Vertebrate species introductions in the United States and its territories

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Abstract At least 1,065 introduced vertebrate species have been introduced in the United States and its territories, including at least 86 mammalian, 127 avian, 179 reptilian/amphibian, and 673 fish species. Examples in each major taxonomic group include domestic cat, small Indian mongoose, red fox, goat, pig, rabbit, rats, house mouse, gray squirrel, nutria, starling, Indian common myna, red-vented bulbul, brown treesnake, red-eared slider, brown trout, tilapia, and grass carp. We briefly review some of these species and the types of damage they cause. We then review the basic types of methods used for control or eradication of each taxonomic group, including physical, chemical, biological, and cultural methods. We discuss some of the challenges in managing these species, including issues with the use of toxicants, land access, public attitudes, and monitoring difficulties. Finally, we list some ongoing research and future research needs, including improved detection methods, improved attractants, improved barriers, improved capture methods, fertility control, and risk assessment methods [Current Zoology 57 (): – , 2011].

Key words Eradication, Introductions, Invasive species, Management, United States

1 Introduction

Vertebrate species have been introduced to almost all parts of the world for thousands of years. The large volume of worldwide trade and transportation has accelerated the rate of introductions in the last 150 years or so. Animals are introduced for many reasons, both purposeful and accidental. Purposeful introductions occur for food and fur, work animals, sport hunting and fishing, companion animals, aesthetics, pets, and pest control. Accidental introductions occur
because of stowaways in transport vehicles, hitch hikers or stow-aways in or on other commodities, escapees, and, in some cases, because of range expansion of a species (often facilitated by human activities and land uses).

While many introduced vertebrate species have provided important resources and economic gains for humans and many do not cause undue adverse effects (especially with appropriate management), some have increased their distribution and have caused serious adverse effects. These include disease and safety hazards, predation and competition with native species, crop consumption and contamination both in the field and during storage, livestock predation, and, in some cases, significant environmental degradation. Unfortunately, for many species of introduced vertebrates, we do not yet know if they are causing, or in the future will cause, significant harm to the environment or human resources. Hence, our frequent use of the term “introduced” rather than “invasive” vertebrate species.

While some lists of vertebrate introductions have been compiled, this has not been done across the various taxa of vertebrates. Additionally, there has generally been little discussion of impacts and control efforts. As political and social awareness has grown, so have efforts to assess introduced species and their economic impacts (e.g., Pimentel et al., 2005). In this paper, we present a list of vertebrate species by taxonomic grouping that have been introduced into the United States and its territories. We also discuss some of the more damaging species and some of the management methods and strategies being used to manage or eradicate invasive vertebrates in the United States. Finally, we consider and discuss some of the remaining challenges in addressing invasive vertebrate management in the United States and some research needs.

2 Vertebrate Species Introduced into the United States

We compiled the list of introduced vertebrate species by taxonomic groups from a variety of sources, including several publications (e.g., American Ornithologist’s Union, 1998; Bury and Luckenbach, 1976; Fuller, 2003; Fuller et al., 1999; Hawaii Audubon Society, 1989; Kraus, 2009; Lever, 1987, 2003; Long, 1981, 2003; Meshaka, 2006; Mooney and Drake, 1986; Moulton and Pimm, 1986; Teer, 2003; Witmer and Lewis, 2001), but also from several federal, state wildlife agency and conservation organisation websites (e.g., www.NIIS.org, www.issg.org, www.nbii.org, www.invasivespecies.net, nas.er.usgs.gov, www.fort.usgs.gov, www.hear.org, myfwc.com). Preliminary lists of common and scientific names of these species were presented in Witmer et al. (2007, non-fish vertebrates) and in Fuller et al. (1999, fish species). Our focus was on the United States mainland and Hawaii, so some of the species introduced to United States territories (e.g., Virgin Islands, Puerto Rico, American Samoa, Guam, and the Commonwealth of the Northern Marianas) have probably been overlooked. An important exception is the inclusion of the brown treesnake Boiga irregularis in Guam as it is a major problem invasive species receiving a considerable investment in research and control efforts. The species list that we have compiled is quite long because we have included many species that are
native to North America, but have been translocated to states, drainages, or regions in which they did not occur historically. We have also included some species that have expanded their historic range in recent decades because, in many cases, this range expansion has been facilitated, at least in part, by the activities and land uses of humans. Many species on this list have failed to reproduce, have been eradicated, or do not have breeding populations. Establishment is often difficult to determine in an area and different agencies use different definitions. For example, Florida agencies use a “10 year rule” of documentation of breeding and establishment in several counties (until it is considered too widespread to be eradicated) before the species is put on its list of introduced and established species. The US Geological Survey’s Nuisance Aquatic Species program defines it as reproducing and overwintering. Others consider establishment to be equivalent to “persisting”, hence long lived species can persist without reproducing or can be maintained through stocking. A large portion of the introduced vertebrates occur in Florida, Texas, California, and Hawaii; however, all states and territories have a number of well-established introductions. While all the reasons for the high numbers of species in Florida, Texas, California and Hawaii are not entirely known, it may be related to factors such as a mild year-round climate which allows animals to survive whether accidently or purposefully released, a climate that allows people to keep wild animals outside year-round and the presence of major live animal port-of-entries. Because of the incompleteness of surveys for introduced species in many areas, our list of species (Appendix 1) is definitely not exhaustive. It should be considered preliminary and we hope to update it periodically. Additionally, some of these introduced populations may die out over time or may be extirpated.

At least 86 species of mammals have been introduced in parts of the United States (Table 1, Appendix 1). Mammals were mainly introduced for sport hunting, but also for food and fur (Kraus, 2003). The largest single group is the ungulates (hooved mammals) with 35 species. This group includes many species used for sport hunting (e.g., aoudad Ammotragus lervia, gemsbok Oryx gazelle, nilgai Boselaphus tragocamelus, eland Taurotragus oryx), but also feral populations of species that were used for work (eg., horses Equus caballus, burros E. asinus) or for food (eg., cattle Bos taurus, pigs Sus scrofa). The second largest group of mammals is the rodents (19), many of which were introduced accidentally via cargo and transport vehicles (commensal rats Rattus spp. and mice Mus musculus), but some were purposefully introduced for fur (e.g., nutria Myocastor coypus). Numerous carnivores (14 species) have been introduced, in some cases for their fur (e.g., foxes Vulpes vulpes, raccoons Procyon lotor), but also in efforts to control pests such as rats and snakes (e.g., mongoose Herpestes auropunctatus, weasels Mustela spp.). There are also large populations of feral, formerly companion animals (e.g., dogs Canis familiaris, cats Felis catus) throughout the United States and its territories. Interestingly, at least 7 species of primates have become established in parts of the United States.

At least 127 species of birds have been introduced in parts of the United States (Table 1, Appendix 1). Most introductions were as pets, but many were introduced for sport hunting (Kraus, 2003). Most of these are passerine birds
(43 species), but many are psitticines (31 species, popular animals in the pet industry). There are also a large number (27 species) of “upland game” (galliformes) birds (both native and non-native) that have been introduced to various parts of the United States. Interestingly, many more avian species have been introduced to Hawaii than the mainland (Lever, 1987). This situation may have changed, however, with the many recent bird introductions in Florida.

At least 179 species of reptiles and amphibians have been introduced in parts of the United States (Table 1, Appendix 1). Most introductions were as pets, but many were also introduced as accidentals in cargo (Kraus, 2003). This is a group of animals that are also very popular in the pet industry. Florida is a very large importer of reptiles and amphibians which may be why that state seems to have the largest number of established species. The largest single group of reptiles and amphibians is the lizards (78 species). Substantial numbers of frog and toad species (42) have also been introduced. Other groups (salamanders and newts, turtles, snakes, crocodilians) comprise smaller numbers (3–26 species) per group.

At least 673 taxa (includes subspecies and hybrids) of fish have been introduced in parts of the United States (Table 1, Appendix 1). This list is derived from the US Geological Survey’s Nonindigenous Aquatic Species database and includes freshwater and marine species from the mainland US, Hawaii, Alaska, Puerto Rico and the Virgin Islands. It comprises all species with documented introductions, even if the introduction is believed to have failed. Hybrids are included if they are stocked as hybrids, but not if the hybrids arise in the wild because of stocking a non-native parent species. About half of these species are non-native to the United States, while the other half are native to the United States, but were translocated from one region to another. While some species of fish were accidental introductions (e.g., round goby Neogobius [Appollonia] melanostomus from sources such as ballast water), most were for sport fishing (e.g., trout Oncorhynchus spp., Salmo spp., Salvelinus spp., bass Micropterus spp.), but many were released pets (e.g., goldfish Carassius auratus, red-bellied pacu Piaractus brachypomus) or bait fish (e.g., numerous species of minnows and shiners) releases (Fuller, 2003). A few were introduced as a food source (e.g., tilapia Oreochromis spp.) and a few species (e.g., grass carp Ctenopharyngodon idella, mosquito fish Gambusia spp.) were widely introduced to control aquatic vegetation or mosquito larvae. The list is dominated by two taxonomic orders (Cypriniformes and Perciformes) comprising at least 400 species (see Table 1).

3 Some Problematic Introduced Vertebrates

A number of species within each major taxonomic group of vertebrates pose serious problems over portions of the United States. We provide a few examples in each group, based on one or more of these criteria: their widespread nature and population sizes, the seriousness of the problems they cause, the amount of investment in prevention and control, and the number of requests of USDA/APHIS Wildlife Services (WS) to deal with specific damage situations.
WS has a mission of reducing conflicts between wildlife and humans for the protection of agriculture, property, human health and safety, and natural resources. WS involvement in invasive vertebrate damage situations was compiled and discussed by Bergman et al. (2002) and Rennie et al. (2004).

Feral cats are found throughout the United States and its territories and cause significant predation of native birds and other native animals (Pimentel et al., 2005; Pitt and Witmer, 2007; Witmer et al., 2005). Likewise, feral dogs can be found in most of the States and territories. They pose human safety issues, prey on livestock, and hybridise with some species of native canids (Pimentel et al., 2005; Witmer et al., 2005). Feral pigs are found in at least half of the states in the US, including some states along the US’ northern border (e.g., Idaho, North Dakota, Wisconsin, Michigan, and New York). They cause serious environmental degradation, prey on native species, damage crops, and pose a disease hazard to livestock and wildlife (Pimentel et al., 2005; Pitt and Witmer, 2007; Witmer et al., 2003). Several species of herbivores (exotic and feral rabbits and introduced nutria) also cause ecosystem and crop damage (Witmer and Lewis, 2001). One or more species of commensal rats and mice occur everywhere worldwide and widely in the United States and its territories. These rodents cause disease and sanitation problems, consumption and contamination of foodstuffs (both in the field and in storage), and property damage (Pimentel et al., 2005; Pitt and Witmer, 2007; Witmer et al., 1995). They have also caused the extinction or endangerment of many endemic species on islands (Howald et al., 2007).

Starlings, pigeons, and house sparrows are found almost worldwide and throughout almost all of the United States and its territories. They are so well established in the United States so as to be considered “naturalised” and many people no longer even consider them invasive species. Nonetheless, they cause sanitation and disease problems, compete with native birds, and consume and contaminate livestock feed (Pimentel et al., 2005; Witmer and Lewis, 2001). Other serious invasive bird problems are of a more localised nature, such as mute swans *Cygnus olor* in several northeastern states. They pose human safety concerns because of their aggressive behaviour and they compete with native bird species (Avery and Tillman, 2005). Populations of monk parakeets have become established in several states where they cause power outages by nesting in transformers (Avery and Tillman, 2005). They also pose a significant threat of crop damage if populations become sizeable in agricultural areas. Finally, ring-necked pheasants were introduced to many states for sport hunting. They cause serious crop damage in some localised situations and may compete for resources with native upland bird species (Witmer and Lewis, 2001).

Perhaps the most widespread invasive amphibian in the United States is the bullfrog *Rana catesbeiana*. While native to the eastern United States, bullfrogs have been introduced to many western states. They prey on many aquatic animal species across all taxa, compete for resources, and have contributed to the threatened or endangered status of many regionally-endemic species of frogs (Pitt et al., 2005; Pitt and Witmer, 2007; Witmer and Lewis, 2001). Other invasive
reptiles and amphibians problems in the United States are much more localised. In Guam, the brown treesnake predates upon, and competes with, native species of vertebrates and has caused the extinction of several of those species; they also regularly cause power outages and pose a safety hazard to people, especially children (Pimentel et al., 2005; Pitt et al., 2005; Pitt and Witmer, 2007). Coqui frogs *Eleutherodactylus coqui* have become well established in Hawaii where their calling all night long disturbs peoples’ rest and has caused a decline in property values (Pitt et al., 2005; Pitt and Witmer, 2007). Several large, aggressive, carnivorous species of reptiles (in particular, Burmese pythons *Python molurus* and Nile monitor lizards *Varanus niloticus*) have become established in parts of Florida. They pose human and companion animal safety hazards, as well as issues of competition and predation with native vertebrate species (Pitt and Witmer, 2007).

The impacts of many of the introduced fish species are unknown, but they can be numerous and significant (Moyle et al., 1986; Fuller, 2003; Fuller et al., 1999). One introduction that people hear perhaps the most about is the sea lamprey *Petromyzon marinus*. This cartilaginous, eel-like fish is native to the Atlantic Ocean, but gained access to the Great Lakes by by-passing natural barriers via man-made canals. The species parasitises native fish such as trout, resulting in large loses of sport and commercial fish. Millions of dollars are spent annually to control sea lamprey (Fuller et al., 1999). Mosquito fish are native to many eastern States, but have been widely introduced into western States to control mosquito larvae. Instead, they have become a significant predator of small native fish, and have even caused the endangerment of numerous species in the western States (Fuller et al., 1999). Brown trout *Salmo trutta* are native to Europe, but were introduced to most States as a sportsfish. They are voracious predators and will eat almost anything they can get in their mouth (Fuller et al., 1999). Blue tilapia *Oreochromis aureus* and other species of tilapia are native to tropical and subtropical Africa, but were introduced to many States as sportfish, a food source, and for aquatic weed control. In some cases, they also escaped or were released from aquaculture facilities. They damage native aquatic vegetation and compete with native fish species for spawning areas, food, and space (Fuller et al., 1999). Likewise, grass carp (native to eastern Asia), were introduced to many states to control aquatic weeds. Instead, they often denude large areas of aquatic plants (Fuller et al., 1999).

### 4 Management and Eradication Methods and Strategies

A wide array of methods is used to manage introduced vertebrates and the damage they cause in the United States. The methods vary somewhat by taxonomic group. Methods include traps and snares, netting, shooting, fishing, frightening devices, decoys, toxicants, dogs, Judas animals, purposely introduced predators, habitat manipulation, barriers, and sterilants. In some cases, cultural methods may also be used (e.g., sanitation, the type of crop selected and the timing of planting and harvest, compensation and insurance programs, etc.). Details on most of these methods, how
they are used, and their advantages and disadvantages were presented by Conover (2002), Dawson and Kolar (2003), Hygnstrom et al. (1994), and VerCauteren et al. (2005). Eradication strategies are more complex and are discussed by taxonomic group.

Management of invasive rodents most often utilises rodenticides, and primarily anticoagulants (Howald et al., 2007). Traps (kill traps, live traps, glue boards) are used in some situations, but to a much lesser extent. These methods are supplemented in and around buildings, with practices of exclusion, sanitation, and habitat modification (Timm, 1994). Day and night shooting is used with some larger species (e.g., nutria; LeBlanc, 1994). Most island eradications have utilised anticoagulant rodenticides-hand broadcast, in bait stations, and/or aerially broadcast (Howald et al., 2007).

A wide array of methods is used for carnivore management and eradication (Nogales et al., 2003; Witmer et al., 2005). Carnivores are captured with leg-hold traps, cage traps and snares. For smaller species, kill traps (e.g., conibear traps) are also used. Shooting (day, night, with calling) is often used. Occasionally, aerial shooting is used. Exclusion is sometimes used, especially to protect small colonies of endangered species. Toxicants are used on a limited basis: toxic baits and the M-44 cyanide device are sometimes used, especially on islands (Nogales et al., 2003; Witmer et al., 2005). A number of methods are not effective with carnivores and rodents (frightening devices, repellents, taste aversion), although research continues on these and other methods. Relatively few carnivore eradications have been attempted in the United States. For example, in the review of 48 worldwide cat eradications on islands, Nogales et al. (2003) reported only three United States islands. However, over a several decades period, introduced foxes have been eradicated from over 40 Aleutian Islands with the use of shooting, traps, and toxic baits (Ebbert, 2000).

A wide array of methods is used for ungulate management and eradication (Butchko et al., 2003; Campbell and Donlan, 2005; Lowney et al., 2005). These include shooting (day, night, over bait, aerial), trapping (individual cage traps, snares, group/corral cage traps), pursuit with dogs, exclusion, food removal, and Judas animals. Eradications have occurred on a few islands and on some sizeable, fenced/contained areas of the mainland (Butchko et al., 2003; Campbell and Donlan, 2005; Lowney et al., 2005; Ramsey et al., 2008). Generally, several methods have been employed to assure success.

Managing birds, even introduced and invasive species, is a sensitive issue because of their charismatic nature and the enthusiasm of bird watchers. Additionally, there are state and federal regulations (e.g., Migratory Bird Treaty Act) protecting many bird species. Methods used to manage invasive bird populations include traps (with or without live bird decoys), shooting, exclusion, and limited use of toxicants (Starlicide [also known as “DRC 1339” from Denver Research Center compound 1339]; Avery and Tillman, 2005; Millet et al., 2004; Pitt and Witmer, 2007; Witmer and Lewis, 2001). Additionally, egg and nest destruction is sometimes used and frightening devices are often used to protect relatively small areas. While few, bird eradications have been conducted in the United States, Millett et al. (2004) used
shooting and toxicants to eradicate invasive common mynahs *Acridotheres tristis* from several small islands in the Seychelles. They noted that larger islands were much more difficult, if not impossible, to eradicate, and that re-invasion was often a problem on all but the most remote islands. The state of Florida has attempted eradication of two species, purple swamphen *Porphyrio porphyrio* and sacred ibis *Threskiornithes aethiopicus* using shooting and trapping by state and federal personnel. To date, efforts to eradicate these two species of invasive birds in Florida have been unsuccessful (Scott Hardin, pers. comm.).

Our tool box for management and eradication of invasive vertebrates is perhaps weakest for amphibians and reptiles (Pitt and Witmer, 2007; Witmer and Lewis, 2001). The most methods development has occurred for brown treesnakes in Guam and coqui frogs in Hawaii (Pimentel et al., 2005; Pitt et al., 2005; Pitt and Witmer, 2007). Trapping, hand-capture or pit fall traps are perhaps most commonly used with amphibians and reptiles. Drift fences are often used to increase effectiveness by directing animals to traps or pit falls. Night search-and-capture with spotlights can be used, and with brown tree snakes, night fence searches are conducted. Detector dogs are used to inspect cargo for brown treesnakes and to help locate Burmese pythons in Florida’s Everglades National Park. Toxicants have been developed and registered for brown treesnakes (acetaminophen) and for coqui frogs (citric acid and hydrated lime solutions; Pitt et al., 2005; Pitt and Witmer, 2007). We are not aware of any eradication of introduced reptiles and amphibians in the United States.

While there are considerable methods that have been developed for invasive fish control, effective control or eradication is seldom achieved because of the complications posed by native species which we do not want to harm excessively (Dawson and Kolar, 2003; Fuller et al., 1999). Some of the methods used include water-level manipulations, barriers, targeted overharvest, stocking predators, sterilants, toxic baits, and gynogenesis (Dawson and Kolar, 2003). Toxicants (piscicides) have been used in some situations for lake-wide invasive or unwanted fish eradication (e.g., Finlayson et al., 2000). Some materials registered for use in the United States include antimycin, rotenone, TFM, and Bayluscide (Dawson and Kolar, 2003). The latter two materials are lampricides developed for invasive sea lamprey control. Generally, multiple methods must be used to achieve a reasonable level of control of the invasive fish species. As with reptiles and amphibians, research is needed to develop more effective and species-specific methods of invasive fish control.

5 Challenges in Addressing Introduced Vertebrates in the United States

While some progress has been, and is being, made with invasive vertebrates in the United States, there are still many challenges and issues to resolve (Pimentel et al., 2005; National Invasive Species Council, 2001). The major emphasis, in terms of attention and funding, for invasive species in the United States has been focused on plants, insects, and
pathogens (Pimentel et al., 2005). This may be because of the greater threat posed by these taxonomic groups to agriculture and human health which are valued more highly than biodiversity or aesthetics. Relatively little effort and resources have been directly dedicated to vertebrates with the main exceptions of brown treesnakes in Guam and feral pigs (on many islands and mainland areas).

Public perception and lack of support have affected efforts to manage or eradicate vertebrate species in the United States, as elsewhere in the world (National Invasive Species Council, 2001). Knowledge levels regarding invasive species and the harm they can cause are relatively low amongst the general public (Conover, 2002; National Invasive Species Council, 2001). Furthermore, the public does not readily distinguish between native and non-native species: as long as an animal looks nice and is not threatening people or causing undue harm, the public tends to view species equally (Wittenberg and Cock, 2001). Regarding importation, once it has been established that a species will not cause undo environmental or human resource harm, it can be placed on a “white” list (Fowler et al., 2007). By and large, species importations are viewed as “innocent until proven guilty” (“gray” list) and what is needed is the development of a much more inclusive prohibited species “black” list (Fowler et al., 2007; Pitt and Witmer, 2007; Witmer and Lewis, 2001). However, the pet industry is a well organised, large, and influential industry in the US (Ginsburg, 2004). Exotic pets are very popular with a sizeable portion of the public. And yet, the pet industry is a major pathway for the introduction of vertebrates into the United States (Kraus, 2003). Very few vertebrate species are prohibited from entry into the United States with a prevailing attitude of “innocent until proven guilty” (Pitt and Witmer, 2007; Witmer and Lewis, 2001). Greater cooperation along with more regulation and enforcement of the pet industry might help remedy this situation (Jenkins, 2007).

The ultimate solution to an invasive species is the eradication of all individuals in a given area; however, much of the public has a strong dislike for the killing of animals (Conover, 2002). Certain species such as feral cats, feral dogs, wild horses, and primates are particularly sensitive species to address. Furthermore, much of the public has a strong fear and distrust of chemicals, and in particular, toxicants. Hence, the management of invasive vertebrates, like all wildlife, is being conducted in an increasingly complex arena (Conover, 2002; Fall and Jackson, 2002).

Access to all relevant land and properties is essential for the successful management and eradication of invasive vertebrates. However, managers often face the situation where the work is needed across a wide array of jurisdictions and ownerships. Getting permission to access all these areas rarely occurs and can prevent the success of even a well-planned, well-funded eradication effort. Furthermore, the land management mandates and regulations of federal and state agencies vary considerably. This affects the type of management activities (burning, chemical use), type of vehicles, and tools (leg-hold traps, firearms, toxicants) that can be used on certain properties. Some laws actually protect invasive vertebrate species, such as the Wild Horse and Burro Act and the Migratory Bird Treaty Act. The latter
was amended in 2004 to exclude protection of some non-native migratory bird species in the United States such as the mute swan. The amendment occurred as a result of findings in a lawsuit focused specifically on halting mute swan control actions in 2003 in Maryland by invoking the Migratory Bird Treaty Act.

Finally, there may be relatively little coordination and cooperation across some jurisdictions and agencies of all levels of government in the United States. Consequently, one of the goals of the National Invasive Species Management Plan (National Invasive Species Council, 2001) is to rectify that situation. Eradicating an invasive vertebrate species is rarely an easy undertaking. Very careful planning is needed, along with adequate resources, public and agency buy-in, highly trained and motivated personnel, contingency plans, and a sustained effort (Broome, 2005). Each situation is unique in one or more ways; hence, a cook-book approach cannot be used (Broome, 2005).

With the possible exception of rodents and ungulates, the methods and strategies used for management, and especially eradication, of invasive vertebrates may benefit from improvement (Wittenberg and Cock, 2001). Much research needs to be conducted to improve detection methods; develop attractants needed to attract individuals to traps, bait stations, and detection stations; and to improve the effective and safe delivery of toxicants, vaccines, and fertility control agents. Trained, rapid response teams are needed for many more invasive species. Accessible databases on potential invasive species are needed that give species identification, biology, ecology, and effective detection and management methods. The databases should also identify expertise and literature that can be consulted. Although a variety of databases and websites exist (Sellers et al., 2005) it would be very useful if these could be centralised and standardised (Sellers et al., 2004). Short of this difficult task, the databases could be made to be searchable from a single portal. Two such efforts are underway and have made significant progress. NISbase (nisbase.org) searches numerous aquatic databases. The Global Invasive Species Information Network (GISIN.org) is building a global system for all species. Finally, risk assessments are needed to determine on which species we should focus our efforts and resources (Hayes, 2003).

6 Conclusions

At least 1,065 species of introduced/invasive vertebrate species occur in the United States and its territories (Appendix 1). We suspect that invasive vertebrate species will continue to challenge land and resource managers, ecologists, and biologists for a long time to come. We also suspect that the list of invasive vertebrate species will continue to grow; but, hopefully, some species will also be removed from the list by being extirpated or by dying out on their own. In the United States, there have been some good successes with invasive species management and eradications, especially on islands, but also on some areas of the mainland. As a result of this, along with our collaborations with international colleagues and a growing interest and involvement by the public and agencies, we are
becoming more knowledgeable and pro-active in responding to invasive vertebrate species. Areas for progress include national organisation and cooperation on these issues, resolving various logistical and financial issues, and improving methods and strategies for many more species.

References


Table 1  Number of vertebrate species introduced into the United States by taxonomic grouping*

<table>
<thead>
<tr>
<th>Taxonomic Group</th>
<th>Taxonomic Order</th>
<th>Number of Species</th>
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<tbody>
<tr>
<td>Mammals (86 spp.)</td>
<td>Didelphimorphia (Opossums)</td>
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<td>Soricimorpha (Shrews)</td>
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<td>Rodentia (Rodents)</td>
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<td>Perissodactyla (Odd-toed ungulates)</td>
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<td>Artiodactyla (Even-toed ungulates)</td>
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<td>Primates (Primates)</td>
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<td>Birds (127 spp.)</td>
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<td>Galliformes (Fowls)</td>
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<td>Caudata (Salamanders, Newts )</td>
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<td>Fishes (673 fish spp.)</td>
<td>Petromyzontiformes (Lampreys)</td>
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<td>Orectolobiformes (Carpet sharks)</td>
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<td>Caracharhiniformes (Ground sharks)</td>
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<td>Polypteriformes (Bichirs)</td>
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<td>Acipenseriformes (Sturgeons, Paddlefishes)</td>
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<td>Semionotiformes (Gars)</td>
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<td>Anguilliformes (Eels)</td>
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<td>Clupeiformes (Anchovies, Herrings)</td>
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<td>Gonorynchiformes (Milkfishes)</td>
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<td>Cypriniformes (Minnows, Suckers, Loaches)</td>
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<td>Characiformes (Leporins and Piranhas)</td>
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<td>Siluriformes (Catfishes)</td>
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<td>Esociformes (Pikes, Mudminnows)</td>
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<td>Osmeriformes (Smelts)</td>
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<td>Salmoniformes (Smolts)</td>
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<td>Gadiformes (Cods)</td>
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<td>Mugiliformes (Mullets)</td>
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<td>Cyprinodontiformes (Killifishes)</td>
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<td>Synbranchiformes (Swamp Eels)</td>
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<td>Perciformes (Perch-like fishes)</td>
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<td>Pleuronectiformes (Flounders, Soles)</td>
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<td>Tetraodontiformes (Puffers, Triggerfishes)</td>
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* See text for a listing of the major references used to compile the species numbers in this table
**Appendix 1  Vertebrate introductions into parts of the United States**

### Part 1  Mammals introduced into parts of the United States

<table>
<thead>
<tr>
<th>Order</th>
<th>Scientific Name</th>
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<td><strong>DIDELPHIMORPHA</strong></td>
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<td>Petrogale penicillata</td>
<td>Gambian giant pouched rat <em>Cricetomys gambianus</em></td>
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<tr>
<td>House shrew</td>
<td>Suncus murinus</td>
<td>House mouse <em>Mus musculus</em></td>
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<tr>
<td><strong>SORICOMORPHA</strong></td>
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<tr>
<td>House shrew</td>
<td>Suncus murinus</td>
<td>Beaver <em>Castor canadensis</em></td>
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<tr>
<td>Pallas’s mastiff bat</td>
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<td><strong>CINGULATA</strong></td>
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<td></td>
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<tr>
<td>Nine-banded armadillo</td>
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<tr>
<td><strong>LAGOMORPHA</strong></td>
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<td>Eastern cottontail</td>
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<td>Stoot ermine, short-tailed weasel <em>Mustela erminea</em></td>
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<td>Lepus americanus</td>
<td>European polecat <em>M. putorius</em></td>
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<td>American mink <em>M. vision</em></td>
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<td>L. europaeus</td>
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<td><strong>RODENTIA</strong></td>
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<td>Fox squirrel</td>
<td>S. niger</td>
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<td>Red squirrel</td>
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<td>Kangarooo rat</td>
<td>Dipodomys ordii</td>
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<td>Clethrionomys rutilus</td>
<td>Camel <em>Camelus bactrianus</em></td>
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<td>Muskrat</td>
<td>Ondatra zibethicus</td>
<td>Axis deer <em>Cervus axis</em></td>
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<td>Polynesian rat kioro</td>
<td>Rattus exulans</td>
<td>Fallow deer <em>Dama. dama</em></td>
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<td>Norway brown rat</td>
<td>R. norvegicus</td>
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<tr>
<td><strong>CARNIVORA</strong></td>
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<tr>
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<td>Canis familiaris</td>
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<td><em>M. putorius</em></td>
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<td><em>M. vision</em></td>
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<td>Jaguarundi <em>Puma yaguaroundi</em></td>
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<td>Feral horse</td>
<td><em>E. caballus</em></td>
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<td><strong>PERISSODACTYLA</strong></td>
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<td>Feral horse</td>
<td><em>E. caballus</em></td>
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<td><strong>ARTIODACTYLA</strong></td>
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<td>Axis deer</td>
<td><em>Cervus axis</em></td>
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### Part 2  Birds introduced into parts of the United States

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<td><strong>PRERISSODACTYLA</strong></td>
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<td><em>C. davaneci</em></td>
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<td>STRIGIFORMES</td>
<td>PASSERIFORMES</td>
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<td>Tiaris olivacea</td>
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<td>Blue-fronted Amazon</td>
<td>Red-crested cardinal</td>
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<td>Red jungle fowl Gallus gallus</td>
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<td>Paroaria coronata</td>
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<td>Orange-winged parrot A. amazonica</td>
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<td>Cardinals cardinals</td>
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<td>Hispanic parrot A. ventralis</td>
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<td>Senegal parrot Poicephalus</td>
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<td>Uraeginthus benglaus</td>
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<td>Dusky-headed parakeet A. weddelli</td>
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<td>Nanday conure black-hooded parakeet</td>
<td>Zebra finch J. subflava</td>
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<td>Black-headed mankin L. malacca</td>
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<td>Warbling silverbill L. malabarica</td>
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<td>Sulphur-crested cockatoo</td>
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<tr>
<td>white-tailed ptarmigan</td>
<td>Cucatua galerita</td>
<td>franciscanus</td>
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</table>
Java sparrow *Padda oryzivora*
House sparrow *Passer domesticus*
European tree sparrow *P. montanus*

Part 3  Reptiles and amphibians introduced into parts of the United States

**ANURA**

American toad *Bufo americanus*
Giant cane toad *B. marinus*
Southern California toad *B. helophillus*
European toad *B. bufo*
Coastal plain toad *B. nebulifer*
Suriname toad *Pipa pipa*
Greenhouse frog *Eleutherodactylus planirostris*
Coqui frog *E. coqui*
Red-eyed coqui *E. antillensis*
Mountain coqui *E. portoricensis*
Rio Grande chirping frog *E. cystignathoides*
Cuban treefrog *Osteopilus septentrionalis*
Rio Grande leopard frog *Rana berlandieri*
American bullfrog *R. catesbeiana*
Northern red-legged frog *R. aurora*
California red-legged frog *R. draytonii*
Pig frog *R. grylio*
Gunther’s frog *R. guentheri*
Northern leopard frog *R. pipiens*
Wrinkled frog *R. rugosa*
Southern leopard frog *R. sphenoecephala*
Wood frog *R. sylvatica*
Black-spotted frog *R. nigromaculata*
Grass (cricket) frog *Fejervarya limnocharis*
Northern cricket frog *Acris crepitans*
American green tree frog *Hyla cinerea*
Barking tree frog *H. gratiosa*
Australian green tree frog *Litoria caerulea*
Eastern dwarf tree frog *L. fallax*
Cuban tree frog *Osteopilus septentrionalis*
Guangdong rice frog *Microhyla pulchra*
Hong Kong whippertail frog *Polypedates megacephalus*
Green and black dart-poison frog
Dendrobatidae australis
Yellow-banded dart-poison frog *D. leucomelas*
Pacitic tree frog *Pseudacris regilla*
Baja California tree frog *Pseudacris hypochondriaca*
Japanese wrinkled frog *Glandirana rugosa*
Red Snouted tree frog *Scinax ruber*
Rio Grande chipping frog *Syrrhopus cystignathoides*
African clawed frog *Xenopus laevis*

**CAUDATA**

Tiger salamander *Ambystoma tigrinum*
Barred tiger salamander *A. mavortium*
Northern dusky salamander *Desmognathus fuscus*
Black-bellied salamander *D. quadramaculatus*
Southern two-lined salamander *Eurycea cirrigera*
Common mudpuppy *Necturus maculosus*
Red-backed salamander *Plethodon cinereus*
Northern gray-cheeked salamander *P. montanus*
Shenandoah salamander *P. Shenandoah*
Japanese fire-bellied salamander *Cynops pyrrhogaster*
Red-skinned newt *Taricha granulosa*

**CROCODILIA**

Spectacled common caiman
Caiman crocodilus
American alligator *Alligator mississippiensis*
American crocodile *Crocodylus acutus*
Nile crocodile *C. niloticus*

**SQUAMATA - SNAKES**

Common boa *Boa constrictor*
Burmesse python *Python molurus*
African rock python *P. sebae*
Reticulated python *P. reticulatus*
Brahminy blind snake
Ramphophis bimaculatus
Javan file snake *Acrochordus javanicus*
Brown treesnake *Boiga irregularis*
Yellow anaconda *Eunectes notatatus*
Green anaconda *E. murinus*
Prairie rattlesnake *Crotalus viridis*
Cottonmouth *Agkistrodon piscivorus*
Southern water snake *Nerodia fasciata*
Northern water snake *N. sipedon*
Diamondback water snake *N. rhombifer*
Brown water snake *N. taxispilota*  
Tessellated water snake *N. tessellate*  
Crab-eating water snake *Fordonia leucobalia*  
Short-headed garter snake *Thamnophis brachystoma*  

**SQUAMATA - LIZARDS**  
Red-headed agama *Agama agama*  
Giant ameiva *Ameiva ameiva*  
Puerto Rican ground lizard *A. exsuls*  
Large-headed anole *Anolis cybotes*  
Green anole *A. sagrei*  

Bark anole *A. distichus*  
Hispanician green anole *A. chloroeycanus*  
Puerto Rican crested anole *A. cristatellus*  
Knight anole *A. eques*  
Jamaican anole *A. grahami*  
Leach’s anole *A. leachii*  
Cuban green anole *A. porcatus*  
Jamaican giant anole *A. garmani*  
Barbados anole *A. extremus*  
Marie Gallant sail-tailed anole *A. ferreus*  
Brown anole *A. sagrei*  
Brown basilisk *Basiliscus vittatus*  
Veiled chameleon *Chamaeleo calyptratus*  
Jackson’s chameleon *Chamaeleo calyptratus*  
Butterfly lizard *Leiolepis belliana*  
Oriental garden lizard *Leiolepis belliana*  
Calotes versicolor  
Blue-crested lizard *C. mystaceus*  
Rainbow whiptail lizard *Leiocephalus carinatus*  
Cremidophorus lemniscatus  
Giant whiptail lizard *C. [Aspidoselis] motaguae*  

New Mexico whiptail lizard *C. neomexicanus*  
Plateau striped whiptail *C. velox*  
Northern curlytail lizard *Leiocephalus carinatus*  
Red-sided curlytail lizard *L. schreibersii*  
Common wall lizard *Podarcis muralis*  
Italian wall lizard *P. sicula*  
Texas horned lizard *Phrynosoma cornutum*  
Black Gray’s spinytail iguana *Ctenosaura similis*  
Mexican spinytail iguana *C. pectinata*  
Green iguana *Iguana iguana*  
Ashy gecko *Sphaerodactylus elegans*  
Ocellated gecko *S. argus*  
Gold dust day gecko *Pseudaactyla laticauda*  
Giant day gecko *P. madagascariensis*  
Orange-spotted day gecko *P. guimbeaui*  
Moorish gecko *Tarentola mauritanica*  
Ringed wall gecko *T. annularis*  
Mourning gecko *T. lugubris*  
Multilating gecko *Gekhrya mutilata*  
Rough-tailed gecko *Cyrtodactylus scabrum*  
Tokay gecko *Gekkko gecko*  
Common house gecko *Gekko gecko*  
Green-necked curlytailed lizard *Leiocephalus cyanus*  
Rough-tailed gecko *Cyrtodactylus scabrum*  

**PETROMYZONTIFORMES**  
Petromyzontidae  
Silver lamprey *Ichthyomyzon unicuspis*  
American brook lamprey *Lampetra appendix*  
Sea lamprey *Petromyzon marinus*  

**ORECTOLOBIFORMES**  
Hemiscyllidae  
Bownanded bamboo shark *Chiloscyllium punctatum*  

**CARCHARHINIFORMES**  
Carcharhinidae  
Pacific sharpnose shark *Rhizoprionodon elongatus*  

**POLYPTERIFORMES**  
Polypteridae  
Bichir *Polypterus delhezi*  

**ACIPENSERIFORMES**  
Acipenseridae  
Sturgeon (eastern species) *Acipenser oxyrinchus*  

**SEMIONOTIFORMES**  
Lepisosteidae  

**Part 4  Fishes introduced into parts of the United States**

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Acipenseridae  
White sturgeon *Acipenser transmontanus*  

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**ACIPENSERIFORMES**  
Acipenseridae  
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**SEMIONOTIFORMES**  
Lepisosteidae  

**Part 4  Fishes introduced into parts of the United States**
Alligator gar *Atractosteus spatula*
Spotted gar *Lepisosteus oculatus*
Shortnose gar *Lepisosteus platostomus*
Florida gar *Lepisosteus platyrinchus*

**AMIIFORMES**

**Amiidae**
Bowfin *Amia calva*

**OSTEOGLOSSIFORMES**

**Hiodontidae**
Goldeye *Hiodon alosoides*
Mooneye *Hiodon tergisus*

**Notopteridae**
Clown knife *Chitala ornata*

**OSTEOGLOSSIDAE**
Arawana *Osteoglossum bicirrhosum*

**ELOPIFORMES**

**Megalopidae**
Tarpon *Megalops atlanticus*

**ALBULIFORMES**

**Albulidae**
Bonefish *Albula vulpes*

**ANGUILLIFORMES**

**Anguillidae**
European eel *Anguilla anguilla*
Shortfin eel *Anguilla australis*
Marbled eel *Anguilla marmorata*
American eel *Anguilla rostrata*
Unidentified eel *Anguilla sp.*

**Muraenidae**
Unidentified moray *Gymnotherax sp.*

**CLUPEIFORMES**

**Clupeidae**
Blueback herring *Alosa aestivalis*
Skipjack herring *Alosa chrysochloris*
Alewive *Alosa pseudoharengus*
American shad *Alosa sapidissima*
Gizzard shad *Dorosoma cepedianum*
Threadfin shad *Dorosoma petenense*
Goldspot herring *Herklotsichthys quadriraculatus*

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**Megalopidae**
Tarpon *Megalops atlanticus*

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Threadfin shad *Dorosoma petenense*
Goldspot herring *Herklotsichthys quadriraculatus*

**COBITIDAE**

Oriental weatherfish *Misgurnus anguillicaudatus*
Chinese fine-scale loach *Misgurnus mizolepis*

**CYPRINIDAE**

Coolie loach *Pangio kuhlii*

**CYPRINIDAE**

Goldfish *Carassius auratus*
Crucian carp *Carassius carassius*
Redside dace *Clinostomus elongatus*
Rosyside dace *Clinostomus funduloides*
Lake chub *Couesius plumbeus*
Grass carp *Ctenopharyngodon idella*
Grass carp x bighead carp *Ctenopharyngodon idella x Hypophthalmichthys nobilis*
Satinfin shiner *Cyprinella analostana*
Whitetail shiner *Cyprinella galactura*
Red shiner *Cyprinella latrensis*
Fieryblack shiner *Cyprinella pyrrhometas*
Spotfin shiner *Cyprinella spiloptera*
Blacktail shiner *Cyprinella venusta*
Steelcolor shiner *Cyprinella whipplei*
Common carp *Cyprinus carpio*
Malabar danio *Danio malabaricus*
Desert dace *Eremichthys acros*
Tonguetied minnow *Esoxolosmus laurae*
Cutlip minnow *Exoglossum maxilligula*
Utah chub *Gila atraria*
Tui chub *Gila bicolor*
Mohave tui chub *Gila bicolor mohavensis*
Lahontan tui chub *Gila bicolor obesa*
Owens tui chub *Gila bicolor nuydryer*
Hot Creek Valley tui chub *Gila bicolor sp.*
Blue chub *Gila coerulea*
Arroyo chub *Gila ounctuiti*
Rio Grande chub *Gila pandora*
Virgin chub *Gila seminuda seminuda*  
California roach *Hesperoleucus symmetricus*  
Brassy minnow *Hybognathus hankinsoni*  
Mississippi silvery minnow *Hybognathus nuchalis*  
Plains minnow *Hybognathus placitus*  
Eastern silvery minnow *Hybognathus regius*  
Bigeye chub *Hybopsis amblops*  
Clear chub *Hybopsis winchelli*  
Silver chub *Hypoptthalmichthys molitrix*  
Bighead chub *Hypoptthalmichthys nobilis*  
Least chub *Iotichthys phlegeothonis*  
Black sharkminnow *Luxilus mexicanus*  
Hitch *Lavinia exilicauda*  
White River spinedace *Lepidomeda mollispinis*  
Big Spring spinedace *Lepidomeda mollispinis pratenisis*  
Ide *Leuciscus idus*  
White shiner *Luxilus albeolus*  
Crescent shiner *Luxilus cerasinus*  
Striped shiner *Luxilus chroscephalus*  
Warpaint shiner *Luxilus coccogenis*  
Common shiner *Luxilus corynus*  
Bandfin shiner *Luxilus zonistius*  
Rosefin shiner *Lythrurus ardens*  
Blacktip shiner *Lythrurus atrapiculus*  
Scarlet shiner *Lythrurus fasciolaris*  
Pinewoods shiner *Lythrurus matutinus*  
Sicklefin chub *Macryhybopsis meeki*  
Pearl dace *Margariscus margarita*  
Spikedace *Meda fulgida*  
Moapa dace *Moapa coriacea*  
Peamouth *Mylocheilus caurinus*  
Black carp *Mylopharyngodon piceus*  
Hornyhead chub *Nocomis biguttatus*  
Bluehead chub *Nocomis micropogon*  
River chub *Nocomis micropogon*  
Bull chub *Nocomis raneyi*  
Golden shiner *Notemigonus crysoleucas*  
Comely shiner *Notropis amoenus*  
Pugnose shiner *Notropis anogenus*  
Popeye shiner *Notropis ariommus*  
Emerald shiner *Notropis atherinoides*  
Rough shiner *Notropis baileyi*  
Red River shiner *Notropis bairdi*  
Bridle shiner *Notropis bifrenatus*  
River shiner *Notropis blennius*  
Bigeye shiner *Notropis boops*  
Silverjaw minnow *Notropis buccatus*  
Smalleye shiner *Notropis buccula*  
Ghost shiner *Notropis buchanani*  
Redlip shiner *Notropis chilicitus*  
Rainbow shiner *Notropis chrosomus*  
Bigmouth shiner *Notropis dorsalis*  
Arkansas River shiner *Notropis girardi*  
Redeye chub *Notropis harperi*  
Eastern blacknose shiner *Notropis heterolepis*  
Spottail shiner *Notropis heterolepis heterolepis*  
Eastern blacknose shiner *Notropis lutipinnis*  
Ozark minnow *Notropis nubilus*  
Sharpnose shiner *Notropis oxyrhythus*  
Ozark shiner *Notropis ozarkamius*  
Club shiner *Notropis potteri*  
Swallowtail shiner *Notropis procne*  
Rosyface chub *Notropis rubellus*  
Saffron shiner *Notropis rubricoe cus*  
Silverband shiner *Notropis shumardi*  
Mirror shiner *Notropis spectrunculus*  
Sand shiner *Notropis stramineus*  
Telescope shiner *Notropis telescopus*  
Weed shiner *Notropis texanus*  
Mimic shiner *Notropis volucellus*  
Coosa shiner *Notropis xenocaecalis*  
Sacramento blackfish *Orthodon microlepidotus*  
Suckermouth minnow *Phenacochilus mirabilis*  
Northern redbelly dace *Phoxinus eos*  
Finescale dace *Phoxinus neogaeus*  
Mountain redbelly dace *Phoxinus oreas*  
Bluntnose minnow *Pimephales notatus*  
Fathead minnow *Pimephales promelas*  
Slim minnow *Pimephales tenellus*  
Bullhead minnow *Pimephales vigilax*  
Woundfin *Plagopterus argentissimus*  
Flathead chub *Platy gobio gracilis*  
Splittail *Pogonichthys macrolepidotus*  
Sacramento pikeminnow *Ptychocheilus grandis*  
Umpqua pikeminnow *Ptychocheilus umpqueae*  
Rosy bar *Puntius conchonius*  
Blackspot bar *Puntius filamentosus*  
Dwarf bar *Puntius gelius*  
Green bar *Puntius semifasciolatus*  
Tiger bar *Puntius tetrazona*  
Relict dace *Relticus solitarius*  
Blacknose dace *Rhinichthys atratulus*  
Longnose dace *Rhinichthys cataractae*  
Speckled dace *Rhinichthys osculus*  
Klamath speckled dace *Rhinichthys osculus klamathensis*  
Lahontan speckled dace *Rhinichthys osculus robustus*  
Bittering *Rhodeus sericeus*  
Redside shiner *Richardsonius balaetus*  
Bonneville redside shiner *Richardsonius balteatus*  
Bonneville redside shiner *Richardsonius balteatus hydrophlox*  
Lahontan redside Richardsonius elegreias*  
Rudd *Scardinius erythrophthalmus*  
Creek chub *Semotilus arromaculatus*  
Fallfish *Semotilus corporalis*  
Leatherside chub *Snyderichthys copei*  
White cloud mountain minnow *Tanichthys albonubes*  
Tench *Tinca tinca*  
*Gyrinocheilidae*  
Chinese algae-eater *Gyrinocheilus aymonieri*  

**CHARACIFORMES**  

**Alestiidae**  
**Congo tetra** *Phenacogrammus interruptus*  

**Anostomidae**  
**Banded leporinus** *Leporinus fasciatus*  

**Characidae**  
**Bloodfin tetra** *Aphyochares anisisti*  
**Banded astyanax** *Astyanax fasciatus*  
**Mexican tetra** *Astyanax mexicanus*  
**Tambauhi Colossoma macrospomum**  
**Black tetra** *Gymnoecorymbus ternetzi*  
**Head-and-taillight tetra** *Hemigrammus ocellifer*  
**Serpae tetra** *Hyphessobrycon serpae*
Granulated catfish
Ripsaw catfish
Brindled madtom
Margined madtom
Tadpole madtom
Orangefin madtom
White piranha
Flat bullhead
White catfish
Corydoras
Red piranha
Yellow bullhead
Black bullhead
Snail bullhead
Ictaluridae
Spotted rafael catfish
Doradidae
Thorny catfish
Raphael catfish
Stonecat
Metynnis
22
Neon tetra
Redeye tetra
Silver dollar
Channel catfish
Pirapatinga, red-bellied pacu
Redhook pacu
Small-scaled pacu
Yaqui catfish
Driftwood catfish
Auchenipteridae
Driftwood catfish
Parauchenipterus galeatus
Callichthyidae
Cascarudo Callichthys callichthys
Green corydoras Corydoras aeneus
Corydoras Corydoras sp.
Brown hoplo Hoplosternum littorale
Clariidae
Walking catfish Clarias batrachus
Whitespotted clarias Clarias fuscus
Doradidae
Spotted rafael catfish Agamyxis pectinifrons
Raphael catfish Platydoras costatus
Ripsaw catfish Pseudodoras niger
Granulated catfish Pterodoras granulosus
Thorntail catfish Pterodoras sp.
Ictaluridae
Snail bullhead Ameiurus brunnneus
White catfish Ameiurus catus
Black bullhead Ameiurus melas
Yellow bullhead Ameiurus natalis
Brown bullhead Ameiurus nebulosus
Flat bullhead Ameiurus platycephalus
Blue catfish Ictalurus furcatus
Yaqui catfish Ictalurus pricei
Channel catfish Ictalurus punctatus
Slender madtom Noturus exilis
Stonecat Noturus flavus
Orangefin madtom Noturus gilberti
Tadpole madtom Noturus gynius
Margined madtom Noturus insignis
Brindled madtom Noturus miurus
Freckled madtom Noturus nocturnus
Flathead catfish Pylodictis olivaris
Loricariidae
Bristlenosed catfish Ancistrus cf. temminckii
Leopard pleco Glytopterichthys gibiceps
Suckermouth catfish Hypostomus plecostomus
Suckermouth catfish Hypostomus sp.
Suckermouth catfish Hypostomus sp. (wattwa group)
Suckermouth catfish Otocinclus sp.
Clown pleco Peckoltia sp.
Southern sailfin catfish Pterygoplichthys anisitsi
Verniculated sailfin catfish Pterygoplichthys disjunctivus
Orinoco sailfin catfish Pterygoplichthys multiradiatus
Amazon sailfin catfish Pterygoplichthys pardalis
Sailfin catfish Pterygoplichthys sp.
Mochokidae
Squeaker Synodontis sp.
Pangasiidae
Iridescent shark Pangasius hypophthalmus
Pimelodidae
Leopard catfish Pterurichthys perruno
Redtail catfish Phractocephalus hemioliopterus
Tiger catfish Pseudoplatystoma fasciatum
Bagre Rhindia quelen
Unidentified shovelnose catfish Sorubim spp.
Firewood catfish Sorubimichthys planiceps
Schilbeidae
False Siamese shark Platypocephalus siamensis
ESOCIFORMES
Esocidae
Redfin pickerel Esox americanus americanus
Grass pickerel Esox americanus vermiculatus
Northern pike Esox lucius
Tiger musklunge Esox lucius x E. masquinongy
Northern pike x amur pike Esox lucius x E. reichertii
Muskelunge Esox masquinongy
Chain pickerel Esox niger
Amur pike Esox reichertii
Umbridae
Alaska blackfish Dallia pectoralis
Olympic mudminnow Novumbra hubbsi
Central mudminnow Umbra limi
OSMERIFORMES
Osmeridae
Wakasagi Hypomesus nipponensis
Delta smelt Hypomesus transpacificus
Rainbow smelt Osmerus mordax
Ayu Plecoglossus altivelis
SALMONIFORMES
Salmonidae
Vendace Coregonus albula
Cisco Coregonus artedi
Lake whitefish Coregonus clupeaformis
Powan Coregonus lavaretus
Maraena whitefish Coregonus maraena
Golden trout Oncorhynchus aguabonita
Cutthroat trout Oncorhynchus clarkii
Yellowstone cutthroat trout Oncorhynchus clarkii bowvieri
Fine-spotted Snake River cutthroat trout Oncorhynchus clarkii carmichaeli
Lahontan cutthroat trout Oncorhynchus clarkii lewisi
Colorado River cutthroat trout Oncorhynchus clarkii pleuriticus
 Paiute cutthroat trout Oncorhynchus clarkii seleniris
Bear Lake cutthroat trout Oncorhynchus clarkii ssp. 1
Pikes Peak cutthroat trout Oncorhynchus clarkii ssp. 2
Greenback cutthroat trout Oncorhynchus clarkii stomias
Bonneville cutthroat trout Oncorhynchus clarkii utah
Rio Grande cutthroat trout Oncorhynchus clarkii virginalis
Gila trout Oncorhynchus gilae
<table>
<thead>
<tr>
<th>Species</th>
<th>Genus</th>
</tr>
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<tbody>
<tr>
<td>Apache trout Oncorhynchus gilae apache</td>
<td>GADIFORMES</td>
</tr>
<tr>
<td>Pink salmon Oncorhynchus gorbuscha</td>
<td>Gadidae</td>
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<tr>
<td>Chum salmon Oncorhynchus keta</td>
<td>burbot Lota lota</td>
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<tr>
<td>Coho salmon Oncorhynchus kisutch</td>
<td>MUGILIFORMES</td>
</tr>
<tr>
<td>Cherry salmon Oncorhynchus masou</td>
<td>Striped mullet Mugil cephalus</td>
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<tr>
<td>Rainbow trout Oncorhynchus mykiss</td>
<td>White mullet Mugil curema</td>
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<tr>
<td>Coast rainbow trout Oncorhynchus mykiss irideus</td>
<td>Kanda Valamugil engeli</td>
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<td>Kamloops trout Oncorhynchus mykiss kumloops strain</td>
<td>ATERINIFORMES</td>
</tr>
<tr>
<td>Redband trout Oncorhynchus mykiss ssp.</td>
<td>Atherinidae</td>
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<tr>
<td>Little Kern golden trout Oncorhynchus mykiss whitei</td>
<td>Mesa silverside Chiromotoma jordani</td>
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<tr>
<td>Kokanee, sockeye Oncorhynchus nerka</td>
<td>False grunion Colpichthys regis</td>
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<tr>
<td>Chinook salmon Oncorhynchus tsawytscha</td>
<td>Brook silverside Labidesthes sicculus</td>
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<tr>
<td>Round whitefish Prosopium cylindraceum</td>
<td>Gulf grunion Leuresthes sardina</td>
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<tr>
<td>Bonneville cisco Prosopium gumiifer</td>
<td>Rough silverside Membras martinica</td>
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<tr>
<td>Mountain whitefish Prosopium williamsoni</td>
<td>Inland silverside Menidia beryllina</td>
</tr>
<tr>
<td>Ohrid trout Salmo letatica</td>
<td>Melanotaeniidae</td>
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<tr>
<td>Atlantic salmon Salmo salar salar</td>
<td>Black-banded rainbowfish Melanotaenia nigrans</td>
</tr>
<tr>
<td>Landlocked Atlantic salmon Salmo salar sebago</td>
<td>BELONIFORMES</td>
</tr>
<tr>
<td>Sambrown Salmo salar x S. trutta</td>
<td>Adrianichthyidae</td>
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<tr>
<td>Brown trout Salmo trutta</td>
<td>Japanese medaka Oryzias latipes</td>
</tr>
<tr>
<td>Tiger trout Salmo trutta x Salvelinus fontinalis</td>
<td>Belonidae</td>
</tr>
<tr>
<td>Arctic char Salvelinus alpinus</td>
<td>Atlantic needlefish Strongyliura marina</td>
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<tr>
<td>Blueback trout, Sunapee trout Salvelinus aureolus oquassae</td>
<td>Asian needlefish Xenentodon cancila</td>
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<tr>
<td>Bull trout Salvelinus confluential</td>
<td>CYPRINODONTIFORMES</td>
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<td>European species of trout Salvelinus</td>
<td>Aplocheilidae</td>
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<tr>
<td>European sp.</td>
<td>Striped panchax Aplocheilus lineatus</td>
</tr>
<tr>
<td>Brook trout Salvelinus fontinalis</td>
<td>Redtail notho Notobranchius guentheri</td>
</tr>
<tr>
<td>Splake Salvelinus fontinalis x S. namaycush</td>
<td>Cyprinodontidae</td>
</tr>
<tr>
<td>Dolly Varden Salvelinus malma</td>
<td>Devils Hole pupfish Cyprinodon diabolis</td>
</tr>
<tr>
<td>Lake trout Salvelinus namaycush</td>
<td>Sonoyta pupfish Cyprinodon evermus</td>
</tr>
<tr>
<td>Arctic grayling Thymallus arcticus</td>
<td>Desert pupfish Cyprinodon maculatus</td>
</tr>
<tr>
<td>PERCOPSIFORMES</td>
<td>Amargosa pupfish Cyprinodon nevadensis</td>
</tr>
<tr>
<td>Amblyopsidae</td>
<td>Owens pupfish Cyprinodon radiosus</td>
</tr>
<tr>
<td>Spring cavefish Forbesichthys agassizii</td>
<td>Red River pupfish Cyprinodon rubroflaviatilis</td>
</tr>
<tr>
<td>Southern cavefish Typhlichthys subterraneus</td>
<td>Salt Creek pupfish Cyprinodon salinus</td>
</tr>
<tr>
<td>Aphredoderidae</td>
<td>Sheepshead minnow Cyprinodon variegatus</td>
</tr>
<tr>
<td>Pirate perch Aphredoderus sayanus</td>
<td>Flagfish Jordanella floridae</td>
</tr>
<tr>
<td>Percopsidae</td>
<td>Fundulidae</td>
</tr>
<tr>
<td>Trout-perch Percopsis omiscomacys</td>
<td>Northern studfish Fundulus catenatus</td>
</tr>
<tr>
<td></td>
<td>Golden topminnow Fundulus chrysotus</td>
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<tr>
<td></td>
<td>Banded killifish Fundulus diaphanus</td>
</tr>
<tr>
<td></td>
<td>Gulf killifish Fundulus grandis</td>
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<tr>
<td></td>
<td>Mummichog Fundulus heteroclitae</td>
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<tr>
<td></td>
<td>Plains killifish Fundulus kansae</td>
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<tr>
<td></td>
<td>Lined topminnow Fundulus lineolatus</td>
</tr>
<tr>
<td></td>
<td>Blackstripe topminnow Fundulus notatus</td>
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<tr>
<td></td>
<td>Plains topminnow Fundulus sciadicus</td>
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<tr>
<td></td>
<td>Seminole killifish Fundulus seminolisl</td>
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<tr>
<td></td>
<td>Southern studfish Fundulus stellifer</td>
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<tr>
<td></td>
<td>Plains killifish Fundulus zebrinus</td>
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<tr>
<td></td>
<td>Bluefin killifish Lucania parva</td>
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<td></td>
<td>Goodeidae</td>
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<tr>
<td></td>
<td>Butterfly splitfin Ameca splendens</td>
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<tr>
<td></td>
<td>Hiko White River springfish Crenichthys baileyi</td>
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<tr>
<td></td>
<td>Railroad Valley springfish Crenichthys nevadae</td>
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<tr>
<td></td>
<td>Pahrump killifish Empetrichthys latos</td>
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<tr>
<td></td>
<td>Peciliidae</td>
</tr>
<tr>
<td></td>
<td>Pike killifish Belonesox belizanans</td>
</tr>
<tr>
<td></td>
<td>Western mosquito fish Gambusia affinis</td>
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<tr>
<td></td>
<td>Largetspring gambusia Gambusia geiseri</td>
</tr>
<tr>
<td></td>
<td>Eastern mosquito fish Gambusia holbrooki</td>
</tr>
<tr>
<td></td>
<td>Pecos gambusia Gambusia nobilis</td>
</tr>
<tr>
<td></td>
<td>Least killifish Heterandria formosa</td>
</tr>
<tr>
<td></td>
<td>Cuban limia Limia vitatta</td>
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<tr>
<td></td>
<td>Amazon molly Poecilia formosa</td>
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<tr>
<td></td>
<td>Lyretail black molly Poecilia hybrid</td>
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<tr>
<td></td>
<td>Sailfin molly Poecilia latipinna</td>
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<tr>
<td></td>
<td>Black molly Poecilia latipinna x P. velifera</td>
</tr>
<tr>
<td></td>
<td>Tamesi molly Poecilia latipunctata</td>
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<tr>
<td></td>
<td>Shortfin molly Poecilia mexicana</td>
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<tr>
<td></td>
<td>Peten molly Poecilia petenensis</td>
</tr>
<tr>
<td></td>
<td>Guapay Poecilia reticulata</td>
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<tr>
<td></td>
<td>Unidentified poeciliid (hybrid) Poecilia sp.</td>
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<tr>
<td></td>
<td>Mexican molly Poecilia sphenops</td>
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<tr>
<td></td>
<td>Guaru Poecilia vivipara</td>
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<tr>
<td></td>
<td>Porthole livebearer Poeciliopsis gracilis</td>
</tr>
<tr>
<td></td>
<td>Gila topminnow Poeciliopsis occidentalis occidentalis</td>
</tr>
<tr>
<td></td>
<td>Green swordtail Xiphophorus hellerii</td>
</tr>
<tr>
<td></td>
<td>Red swordtail Xiphophorus hellerii x X. maculatus</td>
</tr>
</tbody>
</table>
Platyfish/swordtail *Xiphophorus hellerii* x X. variatus
Southern platyfish *Xiphophorus maculatus*
Platyfish/swordtail *Xiphophorus maculatus* x X. variatus
Variable platyfish *Xiphophorus variatus*
Swordtail platy *Xiphophorus xiphidium*

**Rivulidae**
Argentine pearlfish *Cynolebias bellottii*
Blackfin pearlfish *Cynolebias nigripinnis*
Giant rivulus *Rivulus hartii*
Rio pearlfish *Simpsonichthys whitei*

**GASTEROSTEIFORMES**
Gasterosteidae
Fourspine stickleback *Apeltes quadracus*
Brook stickleback *Culaea inconstans*
Three-spine stickleback *Gasterosteus aculeatus*
Ninespine stickleback *Pungitius pungitius*

**SYNBRANCHIFORMES**
Mastacembelidae
Sportfin spiny eel *Macragnostus siamensis*

**SYNBRANCHIFORMES**
Syntomidae
Asian swamp eel *Monopterus albus*
Asian swamp eel *Monopterus sp. (not albus)*

**PERCIFORMES**
Acanthuridae
Whitespotted surgeonfish *Acanthurus guttatus*
Red Sea surgeonfish *Acanthurus sohal*
Orangespine unicornfish *Naso lituratus*
Sailfin tang *Zebrasoma desjardinii*
Yellow tang *Zebrasoma flavescens*
Brown tang *Zebrasoma scopas*
Sailfin tang *Zebrasoma veliferum*
Yellowtail tang *Zebrasoma santhuri*

**Anabantidae**
Climbing perch *Anabas testudineus*
Twospot climbing perch *Ctenopoma nigropinnosum*

**Belontiidae**
Siamese fighting fish *Betta splendens*
Banded gourami *Colisa fasciata*

**Channaidae**
Northern snakehead *Channa argus*

**Acanthuridae**
Thicklipped gourami *Colisa labiosa*
Dwarf gourami *Colisa lalia*
Paradise fish *Macropodus opercularis*
Pearl gourami *Trichogaster leeri*
Blue gourami *Trichogaster trichopterus*
Croaking gourami *Trichopsis vittata*

**Benniniidae**
Tessellated blenny *Hypoblemnis invemer*
Freckled blenny *Hypoblemnis ionthas*
Fang-toothed blenny *Obmorfanchus ferox*
Blenny *Parablennius thyssanus*

**Carangidae**
Green jack *Caranx caballus*
Paloma pompano *Trachinotus patennis*

**Centrarchidae**
Roanoke bass *Ambloplites rupestris*
Ozark bass *Ambloplites salmoides*
Rock bass *Ambloplites rupestris*
Sacramento perch *Archoplites interruptus*
Flier *Centrarchus macropterus*
Bluespotted sunfish *Enneacanthus gloriosus*
Redbreast sunfish *Lepomis auritus*
Green sunfish *Lepomis cyanellus*
Pumpkinsseed *Lepomis gibbosus*
Warmouth *Lepomis gulosus*
Orangespotted sunfish *Lepomis humilis*
Bluegill *Lepomis macrochirus*
Dollar sunfish *Lepomis marginatus*
Longear sunfish *Lepomis megalotis*
Redear sunfish *Lepomis miniatus*
Shoal bass *Micropterus cataractae*
Redeye bass *Micropterus coosae*
Smallmouth bass *Micropterus dolomieu*
Spotted bass *Micropterus punctulatus*
Largemouth bass *Micropterus salmoides*
Guadalupe bass *Micropterus treucili*
White crappie *Pomoxis annularis*
Black crappie *Pomoxis nigromaculatus*

**Chaetodontidae**
Raccoon butterflyfish *Chaetodon lunula*
Red Sea bannerfish *Heniochus intermedius*
Bannerfish *Heniochus sp.*

**Chromisidae**
Northern snakehead *Channa argus*
Blotched snakehead *Channa maculata*
Bullseye snakehead *Channa marulius*
Giant snakehead *Channa micropeltes*

**Cichlidae**
Blue acara *Aequidens pulcher*
Oscar *Astronotus ocellatus*
Butterfly peacock bass *Cichla ocellaris*
Speckled pavon *Cichla temensis*
Sinaloan cichlid *Cichlasoma beani*
Black acara *Cichlasoma bicirrulatum*
Midas cichlid *Cichlasoma citrinellum*
Midas x mayan cichlid hybrid *Cichlasoma citrinellum x C. argenteus*

**Cichlidae**
Yellowbelly cichlid *Cichlasoma salvini*
Blue-eyed cichlid *Cichlasoma nigrofasciatum*
Convict cichlid *Cichlasoma nigrofasciatum*
Jack Dempsey *Cichlasoma octofasciatum*

**Cichlidae**
Butterfly peacock bass *Cichla ocellaris*

**Cichlidae**
Red devil *Cichlasoma labiatum*
Firemouth cichlid *Cichlasoma meeki*

**Cichlidae**
Moga *Cichlasoma nicaraguensis*

**Cichlidae**
Convict cichlid *Cichlasoma nigrofasciatum*

**Cichlidae**
Yellowbelly cichlid *Cichlasoma salvini*
Blue-eyed cichlid *Cichlasoma spilurus*
Redhead cichlid *Cichlasoma synspilum*

**Cichlidae**
Three spot cichlid *Cichlasoma trimaculatum*
Mayan cichlid *Cichlasoma urophthalmus*

**Cichlidae**
Eartheater *Geophagus sp.*
Eastern happy *Haplochromis callipterus*
Banded jewelfish *Hemicromis elongatus*

**Cichlidae**
African jewelfish *Hemicromis letourneuxii*
Banded cichlid *Heros severus*

**Cichlidae**
Serapemmouth cichlid *Labeospermus sp.*
Golden mbuna *Melanochromis auratus*

**Cichlidae**
Bluegray mbuna *Melanochromis Johanni*

**Cichlidae**
Blue tilapia *Oreochromis aureus*
Longfin tilapia *Oreochromis macrochir*
Mozambique tilapia *Oreochromis mossambicus*

**Cichlidae**
Nile tilapia *Oreochromis niloticus*

**Cichlidae**
Wami tilapia *Oreochromis urolepis horrosum*

**Cichlidae**
Wolf cichlid *Parachromis dossii*

**Cichlidae**
Jaguar guapote *Parachromis =Cichlasoma*

**Cichlidae**
Rainbow krib *Pelvicachromis pulcher*
Zebra mbuna *Pseudotropheus zebra*
Three spot damselfish *Dascyllus trimaculatus*

**Scatophagidae**
Seat *Scatophagus argus*

**Sciaenidae**
Freshwater drum *Aplodinotus grunniens*
Bairdiella *Bairdiella icistia*
Spotted seatrout *Cynoscion nebulosus*
Spotted seatrout x orangemouth corvina
*Cynoscion nebulosus x C. xanthurus*
Gulf corvina *Cynoscion othonopterus*
Shortfin corvina *Cynoscion parvipinnis*
Orangemouth corvina *Cynoscion xanthurus*
Spot *Leiostomus xanthurus*
Highfin kingfish *Menticirrhus nasus*
California corbina *Menticirrhhus undulatus*
Gulf croaker *Micropogonias undulatus*
Atlantic croaker *Micropogonias undulatus*
Black drum *Pogonias cromis*
Black drum x red drum *Pogonias cromis x Sciaenops ocellatus*
Red drum *Sciaenops ocellatus*

Totoaba *Totoaba macdonaldi*

**Scombridae**
Gulf sierra *Scomberomorus concolor*

**Scopaeidae**
Lionfish *Pterois volitans/P. miles*

**Serranidae**
Peacock hind *Cephalopholis argus*
Darkfin hind *Cephalopholis urdeta*
Humpback grouper *Chromileptes altivelis*
Blacktip grouper *Epinephelus fasciatus*
Star-spotted grouper *Epinephelus hexagonatus*

Marquesan grouper *Epinephelus irroratus*
Dwarf spotted grouper *Epinephelus merra*
White-streaked grouper *Epinephelus ongus*
Spotted sand bass *Paralabrax maculatofasciatus*

**Stromateidae**
Pacific butterfish *Peprilus simillimus*

**Zanclidae**
Moorish idol *Zanclus cornutus*

**PLEURONECTIFORMES**

**Paralichthyidae**
Fringed flounder *Etropus crossotus*
Cortez halibut *Paralichthys aestuarius*
Gulf flounder *Paralichthys albignuta*
Southern flounder *Paralichthys lethostigma*
Dappled flounder *Paralichthys woolmani*

**Pleuronectidae**
Diamond turbot *Hypopsetta guttulata*
European flounder *Platichthys flesus*
Starry flounder *Platichthys stellatus*

**TETRADONTIFORMES**

**Balistidae**
Clown triggerfish *Balistoides conspicillum*
Lagoon triggerfish *Rhinecanthus aculeatus*
Bursa triggerfish *Rhinecanthus verrucosus*

**Tetraodontidae**
Masked pufferfish *Arothron diadematus*
Spotted green pufferfish *Tetraodon nigroviridis*