Mitigation

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INTRODUCTION

Throughout history, divergence between human interests and raptors has led to impacts upon birds of prey. Direct impacts include deliberate persecution, illegal trade, and collection. Indirect impacts include human activities that may have an unintentional adverse impact on raptors. Unintended adverse impacts often result from technological advancements, including urbanization and pesticide use.

This chapter presents an overview of a number of human activities that affect raptors, and identifies mitigating measures that have been used to counter negative impacts. Sometimes, several activities collectively create an impact requiring several mitigating techniques. Topics covered include some of the most frequently documented examples of human impacts. This chapter builds on Postovit and Postovit (1987), which should be consulted for additional detail.

DIRECT IMPACTS

Direct impacts to raptors include shooting, trapping, and poisoning. Like natural mortality, raptor deaths due to persecution can be either compensatory or additive (Newton 1979). Compensatory mortality occurs when deliberate persecution replaces natural mortality. Additive mortality occurs when persecution adds to the natural mortality. Persecution tends to be most damaging immediately prior to breeding, when the population is at a seasonal low (Newton 1979). Larger species are more vulnerable to persecution than are smaller species because they occur at lower densities, have lower reproductive rates, and take longer to reach maturity (Newton 1979).

When population declines are due to exploitation or persecution, legal protection and education are the most appropriate conservation methods. Education and public involvement are critical to dispel prejudices against raptors (Postovit and Postovit 1987). Although there are many cases in which persecution has had an adverse impact on raptor populations, raptors typically rebound from this threat once direct impacts are reduced or removed (Newton 1979).

Shooting and Trapping

For centuries, raptors were shot and trapped to protect farm and game animals from depredation (Newton 1979). The phenomenon has been widespread, common, and even encouraged through bounties. Alaska, for example, paid bounties for more than 100,000 Bald Eagles (*Haliaeetus leucocephalus*) from 1917 to 1952 to protect salmon stocks (Robards and King 1966). Initially, only larger raptors were persecuted. However, as game bird and poultry farms became common, smaller raptors increasingly were shot and trapped (Newton 1979). Even today, Ospreys (*Pandion haliaetus*) are killed to protect fish at aquaculture farms, and vultures are shot near airports to prevent bird-aircraft collisions. In addition, raptors are shot for recreation at migration bottlenecks (Xirouchakis 2003), along roadsides from utility poles (Olson 1999), and for the illegal feather trade (Delong 2000).

Large diurnal raptors are more frequently shot because they are conspicuous (Snyder and Snyder 1974). Gregarious species, such as vultures, are particularly susceptible to mass shootings (Newton 1979). Immature birds not wary of humans are at greater risk (Ellis et al. 1969).

Raptors are killed deliberately through the use of traps (Brooker 1990). Traps may be set at nests, around live or dead bait, or on artificial perches. The most common traps are leg-hold traps with spring jaws (Newton 1979). When a raptor lands on a spring trap, the jaws snap together and the bird is held until it dies or is removed and killed (Newton 1979).

Mitigation discussion. Today many countries protect raptors from such indiscriminate killing, minimizing impacts on many long-term raptor populations. Yet, despite protection, some persecution persists, which can affect certain populations (e.g., California Condor [*Gymnogyps californianus*] [Cade et al. 2004]). Although there are cases in which raptor predation creates economic hardship (e.g., goshawks killing game birds at release sites [Newton 1979]), overall, depredation is probably negligible. In cases where raptors do create financial hardship, it is best to compensate the landowner for the losses and to work with the property owner to limit future damages. Education is crucial to eliminating prejudices toward raptors (Postovit and Postovit 1987).

Poisoning

Poison baits are used both legally and illegally to control a variety of animal pests (Newton 1990). These baits can result in both intentional and unintentional raptor kills. Unintentional poisoning occurs when a scavenging raptor either eats poisoned bait set out for another animal or feeds on the poisoned carcass of a target animal (i.e., secondary poisoning) (Newton 1979) (see *Indirect Impacts* and *Pesticides and Contaminants* below for details).

Vultures often are impacted by intentional poisoning (Houston 1996). Because these scavengers are gregarious, it is easy to poison large numbers of birds at a single time (Ledger 1988). Eagles also are sometimes intentionally poisoned with acute toxins, such as strychnine, to prevent them from killing lambs (Brooker 1990, Newton 1990).

Birds may fly away after ingesting poison and die elsewhere. As a result, the cause of death may not be apparent. Stock-tank drowning may occur when birds seek water after ingesting poison (Mundy et al. 1992).

Mitigation discussion. As with shooting and trapping, education is critical to eliminate prejudices toward raptors (Postovit and Postovit 1987). Care should be taken when handling raptor carcasses as they may have had contact with a poison. Some organophosphate pesticides, like monocrotophos, are absorbed through the skin (EXTOXNET 1996); therefore, gloves should be used to handle carcasses to prevent possible contamination. If poisoning is quickly diagnosed, there are antidotes for some organophosphorous, carbamate, and rodenticide compounds (Ontario Ministry of the Environment 1995). However, poisoned birds will require a rapid and precise diagnosis, as well as prolonged rehabilitation.

Traditional and Cultural Practices

The ceremonies of some traditional groups entail hunting and sacrificing animals. Birds of prey usually have little importance as a food source, but they often have great symbolic value giving them a powerful role in traditional ceremonies (White 1913). Raptors are sometimes killed due to these beliefs. For example, members of the Hopi Eagle Clan practice an annual ritual requiring the sacrifice of young Golden Eagles (*Aquila chrysaetos*). The eaglets are reared by hand until July when they are smothered. According to the Hopi belief, the sacrificed eagles carry the prayers of the Hopi back to their spirit home (Williams 2001). In South Africa, traditional folklore holds that vultures have such keen eyesight that they can see into the future. Poachers hunt Bearded Vultures (*Gypaetus barbatus*) for their heads, which are prized by gamblers playing the new national lottery (Marshall 2003). Although many modern cultures support the right of traditional peoples to practice traditional customs, such support often fades when the fate of an endangered species is at stake.

Mitigation discussion. Modern peoples often assume that education is the key to halt customs of killing endangered or threatened species. Members of traditional cultures however, may believe that it is modern people who need to be educated about traditional beliefs (Kaye 2001).

INDIRECT IMPACTS

Indirect impacts are numerous, diverse, and often negative. These impacts can be lethal or sublethal. Sublethal impacts may affect raptors in a variety of ways that are difficult to detect (e.g., decreased reproductive rate, eggshell thinning). Additionally, once indirect impacts are detected, they can be difficult to reverse. Unlike direct impacts, raptors cannot learn to recognize many indirect impacts in order to avoid or habituate to them (Postovit and Postovit 1987).

Habitat Loss, Modification, and Fragmentation

Habitat destruction and alteration due to human-population growth impact raptors (Newton 1979). Habitat alteration occurs in many ways. Habitats can be completely replaced or they can be significantly modified. When this occurs, many animals dependent upon these areas are displaced and may not find suitable habitat in surrounding areas.

Habitat fragmentation may result from incremental and cumulative changes to an area. When habitats are split into smaller units, they may provide less favorable habitat for some species, and the relative carrying capacity of the habitat is likewise reduced, supporting fewer individuals. Habitat also can be degraded slowly over a long period, resulting in the disappearance of suitable prey, perching sites, and nest sites. Although some species can adapt to altered areas, fragmented habitats generally are not as productive for native species as natural areas, and raptor numbers are reduced (Newton 1990).

Habitat destruction is probably the most devastating impact raptors face. Raptors requiring unique habitats or large home ranges are at greatest risk. Habitat changes due to urban, suburban, and rural encroachment are most often permanent. Urbanization tends to favor disturbance-tolerant species (e.g., American Kestrels [*Falco sparverius*], Red-tailed Hawks [*Buteo jamaicensis*], and Great Horned Owls [*Bubo virginianus*]) at the expense of less tolerant species. Many raptors are migratory, so it is important to consider breeding habitat, migratory corridors, and wintering grounds.

Mitigation discussion. Areas must be set aside to preserve animals with large territories. Land can be purchased outright or protected with conservation easements (DeLong 2000). Knowledge of landscape needs is essential in order to understand and preserve the distribution of raptor species. Evaluating the effects of habitat change on a species is complex and must address the particular species' needs (Redpath 1995). The structure and dynamics of populations measured at small spatial scales may not reflect the characteristics of the overall population across the landscape (Kareiva and Wennergren 1995).

Transportation

Vehicle collisions. Raptors are drawn to roadways for many reasons. Roadways can provide a steady supply of carrion from vehicle collisions (Platt 1976) and right-of-way mowing. Utility poles along roadways provide attractive hunting and roosting perches for raptors preying on mice, voles, and other rodents (Robertson 1930, Bevanger 1994). During cold winter months, roads may provide a source of heat and salt, both of which may attract prey (Meade 1942, Dhindsa et al. 1988). Road salt also attracts large animals that may become road casualties, providing carrion (Noss 1990). Raptor species adapted to hunting along roadsides are at particular risk of colliding with vehicles.

In areas where birds regularly feed on the carcasses of road-killed animals, carcasses should be pulled off the road. In persistent problem areas, signs can be posted alerting motorists to slow down due to the possibility of encountering raptors on the road (DeLong 2000). Lower speed limits also can be deployed.

Aircraft collisions. In addition to being a risk to human life, bird–aircraft collisions cost the world's aviation industry millions of dollars annually (Sodhi 2002). Most aircraft strikes involve gulls (Laridae), Common Starlings (*Sturnus vulgaris*), and blackbirds (Icteridae), but raptor strikes also have been documented (Lesham and Bahat 1999).

Israel has one of the most sophisticated programs for managing bird–aircraft strikes. The country is along a major bottleneck of bird migration and twice each year millions of raptors fly through Israel's limited air space (Shirihai et al. 2000). Bird migration patterns are monitored and mapped using motorized gliders, drones, radar, and ground observers (Leshem and Bahat 1999). Maps with "Bird Plagued Zones" are updated yearly and provided to military pilots. Air-space restrictions are developed for lower flight altitudes using real time radar (Leshem and Bahat 1999).

In the U.S., the Bird-Wildlife Aircraft Strike Hazard Team (BASH), an organization committed to reducing wildlife-related hazards with aircraft, has developed a bird-avoidance model (U.S. Air Force 2004).

Vegetation management and habitat modification are important tools used to make airports less desirable for birds and other wildlife (Sodhi 2002). Many airports mow vegetation around airstrips to decrease the cover for rodents and other prey. This makes the area less likely to attract raptors. Birds are sometimes hazed using noisemakers or gunshot, but birds often habituate to loud noises (Sodhi 2002). Denying roosting sites can be important and installing anti-perching devices on airport facilities is sometimes used to discourage raptor use (Transport Canada 2001). However, no single anti-perching device will deter all perch-hunting species (Avery and Genchi 2004).

Energy and Communication Infrastructure

Energy and mineral development. The total world consumption of marketed energy is predicted to expand by 54% between 2001 and 2025 (Energy Information Administration 2004). Developing nations, including Asia, China, and India, are expected to account for the greatest increase in world energy consumption (U.S. Department of Energy 2004). The increasing demand for energy will result in more land being used for the exploration and extraction of petroleum, natural gas, and coal. There also will be an increase in the number of dams, nuclear power plants, and renewable energy sources.

The development of these resources will result in direct, indirect, and cumulative environmental impacts. Because many of these activities occur in remote locations, raptors can be impacted adversely (Murphy 1978). Impacts to raptors include habitat fragmentation and loss, displacement from disturbance, and a reduction in prey. Energy development can impact nesting, roosting, and foraging areas. Indirect impacts may result from road construction, soil and vegetation disturbance, and increased air and water pollution.

As with all large construction projects, it is important to conduct and complete an environmental analysis prior to construction. This analysis should include baseline studies of the land, vegetation, water, air, terrestrial and aquatic resources, and of human interactions. Regulatory agencies and communities should be provided an opportunity to comment on projects in an open forum.

Baseline surveys should be conducted for raptor nests, and projects should consider the life histories of raptors. These data should be incorporated into the project plans and environmental assessment, which would address facility construction, operation, and maintenance. Reclamation plans should be developed, when appropriate, and should include revegetation, off-site habitat enhancement, and the construction of artificial nest sites where applicable. If lands are managed properly, reclaimed areas have the potential to provide breeding habitat for raptors (Yahner and Rohrbaugh 1998).

Post-construction monitoring is a critical component of energy development as it is the only way to assess accurately the validity of pre-construction mitigating measures. Ongoing assessment enables corrective measures to be taken if mitigating efforts are determined to be ineffective.

Power-line electrocution. During the 1970s and early 1980s, electric industry efforts in North America to reduce raptor electrocutions were widespread. Predictions about mitigating the problem were overly optimistic and raptors continue to be electrocuted, possibly in large numbers (Lehman 2001). Raptor electrocutions remain a persistent problem throughout the world and although most power line mortality is probably compensatory, in certain parts of the world power lines are responsible for the decline of some raptors. In Spain, for example, electrocution was responsible for the population decline of the Spanish Imperial Eagle (*A. adalberti*) in Doñana National Park (Ferrer and de la Riva 1987).

Electrocution occurs in many ways, depending on pole design (Janss and Ferrer 1999). In North America, power lines typically are constructed using non-conductive wood power poles and wood crossarms (Fig. 1). In

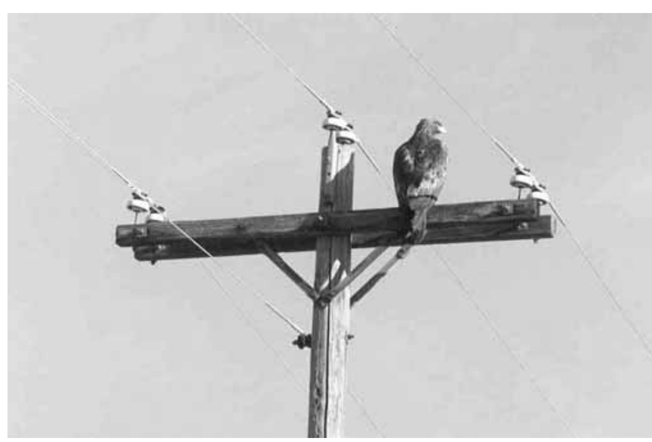

Figure 1. Golden Eagle (*Aquila chrysaetos*) perched on a wooden electricity distribution structure.

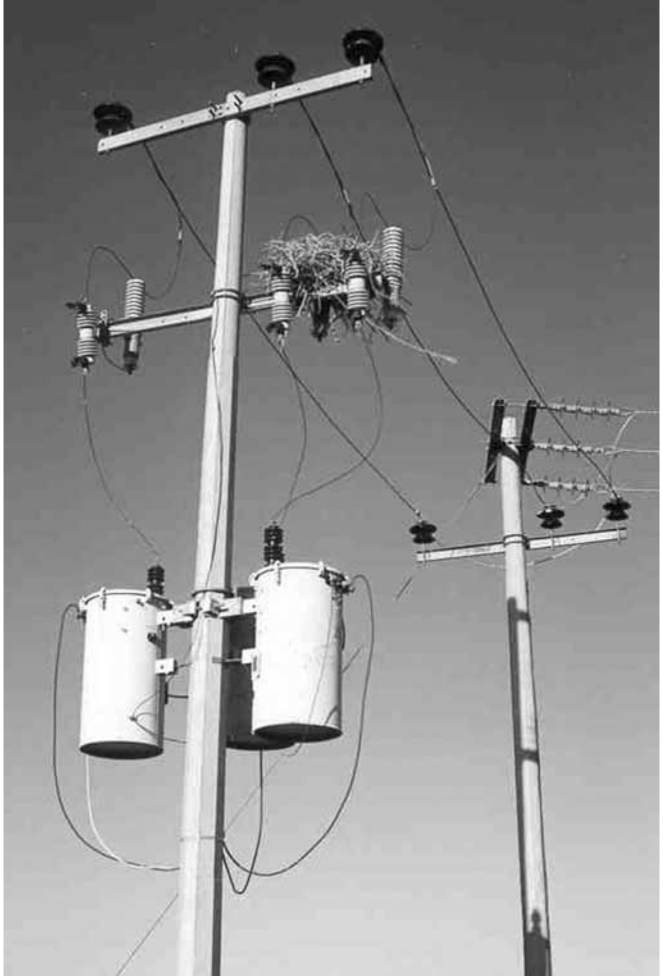

Figure 2 (left). Raptor nest on a concrete electricity pole with steel crossarms.

Figure 3 (above). Swainson's Hawk (*Buteo swainsoni*) on an electric transformer pole.

Europe and in many places elsewhere, conductive steel and concrete poles are more common (Janss and Ferrer 1999). The latter often are fitted with grounded steel crossarms (Fig. 2), resulting in possible wire-to-crossarm, wire-to-pole, and wire-to-wire contacts (Janss and Ferrer 1999). This type of construction affects a broader group of bird species due to the greatly reduced clearances (Janss and Ferrer 1999). The use of steel poles is becoming more prevalent in the U.S., where similar problems have occurred (Harness 1998).

Protecting raptors from electrocution depends on the type of power-line configuration and size of the bird (APLIC 2006). In areas using conductive steel and concrete poles and crossarms, the critical clearance often is body length because a perching bird needs to touch only one energized wire (Janss and Ferrer 1999). For this reason, insulation often is the preferred method to prevent contact with conductive structures. Perch deterrents used to prevent wire-to-wire contacts in North America (APLIC 2006) are less effective on conductive structures (Janss and Ferrer 1999). Equipment, such as transformers (Fig. 3), are universally problematic and should be installed with insulated jumper wires and protective bushing covers (Janss and Ferrer 1999, van Rooyen 2000, Harness and Wilson 2001, Platt 2005).

Because many utility configurations are used even at a regional level, specific construction practices and habitat use must be determined before developing appropriate mitigation measures (Mañosa 2001). Effective retrofitting requires a thorough understanding of the pole configuration, the at-risk birds, and other contributing factors (e.g., bird behavior, size, age, prey species, preferred habitat, season, weather, wind, and topography). Three solid references provide guidance on these issues: *Suggested Practices for Avian Protection on Power Lines: State of the Art in 2006* (APLIC 2006), *Birds and Power Lines — Collision, Electrocution and Breeding* (Ferrer and Janss 1999) and *Suggested Practices for Raptor Protection on Power Lines: The State of the Art in 1996* (APLIC 1996). In Europe, *Caution: Electrocution! Suggested Practices for Bird Protection on Power Lines* is available in German, English, and Russian from the German Society for Nature Conservation (NABU).

Power-line collisions. Although birds of prey spend considerable time in the air, collisions with power lines occur relatively infrequently compared with other species (Bevanger 1994). As discussed in *Mitigating Bird Collisions with Power Lines: The State of the Art in 1994* (APLIC 1994), aerial hunters like raptors possess

Figure 4. Perch deterrents minimize electrocution risks, but potential perch sites remain.

excellent flying abilities along with binocular vision. Furthermore, raptors generally do not fly in restrictive flocks. Although raptors are agile flyers with excellent eyesight, they are likely to be more susceptible to colliding with power lines when preoccupied or distracted (e.g., during territorial defense or prey pursuit) (Olendorff and Lehman 1986, Thompson 1978). Except in the case of a critically endangered species (e.g., California Condor), collisions with power lines are a random, low-level, and biologically inconsequential mortality factor for raptors (Olendorff and Lehman 1986).

Lines with persistent problems or lines that are likely to affect sensitive or rare species should be marked to make them more visible. One reference describing ways to address and mitigate bird collisions is *Mitigating Bird Collisions with Power Lines: The State of the Art in 1994* (APLIC 1994).

Power-line depredation. Raptors regularly use power poles as hunting perches (Benson 1981). For a sensitive species such as the Sage Grouse (*Centrocercus urophasianus*), it is believed that power lines and other artificial structures allow raptors to prey on displaying male grouse, nesting hens, and brooding chicks (Connelly et al. 2004). Additionally, ground-nesting Burrowing Owls (*Athene cunicularia*) can be at risk (Fitzner 1980).

Many products are available to manage raptors perching on utility structures. However, these devices (triangles, spikes, etc.) are specifically designed to prevent bird electrocutions and not to exclude birds from all possible perching locations (EPRI 2001). There are many locations on poles where it is not possible to prevent perching with existing products (Fig. 4). Some researchers have concluded that poles and other perches near critical grouse breeding areas should be eliminated to preclude depredation (Connelly et al. 2000).

Power-line nesting. Power lines can positively impact raptors by providing nesting sites. Steenhof et al. (1993) showed that Ferruginous Hawks (*B. regalis*) nesting on transmission line towers were more successful than those nesting on natural substrates. Ospreys also have benefited from nesting on utility structures (Henny and Kaiser 1996). Significant negative biological impacts from electric and magnetic fields were not documented in birds nesting on power lines by Lee et al. (1979), but see more recent studies on both wild and captive American Kestrels (e.g., Fernie et al. 2000).

Raptors are more likely to nest on poles with double crossarms, which provide a wider platform (EPRI 2001). Where crossarms are required, employing single apitong crossarms rather than double crossarms, eliminates a place for raptors to nest (Fig. 5). When retrofitting existing poles, a stick deflector can be used to deter raptor nesting (Fig. 6). Perch deterrents do not effectively prevent nesting, and may actually facilitate nest construction by providing an anchor to attach sticks (Fig. 7; EPRI 2001).

Raptor nesting on structures should not be discouraged unless it results in operational problems. If a nesting raptor causes outages, the utility company should install a new unenergized pole with a nesting platform on the edge of the right-of-way and relocate the nest to this platform (APLIC 2006). Nearby power poles should be retrofitted to protect fledgling birds from possible electrocution (Dwyer and Mannan 2004).

Wind turbines. Wind-energy facilities (Fig. 8) provide an alternative to fossil fuel electricity production. However, this technology is not without risk to wildlife and may result in an increased threat of collision for raptors (Estep 1989). Factors contributing to increased collision risk include the raptor species present, prey concentrations, turbine design, migration routes, daily movement corridors, topographic features, and the position of a turbine in a string of turbines (Anderson et al. 1999b).

The National Wind Coordinating Committee has published a useful document titled *Studying Wind Energy/Bird Interactions: A Guidance Document* (Anderson et al. 1999b). The United States Fish and Wildlife Ser-

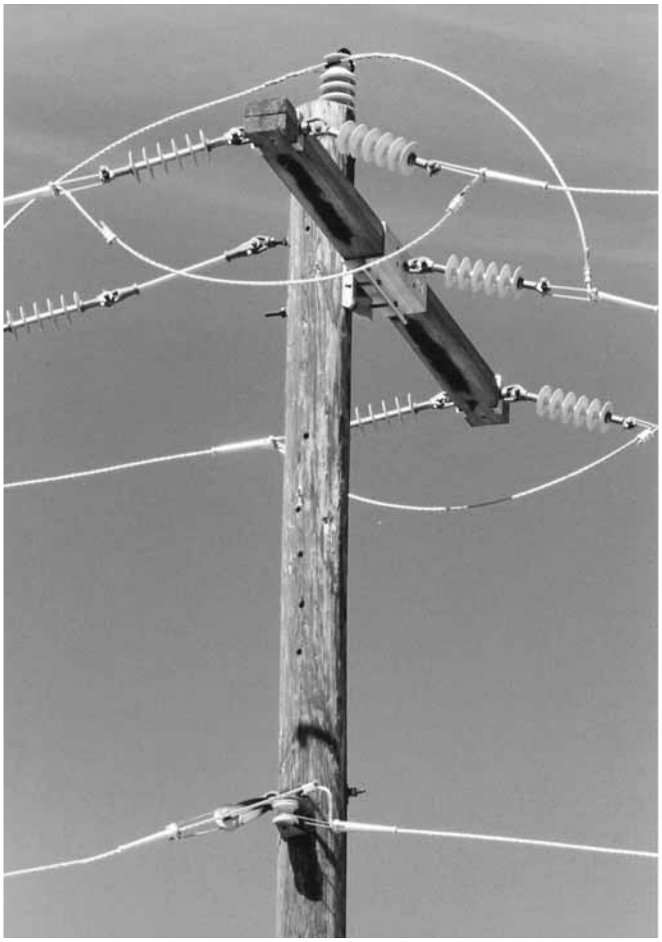

Figure 5. Apitong crossarm used to eliminate nesting attempts.

Figure 6. Stick deflector at a double dead-end structure (Kaddas).

Figure 7. Raptor nest on a structure fitted with anti-perching devices (Tri-State G&T).

Figure 8. Wind turbine with pronghorn antelope (*Antilocapra americana*).

vice (USFWS) also has developed *Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines* (USFWS 2003). The primary objectives of these guidelines are to (1) assist developers in deciding whether to proceed with wind-energy development, (2) describe a procedure to determine pre-construction study needs to verify use of potential sites by wildlife, and (3) provide recommendations for monitoring potential sites post-construction to identify, quantify, or verify actual impacts (or lack thereof). The USFWS also developed a "Potential Impact Index" (PII) as part of the guidelines (USFWS 2003). The PII is a tool used to determine potential impacts to birds and bats from proposed wind-energy development at a particular site.

Communication towers. Bird kills at communication tower sites have come under increased scrutiny. Although some diurnal birds are at risk from these structures, very few raptor collisions with communication towers have been recorded (Avatar Environmental et al. 2004).

Dams and Water Management

Dams and associated water-management actions can have positive or negative impacts. Positive impacts include providing additional habitat for fish, eagles, and Ospreys (Henny et al. 1978, Steenhof 1978, Van Daele and Van Daele 1982, Grover 1984, Detrich 1985). In general, piscivorous raptors benefit from the construction of dams (Postovit and Postovit 1987). Creation of riparian woodlands following the impoundment of water also has benefited some species, including the Common Black Hawk (*Buteogallus anthracinus*) in Mexico (Rodríguez-Estrella 1996).

The height (head) and length of the dam, amount of water released, and presence of fish help determine the suitability of dams as feeding sites for Bald Eagles (Brown 1996). When water is released, prey are concentrated in smaller areas, resulting in increased prey availability and predation (Bryan et al. 1996). Discharge during hydroelectric generation is important because it can release dead and injured fish, which are easy prey for eagles (Stalmaster 1987). Furthermore, below-dam waters often are ice-free throughout the winter, attracting waterfowl and making fish available to eagles. The availability of perch trees near reservoirs is another important component for eagles and other raptors (Stalmaster 1987, Brown 1996).

Impoundments are tradeoffs for the habitat displaced by the water, and altered water levels in them can negatively impact raptors associated with nearby riparian habitats (Schnell 1979). Nesting raptors along reservoir shorelines also may be impacted by recreational activities on and near the reservoir (see *Recreational Disturbance*).

As with dam construction, altering wetlands can negatively impact some species while improving habitat for others. Species at greatest risk from wetland manipulation are those associated with or restricted to wetlands. In the U.S., wetland management has adversely impacted Snail Kites (*Rostrhamus sociabilis*), which depend upon apple snails (*Pomacea paludosa*) in naturally flooded wetlands. Manipulating water levels and otherwise changing water flow impacts the snails and, subsequently, the kites (Sykes 1979, Shapiro et al. 1982).

Mitigation discussion. Advanced planning and robust impact analysis is recommended when manipulating or creating wetlands. Species-specific mitigation measures should be developed on a case-by-case basis, depending on the species affected, extent of the anticipated impacts, and location of the project. Long-term mitigation could include off-site habitat enhancement, human-use restrictions near sensitive areas including nest sites, communal roosts, and feeding areas, and changes to the proposed water management regime.

Forestry

Because the degree to which raptors depend on forests varies among species, forest management exerts a wide range of impacts (Postovit and Postovit 1987). Some forest practices result in dramatic changes in forest structure and composition, resulting in either positive or negative effects on raptors. Thiollay (1996), for example, reported that managed forests in western Indonesia preserve no more than a quarter of the original raptor forest community. In contrast, Reynolds et al. (1982) noted that in western Oregon some accipiters benefit from forest harvest and shortened rotation. Newly constructed roads and trails may lead to increased human access, disturbance, and further habitat fragmentation.

Mitigation discussion. A well-managed forest integrates wildlife-habitat and forest-management goals. Critical considerations include the intensity of logging and the length of forest rotation (Postovit and Postovit 1987). Raptors can use managed forests successfully where the forest structure (snags, canopy, layering, etc.) is adequate for the birds' needs (Horton 1996). To accomplish this, the ecological responses to forest management practices must be known. Managing for forest-dwelling raptors might include preserving diverse habitat features. Buchanan et al. (1999), for example, reported that total snags/ha, shrub cover, canopy closure, and coarse woody-debris cover are important to the Northern Spotted Owl (*Strix occidentalis*). Finn et al. (2002) stated that nesting Northern Goshawks (*Accipiter gentilis*) are more likely to occupy historical nest sites with a high overstory depth and low shrub cover. Forests should be managed to preserve prey species and it should be recognized that altered areas will provide opportunities for non-forest species, including raptors, to compete for limited resources (Kenward 1996).

It may be important to protect existing nest sites of sensitive forest-breeding raptors. These nests should be inventoried, mapped, and species-specific buffer zones established around them, as warranted (Mooney and Taylor 1996). Disturbance during nesting can affect raptors in many ways leading to a variety of impacts, including nest desertion (Newton 1979). Accordingly, forestry activities such as tree marking and logging should be avoided during the critical periods of nest building and incubation to reduce the likelihood of nest abandonment.

Agriculture

Farming and ranching primarily affect raptors by altering habitat. Changes brought about by agriculture can be either positive or negative (Postovit and Postovit 1987). Farming, as opposed to ranching, typically causes greater habitat changes and has more adverse impacts on raptors (Postovit and Postovit 1987). Intensive farming can result in lower prey populations for some raptor species such as the Ferruginous Hawk (Gilmer and Stewart 1983), although ranching typically is more compatible for many raptors (Postovit and Postovit 1987). The removal of native shrublands to “improve” pastures (Hamerstrom 1974, Murphy 1978) and the removal of prey species such as burrowing mammals (Zarn 1974) adversely and significantly impact raptors.

Agricultural activities can create problems through the use of pesticides and other chemicals (Postovit and Postovit 1987). Additionally, removing water from natural sources for agriculture negatively impacts some raptors (Gould 1985). Benefits from agriculture include the planting of trees as wind breaks and their subsequent use as nesting and perching sites for raptors (Postovit and Postovit 1987). Agricultural structures such as windmills and dwellings also may provide nest sites (Olendorff 1973). Other agricultural impacts include fence collisions, stock-tank drownings, and carcass-disposal practices (Anderson 1977, Ledger 1979, Newton 1990).

Fence collisions. Wire fences occasionally are responsible for raptor deaths when birds collide with them, become entangled in the wires, or impale themselves on barbed wire (Anderson 1977). Burrowing Owls also have been killed by electric fences (Staff and Wire Reports 1998).

In problem areas, making fences more visible, including the use of commercially available swinging plates, can help reduce collisions (Harness et al. 2003).

Stock-tank drownings. Raptors may use stock tanks for bathing, drinking (Houston 1996), or perching. In addition, raptors may be attracted to tanks if prey is present in the area (Craig and Powers 1976). Both diurnal and nocturnal raptor species have been known to drown in stock-watering tanks (Anderson et al. 1999a).

In South Africa, Cape Vultures (*Gyps coprotheres*) often drown in stock tanks (Ledger 1979), possibly when they respond to thirst caused by strychnine poisoning (Mundy et al. 1992). The gregarious nature of this species may contribute to mass drownings. The flapping wings of a single trapped individual may attract other vultures that mistakenly interpret the behavior as a feeding opportunity (Mundy et al. 1992).

Solutions include installing plastic floats and wooden planks or branches in water tanks (Anderson et al. 1999a). Keeping the reservoir full also helps animals escape. Farmers can be convinced to modify the tanks by informing them of the problem and emphasizing that carcasses will pollute the water and render it unsuitable for humans and livestock.

Carcass-disposal practices. Many Old World and New World vultures feed on large-ungulate carcasses (Houston 1996). With the conversion of native areas to agriculture, domestic livestock have replaced many native ungulates. Vultures have adapted to this transition in areas where livestock carcasses are available (Houston 1996). However, where carcasses are buried or burned to prevent the spread of disease, access to food can be restricted. In some areas, modern farming has supplanted herding with intensive stock farms (Iezekiel et al. 2004), resulting in fewer carcasses to scavenge. Improved sanitation in many African and Asian cities has reduced access to carcasses (Newton 1990). Furthermore, regulations may prohibit traditional carcass-disposal methods due to concerns regarding diseases, such as bovine spongiform encephalopathy (Camina 2004).

One problem associated with domestic carcasses is the use of the systemic painkiller and non-steroidal anti-inflammatory veterinary drug, diclofenac (Chapter 18). Diclofenac use in South Asia has been shown to cause visceral gout in White-rumped Vultures (*G. bengalensis*) and is believed likely to act similarly in other *Gyps* species. In just over a decade of use in livestock, diclofenac is suspected of causing the near extinction of three vulture species (Oaks et al. 2004).

Vulture "restaurants" (i.e., sites where large animal carcasses are provided as an artificial food source for vultures) have been set up in several countries in an attempt to conserve vultures. These sites provide a regular, uncontaminated food supply (Houston 1996).

Vulture restaurants should be placed away from fences and power lines to reduce collision and electrocution risks (Piper 2003). Plastic bags and other non-food waste should not be dumped at these sites (Piper 2003). Carcasses of livestock euthanized with barbiturates and those containing diclofenac should be removed so scavenging raptors are not indirectly poisoned (Piper 2003).

In addition to maintaining or bolstering populations locally, vulture restaurants provide opportunities for the general public to observe and photograph feeding vultures and conservationists with the chance to educate the public on the benefits of vultures. Vulture restaurants typically attract mammalian scavengers that may need to be managed. Finally, restaurants should be designed so the resulting smell does not offend nearby residents (Piper 2003) (see Chapter 22 for details).

Pesticides

Pesticides are a relatively recent threat to raptors (see Chapter 18 for details). As discussed by Newton (1979), widespread pesticide use began in the 1940s after World War II with the development of inexpensive and, at least initially, effective crop pesticides and herbicides. Pesticides can directly, or indirectly, poison birds. Pesticides also may cause indirect impacts by reducing prey species (Rands 1985). Whereas direct impacts to raptors typically affect local populations, pesticides can impact raptors on a regional or even global scale (Newton 1979).

Organochlorines. The term "organochlorine" refers to a chemical containing carbon, chlorine, and, sometimes, other elements. Organochlorine compounds include herbicides, insecticides, fungicides, and industrial chemicals such as PCBs. Additionally, organochlorine compounds include DDT and cyclodienes such as aldrin, dieldrin, endrin, and heptachlor (European Environment Agency 1995).

As discussed in Newton (1979), organochlorine compounds are very stable, fat-soluble, and environmentally persistent. Organochlorines bioaccumulate in fatty tissue in animals, resulting in further concentrations in successive links in the food chain. When used as insecticides, these chemicals are widely dispersed, increasing the potential exposure to birds and other animals even in remote locations. Raptors at greatest risk of bioaccumulating organochlorines are those that eat birds and fish (Newton 1979).

DDT (dichloro-diphenyl-trichloroethane). Animals metabolize DDT into DDE, which is less toxic than DDT (Newton 1979). Within fat, organochlorines are relatively non-toxic unless the fat is suddenly metabolized, such as during a food shortage or on migration. When this happens, death may result if high concentrations are present (Newton 1979). Furthermore, DDE has been shown to significantly impact reproduction through eggshell thinning, resulting in egg breakage (Newton 1979).

An unprecedented decline in Peregrine Falcons (*F. peregrinus*) in Europe and North America occurred with the widespread use of DDT (Ratcliffe 1967). Subsequent restrictions on the use of this synthetic pesticide are credited with a return to increasing eggshell thickness and dramatic increases in Peregrine Falcon reproductive success in these same countries (Newton 1979, Henny et al. 1999). Because of DDT's persistence (a chemical half-life of 15 years), it still remains a problem in some watersheds in the U.S. (Sharpe 2004). Although no longer widely used in North America and Europe, DDT remains in use in developing nations for disease-vector control (Malaria Foundation International 2006, see also Chapter 18).

Organophosphates. Most broad-spectrum insecticides currently in use are organophosphates (Pesticide News 1996, Chapter 18). Organophosphates are relatively inexpensive and mainly are used to "protect" food crops from insects. These chemicals break down more rapidly than organochlorine pesticides and have largely replaced the latter in agricultural pest control (Pesticide News 1996). Unfortunately, organophosphate compounds affect the nervous system of both vertebrates and invertebrates and as such, include some of the most toxic chemicals used in agriculture.

There are numerous reports of avian deaths attributed to organophosphate compounds through secondary poisoning (Henny et al. 1999). In Argentina, an estimated 20,000 Swainson's Hawks (*B. swainsoni*) died in 1996 after farmers applied monocrotophos to alfalfa fields for grasshopper control (Goldstein et al. 1999). These raptors were killed both by direct exposure and by eating contaminated grasshoppers. Raptors exhibiting gregarious behavior and opportunistically feeding on debilitated prey may be at higher risk (Mineau et al. 1999).

Carbamates. Carbamates are synthetic chemicals widely used as pesticides, including herbicides, insecticides, and fungicides. They are less persistent in the environment than organochlorines. One carbamate, the insecticide carbofuran, is highly toxic to birds (EXTOXNET 1996). Birds are susceptible to carbofuran when they ingest granules of it, which resemble grain seeds (Erwin 1991). Although the granular production of carbofuran generally has been phased out based solely on the danger it presents to birds, some granular formulations are still in use today. Raptors are vulnerable to carbamate poisoning when they scavenge prey poisoned by it (Erwin 1991).

Rodenticides. Rodenticides are second only to insecticides in their use in agriculture (Chapter 18). Rodenticides are either acute neurotoxins or anticoagulants that cause internal bleeding and eventual death (Corrigan and Moreland 2001). Strychnine and zinc phosphide are examples of acute toxins (Corrigan and Moreland 2001). Strychnine is used to control mammalian predators such as gray wolves (*Canis lupus*), foxes (Canidae), and coyotes (*C. latrans*) (Newton 1990).

Anticoagulant rodenticides inhibit the enzymes responsible for vitamin K recycling, which ultimately reduces blood clotting. This results in the increased permeability of capillaries throughout the body and widespread internal hemorrhaging. Death usually occurs several days after bait ingestion or after several feedings. Newer anticoagulants can cause death after only a single dose (Corrigan and Moreland 2001).

The use of rodenticides can result in either primary or secondary poisoning of non-target wildlife (Corrigan and Moreland 2001). Secondary raptor poisoning due to both legal and illegal use has been documented (Newton 1990). There may be a greater chance of raptors being poisoned secondarily by anticoagulants than by acute toxins. Anticoagulants are slower to take effect (1 to 10 days) and during this period poisoned rodents are more susceptible to predation because they are disoriented and sluggish (Delong 2000).

1080 (sodium monofluoroacetate). 1080 is a water-soluble salt that is highly toxic to mammals (Green 2004). The compound was developed in the 1940s to control rodents and predators. The bulk of world usage is in New Zealand and, to a lesser extent, Australia (Green 2004), where it is used to control possums, rabbits, foxes, and other introduced vertebrate pests. Although birds have a relatively high tolerance to 1080, kites and eagles have died from secondary poisoning (McIlroy 1984).

Mitigation discussion. Landowners who apply pesticides should do so strategically and with caution. The use of pesticides should be regarded as just one tool in an overall pest management program. The key to good pest-management includes implementing proper sanitation practices, removing food sources, and using appropriate biological control. All pesticides must be used in accordance with their legally binding labels. In the case of rodent control, this includes searching for carcasses and burying or burning them to avoid secondary exposures (Corrigan and Moreland 2001). Granular formulations toxic to avian species should be limited because they are sometimes mistaken as grain by birds (Henny et al. 1999).

Industrial Contaminants

Contaminants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and heavy metals are another relatively recent threat to raptors (Chapter 18).

PCBs (polychlorinated biphenyls). PCBs are industrial products used in transformers and capacitors for insulating purposes. They also are used as lubricants and as plasticizers in paints (Eisler and Belisle 1996). Unlike pesticides, these chemicals are not deliberately released into the environment. Organochlorine contaminants persist in the environment and have been found in many organisms (Eisler and Belisle 1996). In birds, PCBs have been correlated with embryo deaths and deformations (Ludwig et al. 1996). They also may enhance the effect of organochlorine pesticides as endocrine disrupters (Lincer 1994, cited in Henny et al. 1999). Today, many industries have restricted or eliminated their use of PCBs. Even so, low levels still are being detected in fish-eating birds (Braune et al. 1999).

PBDEs (polybrominated diphenyl ethers). Chemical fire retardants have become common in many consumer products. One of the most frequently used is a class of bromine-based chemicals known as polybrominated diphenyl ethers, or PBDEs (Chapter 18). PBDEs occur in numerous products and, because PBDEs are not chemically bonded to plastics or foam products, they often leach out into the environment. PBDEs and other brominated fire retardants (BFRs) are similar in chemical structure to PCBs. Like PCBs, they are persistent in the environment, soluble in fats, and can bioaccumulate in the food chain.

While human health impacts of these chemicals are not well studied, they are known to cause neurological damage in laboratory animals. PBDEs have been detected in Peregrine Falcon eggs in Sweden (Lindberg et al. 2001).

Manufacturers are working to develop substitutes for PBDEs, and the European Union (EU) banned all PBDEs in electronic products beginning in 2006. Similar restrictions have been proposed in the U.S.

Mercury. Mercury is a naturally occurring element present throughout terrestrial and aquatic environments (Chapter 18). Human sources of environmentally active mercury include coal-burning power plants, industrial boilers, hazardous-waste incineration, and chlorine production. When mercury enters aquatic environments, microorganisms convert it into methylmercury (Eisler 1987). Methylmercury is a toxic form of mercury, and elevated levels can cause serious reproductive effects and addled eggs (Newton 1979). Methylmercury is the most common form of organic mercury found in the environment and is soluble in water and fat, allowing it to bioaccumulate in organisms (Newton 1979).

Organisms in aquatic ecosystems tend to have the highest levels of methylmercury (Eisler 1987). As a result, fish-eating raptors including Ospreys and fish eagles are particularly vulnerable to this toxin (Stjernberg and Saurola 1983).

Lead. Raptors are exposed to lead when they consume animals that have ingested lead shot or have been shot with lead pellets (Kramer and Redig 1997, Henny et al. 1999, Chapter 18). Secondary lead detection has been documented for 35 raptor species in 18 countries (Miller et al. 2002). Spent gunshot and fishing weights are the primary source of lead in wildlife (Scheuhammer and Norris 1996, Henny et al. 1999). Waterfowl ingest lead from the bottom of ponds while foraging (Kramer and Redig 1997).

Bullet fragments containing lead can adversely impact raptors (Newton 1990). Eagles have been poisoned after eating carrion containing lead fragments. The response to ingested lead varies. One study showed that as few as 10 lead pellets can kill a Bald Eagle (Pattee et al. 1981). In Japan, both Steller's Sea Eagles (*H. pelagicus*) and White-tailed Eagles (*H. albicilla*) have died after eating lead fragments from rifle bullets in deer carcasses (Masterov and Saito 2003). Scavenging raptors, including the California Condor, are especially vulnerable to lead poisoning (Janssen et al. 1986). Unlike eagles, condors do not regularly "cast" indigestible materials such as bones and fur or feathers and this may increase their exposure to this threat (Graham 2000).

In addition to direct mortality, sublethal effects may weaken raptors and leave them unable to hunt (Kramer and Redig 1997). Another sublethal effect is severe visual impairment (Redig 1979).

Canada and the U.S. have banned the use of lead shot for hunting waterfowl, however eagles still are poisoned after ingesting lead from hunter-shot upland game (Craig and Craig 1995, Kramer and Redig 1997). More attention is being paid to lead in all environmental contexts, and today non-lead shot, bullets, and fishing sinkers are available, but unfortunately, are not yet widely accepted (Graham 2000).

Introduced Diseases

The introduction of non-native species and diseases is a global problem. As human mobility increases, many organisms associated with people will continue to be dispersed throughout the world, often with adverse consequences.

A number of diseases (bacterial, viral, and fungal) and parasites (internal and external) afflict raptors (Cooper 1969, see Chapter 17, part 1 for details). It can be difficult to assess the impact of diseases because their presence in raptors may be masked by other conditions, including starvation. The solitary nature of many raptors probably affords them some protection from outbreaks of major diseases. However, diseases and parasites can be spread among raptor and vulture species using communal roosts or during migration (Cooper 1990).

The effects of West Nile virus (WNV) on North American bird populations remain a concern. After the mosquito-born disease first appeared in New York in 1999, the virus spread across the continental U.S. in 5 years (U.S. Geological Survey 2003). Diurnal and nocturnal raptors are reported to have a high incidence of WNV infection (Fitzgerald et al. 2003). In the U.S., Great Horned Owls and Red-tailed Hawks particularly have been affected by WNV (Saito et al. 2004).

The introduction of the aquatic plant, hydrilla (*Hydrilla verticillata*), into the U.S. in the 1960s for use in aquariums has been detrimental to navigation, power generation, water intakes, and water quality. Recent field and feeding studies also have implicated exotic hydrilla and an associated epiphytic cyanobacteria species as a link in an emerging avian disease in waterbirds and eagles feeding on them (Wilde 2004). A neurotoxin produced by the bacterial epiphyte may have caused avian vacuolar myelinopathy reported in Bald Eagle deaths beginning in 1994 (National Wildlife Health Center 2001).

Mitigation discussion. Vaccines have been developed for WNV and are available for use in free-ranging raptors including threatened or endangered species (e.g., Aplomado Falcon [*F. femoralis*], California Condor). However, since the animal must be captured for treatment, vaccines may not be effective for wild populations. Their use in captive raptors, on the other hand, may reduce the risk that these diseases pose for wild raptors.

Recreational Disturbance

The effects of recreational disturbance on raptors vary, depending on the species and disturbance type, magnitude, and duration (Preston and Beane 1996). Nesting birds are particularly susceptible to disturbance, which can result in altered foraging patterns, foraging efficiency, and reproductive success (Steidl 1995). Some raptors readily adapt to a human environment while others do not (Fletcher et al. 1999). Studies indicate that raptors are more sensitive to humans approaching on foot than to humans in vehicles (Skagen 1980, Chapter 19). Birds not subjected to direct human persecution might habituate to human activity (Keller 1989), although the extent to which they do so may depend on a number of factors, including the timing, extent, and the type of activity involved.

Mitigation discussion. For sensitive raptor species, management zones are used to protect raptors from human impacts during nesting (Olendorff et al. 1980). A primary zone is established around a nest to protect critical habitat throughout the year, and to seasonally protect all disturbance during nesting. Disturbance from low-flying aircraft may be included. A larger secondary zone generally is used to provide an additional buffer from extreme disturbances such as logging, land clearing, and construction activities during the nesting season. Minor activities such as hiking, bird-watching, camping, and fishing may be permitted in the secondary zone throughout the year, or there may be temporal or seasonal restrictions.

As urbanization and recreational pressures increase, additional research is needed to determine both the magnitude of human-caused disturbance and the proper way to manage it. Public education is a critical component to explain the reason for recreational restrictions (Steenhof 1978).

Urbanization

The Raptor Research Foundation held a symposium titled “Raptors Adapting to Human-Altered Environments” in 1993 during which papers were presented on both negative and positive impacts of raptors in human-altered landscapes. The book *Raptors in Human Landscapes* (Bird et al. 1996) that resulted from this symposium is an excellent reference for this area of conservation concern.

CONCLUSIONS

As research on birds of prey continues, additional impacts and mitigating measures will come to light. Increasingly, raptor biologists will be confronted not only with determining the source and scope of these impacts, but also will have to define ecological and political processes to reverse them. To do so effectively, researchers will need to use rigorous science and good communication skills to promulgate their conservation efforts among those trying to protect raptors.

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