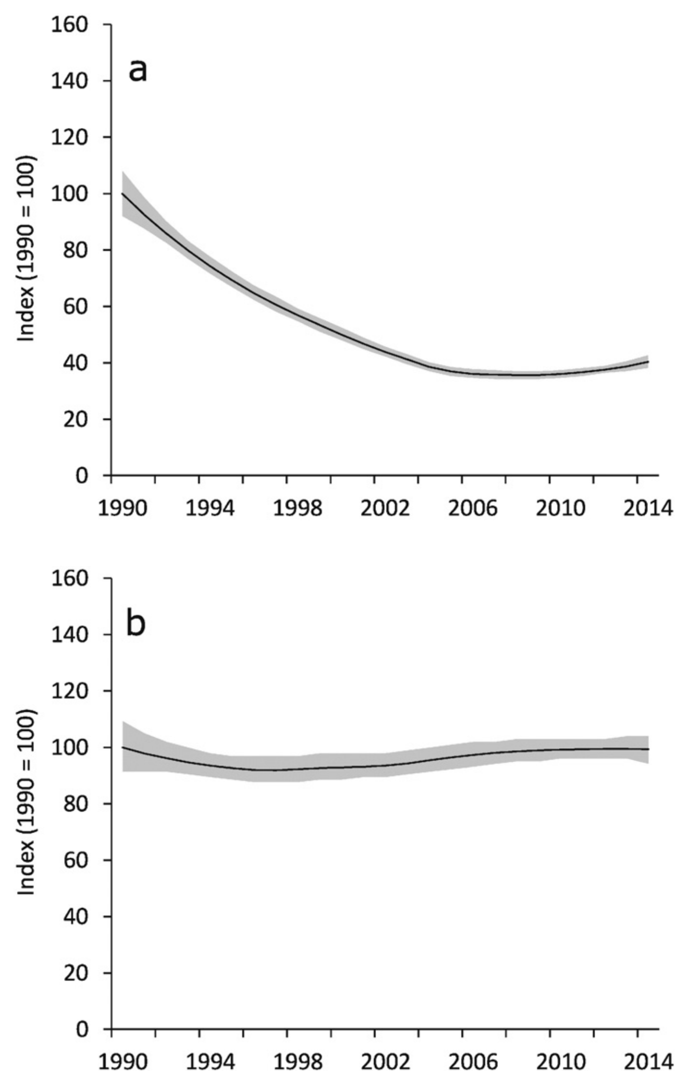

Fig. 4. Living Planet Index (±95% confidence intervals) for (a) open semi-natural areas (n = 46 species) and (b) woodland (n = 36 species).

al., 2013), the level still exceeds the critical load for almost all open habitat types (Bobbink et al., 2010; Dise et al., 2011). Nitrogen deposition enhances mineralization and biomass accumulation in dune, heathland and semi-natural grassland communities. Nitrophilous grasses and shrubs have replaced the original low vegetation, limiting reproduction and foraging possibilities for specialists of early successional habitats, among which are butterflies (WallisDeVries and Van Swaay, 2006) and birds (Van Oosten et al., 2014).

The expansion of woodland area (CBS et al., 2014) and the maturation of existing forest stands may have contributed to stabilise the woodland LPI. Also the recent practice of leaving dead wood in the woods to decompose, the conversion of coniferous stands into deciduous stands and the selective cutting of non-native tree species may have been beneficial (CBS et al., 2014).

Although many threatened terrestrial species are in decline, a considerable number have increased (Table 3). Many threatened species were facilitated by dedicated measures to safeguard or even re-introduce them, e.g. Scarce large blue (*Phengaris teleius*; Wynhoff, 2001). These measures led to viable and stable populations for some species (e.g. Beaver). Other species, however, are confined to open semi-natural habitats or to small fragments of often degraded habitat and ongoing efforts are needed to save them from extinction, e.g. Hamster (*Cricetus cricetus*; La Haye et al., 2010).

Climate change is triggering many species to expand northwards (Devictor et al., 2012) and so far, the Netherlands sees more species coming than going. For some species groups, like dragonflies, climate change is even considered to be one of the major drivers for their increase, in addition to improved water quality (Termaat et al., 2015). In the long run, it is deemed likely that climate change will threaten the persistence of species preferring a cool climate (Kampichler et al., 2012), but to date there is little evidence of a negative impact of climate change on biodiversity in the Netherlands.

4.3. Flaws

Our LPI contains not only abundance trends, but also occupancy trends. The abundance of species may respond more strongly to environmental drivers than their distribution (Gaston et al., 2000), so potentially the inclusion of occupancy trends alters the LPI. Indeed, the freshwater LPI based on population trends only (78.4 ± 9.7%; n = 41) has a stronger positive trend than the LPI made of occupancy trends (20.7 ± 9.7%; n = 106), suggesting that we might have underestimated the increase in freshwater LPI. For terrestrial LPI's, no difference is found if occupancy trends were used instead of abundance trends (−6.4 ± 2.5%; n = 203 and −7.1 ± 16.7%; n = 11, respectively). The terrestrial LPI is almost exclusively (95%) composed of abundance trends, so hardly any bias can occur due to occupancy trends.

For some species groups several yearly indices are missing because data are lacking, mainly in 1990–1992 and 2013–2014 (see Table 1). To test whether the LPI's are robust against such data gaps, we repeated the analysis for the shorter period 1993–2013. The LPI's obtained did not differ much from those in Figs. 1–4 (all-species 11.8 ± 3.4%; terrestrial habitats 1.0 ± 2.8%; freshwater 30.9 ± 8.5%; farmland −23.8 ± 4.4%; open semi-natural areas −48.8 ± 2.4%; woodland 9.4 ± 6.0%). So, the missing annual values do not affect our findings.

The Dutch LPI's are based on vertebrate populations, as is the global LPI, plus almost all butterfly and dragonfly species. Remarkably, the LPI for invertebrates is not significantly different from the LPI based on vertebrate species (Table 2). Thus, the LPI's appeared to be robust against species group selection. This is because trend directions are mostly consistent between species groups when considered for separate habitat types. In the distinguished terrestrial habitats, the trends of birds correspond with those of butterflies, while other species groups showed slight deviations. In freshwater, trends of marshland birds and dragonflies were positive and also the majority of amphibian species increased. Fish species did not increase as a group. However, in line with the positive response of the other aquatic groups to the improvement of water quality, fish species preferring clear water have increased (43.7 ± 6.7%; n = 8). Fish species that tolerate some pollution showed a slight decline, perhaps by increased competition or predation (−25.5 ± 2.2%; n = 6).

4.4. Conclusions

We showed that the LPI is a useful indicator to monitor changes in biodiversity on a national level. More than 350 species from seven taxonomic groups were included in the Dutch LPI, and we were able to disaggregate the figures for different habitat types and to produce a coherent and consistent picture of biodiversity losses and gains on an annual basis. This makes the LPI a powerful tool in communicating biodiversity changes to a wider audience, such as policy makers and the general public. Yet, our LPI needs to be elaborated further. Some urgent improvements are to include trends in marine and coastal species. A further improvement will be to incorporate trends in higher plants and more insect groups for which there are many occupancy data available.

Although in the Netherlands more data are available than in many other countries, we believe that our approach to compose robust summary statistics beyond individual taxonomic groups is feasible in other countries as well, as we successfully included opportunistic data. Such data are often available when no standardised monitoring is being conducted, but are typically not fully exploited.

It is encouraging to see that, after decades of severe biodiversity loss (Van Veen et al., 2008), some recovery takes place in a densely populated and highly developed western European country. Although, until now, the improvement is most obvious in freshwater habitats, it may be heralding recovery of biodiversity in other habitats as well. It suggests that the aim to stop the loss of biodiversity may be feasible, though many efforts remain needed.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.biocon.2016.05.031.

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