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Policy implications of ecosystem services provided by birds

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Abstract

Ecosystem services are natural processes that benefit humans. Here we first provide a brief primer of ecosystem services provided by birds. We then consider government policy in light of these services. Birds contribute the four types of services recognized by the UN Millennium Ecosystem Assessment- cultural, provisioning, regulating, and supporting services. Most of the services fall into the regulating and supporting categories. These services include pest control, seed dispersal, pollination, and scavenging animal carcasses. Provisioning services include provisioning of meat, eggs, nests and guano (fertilizer). Cultural services include artistic and religious expression, bird watching, and photography. Maintenance of bird-contributed ecosystem services depends upon maintenance of the bird species performing them, and in some cases, enhancing their ability to provide those services. Policies that promote long-term conservation of bird species and their populations are thus critical, and include those that focus on global climate; timber and food production; energy production; emerging diseases; land management (habitat preservation and restoration); wild bird trade and endangered species; and world trade.

Key words*: biofuels; conservation reserve program; habitat preservation; native bird populations*

Introduction

"Ecosystem services" are natural processes that benefit humans. Following the United Nations Millennium Ecosystem Assessment (1-2), we recognize four principal types of ecosystem services:

- Cultural services;
- Regulating services;
- Supporting services;
- Provisioning services.

Birds contribute each of these types of services. Here we first provide a brief summary of ecosystem services provided by birds (see 3 for detailed review). We then consider these services in light of public and private policy.

Critical issues involve:

- Global climate change;
- Agriculture, food, and timber production;
- Energy production, particularly biofuels;
- Emerging diseases;
- Land management, habitat preservation and restoration;
- Wild bird trade;
- World trade and international treaties.

Bird characteristics and ecosystem services

Birds possess several characteristics that facilitate their contribution of ecosystem services. Most birds fly, making them highly mobile and capable of long-distance movements. Flight allows birds to respond to irruptions or pulsed resources in ways not possible by most other vertebrates. The regular migratory movements of many species link ecosystem processes and fluxes in different geographic areas. Birds exhibit a wide array of social structures, which, in some cases, shift seasonally during the annual cycle. While many species are territorial while breeding, they may congregate in vast, often multi-species flocks when not breeding. Hence, their impacts also potentially vary during the annual cycle.

Cultural services

Humans have interacted with birds for thousands of years. Examples of this long history include the 16,500 year-old cave paintings in Lascaux, France, clearly depicting a bird and 3,000 year-old murals of ancient Egyptians with domesticated ducks and cranes. These two examples also illustrate that while the human-bird interaction was im-

portant enough for the people at the time to document, the process of documentation can transcend the original use of birds to something of larger cultural significance. While the domestication of birds for food was no doubt important for the Egyptians, the murals depicting those scenes transform a product-driven ecosystem service with quantifiable economic value into an intangible social service.

One aspect of cultural services provided by birds that can be quantified to some degree is recreation. Prominent among recreational uses of birds is bird watching. Some 45 million people in the United States enjoy watching birds. In 2001 U.S. bird watchers spent $32 million enjoying their hobby, creating $85 million in indirect economic impact and supporting nearly 1 million jobs (4-5). The rise in popularity of bird watching, especially in the past 50 years, spawned an entire genre of books, field identification guides, that now goes well beyond birds. Similarly, the demand for bird watching trips contributes to the current boom in ecotourism. An offshoot of recreational interest in birds is the rise of citizen science programs that use knowledgeable volunteers to help monitor bird populations on a large geographic scale.

Regulating and supporting services

Most regulating and supporting services arise via top-down effects of resource consumption. With over 10,000 bird species on earth, birds consume a wide variety of resources in terrestrial, aquatic, and aerial environments. In many cases, the consumed resource is a pest of agricultural crops or forests. In other cases, bird resource consumption facilitates pollination, or movement and deposition of seeds, promoting successful plant reproduction in a surprising number of plant species. When the plants are of economic or cultural significance, these services can obviously benefit humans. Bird regulating services also include consumption of animal carcasses. Whelan et al. (3) discuss these regulating services in great depth. Of particular importance is the global reach of these services, especially with regard to insect control, seed dispersal and scavenging. Through these services birds have a large, but as yet mostly un-quantified, impact on ecosystems. Developing methods to quantify the impact of birds is a critical research need.

Provisioning services

Many bird species are hunted or kept as pets. As such, these species are products for human consumption and/or commerce. Non-domesticated birds have been important components of human diets historically (6), and many are still today (7). In developed countries, many are hunted for consumption and sport (8). Domesticated birds (poultry) are important sources of protein around the world. Broiler exports from the U.S. are estimated at 6.67 billion pounds for 2008 (9). Bird feathers provide bedding, insulation, and ornamentation (10-11). Many bird species modify their environment by activities like nest construction and in colony-nesting bird species, deposition of guano. In these instances, birds contribute both provisioning and supporting services.

Policy Implications

Clearly birds are important components of ecosystems through the contributions of cultural, regulating, supporting, and provisioning services. Their services are most evident when reduced by population declines or removed during experimental manipulations. Maintenance of bird-contributed ecosystem services depends upon maintenance of viable populations of the bird species performing them. We have already lost some ecosystem services that were provided by birds that have gone extinct or are nearly extinct. In the U.S., notable species include the Ivory-billed Woodpecker (regulating – insect pest control), the Passenger Pigeon (supporting – consumption of chestnut, oak, and beech mast), and the Carolina Parakeet (provisioning – feathers and pet trade; and regulating – cocklebur pest control). Unfortunately, populations of many bird species are declining, including many species in the U.S. (12-13), mostly due to habitat destruction. Accordingly, policies that promote the services provided by birds should: 1) enhance population size of threatened, endangered, and declining common species, and 2) augment the ability of all bird species to provide the ecosystem services. Conservation legislation such as the Endangered Species Act must be fully enforced.

Many human activities potentially affect birds, in some cases negatively, in other cases positively. While we understand the response of some bird species to some human activities, for other species or circumstances, we do not. Policies must recognize the value of indirect benefits resulting from supporting and regulating ecosystem services (e.g., control of herbivorous insects) rather than focusing exclusively on the more direct benefits of provisioning services (e.g., guano; meat, eggs). We have sufficient information to predict the short term impact of human activ-

ities on local bird communities, and in turn, the influence on the ecosystem services they provide. However, we also need research to fill existing knowledge gaps.

Policy must support research; education and dissemination of new research results; implementation of management based on science; and monitoring of the implemented management to assess attainment of management objectives. Research should investigate birds as ecosystem service providers, and how management can enhance provision of those services. Government policies should create incentives that encourage public and especially private land holders to promote bird conservation. Finally, government scientists and science advisors must be allowed to do their jobs unfettered. Policy must be guided by the best available scientific evidence.

Bird distribution and abundance

Birds are found within environments to which they are physiologically adapted. Beyond that, each species needs resources that allows it to feed, successfully mate and reproduce, escape enemies and avoid inclement conditions. Each species meets these needs in specific ways. Hence, environmental circumstances that benefit one species may be less beneficial, or even detrimental, to another. Human activities that cause local or even widespread reductions in populations of some bird species may simultaneously cause population increases in others. Thus, there are few, if any, "one size fits all" prescriptions regarding public policy. Many of the specific areas we discuss below are inextricably intertwined, and policy that affects any one is likely concomitantly to affect others. Although we recognize their inter-relatedness, for clarity, we discuss each area separately.

Global climate change

Global climate change is of concern in its own right, but also through its effects on other issues, including food production and development of alternative energy sources. Policy recommendations pertaining specifically to food and energy are discussed below. Global climate change is already causing shifts in the timing of ecological processes (14), and abundance and distributions of numerous organisms, both animal and plant (15). Changes in abundance and distribution of species are linked to emergence of disease. The timing of nesting and migration of some bird species, in particular, has already changed (16), and may reduce the ability of insectivorous birds to control populations of plant-eating insects that can influence the productivity of forest and agricultural systems.

Ecosystem services affected:
Global climate change may affect virtually all ecosystem services provided by birds, largely in negative ways. Climate-driven changes in habitat may lead to population declines if habitat changes proceed more quickly than bird species can adjust ecologically or evolutionarily. Reduced populations will be less effective at delivering services.

Policy recommendation:
Policy must promote reduction of greenhouse gas emissions to reduce effects of climate change on birds and other wildlife. Policy must foster research that anticipates how continued climate change will impact habitats and the natural resources they support, including birds and their prey.

Agriculture, food and timber production

No other human activity has converted more of the earth's surface from naturally occurring habitat to human-modified habitat than has agriculture. Currently, about 38% of the land surface area of the earth is occupied by some form of agricultural production (arable – or row cropped; orchards and vineyards; meadow and pasture). As human populations continue to grow, this amount of land dedicated to agriculture is not likely to decline: world food demand is expected to double by 2050 (17). Some agricultural practices, such as pastoral livestock grazing, can be relatively benign for many bird species. Others, such as intensive row cropping, can be severely detrimental for most species. We need agricultural practices that promote efficiency of production without sacrificing suitability of habitat. Two alternative strategies have been advocated: "land sparing" and "wildlife-friendly farming." Fischer et al. (18) discuss these alternatives in depth and offer a number of policy recommendations.

Birds can be effective pest control agents in both natural and managed ecosystems. Relatively simple and inexpensive actions, like deployment of nest boxes, hunting perches, and nesting platforms, boost their effectiveness. We thus favor wildlife-friendly farming options whenever feasible. Agricultural set-aside programs, like the Conservation Reserve Program (CRP), which encourage farmers to convert marginal agricultural tracts from row crops to fallow vegetation, have increased populations of some

bird species (19). CRP (and similar programs) may also enhance pest control exerted by birds. This, and related research, should be encouraged by specific requests for proposals (RFPs) within the funding arms of the USDA and the NSF.

We believe the CRP could serve as a useful model for exploring alternative strategies of farm management. For instance, similar incentives to those that encourage farmers to enroll in CRP could encourage farmers to collaborate with researchers to devise strategies that combine provisioning wildlife (bird) habitat with sustained yield and reduced reliance on pesticides. This proposal revives "economic ornithology" as first envisioned in the late nineteenth century as "the interrelation of birds and agriculture" (20). This revival may be accomplished, in part, by habitat management for wildlife (e.g., pest-controlling bird species) as a component of integrated pest management (IPM). Research could examine how tactics like growing hedge rows or wind breaks among row cropped fields, no-till practices, direct seeding, etc., simultaneously contribute to bird habitat needs while affecting crop yield. The goal is to manage agro-environments in ways that provide for high bird species diversity while maintaining vigorous agricultural production. Milsom et al. (21) consider related issues with respect to wading birds inhabiting coastal grasslands in England.

An instructive analysis is that of shade coffee in the tropics (22-23). Currently, IPM programs incorporate invertebrate predators, but as demonstrated above, vertebrate predators, including birds, can also be effective. Hence, their inclusion in IPM programs should be implemented where feasible. Use of agroforests and polycultures should be encouraged especially for perennial crops as bird effects in agroforests (timber and agricultural crops grown together) may be equivalent to natural forest habitats (24).

Impacts of forest management practices (timber extraction) in North America on bird populations, and in turn their impacts on forest leaf-feeding insects, illustrate this issue. In so-called even-aged management, patches of forest are clear-cut. In contrast, uneven-aged management simply thins the forest through selective harvest. In the latter, although no one location is heavily impacted, all locations receive some impact. Bird populations are equally affected over the entire logged area. Under even-aged management, successional species, essentially absent from closed canopy forest, colonize clear-cuts, while bird communities in adjacent uncut forest are largely unaffected. Bird species richness at the landscape level may be greater than that found with uneven-aged management. Uneven-aged management is somewhere between even-aged management and no harvest in terms of the number of bird species potentially impacted.

The implications for control of leaf-feeding insects (and resulting tree growth) are not clear at this time. Proliferation of early successional plant species may lead to high abundance of insect food in clearcuts. Higher bird abundance may result in greater predation pressure on herbivorous insects attacking regenerating late-successional plant species and neighboring closed canopy forest.

In eastern North America, clearing of forest at a larger scale is likely to lead to proliferation of generalist nest predators and brown-headed cowbirds, obligate brood parasites that lay their eggs only in the nests of other species. The combination of brood parasitism and nest predation reduces reproductive success and offspring production, ultimately contributing to widespread population declines of many species. Thus intensive timber extraction at a local scale may actually promote bird species richness at a landscape scale, but too much clearing will be detrimental. At this time, we can only guess as to the effects on forest-feeding insects.

The obvious instrument available to guide farm practice in the U.S. is the Farm Bill, which is re-authorized by Congress every five years. Within the U.S. public and congress, the Farm Bill has both detractors and supporters. Detractors highlight direct price supports and tariff rate quotas that limit imports. These policies cause trade distortions in world markets to the detriment of U.S. consumers and farmers in poor countries. Supporters point to conservation provisions like the CRP, the Wetlands Reserve Program (WRP), the Grasslands Reserve Program (GRP), the Environmental Quality Incentives Program (EQIP), and the Wildlife Habitat Incentives Program (WHIP). These programs promote conservation of land and water resources and the wildlife that inhabit the set-aside acres.

Ecosystem services affected:
Agricultural policies that convert natural habitat to intense crop production negatively affect all ecosystem services by causing population declines in affected bird species. Policies that promote wildlife-friendly agricultural practices will positively affect many ecosystem services,

particularly pest control, pollination, and seed dispersal. If wildlife-friendly agricultural practices enhance bird diversity and abundance, they may also lead to greater opportunities for wildlife watching and hunting, thus promoting cultural and provisioning services.

Policy recommendation:
Policy should enhance the diversity and population sizes of native bird species, on the one hand, and encourage inclusion of birds in integrated pest management strategies in agriculture and timber production, on the other. Programs modeled on the Conservation Reserve Program should encourage farmers to work with scientists to devise farming practices that promote both high yield and habitat-friendly strategies. Future reauthorization of the Farm Bill should maintain the conservation-related provisions like CRP. Furthermore, because crop subsidies and tariffs cause trade distortions that harm farmers in developing countries, with negative consequences for conservation of birds and other wildlife, future re-authorization of the Farm Bill should reduce or eliminate subsidies and tariffs (see below).

Energy production, particularly biofuels

Energy fuels our society. Reduced reliance on fossil fuels requires developing alternative energy sources. These alternatives may include renewable sources like solar and wind, and biofuels like ethanol. Each of these potential energy sources has some promise and will play some role, but each has potential drawbacks. Of these alternatives, biofuels appear to pose the greatest threats to the greatest number of bird species.

High demand for corn-based ethanol is particularly fraught with potential problems. Corn, or maize, is one of the world's staple foods, particularly in developing countries, and it is widely used in livestock production. Diverting corn from food (human and livestock) to ethanol production creates numerous down-stream consequences. These include higher food prices, conversion of soy to corn production, reduced CRP enrollment and conversion of lands from non-agricultural uses to corn production (25). A particularly alarming finding is that shifting production from soy to corn in the U.S. leads to clearing of forest and savannah in Brazil for soy production (26). In this way, corn-based ethanol production decreases natural habitat for birds in the U.S. as well as in the tropics, thus doubly impacting some species.

Technology to produce ethanol from cellulose is expected. Like other biofuels, cellulosic ethanol involves trade-offs that could impact birds and other wildlife negatively. In the absence of incentives or regulations, cellulosic ethanol may cause conversion of CRP fields and other wildlife habitat into cellulose production areas. We should implement policies that promote wildlife habitat and energy production simultaneously, such as low-input high diversity native grasslands. Evidence suggests that these may provide greater energy, higher carbon sequestration, and less agrochemical pollution than single species plantings, while providing habitat for wildlife, including birds (27).

Solar and wind-powered electrical generation reduce our dependence on carbon-based energy production. Solar and wind can be implemented at small and large scales. At small scales neither may pose much threat to bird conservation. At large scales, both pose considerable threat. Large-scale solar farms must be sited carefully to avoid conflicting with habitat needs of fauna and flora. Large-scale wind farms pose the greatest threat to birds and bats from aerial collisions (28). Careful placement of wind turbines must minimize such negative effects. Both technologies require upgrades to the existing electrical grid (29). Hence, federal and/or state policy regulations must guide the placement, operation and maintenance, and monitoring of both solar and wind facilities, and the transmission line corridors that connect them to the power grid, to ensure minimal negative consequences to wildlife. We also encourage grid improvements to accommodate the electricity generated by them. Policies that support micro-generation (such as roof-top photovoltaic panels) and net-metering will limit the need for new large power plants, wind farms, and transmission line corridors that cause many environmental concerns.

Nuclear power may be the most controversial alternative to fossil fuels. With available technology, nuclear offers the advantages of high production capacity with no greenhouse gas emissions and a total carbon footprint comparable to wind production. Nuclear power will play a role in future energy production. Policies must assure safe use of the technology and conversion/storage of radioactive wastes. A potential advantage of nuclear power generation is the reduction of the need for wind turbines, which, as noted above, can lead to death of birds and bats.

Ecosystem services affected:
Energy production can negatively affect all ecosystem services provided by birds if placement of production fa-

cilities conflicts with habitat needs of birds, or through increased mortality due to collisions. Biofuels likely pose the greatest threat to the greatest number of bird species, and hence their services, because many biofuel alternatives require diversion of lands used for human food, livestock feed, or natural habitat to biofuel production.

Policy recommendation:
Promote energy production technologies other than those based on fossil fuels or biofuels. Biofuel produced from garbage streams are preferable to those based on corn or other biomass crops. If biofuel production is necessary, it should be based on growing diverse assemblages of perennial native plant species, thus providing habitat for birds that control pests. Federal and/or state policy regulations must guide the placement, operation, maintenance, and monitoring of both solar and wind facilities to ensure minimal negative consequences to wildlife. Policy must also facilitate improvements to the nation's electric grid to accommodate the electricity generated by solar and wind facilities. Oversight and regulation of nuclear energy production must assure safe implementation and storage or conversion of wastes. Policies that anticipate and minimize the environmental impacts of cellulosic ethanol production should be developed.

Emerging infectious disease

With climate change, increased global travel, and continued habitat destruction, among other factors, emerging infectious disease is of growing concern (30-31). Some diseases for which birds serve as reservoirs, like West Nile virus (WNV) and highly pathogenic avian influenza (HPAI) type 'A' virus (known as HPAI H5N1) infect humans, sometimes fatally, and domestic livestock. WNV spread through the Western Hemisphere quickly following its introduction to the east coast of the U.S. in 2000 via migratory birds. HPAI H5N1 has not yet appeared in the western hemisphere, but it spread widely throughout much of the Eastern Hemisphere. It may simply be a matter of time before it is introduced to the Western Hemisphere. An analysis of 52 introduction events of HPAI H5N1indicates that both wild and domestic birds are involved (32). These authors hypothesize that introduction of HPAI H5N1 will most likely arise via importation of domestic poultry but that subsequent spread throughout the mainland will be via wild, migratory bird species.

Ecosystem services affected:
Emerging diseases will negatively affect ecosystem services provided by affected bird species by decreasing their populations and, therefore, their capacity to provide the services.

Policy recommendation:
Promote monitoring of domestic and wild birds to detect disease threats, along with appropriate control measures. Mosquito control to reduce transmission of diseases like WNV and avian pox, and current vectors for other avian diseases, needs to follow procedures that minimize non-target organisms, many of which serve as prey for many wild bird species. Monitoring of mosquitoes in particular at ports of entry must be sufficiently funded as to be effective.

Land management, and habitat preservation and restoration

Although considerable land area in the U.S. and around the world is protected in reserves, policies that increase the number of reserves and the total overall area of protected lands are critical. In addition, we need policies that foster best practices concerning multiple-use of protected sites. Areas negatively affected by past mismanagement can be restored or rehabilitated to increase usefulness for wildlife (bird) conservation. An emerging issue regarding habitat protection is whether geographic distributions of birds will shift in response to climate change while park and refuge boundaries remain fixed. Even without range shifts the land protected in national parks, forests, and wildlife refuges is insufficient to preserve biodiversity in the US. Policies that foster good stewardship on private land are urgently needed. Similarly, public lands not primarily designated for conservation, such as many military bases, often contain significant biological resources. Incentives to protect these sites, regardless of the presence of threatened or endangered species, while preserving the primary mission, should be strengthened.

While pro- and anti-development advocates may view preservation, restoration, management, and development in zero-sum terms (and in cases this is undoubtedly so), there are many situations in which development and habitat preservation, management and/or restoration can stably co-exist. Greenways and embedded and connected parks provide relief from human population congestion for both humans and wildlife alike, while reduced sprawl concentrates the overall impact of human living activities.

Ecosystem services affected:
Land management emphasizing sustainable development, and habitat preservation and restoration, will positively affect all ecosystem services provided by birds.

Policy recommendation:
Policies should foster sustainable development and account for needs of people, birds, and other wildlife and flora. We must include ecosystem services as benefits in cost-benefit analyses of critical habitat by the U.S. Fish and Wildlife Service, logging restrictions by the U.S. Forest Service, land reuse plans for military base closure sites, and lands under the jurisdiction of the Bureau of Land Management. We must develop incentives, like CRP and other programs mentioned above, for conservation on non-agricultural private and public lands. Finally a small excise tax, similar to that prescribed by the Pittman-Robertson Act, on gear related to wildlife recreation (e.g., binoculars, spotting scopes; bird feed and feeders) should be implemented to generate additional funds to be used specifically to acquire lands for non-game wildlife habitat and to promote management and/or restoration of lands for non-game wildlife conservation and research. Bird watchers should be encouraged to buy Federal Duck Stamps, and we should develop a similar program of collectible permits for non-game species.

Wild bird trade

Trade in wildlife, including birds, is a global phenomenon that impacts untold animals. Wildlife trade not only threatens conservation of wildlife, it also threatens human livelihood via transmission of disease to humans and livestock, disruption of trade, and the health of ecosystems (33). Imported wildlife are more likely to escape and establish than their captive bred counterparts (34). Often, rare, threatened and endangered species demand higher prices for the traders and garner more prestige for the owner (35). While all of these considerations may argue for complete bans on wild bird trading, Cooney and Jepson (35) advocate an alternative approach based on the "conservation potential of market-led mechanisms that seek to reform trade chains to make them more ethical and sustainable" (p. 18).

Ecosystem services affected:
Wild bird trade causes population declines of some species, though largely in countries other than the U.S. To the extent that such declines affect ecosystems harboring U.S. migrants, such declines could affect populations of species that provide regulating and supporting services in the U.S. Escape and establishment of imported exotics can be extremely disruptive and damaging to ecosystems in the U.S., and could negatively affect services provided by all affected native species. Decline of cavity-nesting species like woodpeckers, nuthatches, and bluebirds following the establishment of the European Starling, for instance, decreased the effectiveness of insect pest control provided by the affected species.

Policy recommendation:
Policy should promote research investigating effectiveness of control versus market approaches to regulating wild bird trade. Policies should also promote improved management of wild bird trade and enforcement of trade controls.

World trade and international treaties

Many of the world's bird species are migratory, including a majority of the species inhabiting the U.S. Conservation of these species, therefore, must account for their habitats and resources during migration and on their wintering area. Most long-distance migrants that breed in the U.S. overwinter in Central and South America, as well as the islands of the Caribbean Sea. The U.S. has international treaties and agreements with other nations the goal of which is to conserve biodiversity and sustain the biosphere. For such agreements to be effective, governments must be willing to enforce them, and this means providing sufficient funds and personnel.

Beyond international agreements relating directly to conservation are those governing business and commerce, like the North American Free Trade Agreement (NAFTA). While some see free trade agreements and globalization as threats to sustainability and environmental quality, others argue that such agreements are critical for raising standards of living (36-37). Trade distortions work against development of sustainable agriculture, food and timber harvest in developing nations (36). In particular, large subsidies for U.S. farmers work against farmers in developing nations. Lowering U.S. barriers on farm trade can boost incomes of farmers in poor countries, and thereby reduce global poverty (38). Increasing standards of living in developing countries may, in turn, benefit conservation practices in those countries and raise the capacity of those countries to purchase U.S. products. Improved conservation measures in developing countries will likewise

benefit both resident and migratory birds that spend parts of their annual cycles in those countries.

Ecosystem services affected:
To the extent that trade policy enhances conservation practices at home and abroad, potentially all ecosystem services provided by birds will be positively affected.

Policy recommendation:
Policies should be adopted that reduce or eliminate trade distortions via trade agreements (such as the Doha Round negotiations of the World Trade Organization) and through revision of domestic bills like the Farm Bill when periodically re-authorized.

Adequate monitoring

Monitoring programs critically inform conservation and restoration efforts. Birds are ideal bio-indicators because they occur in nearly every habitat worldwide and occupy a variety of trophic levels and functional groups. Birds are ideal for monitoring programs because they provide so many ecosystem services. A comprehensive monitoring program should estimate population sizes and trends, demographic variables such as nesting success, and some measure of habitat use (39). The most useful programs monitor all species in an area (40) although no specific survey method works equally well for all species. Identifying population declines and their causes allows action to reverse declines before needing to list a species as endangered or threatened, a strategy more cost effective than currently is the case under the Endangered Species Act.

Existing bird monitoring programs include the Christmas Bird Counts (CBC, since December 25, 1900) and Breeding Bird Survey (BBS, since 1966). The CBC is conducted once every year between December 14 and January 5 at sites across North America. It has proven useful for tracking trends in wintering bird populations. The BBS is also conducted once each year but in late May or early June and has yielded data on breeding bird population trends. An additional benefit of the CBC is the participation of (indeed the reliance upon) volunteers. Because neither program includes a habitat component, causes of populations trends cannot be directly determined. Two more recent nation-wide monitoring networks (LTER-Long Term Ecological Research, and NEON-National Ecological Observatory Network) are much more comprehensive but unfortunately lack systematic nation-wide bird monitoring components.

Policy recommendation:
National monitoring programs should be supported. This will require investment of money and personnel to adequately staff agencies in charge of the programs as well as implementing the Endangered Species Act. Volunteer "citizen scientists" can be used to the extent possible.

Monitoring needs to track:
- Demographic changes of bird species, particularly threatened, endangered and other species of conservation concern;
- Incidence of diseases in wild and domestic species;
- Incidence of bird mortality at wind turbine farms;
- Number and identity of birds subject to trade;
- Pesticide levels in vulnerable species.

Conclusions

The world supports something over 10,000 different bird species. Birds are found on every continent. Birds contribute important ecosystem services that enrich humans culturally, enhance food and timber production, and support the earth's ecosystems. Perpetuation of the numerous and important services provided by birds requires perpetuation of the species providing them. No single species or small group of species can sustain such services by itself. Thus preservation of the world's entire avian fauna is required. Policy must first and foremost enhance conservation of the world's bird species.

Specific recommendations

Bird conservation
Promote bird services by: 1) enhancing population size of threatened, endangered, and declining common species, and 2) augmenting the ability of all bird species, threatened or not, to provide their services. Fully enforce conservation legislation such as the Endangered Species Act.

Global climate change
Foster research that anticipates how continued climate change impacts habitats and the natural resources they support, and the distribution and timing of activities of birds and their prey.

Agriculture, food and timber production
Include birds in integrated pest management strategies in agriculture and timber production. Programs modeled on the Conservation Reserve Program could encourage

farmers to work with scientists to devise farming practices that promote both high yield and wildlife habitat. Future re-authorization of the Farm Bill should reduce or eliminate subsidies and tariffs that cause trade distortions, while maintaining conservation-related provisions.

Energy production, particularly biofuels
Promote production of alternatives to fossil fuel and biofuels, particularly the use of solar and wind energy. Federal and/or state policy regulations must guide the placement, operation and maintenance, and monitoring of both solar and wind facilities to ensure minimal negative consequences to wildlife. Oversight and regulation of nuclear energy production must assure safe implementation and storage of wastes.

Emerging infectious disease
Promote the monitoring of domestic and wild birds for current and emerging disease threats, and, when available, appropriate control measures. Mosquito control to reduce transmission of diseases like West Nile virus and avian pox, and current vectors for other avian diseases, must follow procedures that minimize non-target organisms, many of which serve as prey for many wild bird species.

Land management, and habitat preservation and restoration
Foster sustainable development accounting for the long-term needs of people, birds, other wildlife, and flora.

Wild bird trade
Promote research that investigates effectiveness of control versus market approaches to regulating wild bird trade. Promote policies that emphasize improvements in trade management or enforcement of trade controls.

World trade and international treaties
Reduce or eliminate trade distortions through trade agreements (such as the Doha Round negotiations of the World Trade Organization) and through revision of domestic bills like the Farm Bill when periodically re-authorized.

Monitoring
Support and promote national monitoring programs. This requires investment of money and personnel, and should use volunteer "citizen scientists" to the extent possible.

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