# Impacts of livestock on shorebirds: a review and application to shorebirds of the western Great Basin

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Shorebird survival and reproductive success may be affected directly by contact with livestock or indirectly through influences of livestock on habitat features. Direct effects include disturbance to individuals and trampling of nests or chicks. Indirect effects include changes in vegetation, shorebird prey biomass or accessibility, predator pressure, and competitive outcomes. Livestock management in the west has been a massive uncontrolled experiment at landscape and regional levels. Few studies of grazing impacts on shorebirds breeding in the Great Basin have been conducted. A large proportion of the Great Basin desert that contains water is within farms and ranches. As landowners are unlikely to sacrifice economic endeavors to benefit shorebirds alone, it is imperative that conflicts between livestock and waterbirds be fully understood and compatibility explored. The development of management strategies that exploit compatibility will help promote cooperation between landowners, public land managers, and policy makers. Here we review the limited information on livestock impacts on shorebirds in the Great Basin and summarize studies in diverse habitats, such as the American Great Plains and European meadows. We attempt to provide an understanding of potential effects of livestock on Great Basin shorebirds and their habitats.

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## Introduction

Impacts of livestock on ecosystems are receiving increasing attention (*e.g.*, Kauffman *et al.* 1985; Kovalchik & Elmore 1992; Noss 1994; Brussard *et al.* 1994). Livestock may be keystone species (Paine 1969), exerting dramatic influences on habitats in which they graze (Bock *et al.* 1993; Fleischner 1994). In the ongoing debate over the legitimacy of grazing livestock over vast areas of land, it has been argued that some environments, such as the grasslands of Africa (McNaughton 1986) and the American Great Plains (Mack & Thompson 1982), evolved with large herds of wild ungulates and therefore are adapted to withstand herbivory (Milchunas *et al.* 1988). It is suggested that livestock may fill niches once occupied by presettlement ungulates, and, therefore, may enhance forage production and wildlife habitat (Rees 1982; Bodkam & Wallis de Vries 1992; Kirby *et al.* 1992; Payne 1992; Noss & Cooperrider 1994). Others contend that in some environments the effects of grazing on ecosystem composition, structure, and function are detrimental at past and present management levels, and the degraded condition of public rangelands in the western United States is evidence of inappropriate land use (Fleishner 1994; Noss & Cooperrider 1994). Changes attributed to livestock grazing include 1) altered vegetation composition, structure, and vigor (Ellison 1960; Holmgren & Hutchings 1972; Medin 1986), 2) compaction and increased erosion of soil (Blackburn 1984; Gamougoun *et al.* 1984; Wentz & Wood 1986; Wilcox & Wood 1988), 3) decreased water quality due to channeling, increased siltation and removal of protective vegetation (Platts 1979; Kauffman & Krueger 1984), and 4) changes in plant and animal species diversity (Page *et al.* 1978; Bock *et al.* 1984).

Great Basin desert and associated marsh and riparian areas are used widely for grazing livestock, predominately cattle (Young & Sparks 1985). In Nevada, over 79% of the land area is rangeland (National Research Council 1982), and only 3% of the land has water (Nappe 1991). It has been argued that shrub-steppe vegetation of the Intermountain West did not evolve in the presence of large ungulate herds, and is not adapted to withstand herbivory by large-hooved animals that tend to congregate near water (Mack & Thompson 1982). Typical spring and summer cattle grazing throughout the cold desert has resulted in loss of the cryptobiotic layer, a decrease in perennial grasses and forbs, and an increase in shrubs and non-native plants (Bock *et al.* 1993). With low annual precipitation, a short growing season, and an early dormancy period, vegetation in arid environments may have low tolerance of herbivory (Wagner 1977).

Wetlands within the western Great Basin are vital stop-overs and staging sites for waterbirds (Jehl 1986; Kadlec & Smith 1989; Oring & Reed, this volume; Robinson & Warnock, this volume), with several sites being designated of hemispheric importance to shorebirds (Myers *et al.* 1987; Neel & Henry, this volume). The western Great Basin also provides important breeding habitat for nine shorebird species, including two Species of Special Concern: Long-billed Curlew (*Numenius americanus*) (Bicak *et al.* 1982) and Snowy Plover (*Charadrius alexandrinus*) (Page *et al.* 1991).

A number of studies have examined grazing effects on waterfowl and game species habitat (Bue *et al.* 1952; Mundinger 1976; Autenrieth *et al.* 1977; Molini 1978; Rees 1982). Other research has addressed livestock management interactions with shorebirds in North American prairies (Bowen & Kruse 1993) and in European meadows (Galbraith 1987; Guldemond *et al.* 1993). Few studies of grazing impacts have been conducted on shorebird species breeding in the Great Basin (*e.g.*, Bicak *et al.* 1982). Given the extent of grazing in the Great Basin and the importance of marshes to shorebird populations for breeding and migration, it is clear that more attention should be focused on determining potential impacts in this arid environment. Compiling figures from several land management agencies, McAdoo *et al.* (1986) estimated that as much as 85% of Nevada's lowland meadow habitat, including riparian and marshland areas, is privately owned. As landowners are not likely to cease economic activities, such as ranching, for the sole benefit of waterbirds, it is imperative that conflicts between shorebirds and livestock be fully understood and management strategies that promote compatibilities be explored and developed (Payne & Wentz 1992).

The purpose of this paper is to review studies on shorebird habitat use and grazing impacts that may be applicable to shorebirds using the western Great Basin. We begin by discussing general information and studies on livestock grazing and shorebird interactions from other regions, and follow with more specific discussion on key shorebirds that breed or migrate through the western Great Basin. It is not our intention to advocate the continuation or the cessation of grazing, but to evaluate knowledge on interactions of domestic grazers with shorebirds and to suggest areas for future research.

## General requirements of shorebirds and potential effects of grazing

Habitat requirements of breeding shorebirds include 1) sites for courtship, nesting, and roosting, 2) foraging areas with adequate prey bases to support reproduction, 3) brood-rearing habitat, and 4) sites for refuge from predators and environmental stress. Although breeding shorebirds are influenced strongly by proximity of nesting sites to wetland foraging areas, specific habitat elements and characteristics important in habitat selection vary significantly among species (Colwell & Oring 1988, 1990). Shorebirds vary in their use of areas of different vegetation heights and densities, and in the degree of importance of bare ground and habitat heterogeneity. The extent and depth of water used by different shorebird species varies along a gradient (Colwell & Oring 1988). Variation in habitat use observed for a subset of shorebirds breeding in or migrating through the Great Basin is shown in Table 1. Note the lack of information specific to shorebirds in the Great Basin. Some of the studies represented in Table 1 are from habitats, such as the American Great Plains and European peat bogs, that differ from those found in the Great Basin desert. Generally, plovers use short, sparse vegetation and nest near conspicuous objects, *e.g.*, old manure piles (Mace 1971; Paton & Bachman, this volume). Other shorebird species, such as Common Snipe and Wilson's Phalarope, use taller or denser structure (Mason & MacDonald 1976, Colwell & Oring 1990). Snipe and phalarope tend to use wetter zones (Beintema 1986), while Long-billed Curlew use drier areas (Paton & Dalton 1994). Some species, such as American Avocet and Black-necked Stilt, use islands and hummocks for nesting and loafing habitat (Alberico 1993). Generally, water depth appropriate for feeding appears to correspond to culmen and tarsus length. Small sandpipers and plovers forage primarily along the shoreline and on mudflats, while longer-legged avocets and stilts forage while wading in deeper water. Some shorebirds, such as curlews and Willets, feed in uplands as well.

**Table 1.** Variation in habitat use of breeding shorebirds in the western Great Basin.

| *Species* | *Vegetation density* | *Vegetation height* | *Citations* |
|---|---|---|---|
| Snowy Plover | None to sparse | None to short | concluded from Mono Basin Ecosystem Study Committee (1987), Colwell & Oring (1990) |
| Killdeer *Charadrius vociferus* | None to sparse | None to short | Colwell & Oring (1990), pers. obs. |
| Black-necked Stilt *Himantopus mexicanus* | Sparse to moderate | Short to tall | concluded from Hamilton (1975), Richards (1988), LCP pers. obs. |
| American Avocet *Recurvirostra americana* | None to sparse | None to short | Colwell & Oring (1990), LCP pers. obs. |
| Willet *Catoptrophorus semipalmatus* | Sparse to moderate | Short to moderate | concluded from Burger & Shisler (1978), Howe (1982), Ryan & Renken (1987), Colwell & Oring (1990) |
| Spotted Sandpiper *Actitis macularia* | Sparse to dense | Short to moderate | concluded from Miller & Miller (1948), Kings River Conservation District (1985), L. W. Oring, pers. comm. |
| Long-billed Curlew | Sparse | Short | concluded from Allen (1980) |
| Common Snipe *Gallinago gallinago* | Dense | Moderate to tall | concluded from Tuck (1972), Mason & MacDonald (1976) |
| Wilson's Phalarope *Phalaropus tricolor* | Dense | Short to tall | Colwell & Oring (1990), L. W. Oring, pers. comm. |

**Table 2.** Potential direct and indirect effects of livestock on shorebirds.

| *Potential effect* | *Direction of effect* | *Species (Reference)* |
|---|---|---|
| Direct | | |
| Trampling | - | Northern Lapwing (*Vanellus vanellus*), Black-tailed Godwit (*Limosa limosa*), Eurasian Oystercatcher (*Haemantopus ostralegus*) (Beintema & Muskens 1987) |
| | - | Redshank (*Tringa totanus*) (Beintema & Muskens 1987; Guldemond *et al.* 1993) |
| | - | Ruff (*Philomachus pugnax*) (inferred from Guldemond *et al.* 1993) |
| | - | Common Snipe (Mason & MacDonald 1976) |
| | - | Long-billed Curlew (Redmond & Jenni 1986; Cochrane & Anderson 1987) |
| Disturbance | - | Long-billed Curlew (Allen 1980) |
| | - | Mountain Plover (*Charadrius montanus*) (Graul 1975) |
| | - | Black-tailed Godwit, Redshank, Ruff (Guldemond *et al.* 1993) |
| | - | Northern Lapwing, Eurasian Oystercatcher (Beintema 1986; Guldemond *et al.* 1993) |
| | | Wilson's Phalarope (Colwell 1992) |
| Indirect | | |
| On habitat | + | Mountain Plover (Kantrud & Kologiski 1982) |
| | + | Greater Yellowlegs (*Tringa melanoleuca*) (Crouch 1982) |
| | + | Stone-Curlew (*Burhinus oedicnemus*), Snowy Plover (Kohler & Rauer 1991) |
| | + | Long-billed Curlew (Bicak *et al.* 1982; Kantrud & Kologiski 1982; Cochrane & Anderson 1987; Clary & Medin 1992) |
| | + | Killdeer (Page *et al.* 1978; Crouch 1982; Kantrud & Kologiski 1982; Schulz & Leininger 1991; Clary & Medin 1992) |
| | + | Spotted Sandpiper (Crouch 1982; Taylor 1986) |
| | + | Willet (Clary & Medin 1992) |
| | - | Upland Sandpiper (*Bartramia longicauda*) (Bowen & Kruse 1993) |
| | - | Common Snipe (O'Connor & Shrubb 1986) |
| | - | Greater Golden Plover (*Pluvialus apricaria*) (Thompson *et al.* 1995) |
| On foraging | + | Northern Lapwing (Galbraith 1987; Beintema *et al.* 1991) |
| | + | Greater Golden Plover (Barnard & Thompson 1985) |
| | + | Common Snipe (Granval *et al.* 1993) |
| | - | Eurasian Dotterel (*Charadrius morinellus*) (Galbraith *et al.* 1993) |
| | - | Prey (Beintema *et al.* 1991) |
| | ? | Prey (Smith 1940) |
| | - | Foraging habitat (Wagner 1977; Kadlec & Smith 1989; Green & Robins 1993) |
| | + | Foraging habitat (Colwell & Dodd 1995) |
| On predation | - | Upland Sandpiper (Kirsch & Higgins 1976; Bowen & Kruse 1993) |
| | ? | Changes in predator assemblages (O'Connor & Shrubb 1986; Crouch 1982) |
| | ? | Changes in rodent assemblages (Smith 1940; Wagner 1977; Page *et al.* 1978) |

Given the gradient of habitat used by shorebirds, conditions favoring one species of shorebird may not benefit another. As shorebird habitat use varies by species along several continua, livestock grazing can have multiple direct and indirect effects on birds, their habitat, and interrelationships with other species and taxa across each continuum. To assess the potential outcomes of grazers on shorebird habitat, one must consider bird species individually and use caution when applying generalities obtained from studies in diverse locations.

The presence of livestock may have direct or indirect effects on shorebirds through influences on survival and reproductive success. Direct effects include disturbance to individuals and trampling of nests or chicks. Potential indirect effects include changes in vegetation species and physiognomic characteristics, changes in shorebird prey biomass or accessibility, changes in predator pressures, and changes in competitive outcomes. Table 2 lists some direct and indirect impacts that livestock can have on shorebirds.

## Principles of grazing management

Because shorebird species vary in their habitat needs, we presume they vary in how they are affected by grazing (Kantrud & Kologoski 1982; Laycock 1983; Schulz & Guthery 1988). Four variables involved in any grazing system are 1) the species of grazing animal, 2) the stocking rate, 3) the timing of grazing, and 4) the distribution of grazers across the landscape.

### Species of grazer

Each grazer has different requirements, and individuals exhibit behaviors that result in varying effects on habitat and other species dependent upon the same environment (*e.g.*, Bicak *et al.* 1982). For example, cattle and sheep differ in diet selection and subsequent effects on vegetation (Laycock 1967; Grant *et al.* 1985). Sheep more readily use steeper upland terrain and more often avoid wet, marshy conditions than do cattle (Glimp & Swanson 1994).

At comparable grazing intensity on similar sites, sheep and cattle may have different effects on water infiltration rates and sediment production (Glimp & Swanson 1994). The body condition of the animal, such as pregnancy, lactation, and age, and the range experience of grazing animals are other factors that influence livestock foraging and the consequent results on the habitat (Arnold 1975).

## Stocking rate

Effects of livestock grazing on other taxa, such as shorebirds, also can vary with the stocking rate and level of grazing intensity (Monson 1941; Baker & Guthery 1990). For example, while grazers individually did little harm, increases in the densities of cattle and sheep on Dutch pastures profoundly reduced nesting success of meadow-birds due to trampling and disturbance (Beintema & Muskens 1987). Heavy, moderate and light grazing levels have varying effects on vegetation and surface hydrology (Kantrud & Kologoski 1982; Blackburn 1984; Baker & Guthery 1990).

## Timing of grazing

In addition, the timing of grazing also influences the resulting effects on other species and on the habitat (Medin 1986). For instance, due to seasonal differences in forage selectivity in sheep, heavy grazing on sagebrush-grass rangeland in spring resulted in decreased grasses and forbs, while heavy grazing in the fall tended to increase grass and forb cover and reduce shrubs (Laycock 1967).

## Distribution of grazers

Many factors, such as availability and location of sources of water, salt, and relief from environmental stress, and herd management practices influence distributions of grazing animals across the land. Cattle have been shown to spend proportionally more time foraging in riparian areas where water and shade are available, than in surrounding uplands (Reid & Pickford 1946; Roath & Krueger 1982; but see Marlow & Pogacnik 1986). Sheep management involving continued use of the same areas for bedding grounds and holding sites along trails led to riparian habitat damage (May & Davis 1982, Platts 1982).

## Direct effects

Shorebird species differ in sensitivity to the presence of large herbivores in their midst. Individuals of some species attempt to actively defend or distract livestock approaching nests [*e.g.*, Mountain Plover (Graul 1975), Northern Lapwing and Eurasian Oystercatcher (Beintema & Muskens 1987)] while others flush from nests and display little or no defense [(Black-tailed Godwit and Redshank (Beintema & Muskens 1987)]. Due to increased expenditure of time and energy, these reactions may result in decreased adult body condition that may affect survival or reproductive output, although no data exist to test this hypothesis. Decreased incubation time and increased exposure of nests to predation while adults are away can result in lower hatching success. Ground-nesting shorebirds vary in susceptibility of nests to trampling and in response of breeding pairs to partial or total destruction of nests. Guldemond *et al.* (1993) reported a 10% nest loss in Redshanks due to trampling by cattle and sheep even when protective structures were placed over nests. In the same study, no Ruff nests were trampled. In a study of pastured lands in the Netherlands, four species of meadow-birds deserted nests after the damage of one egg, with 23-52% of nest loss attributed to trampling by cattle (Beintema & Muskens 1987). The amount and timing of egg damage affect abandonment rates in other shorebirds as well (Delehanty & Oring 1993).

Direct effects of livestock on shorebirds also vary with species of grazing animal and with livestock management practices. In a comparison of impacts of different grazers on the survival rate for nests of meadow-birds on Dutch agricultural grasslands, yearling cattle were the most destructive, followed by dairy cows, with sheep the least detrimental per individual animal (Beintema & Muskens 1987). On Dutch dairy farms with overall stocking rates of 3-4 head/ha, a rotational grazing system was employed that actually resulted in densities of several dozens of grazing animals/ha for short periods of time. Under this scheme, the probability of meadow-bird nest survival was close to zero (Beintema 1986; but see Koerth *et al.* 1983). The effects of disturbance and trampling on reproductive success are further complicated by interspecific differences in the tendencies of shorebirds to renest after initial failure and by differences in success rates of earlier versus later nests (Beintema & Muskens 1987; Redmond & Jenni 1986).

## Indirect effects

Livestock can affect shorebirds indirectly by altering the quantity or quality of habitat features. Dramatic changes in vegetative composition and structure have been attributed to grazing livestock (see Fleischner 1994 for review; Brandt & Rickard 1994). Vegetation structure is altered through herbivory or trampling (Holmgren & Hutchings 1972; Thompson *et al.* 1995). Changes in vegetation composition occur through selective foraging by grazers and the introduction of exotic plant species, either inadvertently through supplemental feed or invasion, or directly through plantings for range forage improvement (Laycock 1967; Reynolds & Trost 1980; National Research Council 1982; Medin 1986). Livestock also alter habitat heterogeneity through soil compaction or disturbance, formation of trails, altered percentage of bare ground and litter, and addition of manure piles (Weller 1978; National Research Council 1982; Baker & Guthery 1990; Wilkins & Swank 1992; Fleischner 1994).

Some studies have suggested positive indirect effects on shorebird habitat as a result of grazing (Colwell & Dodd 1995). Crouch (1982) reported results from a post-breeding season survey along the south Platte River on the American Great Plains, an area historically grazed by herds of both wild and domestic ungulates. The study showed significantly more aquatic birds, including Killdeer, Spotted

Sandpiper, and Greater Yellowlegs on grazed (mostly cattle) bottomlands than on bottomlands protected from grazing for seven years. This was believed to be due to shorter vegetation, reduced shrub cover, and increased proportions of sandbars and shallow water associated with grazing. The density and height of shrubs, grasses, and forbs differed significantly between grazed and ungrazed tracts, with some ungrazed sites impenetrable due to dense vegetation. Kohler & Rauer (1991) described a study undertaken in an area of alkaline meadows and historically extensively grazed steppes that provide breeding and staging sites for important shorebird populations in Austria. Discontinuance of grazing and changes in drainage and agricultural practices resulted in a shift from bare shoreline to tall, dense reed coverage around lakes and invasions of *Phragmites* in meadows. As a result of habitat change, Stone Curlews no longer bred in the area, and Snowy Plover populations dropped to one fourth previous levels. In alkaline grasslands characterized by low productivity, measurements of vegetation height and density in chick-rearing areas of two shorebird species compared to vegetation measurements in areas where grazing was being reintroduced, revealed that a cattle density of half an animal/ha provided suitable shorebird habitat.

The association between shorebird numbers in grazed and ungrazed riparian habitats has been assessed in several other studies. Higher numbers of Killdeer (Page *et al.* 1978; Schulz & Leininger 1991; Clary & Medin 1992), Willet (Clary & Medin 1992), Spotted Sandpiper (Taylor 1986), and Long-billed Curlew (Clary & Medin 1992) were reported in grazed areas. Most of these studies had inadequate data for hypothesis testing, but these results can be treated as hypothesized effects of grazing.

Other studies suggest a negative correlation of grazing with suitable shorebird habitat. Thompson *et al.* (1995) discussed the conversion of British upland heather moorland to grassland as a result of heavy grazing of domestic sheep. Damage or loss of this habitat occurred when grazing removed >40% of the current season's growth and resulted from stocking rates of >2 ewes/ha. Declines in the breeding ranges and/or populations of several shorebird species coincided with the reduction of heather moorland areas brought about by grazing and other intensive land use practices. O'Connor & Shrubb (1986) discussed grazing practices and a post-war increase in cattle stocking rates in relation to the decline of Common Snipe habitat in Europe. Tussock structure of the grasses used by snipes in nest site selection was diminished by field drainage and increased cattle grazing pressure on pastures. It was suggested that high rates of nest predation resulted from reduced nesting cover and contributed to snipe population decline. Bowen & Kruse (1993), studying Upland Sandpiper in North Dakota, reported lower sandpiper nesting densities and reproductive success in fields where cattle grazing altered vegetation structure to <50 cm. However, the authors suggest that in areas where vegetative growth tends to become much taller and denser, grazing may produce suitable sandpiper habitat of moderate vegetation height and density.

Shorebird habitat must provide an adequate, accessible prey base for breeding and migratory birds. Livestock and related land management practices may have indirect impacts on shorebirds by affecting foraging habitat and/or prey availability. Some examples of potential positive effects of livestock on shorebird foraging opportunities have been reported. In Spain, wintering snipe were more numerous on grazed meadows, which supported greater earthworm abundances than ungrazed plots (Granval *et al.* 1993). Grazing animals can increase abundance of excrement-associated invertebrates or make them more active and accessible to foraging shorebirds (Thompson *et al.* 1982; Barnard & Thompson 1985). Northern Lapwing chicks forage on fauna living in cow dung (Beintema *et al.* 1991). In Britain, Northern Lapwing prey biomass was greater on permanent pasture than on rough grazing areas, such as unimproved marginal upland grasslands, resulting in better female body condition and larger eggs and chicks (Galbraith 1987).

Other studies point to potential negative effects of livestock on shorebird foraging habitat and prey. Excessive grazing has been reported to increase erosion, potentially destroying shallow water habitat (Kadlec & Smith 1989). Grazing on marsh edges can result in a decrease in emergent vegetation (Wagner 1977), which is important for larval and pupal attachment of aquatic invertebrate prey species (Mono Basin Ecosystem Study Committee 1987). Drainage of land to permit earlier introduction of livestock on floodplains in Britain had adverse effects on shorebirds by reducing foraging habitat (Green & Robins 1993). Feeding conditions, while adequate at the initiation of the breeding season, often were not sufficient to support completion of incubation and brood-rearing. In the Netherlands, intense grazing corresponded with a temporary decrease in arthropod abundance in late spring (Beintema *et al.* 1991). Smith (1940) reported changes in invertebrate abundances and assemblages due to livestock grazing. Indirect effects of livestock and management practices on shorebird foraging opportunities can have great impacts on shorebird survival and reproduction.

Shorebirds incur varying degrees of predation on eggs, chicks and adults. Bowen & Kruse (1993) and Kirsch & Higgins (1976) found higher predation of Upland Sandpiper nests on grazed than ungrazed lands. Management of grazing livestock may affect habitat, type, abundance, and efficiency of predators, and also may affect alternative prey communities (*e.g.*, Page *et al.* 1978; Crouch 1982; O'Connor & Shrubb 1986; Bowen & Kruse 1993). Substantial changes in rodent populations and assemblages on grazed lands have been reported (Smith 1940; Wagner 1977; Page *et al.* 1978). The impacts of changes in rodent populations on shorebirds are likely to be complex. Rodents are known to depredate shorebird eggs (Maxson & Oring 1978), but they are also alternative sources of prey for other predators of shorebird eggs and chicks. Changes in abundance and accessibility of alternative prey sources for predators can result in variation in depredation rates on shorebird eggs and young (*e.g.*, Beintema & Muskens 1987; Redmond & Jenni 1986).

# Livestock grazing and breeding shorebirds in the western Great Basin

### Long-billed Curlew

Curlews are among the most-studied shorebirds in terms of habitat needs and impacts of grazing. Once common in North America, they are declining over much of their range (Page & Gill 1994). Long-billed Curlews breed in the western Great Basin, and are currently considered a Species of Concern by the U.S. Forest Service (USFS) (Finch 1992). Curlew nesting territories are typified by short vegetation with areas of shrubs and clumps of taller grass, some bare ground, and habitat heterogeneity (Allen 1980; Cochrane & Oakleaf 1982; McAdoo *et al.* 1986). While curlews do use managed and altered lands, hunting, plowing, heavy grazing during nesting, and conversion of meadows to taller, cultivated fields are listed as causes of their decline (Allen 1980; Cochrane & Oakleaf 1982; Cochrane & Anderson 1987).

Potential positive and negative direct and indirect impacts of livestock grazing on Long-billed Curlew have been suggested in several studies. Egg survival is negatively correlated to the number of grazing animals present (Redmond & Jenni 1986). Cattle and sheep crush or dislodge eggs, resulting in loss of eggs as adults abandoned disturbed nests (Redmond & Jenni 1986). In Washington state, once a nest is destroyed or abandoned, curlews did not renest (Allen 1980). In a Wyoming study of curlew habitat, Cochrane & Anderson (1987) found that summer grazing of cattle enhanced habitat by providing more short-stature vegetation, but was also a predictor of nest failure presumably due to trampling and disturbance. In southwestern Idaho, Bicak *et al.* (1982) found numbers of curlews to be negatively correlated with vegetation height and vertical coverage during pre-laying and laying, which are negatively correlated with intensity of spring and fall grazing of sheep and cattle. Sheep grazing, which occurred at higher densities and involved active herding, resulted in more suitable habitat than did cattle grazing. Pasture rest periods that resulted in heavy cover in spring were detrimental. Year-round grazing was the least beneficial, presumably due to direct effects on nesting birds.

Land management related to grazing found to adversely affect curlews includes dragging fields to break up manure, leveling land, seeding, fertilizing, and irrigating that results in tall, dense pasture growth or that occurs during incubation (Cochrane & Anderson 1987; Cochrane & Oakleaf 1982). Curlews are sensitive to physical disturbance during incubation, and flushed adults take up to an hour to return to the nest. Disturbance during hatching may cause the brood to leave the nest prematurely before all chicks are fully mobile (Allen 1980). However, most of these observations were not the result of controlled experiments (*cf.* Elphick, this volume).

### Other Species

A number of other shorebird species breed in Great Basin desert wetlands and are potentially impacted by livestock grazing practices. Studies pertaining to effects of livestock grazing on these species are lacking for the Great Basin. The western subspecies of the Snowy Plover is another USFS Species of Concern (Finch 1992) that is a breeder and migrant in the Great Basin (Oring & Reed, this volume). Snowy Plover numbers have apparently declined in Nevada (Bradley *et al.* 1991, 1994; Page & Gill 1994) due to loss of habitat, disturbance, and destruction of nests (Ehrlich *et al.* 1992). As cited in the section on indirect effects of grazing, European studies suggest that some livestock grazing may provide suitable habitat for nesting plovers by reducing dense shoreline vegetation (Kohler & Rauer 1991). Other shorebirds that commonly breed in desert wetlands are Killdeer, Black-necked Stilt, American Avocet, Willet, Spotted Sandpiper, Common Snipe, and Wilson's Phalarope. Grazing impacts on these species require careful study.

## Conclusion

Any livestock grazing and intrusive management activities occurring on or very near nesting areas during the shorebird breeding period may result in negative direct effects due to trampling of nests or chicks and disturbance of breeding adults. Based on observed habitat-use patterns for shorebirds in the Great Basin, non-breeding season grazing might benefit some shorebird species by maintaining suitable habitat characteristics, including short, sparse vegetation, patches of barren ground, and manure piles.

Shorebirds using sparsely vegetated areas, such as the Snowy Plover, Killdeer, and Long-billed Curlew, may benefit from heavier grazing by cattle or sheep that greatly reduces vegetation stature. Species, like the Black-necked Stilt and Willet, that use more vegetated areas for nesting or for brood-rearing, may profit from moderate grazing but suffer negative impacts from heavy grazing if vegetation of nest sites or nursery areas is reduced below a critical level. Common Snipe and Wilson's Phalarope might benefit from pasture development and management that produces taller, dense growth, and may tolerate lower levels of sheep or cattle grazing, but may respond negatively to more intense grazing that substantially reduces the height and density of the vegetation.

As species vary in their tendencies to use wetland edge or upland areas in establishing nesting sites, grazing management in these diverse habitats would be expected to result in different responses from shorebird species. Migrant shorebirds would probably benefit from levels of grazing that result in substantial areas of exposed shoreline for foraging with residual vegetation that offers roosting shelter. Cattle or sheep grazing and management practices that increase erosion or destroy shallow water habitat, eliminate emergent vegetation, reduce invertebrate prey, reduce habitat diversity, increase predator numbers or efficiencies, or reduce residual vegetation to the degree that it offers no relief from predator pressure or environmental stress, would be expected to be detrimental to all shorebird species.

### Future research

Given the paucity of data from carefully controlled studies, there is a need for an understanding of interactions of livestock grazing and the aforementioned shorebird species in the Great Basin. Predictions such as those above should be tested (*cf.* Elphick, this volume) by experiments aimed at determining the direct and indirect effects of 1) different species of domestic grazers, 2) varying grazing intensities, 3) season of grazing, and 4) varying effects in different habitat types.

In presenting results from future studies, details about habitat types and conditions, specific information about grazing regimes employed, and in-depth descriptions of the responses of shorebird species are necessary to assess the potential for application of such results to diverse situations. Greater understanding of the conflicts and the compatabilities of domestic livestock with wildlife species will aid landowners and public agencies in setting sound land management goals.

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