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Assessing effects of alternative agricultural practices on wildlife habitat in Iowa, USA

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Abstract

A habitat-change model was used to compare past, present, and future land cover and management practices to assess potential impacts of alternative agricultural practices on wildlife in two agricultural watersheds, Walnut Creek and Buck Creek, in central Iowa, USA. This approach required a habitat map for each scenario based on soil type and land cover, a list of resident species, and an estimate of the suitability of each of 26 habitat classes for every species. Impact on wildlife was calculated from median percent change in habitat area relative to the present. Habitat classes with the highest species richness for native vertebrates were ungrazed riparian forest, upland forest and wet prairie. Differences in habitat composition and configuration were evident among maps of the watersheds for the past, present, and three alternative future scenarios (Production, Water Quality, and Biodiversity). The Production scenario ranked lowest in providing habitat for all native taxa. For most taxa, changes in wildlife habitat due to land use changes in the Biodiversity, Water Quality, and Past scenarios were similar, resulting in greater habitat than either the present landscape or the Production scenario. For native birds, amphibians, mammals, and rare species in both watersheds, the Biodiversity scenario ranked highest in providing habitat, and the Water Quality scenario was similar to or slightly below the Biodiversity scenario. The Water Quality scenario was similar to or slightly better than the Biodiversity scenario for reptiles and butterflies in both watersheds, and both ranked higher than the Production scenario for these taxa.

Keywords: Future scenarios; Iowa watersheds; Landscape change; Wildlife habitat; Butterflies

1. Introduction

To address concerns about environmental and ecological degradation from modern agriculture (Freemark, 1995; Krebs et al., 1999; Tilman et al., 2001) a shared vision of landscape design and management alternatives is needed (Meadows, 1996; Runge, 1997; Ahern, 1999). Planners and policymakers need better tools for understanding landscape-level effects of planning and policy. A relatively recent innovation that addresses these needs is the use of scenario-based alternative futures, made feasible by advances in landscape ecology, landscape design, geographic information systems, and computer modelling of ecological and economic processes. Consideration of the alternative futures that emerge from different scenarios can help decision-makers and stakeholders envision and evaluate choices in a way specific to place and time (Costanza, 2000; Nassauer et al., 2002; Steinitz et al., 2003; Baker et al., 2004; Santelmann et al., 2004).

A collaborative, interdisciplinary study applying a scenario-based alternative futures approach was initiated in 1996 for two watersheds in central Iowa to design and evaluate alternative future scenarios that might result from different priorities for agricultural production, native biodiversity, water quality, social and economic considerations (Santelmann et al., 2001; Nassauer et al., 2002;

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Nassauer and Corry, 2004). The research described here is one of several modelling approaches (Coiner et al., 2001; Vaché et al., 2002; Rustigian et al., 2003; Santelmann et al., 2004) used to evaluate potential impacts of habitat change on wildlife. In addition, a reconstructed presettlement landscape was evaluated to provide a historical perspective on changes in habitat for native species in the study watersheds.

The response of native plant and animal species to changes in land cover and management practices may be among the most sensitive indicators of ecosystem response, and thus is considered a valuable indicator in ecosystem risk assessments (Pratt and Cairns, 1992; White et al., 1999). The approach described here, modified from White et al. (1997), is based on the premise that impact on a species increases as its habitat is depleted or degraded. It requires a habitat map for each scenario, a list of resident species, and an estimate of the suitability of each habitat for each species. Impact on wildlife habitat is calculated for a set of species as the median percent change in habitat for that set of species relative to the present. Life history requirements of species (e.g., minimum area requirements) can be incorporated but were not employed here.

2. Methods

Two watersheds (Fig. 1) were studied, Walnut Creek in Boone and Story Counties (5130 ha) in the Des Moines Lobe Region and Buck Creek watershed, Poweshiek County (8820 ha) on the Southern Iowa Drift Plain. The Des Moines Lobe is relatively flat with rich, productive soils, corn and soybeans covering more than 80% of the land area. The Southern Iowa Drift Plain has a rolling topography and more varied land cover (Prior, 1991). The Walnut Creek watershed was once dominated by prairie, dotted with prairie pothole wetlands, most of which have now been drained for row crops (Hewes, 1951). The Buck Creek watershed was located on an older, glaciated surface with well-drained soils. Its hills and valleys provided firebreaks that allowed the growth of more extensive riparian forest, particularly in the southern end of the watershed.

Present land cover for the Buck Creek and Walnut Creek watersheds (hereafter termed the present) was digitized from 1:20,000 aerial photographs taken in 1990, and ground-truthed in 1993–1994 (Freemark, 1995; Bergin et al., 2000) at a spatial resolution of three meters. With respect to current agricultural set-aside programs, 16% of the land area in the Buck Creek watershed was enrolled in the Conservation Reserve Program (CRP) in 1994. Walnut Creek had no CRP land enrolled in 1994.

2.1. Scenarios evaluated

An iterative, interdisciplinary, GIS-based process was used to develop and map three future scenarios for both watersheds (Nassauer et al., 2002; Nassauer and Corry, 2004) that could result in 2025 from different sets of policy choices.

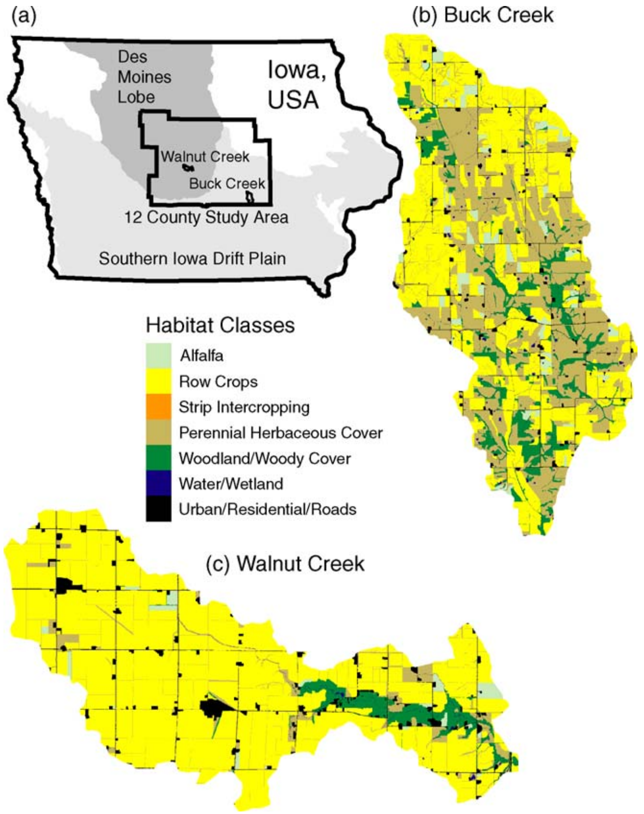

Fig. 1. (a) Location of Buck and Walnut Creek watersheds in Iowa, USA, and present habitat cover (ca. 1994) for (b) Buck Creek watershed (8820 ha) and (c) Walnut Creek watershed (5130 ha). Habitat classes were combined from 26 to 7 for visualization (Table 1 shows how map classes in the figures correspond to the various habitat classes).

The Production scenario (a) is perceived as the future most likely to emerge if profitable agricultural production remains the dominant objective of landscape management (Figs. 2a and 3a). In this scenario, more land is converted to cultivation, woodlands have nearly disappeared, riparian areas have narrow (3–6 m) grass buffers, corn and soybeans are grown with limited crop rotations, and there is little land area in pasture or alfalfa.

The Water Quality scenario (b) assumes that land cover patterns in both watersheds (Figs. 2b and 3b) have evolved as landowners strive to meet water quality standards. In this scenario, woodlands have been maintained, riparian buffers have been widened from 3–6 to 15–60 m, small wetlands have been created to process flow from tile drains, and substantial areas are in pasture and alfalfa production.

The Biodiversity scenario (c) is based on the assumption that land cover patterns have changed to increase habitat for indigenous wildlife. In this scenario, at least 260 ha of each watershed have been set aside in permanent, indigenous ecosystem core reserves. The reserve in Buck Creek is a

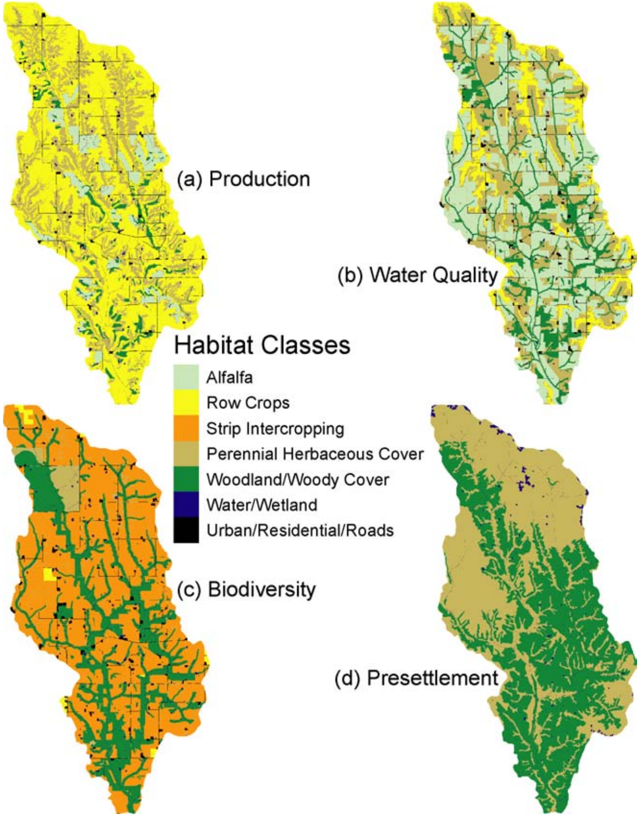

Fig. 2. Map of alternative futures and the presettlement past for Buck Creek watershed. Habitat classes as in Fig. 1.

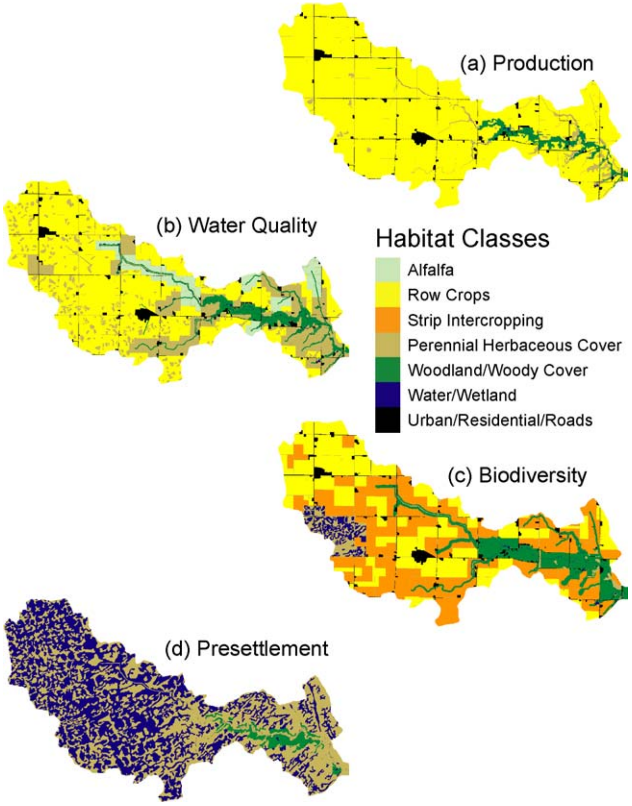

Fig. 3. Map of alternative futures and the presettlement past for the Walnut Creek watershed. Habitat classes as in Fig. 1.

mosaic of prairie, savanna and forest (Fig. 2c), whereas reserves in Walnut Creek consist of a large prairie-wetland complex in the western portion of the watershed and a riparian forest reserve along the creek (Fig. 3c). Riparian areas are 30–90 m wide, agroforestry and strip intercropping have developed, in which native perennial species are interspersed with corn and soybeans.

The presettlement scenario reflected the land cover of the early 1800s, and was drawn from the Iowa Soil Properties and Interpretations Database (ISPAID; http://www.ia.nrcs.usda.gov/soils/icss_data.html) based on soil attributes (cf. Galatowitsch and van der Valk, 1994).

2.2. Species–habitat associations

The wildlife species considered were all bird, mammal, reptile, amphibian, and butterfly species currently recorded in central Iowa or likely to be reintroduced or to expand their current ranges into central Iowa (Jackson et al., 1996; Kent and Dinsmore, 1986).

Twenty-six wildlife habitat classes (Table 1 and Appendix A) were derived from land cover classes primarily by reviewing bird species' use of habitats (Best et al., 1995) and evaluating potential differences for other vertebrates. A matrix of species–habitat associations, ranking habitat suitability for each species in each potential habitat type was then generated through review of the literature and expert judgment. Eight introduced and 239 native vertebrate species (146 birds, 52 mammals, 29 reptiles, 12 amphibians), and 117 butterfly species were included. Ungrazed riparian and upland forest had the highest species richness, with 171 and 140 species, respectively. Few vertebrate species were unique to any single habitat type, semi-permanent wetland and ungrazed riparian forest having the most unique species (five and four, respectively).

For groups other than birds, a 0–4 point scale was used, as follows: 0 = habitat not used by the species; 1 = sink or marginal habitat of the lowest quality; 2 = sink or marginal habitat of a quality that can maintain a population for short periods of time; 3 = source habitat capable of supporting individuals during the life-stages that are most critical for sustaining populations for long periods of time; 4 = optimal habitat in which the species has the highest reproduction and/or survival, capable of sustaining populations indefinitely.

For birds, habitat associations were assigned from the literature (Best et al., 1995, 2001; Freemark et al., 1991; Jackson et al., 1996; Kent and Dinsmore, 1986; Stallman and Best, 1996; Lokemoen and Beiser, 1997), and by expert opinion. Habitat suitability scores for birds were initially based on the 0–5 point abundance scale used by Best et al. (1995), adjusted to increase value of habitat used for nesting by one point, then weighted to correspond to the 0–4 point scale used for the other taxa. For mammals, habitat affinities

Table 1
Number of species in various categories[a] for the 26 habitat classes[b]. The seven land cover classes mapped in Figs. 1–3 are shown in column 2, and the average suitability score for each habitat class, averaged over all native vertebrate species (av. suit), in column 5

Code	Map class	Habitat	Vertebrate species categories								
			native	av.suit	amph	rept	mamm	bird	intro	s1s2	Leps
1	2	rc.cp	91	0.66	0	16	24	51	7	5	10
2	2	rc.ct	103	0.9	0	16	36	51	7	7	10
3	3	rc.ns	122	1.19	0	16	44	62	7	12	16
4	4	rc.sg	69	0.58	0	16	24	29	7	7	2
5	4	rc.fall	61	0.67	0	16	41	4	3	7	1
6	3	rc.os	115	1.25	0	16	42	57	7	11	12
7	2	rc.o	92	0.79	0	16	23	53	7	7	11
8	7	farmstead	110	1.36	0	20	36	54	7	8	40
9	4	strip.h	115	1.47	0	25	45	45	6	11	21
10	5	strip.w	113	1.6	0	23	37	53	4	10	10
11	4	grass.crp	117	1.53	0	26	44	47	5	16	57
12	1	grass.hay	112	1.11	0	27	40	45	5	16	39
13	4	grass.pd	115	1.55	0	27	45	43	5	18	81
14	6	grass.pw	128	1.91	10	26	43	49	5	16	76
15	4	shrub.past	127	1.4	2	27	44	54	6	16	53
16	4	shrub.ung	128	1.71	2	27	43	56	5	11	55
17	5	for.50	125	1.68	0	27	33	65	4	8	36
18	5	for.rug	171	2.29	7	27	34	103	3	12	40
19	5	for.upug	140	1.86	0	26	32	82	3	8	35
20	5	for.upg	125	1.56	0	26	32	67	3	8	27
21	5	for.sug	100	1.39	0	27	47	26	3	11	64
22	5	for.sg	94	1.14	0	27	42	25	3	12	64
23	6	wet.sp	111	1.5	12	26	11	62	2	10	26
24	6	wet.pond	92	1.39	12	27	13	40	0	9	14
25	6	wet.st	63	1.05	7	28	13	15	0	8	33
26	6	wet.eng	90	1.11	8	26	12	44	0	6	24
Total			239	na	12	29	52	146	8	24	117

[a] native: all native vertebrates, amph: amphibians, rept: reptiles, mamm: mammals, bird: birds, intro: introduced, S1S2: threatened and endangered, Leps: butterflies.

[b] Key to habitat classes: rc.cp: row crop chisel plow, rc.ct: row crop conservation tillage, rc.ns: row crop native strip, rc.sg: small grains, rc.fall: fallow, rc.os: row crop organic strip, rc.o: row crop organic, farmstead, strip.h: herbaceous strip, strip.w: woody strip, grass.crp: Conservation Reserve Program, grass.hay: alfalfa/hay, grass.pd: dry prairie, grass.pw: wet prairie, shrub.past: pasture, shrub.ung: ungrazed shrubland, for.50: ungrazed forest less than 50 years old, for.rug: ungrazed riparian forest, for.upug: ungrazed upland forest, for.upg: grazed upland forest, for.sug: ungrazed savanna, for.sg: grazed savanna, wet.sp: semi-permanent wetland, wet.pond: pond, wet.st: stream, and wet.eng: engineered wetland.

were gathered from the literature (Baker, 1983; Caire et al., 1989; Clark and Young, 1986; Hayslett and Danielson, 1994; Kurta, 1995; Schwartz and Schwartz, 1981; Snyder and Best, 1988; Stallman and Best, 1996) and those scored as most suitable were those in which individuals of the species were known to reproduce and spend the majority their time. A species–habitat association matrix was constructed for reptiles and amphibians based on the published literature for the Midwest (Smith, 1961; Minton, 1972; Vogt, 1981; Christiansen and Bailey, 1991; Collins, 1993; Oldfield and Moriarty, 1994; Casper, 1996; Harding, 1997) and expert judgment. For butterflies, the species–habitat association matrix was constructed by a local expert with reference to Scott (1986). The complete species–habitat association matrix is available from the authors.

Habitat associations were used to prepare a habitat map for each species in the past, present and each future scenario. Each map consisted of the score for a species in the habitat at each pixel location. From these maps of habitat scores the total amount of habitat for a species in a landscape was estimated as the sum of all the scores across the landscape. The percentage change in habitat for each species relative to the present was then calculated for the three future scenarios and for the past. Finally, the median of the percentage changes for different groups of species was used as a summary statistic, following the statistical approach to measuring habitat change developed in White et al. (1997).

The formula used for calculating the habitat change score, HC_j, for a specific group of species for one of the future landscapes, or for the past landscape, was:

$$HC_j = \text{median}\left(\sum_{i}^{\text{species}} \frac{\text{hab}_{i,j} - \text{hab}_{i,\text{present}}}{\text{hab}_{i,\text{present}}} \times 100\right),$$

for a future or past landscape, j, $\text{hab}_{i,j}$ being the suitability-weighted abundance of species i in the future or past landscape j, and $\text{hab}_{i,\text{present}}$ the suitability-weighted abundance of species i in the present landscape. Positive values of the median percent change statistic meant that more habitat for the species occurred in the watershed in the future or past landscape than in the present, and negative values the reverse.

2.3. Data analysis

For analysis, species were grouped into native birds, mammals, reptiles, amphibians and butterflies, all native vertebrates, all introduced vertebrates, and all rare vertebrates. The rare vertebrates were defined as those species with state conservation ranks of rare and vulnerable, as determined by the Iowa Natural Areas Inventory (http://www.state.ia.us/dnr/organiza/ppd/nai.htm).

To investigate the effects on the habitat change statistics of possible errors in the species–habitat suitability scores, a Monte Carlo simulation study was conducted. The suitability scores were altered under an assumed error model and variability in the results computed. Scores were assumed to have errors that could be represented by a normal distribution with a mean of 0 and a standard deviation of an integral number of score levels.

A modified species–habitat suitability matrix was generated containing a modified suitability score for each species in each habitat. The modified scores were generated by combining a term generated from the error model with the original scores. If the resulting score was less than 0 it was set to 0; if greater than the maximum score it was set to the maximum score. Scores originally set to 0 were maintained at 0 and not altered. A species could thus change from present to absent if the score became 0, but could never change from absent to present. Errors were generated in this way and the habitat statistics were calculated for each taxonomic group as well as introduced and rare vertebrate species subsets. The error generation process was repeated 1000 times and the mean and standard deviation of the median statistics were calculated.

3. Results

Differences between scenarios in habitat composition and configuration were evident between Buck and Walnut Creek watersheds, as well as between the reconstructed past and the alternative futures (Figs. 2 and 3). More of Walnut Creek was cropped in all future scenarios compared to Buck Creek, consistent with current agricultural practices and land capability. Cropping was most extensive in both watersheds under the Production scenario, and row crops were exclusively corn and soybeans. Because of its topography and highly erodible soils, most of Buck Creek was in perennial herbaceous cover under the Water Quality scenario in contrast to Walnut Creek. Bioreserves in the Biodiversity scenario were restored to upland woodland, savanna, and prairie in Buck Creek; and to prairie pothole wetlands interspersed with upland prairie, and a riparian woodland reserve in Walnut Creek. Strip intercropping was extensive in both watersheds under the Biodiversity scenario, and woodland and woody cover were more extensive compared to the present.

3.1. Habitat changes

Changes in habitat area relative to the present for butterflies and for vertebrates by taxon (Fig. 4) and for vertebrates by species of concern (Fig. 5) varied between watersheds and among scenarios (Table 2). Variability in median percent change in habitat area was generally less than 20% (±1 S.D.) except for amphibians and introduced species, which were more variable owing to the small number of species involved (Table 3).

All native taxa (Fig. 4a) had more habitat in the past relative to the present in Buck Creek (27 ± 8 to 164 ± 17%). In Walnut Creek (Figs. 4b and 5b), native vertebrates overall and most taxa (particularly amphibians and butterflies) had more habitat in the past relative to the present (34 ± 10 to 11529 ± 1425%). Native bird species not associated with

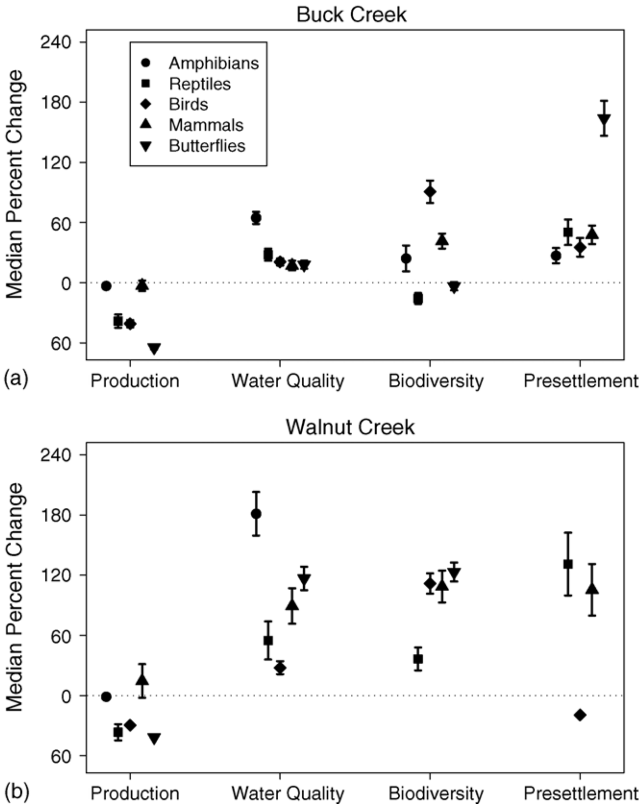

Fig. 4. Median percent change (±1 S.D.) in habitat area (adjusted by suitability), compared to the present, for taxa of native species (excluding introduced, extinct and extirpated species) and butterflies, for (a) Buck Creek watershed and (b) Walnut Creek watershed. Values >0 indicate habitat gain compared to the present; values <0 indicate habitat loss compared to the present. Species groups with changes greater than 200% are not shown (Walnut Creek amphibians in Biodiversity and Presettlement, and butterflies in Presettlement). See Table 3 for values.

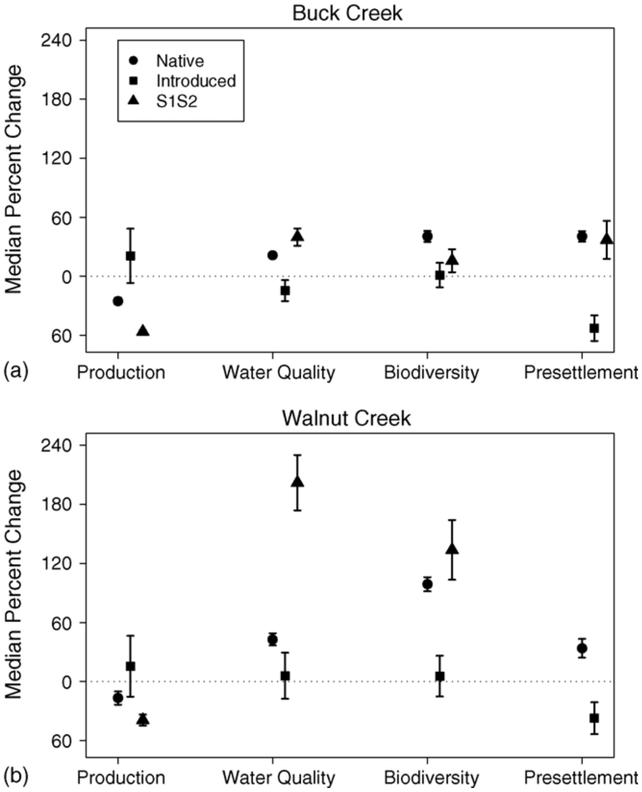

Fig. 5. Median percent change (±1 S.D.) in habitat area (adjusted by suitability), compared to the present, for all native vertebrate species, introduced vertebrate species, and rare (S1–S2) vertebrate species for both watersheds. Values >0 indicate habitat gain compared to the present; values <0 indicate habitat loss compared to the present. Results for S1–S2 species for Presettlement in Walnut Creek not shown because values were greater than 200% (723.9%, see Table 3 for values).

wetland habitat had less habitat in the past relative to the present (−19 ± 0.1%). Also, the change statistic does not include species associated only with ephemeral or semi-permanent wetlands, since such species have no habitat in the present. However, wetland-associated species would have had extensive habitat in the Walnut Creek watershed in the past. Studies by Rustigian et al. (2003) indicate that the presence of prairie pothole wetlands greatly increased modelled population sizes for amphibian species in Walnut Creek watershed. Introduced species had less habitat in the past relative to the present in both watersheds, whereas rare species had more habitat in the past relative to the present, particularly in Walnut Creek watershed (Fig. 5).

In the Production scenario, all taxa (Fig. 4) and native vertebrates overall (Fig. 5) lost habitat in both watersheds (−1 ± 0.2 to −65 ± 2%) except mammals, for which habitat remained stable because conservation tillage in row crops provided more cover to small mammals than conventional-till practices. Habitat for introduced species remained about the same while rare species lose habitat in both watersheds in this scenario.

In the Water Quality scenario, all taxa (Fig. 4) and native vertebrates overall (Fig. 5) had more habitat in both Buck Creek (17 ± 5 to 65 ± 6%) and Walnut Creek (28 ± 7 to 181 ± 22%) relative to the present (Fig. 4). Introduced species lost habitat in Buck Creek watershed but remained about the same in Walnut Creek watershed, while rare species gained habitat in both (Fig. 5).

In the Biodiversity scenario, all taxa (Fig. 4) and native vertebrates overall (Fig. 5) had more habitat in Walnut Creek (37 ± 11 to 1617 ± 128%), and in Buck Creek (24 ± 13 to 91 ± 11%), except for reptiles (−16 ± 5%) and butterflies (−4 ± 4) in the latter. The conversion of pasture, alfalfa, and CRP to strip intercropping appeared to be responsible for the decline in habitat area for reptile species in this scenario for Buck Creek (Table 1). Alfalfa, pasture, and CRP were assigned as habitat for 27, 27, and 26 reptile species, respectively, strip intercropping for only 16 reptile species (Table 1). Similarly, more butterfly species were associated with alfalfa, pasture, and CRP (39, 53, and 57 species, respectively) than with strip intercropping (16 species). Habitat for introduced species remained about the same while rare species gain habitat in both watersheds (Fig. 5).

For most taxa, estimated changes in wildlife habitat under the Biodiversity and Water Quality scenarios were similar to each other and to those for the reconstructed past, and indicated greater habitat than the present landscape or the Production scenario. For native vertebrates overall, birds, amphibians, and rare species in both watersheds the Biodiversity scenario ranked highest in providing habitat, followed by the Water Quality scenario and the Production scenario. For mammals in Walnut Creek watershed, the Water Quality and Biodiversity scenarios were equivalent, and both ranked higher than the Production scenario. For reptiles and butterflies in both watersheds, the Water Quality scenario was similar to or slightly better than the Biodiversity scenario, and both ranked higher than the Production scenario. Future scenarios were generally similar to the present with respect to habitat area for introduced species.

3.2. Species richness changes

The existing landscape showed "hotspots" for species richness of native vertebrates in the riparian forests and perennial herbaceous cover and "coldspots" in row crops (Table 1). Effects of habitat changes on native vertebrates between the past and future scenarios compared to the present were evident in terms of species richness for both watersheds. Presettlement habitat in each watershed supported higher species richness over more area than in the present. The difference in species richness was largely due to the difference between the species richness of row crops as compared to wet and dry prairie in Walnut Creek and to dry prairie and upland forest in Buck Creek (Table 2). Species richness was lower in the past compared to the present in areas which had been dry prairie in the past but were converted to pasture and ungrazed upland woodland in the present.

Table 2
Habitat conversions (in % of watershed area) from the present to each alternative future or past scenario (P: Production, WQ: Water Quality, B: Biodiversity, and PS: Past) and effect on species richness of native vertebrates for Buck Creek and Walnut Creek

Scenario	Habitat type in the present	Habitat type in future or past	Area (%) Buck Cr.	Area (%) Walnut Cr.	Number of species
P	Upland ungrazed	Row crop conservation till	3.78	1.16	−37
P	Pasture	Row crop conservation till	10.77	2.21	−24
P	Pasture	Alfalfa/hay	2.59	na	−15
P	Crp	Row crop conservation till	12.68	na	−14
P	Crp	Alfalfa/hay	2.86	na	−5
P	Herbaceous	Row crop conservation till	1.98	1.57	−12
P	Alfalfa/hay	Row crop conservation till	7.96	2.52	−9
P	Farmstead and urban	Row crop conservation till	na	1.27	−7
P	Row crop chisel plow	Row crop conservation till	42.86	80.75	12
WQ	Upland ungrazed	Upland grazed	5.56	2.35	−15
WQ	Row crop chisel plow	Row crop conservation till	10.79	53.61	12
WQ	Alfalfa/hay	Pasture	3.49	1.14	15
WQ	Row crop chisel plow	Alfalfa/hay	22.89	7.26	21
WQ	Row crop chisel plow	Crp	3.27	5.71	26
WQ	Row crop chisel plow	Pasture	3.26	12.88	36
WQ	Row crop chisel plow	Herbaceous	1.16	na	24
WQ	Pasture	Alfalfa/hay	1.67	na	−15
WQ	Savanna ungrazed	Savanna grazed	1.05	na	−6
WQ	Crp	Alfalfa/hay	11.54	na	−5
WQ	Crp	Pasture	2.08	na	10
WQ	Herbaceous	Alfalfa/hay	1.18	na	−3
WQ	Pasture	Riparian ungrazed	1.21	na	44
WQ	Row crop chisel plow	Riparian ungrazed	1.55	na	80
B	Row crop chisel plow	Row crop conservation till	na	32.14	12
B	Row crop chisel plow	Organic strip	na	2.73	24
B	Row crop chisel plow	Prairie dry	na	1.47	24
B	Row crop chisel plow	Row crop native strip	34.95	35.07	31
B	Row crop chisel plow	Upland grazed	1.25	1.8	34
B	Row crop chisel plow	Prairie wet	na	3.02	37
B	Row crop chisel plow	Riparian ungrazed	4.88	3.36	80
B	Pasture	Prairie dry	1.41	na	−12
B	Pasture	Row crop native strip	7.74	na	−5
B	Pasture	Upland grazed	1.08	na	−2
B	Pasture	Riparian ungrazed	2.64	na	44
B	Crp	Row crop native strip	10.91	na	5
B	Crp	Upland grazed	1.04	na	8
B	Crp	Riparian ungrazed	2.77	na	54
B	Herbaceous	Row crop native strip	1.41	na	7
B	Alfalfa/hay	Row crop native strip	6.48	na	10
PS	Upland ungrazed	Prairie dry	1.74	1.62	−25
PS	Pasture	Prairie dry	5.32	1.68	−12
PS	Crp	Prairie dry	5.29	na	−2
PS	Alfalfa/hay	Prairie dry	3.61	1.51	3
PS	Farmstead and urban	Prairie dry	na	2.17	5
PS	Herbaceous	Prairie wet	na	1.46	13
PS	Pasture	Upland ungrazed	8.31	na	13
PS	Crp	Upland ungrazed	10.63	na	23
PS	Alfalfa/hay	Upland ungrazed	5.32	na	28
PS	Herbaceous	Upland ungrazed	1.39	na	25
PS	Row crop chisel plow	Upland ungrazed	12.23	na	49
PS	Row crop chisel plow	Semi permanent wetland	na	3.34	20
PS	Row crop chisel plow	Prairie dry	30.35	39.28	24
PS	Row crop chisel plow	Prairie wet	na	38.56	37

Habitat classes as in Table 1, descriptions in Appendix A.

In the Production scenario, the area of habitat with high species richness decreased over much of Buck Creek watershed relative to the present, primarily from conversion of woodland, alfalfa/hay, pasture and Conservation Reserve Program set-aside to row crop (Table 2). Gains in habitat with high species richness in both watersheds were mostly from conversion of conventional- to conservation-till row crop. The Biodiversity and Water Quality scenarios supported higher species richness gains and lower species richness losses over more area relative to the present than the

Table 3
Means and standard deviations of 1000 replicates of Monte Carlo estimates of median percent change in suitability-weighted habitat for selected groups of species. The first column shows the total number of species in each group (''Total Nspp''), followed by four sets of two columns that correspond to the three future landscapes and the past landscape. The first and second columns in each set are the mean and standard deviation, respectively, of the median percent change for the group

Group	Total Nspp	Production	S.D.	Water quality	S.D.	Biodiversity	S.D.	Presettlement	S.D.
Buck Creek									
Amphibians	12	−3.2	0.3	64.6	6.0	24.2	12.9	27.0	7.6
Reptiles	29	−38.3	6.6	27.9	6.0	−15.7	5.4	50.3	12.7
Birds	146	−40.9	3.6	20.7	3.5	90.7	11.2	35.3	9.3
Mammals	52	−3.0	5.2	17.1	4.8	41.5	7.5	47.8	9.2
Native Vert	239	−25.1	3.4	21.4	2.3	40.6	5.5	40.6	5.4
Introduced Vert	8	20.8	27.6	−14.5	10.7	1.3	12.4	−52.6	13.0
S1–S2	24	−56.4	1.6	39.9	8.8	15.8	11.7	37.1	19.3
Lepidoptera	117	−64.6	1.9	18.0	4.0	−3.5	4.1	164.0	17.4
Walnut Creek									
Amphibians	12	−1.2	0.2	181.3	21.7	1617.3	128.1	11529.3	1425.4
Reptiles	29	−36.6	8.1	54.9	19.0	36.5	11.4	131.1	31.3
Birds	146	−29.5	1.2	27.8	6.5	111.7	10.1	−19.4	0.1
Mammals	52	14.5	16.8	89.3	17.7	108.7	15.9	105.5	25.7
Native Vert	239	−16.8	6.7	42.9	6.2	98.9	7.2	33.8	9.6
Introduced Vert	8	15.5	30.9	5.9	23.4	5.5	20.7	−37.2	16.2
S1–S2	24	−39.1	5.7	202.1	28.1	133.8	30.3	723.9	130.6
Lepidoptera	117	−41.6	0.9	116.8	11.7	123.2	9.4	1189.9	105.6

Production scenario. In Buck Creek, the Biodiversity scenario resulted in more area with higher species richness gains. The conversion of conventional-till row crop, alfalfa/hay, and Conservation Reserve Program lands to conservation-till and native-strip row crop resulted in an increase in species richness, as did the conversion of row crop in riparian areas to wet prairie and forest (Table 2). There were also some areas of species richness loss due to conversion of pasture to native strip row crop (Table 2). The Biodiversity scenario for Buck Creek showed a loss of species richness in some areas, because pasture, alfalfa/hay, and Conservation Reserve Program lands in the present were coded as suitable for more bird species (Tables 1 and 2) than savanna and dry native prairie. Savanna and dry prairie were the land cover restored in the reserve in the Biodiversity scenario. The greater number of animal species coded to pasture but not prairie was in part an artifact of splitting restored prairie into wet prairie and dry prairie classes in the species–habitat association matrix, whereas pasture was represented by a single class. In Walnut Creek watershed, the area of species richness gains was about the same in the Biodiversity and Water Quality scenarios, primarily due to conversion of conventional- to conservation-till row crop in the Water Quality scenario and to conservation-till and native-strip row crop in the Biodiversity scenario (Tables 1 and 2) although the resulting landscape configuration was quite different between scenarios.

4. Discussion

The development and evaluation of alternative future scenarios is one approach to engage people in a visioning process and to help quantify the ecological and socio-economic impacts that could result from implementation of the alternatives (Nassauer et al., 2002; Steinitz et al., 2003). Comparison of presettlement landscapes to the present and alternative futures can help calibrate the impacts of future landscape change based on changes that have already occurred. The scenarios included in this study were intended to be a provocative but plausible basis for envisioning future directions for agricultural policy in the USA.

Further intensification of agriculture as envisioned in the Production scenario will lead to further decline of wildlife from loss of habitat in farmland, whereas alternative cropping and management practices, as envisioned in the Water Quality scenario or Biodiversity scenario would both benefit wildlife. Divergence in the effects of different scenarios was evident among taxa, particularly for reptiles as compared to other vertebrate taxa, and for butterflies as compared to most vertebrate taxa. Consideration of life history requirements of individual species or sets of species is thus necessary to provide information regarding those species most likely to be at risk from habitat loss as the landscape changes.

The modelling approach developed by White et al. (1997) has been quite flexible and robust in its applications (Hulse et al., 2000; Freemark and Olson, 2002; Santelmann et al., 2004). Model results were relatively robust across moderate uncertainty in habitat scores (Table 3). The modelling approach used in this study was responsive to changes in landscape composition but not landscape configuration. More complicated decision rules on what constitutes habitat can be incorporated when known (White et al., 1997; Hulse et al., 2000). The use of spatially-explicit population models run on the same future scenarios provides additional estimates of impacts on wildlife from landscape change (Rustigian et al., 2003; Clark and Danielson, Unpublished) that should be considered by decision makers and those developing agricultural policy.

The potential effects of global climate change on farmland should also be considered and potential ecological impacts investigated. Information on the nature of potential climate change, landforms, landscape structure, and dynamics of species' distributions across a hierarchy of spatial and temporal scales will need to be integrated (Kareiva et al., 1993). Comparative studies across landscape gradients, regions, or larger geographic areas will be particularly important for predicting the impacts of changes in landscape structure produced by global change and associated land-use change. For example, the possible effects of changes in the diversity within agricultural and forestry production systems on ecological complexity and function at the regional scale may be relevant. Agricultural and forestry production systems that are more diverse and complex may be not only more sustainable, but also more conducive to the migration of species among nature reserves, and hence lead to reduced rates of extinction as species cope with rapidly changing environmental regimes.

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Appendix A. Descriptions of habitat classes

Class	Code	Name of land cover	Land cover description
1	rc.cp	Row crops, chisel plow	Row crops planted and cultivated using conventional cropping methods
2	rc.ct	Row crops, conservation till	Row crops planted and cultivated using conservation tillage and residue management
3	rc.ns	Strip intercropping with native perennials	Innovative agricultural practice in which strips of corn and soybeans (rotated annually) are alternated with permanent strips of native perennial grasses and forbs
4	rc.sg	Small grains (e.g., oats)	Fields of small grains such as oats, barley etc.
5	rc.fall	Row crop fallow (field skips)	Field skips to which no fertilizer is applied, and which are not harvested but allowed to fallow with some kind of herbaceous cover desired by farmer
6	rc.os	Organic strip intercropping	Strip intercropping of organic corn and soybeans
7	rc.o	Organic row crops	Organic corn and soybeans in large fields, not strip intercropping
8	farmstead	Farmstead and urban	Farmsteads and small towns
9	strip.h	Herbaceous strip cover	Grass waterways, fencerows, and other herbaceous cover found in narrow strips
10	strip.w	Woody strip cover	Fencerows, shelterbelts and other cover planted in narrow strips
11	grass.crp	Conservation reserve program	Conservation reserve program; fields on highly erodible land that are planted to grass and forb mixtures and set-aside, not cropped, grazed or mowed
12	grass.hay	Alfalfa/hay	Alfalfa, hay, and other patches of mowed herbaceous cover
13	grass.pd	Dry prairie	Patches of native tallgrass prairie in dryer upland areas
14	grass.pw	Wet prairie	Patches of native wet prairie in wet lowland areas
15	shrub.past	Pasture	Grazed herbaceous cover with occasional patches of shrubs, managed and seeded
16	shrub.ung	Ungrazed shrubland	Patches of shrub-covered areas that are not grazed
17	for.50	Forest less than 50 years old	Ungrazed forest planted less than 50 years previously
18	for.rug	Riparian forest ungrazed	Forested areas along streams and wetlands, ungrazed
19	for.upug	Forested upland ungrazed	Forested areas in uplands, ungrazed
20	for.upg	Forested upland grazed	Forested area in uplands that are grazed
21	for.sug	Savanna ungrazed	Savanna areas that are ungrazed
22	for.sg	Savanna grazed	Savanna areas that are grazed
23	wet.sp	Semipermanent wetland	Prairie pothole wetlands that have water much of the year
24	wet.pond	Farm ponds	Ponds on farmsteads
25	wet.st	Streams	Streams
26	wet.eng	Engineered wetlands	Wetlands placed at outlet of tile drains or along roadsides to filter tile drainage water and runoff from the road

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