SOIL HEALTH, FISH & WILDLIFE

A REPORT BY DUANE HOVORKA, KATE HANSEN

JUNE 2024

INTRODUCTION

THERE IS AN URGENT NEED TO RESTORE THE HEALTH OF OUR NATION'S SOILS.


Photo: Catherine Ulitsky, U.S. Department of Agriculture

Since we began tilling the land for modern agriculture, America has lost tens of billions of tons of topsoil. At current rates of erosion, we are on track to lose half of an inch of topsoil by 2035, more than eight times the loss during the Dust Bowl.[1] The levels of organic matter in our soil – the combination of dead plant material, bacteria, fungi, and critters that is critical to keeping soil healthy – has fallen by half or more since Colonial times.[2]

The continued erosion of topsoil puts our food system at risk. Fortunately, farmers, ranchers and soil health scientists have identified key agricultural principles and practices that restore and maintain the organic matter and biological health of our soils. Better yet, the same soil health practices that can help restore healthy soils can provide significant habitat benefits for fish and wildlife, and restore and protect the health of the rivers, lakes, and wetlands that our fish and aquatic life depend on. These practices can provide widespread benefits for waterfowl and other birds, large and small mammals, fish and amphibians, pollinators and other wildlife. They can also help slow climate change by reducing greenhouse gas pollution and storing carbon in the soil.

The United States Department of Agriculture (USDA), academic experts, and non-governmental organizations have identified key farming principles that can restore and maintain healthy soil: minimizing soil disturbance, maximizing soil cover, maximizing biodiversity and maximizing the presence of living roots.[3]

Different soils, climates and farming systems may require different combinations of practices to restore healthy soils, but the soil health principles can be applied anywhere. Soil health practices include eliminating or reducing tillage, planting cover crops, reducing the use of chemical fertilizers and pesticides, diversifying crop rotations, well-managed rotational grazing, integrating livestock into cropland systems, and planting diverse perennial grassland cover to restore degraded cropland. Together, these practices can protect and feed the diverse population of microbes and other soil-dwelling critters vital for restoring soil health.[4]

While providing benefits for fish and wildlife, water quality and soil health, investments in soil heath practices can also reduce need for expensive inputs like fertilizer, pesticides and fuel while maintaining or increasing yields. That makes soil health practices a win-win-win and can ensure they represent enduring solutions.

The purpose of this report is to highlight key fish and wildlife benefits of soil health practices based on the best available science. We hope it will contribute to important public debate as Congress, state legislatures, and federal, state and local agencies consider whether and how to craft policies and programs that speed the widespread adoption of soil health practices needed to restore the health of our food system.

SOIL HEALTH PRACTICES

Soil health practices vary from farm to farm depending on soil types, climate, management systems, available equipment and farmer preferences, but some key practices can be effective almost everywhere to boost soil health on cropland or grazing land.

No-till eliminates mechanical tillage (plowing, discing, or cultivating), while *conservation tillage* (or reduced tillage) relies on shallow, infrequent tillage passes to minimize disturbance of the soil. Tillage destroys mychoryzal fungi and soil aggregation, disrupting the biology that produces healthy soil. Tillage also leaves the soil without armor, which can result in more erosion and excess summer temperatures that can harm soil microbes.

Cover crops are typically non-cash crops planted to provide living cover, feed exudates to soil microbes and reduce erosion after an annual cash crop is harvested, or when weather prevents the planting of a cash crop. Cover crops add nutrients to the soil and can be grazed by livestock to increase return on investment.

Conservation crop rotations are crop rotations that are more diverse than typical conventional one-crop (e.g. continuous corn) or two-crop rotations (e.g. corn-soybeans). With three, four, or more crops planted in rotation, crop pest cycles can be broken up and more diverse soil microbes supported.

Integrated pest management involves a combination of techniques, such as scouting for pests, tillage and crop rotation, biological controls, and spot spraying rather than whole-field spraying. Chemical controls are typically used only with triggers based on pest abundance, yield impacts, and economic costs. The goals are to prevent unacceptable levels of pest damage while minimizing the risk to people and the environment and slowing the evolution of pest resistance to pesticides.[5]

Nutrient management can use a combination of strategies to ensure plants have adequate nitrogen, phosphorus, potassium and other nutrients to thrive, including soil testing, planting cover crops, integrating livestock into crop production, and carefully targeting nutrients in the right amounts and timed to meet crop needs. Chemical nutrients can disrupt the biology that sustains healthy soil.

Management intensive rotational grazing (or just rotational grazing) involves moving pasture-based livestock frequently to provide rest and recovery periods (often 30-60 days) for the plant community. This practice helps strengthen plants and rebuild and maintain healthy grassland soils.

Integrating livestock into cropping systems improves soil organic matter storage and adds diversity to the soil microbe population.[6]

WATERFOWL AND OTHER BIRDS

Multiple soil health practices provide benefits for resident and migratory birds, and the practices are likely even more effective when used together.

In Canada, the Prairie-Parkland region in the northern plains provides breeding habitat for over half of North America's continental mallard population. At least 80% of the region is under intensive cultivation, and the region has seen substantial wetland loss as well. With a shortage of wetlands and native prairie available for nesting habitat, ducks must often nest in cultivated fields.

Researchers there in 1982 found that total duck production was several times higher in crop fields with no tillage than in conventionally tilled croplands. They found farmers can have additional impacts on duck numbers by taking action to avoid crushing nests and covering nests during seeding operations, and by their choice of equipment and timing.[7]

After harvest, no-till wheat fields in the Great Plains provide cover and habitat for migrating ducks, geese and other waterfowl, as well as habitat for the insects those waterfowl can feed on.[8]

No-till provides substantial benefits for birds and other wildlife by leaving residue on fields that provides food and cover. Research at the University of Illinois Urbana-Champaign documented significantly greater density of birds, a greater density of nests, and a greater diversity of bird species nesting in no-till soybean fields than in conventional tilled soybean fields.[9] The conservation value of the bird community in no-till soybean fields was also greater.[10] Research at Southern Illinois University at Carbondale showed that birds, invertebrates and small mammals are more abundant in a no-till corn field than a conventionally tilled corn field.[11]

Photo: Steve Maslowski, U.S. Fish and Wildlife Service

Avian use of crop fields has been shown to increase as residue cover increases, as happens when farmers use no-till and cover crop systems.[12] In another study, quail chicks needed to spend just six hours a day foraging in a no till field to meet their nutritional needs, one-third of the 20 hours of foraging needed in a conventionally tilled field.[13]

Fields with cover crops provide shelter and forage for birds and other wildlife, which can be especially helpful in providing winter cover for birds that don't migrate. Research in eastern Illinois documented substantially higher numbers of migratory and resident birds in the spring in corn and soybean fields with cover crops than in fields without cover crops. That research also showed a higher diversity of species in fields with cover crops, and the fields with cover crops hosted birds of higher conservation concern, like the Eastern meadowlark.[14]

Research at the University of Missouri has documented the habitat provided by cover crops for quail, and the increased potential for quail nest survival in cover crops compared to fields with no cover crops. While that increase in nest survival was not particularly large, it could be significant when multiplied by the large expanse of cropland acres that could be planted to cover crops.[15] The research also documented the use of cover crops as winter forage by rabbits, deer, turkey and other wildlife.

Different grassland songbird species prefer different types of vegetation, from tall and dense to short and sparse. Rotational grazing results in a mosaic of vegetative cover that can help provide that diversity of habitat.[16] In North Dakota, rotational grazing was found to provide benefits for livestock operations while providing benefits in some years for a grazing-sensitive group of birds that included grasshopper sparrow, Savannah sparrow, Western meadowlark, bobolink, and Baird's sparrow.[17]

In a review of 122 studies of bird species associated with farmlands and grasslands in North America, Canadian researchers concluded that "pesticides (42% of all studies), followed by habitat loss or alterations (27%), were most predominant in negatively affecting farmland birds, with pesticides (93% negative) and mowing/harvesting (82% negative) having the most consistently negative effects." The researchers also noted, "modifications to farmland management such as reducing pesticide inputs through integrated pest management and maintaining or restoring uncultivated field margins and native habitat could positively influence farmland birds without significantly reducing agricultural crop yields."[18]

A 2013 study of the causes of grassland bird decline said: "Best predictors of species declines were the lethal risk from insecticide use modeled from pesticide impact studies, followed by the loss of cropped pasture [...] this suggests that, in the U.S. at least, pesticide toxicity to birds should be considered as an important factor in grassland bird declines." Many of the grassland bird species of conservation concern have been recorded killed directly in pesticide field trials, and many of the pesticides used are also designed to kill insects that serve as food for grassland birds and other wildlife.[19]

In the southeast, researchers found two to three times as many Bobwhite quail on farms with field borders compared to similar farms lacking field borders, and those field borders improve nesting and brood-rearing habitat.[20] A study of breeding season bird densities in crop fields with and without native grass buffers in 14 states showed higher densities of 5 of 6 targeted bird species near fields with native grass buffers in most regions, with the relative effect greatest for Northern bobwhite, Dickcissel, and field sparrow.[21]

While buffer areas do not provide ideal habitat for grassland birds that prefer large blocks of habitat (e.g., lesser prairie chickens), the smaller patches typical of buffer strips delivered bird abundance similar to larger patches for a suite of shrub-land birds that includes Bell's vireo, Northern bobwhite, yellow-billed cuckoo, field sparrow and willow flycatcher.[22] During winter, conservation buffers can provide critical bird habitat in an area, even where they involve a relatively small change in the primary land use (e.g., 7% of the landscape).[23]

LARGE AND SMALL MAMMALS

Large and small mammals can benefit from a number of soil health practices that provide food and cover in the winter, and better management of grasslands.

Elk in Montana saw benefits from a rotational grazing system put in place to address conflicts between elk and livestock on a wildlife management area. The system provided winter cover and forage for elk, enhanced native vegetation, and provided forage for cattle in the spring, summer, and fall.[24] Neighboring cattle ranchers also saw benefits because the improved elk winter habitat on the wildlife management area reduced the elk use of nearby private lands during the winter.

Livestock tend to congregate in riparian areas, especially in more arid western parts of the country. Livestock overuse can have a negative impact on vegetation, fish habitat and wildlife. Riparian areas are also considered some of the most productive and critical habitats for wildlife.[25] Amphibians, water-dependent mammals like river otter, beaver, and mink, and birds and other wildlife that use the lush vegetation typical of riparian areas can all benefit from a rotational grazing system that limits the duration of livestock presence in riparian zones and provides substantial rest periods.

Deer may eat many of the species used for cover crops, and often bed down in fields with cover crops. Cover crop vegetation can hide rabbits, mice and other small mammals from predators, and can provide food and habitat over the winter. Cover crops and the crop residue in no-till fields can provide habitat for a wide variety of insects that provide a food base for smaller mammals and birds, which can in turn provide food to support raptors, coyotes and other larger predators.[26]

Research in no-till corn fields in southwest Iowa showed that the diversity of small mammal species was greater in no-till fields, although populations were no more abundant in no-till fields compared to tilled fields.[27]

Waste grain left on the surface can feed deer, small mammals, migrating waterfowl, and upland game birds like turkey, quail and pheasant. Wildlife can, in turn, return benefits to the farmer. Research at Iowa State University showed that field mice will eat a large share of the weed seeds in a no-till field, reducing the need for herbicides.[28] Research in Indiana showed that field mice help farmers by consuming weed seeds and waste grains over the winter.[29]

A wide variety of wildlife will use buffer strips as habitat, depending on the vegetation planted and the region of the country. In Texas, white-tailed deer, wild turkey, cardinals, woodpeckers, owls, turtles, frogs, and insects will use riparian forest buffers.[30]

FISH AND AQUATIC LIFE

Fish and other aquatic life see benefits in reduced runoff of sediment and phosphorus into streams, wetlands and lakes that results from soil health practices like reduced tillage, cover crops, and better grazing management, and from a reduction in the use of pesticides. By restoring the health of our soils, we can restore and protect the health of our rivers, lakes and wetlands.

Many studies have documented the impact excess sediment can have on aquatic species, especially trout and salmonids.[31] Excess phosphorus can feed algae, causing it to grow and multiply faster than the ecosystem can handle. These algal blooms then die, and the bacteria that breaks down the decaying algae can use up the oxygen in the water, causing kills of fish and other aquatic species.

According to the U.S. Geological Survey, many fish kills are caused by low levels of dissolved oxygen, which can occur naturally but is often the result of excess nutrients.[32] According to the Environmental Protection Agency, in some farm states like Illinois (89%), Kansas (81%) and Nebraska (76%), a large share of the lakes and reservoirs that were assessed failed to meet water quality standards because of nutrient-related impairment.[33] Reducing polluted runoff stands to benefit fish and other aquatic species locally as well as downstream.

Below, a review of the science by Iowa State University researchers provides benchmark numbers for the substantial long-term reductions in nitrogen and phosphorus that can be expected from implementing soil health practices.[34]

Soil Health Practice	Nitrogen Runoff	Phosphorus Runoff
Conservation tillage	-3%	-33%
No-till	-10%	-90%
Cover crops	-30%	-29%
Diverse crop rotation	-42%	Data not available
Buffer strips (no tile)	-90%	-58%
Pasture or CRP	-85%	-60-75%

Pesticides are another factor contributing to the decline of aquatic species, and pesticides have been responsible for fish kills as well as harming frogs, turtles, mussels, water birds and other wildlife.[35] The reduction in pesticides that results from integrated pest management practices, and from the reduction in need for pesticides as soil health improves, should also benefit fish and other aquatic species.

Insecticides, herbicides, fungicides and rodenticides can have serious and sometimes unexpected impacts on fish and other non-target aquatic species they touch. One study of four commonly used pesticides found that two insecticides, carbaryl (Sevin) and malathion introduced into an aquatic system substantially reduced aquatic species richness (by 15% with Sevin, and 30% with malathion). Herbicide glyphosate (Roundup) reduced species richness by 22%, while the more selective broadleaf herbicide 2,4-D had no impact on species richness. The two insecticides reduced the diversity of predatory insects, while the two herbicides had no impacts on predatory insects or snails. Glyphosate completely eliminated two species of tadpoles and nearly exterminated a third species, resulting in a 70% decline in species richness of tadpoles.[36]

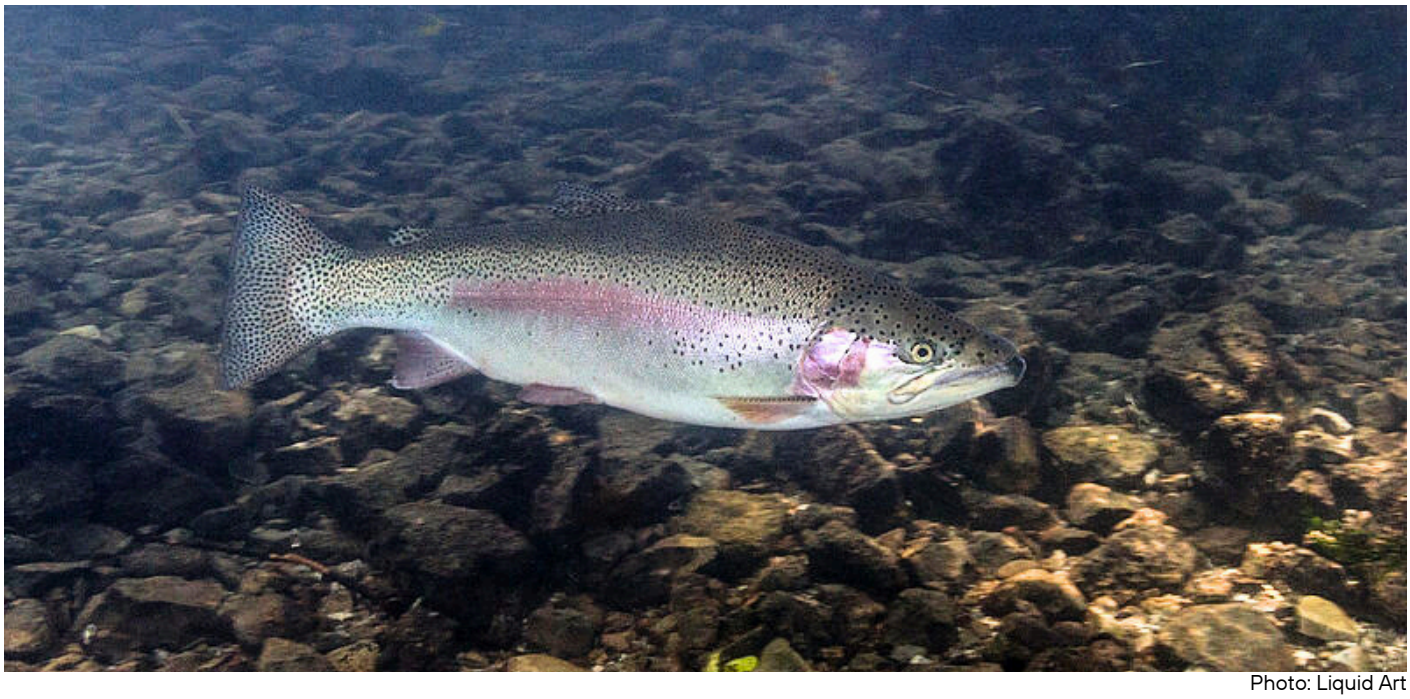

Photo: Liquid Art

Buffer strips are also effective at reducing runoff of pesticides into streams. For example, Iowa State University cites research by Arora, K. et al showing that in a rainfall event where a field had 35% water infiltration, buffer strips captured 57% of sediment and 44% of the Atrazine, but in an event with 69% infiltration, buffer strips retained 86% of sediment and 58% of Atrazine.[37]

In Wisconsin, research showed that an intensive rotational grazing system resulted in a reduction in streambank erosion and a reduction in fine substrate in the channel, and that an intensive rotational grazing system performed as well as a grass buffer strip, and better than either a woody buffer strip or continuously grazed pasture, in protecting and rehabilitating Wisconsin trout streams.[38]

No-till, cover crops, diverse crops rotations, nutrient management and buffer strips used in combination can virtually eliminate sediment and nutrient runoff into nearby streams in most situations. These practices in combination with integrated pest management can substantially reduce or eliminate the risk to aquatic wildlife of pesticide drift or runoff.

POLLINATORS

Honeybees, hundreds of species of native bees, and thousands of species of butterflies, flies, wasps and beetles pollinate crops and other plants. Pollinators feed from pollen and nectar from flowering plants, including cover crops and perennial vegetation that flowers, and they help pollinate a wide variety of cash crops. Soil health practices can provide nesting habitat, cover, and food for pollinators, and can reduce the impact of agrichemicals on pollinators. The same practices can support other beneficial insects that can kill insects that eat crops. Pollinators and other insects in turn provide a food base for birds and small mammals.

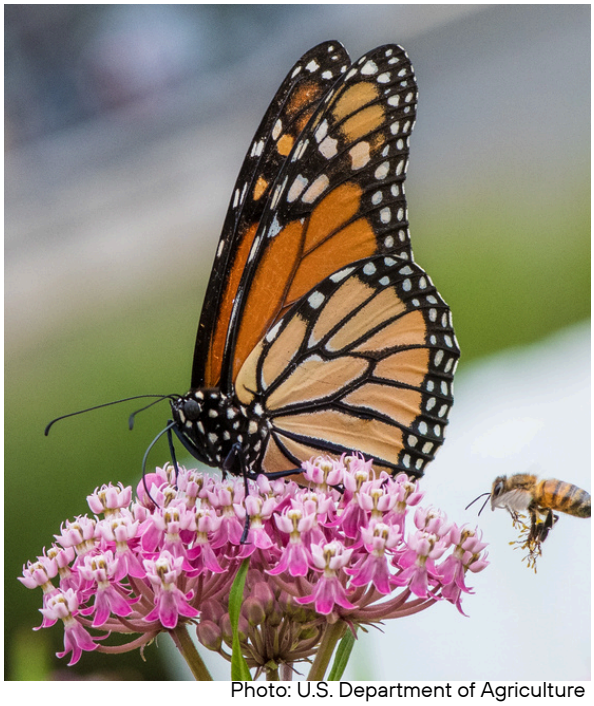

Photo: U.S. Department of Agriculture

Rotational grazing results in a mosaic of grassland heights, and with adequate rest between grazing passes plants are more likely to mature and flower, providing benefits for pollinators. Research in France comparing rotational grazing with continuous grazing of cattle and sheep showed rotational grazing resulted in increased abundance and species richness of flower-visiting butterflies and bumblebees without reducing animal performance or herbage mass.[39]

Field margins with a naturally diverse flora provide habitat for a relatively high abundance and diversity of above-ground arthropods, and those areas can provide important habitat for pollinators and other beneficial insects.[40] Beneficial insect abundance was shown to be greater in fields with field borders,[41] and the benefits of conservation buffers for pollinators can be increased with the addition of forbs and flowering shrubs.[42]

There have been few studies we can find directly assessing the impact of integrated pest management on wildlife generally, although there is some research on the impact of the strategies on beneficial arthropods.[43] Beneficial insects, including pollinators like bees and butterflies, should benefit from reductions in the use of broad spectrum pesticides.

Photo: Dennis Larson, Natural Resources Conservation Service

CONCLUSION

We are faced with an urgent need to reverse the decline of our country's soil health, to halt the ongoing erosion of topsoil and loss of organic matter in our soils. While we have much to learn, a growing body of science has identified a suite of key farm and ranch practices that, when used in combination, can begin to restore the health of our soils. Those soil health practices provide economic benefits for farmers and ranchers, which stand to make them enduring solutions once put in place.

Fortunately for our nation's fish and wildlife – and the hunters, anglers, bird-watchers, and others who love them – those same soil health practices provide many benefits for waterfowl and other birds, large and small mammals, fish and other aquatic life, and pollinators and other insects. Until now, the benefits of soil health practices to fish and wildlife may have gone largely unrecognized. More research and education are needed, but the implications of the research highlighted in this report is clear: healthy soil and healthy fish and wildlife populations go hand in hand.

REFERENCES

1. Union of Concerned Scientists, Rates on Track to Repeat Dust Bowl-era Losses Eight Times Over, ucsusa.org/about/news/national-soil-erosion-rates-track-repeat-dust-bowl-era-losses-eight-times-over, December 2020.

2. Baumhardt, R.L., Stewart, B.A., Sainju, U.M., North American Soil Degradation: Processes, Practices, and Mitigating Strategies, Sustainability 2015, 7(3), 2936-2960.

3. U.S. Department of Agriculture, Soil Health, https://www.farmers.gov/conservation/soil-health

4. Montgomery, David and Bikle, Ann, The Hidden Half of Nature: The Microbial Roots of Life and Health, W.W. Norton 7 Company, 2015.

5. U.S. Department of Agriculture, Integrated Pest Management, www.usda.gov/oce/pest/integrated-pest-management

6. Thapa, Vesh, et al, Land Use Effects on Soil Health in Semiarid Drylands, Agricultural & Environmental Letters, Vol 3, Issue 1, August, 2018.

7. McLaughlin, Alison and Mineau, Pierre, The Impact of Agricultural Practices on Biodiversity, Agriculture Ecosystems & Environment, 55:201-212, 1995.

8. Stockwell, Ryan, No Till, Cover Crops and Wildlife: A Lively Combination, National Wildlife Federation Blog, November 5, 2013, http://blog.nwf.org/2013/11/no-till-cover-crops-and-wildlife-a-lively-combination.

9. VanBeek, Kelly, Avian Breeding Ecology in Soybean Fields: Does No-Till Provide Any Benefits? University of Illinois at Urbana-Champaign Masters Theses, 2012.

10. Van Beek, Kelly, Does No-till Soybean Farming Provide Any Benefits for Birds? Agriculture, Ecosystems and Environment, 2014, 185:59-64.

11. Warburton, D.B. and Klimstra, W.D., Wildlife Use of No-till and Conventionally Tilled Corn Fields, Journal of Soil and Water Conservation, 1984, vol. 39 no. 5.

12. Basore, N.S., Breeding Ecology of Upland Birds in No-tillage and Tilled Cropland, Iowa State University M.S. Thesis, 1984.

13. Stockwell, Ryan, Environmental Impacts of Cover Crops, presentation at the National Conference on Cover Crops and Soil Health, March, 2014.

14. Wilcoxen, Cassandra, et al, Use of Cover Crop Fields by Migratory and Resident Birds, Agriculture, Ecosystem and Environment, Volume 252, 15 January 2018.

15. Wright, Ray, Effect of Diverse Cover Crops on Insects and Wildlife, University of Missouri; Wright estimated quail nest survival in cover cropped areas at 15% to 30%.

16. Krausman, Paul R. et al, Livestock Grazing, Wildlife Habitat, and Rangeland Values, Society for Range Management, October 2009.

17. Schneider, Natoma, Passerine Use of Grasslands Managed With Two Grazing Regimes on the Missouri Coteau in North Dakota, South Dakota State University masters thesis, 1998, Electronic Theses and Dissertations, 393.

18. Stanton, R.L, et al, Analysis of Trends and Agricultural Drivers of Farmland Bird Declines in North America: A Review, Agriculture, Ecosystems, and Environment 254 (2018), 244-254.

19. Mineau, P. and Whiteside, M., Pesticide Acute Toxicity is a Better Correlate of U.S. Grassland Bird Declines than Agricultural Intensification, (2013) PLoS ONE 8(2). Doi"10.1371/journal.pone.0057457.

20. Berger, L. Wes et al, Conservation Buffers: Wildlife Benefits in Southeastern Agricultural Systems, USDA, Forest & Wildlife Research Center Research Advances, January, 2006.

21. Evans, K.O, et al, Assessing Multiregion Avian Benefits from Strategically Targeted Agricultural Buffers, Conservation Biology, 2014, August, 28(4):892-901.

22. Reiley, Bryan, Habitat Use, Population Size, and Nesting Ecology of Conservation Priority Bird Species Using Restored Fields in Agricultural Landscapes, PhD Dissertation, University of Illinois at Urbana-Champaign, 2017.

23. Evans, Kristine O., Avian Response to Conservation Buffers in Agricultural Landscapes During Winter, Wildlife Society Bulletin, 2014, 38(2):257-264.

24. Alt, Kurt, et al, Coordinated Management of Elk and Cattle, A Perspective – Wall Creek Wildlife Management Area, Rangelands 14(1), February, 1992.

25. Krausman, Paul R. et al, ibid.

26. Clark, Andy, Cover Crop Effects on Deer and other Mammalian Wildlife, USDA Sustainable Agriculture Research and Education.

27. Young, Richard E., Response of Small Mammals to No-till Agriculture In Southwestern Iowa, Masters Degree dissertation, 1984, Iowa State University, Retrospective Theses and Dissertations, 17291.

28. Maulsby, Darcy, Free Weed-control Service: Mice, Rodale Institute web site, at www.newfarm.org/features/2006/0306/weedcontrol/maulsby.shtml

29. Berl, Jacob, Functional Role of Native Mice in Midwestern Agroecosystems: Unwanted Pests or Friendly Neighbors? Sustainable Agriculture Research & Education grant report GNC15-199, May, 2017.

30. USDA, Texas Buffers for Wildlife, Natural Resources Conservation Service, Temple, Texas, March 2000.

31. Castro, Janine, and Reckendorf, Frank, Effects of Sediment on the Aquatic Environment: Potential NRCS Actions to Improve Aquatic Habitat – Working Paper No. 6, August, 1995, Oregon State University.

32. USGS, Water Questions and Answers, What Causes Fish Kills? water.usgs.gov/edu/qa-chemical-fishkills.html

33. U.S. Environmental Protection Agency, Waters Assessed as Impaired Due to Nutrient-Related Causes, at www.epa.gov/nutrient-policy-data/waters-assessed-impaired-due-nutrient-related-causes

34. Iowa State University, Reducing Nutrient Loss: Science Shows What Works, February, 2017, and Dinnes, Dana, Assessments of Practices to Reduce Nitrogen and Phosphorus Nonpoint Source Pollution of Iowa's Surface Waters, USDA-ARS National Soil Tilth Laboratory, 2004.

35. Helfrich, Louis, Pesticides and Aquatic Animals: A Guide to Reducing Impacts on Aquatic Systems, Virginia Cooperative Extension, VCE Publications/420/420-213.

36. Relyea, Rick, The Impact of Insecticides and Herbicides on the Biodiversity and Productivity of Aquatic Communities, Ecological Applications, April, 2005.

37. USDA, Conservation Buffers & Water Quality, Iowa State University Extension, July, 2003.

38. Lyons, J., et al, Influence of Intensive Rotational Grazing on Bank Erosion, Fish Habitat Quality, and Fish Communities in Southwestern Wisconsin Trout Streams, Journal of Soil and Water Conservation, 2000, Vol 55 No. 3, p. 271-276.

39. Enri, Simone Ravetto et al, A biodiversity-friendly rotational grazing system enhancing flower-visiting assemblages while maintaining animal and grassland productivity. Agriculture, Ecosystems & Environment, Vol 241, 1 April 2017, pages 1-10.

40. Lagerlof, J. and Wallin, H., The Abundance of Arthropods Along Two Field Margins With Different Types of Vegetation Composition: an Experimental Study, Agriculture, Ecosystems & Environment, 43:141-154, 1993.

41. Berger, L. Wes et al, Conservation Buffers, ibid.

42. Wratten, Stephen et al, Pollinator Habitat Enhancement: Benefits to Other Ecosystem Services, Agriculture, Ecosystems & Environment, 15 September 2012, Vol. 159, 112-122.

43. Macfadyen, Sarina et al, Reducing Insecticide Use in Broad-Acre Grains Production: An Australian Study, PLOS One, 19 February 2014, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0089119.