Chapter 4

Invasive Species in Southern Nevada

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Introduction

Southern Nevada contains a wide range of topographies, elevations, and climatic zones emblematic of its position at the ecotone between the Mojave Desert, Great Basin, and Colorado Plateau ecoregions. These varied environmental conditions support a high degree of biological diversity (Chapter 1), but they also provide opportunities for a wide range of invasive species. In addition, the population center of the Las Vegas valley, and the agricultural areas scattered throughout Clark, Lincoln, and Nye counties, all connected by a network of roads and highways, plus ephemeral and perennial watercourses, provide abundant opportunities for new invaders to be transported into and within southern Nevada (Brooks 2009; Brooks and Lair 2009).

Invasive species are a concern for land managers because they can compete directly with native species (Brooks 2000; Chambers and others 2007; DeFalco and others 2003, 2007; Mazzola and others 2010), change habitat conditions (Brooks and Esque 2002; Esque and others 2010; Miller and others 2011), and alter ecosystem properties (Brooks and Matchett 2006; Brooks and Pyke 2001; Evans and others 2001). Many invasive species have already established and spread to the point that they are now considered to pose significant problems in southern Nevada. However, there are likely many more that have either not been transported to or colonized the region, or have established but for various reasons not spread or increased in abundance to the point where they have a significant impact. Land managers must understand both current and potential future problems posed by invasive species to appropriately prioritize management actions.

This chapter addresses Sub-goal 1.2 in the SNAP Science Research Strategy (table 1.3; Turner and others 2009), which is to protect southern Nevada's ecosystems from the adverse impacts of invasive species. It provides a brief overview of the key concepts associated with the ecology and management of invasive species, and includes information relevant to all five strategic goals identified by the National Invasive Species Council: prevention, early detection and rapid response, control and management, restoration, and organizational collaboration (National Invasive Species Council 2001, 2008). Restoration also is discussed in a broader context in Chapters 5 and 7. This chapter does not present a comprehensive review of all invasive species or associated land management issues in southern Nevada, but rather uses key species of concern to illustrate invasion ecology concepts and management strategies. It is focused on terrestrial and aquatic plants and animals, and does not address potential invasive taxa from the other Kingdoms. The information presented herein is intended to provide a foundation upon which land management plans can be developed and project-level decisions can be made relative to the management of invasive species in southern Nevada.

Overview of Invasive Species Management

Executive Order 13112 issued by President Clinton in 1999 called for the establishment of the inter-departmental National Invasive Species Council (NISC) and directed its members to create a national plan to serve as a comprehensive blueprint for Federal action on invasive species. This plan was published in 2001 (National Invasive Species Council 2001) and was updated in 2008 (National Invasive Species Council 2008). It identifies five strategic goals: prevention, early detection and rapid response, control and management, restoration, and organizational collaboration. It also includes priority strategic action plans with objectives and implementation tasks for 2008 through 2012. These documents provide the guiding principles and priorities for invasive species management on Federal lands, including those in southern Nevada.

Invasive species are defined as "a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health" (National Invasive Species Council 2001). Many non-native species do not cause harm, and are actually beneficial to humans (e.g., crop species). Others are clearly invasive and harmful outside of their native range (e.g., European starling). Still other non-native species are considered invasive by some, but beneficial or otherwise desirable by others (e.g., some ornamental plants, wild and free roaming horses and burros). Land managers, policy makers, and society in general must determine which non-native species are invasive and pose the greatest threats, and which are the most important to actively manage.

Species invasions proceed through the general phases of transport (long distance dispersal), colonization, establishment, and spread (Booth and others 2010). Each stage presents unique challenges and opportunities for management actions to control invasive species. As a general rule, preventing transport and colonization of potential invaders is the most effective approach to invasive species management. This is accomplished by state and Federal noxious species lists and associated quarantine and inspection processes preventing the import and sale of these species as a first and most effective line of defense.

There is also a need for early detection, prioritization, and rapid response to manage invading species that slip through the inspection and prevention cracks. Because there are more species than can be managed, a prioritization process is key to refining early detection plans and to improving the detectability of the highest priority species. Depending on the types of existing information and resources available to process the information, a generalized, prioritized, or optimized monitoring plan can be developed to improve the efficacy of monitoring efforts (Brooks and Klinger 2009; fig. 4.1). These same concepts can be used to prioritize sites and species for control efforts. Species invasions often stall at the establishment phase when spread of local populations may be constrained by dispersal and/or environmental barriers (Richardson and others 2000). This lag in spread may persist for decades, offering the best opportunity to prioritize and control locally established populations.

Understanding the mechanisms of propagule pressure and resource availability can facilitate both detection and control efforts (Brooks 2009; Mazzola and others 2010; fig. 4.2). Propagule pressure is related to the number or density of seeds and other plant parts capable of dispersing and establishing. Resource availability refers to amount of resources necessary for plant growth. A generalized monitoring plan can be developed with a basic understanding of where propagule pressure is likely to be highest (e.g., along roadsides, near urban or agricultural centers) and where resource availability is highest (e.g. riparian areas, mid elevation ecosystems, intermittent washes, roadsides) (Brooks 2009). In addition, depending on the relative significance of propagule pressure or resource availability, management actions can either focus on reducing numbers of plants and propagules (e.g., herbicides, mechanical thinning) or reducing resource availability (e.g., increasing nutrient uptake by soil microbes or promoting the growth of competitive plants).

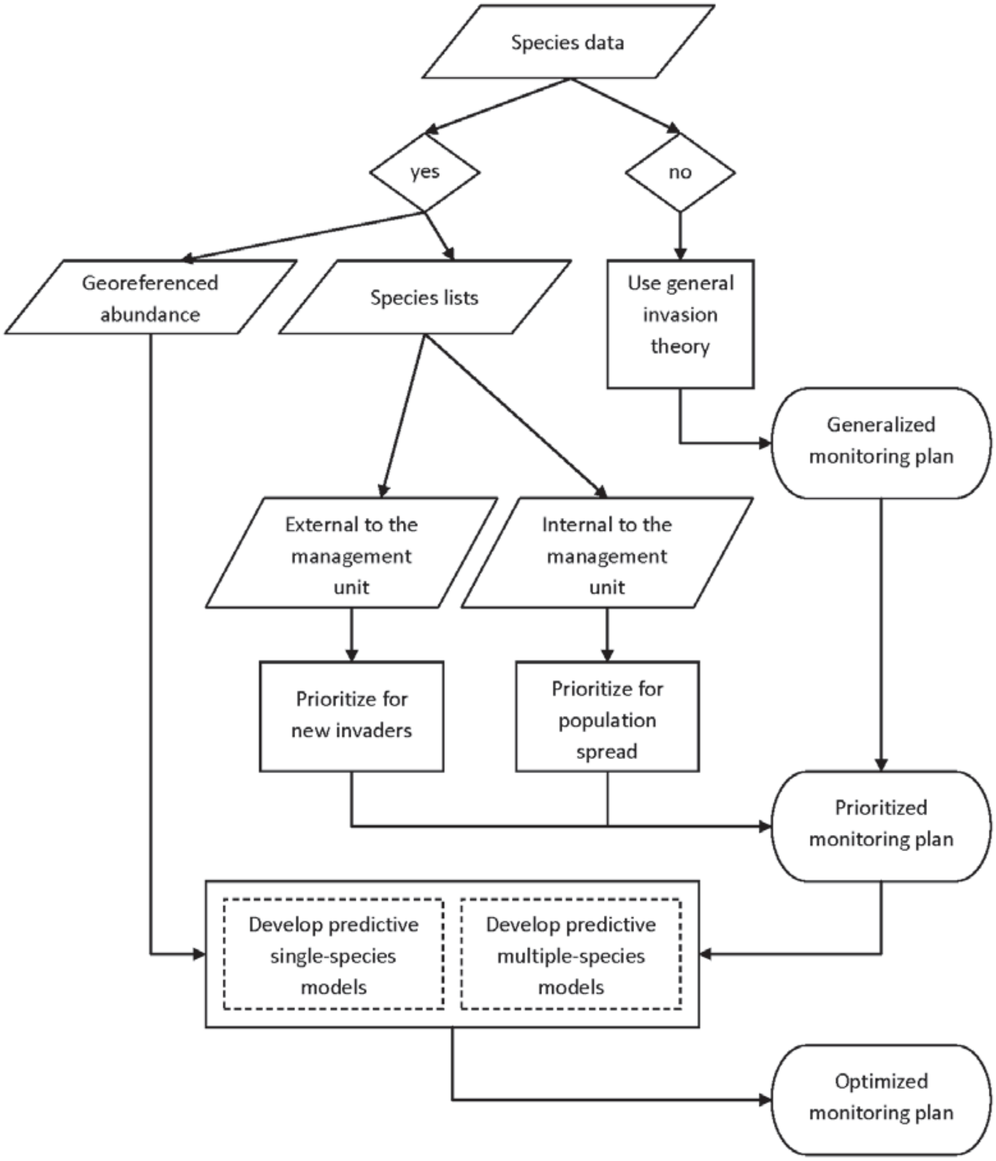

Figure 4.1—Steps for developing early detection monitoring plans (reprinted with permission from Brooks and Klinger 2009).

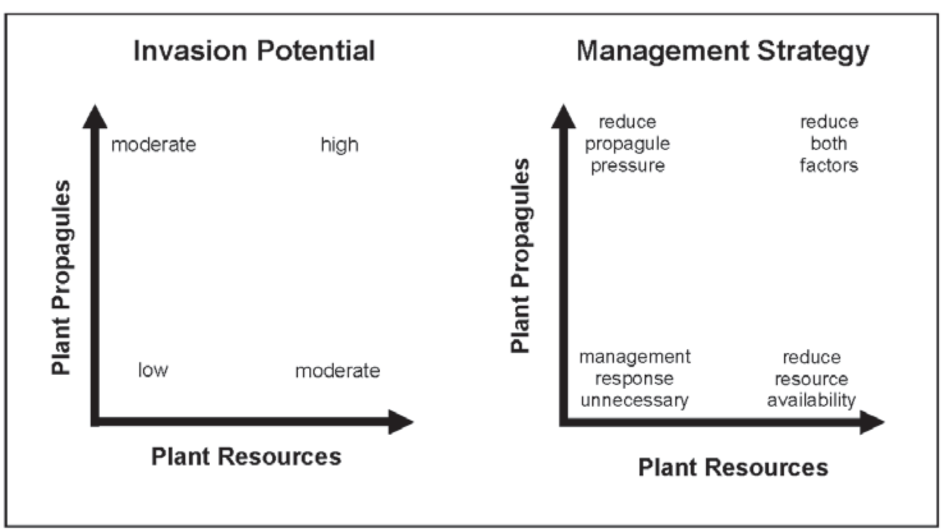

Figure 4.2—Main factors affecting plant invasions and management responses (modified with permission from Brooks and Lusk 2008).

The Interagency Weed Sentry Project in Clark County, Nevada, was a significant early detection effort that began in 2004 with protocol development and lasted through 2009. It was focused on surveying roadsides, trails, and shorelines (Lake Mead and Lake Mojave) to detect and record the location of new plant invaders (Abella and others 2009). These survey areas represent centers of propagule dispersal and locally high resource availability, and corridors of movement of species among regions (Brooks and Lair 2009). However, other recognized pathways of invasion in the Mojave Desert occur along riparian and dry wash corridors (Abella and others 2009; Brooks 2009), and it is possible that many species are missed by not surveying these areas. The Weed Sentry Program also focused search efforts on a subset of likely invaders with the most potential to cause the greatest management problems. Although this approach ignored established species, some of which cause the greatest management problems (e.g., *Bromus* spp. that alter fire regimes) (Brooks and Esque 2002; Brooks and Pyke 2001), it provided for a more efficient survey approach for newly invading species (Abella and others 2009; Brooks and Klinger 2009). This early detection program was discontinued in 2010, but agencies have continued to inventory invasive species on their own lands through various methods including aerial surveys and incidental observations associated with other field efforts.

Once new populations of invading species are identified, they need to be prioritized for control efforts. Species prioritization is typically based on relative threats posed, dispersal and spread potential, current range and extent patterns, and in some cases feasibility of control (Warner and others 2003). Site prioritization considers the conservation value of the site, the location relative to other nascent populations (especially if it is on the leading edge of the invasion front), and feasibility of control at the site. Control efforts may include chemical, mechanical, or cultural treatments, alone or in combination with each other. Follow-up control treatments are often required to improve efficacy.

Although much of invasive species management is focused on detection, prioritization, and control efforts, the most efficient and effective way to manage these species is to restore or maintain resistance of southern Nevada ecosystems to invasion. For example, functional diversity of plants is positively correlated with resistance to invasion (Brooks and Chambers 2011), so managing ecosystems to restore or maintain a wide array of plant life forms can hinder plant invasions. More detailed discussion of this topic is presented in Chapters 1 and 7.

Invasive Plants

Uplands

What are upland invasive plants and how did they get here?—The majority of invasive plant species that dominate upland areas in southern Nevada are annual life forms (Brooks and Esque 2002). Annuals complete their entire lifecycle in 1 year, germinating, growing, reproducing, and dying, typically within the winter to spring time period. They are ideally suited to avoid the inhospitable arid conditions that characterize most of the year by remaining dormant as seeds in the seedbank. Seeds also provide an ideal mechanism for dispersal, allowing annual species to spread both within and among areas (Brooks 2009).

Invasive annual grasses are significant components of all southern Nevada ecosystem types except for the alpine and bristlecone pine ecosystem types. Cheatgrass (*Bromus tectorum*) is found mostly in the mixed conifer, piñon-juniper, sagebrush, and blackbrush/shadscale types. Within the Mojave Desert scrub ecosystem, red brome (*Bromus rubens*) dominates the upper elevations, and Mediterranean split-grass (*Schismus barbatus*, *Schismus arabicus*) the lower elevations. The most widespread invasive forb is red-stemmed filaree (*Erodium cicutarium*), which occurs in significant numbers from the piñon-juniper, ecosystem all the way down to the lower elevations of Mojave Desert scrub. Other species of note include various mustard species (*Brassica tournefortii, Hirshfeldia incana, Sisymbrium irio, Sisymbrium altissimum*, *Malcomia africana*), which occur mostly within the Mojave Desert scrub type. Burr buttercup (*Ceratocephala testiculata*), prickly Russian thistle (*Salsola tragus*), and Russian knapweed (*Acroptilon repens*) are common invaders in sagebrush, piñon-juniper, and mixed-conifer ecosystems. The invasive perennial green fountaingrass (*Pennisetum setaceum*) also is escaping ornamental plantings and spreading by windblown and sheet flooded seed along dry washes much as it has done in the southern Mojave Desert and Sonoran Desert (Matthew Brooks, personal observation while living and working in the Las Vegas Valley during the 2000s). Specific locations of spread in southern Nevada are from ornamental planting in the Las Vegas valley and Laughlin areas into upland springs in the Newberry Mountains and along the shorelines of Lake Mohave and Lake Mead (C. Deuser, personal communication).

What are effects of upland invasive plants?—The greatest and most well documented threat that annual invasive plants pose to upland areas of southern Nevada is the alteration of fire regimes (Chapter 5). Most of southern Nevada is characterized by Mojave Desert scrub, which, because of its relatively low native plant cover, has experienced little historic fire. Accordingly, species that inhabit this ecosystem type have generally not evolved tolerance to fire (Brooks and Minnich 2006). Cheatgrass and red brome colonized North America during the late 1800s, have spread into southern Nevada, and since at least the 1930s have filled the interspaces between native perennial plants and persisted as standing fuels creating a continuous fuelbed that can carry fire. These same invasive grasses typically increase in dominance following fire and promote a shortened fire return interval that facilitates type-conversion of native shrublands into non-native invasive grasslands. Fire is considered one of the primary threats to the recovery of the desert tortoise (*Gopherus agassizii*), a Federally threatened species (USFWS 1994). Fire in Mojave Desert scrub also may have negative effects on forage production, aesthetic and recreational resources of value, and soil stabilization (Chapter 5).

Invasive plants also can outcompete individual native plants for limiting resources, especially in the seedling stage (e.g., Defalco and others 2003, 2007), although it is unknown what the net effects of competition are on native populations and communities. In addition, the seeds of some invasive plants (e.g., red brome, red-stemmed filaree) are eaten and also dispersed by native granivores, although these seeds may have differing nutritional quality compared to native species (Kelnick and MacMahon 1985). The desert tortoise will consume standing crops of red brome if there is little else to eat (Esque 1994), and this may cause physiological problems associated with potassium levels (Nagy and others 1998).

How can upland invasive plants be managed?—Annual plants are notoriously difficult to manage. Their seeds are easily dispersed and often remain viable for many years. Preventing their transport into new areas of southern Nevada is the best first line of defense, followed by eradication or containment of nascent populations (Brooks 2009). Washing of equipment and removal of propagules from shoes and clothing before leaving infested areas also can help reduce dispersal rates (Brooks and Lusk 2008). Repeated treatment over a period of years, typically with herbicides, is generally required until the soil seedbank becomes exhausted. Supplemental watering to stimulate seeds to germination may help expedite multi-year control efforts. However, repeated control treatments of the same type, especially herbicide treatments, may lead to selection for resistant invasive plant genotypes and thus complicate future control efforts (Radosevich and others 1997).

Management aimed at increasing the ecological condition of degraded ecosystems and restoring disturbed ecosystems also are viable strategies for managing invasive plant species (Chapters 5 and 7). Resistance to annual bromes is significantly increased by native perennial species, especially grasses and forbs, which are their strongest competitors (Allen and others 2002; Booth and others 2003; Chambers and others 2007). Because sagebrush, piñon-juniper, and mixed conifer ecosystems evolved with fire and periodic disturbance, vegetation management treatments that reinitiate succession and maintain high structural and functional diversity can increase resistance to invasion and prevent conversion to invasive species dominance following disturbances like fire or drought. Wildland use fire, prescribed fire, and mechanical treatments can be used to decrease woody species dominance, prevent high severity fire, and increase the competitive abilities of native grasses and forbs (Brown and others 2000; Pyke 2011). Due to inherently low resistance of Mojave Desert scrub ecosystems to invaders, management must focus on protection and eliminating or reducing stressors such as fire, dispersed recreational activities, ORV use, and overgrazing by wild horses, burros, and cattle.

Riparian/Aquatic and Springs

What are riparian/aquatic invasive plants and how did they get here?—Riparian and spring ecosystems are characterized by both annual and perennial invasive plant species but the most apparent are often perennials (Dudley 2009). Perennial species that have clonal or rhizomatous life forms or that are capable of root sprouting are ideally suited to survive the scouring floods and sediment deposition that often typify arid riparian ecosystems. These species also are often highly competitive with native riparian species. The most infamous perennial invader in southern Nevada is tamarisk or saltcedar (primarily *Tamarix ramossisima, T. aphylla*), which occurs in both riparian and spring ecosystems. This species was introduced to North America as an ornamental in the 1800s, and has subsequently spread throughout the continent (Dudley 2009). Most invasive species in these ecosystems are facultative or obligate riparian species that require elevated water tables for their establishment and persistence (USDA Plants Database 2012). Facultative or obligate riparian species in southern Nevada include the perennials, giant reed (*Arundo donax*), Russian olive (*Elaeagnus angustifolia*), camelthorn (*Alhagi pseudalhagi*), and perennial pepperweed (*Lepidium latifolium*), and the annual rabbitsfoot grass (*Polypogon monspeliensis*). Upland species that utilize seasonal increases in water availability or that occur at the periphery of these ecosystems include Russian knapweed (*Acroptilon repens*), invasive annual grasses such as ripgut brome (*Bromus diandrus*), red brome, and cheatgrass, and invasive mustards.

There are few aquatic plant invaders in southern Nevada, and those that are currently present do not pose serious threats. However, there are a few poised to invade that do pose real threats. Eurasian water-milfoil (*Myriophyllum spicatum*) has been reported along the Colorado River in the vicinity of Parker Arizona (Jacono and Richarson 2011) and giant salvinia (*Salvinia molesta*) has been reported farther downstream at the Imperial National Wildlife Refuge (Howard 2011).

What are the effects of riparian/aquatic invasive plants?—Because of their growth over many years, perennial species can attain large size, displace native vegetation, and significantly affect the physiographic structure of vegetation stands (Dudley 2009).

For example, conversion of native riparian vegetation to tamarisk stands can affect wildlife habitat quality and ecosystem properties associated with fire and hydrologic regimes (Dudley 2009). However, this ecosystem continues to support a diversity of species including two birds of conservation concern—the yellow-billed cuckoo (*Coccyzus americanus*) and the southwestern willow flycatcher (*Empidonax traillii extimus*)—that utilize tamarisk stands to forage and even nest in when native vegetation is unavailable (Bateman and Ostoja 2012). Giant reed, Russian olive, perennial pepperweed, Russian knapweed, and camelthorn can also significantly alter the structure of riparian communities, but are currently confined to a few localized populations in southern Nevada.

Eurasian water-milfoil and giant salvinia have the potential to choke out waterways, increase eutrophication, disrupt food webs, and otherwise significantly alter aquatic habitats of southern Nevada (Howard 2011; Jacono and Richarson 2011). These changes could threaten everything from endemic animals such as pupfish and spring snails, to game species such as sunfish, bass, and trout.

How can riparian/aquatic invasive plants be managed?—Challenges associated with controlling and managing riparian invasive plants differ from those of uplands. Many perennial species have persistent below-ground roots and rhizomes that make eradicating populations difficult (e.g., giant reed, perennial pepperweed). Also, seeds and other propagules are readily transported in flowing water and by the animals that utilized these ecosystems. Mechanical or prescribed fire treatments are often used initially to reduce aboveground biomass and stimulate resource re-allocation from belowground to aboveground tissue. Then, after regrowth has occurred, chemical treatments are used as a follow up to kill the plants. Treatment of resprouts may be necessary during subsequent years. Recently a biocontrol leaf eating beetle introduced to control tamarisk has spread into southern Nevada along the Virgin River corridor and is in the process of killing or at least reducing the vigor of tamarisk plants in that region (Bateman and others 2010). Long-term success of control treatments often requires restoration with native species and continued monitoring to detect reoccurring or new invasions.

Options for controlling aquatic plants are limited once the species have established local populations. Educational programs promoting watercraft washing and periodic inspections at entry points are potentially the most effective way to prevent transport and colonization of new waterways.

Invasive Animals

Terrestrial

What are terrestrial invasive animals and how did they get here?—While perhaps less conspicuous and less abundant than invasive plants, invasive animals can have significant ecological and economic consequences in southern Nevada. Small cryptic species like Argentine ants (*Linepithema humile*) and imported red fire ants (*Solenopsis* spp.) are difficult to detect and can be challenging to identify. Red imported fire ants, native to South America, were originally introduced to the southern United States between 1918 and 1930. While the ecological effects of this introduction are not fully known, existing data suggest cause for concern (Dowell and others 1997; Porter and others 1988). Native to Brazil and Argentina, Argentine ants are thought to have been originally introduced by coffee ships in the southern United States and have slowly moved west in landscape material and potted plants (Suarez and others 2001).

Africanized honey bees have also recently invaded southern Nevada from initial introductions in South America. Other non-native species like the heavily managed wild horses (*Equus ferus*) and burros (*Equus asinus*) represent a historical place holder for the American West and are thought by many to be a national cultural treasure, emblematic of the pioneer spirit of the West. In fact, the 1971 Wild Free-Roaming Horse and Burro Act (Public Law 92-195) specifically states, that "It is the policy of Congress that wild free-roaming horses and burros shall be protected from capture, branding, harassment, or death; and to accomplish this they are to be considered in the area where presently found, as an integral part of the natural system of the public lands…" Nonetheless, wild horses and burros come with an ecological cost (Abella 2008; Beever and Brussard 2004), and could potentially be categorized as invasive species as defined by the National Invasive Species Council (National Invasive Species Council 2001) if not for their specific exclusion from such distinction. Burros specifically were heavily used in the 1800s to assist with mining operations but were released or escaped and became wild as operations declined (Abella 2008). Effects of wild or otherwise free roaming cattle are also of concern especially near watering sites, and feral dogs (*Canis familiaris*) and cats (*Felis catus*) can pose significant threats to native animals near urbanized areas.

What are the effects of terrestrial invasive animals?—Argentine ants are successful and voracious predators in part because they will combine territories and attack other insects including native ant colonies, lizards, snakes, and small mammals (Grover and others 2008). Red imported fire ants compete with native fire ants, prey on invertebrates and vertebrates, and may affect plant assemblages by selective seed removal. In addition, red imported fire ants prey on solitary bees that pollinate native plant species (Vinson 1997). Because these ant species prefer relatively moist areas, their impacts will most likely be near urbanized areas and springs, seeps, and riparian areas.

Even though wild horses and burros maintain that iconic image of the American West and are protected on public lands under the 1971 Wild Free-Roaming Horse and Burro Act, some studies suggest they can cause significant ecological effects (Abella 2008; Beever and Brussard 2004). Heavy use by horses and burros can result in reduced plant cover and diversity and increased soil disturbance and potential erosion. Abella (2008) found that wild burros prefer grasses and forbs and are more likely to consume native Indian ricegrass (*Achnatherum hymenoides*) than would be expected by chance. Wild horses can cause damage by trampling vegetation, soil compaction, and overgrazing (Ostermann-Kelm and others 2008). Bighorn sheep (*Ovis canadensis nelson*) are reported to avoid water sources when wild horses are present and their densities are reduced by 75% where horses are present (Ostermann-Kelm and others 2008).

The full impact of feral cats and dogs is not well known for southern Nevada, but due to extensive urban development there is a continuous supply of feral pets that have the potential to directly and indirectly impact native wildlife groups (Denny 1974; Lowry 1978). It is known that feral cats and dogs are among the main predators of the Federally protected desert tortoise (Bergman and others 2009) in addition to birds and other wildlife. Dogs hybridize with native canids (coyotes, *Canis latrans*, in the case for Southern Nevada) and the highest ratio of dog-coyote hybrids is near large human population centers (Mahan and others 1978). Packs of feral dogs also pose a direct threat to humans and could negatively affect recreational use of public lands in southern Nevada.

How can terrestrial invasive animals be managed?—Control of invasive ants can be difficult. Aside from baiting and chemical control, few options exist and even these may have some residual impact to non-target groups. Because wild horses and burros are Federally protected on public lands under the Wild Horse and Burro Act, local resource managers need to review options and assess impacts against desired conditions when it comes to their control and management. Removals are conducted, but require continued monitoring and follow-up control efforts. Local exclosures can be used to protect critical habitat features and resources, and fertility control is a recent option that requires additional study. Feral cat and dog control can also be very tricky. Trapping is considered an effective control strategy for feral cats and dogs, but requires close coordination with adoption groups and is usually coupled with fertility control. (Barnett 1986). However these methods are difficult to implement due to negative public responses associated with animal rights concerns as well as complexity and costs.

Aquatic

What are aquatic invasive animals and how did they get here?—Several notable aquatic invasive species exist in southern Nevada including the quagga mussel (*Dreissena rostriformis*), bullfrogs (*Rana catesbeiana*), red swamp crayfish (*Procambarus clarkii*), and various species of fishes (Bradley and Deacon 1967). Quagga mussels are freshwater mollusks and are perhaps the most notorious aquatic invasive species in the region. This small zebra-shell-patterned mussel has spread across the western United States as larva in boat livewells and bilges and as adults when attached to boat hulls, engines, aquatic weeds, or other surfaces. Quagga mussels are present in Lake Mead and Lake Mojave and may have spread to various upland freshwater sources. The American bullfrog was introduced to southern Nevada in the 1920s (Jennings and Hayes 1994) and is now widespread in wetlands in Las Vegas Valley, Indian Springs Valley, and the Muddy and Virgin River valleys and in several upland springs in the region. The red swamp crayfish is native to the southeastern United States, is commonly used as bait by fishermen, and has become established in southern Nevada. Various species of fishes, including the mosquitofish (*Gambusia* spp.), red shiner (*Notropis leutrensis*), shortfin molly (*Poecilia mexicana*), cichlids (*Oreochromis* spp.), and tilapia (*Tilapia* spp.) have been introduced to southern Nevada. The mosquitofish was intentionally introduced to the region for control of mosquitos in ponds and other abandoned water sources (Bence 1988). Cichlids were introduced in various fresh water sites around Lake Mead NRA. Red shiners are thought to have been introduced through the emptying of bait buckets, but it is also a common aquarium fish (Nico and Fuller 2010; Nico and others 2011).

What are the effects of aquatic invasive animals?—Quagga mussels directly threatened water supplies and associated water diversion and management operations since they can clog pipes and compromise water intake systems. In addition, they can clog engines and encrust boats, docks, and associated facilities, alter the aquatic food web, impact sport fishing, and litter beaches with their small sharp shells. The economic cost associated with quaggas can easily reach millions of dollars.

Bullfrogs are aggressive and voracious predators of native toads and frogs, reptiles, small mammals, and birds; some of which are listed under the Endangered Species Act. Along the Muddy River, bullfrogs and red swamp crawfish are thought to be responsible for the elimination of the relict leopard frog (Bradford and others 2004) and have preyed on other amphibians in other regions (Gramradt and Kats 1996).

The mosquitofish, red shiner, and cichlids have adversely affected native invertebrates, amphibians, and fishes (USFWS 1995). Mosquitofish have been known to harm, kill, and outcompete other small fishes, including natives (Haynes and Cashner 1995; Hubbs and Deacon 1964) and prey on native treefrog (*Hyla regilla*) tadpoles (Goodsell and Kats 1999). In addition, mosquitofish have been shown to contribute to algal blooms by directly preying on zooplankton grazers (Nico and others 2011), suggesting impacts on aquatic food webs. Shortfin mollies prey on larval fish including the Federally endangered Moapa dace (*Moapa coriacea*) and Moapa White River springfish (*Crenichthys baileyi moapae*) (Scoppettonne 1993). Information from the 1980s indicates that relict leopard frogs and cichlid fish coexisted in Blue Point and Rogers Springs (Courtenay and Deacon 1983), and although recent surveys indicate that relict leopard frogs still occur at these sites (collection sites 17 and 18; Bradford and others 2004) there is evidence of substantial predation by cichlids and other non-native fishes on larval frogs and eggs (J. Jaeger, personal communication).

How can aquatic invasive animals be managed?—Prevention is the key to quagga mussel control because even if adults are killed the larvae have the ability to evade control measure, spread great distances, and later recolonize. It is important that all mud, plants, and aquatic organisms are cleaned and removed before vehicles or equipment are transported. Gear, equipment, and vehicles that come in contact with water should be drained, dried, and cleaned before moving (boat washing locations can be found on the internet). Bullfrog control can be difficult, but gigging has proven effective in some sites. Physical methods for control of bullfrogs and crayfish include de-watering and temporary habitat removal, but this can also affect native species. Because crayfish, and to some degree bullfrogs, are able to travel long distances over ground, physical methods have limited utility. However, an exclusion fence installed by the U.S. Bureau of Land Management around Perkins Pond in the Warm Springs area, following dewatering to remove bullfrogs, has been able to keep this frog from recolonizing. Crayfish moving up the Muddy River will likely threaten the pond in the future, but the hope is that the fence will also limit colonization by this species (J. Jaeger, personal communication). Chemical control methods include biocides, piscicides (e.g. rotenone), and pheromones, but the effective dosage required often kills other non-target organisms (McClay 2000; Oberg 1967).

Knowledge Gaps

Most invasive plant research from southern Nevada and the greater Mojave Desert has focused primarily on a few species, most notably red brome and cheatgrass in upland areas, tamarisk in riparian areas, and animal invaders in aquatic habitats. Even with this information, many key questions still remain relative to these well-studied species: (1) what are their net effects on native plants and animals; (2) what are the best combinations of control and restoration strategies to eradicate them and prevent their re-establishment, or at least minimize their dominance and negative effects; and (3) how will their abundance and effects change in the future? Very little is known about the potential effects of the vast majority of invasive plants, making it difficult to prioritize among them for early detection and rapid response control efforts. This information is especially urgent for some notable species, such as green fountaingrass, giant salvinia, and Eurasian water-milfoil, that are poised to colonize or spread from localized populations in southern Nevada.

Even less research has focused on the effects of invasive and non-native animals within the Mojave Desert; most information must be inferred from studies done in other regions, which can pose extrapolation problems. For example, ecological effects of non-native wild horses, burros, and cattle may differ in the more arid Mojave Desert from elsewhere in the Intermountain West where most of the studies on these species have occurred. In contrast, some species that are generalist predators likely have similar effects wherever they occur. Species such as feral dogs may pose obvious threats to prey species such as individual desert tortoises, but it is much more difficult to estimate their effects on desert tortoise populations. In general, the net effects of invasive animals on natural resources of value are of ultimate concern, yet there is very little information available to make these predictions.

Among the five strategic goals for invasive species management identified by the National Invasive Species Council (2008), there is probably the least urgent need for new information regarding prevention and organizational collaboration. There is somewhat of a need for information on control and management, although numerous control studies from both within and beyond southern Nevada provide decent information on how to control some of the most problematic perennial invasive species (e.g., tamarisk). Effective control strategies for annual invasive species remain limited by soil seedbanks that often elude control treatments and ongoing stressors that promote the spread and persistence of these species. The greatest need is for information to help inform early detection and rapid response and restoration efforts including minimizing or eliminating stressors. The former requires knowledge of the areas that are most susceptible to invasion and an understanding of the potential effects of newly invading species to prioritize efforts to monitor and control them. Unfortunately, published literature may not always be the best source of data because species that are documented to cause significant problems in other ecosystems may or may not do the same in southern Nevada. Local assessments are clearly needed. Restoration treatments could provide the ultimate defense against invasions because robust native communities are more resistant to invasion than are depleted communities. Unfortunately, restoration actions have a high degree of failure in the Mojave Desert without significant investments of time and funding, which is often a limiting factor. The specific aspects of native communities that confer the greatest resistance to invasion are just beginning to be understood (e.g. Abella and Newton 2009; Abella and others 2012). Thus, information is most needed to address prioritization and restoration actions tailored for southern Nevada, and to understand how various stressors described in Chapter 2 interact with and affect species invasions.

Management Implications

Prevention is clearly the first line of defense against invasive species. The most effectively managed invasive species are those that are kept from being transported to, and colonizing within, southern Nevada. Species can be transported accidentally by people and equipment, and this mode of transport can be minimized by washing tools and vehicles, especially when leaving sites with known local infestations. Other species can be transported purposefully into a region, then spread on their own into wildland areas. These purposeful transportations can be discouraged by preventative regulations for state and Federal noxious species. Success may also be realized through public education and partnerships with the agricultural and ornamental horticultural community for other high priority species to help find less invasive alternative species.

Early detection and rapid response requires significant pre-planning to be effective. Prioritization is necessary to focus detection efforts on sites that are most invasible and species that are most likely to cause significant management problems if they are allowed to colonize, establish, and spread. Information provided in the introduction section explains how the effectiveness of early detection monitoring plans can be maximized.

Control and management also require prioritization to triage nascent populations for rapid response control actions. It is also important to continue monitoring and retreating these areas for a few years to ensure there are no surviving individuals. Ideally, monitoring should be designed to evaluate the efficacy of control treatments, and adjust them accordingly in the future. If the ultimate objectives of control treatments are to benefit other species (e.g. natives), biodiversity (e.g. native species diversity), or ecosystem properties (e.g. reduce fire spread potential), then those factors should also be targeted for monitoring to determine if objectives are met.

Restoration of robust native ecosystems can increase the resilience of degraded areas to subsequent biological invasions. Unfortunately, the specific factors that increase resistance to invasion are poorly understood, so restoration guidelines are generally focused on maximizing characteristics like abundance and diversity of native species, diversity of functional types, and groups of species important for critical aspects of ecosystem function (e.g. nutrient cycling). All restoration projects should be carefully monitored to both determine if their restoration targets are achieved and to evaluate their effects on invasion resistance.

Organizational collaboration is required to effectively manage invasive species because they truly know no political boundaries, and if neighboring land owners are not doing their part, then efforts to prevent invasions and the problems that follow will often be in vain. Sharing resources and expertise by Federal and local agencies through cooperative agreements and through the interagency Southern Nevada Restoration Team can assist with the process of collaboration. Cooperative Weed Management Areas (CWMA) are formal groups that can also facilitate this process, especially in ensuring that species priorities are consistent across land management units and that coordinated management plans are maintained over time.

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