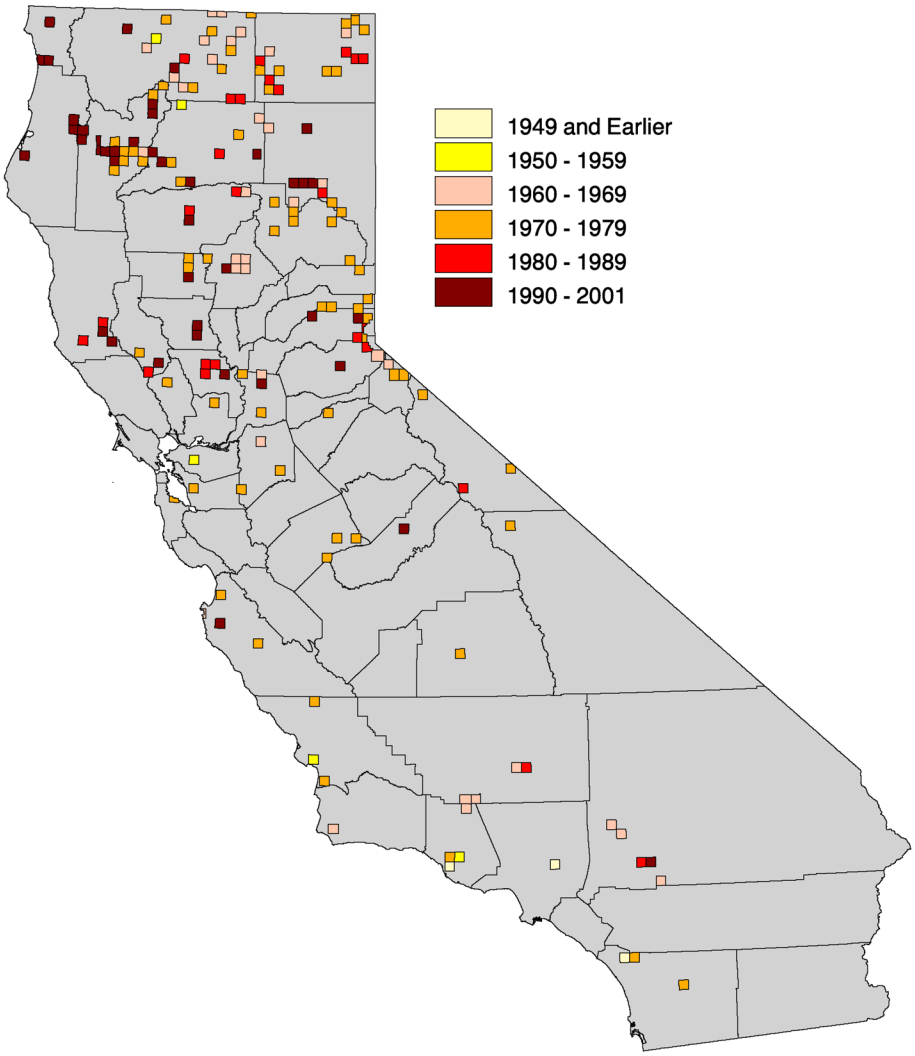
Dalmation toadflax

Dalmation toadflax (*Linaria genistifolia*) (California Department of Food and Agriculture Noxious Weed List) is found throughout California with the exception of the Great Basin and desert regions (Figure 7). This species is native to Europe and was introduced to North America as an ornamental in the mid to late 1800s but escaped cultivation. This species invades disturbed open sites, fields, pastures, and degraded rangelands where soils are generally coarse with neutral to slightly alkaline pH. Overgrazing, soil disturbance, or removal of established vegetation enhances survival of seedlings and is closely related to the invasion potential of this species. Dense infestations reduce grazing capacity and result in displacement of native plants. Grazing may facilitate dispersal since the small seeds are carried on the animal or through its digestive system.

Figure 7. Expansion of Dalmatian toadflax (1949-2001)

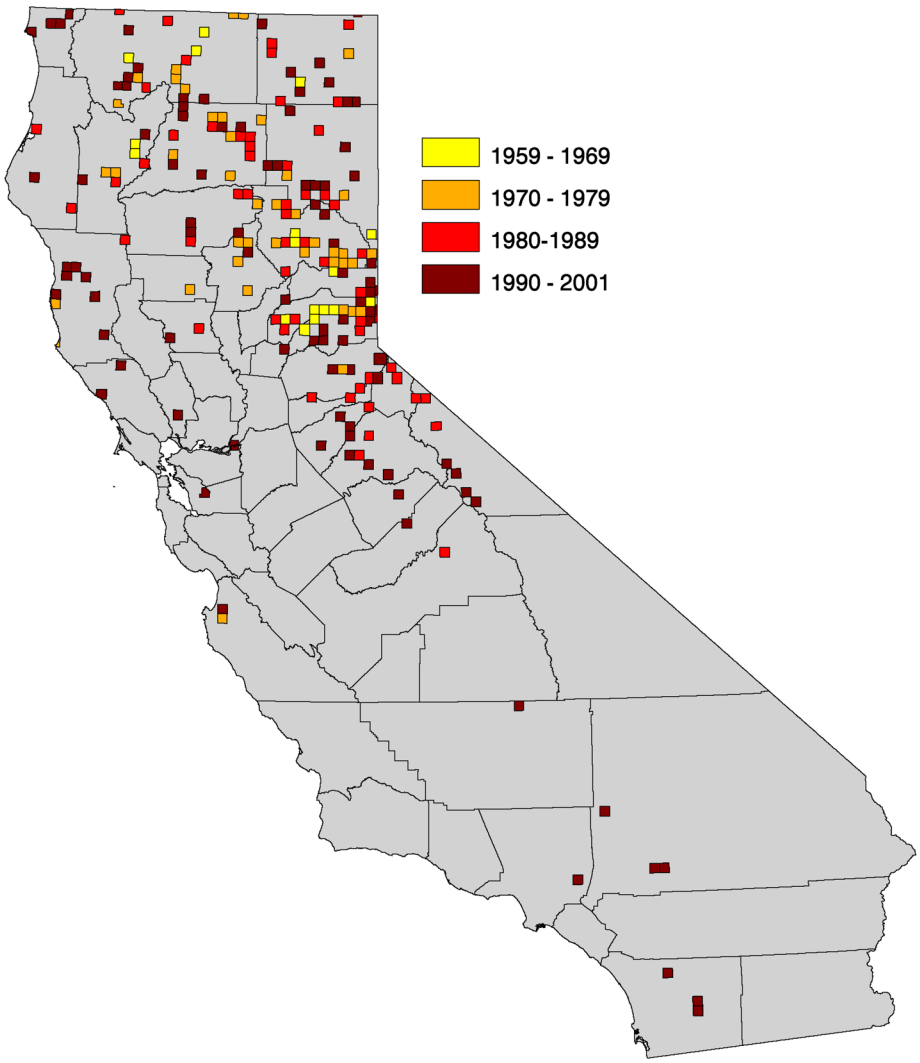


Source: CDFA, 2002a

Spotted knapweed

Spotted knapweed (*Centaurea maculosa*) (California Exotic Pest Plant Council Red Alert and California Department of Food and Agriculture Noxious Weed List) is found in scattered populations throughout much of California typically to 6,500 feet in elevation (Figure 8). This species, introduced from Europe, rapidly establishes itself in disturbed roadside, rangeland, wildland, or recreation areas. Seed production may range from 1,000 to 18,000 seeds per plant. Seed or plant fragments are transported to new areas of infestation via attachment to vehicles or by transporting contaminated animal forage. Although this species does not present a significant nuisance in agricultural cropping areas, the species will proliferate in non-crop areas of soil disturbance.

Figure 8. Expansion of spotted knapweed (1959-2001)

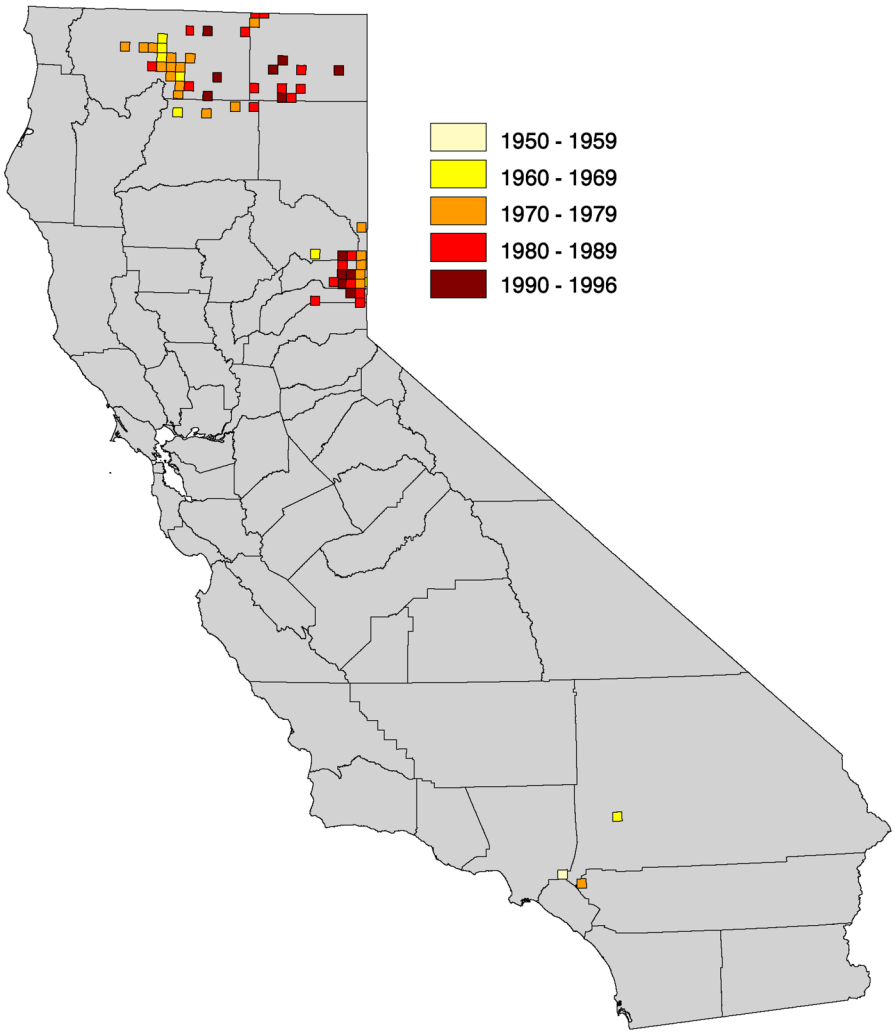


Source: CDFA, 2002d

Musk thistle

Musk thistle (*Carduus nutans*) (see California Exotic Pest Plant Council List A and California Department of Food and Agriculture Noxious Weed List) originated from Europe and typically colonizes disturbed soils, roadsides, pastures, and annual grasslands (Figure 9). This species is found in elevations up to 4,000 feet within the Klamath and Cascade Ranges, the northern Sierra Nevada mountains, and the Modoc Plateau. The musk thistle reproduces by seed that is dispersed by wind, water, wildlife, and human activity. Musk thistle seeds possess allelopathic properties in that they can inhibit germination and growth of other plant species but stimulate or have no effect on germination or growth of their own species. The species, in areas of heavy infestation, may induce a long-term decline in soil nitrogen input, thereby creating conditions that favor their proliferation.

Figure 9. Expansion of musk thistle (1950-1996)



Source: CDFA, 2002b

Efficient and effective control programs and strategies are characterized by efforts that prevent invasions and quickly detect new occurrences.

Efficient and effective control programs and strategies are characterized by efforts that prevent invasions and quickly detect new occurrences so that the species may be removed or contained before spreading (Randall and Hoshovsky, 2000). The CDFA prioritizes species and program efforts based on criteria of potential for spread and effectiveness of available control mechanisms. The highest priority is given to species whose populations have not spread extensively and/or can be readily controlled. Some species such as yellow starthistle, with the possible exception of developing biological control techniques, are beyond conventional means of large-scale control or eradication. Native species will be better protected if new non-native species that pose a threat are recognized quickly and action taken to prevent or slow their spread (Randall and Hoshovsky, 2000).

Findings on exotic animal species

Non-native animal species are also increasingly recognized as one of the principal threats to the maintenance of biological diversity (Table 1, Figure 10). Overall, approximately 14 percent of California's animal (terrestrial and aquatic vertebrate) species are established non-natives.

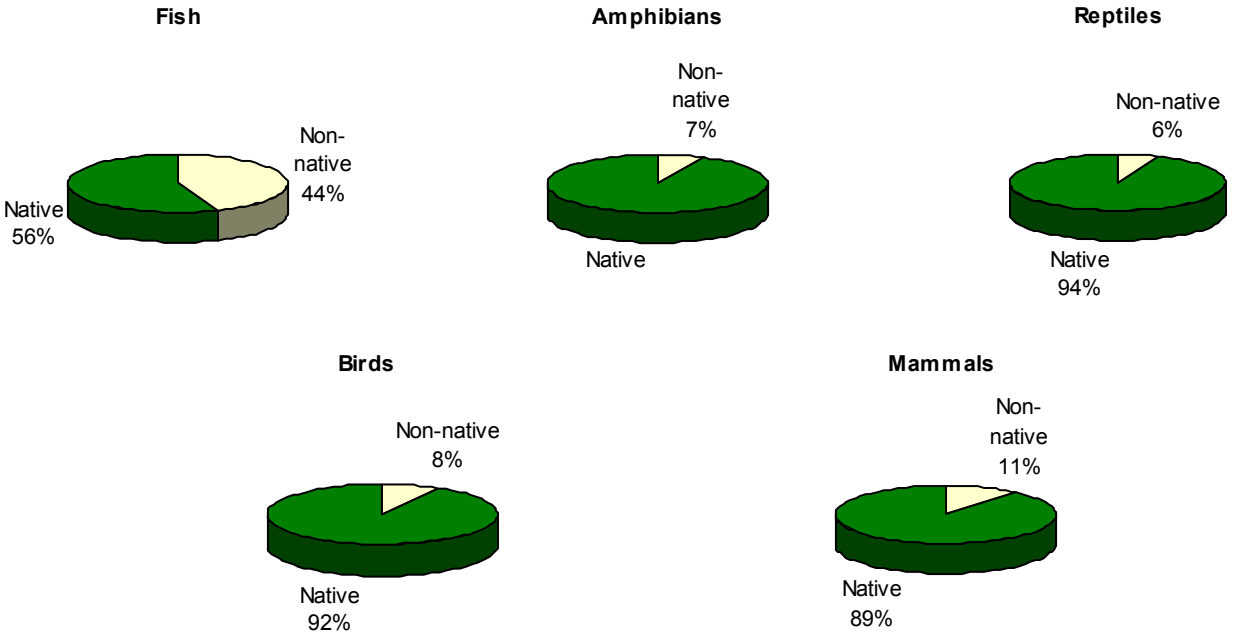
Table 1. Established (sustained breeding populations) non-native animal species

Species*	Native	Non-native	Total	Non-native percentage of total	Native percentage of total
Fish**	66	51	117	44	56
Amphibians	52	4	56	7	93
Reptiles	83	5	88	6	94
Birds	289	25	314	8	92
Mammals***	166	21	187	11	89

**Does not include subspecies*
***Includes freshwater, estuarine, and anadromous*
****Does not include 32 non-breeding marine mammals or introduced subspecies*

Source: Grenfell et al., 2000; Moyle and Davis, 2000; Moyle 2001; California Bird Records Committee, 2000; Jurek, 1992

Figure 10. Proportion of established non-native animal species by taxa



Source: Grenfell et al., 2000; Moyle and Davis, 2000; Moyle, 2001; California Bird Records Committee, 2000

Fish

Northern pike. Photo courtesy of California Department of Fish and Game.

Introduction of non-native fish species is considered one of the three main reasons (habitat change and over-fishing being the other two) for the endangerment or extinction of what once were some of the most abundant native fish species in aboriginal California (Moyle, 1976). Introduced fish species make up 53 of the 120 freshwater species found in California (Moyle and Davis, 2000). These species, now the most abundant fish in many of California's waterways, were introduced primarily to improve sport and commercial fishing, as an agent of pest control, for agriculture, or by accident. The introductions have generally worked in concert with habitat degradation to force the extirpation or extinction of native species through introduction of disease, competition for food or space, predation, habitat change brought about by the introduced species, or genetic swamping through hybridization (Moyle, 1976).

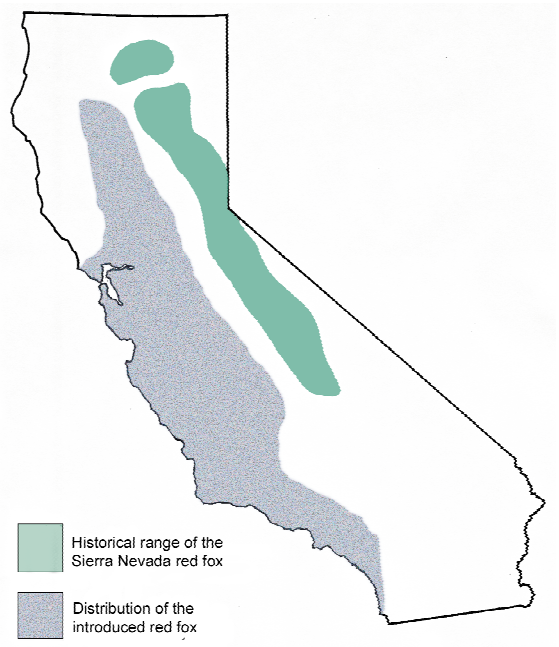
Non-native red fox

Red foxes are the "litmus test that determines whether people are conservationists or animal rights people. If not checked soon, red foxes will account for more extinctions of bird species in the State than any other single factor in history" (Lloyd Kiff, Western Foundation of Vertebrate Zoology) (BioSystems Analysis, 1994). Red foxes are one of the world's most widely distributed and adaptable carnivores. In California, two subspecies can be found—the Sierra Nevada red fox (*Vulpes vulpes necator*) and a non-native

subspecies that appears closely related to those found on the Northern Great Plains (*Vulpes vulpes regalis*). The Sierra Nevada red fox occupies the high elevation coniferous forests of the Sierra Nevada Mountains and the Cascade Range, primarily above 7,000 feet, is very rare, and has been protected as a threatened species under the California Endangered Species Act since 1980. The non-native red fox was introduced to California during the late 1800s and early 1900s for fur farming, live exhibition, and for use in films (Jurek, 1992). Those that escaped or were released from these ventures likely formed the beginnings of the earliest known population in the southern Sacramento Valley in the 1870s.

By the 1970s, the non-native red fox was well established in the Sacramento Valley and the Los Angeles area and was expanding its range. Today, the introduced subspecies is found, in varying population densities, from Shasta County south through the Sacramento and San Joaquin Valleys and southern Sonoma County south to San Diego County. They are considered abundant in the San Francisco Bay area, Monterey Bay area, and southern California coastal counties (Jurek, 1992; Lewis et al., 1993). Figure 11 shows the approximate distribution of introduced red fox as well as the historical range of the Sierra Nevada red fox.

Figure 11. Red fox range



Source: California Department of Fish and Game (DFG), 2000

The introduction and relatively recent range expansion of the introduced subspecies in California provides one example of the successful establishment of a non-native species. Changing land uses, reductions in numbers of predators in and adjacent to urban areas (e.g., coyotes), as well as artificial feeding efforts and relocation by people have ensured the successful establishment of this predator. The non-native red fox, and to a lesser degree other sources of non-native predation, has had a demonstrably negative effect on native species and biological diversity. Examples are numerous (Jurek, 1992) (see Red Fox) and include:

- Predation by non-native red fox and feral cats on the endangered California clapper rail (*Rallus longirostris obsoletus*) in San Francisco Bay marshlands is considered the principal cause for reduction of population levels from 1,200-1,500 in the 1980s to less than 500 in the early 1990s. Following the initiation of predator management, rail numbers rebounded and now number 1,000-1,200.
- Expanding populations near Fresno and Bakersfield have increased predation rates and displacement of the San Joaquin kit fox (*Vulpes macrotis mutica*), a State-listed threatened species.
- Near complete loss of endangered California least tern (*Sterna antillarum browni*) nest production from a Ventura County colony.
- Reduction of endangered light-footed clapper rail (*Rallus longirostris levipes*) populations at the Seal Beach National Wildlife Refuge, Orange County, to only two to seven birds in 1984-1986 prior to intensive fox control efforts.
- Complete loss and abandonment of the largest heron and egret colony located in the San Francisco Bay areas' Blair Island State Ecological Reserve and National Wildlife Reserve.
- In 1990, non-native red foxes were considered responsible for the loss of all Caspian tern (*Sterna caspia*) nests in the Mowrey Slough Caspian tern colony (one of five nesting colonies along the central and northern California coast). Red foxes repeatedly took eggs produced in renesting attempts and the nesting colony was subsequently abandoned (U.S. Fish and Wildlife Service (FWS), 1991).
- Trapping and predator control efforts were not used at the Oakland Airport to protect a California least tern colony and the colony no longer exist. Conversely, a nearby Alameda County least tern colony is protected by trapping efforts and is increasing.

Continuing debate over predator control: Needs for control efforts to protect native species will likely increase in the future as the non-native red fox population increases and distribution in California expands. Recovery of threatened and endangered species and the protection of biological diversity frequently require management of a variety of environmental factors. These include regulating land use, habitat restoration and protection, protection from human disturbance, and depending on the natural history of the species of concern, protection from predation. FWS is involved in a variety of efforts to control non-native red fox and improve habitat conditions for species negatively impacted by the presence of this predator. From 1991-1999, the FWS removed 458 foxes and 136 feral cats from national wildlife refuges in the San Francisco Bay area. As a result, the California rail population has more than doubled (Williams, 1999).

The availability of effective red fox and other predator control methods was significantly challenged with passage of California Proposition 4 in November 1998. This initiative, put forward by animal protection organizations, made it "unlawful for any person, including employees of the federal, State, county or municipal government, to use or authorize the use of any steel-jawed leghold trap, padded or otherwise, to capture any game mammal, fur-bearing mammal, non-game mammal, protected mammal, or any dog or cat." The initiative prohibited the use of padded leghold traps, used by wildlife managers to protect endangered species and other vulnerable wildlife from mammalian predators. Subsequent to passage of the initiative, the National Audubon Society and FWS sought and received a U.S. District Court ruling that permitted the use of padded leghold traps.

This ruling by the U.S. District Court declared that the prohibitions within Section 3003.1(c) of the California Fish and Game Code (see California Fish and Game Code) cannot be applied to the activities of agencies, employees, or contractors of federal agencies engaged in the management of wildlife on federal lands or in other conservation efforts under federal law. The decision allowed the FWS to use leghold traps to protect federal trust species, which include migratory birds and species listed under the federal Endangered Species Act. This decision is currently under appeal by the animal protection groups that sponsored Proposition 4 (Buffa, 2002).

Wild pig

The wild pig (*Sus scrofa*), an introduced species native to Eurasia, ranges from Humboldt and Shasta counties in the northern part of the State south to Santa Barbara County. The species is also found in lower numbers along the western slope of the Sierra Nevada foothills to the Tehachapis in Kern County and in isolated areas of Siskiyou, Modoc, San Bernardino, Riverside, Ventura, and Los Angeles Counties. Although concentrated in the Coast range, the wild pig is expanding its range in California. Wild pigs are found in at least 48 of the State's 58 counties (DFG, 2001). Preferred habitat includes hardwoods, chaparral, grassland, and riparian areas where cover and a variety of food sources are available.

Wild pig. Photo by G. Donald Bain, University of California at Berkeley

Although wild pigs are a frequently sought after big game species, they compete with a variety of other native species for food, destroy vegetation with their rooting behavior (Graber, 1996), and consume native plants and animals. Of particular concern is the high population density of introduced feral pigs in oak woodland habitats. They create a serious management threat because of their omnivorous diet and rooting disturbance potentially causing severe disturbance to soils and species. They may impact a wide variety of plants and animals directly by consumption and indirectly through increased soil erosion, invasion of exotic plants, and preference to acorns, which impact oak regeneration (Sweitzer and Van Vuren, 2001) (see Feral Pigs and Oak Woodland Vegetation).

California's wild pig population was estimated at nearly 133,000 in 1996 (Waithman et al., 1998) based on known wild pig densities and habitat extent. Hunter survey data describing wild pig kill per unit of hunter effort indicates that until the early 1990s the wild pig harvest has steadily increased as have the number of counties where wild pigs are present (Table 2) (DFG, 2001).

Table 2. Wild pig hunting, harvest and success

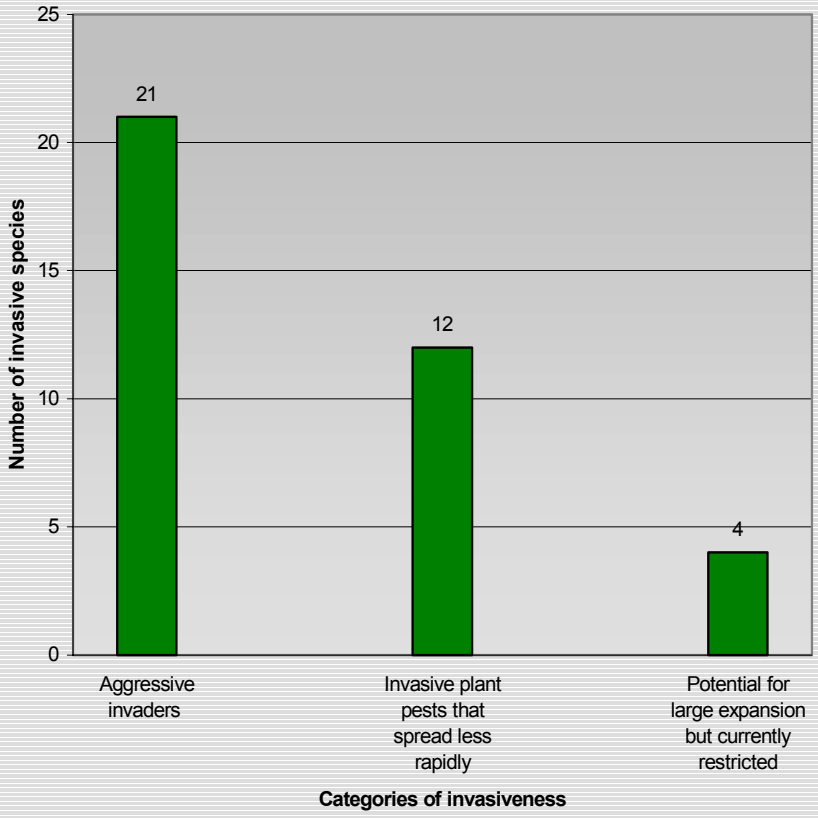
Decade	Average successful hunters	Average unsuccessful hunters	Average total hunters	Average harvest	Average harvest per successful hunter
1957-59	367	2,267	2,633	434	1.1
1960-69	4,250	9,570	13,820	8,940	2.1
1970-79	10,130	17,130	27,260	22,710	2.2
1980-89	15,670	24,426	40,096	40,120	2.6
1990-98	12,656	22,291	35,633	30,311	2.5
1990-99	12,700	21,978	35,296	30,225	2.5

Source: DFG, 2001

Non-native species in the Sierra Nevada mountains

Plants: The low to mid elevations of the Sierra Nevada Mountains are the areas most heavily affected by non-native plant species. Foothill grassland, oak savanna, and riparian habitats on the western slope and lower elevations on the east side of the range are the regions most affected (Figure 12). Non-native plant species presence is most closely associated with the amount and extent of human disturbance (Schwartz et al., 1996). Expansion of human populations into higher elevations of the Sierra combined with a desire for new horticultural varieties that thrive in those environments will likely result in the introduction of new potential plant pests.

Figure 12. Number of invasive plant species in the Sierra bioregion



Source: California Exotic Pest Plant Council, 2002a, 2002b, and 2002c

Fish: The introduction of non-native fish species is considered the single biggest factor associated with native fish declines in the Sierra Nevada Mountains (Table 3). The historically fishless streams and lakes above 6,000 feet in elevation may be the most altered ecosystems of the Sierra Nevada mountains due to native and non-native trout introductions (Moyle et al., 1996).

Thirty species of non-native fishes have been introduced or have invaded most waters including those that were once fishless. While the purposeful introduction of trout into several thousand originally fishless bodies of water has expanded fishing opportunity, it has also caused the decline of aquatic invertebrates and amphibians (Moyle et al., 1996). In addition, of the 20 native species of fish considered to be in decline, introduced species have strong negative effects on half of those species. Introductions of new species of predatory fish continue today. Recent introduction of northern pike (*Esox lucius*) (see Northern Pike), which, if eradication efforts fail, will result in additional changes to California's native fish assemblages (Moyle et al., 1996).

Terrestrial vertebrates: Graber (1996) summarized the status of 15 non-native terrestrial vertebrate species now considered well established in the Sierra Nevada Mountains (Table 3). Of these, four were introduced by DFG as potential game species (wild pig *Sus scrofa*, chukar *Alectoris chukar*, white-tailed ptarmigan *Lagopus leucurus*, and wild turkey *Meleagris gallopavo*). Although many of the introduced terrestrial vertebrate species are limited in their distribution to areas of human habitation or agricultural areas, several, most notably the brown-headed cowbird (*Molothrus ater*), bullfrog (*Rana catesbiana*), and wild pig have had a markedly negative effect on native species in the Sierra Nevada mountains.

Table 3. Non-native vertebrate species established in the Sierra Nevada Mountains and proportion of total fauna by taxa

Type	Native species	Non-native	Percentage of non-native	Non-native species
Fish	40	30	75	American shad, threadfin shad, wakasagi, kokanee, Colorado cutthroat trout, brook trout, lake trout, brown trout, Arctic grayling, common carp, goldfish, golden shiner, fathead minnow, channel catfish, white catfish, brown bullhead, black bullhead, western mosquitofish, striped bass, white bass, Sacramento perch, black crappie, white crappie, green sunfish, bluegill, pumpkinseed, largemouth bass, spotted bass, smallmouth bass, redeye bass
Amphibians	24	1	4	bullfrog
Reptiles	32	0	0	
Birds	225	7	3	chukar, white-tailed ptarmigan, brown-headed cowbird, house sparrow, European starling, rock dove
Mammals	104	8	8	black rat, feral cat,non-native red fox (subspecies regalis), wild pig, muskrat, Virginia opossum, house mouse, brown rat

Source: Graber, 1996; Palazzo, 1994; Moyle et al., 1996

Only one terrestrial vertebrate species, the least Bell's Vireo (*Vireo bellii pusillus*), has been extirpated from the Sierra Nevada Mountains region because of range and population expansion of a non-native species. Although reduction of willow dominated riparian habitat capability likely played a significant role in the decline of the least Bell's Vireo, increasing numbers of brown-headed cowbirds are consistently implicated as a factor in the decline of this species. Brown-headed cowbirds were first noted breeding in California in 1870 and were likely self-introduced. The species expanded its range and population with large-scale changes in land use. Brown-headed cowbirds are a brood parasite that lay their eggs in the nests of other birds. This act leaves the unsuspecting host species to raise the cowbird nestling to the detriment of their own young.

Other preferred host species in the Sierra Nevada Mountains such as the willow flycatcher (*Empidonax traillii*), yellow warbler (*Dendroica petechia*), chipping sparrow (*Spizella passerina*), and song sparrow (*Melospiza melodia*) have also exhibited population declines (DeSante, 1995; Graber, 1996).

The bullfrog, a native of the eastern United States, and introduced for commercial uses is now widespread in California where ponds and slow moving water occur below 6,000 feet. This species has almost completely replaced other native ranid frog species like the foothill yellow-legged (*Rana boylei*) and red-legged frogs (*Rana aurora*) of the Sierra Nevada Mountains. In addition, they are an efficient predator and have been implicated as one of the sources of population decline in western pond turtles (*Clemmys marmorata*).

It is likely that a variety of interacting factors have contributed to the decline of amphibians in the Sierra Nevada Mountains. However, the most important appear to be related to habitat alteration, fragmentation, and the introduction of aquatic predators. The introduction of non-native fishes into Sierran waters is considered a significant threat to aquatic amphibian fauna and limits the distribution and populations of native amphibians. Introduced bullfrogs, fishes, and crayfishes are particularly problematic for many amphibian species because these species did not co-evolve with the suite of aquatic predators they now encounter (Jennings and Hayes, 1994; Jennings, 1996).

Glossary

CDFA: California Department of Food and Agriculture.

DFG: California Department of Fish and Game.

ecosystem components: Kinds and numbers of organisms and physical attributes.

ecosystem function: The operational role of ecosystem components, structure and processes.

ecosystem processes: The flow or cycling of energy, materials, and nutrients through space and time.

ecosystem structure: Spatial distribution or pattern of ecosystem components.

exotic or non-native species: A species of plant or animal introduced from another country or geographic region outside its natural range (Helm, 1998).

extirpation: Driven out or eliminated from an area.

FWS: U.S. Fish and Wildlife Service.

invasive species: A species of plant or animal that is able to proliferate and alter native biological communities and ecosystem function.

native species: A species of plant or animal present prior to European occupation.

noxious weed: A plant defined as a pest by law or regulation.

noxious weed list A: List of plants of known economic importance subject to State enforced action involving: eradication, quarantine, containment, rejection, or other holding action.

noxious weed list B: List of plants of known economic importance subject to: eradication, containment, control or other holding action at the discretion of the individual county agricultural commissioner.

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