

ADDRESSING STATE FUNDING ASSISTANCE THROUGH THE ARIZONA  
STATE AQUATIC NUISANCE SPECIES MANAGEMENT PLAN:  
AN EXERCISE IN POLICY WRITING

By

Chad Eric King

---

A Thesis Submitted to the Faculty of the  
DEPARTMENT OF SOIL, WATER AND ENVIRONMENTAL SCIENCE

In Partial Fulfillment of the Requirements  
For the Degree of

MASTER OF SCIENCE  
WITH A MAJOR IN ENVIRONMENTAL SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

2002

### STATEMENT BY AUTHOR

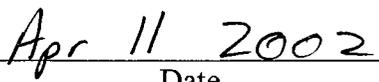
This thesis has been submitted in partial fulfillment of the requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED:  \_\_\_\_\_

### APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

 \_\_\_\_\_  \_\_\_\_\_  
Kevin Fitzsimmons Date  
Professor of Environmental Science

## ACKNOWLEDGEMENTS

I would like to thank the National Fish and Wildlife Foundation for funding the project that included the writing of the Arizona State Aquatic Nuisance Species Management Plan.

## DEDICATION

This one goes out to the one I love.

## TABLE OF CONTENTS

ABSTRACT.....	8
INTRODUCTION.....	9
<b>The History of Aquatic Nuisance Species (ANS).....</b>	9
<b>The Situation in the United States.....</b>	10
<b>The Arizona Situation.....</b>	13
<b>A Case Study From Arizona.....</b>	14
<b>Legal Authorities Dealing With Invasive Species.....</b>	17
<b>Economic Impacts of Nuisance Species.....</b>	21
METHODOLOGY.....	26
<b>Identification of Arizona ANS.....</b>	26
<b>Collaboration with Participating Entities.....</b>	28
<b>General Plan Formatting.....</b>	33
RESULTS.....	35
<b>Arizona State Aquatic Nuisance Species Management Plan.....</b>	36
DISCUSSION.....	83
CONCLUSION.....	86
APPENDIX A: ANS Website.....	90
APPENDIX B: ANS Flyer.....	95
APPENDIX C: ANS Water Bill Insert.....	98
APPENDIX D: ANS Lesson Plans .....	99

APPENDIX E: *Salvinia molesta* and Aquatic Weed Management Areas..... 106

REFERENCES..... 109

## LIST OF ILLUSTRATIONS

Figure 1.1, Homepage for Arizona ANS website.....	90
Figure 1.2, Homepage, part 2.....	91
Figure 1.3, Homepage, part 3.....	91
Figure 2, Links to Information on Threatening ANS.....	92
Figure 3, Links to Other Management Plans and Areas.....	92
Figure 4, Links to Entities Across the U.S. Involved in Nuisance Species.....	93
Figure 5.1, First half of <i>Salvinia molesta</i> Link.....	94
Figure 5.2, Second half of <i>Salvinia molesta</i> Link.....	94
Figure 6, Distribution of <i>Salvinia molesta</i> .....	106
Figure 7, Aquatic Weed Management Area, Arizona.....	107
Figure 8, <i>Salvinia molesta</i> Weed Management Area, Arizona.....	108

## LIST OF TABLES

Table 1, Participating Entities in Addressing ANS in Arizona.....	29
Table 2, Collaborative Meetings for Dealing with ANS.....	32

## ABSTRACT

### Addressing State Funding Assistance Through the Arizona State Aquatic Nuisance Species Management Plan: An Exercise in Policy Writing

Aquatic nuisance species (ANS) represent a growing problem in Arizona that is receiving little funding attention. With the objective of addressing this problem in a coordinated manner between state and federal agencies, the task of writing the Arizona State Aquatic Nuisance Species Management Plan was undertaken, this process and its results will be discussed. Section 1204 of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (P.L. 101-646), provides opportunity for federal cost-share upon adoption of a state management plan. Methodology included gathering input towards reworking an early draft of the plan at a number of meetings, including the Lower Colorado Giant Salvinia Task Force, the *Salvinia molesta* National Convention, and Southwest Vegetation Management Association, and researching the format and process used in writing plans recently adopted in other states. Developments in management needs were incorporated, several of the plan's tasks were initiated and the plan was presented to agency members for comments and review. The resulting management plan is now ready to be signed into action, requiring approval by the state governor as a final step towards providing additional funds to fight ANS.

## INTRODUCTION

### **The History of Aquatic Nuisance Species (ANS)**

The history of human involvement in the transport of ANS and the following devastation of native fauna and flora has been traced back as far as 3000 – 1000 BCE. Loope and Mueller-Dombois (1989) found that humans colonizing Melanesia, Micronesia, and Polynesia carried with them 40-50 species of plants and animals that caused the extinction of approximately 60 species. These early ANS have since caused the extinction of an estimated 1940 more species of the Hawaiian Islands. Crosby (1986) estimated that by as early as 1600 AD, the weed flora that dominated central Mexico was identical to that of the Iberian Peninsula. Early explorers of the New World commonly would carry with them plants and animals such as goats to establish them on islands they would frequent, so as to have a better supply of food flourishing there when they would return.

Worldwide problems of the transport of exotics have increased as methods of transportation became faster and more frequently used. From 1980-1993, 205 new exotic species to the U.S. were identified, increasing the number of exotics in the U.S. to 6600 since the European discovery. This translates to between 2 and 8% of the total biota of the continental US (Cox 1999). Eurasia is the source of the majority of these exotics in the US, accounting for 87.9% of all US exotics (Foy *et al* 1983). In Canada, this changes slightly, with only 79.7% from Eurasia, and 10.7% from Central and South America (Rejmanek *et al* 1991). Exotics are by no means only a North American problem, as 21-

44% of all Southern Australia flora is thought to be exotic, and nearly 47% of the total flora in New Zealand is exotic.

While these recent references have been to exotics, that is not to say that every exotic introduced to an area will become established, much less a nuisance. A general statistical relationship was determined by Williamson and Fitter (1996) to determine the relationship between the rate of spread of exotics and nuisance species. This is commonly known as the tens rule. It states that of all of the kinds of exotic species that are brought into a region, only around 10% of those will appear in the wild. Of those that appear in the wild, only approximately 10% will establish reproducing populations, becoming an introduced species. Finally, out of these populations, only 10% will prove to be significant problem species, otherwise known as nuisance species.

### **The Situation in the United States**

In the US, the establishment of exotics or nonindigenous species (NIS) has had enormous impact economically and environmentally. From 1906-1991, the fight against 79 nonindigenous species (terrestrial and aquatic) has cost the US \$79 billion (ANS Task Force, 2002). The introductions keep getting harder to fight, as 15 recent species could cost \$134 billion by 2050. Yearly costs of fighting NIS are equally astounding, as the US and Canada spend \$12 million/year on controlling sea lamprey. Purple loosestrife alone costs the US \$45 million/year in management cost and lost forage. Six federal agencies spend \$11 million/year on weed related expenses. Zebra mussel control/adaption costs to major raw water users in the Great Lakes are \$30 million/year, and if the ruffe population

in the Great Lakes becomes fully developed, the expected decreased value of fisheries is \$119 million (ANS Task Force, 2002).

ANS also cause severe ecological damage that may be difficult to quantify monetarily. ANS impact native species by out competing them for natural resources, by crowding them out of areas they once inhabited, by altering natives' genetic integrity with crossbreeding, and by altering the base of native food chains, at times endangering higher order species. Many times the aggressive reproductive nature of these invasives, coupled with their lack of natural predators simply allows them to spread like wildfire. Such is the case with species such as purple loosestrife, which can produce up to 2.7 million seeds per plant yearly allowing established populations to spread across approximately 480,000 additional hectares of North American wetlands each year. The tamarisk species are also notorious for their reproduction rate, as they produce viable seeds within a year of sprouting. When established a mature plant can produce over half a million seeds annually (Crawford *et al* 1996). Vegetative reproduction also allows many of these noxious species to spread rapidly. Such is the case with many of the aquatic weeds such as *Salvinia molesta*, Eurasian watermilfoil, and hydrilla. Tamarisk species are also able to reproduce from adventitious shoots off of its widespread root system.

The rate of growth of these ANS is another method of out competing the native populations. *Salvinia molesta* can double its coverage area in less than three days. Salt cedar plants can grow 10-13 feet in their first year. In the seventies in Orange Lake, Florida, hydrilla went from a new introduction to covering 90% of the lake's surface

waters. From 1990 to 1993, tropical soda apple infestations in Florida expanded from 25,000 acres to 150,000 acres. Including terrestrial plants, the rate of infestation of Federal lands by weeds is currently around 4,600 acres per day (ANS Task Force, 2002). The decimating potential of such species are evident as a sole result of growth rates.

Species such as the lake trout cause several additional harmful impacts. In Yellowstone Lake, Wyoming, it is causing the decline in native Yellowstone cutthroat trout populations. Besides threatening a world-famous fishery, it is displacing an important niche in the food chain. The cutthroat trout are a food source for 42 mammals and birds in the area, including the endangered grizzly bear and bald eagle. Many of these species rely on the cutthroat, a food niche that will not be filled by the lake trout (ANS Task Force, 2002). Trout stocking in the White Mountains of Arizona, the native range of the Apache trout have led to hybridization of the native populations, threatening the integrity of the Apache trout. In fact, of 31 populations sampled in the late 1980s, 20 of them showed some levels of hybridization (Carmichael *et al* 1993). Therefore, long term effects of invasive populations must not be overlooked, both in impacts to regional food webs, and through genetic pollution.

Many of these ANS also inhibit attempts at restoration of native or endangered species. In the southwest, the salt cedar and Russian olive species have proven to be problematic to efforts to restore native cottonwood and willow stands. In Lake Mojave on the Colorado River, channel catfish, black bullheads and rainbow trout are predators limiting the survival of the endangered humpback chub (Minckley *et al* 1991).

## The Arizona Situation

Aquatic nuisance species are an immediate and a future threat to the state of Arizona. Because of the relative lack of water habitat in the state and because of a lack of knowledge about which species are native and often endemic to this region, these invasions have not been given proper attention or funding. Much controversy arises when discussing many of the nuisance fish species, which are also some of the most sought after sport fish, but agreement can be reached on a number of other species that are in the state, or threatening to enter. Many of these are aquatic weeds, such as hydrilla, Eurasian water milfoil, parrotfeather, purple loosestrife and *Salvinia molesta*. Others are invertebrates such as the virile crayfish, Asian clam and the infamous zebra mussel. Aquatic nuisance species also include amphibian species such as the bullfrog. Several of these species have been introduced to Arizona waters, but not all of them have become established yet. Others such as the zebra mussel have done millions of dollars worth of damage in other areas, and are steadily nearing the state, having been found on trailered boats that have crossed the state (Biology Web Team, 2002). This places us at a critical time of being able to act proactively in our approach to these aquatic invaders, something that is rarely done with nuisance species. In many cases, organization between all agencies involved has been slow in formation, allowing the species to spread beyond the scope of possibility of eradication, causing rising costs orders of magnitude higher than would have been necessary if prevention and rapid response methods were employed. The impacts of aquatic nuisance species threaten to be tremendous in a state

such as Arizona, which gains much electrical power, recreational value, and municipal water from reservoirs and canals, where maintenance costs will greatly increase as invading species spread. These canals can also work as a transportation network to spread these species around the state, further increasing the risk of rapid statewide infestations.

### **A Case Study From Arizona**

One specific and pressing example of the threat of ANS to Arizona is that of *Salvinia molesta*. Commonly known as giant salvinia, Kariba weed, African pyle, aquarium water moss or koi kandy, *Salvinia molesta* D.S. Mitchell is native to southern Brazil, but has been widely distributed to many parts of the world (Mitchell, 1979). Under favorable conditions, this floating water fern can become a devastating aquatic nuisance, disrupting native species as well as human activities by rapidly covering large areas. Capable of explosive growth, *S. molesta* can block waterways, hindering both fishing and recreation (Mitchell *et al* 1980). *S. molesta* was first transported out of its native range in 1939, when introduced by the botany department at the University of Columbo in Sri Lanka (Williams, 1956). It has since moved to Australia, Papua New Guinea, Southern India, Namibia, Botswana and South Africa (Room 1986b, 1990). Experimentation and research into the biological control of this rapidly growing weed, has brought its population under control in each of these countries.

*Salvinia molesta* is a free-floating, clonal fern that can only reproduce vegetatively. Outside of its natural habitat, the plant is eaten by few herbivores, allowing

it to grow unfettered. It thrives in warm, slow moving waters. In most cases the range of this plant is temperature limited, with extremes at -3 and 43°C (Whiteman and Room, 1991) and a preference of 24 to 28°C for optimal growth (Cary and Weerts, 1984). Stands of giant salvinia can double in 2.2 days when supplied with adequate nutrients (Cary and Weerts, 1984). During periods of high growth, leaf size decreases and both leaves and stems fold, doubling and layering to cover more of the water surface (Room and Julien, 1994). This thick growth has proven to be quite harmful to other species, as it blocks light to plants growing below, reduces gas exchange and increases biological oxygen demand as old growth falls to the bottom and decomposes (Thomas and Room, 1986). Additionally, loss of open water has been shown to cause migrating birds to pass over ponds that are no longer visible. For these reasons, the occurrence of *Salvinia molesta* in the U.S. raised immediate concern.

In the US, salvinia has recently become a growing problem, quickly spreading from the first sightings on the east coast, to the west coast in less than five years. This plant has been imported and cultivated in the states as an ornamental plant for aquatic gardens. As it began to be found in the wild, concern was raised. *Salvinia molesta* was first reported in southeastern South Carolina in 1995 in a 1.5 acre pond, making it fairly simple to eradicate with chemical treatment before the plants spread. Next, salvinia was discovered in Texas in a Houston school's demonstration pond in 1997. September 1998 brought discoveries of salvinia on the Texas/Louisiana border at the Toledo Bend Reservoir. In July of 1998 salvinia had shown up in Louisiana. In February 1999, it was determined that the plants in a canal in Florida that were being treated as *Salvinia minima*

were actually *Salvinia molesta*. In 1999, outbreaks were found in Alabama. In April of 1999, salvinia was found on Oahu, Hawaii, where it is threatening the habitat of three endangered waterbird species. The summer of 1999 found the weed spreading through Texas, including reservoirs feeding into irrigation districts. By August of 1999, *Salvinia molesta* was discovered in Georgia, and by September of 2000, three areas of southeastern North Carolina were discovered to have multiple new infestations. In August of 1999, salvinia was found on the lower Colorado River, where it was subsequently traced to a drainage ditch from the Palo Verde Irrigation District (PVID) on the California side of the river (Jacono, 2002). The rate at which *Salvinia* has spread throughout the U.S. has provided impetus for PVID and state and federal agencies in California and Arizona to address the problem quickly. This potential for growth and spread of the weed also provided the motivation behind initiation of writing a state plan for the management of aquatic nuisance species. Problems of funding were highlighted early in the response to the Arizona problem, as treatment strategies were discussed in meetings of the Lower Colorado Giant *Salvinia* Task Force. Budget planning for most agencies is done two to three years in advance, leaving only leftovers for treating such emergencies. In hopes of procuring federal funds to assist the state of Arizona in this matter, the process of creating the Arizona State Aquatic Nuisance Species Management Plan began.

## **Legal Authorities Dealing With Invasive Species**

Executive Order 13112, issued on February 3, 1999 by then president Bill Clinton, is the most recent attempt to draw attention and money to the growing problem of invasive species. This document reiterates and expands on other recent legislation dealing with invasives, namely the federal Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (Public Law 101-646) (NANPCA), which delineated the basic role of federal, regional and state government in the act's implementation. Many legal authorities are involved in the control of ANS in the United States, with varying degrees of effectiveness. In the Department of Agriculture, some authorizations are: the Plant Protection Act (PPA, 7 U.S.C. 7701 *et seq.*) - which consolidated many plant-related statutes to prohibit or restrict the importation or interstate movement of plant species or products; Animal Quarantine Laws (21 U.S.C. 101 through 135b and 19 U.S.C. 1306) – a group of laws that gives authority to regulate importation and interstate movement of invasive animal species, the Multiple-Use Sustained-Yield Act of 1960 (MUSY, 16 U.S.C. 528-531) – covering management of National Forests for multiple uses, including watershed, wildlife and fish purpose; the Federal Noxious Weed Act of 1974 (7 U.S.C. 2814) –that though having been mostly superceded by the Plant Protection act, still requires management of undesirable plant on federal lands; and the Food Security Act of 1985 (16 U.S.C. 3839aa-3839aa-8) – administering the Environmental Quality Incentives Program that deals with prevention, control and restoration of areas impacted by ANS.

The main authorities dealing with the above mandates include USDA Animal and Plant Health Inspection Service (APHIS), and the Forest Service.

Another active participant is the Department of Commerce, with several legal authorizations including: Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA, P.L. 101-636, as amended (16 U.S.C. 4701-4741)) – this act gives the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service (FWS) authority to implement prevention provisions, provides some moneys for control and management, and funds research; the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1855) – providing reviews of actions which could affect essential fish habitat, including ANS; the Fish and Wildlife Coordination Act – which makes funds available for use on projects including invasive species..

Several statutes relating to the transport of certain organisms give the Department of the Interior authority on the issue of invasive species in general. The Lacey Act (18 U.S.C. 42) limits importation and shipment into and between states. However, this law is limited only to specific “wild” animals that may be injurious to resources of the United States, and tends to be limited in its ability to address nuisance species introductions. Another law also known as the Lacey Act (16 U.S.C. 3371 *et seq.*) has the authority to make it a crime to transport and sell certain plants and animals, but is ambiguous in the scope of organisms that it may include. The Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990 (P.L. 101-646, as amended through 10/26/96) also could fit under the auspices of the Department of the Interior with its

potential to affect the introduction and dispersal of invasive species. This act creates a task force with the purpose of minimizing the risk of introduction of ANS. NANPCA makes it clear that ANS are any species not native to a particular region of the US, not limiting the list to only foreign invaders. The Endangered Species Act (ESA, 16 U.S.C. 1531 *et seq.*) is administered by both the Secretaries of Interior and Commerce. When an invasive species proves to be a direct threat to an endangered species, the ESA can become a powerful management tool. The agencies within the Department of the Interior working with ANS include the Bureau of Land Management, the U.S. Geological Survey, the National Park Service, and the Bureau of Reclamation.

The Environmental Protection Agency also has some legal authority. This falls mainly in the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), which proves critical in the treatment – both chemical and biological – of invasive species. The Clean Water Act may also provide authority in protecting wetlands and other aquatic habitats from invasive species. All federal agencies responses to invasive species are controlled by the National Environmental Policy Act (NEPA), which requires agencies to be fully informed of the consequences of their actions before they proceed towards treatment of invasives.

Many global and regional agreements direct the roles of the US in interactions on a larger scale. Some of these include: the Convention on Biological Diversity (CBD), 1993, which provides that each participant shall prevent the introduction of alien species that threaten ecosystems, habitats or species; the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary (SPS) Measures, 1995, calls

for actions that prevent or limit damage through the spread of pests; the International Civil Aviation Organization (ICAO), Assembly Resolution, 1998, where this specialized agency of the United Nations (UN) directed work with of other UN agencies encouraging aviation authorities to assist in the prevention and control of invasive species; and the North American Free Trade Agreement (NAFTA), 1994, calling for the adoption of measures necessary to protect animal or plant life and health, considering relevant diseases and pests.

Of particular interest in the case of addressing the problem of aquatic nuisance species in Arizona is NANPCA. Prevention, monitoring, control, research, technical assistance, and education are all goals of the national task force that was created from NANPCA (Section 1202). This act directly impacted western states through the creation of the Western Regional Panel. The mandate to this panel is to prioritize ANS responses, to work towards prevention of zebra mussel spread west of the 100<sup>th</sup> Meridian, to coordinate ANS work in the west, develop rapid response strategies for addressing new invasions in the region, and provide information for public awareness of ANS (Section 1203).

Section 1204 focuses on the creation, implementation and funding of state management plans. This section allows for Governors of each state, or jointly in collaboration with other states, to prepare and submit a management plan that addresses areas or activities that require technical, enforcement, or financial assistance to eliminate or reduce risks associated with ANS. Specifically, plans are to identify State and local programs to prevent and control target ANS, to identify the need for Federal assistance in

these endeavors, to identify areas of weakness in regards to authority to control the spread of these organisms, and to provide a schedule for implementing the plan, with annual objectives that will be updated. Consultation in creation of the plan is called for by state, local and federal organizations that have expertise in these matters. State plans must be approved by the national ANS Task Force, after which they may qualify the state for state grants. Federal cost share is also provided to all states with approved management plans, which currently is disseminated by evenly splitting a set amount of federal money between all states with management plans. While this plan was originally enacted with the main purpose of addressing the rapid spread of the Zebra mussel from east to west, this federal assistance can apply to any ANS, and is one of the factors driving the creation of the Arizona State plan. The financial need became evident in many meetings addressing the outbreak of *Salvinia molesta* in the Colorado River, where all involved agencies required budgets to be made several years in advance, leaving very little for addressing emergencies. Relevant economic impacts with regard to ANS are discussed in more detail below.

### **Economic Impacts of Nuisance Species**

Aquatic nuisance species carry with them a variety of economic impacts. Many of these impacts can be viewed as direct economic losses. ANS may cause crop losses in agriculture (especially in rice production) and aquaculture, or they may require direct treatment to maintain needed functions such as industrial water intake. Other losses are

more difficult to quantify. These include lost recreational areas, health costs and losses in biodiversity as the invaders out-compete native species. This danger of biodiversity loss is highlighted by the fact that approximately 400 of the 958 species listed as threatened or endangered under the Endangered Species Act are considered to be at risk primarily because of competition with and predation by nonindigenous species (TNC 1996, Wilcove *et al* 1998). Along with the problems involved with valuation of biodiversity, only preliminary work has been done investigating the differences in long-term costs when studying the cost variance between attempts at eradication versus trying to slow the spread of species. With aquatic nuisance species, and the wide range of problems that accompany them, as can be imagined, a variety of economic issues are involved in explaining the impacts.

To solve the problem of aquatic nuisance as outlined in Executive Order 13112, much cooperation is required between many of the agencies whose lands are negatively impacted. While no published literature studies the transaction costs involved in the meetings and travel to coordinate cooperation, these are significant costs that must be evaluated. These costs include travel, seminars, meetings, mediators, lost time of agency employees, lodging and food during conferences, and salaries for regional and national level coordinators. An example of this is the number of conferences related to the control of *Salvinia molesta* in Arizona that have taken place in the last year. The Lower Colorado River Giant Salvinia task force of California and Arizona has met several times at the site of the infestation, a national aquatic nuisance species task force has met multiple times across the nation, a national giant salvinia conference took place in Houston, TX,

members of the 100<sup>th</sup> meridian plan (designed to focus on the spread of invasive species westward across the 100<sup>th</sup> meridian) convened, and the southwest aquatic plant management society, the southwest plant management society, and a regional stakeholder group working on the Sonoran Desert Conservation Plan all have held meetings or conferences. When one considers all of the hours of paid time focused on invasive species, as well as the many other transaction costs, it becomes clear that while they fund worthwhile services, these costs will definitely lower the amount of money available for actually combating the problem of aquatic nuisance species, thereby lowering the effectiveness of the available funding.

When determining direct costs of *Salvinia molesta* or other aquatic invaders as they impact cash crops, several economic issues are raised. One of these is the change in supply of goods such as rice or fish when production of these goods is lowered due to invasive species impacts. A decrease in the amount of available space and nutrients for growth of these goods can result in less availability of the goods, which could drive market prices up until weed management can be achieved and production rates increased. Pimental *et al* (2000) quantify direct losses due to aquatic weeds in the United States to be at approximately \$10 million annually, with \$24.4 billion in losses to terrestrial crop weeds, and \$1 billion annual losses to the Asian clam. As losses such as these lower supply, demand for the goods will cause a raise in prices, further impacting the economy.

Another economic issue associated with the treatment of nuisance species is the presence of externalities often associated with certain methods of treatment. This can be exemplified with the attempts to eradicate fire ants from the southern United States in the

late 1950s. In 1957, Congress designated \$2.4 million to the efforts of eradication. Initially heptachlor was applied to ant infested areas, where it caused wildlife and cattle deaths. Next, mirex bait was used, which was also found to harm non-target organisms. By 1977, application costs had climbed to \$200 million, and the range of fire ants had expanded dramatically during the eradication campaign (Simberloff 1996). While several economic examples could be drawn from this unfortunate case, the main issue of relevance is the cost of externalities due to the chemical applications. Wildlife and cattle losses exemplify this negative externality impacting the production of other local goods. In this case the chemicals became an input to the cattle farmers' system, which was out of the farmers control even as it lowered their production, an example of the effect of a negative externality.

A large part of the impact of nuisance species is their impact on public goods. These are goods that are non-excludable (unable to be contained in order to limit visitation), and non-rival (meaning that one person's use of the goods doesn't consume the good, it is still available for others). One of the difficulties of economic analysis of impacts to these goods is the assigning of a price to something that's typically taken for granted, such as air or water quality, use of a hiking trail, or in this case biodiversity and recreational activities. Public goods affected by nuisance species also include public fishing areas, and may include air or soil quality in the case of invasives like the tamarisk, which excludes salt, increasing soil salt concentrations. It also burns rapidly and at a higher intensity than native plants, decreasing air quality. A major part of any economic analysis of invasive species must be the cost of losses or damages to these public goods.

As is evidenced previously, the economics of treating nuisance species are quite complex, often making treatment politicized, if the funds are present for treatment.

## METHODOLOGY

The approach taken towards completion and approval of the Arizona State Aquatic Nuisance Species Management Plan had a threefold focus. First, research was focused on the literature as well as various current websites and personal communication to determine historical references to the presence of ANS, as well as their origin and locations in Arizona. Second, considerable effort was given towards collaboration with involved entities at the local, state, regional and federal levels. This included participation in a number of conferences and meetings in order to best understand what was happening within each of these entities as a means of addressing the ANS problem in the southwest, and Arizona in particular. A third focus was on the process that other states took in the creation of state plans that were approved. Between states and regions, a certain camaradery exists in helping each other find new means for fighting a common evil, namely nuisance species. Assistance between states and regions also proves to be a mutualistic relationship where each can benefit from a neighboring state reducing the spread of ANS.

### **Identification of Arizona ANS**

Identification of nuisance species in Arizona is an area requiring more funding and field studies. The literature contains examples of complete studies of waterways, surveyed for the presence of ANS. However, in the western states, this has only been done for some of the coastal waterways where shipping traffic is high, elevating the

concern of species transport, even through intercontinental methods such as ballast water discharge. Thorough studies have not been completed for Arizona, which is surprising for a state that regulates its water resources so highly. Compiling a list of nuisance species present in the state, and species threatening the state required research, personal communication, and referencing state restricted species lists and current agency websites that monitor ANS distribution.

The Arizona Department of Agriculture has authority over plants in the state, so reference was made to the posted list of noxious weeds, which restricts transport into the state without proper state and federal permits. Arizona Game and Fish has authority over fish and other wildlife, so the posted list of restricted live wildlife was referred to in creating a list of restricted species for the state. Discrepancies between the Arizona Game and Fish restricted list and the agency's actions have the potential to politicize the plan. "Restricted live wildlife" are defined as "living wildlife which has been determined by the commission to be an actual or potentially significant threat to indigenous wildlife by competition, disease or parasites, habitat degradation, predation or impact on population management; or an actual or physical threat, property damage or nuisance..." (Game and Fish Commission, R12-4-401). Included in the restricted live wildlife list (R12-4-406) are "Bass, all species of the family Serranidae," and "Trout, all species of family Salmonidae," which both contain species raised and stocked by Arizona Game and Fish as a part of their mission to provide wildlife resources for the enjoyment, appreciation, and use by present and future generations. In order to reduce conflict and respond to agreed upon nuisance species, the focus of the plan leans heavily towards

aquatic nuisance plants. To compile the list of ANS found in Arizona, references were drawn from the U.S. Geological Service (USGS) Nonindigenous Aquatic Species site, which has been established “as a central repository for accurate and spatially referenced biogeographic accounts of nonindigenous aquatic species. Provided are scientific reports, online/realtime queries, spatial data sets, regional contact lists, and general information” (<http://nas.er.usgs.gov>). Individual species profiles are also available on the National Biological Information Infrastructure (NBII), a branch of the Nature Conservancy (<http://www.invasivespecies.gov/profiles/main.shtml>).

### **Collaboration with Participating Entities**

In order to explore the position of a variety of agencies on the treatment of and response to ANS, it became necessary to learn the mandate of these entities. In order to best address the needs of the state, observations were made to determine the regional activities of participating agencies and stakeholders. Stakeholders in these cases ranged from herbicide applicators to environmental groups concerned with the protection of native species, to persons representing the Bureau of Land Management, the Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Department of Agriculture APHIS, Arizona Department of Agriculture, Arizona Game and Fish, California Department of Food and Agriculture, California Department of Fish and Game, and many other involved agencies and stakeholder groups (Table 1).

Table 1: Participating Entities and Their Respective Mission Statements That Mandate Involvement with ANS in Arizona

	<b>Agency</b>	<b>Mission</b>
<b>Federal</b>		
	Bureau of Land Management	To sustain the health, diversity and productivity of the public lands for the use and enjoyment of present and future generations.
	Bureau of Reclamation	To manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.
	National Park Service	To promote and regulate the use of the...national parks...which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.
	U.S. Fish and Wildlife Service	To conserve, protect, and enhance fish and wildlife, and their habitats for the continuing benefit of the American people.
	U.S. Department of Agriculture, Animal Plant and Health Inspection Service (APHIS)	To protect America's animal and plant resources by: Safeguarding resources from exotic invasive pests and diseases, monitoring and managing agricultural pests and diseases existing in the United States, resolving and managing trade issues related to animal or plant health, and ensuring the humane care and treatment of animals.
	International Boundary Waters Commission (IBWC), U.S. and Mexico Sections	To provide environmentally sensitive, timely and fiscally responsible boundary and water services along the U.S. and Mexican border region.
	Comision Nacional del Agua	To administer and preserve the national

	(National Water Commission, Mexico)	waters, with the participation of society, to achieve sustainable use of the resource.
<b>State</b>		
	AZ Game and Fish	To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations
	California Regional Water Quality Control Board	To preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations.
	California Department of Fish and Game	To manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public.
	Arizona Department of Agriculture	To regulate and support Arizona agriculture in a manner that encourages farming, ranching, and agribusiness while protecting consumers and natural resources.
<b>Regional</b>		
	Palo Verde Irrigation District (PVID)	To construct water conservation works and do every act necessary that sufficient water be furnished each landowner or inhabitant for irrigation and domestic purposes; may supply water to mutual water companies within the district; may permit recreational use of facilities
	Pima County Flood Control District	To enhance wildlife, recreation and riparian habitats along watercourses and floodplains
	Central Arizona Project	To deliver its full allocation of Colorado River water to central Arizona reliably,

		cost effectively and in an environmentally sound manner with the highest regard for evolving public needs and customer satisfaction.
--	--	--

\*All mission statements taken from the homepages of each respective entity

These entities are working together through a variety of larger organizations and mandates. Some of these include the Western Interior 100<sup>th</sup> Meridian Initiative, the Lower Colorado River Giant Salvinia Task Force, the Western Aquatic Plant Management Society, and the Southwest Plant Management Association. Participation in eight meetings that focused on a variety of approaches to aquatic nuisance species control in the southwest was used to determine how to best integrate the Arizona State Aquatic Nuisance Species Management Plan into existing action plans. These collaborations occurred over the course of one year. Table 2 provides a list of these meetings, along with brief agenda overviews. At this stage in response to aquatic nuisance species of all kinds, most of the meetings were used as venues to discuss invasive species of concern. Special interest meetings, such as the Lower Colorado Giant Salvinia Meetings, which focused on one species or issue were often simply used to update the many involved agencies on the work of a few people who were actually doing cleanup or working with producing biological control agents. Many of the same issues were repeated in this setting, however effort was made to encourage collaboration between states to better learn what is effective against these weeds.

Table 2: Collaborative Meetings for Dealing with ANS

Meeting	Location	Date	Overview
Aquatic Weed Management Short Course	Tucson, AZ	Aug. 19, 2000	Instruction of pesticide applicators in the use of Integrated Pest Management for control of aquatic weeds. Explained aquatic weed management areas.
Lower Colorado Giant Salvinia Meeting	Blythe, CA	Sep. 12-13, 2000	Representatives from California and Arizona addressing the problem of the current infestation of <i>Salvinia molesta</i> in the PVID and Colorado River. A plan of action was determined, but a lack of available funds is noted as slowing the process of removal of the weed. The plan of action includes cleaning the ditch of all vegetation to allow for more effective chemical treatment.
Western Interior 100 <sup>th</sup> Meridian Workshop	Las Vegas, NV	Oct. 25, 2000	Stakeholders from the Pacific Northwest and the Colorado River Basin interested in stopping aquatic nuisance species present in eastern waters from invading waters west of the 100 <sup>th</sup> meridian. Main focus is zebra mussels, but is being broadened to include many other ANS.
Southwestern Plant Management Association	Flagstaff, AZ	Oct. 31-Nov. 3, 2000	Stakeholders present from a number of southwestern states included members of several federal agencies, the department of transportation from several states, tribal members from local reservations, and ranchers. Rangeland management was a key issue. <i>Salvinia molesta</i> was introduced to increase awareness of ANS.
Reducing the Exotic Aquatic Species Threat	Tucson, AZ	Feb. 27, 2001	Workshop on control of aquatic weeds and ANS in Pima County. Review how control of aquatic weeds fits within the Sonoran Desert Conservation Plan, and how aquatic weed management area overlaps with other weed management efforts. Focus on protection of native species.
Giant Salvinia Control National	Houston, TX	Mar. 13-15, 2001	National and international <i>Salvinia molesta</i> experts, many agencies and stakeholders represented. Discussed plans

Meeting			for control and eradication of <i>Salvinia</i> and other nuisance aquatic plants. Reviewed Texas control plans with comparisons to Arizona plans. Reviewed the State of Washington ANS plan and how parts of that plan could be used as an example for parts of the Arizona plan. Discussed bio-control trials with APHIS staff.
Western Aquatic Plant Management Society Meeting	Las Vegas, NV	Mar. 29-30, 2001	Workshop with mainly federal agency land managers. Discussion on management plans focused on ANS controls. Discussed how the Arizona Aquatic Weed Management Area fit into other management plans, reducing the workload by allowing aquatic system managers to utilize existing management criteria described in the Arizona plan.
Lower Colorado Giant <i>Salvinia</i> Meeting	Blythe, CA	Oct. 25, 2001	Reviewed Action Plan and progress on eradication of <i>Salvinia molesta</i> from West Drain. Discussed spread of <i>Salvinia</i> into Mexico with Government of Mexico officials.

### General Plan Formatting

To create a user-friendly version of the Arizona State ANS Management Plan, a number of other plans were studied. The National Aquatic Nuisance Species Task Force maintains a website with links to each of the plans that have been approved. These include both regional and state plans. To date, plans are listed for New York, Michigan, Ohio, Illinois, and Washington states, as well as the St. Croix River Basin (Minnesota/Wisconsin), and the Great Lakes Commission Model State Plan. Personal communication with Scott Smith, who drafted the Washington State plan, was also used in modeling formatting for the following plan. From these resources a “user-friendly”

format was modeled in the creation of the Arizona plan, which contains a layout highly influenced by these collaborations.

## RESULTS

The results section contains the Arizona State Aquatic Nuisance Species Management Plan in its entirety, the result of this body of work on policy writing. This draft of the plan has been presented to members of many of the entities participating in the response to ANS in Arizona as listed above. Feedback from those responses was incorporated in revisions. The management actions have been created by participating agencies that will carry out the tasks and actions. In a like manner, the planned efforts implementation table will be completed by the respective agencies addressing each action.

# **Arizona State Aquatic Nuisance Species Management Plan**

**June, 2001**

## Executive Summary

---

---

Aquatic nuisance species (ANS) are a growing problem in Arizona. This document is an important step in the coordinated response to the problem and serves as an efficient means of communicating the scope of activities necessary to effectively address the issue. Several projects across the state have focused on isolated ANS plant and animal problems. The purpose of the Arizona State Aquatic Nuisance Species Management Plan is to provide guidance on management actions to address the prevention, control and impacts of unwanted nonindigenous aquatic nuisance species that have invaded or may invade Arizona.

State, federal and international ANS authorities and programs are briefly discussed to provide an understanding of our current ability to regulate and manage ANS. The development of a state management plan, as called for in Section 1204 of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (P.L. 101-646) (NANPCA) provides an opportunity for federal cost-share support for implementation of the plan. Approval of this management plan by the national Aquatic Nuisance Species (ANS) Task Force is also required for Arizona to be eligible for federal cost-share support. Freshwater nonindigenous species that are known to have been found in Arizona are listed. Very little is known about the impact of many nonindigenous species and some have high commercial, recreational and aesthetic values. The plan identifies a small number of priority nonindigenous ANS that are considered to be highly detrimental, and worthy of immediate or continued management action. The management actions outlined in this plan concentrate on these priority species.

The goal of this plan is as follows:

To fully implement a coordinated strategy designed to prevent new unintended introductions of nonindigenous aquatic nuisance species into the Colorado River and inland waters of the state, to limit the spread of established populations of nonindigenous aquatic nuisance species into uninfested waters of the state, and to abate harmful ecological, economic, social and public health impacts resulting from infestation of nonindigenous aquatic nuisance species.

Section 1204 requires that this management plan "identifies those areas or activities within the state, other than those related to public facilities, for which technical and financial assistance is needed to eliminate or reduce the environmental, public health and safety risks associated with aquatic nuisance species." This plan focuses on the identification of feasible, cost-effective management practices and measures to be taken on by state and local programs to prevent and control ANS infestations in a manner that is environmentally sound. The three main goals identified in the plan are structured to be achieved through the implementation of strategic actions and tasks designed to solve specific problems. The plan will be periodically revised and adjusted based upon the

practical experience gained from implementation, scientific research, and new tools, as they become available.

The implementation table summarizes the plan's funding from all sources. Implementing the programs outlined in this plan will require a coordinated tribal, Federal, State and private effort, and the dedication of significantly greater funding than is currently available.

## Introduction

---

The introduction of non-indigenous aquatic nuisance species (ANS) into the lower Colorado River and the inland waters of Arizona threatens the ecological integrity of the state's water resources, as well as economic, public health and social conditions within our state. Because they have few natural controls in their new habitat, ANS spread rapidly, destroying native plant and animal habitat, damaging recreational opportunities, lowering property values, clogging waterways, and impacting irrigation and power generation. The coordinated efforts contained within this plan are designed to protect the citizens of Arizona from the multitude of losses associated with ANS animals and plants. This plan focuses on eliminating the threat of accidental ANS introductions. The intentional introduction of nonindigenous species for aquaculture, commercial, or recreational purposes is addressed to insure that these beneficial introductions do not result in accidental ANS introductions, and to improve information sharing among those agencies responsible for regulating intentional introductions.

The introduction of nonindigenous species is not a new phenomenon in Arizona. Numerous species are causing or threaten to cause significant problems throughout the state, from the Colorado River on the north and the west to the San Francisco Drainage on the east, and in many of the reservoirs created in between. It is likely that nonindigenous species will continue to cause problems and damage across the state of Arizona. The reasons for this are obvious. With its many reservoirs and warm weather, Arizona is a popular vacationing spot for boaters from the East. This opens an easy method of transfer, especially for species such as the dreaded Zebra Mussel, which has not yet established in the state, but has been found on boats that have crossed the state from the east. For decades, sport fishing has brought numerous nonindigenous fish species into the state, from the eastern states and abroad. While restrictions now prohibit intentional introductions of many species, unintentional and illegal introductions will remain a concern. The growing aquaculture industry in the state as well as aquarium trade and backyard water gardening has brought many tropical aquatic species from around the world which easily become established in the warm climate that Arizona has yearlong. The alteration of Arizona watersheds with the building of reservoirs has altered the riparian habitat in many areas of the state, often in ways that favor nonindigenous species over those native and often endemic to the state.

The potential for significant additional introductions appears great for Arizona. Various new species seem to be poised to enter Arizona without the establishment of proper prevention methods. Having eradicated the growth of purple loosestrife that occurred in the 1980s, Arizona is the lone state out of the continental US to not have an established population of the weed. Giant salvinia has invaded portions of the lower Colorado, but has not become established in any reservoirs that provide water to the majority of the state. Zebra mussels have been found on trailered boats entering California after crossing the state, but none have become established in state waters. Each of these species has the

potential to cause costly environmental, ecological, agricultural and industrial impacts. If any of these non-indigenous species would become established in the reservoirs that feed the extensive canal system in Arizona, the impact on water users across the state could be widespread. These canals could provide a rapid means of transport to waters across the state, and the cost would be immense to eradicate invaders such as mussel and plants that may plug water intakes and pumping stations. Arizona therefore is in a unique position to focus preventative efforts on several of these species that have caused losses in the millions of dollars for control in other states.

Numerous ANS have been introduced and dispersed in the Colorado River and the inland waters of Arizona by various pathways. The environmental and socioeconomic costs resulting from ANS infestation will only continue to rise with further successful ANS introductions. Although an awareness of the problems caused by ANS is emerging, the solutions to these problems are not readily apparent. This comprehensive state management plan for nonindigenous ANS provides guidance on management actions to prevent, control and limit the impacts of ANS that have invade or may invade the Colorado River basin and inland waters.

Arizona's ANS Management Plan will be reviewed and revised annually, or more frequently if necessary. New ANS threats can arrive unexpectedly. Advances in our knowledge of ANS management techniques could warrant alterations in our management strategies. The specific tasks employed to accomplish our goals and objectives must remain flexible to assure efficiency and effectiveness. This version of the Arizona State ANS Plan is a good first step towards identifying and integrating existing ANS programs, and implementing new programs, but future editions will be necessary to fully accomplish our goal.

## Non-indigenous Species Authorities and Programs

---

This section provides a brief discussion of non-indigenous species authorities and programs in Arizona State, as well as federal law and international agreements. Arizona State laws relating to non-indigenous species cannot be discussed without a basic understanding of federal and international authorities. The policies regarding non-indigenous species are controlled and enforced by a network of regulatory agencies and organizations. Not all state and federal laws relating to ANS are included in this section of the plan.

### State Authorities and Programs

State and local efforts play a large role in controlling the spread of non-indigenous species. States have authority to decide which species can be imported and/or released. However, the United States Constitution vests the power to regulate international and interstate commerce to Congress. Federal law may preempt state law, but states retain almost unlimited power to define which species are imported and/or released. The state of Arizona currently has a number of statutory and regulatory authorities with which it addresses or potentially can address the issue of prevention and control of nonindigenous ANS. Additional information on regulated pathways of introduction for non-indigenous species can be found in Appendix D.

#### **Arizona Animal Programs and Regulations**

Currently the state restrictions concerning the regulation of non-indigenous animals are based on the movement of wildlife, especially when fishing. R12-4-313 and R12-4-316 both deal with the transport of baitfish, while R12-4-401 lists a number of restricted species, in regard to their movement and sale. This restricted list deals with many non-indigenous species, while R12-4-406 specifically lists the zebra mussel as restricted.

#### **Arizona Plant Programs and Regulations**

Few restrictions exist concerning the control of plants, especially aquatic plants in Arizona. R3-4-244 lists regulated and restricted noxious weeds that are present in the state and are being monitored or controlled. R3-4-245 lists prohibited noxious weeds that may not be transported into the state. Both of these laws include several threatening ANS. R3-205.01 gives the jurisdiction to control noxious weeds to the Arizona Department of Agriculture. This includes the right to quarantine areas, to call on land-owners to control noxious weeds and to update the noxious weeds list as necessary.

### Current Known Gaps in Arizona State programs

All the state regulations and laws have been developed over time in response to individual target species and a variety of concerns as they arose. Therefore, there is not currently a comprehensive, coordinated and vigorously enforced policy framework to deal with problem species and their impacts. Clearly, one task must be to identify gaps within the state's policies and statutes and to develop recommendations for improvements. Such improvements may entail developing new legislation and regulations, revising existing authorities, and developing methods for improving enforcement, coordination, and information dissemination regarding new or existing authorities.

## **Federal Regulations**

The current federal effort regarding the management of ANS is a patchwork of laws, regulations, policies, and programs. At least twenty agencies currently work at researching and controlling non-indigenous species. The Federal Agencies Table in Appendix D outlines the responsibilities of a number of these government agencies and summarizes their current role in the control of introduced species.

Federal laws that apply directly to the introduction of non-indigenous species include the Lacey Act, the Federal Noxious Weed Act, the Federal Seed Act, the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990, and the National Invasive Species Act of 1996. (The full text of these laws will not be included in this report.) The Endangered Species Act could also have indirect application if an ANS was shown to threaten the survival of a federally listed species, such as the humpback chub.

## **International Agreements**

- In addition to state and federal regulations, a number of international agreements address the issue of non-indigenous aquatic species. Several other international treaties and plans call for safeguards against the spread of ANS. Some of these include: The General Agreement on Tariffs and Trade (GATT) in which Article XX (b) Acknowledges the need for parties to protect themselves from harmful exotic species. This article legitimizes trade restraints, such as quarantine regulations, that are necessary to protect the life or health of humans, animals, or plants;
- The International Plant protection convention (1972), covering agricultural pests;
- The International Convention on Biological Diversity (signed 1993, but not yet ratified by the U.S. Senate) which contains a provision to control, eradicate, or prevent the introduction of those alien species that threaten ecosystems, habitats, or species: The Convention Concerning the Protection of World Cultural and Natural

Heritage (1973); The Convention on International Trade in Endangered Species (1975); The Convention on Wetlands of International Importance (1985, especially involved with waterfowl habitat); and The Convention on Nature protection and Wildlife Preservation in the Western Hemisphere (1942).

## Non-indigenous Species Problems and Concerns in the State of Arizona

---

A growing number of non-indigenous aquatic plant and animal species have adversely impacted the productivity and biodiversity of Arizona's native species, and altered a variety of aquatic ecosystems. Most introductions are the result of human activities. There are many ways organisms may be transported. Major pathways through which nonnative species are introduced into inland and coastal waterways include aquaculture, aquarium trade, biological control (shoreline stabilization, agricultural uses), transport via recreational boating and fishing, research activities, and movement of nonnative species through channels and canals. Some pathways, such as the aquaculture industry, are currently regulated to minimize the risk of new ANS introductions, while other pathways have developed few or no precautions. Additional information regarding regulated pathways is listed in Appendix D.

### Threatened Impact of Non-Indigenous Species

Potential threats may be evidenced by the degree of negative impact these species have upon the environment, industry and the economy. Negative impacts include:

- loss of biodiversity;
- threaten ESA listed species like the desert pupfish (*Cyprinodon macularius*) and the Gila topminnow (*Poeciliopsis occidentalis*);
- change estuary ecology;
- alterations in nutrient cycling pathways;
- decreased habitat value of infested water;
- threaten aquaculture production;
- decreased water quality;
- stunted fish populations due to dense biomass of introduced species;
- decreased recreational opportunities;
- increased safety concerns for swimmers;
- increased costs of canal maintenance;
- decrease in property values;
- fouled water intakes;
- frequently burned out irrigation pumps;
- impacts on power generation;
- increased risk of flooding due to increased biomass in water or clogging lake outlets;
- impeded water flow and interference with efficiency of water delivery systems.

The following section on freshwater animals and plants provides information on non-indigenous species and discusses priority species. Draft lists for each category (freshwater and marine) are intended to provide a basis for discussion and further work identifying the presence, distribution, status, and threat of non-indigenous species. The will be updated, maintained, categorized and standardized as new information is received and assimilated.

## Freshwater Animals and Plants

### **Freshwater Animals**

A draft list of freshwater non-indigenous animals in Arizona is included in Appendix B. The list is incomplete, since there is little published information non-indigenous aquatic species in Arizona. Currently, more funding and research is needed regarding the management and control of ANS animals. The freshwater ANS animals which are presently of most concern for Arizona include:

The zebra mussel (*Dreissena polymorpha*) has not been found in Arizona waters to date, but it is considered to be a priority species due to the degree of impact it has had in the Great Lakes region to date, and with regards to its rapid westward spread. Zebra mussels have been found on trailered boats at Lake Pleasant and on boats that had crossed Arizona and were entering California.

Several other species of concern are those that could be spread by the pet trade that are native to warm areas and are injurious to humans. These species include piranha, alligators, snapping turtles and electric eels.

More detailed information on these priority species is included in Appendix C.

### **Freshwater Plants**

Invasive and aggressive non-indigenous freshwater weeds pose a serious threat to Arizona State waters. Several non-indigenous freshwater species are currently present in Arizona. Some cause serious problems; the impacts of others are still yet to be determined. The freshwater non-indigenous plant species found in Arizona are listed in Appendix C, along with information on pathways of introduction, more detailed information on priority plant species and their impacts.

Hydrilla (*Hydrilla verticillata*), Brazilian elodea (*Egeria densa*), and Parrotfeather (*Myriophyllum aquaticum*) are priority freshwater submersed species in Arizona.

Purple loosestrife (*Lythrum salicaria*) is a priority emergent species that has spread throughout the continental US, but has not yet become established in Arizona. We have

the opportunity to work to exclude this ecosystem altering invader from our state. Saltcedar (*Tamarix ramosissima*) is another priority emergent species that is rapidly taking over riparian areas around the state.

Giant Salvinia (*Salvinia molesta*) is a priority floating plant that is currently found only in the Lower Colorado River. This aquatic fern has had major impacts to slow moving waters in the southeast as well as around the world.

### Priorities for Action

The purpose of the Arizona State Aquatic Nuisance Species Management Plan is to coordinate all ANS management actions currently in progress within Arizona, and to identify and provide funding for additional ANS management actions, especially those relating to priority ANS plants and animals. This plan focuses on the priority species identified below, but the major focus will be to develop and implement new programs designed to prevent or control the introduction of the zebra mussel and the spread of *Salvinia molesta*. Arizona is currently lacking projects for preventing and controlling ANS animals.

### Priority Species

Non-indigenous species considered to be priority species and worthy of immediate or continued management action include:

- zebra mussel (*Dreissina polymorpha*);
- hydrilla (*Hydrilla verticillata*);
- Brazilian elodea (*Egeria densa*);
- parrotfeather (*Myriophyllum aquaticum*);
- purple loosestrife (*Lythrum salicaria*);
- giant salvinia (*Salvinia molesta*)
- water hyacinth (*Eichhornia crassipes*);

The management actions outlined herein focus on these priority species. By addressing the pathways of introduction for priority species, the introduction of other lower priority, or perhaps unidentified ANS, may also be prevented, since many share common pathways of introduction.

## Management Actions

The goals of the Arizona comprehensive management plan are designed to address different stages of ANS invasion:

1. the introduction of the nonindigenous species transported from water bodies from other parts of the continent or world;
2. the spread of a reproducing ANS population, once establishes, within a waterway or to other water bodies; and
3. the colonization of ANS populations within water bodies, including the harmful impacts resulting from colonization.

The three goals on which the Arizona comprehensive state management plan is based are as follows:

**Goal I:** Preventing new and unintended introductions of nonindigenous aquatic nuisance species into the Colorado River and Arizona's inland waters.

**Goal II:** Limiting the spread of established populations of nonindigenous aquatic nuisance species into uninfested waters of the state.

**Goal III:** Abating harmful ecological, economic, social and public health impacts resulting from infestation of nonindigenous aquatic nuisance species.

Note, all italicized sections describe actions in progress.

### **Goal I:**

**Preventing new and unintended introductions of nonindigenous aquatic nuisance species into the Colorado River and inland waters of Arizona.**

#### **Problem:**

**Strategic Action IA:** In partnership with cooperators, develop state-specific and regional listings of aquatic nuisance species that have the potential to infest Arizona's waters. As part of this cooperative effort, identify existing and potential transport mechanisms that facilitate new ANS introductions.

**Task IA1:** Research and/or support research on the movement of aquatic nuisance species on a continental scale, and use findings to help predict potential ANS invasions into Arizona waters.

**Strategic Action IB:** Establish inter-jurisdictional approaches to facilitate legislative, regulatory and other actions needed for the prevention of new ANS introductions to Arizona's waters.

Task IB1: Establish and support coalitions among cooperators, including ANS officials from the state and federal natural resource agencies, tribal groups, recreational boater and angler groups and other concerned resource users. Assist coalitions in promoting federal legislation and programmatic support for the prevention of new ANS introductions in the region/state.

Task IB2: Establish and support an inter-jurisdictional process to ensure compatibility and consistency between states and federal agencies.

*Formed interagency committees on Salvinia molesta control, ANS control through the Western Interior 100<sup>th</sup> Meridian Plan.*

Task IB3: Initiate and implement a regional approach through a regional weed management plan on Aquatic Nuisance Species to prevent new introductions of aquatic nuisance species into Arizona's waters.

Strategic Action IC: Promulgate, publicize and enforce state legislation and regulations to prevent new ANS introductions into state waters.

Task IC1: Establish an interagency task force (with representation from public and private sectors) to develop regulations for state legislative consideration.

Task IC2: Develop and implement an outreach program that informs relevant groups of the regulations, their rational and compliance procedures.

Task IC3: Develop and implement enforcement programs.

Strategic Action ID: Develop/maintain monitoring programs to provide for early detection and prevention of infestations of aquatic nuisance species into unaffected watersheds.

Task ID1: Establish/participate in monitoring programs that emphasize partnerships between federal/state/local agencies; business/industry; academic institutions; and resource user groups. The feasibility of various technologies (e.g., Geographic Information Systems (GIS)) should be explored in designing such programs.

*AZ is included in the 100<sup>th</sup> Meridian GIS currently in process showing Zebra mussel monitoring and marking any outbreaks, with possibility of layering other ANS into the same GIS. USGS has noxious weed GIS in process with multiagency reporting that could include aquatic weeds*

Strategic Action IE: Conduct or support research regarding management options that will help prevent new introductions of aquatic nuisance species into Arizona's waters.

Task IE1: Assess the transport mechanisms potentially responsible for new ANS introductions into Arizona's waters. Develop preventive action plans to interrupt pathways of introduction.

Strategic Action IF: Conduct an effective information/education program on the prevention of new ANS introductions in Arizona's waters.

Task IF1: Identify the relevant Arizona user groups (i.e. aquaculture business, recreational boating/angler groups, bait and tackle establishments, state agency stocking programs, nursery and landscape trades, aquarium and ornamental ponds, etc.) and secure representation from each group on an advisory team that takes an active role in the development of the ANS state management plan.

Task IF2: Develop information/education strategies for resource user groups identified as playing a significant role in ANS introduction. Information/education efforts should focus on the practices that can help prevent ANS transport and introduction into Arizona's waters. As part of information/education initiatives, identify, when appropriate, the need for a regulatory approach in the prevention of ANS introductions.

*ANS information placed in AGFD Fishing and Boating regulations Fishing tournament managers including education on spread of ANS as a part of tournament activities. Noxious aquatic weeds included in herbicide applicators classes.*

Task IF3: Establish monitoring/tracking programs to evaluate the effectiveness of information/education efforts.

## **Goal II:**

**Limiting the spread of established populations of nonindigenous aquatic nuisance species into uninfested waters of the state.**

Problem: The spread of established populations of nonindigenous aquatic nuisance species into uninfested state waters is largely via human activity, such as boat transfers, bait handling, water transport, and ornamental and landscape practices. Limiting the spread of such populations is problematic due to the numerous pathways of dispersal, the complex ecological characteristics associated with ANS populations, and the lack of feasible technology that is needed to limit the spread. Many public and private resource user groups are not aware of existing infestations of ANS in the Colorado river and its reservoirs, the Verde and Salt Rivers, and inland waters of Arizona, and why they cause priority problems locally, regionally and beyond. The probability of ANS spread to other waters can increase when resource user groups are not aware of how their routine activities can cause the dispersal of ANS into uninfested water bodies. An information/education program is needed to provide information on why the spread of

ANS populations needs to be limited, how the ANS populations can be reduce, and also the value of a healthy aquatic ecosystem that supports a diverse native aquatic community. Information/education programming is also critical to strengthening public/private support for and statewide participation in ANS management strategies. It is also difficult to manage the spread of ANS since infestation frequently occurs in watersheds that occupy more than one state. Cooperation among states in the Colorado River watershed sharing ANS infested watersheds is needed to implement consistent management strategies that will effectively limit the spread of ANS populations.

Strategic Action IIA: Identify and prioritize aquatic nuisance species whose spread should be limited.

Task IIA1: Establish an advisory group, with representation from all stakeholders affected by the ANS problems in the state, to guide in the selection of aquatic nuisance species that merit management.

Task IIA2: Develop and implement a process to prioritize those aquatic nuisance species that merit management. (Note: An assessment of ANS impacts discussed under Goal III is recommended for this process. Also, a recommended resource to facilitate this prioritization process is the National Park Service publication, Handbook for Ranking Exotic Plants for Management and Control (see literature citations).)

*Also note Arizona Department of Agriculture noxious weed laws divide weeds into three groups. Regulated noxious weeds are found within the state and are to be controlled to prevent further infestation or contamination. Restricted noxious weeds are found within the state and are to be quarantined to prevent further infestation or contamination. Prohibited noxious weeds are prohibited from entering Arizona and shippers must have a permit to transport them through the state. (Rules for abatement published in Arizona Administrative Code R3-4-243 and R3-4-245.*

Strategic Action IIB: Monitor the spread of ANS determined to be a state priority.

Task IIB1: Design a monitoring program to provide information that will help in developing an effective strategy to limit the spread of selected ANS populations. A network approach, including federal/regional/state/local agencies, public/private groups and academic institutions, is recommended. Variables to monitor include population size, structure and range; rate of growth; type of habitat; distribution; impacts on native species; and economic and other impacts on human communities.

*Basic boat monitoring for zebra mussels is being done in Glenn Canyon. Monitoring of lower Colorado River at least biannually by USFWS using established protocol.*

Task IIB2: Develop identification materials for each aquatic nuisance species that is being monitored to facilitate participation of all stakeholders.

*Informational pamphlets have been created for Eurasian water milfoil, hydrilla, Salvinia molesta, and zebra mussels. Signs warning of spread of ANS have also been created for placement at marinas, boat ramps and docks.*

Strategic Action IIC: Develop and implement management strategies to limit the spread of each aquatic nuisance species determined to be a state priority.

Task IIC1: Based on identified dispersal pathways, develop voluntary and regulatory approaches to limit the spread of aquatic nuisance species. Also, identify the best available technology for each management strategy and include an environmental impact assessment, where necessary.

*Glenn Canyon boat surveys. Tried voluntary boat checks along 100<sup>th</sup> meridian, but with a low success rate Seminar for DPS employees encouraging random boat checks and increased awareness*

Task IIC2: Implement a watershed approach to limit the spread of aquatic nuisance species within the state.

Task IIC3: Establish cooperative policies among the Colorado River Basin States sharing watersheds to limit the spread of ANS populations.

Strategic Action IID: Inform and educate the appropriate resource user groups on the management strategies needed to limit the spread of targeted ANS populations. To support this effort, the target groups should be informed on how the spread of aquatic nuisance species threatens the health of a diverse native aquatic community, and other harmful ANS impacts. Volunteer groups, such as lake associations and outdoor recreation groups, should be actively involved in these outreach efforts.

Task IID1: Assess existing ANS information/education programs (i.e., Sea Grant, cooperative extension, state natural resource agencies). Build on the strengths and address the weaknesses of these programs.

Task IID2: Identify pathways that disperse aquatic nuisance species (i.e., recreational boaters/anglers, commercial and sport fishers, bait handling, water transport, ornamental and landscape practices) and inform these groups on practices to help limit the spread. This outreach program should focus on changing the behavior of user groups to limit the spread of targeted ANS populations to Arizona's waters.

*Arizona Department of Agriculture has contacted several nurseries in the Phoenix area, bass tournament groups are cooperating, information in boating and fishing regulations as previously mentioned.*

Task IID3: Coordinate with state and local programs to ensure, where appropriate, that public access projects and interpretive displays include information about aquatic nuisance species.

*Bulletins on ADA website, UA extension website, informative pamphlets and signs are being dispersed.*

Task IID4: Establish monitoring/tracking programs to evaluate the effectiveness of information/education efforts.

Strategic Action IIE: Promulgate, publicize and enforce state regulations to limit the spread of aquatic nuisance species within the state.

Task IIE1: Establish an interagency task force (with representation from public and private sectors) to develop regulations for state legislative consideration.

Task IIE2: Develop and implement an outreach program that informs relevant groups of the regulations and why they exist, and compliance procedures.

Task IIE3: Develop and implement enforcement programs.

*ADA procedure: can eradicate restricted noxious weeds and charge land or commodity owners for the cost of treatment. Property liens can be imposed to recover cost.*

Strategic Action IIF: Support/coordinate scientific research between state and federal agencies and academic institutions that investigate potential management strategies to limit the spread of ANS populations and associated environmental impacts.

Task IIF1: Prioritize research needs to help in establishing program structure.

Task IIF2: Conduct priority research, or promote the conduct of such research via federal research initiatives, academia or the private sector.

*Research on use of Clearigate done in PVID drain, BOR Denver office also researching chemical use, USDA APHIS in CA testing weevil as biological control, UA to test use of grass carp and tilapia as biological control pending facilities inspection.*

Task IIF3: Develop a technology transfer program to be used in distributing research findings.

### **Goal III:**

**Abating harmful ecological, economic, social and public health impacts resulting from infestations of nonindigenous aquatic nuisance species.**

**Problem:** The infestation of ANS in the Colorado River and inland state waters can alter or disrupt existing relationships and ecological processes. Without co-evolved parasites and predators, some nonindigenous aquatic species out-compete and even displace aquatic native plant or animal populations. As part of this process, the invading species can also influence to some extent the food webs, nutrient dynamics, and biodiversity of the ecosystems. To abate the ecological impacts of the invading organism, it is necessary to understand the mechanisms by which the species disrupts the natural balance of the ecosystem. The Colorado, Verde, and Salt Rivers and inland waters of Arizona provide valuable economic benefits for Arizona, some of which include potable water supplies, irrigation water, commercial and sport fisheries, recreational use, and water usage by manufacturers, industry and electric power companies. Some introduced ANS to the Colorado River Basin/state have provided economic benefits, such as those supporting the aquaculture business and sport fishing industry. However, several ANS have been found to cause adverse economic impacts. For instance, the Eurasian watermilfoil forms thick mats on the surface of water which can interfere with many types of water recreational activities, such as swimming and water skiing, as well as potentially clogging irrigation canals and water intakes. Organisms invading the Colorado River Basin and inland state waters can threaten public health through the introduction of disease, concentration of pollutants, contamination of drinking water, and other harmful human health effects. An extensive abatement system for these ANS needs to be established to prevent human health problems from occurring in the waters of Arizona. These control strategies must also be designed so as not to cause significant environmental impacts.

**Strategic Action IIIA:** Assess the ecological, socio-economic and public health impacts of aquatic nuisance species in Arizona's waters. Use this assessment as guidance to develop action levels that warrant implementation of control strategies (Note: Consult New York State's Department of Environmental Conservation (NYSDEC) management plan for a useful assessment of ANS impacts (i.e., beneficial, innocuous, nuisance, detrimental), which may be helpful in determining action levels for control. Also, a recommended resource to facilitate this process is the National Park Service publication, "Handbook for Ranking Exotic Plant for Management and Control".

**Task IIIA1:** Identify and assess the damages of aquatic nuisance species that threaten the ecological health of Arizona's ecosystems.

**Task IIIA2:** Identify and assess the damages of aquatic nuisance species that threaten public safety and/or human health of the state's residents.

**Task IIIA3:** Identify and assess economic costs for each aquatic nuisance species causing damage to water users.

*CAP estimates that a zebra mussel infestation would increase operational and maintenance costs \$4-5 million annually.*

**Strategic Action IIIB:** Based on the above impact assessments, develop and implement control strategies, including physical, chemical and biological mechanisms, to eradicate or reduce populations of targeted aquatic nuisance species in the Colorado River and inland state waters (i.e., those aquatic nuisance species identified by the state as causing detrimental ecological, economic, social and/or public health impacts).

**Task IIIB1:** Establish protocols that will provide guidance in designing and implementing control strategies.

- The control strategy must not create problems greater than those related to the aquatic nuisance species itself;
- A control strategy must not have serious, long-term impacts to the environment or non-target organisms;
- There must be a need to control the aquatic nuisance species due to causing, or the potential of causing, adverse impacts;
- The control strategy must not reduce the human utilization of the water body (with the exception of those waters with special resource designation) or threaten human health;
- Control efforts should be directed against the areas significantly impacted, and not be broad and general in nature;
- The control strategy must have a reasonable likelihood of succeeding

**Task IIIB2:** Support/coordinate scientific research between state and federal agencies and academic institutions that investigate potential control strategies and associated environmental impacts. Develop a technology transfer program to be used in distributing research findings.

**Task IIIB3:** Establish mechanism(s) to ensure that the control strategies developed and implemented by the state are done so in coordination with federal agencies, tribal authorities, local governments, inter-jurisdictional organizations and other appropriate entities (NANPCA, Section 1202).

**Task IIIB4:** Establish mechanism(s) to ensure that the control strategies are based on the best available scientific information and conducted in an environmentally sound manner (NANPCA, Section 1202).

**Strategic Action IIIC:** Conduct an information/education program providing information on ANS impacts and related control strategies. Utilize existing groups/programs responsible for information dissemination when appropriate.

**Task IIIC1:** Design programs targeting public agencies needed in promoting management action to abate impacts; user groups needed for effective control of targeted species; and communities that need to learn how to live with aquatic nuisance species problems.

**Task IIC2: Establish monitoring/tracking programs to evaluate the effectiveness of information/education efforts.**

# **Planned Efforts Implementation Table**









<p><b>SA IID</b></p>	<p>Inform and educate resource user groups on the management strategies needed to limit the spread of targeted ANS populations.</p>									
<p><b>SA IIIA</b></p>	<p>Assess the ecological, socio-economic and public health impacts of ANS in Arizona's waters</p>									
<p>III A1</p>	<p>Quantify the damages ANS that threaten the ecological health of Arizona's ecosystems.</p>									
<p>III A2</p>	<p>Quantify the damages of ANS that threaten public safety and/or human health of the state's residents.</p>									
<p>III A3</p>	<p>Identify and assess economic costs for each aquatic nuisance species causing damage to water users.</p>									
<p><b>SA IIIB</b></p>	<p>Develop and implement control strategies to eradicate or reduce populations of priority ANS in the Colorado River and inland state waters.</p>									
<p>III B1</p>	<p>Establish protocols that will provide guidance in designing and implementing control strategies.</p>									

<p>III B2</p>	<p>Support/coordinate scientific research that investigate potential control strategies and associated environmental impacts. Develop an information/technology transfer program for findings.</p>										
<p>III B3</p>	<p>Establish mechanism(s) to ensure coordination with all appropriate authorities (NANPCA, Section 1202).</p>										
<p>III B4</p>	<p>Establish review board to ensure that the control strategies are based on sound environmental science (NANPCA, Section 1202).</p>										
<p>SA IIC</p>	<p>Conduct an information/education program providing information on ANS impacts and related control strategies.</p>										
<p>IIIC1</p>	<p>Design programs targeting public agencies needed in promoting management action to abate impacts; user groups needed for effective control of targeted species; and communities that need to learn how to live with aquatic nuisance species problems.</p>										

III C2	Establish monitoring/tracking programs to evaluate the effectiveness of information/education efforts.									
--------	--	--	--	--	--	--	--	--	--	--

## Glossary

---

---

**Accidental introduction:** an introduction of non-indigenous aquatic species that occurs as the result of activities other than the purposeful or intentional introduction of the species involved, such as the transport of non-indigenous species in ballast water or in water used to transport fish, mollusks, or crustaceans for aquaculture or other purposes.

**Aquatic nuisance species:** a plant or animal species that threatens the diversity or abundance of native species, the ecological stability of infested waters, or commercial, agricultural, aquacultural, or recreational activities dependent on such waters. (Note: for the purposes of the State management plans, reference to an aquatic nuisance species will imply that the species is non-indigenous.)

**Baitfish:** fish species commonly sold for use as bait for recreational fishing.

**Control:** limiting the distribution and abundance of a species.

**Cryptogenic species:** a species that may or may not be indigenous to an area.

**Ecological integrity:** the extent to which an ecosystem has been altered by human behavior; an ecosystem with minimal impact from human activity has a high level of integrity; an ecosystem that has been substantially altered by human activity has a low level of integrity.

**Ecosystem:** the biological organisms in an ecological community and the non-living factors of the environment.

**Environmentally sound:** methods, efforts, actions, or programs to prevent introductions or to control infestations of ANS that minimize adverse environmental impacts. The impact of management actions should be less than the impact of the ANS.

**Eradicate:** the act or process of eliminating an aquatic nuisance species.

**Exotic:** (same as non-indigenous) any species or other variable biological material that enters an ecosystem beyond its historic range, including such organisms transferred from one county to another.

**Intentional introduction:** all or part of the process by which a non-indigenous species is purposefully introduced into a new area.

**Non-indigenous species:** any species or other variable biological material that enters an ecosystem beyond its historic range, including such organisms transferred from one country to another .

**Pioneer infestation:** a small ANS colony that has spread to a new area from an established colony.

**Priority species:** an ANS that is considered to be a significant threat to Washington waters and is recommended for immediate or continued management action to minimize or eliminate their impact.

**Watershed:** an entire drainage basin including all living and nonliving components

# **Appendices and References**

## Appendix A

### **Section 1204 of the National Invasive Species Act of 1996**

---

#### **SEC. 1204. STATE AQUATIC NUISANCE SPECIES MANAGEMENT PLANS.**

##### **(a) STATE OR INTERSTATE INVASIVE SPECIES MANAGEMENT PLANS.**

(1) **IN GENERAL.** -- After providing notice and opportunity for public comment, the Governor of each State may prepare and submit, or the Governors of the States and the governments of Indian Tribes involved in an interstate organization, may jointly prepare and submit –

(A) a comprehensive management plan to the Task Force for approval which identifies those areas or activities within the State or within the interstate region involved, other than those related to public facilities, for which technical, enforcement, or financial assistance (or any combination thereof) is needed to eliminate or reduce the environmental, public health, and safety risk associated with aquatic nuisance species, particularly the zebra mussel; and

(B) a public facility management plan to the Assistant Secretary for approval which is limited solely to identifying those public facilities within the State or within the interstate region involved for which technical and financial assistance is needed to reduce infestations of zebra mussels.

(2) **CONTENT.** -- Each plan shall, to the extent possible, identify the management practices and measures that will be undertaken to reduce infestations of aquatic nuisance species. Each plan shall –

(A) identify and describe State and local programs for environmentally sound prevention and control of the target aquatic nuisance species;

(B) identify Federal activities that may be needed for environmentally sound prevention and control of aquatic nuisance species and a description of the manner in which those activities should be coordinated with State and local government activities;

- (C) identify any authority that the State (or any State or Indian Tribe involved in the interstate organization) does not have at the time of the development of the plan that may be necessary for the State (or any State or Indian Tribe involved in the interstate organization) to protect public health, property, and the environment from harm by aquatic nuisance species; and
- (D) a schedule of implementing the plan, including a schedule of annual objectives, and enabling legislation.

(3) CONSULTATION –

- (A) In developing and implementing a management plan, the State or interstate organization should, to the maximum extent practicable, involve local governments and regional entities, Indian Tribes, and public and private organizations that have expertise in the control of aquatic nuisance species.
- (B) Upon the request of a State or the appropriate official of an interstate organization, the Task Force or the Assistant Secretary, as appropriate under paragraph (1), may provide technical assistance in developing and implementing a management plan.

- (4) PLAN APPROVAL. -- Within 90 days after the submission of a management plan, the Task Force or the Assistant Secretary in consultation with the Task Force, as appropriate under paragraph (1), shall review the proposed plan and approve it if it meets the requirements of this subsection or return the plan to the Governor or the interstate organization with recommended modifications.

(b) GRANT PROGRAM. –

- (1) STATE GRANTS. – The Director may, at the recommendation of the Task Force, make grants to States with management plans approved under subsection (a) for the implementation of those plans.
- (2) APPLICATION. – An application for a grant under this subsection shall include an identification and description of the best management practices and measures which the state proposes to utilize in implementing an

approved management plan with any Federal assistance to be provided under the grant.

(3) FEDERAL SHARE. –

(A) The Federal share of the cost of each comprehensive management plan implemented with Federal assistance under this section in any fiscal year shall not exceed 75 percent of the cost incurred by the State in implementing such management program and the non-Federal share of such costs shall be provided from non-Federal sources.

(B) The Federal share of the cost of each public facility management plan implemented with Federal assistance under this section in any fiscal year shall not exceed 50 percent of the cost incurred by the State in implementing such management program and the non-Federal share of such costs shall be provided from non-Federal sources.

(4) ADMINISTRATIVE COSTS. – For the purposes of this section, administrative costs for activities and programs carried out with a grant in any fiscal year shall not exceed 5 percent of the amount of the grant in that year.

(5) IN-KIND CONTRIBUTIONS.—In addition to cash outlays and payments, in-kind contributions of property or personnel services by non-Federal interests for activities under this section may be used for the non-Federal share of the cost of those activities.

(c) ENFORCEMENT ASSISTANCE.—Upon request of a State or Indian Tribe, the Director or Under Secretary, to the extent allowable by law and in a manner consistent with section 141 of title 14, United States Code, may provide assistance to a State or Indian Tribe in enforcing an approved State or interstate invasive species management plan.

## Appendix B

# **Arizona Aquatic Nuisance Species Management Plan Public Review Information**

---

TO CONTAIN INFORMATION COVERED IN PUBLIC MEETINGS OF INVOLVED  
STAKEHOLDERS FOR RATIFYING THE PLAN

## Appendix C

### Non-indigenous Aquatic Species in Arizona

#### List of Non-indigenous Freshwater Animal Species found in Arizona

Common name	Species name
<b>Amphibians</b>	
African clawed frog	<i>Xenopus laevis</i>
Bullfrog	<i>Rana catesbeiana</i>
Mountain treefrog	<i>Hyla eximia</i>
Tiger salamander	<i>Ambystoma tigrinum</i>
Pacific chorus frog	<i>Pseudacris regilla</i>
Rio Grande leopard frog	<i>Rana berlandieri</i>
<b>Fish</b>	
American eel	<i>Anguilla rostrata</i>
American shad	<i>Alosa sapidissima</i>
Arctic grayling	<i>Thymallus arcticus</i>
bighead carp	<i>Hypophthalmichthys nobilis</i>
bigmouth buffalo	<i>Ictiobus cyprinellus</i>
black bullhead	<i>Ameiurus melas</i>
black buffalo	<i>Ictiobus niger</i>
black crappie	<i>Pomoxis nigromaculatus</i>
blue catfish	<i>Ictalurus furcatus</i>
bluegill	<i>Lepomis macrochirus</i>
blue tilapia	<i>Oreochromis aureus</i>
brook trout	<i>Salvelinus fontinalis</i>
brown bullhead	<i>Ameiurus nebulosus</i>
brown trout	<i>Salmo trutta</i>
channel catfish	<i>Ictalurus punctatus</i>
coho salmon	<i>Oncorhynchus kisutch</i>
common carp	<i>Cyprinus carpio</i>
convict cichlid	<i>Cichlasoma nigrofasciatum</i>
cutbow trout	<i>Oncorhynchus clarki x mykiss</i>
cutthroat trout	<i>Oncorhynchus clarki</i>
driftwood catfish	<i>Parauchenipterus galeatus</i>
fathead minnow	<i>Pimephales promelas</i>
firemouth cichlid	<i>Cichlasoma meeki</i>

flathead catfish  
 golden shiner  
 goldfish  
 grass carp  
 green sunfish  
 green swordtail  
 golden trout  
 guppy  
 largemouth bass  
 leatherside chub  
 longjaw mudsucker  
 Mexican tetra  
 Mexican molly  
 mosquitofish  
 mottled sculpin  
 mountain sucker  
 muskellunge  
 Nile tilapia  
 northern pike  
 plains killifish  
 pumpkinseed  
 quillback  
 rainbow trout  
 redbelly tilapia  
 redear  
 red shiner  
 redbelly shiner  
 Rio Grande cichlid  
 Rio Grande sucker  
 rock bass  
 Sacramento perch  
 sailfin molly  
 sand shiner  
 shortfin molly  
 silver carp  
 smallmouth bass  
 smallmouth buffalo  
 sockeye salmon  
 spiketail  
 spotted bass  
 spotted tilapia  
 striped bass  
 suckermouth catfish  
 tench

*Pylodictis olivaris*  
*Notemigonus crysoleucas*  
*Carassius auratus*  
*Ctenopharyngodon idella*  
*Lepomis cyanellus*  
*Xiphophorus helleri*  
*Oncorhynchus aguabonita*  
*Poecilia reticulata*  
*Micropterus salmoides*  
*Gila copei*  
*Gillichthys mirabilis*  
*Astyanax mexicanus*  
*Poecilia sphenops*  
*Gambusia affinis*  
*Cottus bairdi*  
*Catostomus platyrhynchus*  
*Esox masquinongy*  
*Oreochromis niloticus*  
*Esox lucius*  
*Fundulus zebrinus*  
*Lepomis gibbosus*  
*Carpiodes cyprinus*  
*Oncorhynchus mykiss*  
*Tilapia zillii*  
*Lepomis microlophus*  
*Cyprinella lutrensis*  
*Richardsonius balteatus*  
*Cichlasoma cyanoguttatum*  
*Catostomus plebeius*  
*Ambloplites rupestris*  
*Archoplites interruptus*  
*Poecilia latipinna*  
*Notropis ludibundus*  
*Poecilia mexicana*  
*Hypophthalmichthys molitrix*  
*Micropterus dolomieu*  
*Ictiobus bubalus*  
*Oncorhynchus nerka*  
*Meda fulgida*  
*Micropterus punctulatus*  
*Tilapia mariae*  
*Morone saxatilis*  
*Hypostomus sp.*  
*Tinca tinca*

threadfin shad  
 Utah chub  
 variable platyfish  
 walleye  
 Wami tilapia  
 warmouth  
 woundfin  
 white bass  
 white crappie  
 white sturgeon  
 yellow bass  
 yellow bullhead  
 yellow perch

*Dorosoma petenense*  
*Gila atraria*  
*Xiphophorus variatus*  
*Stizostedion vitreum*  
*Oreochromis urolepis*  
*Chaenobryttus gulosus*  
*Plagopterus argentissimus*  
*Morone chrysops*  
*Pomoxis annularis*  
*Acipenser transmontanus*  
*Morone mississippiensis*  
*Ameiurus natalis*  
*Perca flavescens*

#### Invertebrates

Asian clam  
 big-ear radix  
 Chinese mysterysnail  
 crayfish  
 crayfish, red swamp  
 crayfish, virile  
 red-rim melania  
 shrimp, riverine grass  
 zebra mussel

*Corbicula fluminea*  
*Radix auricularia*  
*Cipangopaludina chinensis malleata*  
*Orconectes causeyi*  
*Procambarus clarkii*  
*Orconectes virilis*  
*Melanoides tuberculatus*  
*Palaemonetes plaudosus*  
*Dreissena polymorpha*

#### Reptiles

American alligator  
 alligator snapping turtle  
 false map turtle  
 red-eared slider  
 slider  
 snapping turtle  
 southern painted turtle  
 spectacled caiman  
 spiny softshell  
 Texas spiny softshell  
 water monitor  
 western painted turtle  
 yellowbelly slider  
 yellow mud turtle

*Alligator mississippiensis*  
*Macrolemys temminckii*  
*Graptemys pseudogeographica*  
*Trachemys scripta elegans*  
*Trachemys scripta*  
*Chelydra serpentina*  
*Chrysemys picta dorsalis*  
*Caiman crocodilus*  
*Apalone spinifera*  
*Apalone spinifera emoryi*  
*Varamus salvator*  
*Chrysemys picta bellii*  
*Trachemys scripta scripta*  
*Kinosternon flavescens flavescens*

### List of Non-indigenous Freshwater Plants

Common Name	Scientific Name	Habitat
<u>Plants that are currently causing problems in Arizona</u>		
Brazilian elodea	<i>Egeria densa</i>	submersed species
curly leaf pondweed	<i>Potamogeton crispus</i>	submersed
giant salvinia	<i>Salvinia molesta</i>	floating in calm waters
hydrilla	<i>Hydrilla verticillata</i>	submersed species
parrot-feather	<i>Myriophyllum aquaticum</i>	mat-forming emergent grows along lake and river shorelines
water-cress	<i>Nasturtium officinale</i>	cold water streams
<u>Plants with Apparent Limited Distribution and Weedy Potential</u>		
Eurasian water-milfoil	<i>Myriophyllum spicatum</i>	submersed species
<u>Species of Concern Being Sold in Arizona, But Not Established in the Wild</u>		
water-hyacinth	<i>Eichhornia crassipes</i>	floating plant with dangling roots (sold as an aquatic garden plant)
<u>Introduced Plant Species, But Not Causing Problems</u>		
dotted duckweed	<i>Landoltia (Spirodela) punctata</i>	floating leaved in shallow water
yellow floating-heart	<i>Nymphoides peltata</i>	floating leaved in shallow water
<u>Species Of Concern in Other States, Not Yet Introduced to Arizona</u>		
Anchored waterhyacinth <i>Eichhornia azurea</i> (SW)		
Water-chestnut	<i>Trapa natans</i> L.	

List of Arizona Game and Fish Restricted Non-indigenous  
**Freshwater Animal Species of Concern**

Common name	Species name
<b>Amphibians</b>	
clawed frogs	all species of the genus <i>Xenopus</i>
giant or marine toads	<i>Bufo horribilis</i> , <i>Bufo marinus</i> , <i>Bufo paracnemis</i>
<b>Fish</b>	
Arctic grayling	<i>Thymallus arcticus</i>
bass	all the species of the family Serranidae
bighead carp	<i>Hypophthalmichthys nobilis</i>
bony tongue	<i>Arapaima gigas</i>
bowfin	<i>Amia calva</i>
catfish	all species of the family Ictaluridae
Crucian carp	<i>Carassius carassius</i>
electric eel	<i>Electrophorus electricus</i>
European whitefish	<i>Leuciscus idus</i> , <i>Idus idus</i>
freshwater drum	<i>Aplodinotus grunniens</i>
freshwater stingray	all species of the family Potamotrygonidae
gars	all species of the family Lepisosteidae
goldeye	all species of the family Hiodontidae
herring	all species of the family Clupeidae
Indian carp	all of the species <i>Catla catla</i> , <i>Cirrhina mrigala</i> , and <i>Labeo rohita</i>
lampreys	all species of the family Petromyzontidae
mooneye	all species of the family Hiodontidae
Nile perch	all species of the genus <i>Lates</i>
pike	all species of the family Clupeidae
pike topminnow	<i>Belonesox belizamus</i>
piranha	all species of the genera <i>Serrasalmus</i> , <i>Serrasalmo</i> , <i>Phygocestrus</i> , <i>Teddyella</i> , <i>Fooseveltiella</i> , and <i>Pygopristis</i>
Rudd	<i>Scardinius erythrophthalmus</i>
shad	all species of the family Clupeidae except threadfin shad, species <i>Dorosoma petenense</i>
sharks	all species, marine and freshwater of orders

	Hexanchiformes, Heterodontiformes, Squaliformes, Pristiophoriformes, Squatiniformes, Orectolobiformes, Lamniformes, and
Carcharhiniformes	
silver carp	<i>Hypophthalmichthys molitrix</i>
snakehead	all species of the family Ophicephalidae
South American parasitic catfish	all species of the family Trichomycteridae and Cetopsidae
sunfish	all species of the family Centrarchidae
tetras	all species of the genus <i>Astyanyx</i>
tiger fish	<i>Hoplias malabaricus</i>
trout	all species of the family Salmonidae
white amur, grass carp	<i>Ctenopharyngodon idella</i>
walking catfish	all species of the family Clariidae
walleye	<i>Stizostedion vitreum</i>
white perch	<i>Morone americanus</i>
yellow perch	<i>Perca flavescens</i>
Invertebrates	
Asiatic mitten crab	<i>Eriocheir sinensis</i>
Crayfish, Australian	all species of family Parastacidae
zebra mussel	<i>Dreissena polymorpha</i>
Reptiles	
caimans	
crocodiles	all species of order Crocodylia
alligators	
snapping turtles	all species of family Chelyridae
sea snakes	all species of family Hydrophiidae
Priority Species	
• zebra mussel ( <i>Dreissina polymorpha</i> )	
• hydrilla ( <i>Hydrilla verticillata</i> )	
• Brazilian elodea ( <i>Egeria densa</i> )	
• parrotfeather ( <i>Myriophyllum aquaticum</i> )	
• purple loosestrife ( <i>Lythrum salicaria</i> )	
• giant salvinia ( <i>Salvinia molesta</i> )	
• water hyacinth ( <i>Eichhornia crassipes</i> )	

## Appendix D

### Non-indigenous Species Authorities and Programs

#### Federal Agencies Regulating the Transport of Live Aquatic Products

Federal Agencies Regulating the Transport of Live Aquatic Products (Olson and Linen 1997).

	Restrict Movement Into U.S.	Restrict Interstate Movement	Regulate Product Content or Labeling
Plants	APHIS	APHIS	APHIS
	DOD	AMS	AMS
	Customs		
	DEA		
Fish	FWS	FWS	FWS
	Customs		
	USCG		
Invertebrates	APHIS	APHIS	FWS
	FWS	FWS	
	ARS		
	PHS		
	Customs		
	USCG		

List of abbreviations and descriptions of authority (Olson and Linen 1997)

Organization	Description
APHIS	The Animal and Plant Health Inspection Service, U.S. Department of Agriculture, has broad mandates related to the importation and interstate movement of exotic species, under the Federal Plant Pest Act, the Plant Quarantine Act, and several related statutes. The primary concern is species that pose a risk to agriculture. Restricts the movements of agricultural pests and pathogens into the country by inspecting, prohibiting, or requiring permits for the entry of agricultural products, seeds, and live plants and animals. Restricts interstate movements of agricultural plant pests and pathogens by imposing domestic quarantines and regulations. Restricts interstate transport of noxious weeds under the Federal Noxious Weed Act.
AMS	The Agricultural Marketing Service, U.S. Department of Agriculture, works closely with states in regulating interstate seed shipments. Regulations require accurate labeling and designation

of “weeds” or “noxious weeds” conforming to the specific state’s guidelines.

ARS	The Agricultural Research Service, U.S. Department of Agriculture, the research branch of USDA, conducts and funds research on the prevention, control, or eradication of harmful exotic species often in cooperation with APHIS. Projects include aquaculture techniques and disease diagnosis and control.
DEA	The Drug Enforcement Agency restricts imports of a few non-indigenous plants and fungi because they contain narcotic substances.
DOD	The Department of Defense has diverse activities related to non-indigenous species. These relate to its movements of personnel and cargo and management of land holdings. Armed forces shipments are not subject to APHIS inspections. Instead, the DOD uses military customs inspectors trained by APHIS and the Public Health Service.
FWS	The Fish and Wildlife Service, U.S. Department of the Interior, has responsibility for regulating the importation of injurious fish and wildlife under the Lacey Act. Maintains a limited port inspection program. In 1990, FWS inspectors inspected 22 percent of the wildlife shipments at international ports of entry. Interstate movement of state-listed injurious fish and wildlife is a federal offense and therefore potentially subject to FWS enforcement. Also provides technical assistance related to natural resource issues and fish diseases to state agencies and the private sector (aquaculture in particular). Helps control the spread of fish pathogens.
NOAA and NMFS	The National Oceanic and Atmospheric Association and National Marine Fisheries Service, U.S. Department of Commerce, inspect imported shellfish to prevent the introduction of non-indigenous parasites and pathogens. Cooperative agreements with Chile and Australia; Venezuela has requested a similar agreement.
PHS	The Public Health Service, U.S. Department of Health and Human services, regulates entry of organisms that might carry or cause human disease.
Customs	Customs Service, U.S. Department of the Treasury. Customs personnel inspect passengers, baggage, and cargo at U.S. ports of

entry to enforce the regulations of other federal agencies. They inform interested agencies when a violation is detected and usually detain the suspected cargo for an agency search.

USCG

The Coast Guard, U.S. Department of Treasury, was given certain responsibilities under the Non-indigenous Aquatic Prevention and Control Act of 1990, relating to preventing introductions (mostly dealing with ballast water exchange).

### Federal Law Addressing Aquatic Nuisance Species

#### **The Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990**

The Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 created the Interagency Aquatic Nuisance Species Task Force. This group is required to develop a program to prevent, monitor, and control unintentional introductions of exotic species. Many of the agencies that in some way regulate the introduction of species are represented on this task force.

#### **The National Invasive Species Act of 1996**

The National Invasive Species Act of 1996 re-authorizes and amends the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (the “Zebra Mussel Act”). It expands the scope of the Act beyond the zebra mussel and ballast water and begins to “address introductions and infestations of [non-indigenous aquatic] species that may be as destructive as the zebra mussel.” To this end, the Act authorizes a Western Regional Panel to identify priorities for the western region; develop emergency response strategies for stemming new invasions; and advise public and private sectors concerning the prevention and control of exotic species. Furthermore, the Act advises state and Tribal governments to prepare invasive species management plans and provides for ecological surveys to study species attributes and patterns of invasions.

Finally, the National Invasive Species Act of 1996 authorizes U.S. spending \$1.25 million to “fund research on aquatic nuisance species prevention and control in San Francisco Bay and the Pacific Coast.”

The expanded scope of the National Invasive Species Act of 1996 demonstrates that federal efforts to control the transport and accidental release of exotic species are becoming more stringent. Concern over the disastrous spread of the zebra mussel has

heightened public awareness of the issue and, as a consequence, government regulations are likely to become more developed in coming years.

### **International Instruments Addressing Non-indigenous Species**

Additional International Agreements Addressing Non-indigenous species include:

- The General Agreement on Tariffs and Trade (GATT) in which Article XX (b) Acknowledges the need for parties to protect themselves from harmful exotic species. This article legitimizes trade restraints, such as quarantine regulations, that are necessary to protect the life or health of humans, animals, or plants;
- The International Plant protection convention (1972), covering agricultural pests;
- The International Convention on Biological Diversity (signed 1993, but not yet ratified by the U.S. Senate) which contains a provision to control, eradicate, or prevent the introduction of those alien species that threaten ecosystems, habitats, or species;

Furthermore, there are a number of bilateral of multilateral treaties that indirectly affect exotic species, including:

- The Convention Concerning the Protection of World Cultural and Natural Heritage (1973);
- The Convention on International Trade in Endangered Species (1975);
- The Convention on Wetlands of International Importance (1985)(especially involved with waterfowl habitat);
- The Convention on Nature protection and Wildlife Preservation in the Western Hemisphere (1942).

## Appendix E

### References

---

- Aquatic Nuisance Species Task Force (D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere and Mollie Beattie, Director of U.S. Fish and Wildlife Service). 1994. *Report to Congress: Findings, Conclusions, and Recommendations of the Intentional Introductions Policy Review*.
- Carlton, J.T. 1985. *Transoceanic and Interoceanic Dispersal of Coastal Marine Organisms: The Biology of Ballast Water*. Oceanography and Marine Biology, An Annual Review: volume 23.
- Hushak, L.J., Y. Deng, M. Bielen. 1995. *The Cost of Zebra Mussel Monitoring and Control*. ANS Digest: volume 1, number 1.
- Leigh, P. 1994. *Benefits and Costs of the Ruffe Control Program for the Great Lakes Fishery*. National Oceanic and Atmospheric Administration Report.
- New York State Department of Environmental Conservation, Division of Fish and Wildlife. 1993. *Nonindigenous Aquatic Species Comprehensive Management Plan*.
- Ohio Sea Grant College Program. 1995. *Sea Grant Zebra Mussel Report: An Update of Research and Outreach: 1988-1994*. The Ohio State University.
- Olson, A.M., and E.H. Linen. 1997. Exotic Species and the Live Aquatics Trade. Proceedings of Marketing and Shipping Live Aquatics '96: conference and Exhibition, Seattle, Washington, October 1996. School of Marine Affairs, University of Washington, Working Paper No. 6.
- Ruiz, G.M., A.H. Hines, L.D. Smith, J.T. Carlton. 1995. *An Historical Perspective on Invasion of North American Waters by Nonindigenous Aquatic Species*. ANS Digest: volume 1, number 1.
- U.S. Congress, *Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990*, Public Law 101-646.
- U.S. Congress, Office of Technology Assessment. 1993. *Harmful Nonindigenous Species in the United States*. OTA-F565.
- U.S. Department of the Interior, National Park Service. 1991. *Handbook for Ranking Exotic Plant for Management and Control*. Authored by R.D. Hiebert and James Stubbendieck. (Copies of this report (Natural Resources Report NPS/NRMWRO/NRR-

93/08) are available from: Publications Coordinator, National Park Service, Natural Resources Publications Office, P.O. Box 2587 (WASO-NRPO), Denver, CO 80225-0287).

U.S. Fish and Wildlife Service, Department of the Interior. 1995. *Report to Congress: Great Lakes Fishery Resources Restoration Study*.

## DISCUSSION

While a coordinated plan is a start in a statewide response to ANS, success will be limited unless efforts are supported by the state's populace. Through personal communications and observations in various meetings, it became evident that there is a definite need for public awareness of aquatic nuisance species in this state that is known for its deserts, not its water. Public awareness was addressed in a number of ways. These included the creation of a state ANS website, creation of mailings and brochures, teacher materials in the form of lesson plans on ANS, and through the dissemination of posters and signs.

An Arizona ANS website was created to provide all interested parties with current and relevant information on issues surrounding responses to ANS in the state. Appendix A contains pages from this website, which highlighted three main areas: ANS in or threatening the state, agencies (state and federal) involved in dealing with ANS, and drafts of other management plans for review. Also included were minutes from some of the meetings, and current drafts of the Arizona State Plan, along with additional information. This site was hosted by the University of Arizona in hopes of receiving attention from aquaculturalists and others who might be browsing the University's site. Information on species of concern for the state ranged from where the species was found to what was being done for control, mostly provided through links to other sites. This was also used as a public forum, asking for feedback on the current draft of the plan.

As a means of providing hard copies of information on species of concern for the state, a brochure and a mailing flier were created. These can be found in Appendices B and C respectively. The brochure was created for mass distribution at marinas, bait shops and nurseries across the state, with the goal of providing stakeholders with a reference with which to identify and raise awareness of ANS. Due to a previous lack of funding, this brochure has not yet been printed. The flyer in Appendix C was created for use as an informational leaflet, to be enclosed along with water bills, or in boater and fishing registration books. This flyer was provided as a service to several agencies. To reach the next generation of water users, lesson plans were also created to provide teachers with the resources to teach knowledgeably on the dangers of ANS. As can be seen in Appendix D, these lessons all link to informational sources covering a thorough background on ANS. Signs were also posted at several marinas in southern Arizona to alert boaters to the potential of carrying ANS from one body of water to the next with negative result. While these steps are by no means all inclusive, they represent a move towards educating the public of current and future threats to state waterways.

Many agencies use a weed management area as a way to focus their attempts at treatment and control of a nuisance species. Using current information on the distribution of *Salvinia molesta* in the Colorado River, a weed management area for the state was created. This area is composed of the watersheds where salvinia is currently found, providing a physical representation of the locations where the weed is most likely to be found in the state. Efforts of quarantining the species can then be focused on this area with hopes of limiting the spread to other watersheds and inland waters of the state. The

current range of *Salvinia molesta* and the weed management area can be found in Appendix E.

## CONCLUSION

While much remains to be done with regards to prevention, control, and response to aquatic nuisance species in Arizona, this plan is two steps away from being functional and a source of additional funds for dealing with ANS. As outline in section 1204 of NANPCA, the governor of each state must approve the plan before it goes before the National ANS Task Force for final approval. Currently this management plan has been passed on to Arizona Game and Fish, members of which are seeking a forum with the governor. As with any project, many aspects require further work, and several extensions of this project have already been started.

Public awareness will continue to be one of the biggest challenges in successfully managing the spread of any nuisance species. The increasing mobility of people around the world increases the potential for species to hitchhike to many areas where they are not native and will be free from controlling predators. Even within states, the occurrences of ANS spread are usually by people who are unaware of the circumstances that may result from their actions, such as not thoroughly cleaning boats or fishing equipment of weeds or pockets of water. In order to continue to provide a resource for the state, the ANS website that was created will continue to be maintained. Another website will also be added, as the U.S. Fish and Wildlife Service Salvinia website will be mirrored and hosted alongside the state page. Flyers and brochures will also be printed and distributed. Word of mouth will also continue to be used as an effective method of information distribution, especially to students, educators, and stakeholders in the state's water. In all these ways,

the hope remains that with more people alert to potential problems, more ANS populations will be found, and less will be spread.

Another way to further the work done here is specifically with *Salvinia molesta* research, as this growing problem on the Colorado has yet to be solved. Recent developments have led to the release of a biological control agent (*Cyrtobagous salvineae*) in parts of Texas and Louisiana. Prerelease studies on the use of this weevil in Arizona are being finished by USDA APHIS. When the species is released, the population dynamics will need to be monitored and analyzed to determine the effectiveness of this flightless organism in a lotic system.

Additional work will continue to be needed in updating and managing the management plan from year to year. With so many agencies involved, it will be a challenge to annually update the plan with involvement from all entities. Some states have created a salaried position with this management as one of the key mandates of the job. This may be one direction for Arizona, in order to have one person with the responsibility to stay current on responses to ANS across the state and keep contact with all agencies to track spending and determine where funds need to be appropriated in the annual budgeting from the federal funds received to assist the state in carrying out the plan.

It is likely that nonindigenous species will continue to cause problems and damage across the state of Arizona. The reasons for this are obvious. With its many reservoirs, Arizona is a popular vacationing spot for boaters from the North and East. This opens an easy method of transfer, especially for species such as the Zebra Mussel,

which has not yet established in the state, but has been found on boats that have crossed the state from the east. For decades, sport fishing has brought numerous nonindigenous fish species into the state, from the eastern states and abroad. While restrictions now prohibit some of these introductions, illegal introductions will remain a concern. The growing aquaculture industry in the state as well as aquarium trade has brought many tropical aquatic species from around the world, which easily become established in the warm climate that Arizona has yearlong. The alteration of Arizona watersheds with the building of reservoirs has altered the riparian habitat in many areas of the state, often in ways that favor nonindigenous species over those native and often endemic to the state.

The potential for major additional environmental, ecological, agricultural and industrial impacts appears great for Arizona. Various new species seem to be poised to enter Arizona without the establishment of proper prevention methods. Having eradicated the growth of hydrilla that occurred in the 1980s, Arizona is one of the lone states in the continental US to not have an established population of the weed. *Salvinia molesta* has invaded portions of the lower Colorado, but has not become established in any reservoirs that provide water to the majority of the state. Zebra mussels have been found on trailered boats entering California after crossing the state, but none have become established in state waters (Biology web team, 2000). If any nonindigenous species would become established in the reservoirs that feed the extensive canal system in Arizona, the impact on water users across the state could be immense. These canals could provide a rapid means of transport. Therefore, this Arizona State Aquatic Nuisance Species Management Plan is a timely document as a means of coordinating the state

response while providing financial assistance. Given the concerns mentioned above, the importance and urgency of writing, reviewing and adopting this plan is clear.

APPENDIX A:  
Arizona Aquatic Nuisance Species Website

Figure 1.1: Homepage for Arizona ANS website (first of three pictures of the page).

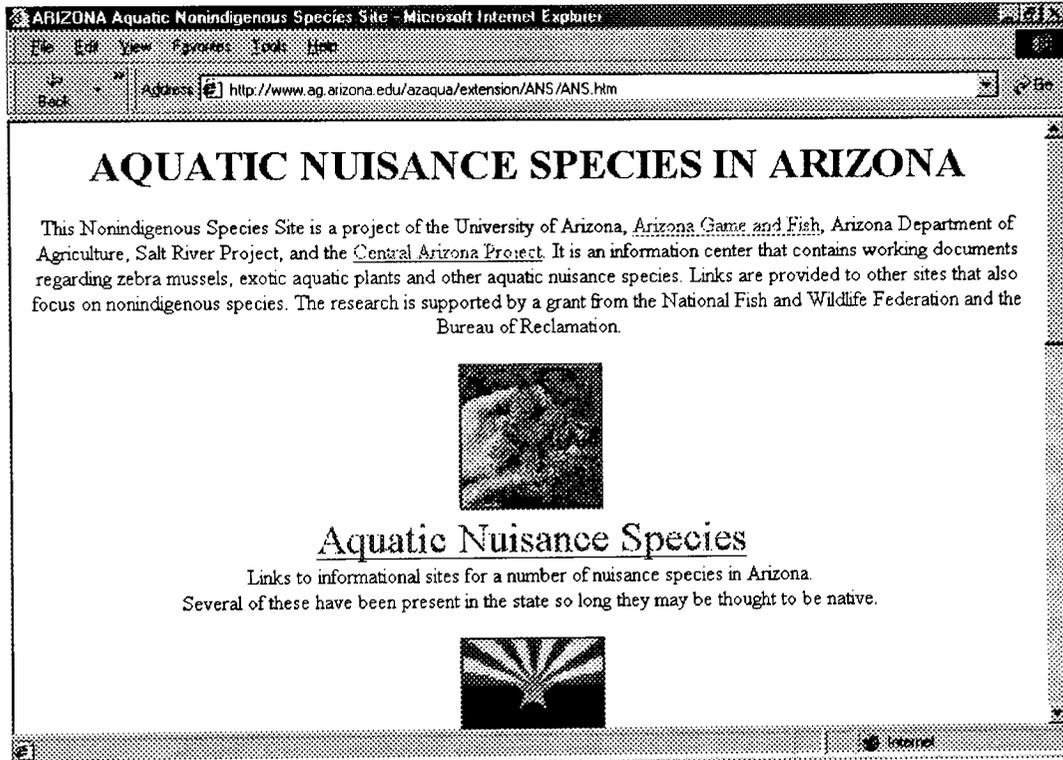


Figure 1.2: Homepage, part 2

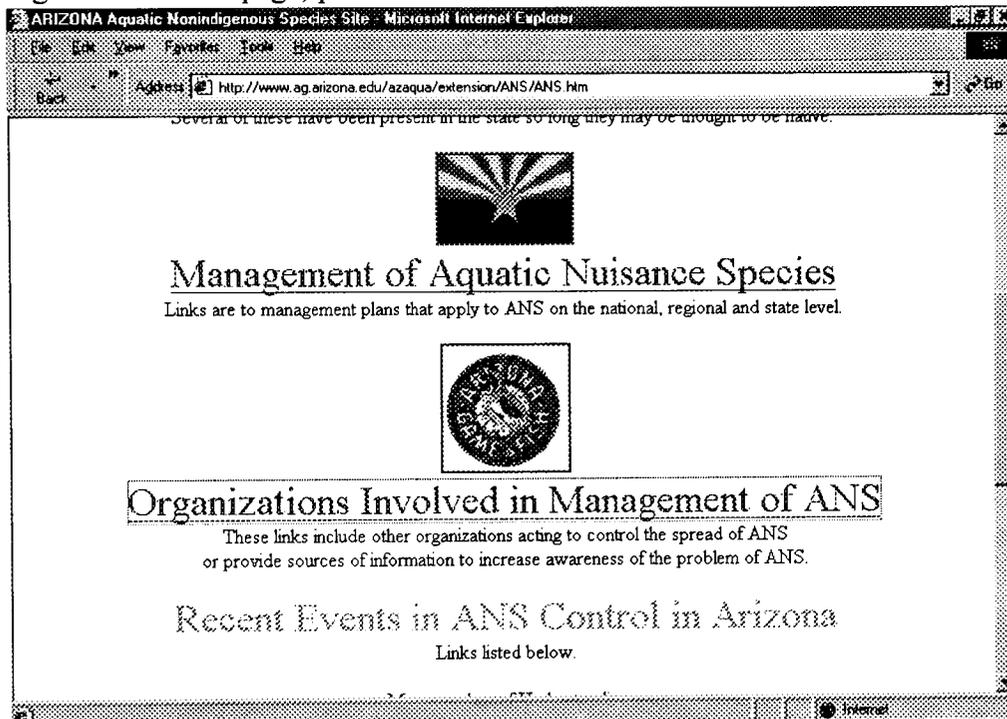


Figure 1.3: Homepage, part 3

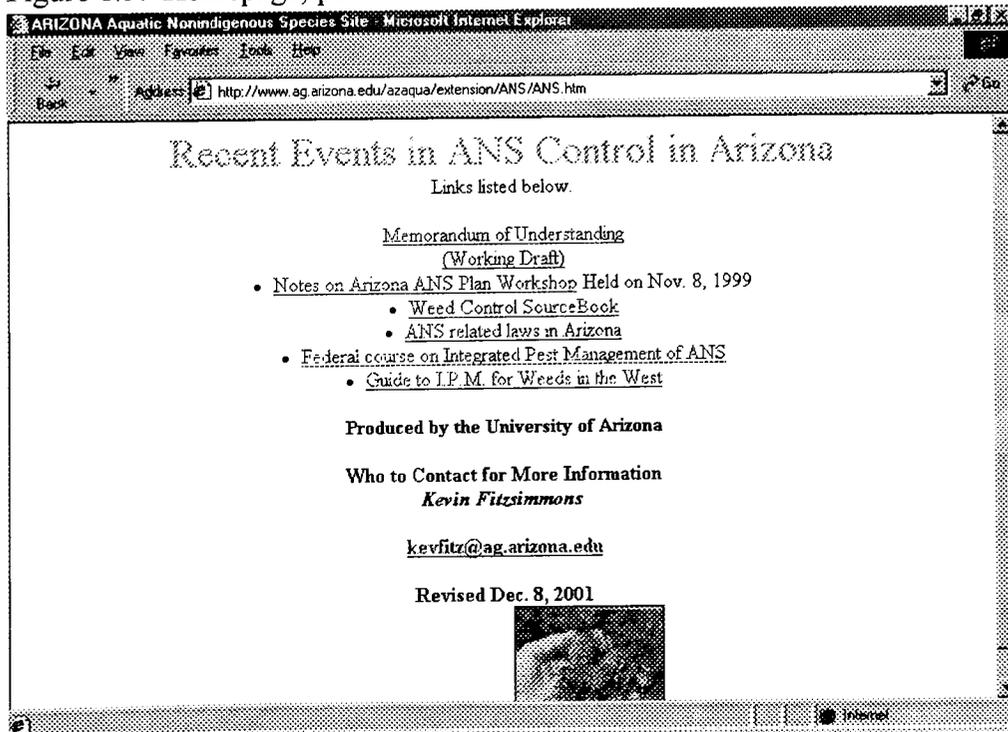


Figure 2: Links to Information on Threatening ANS

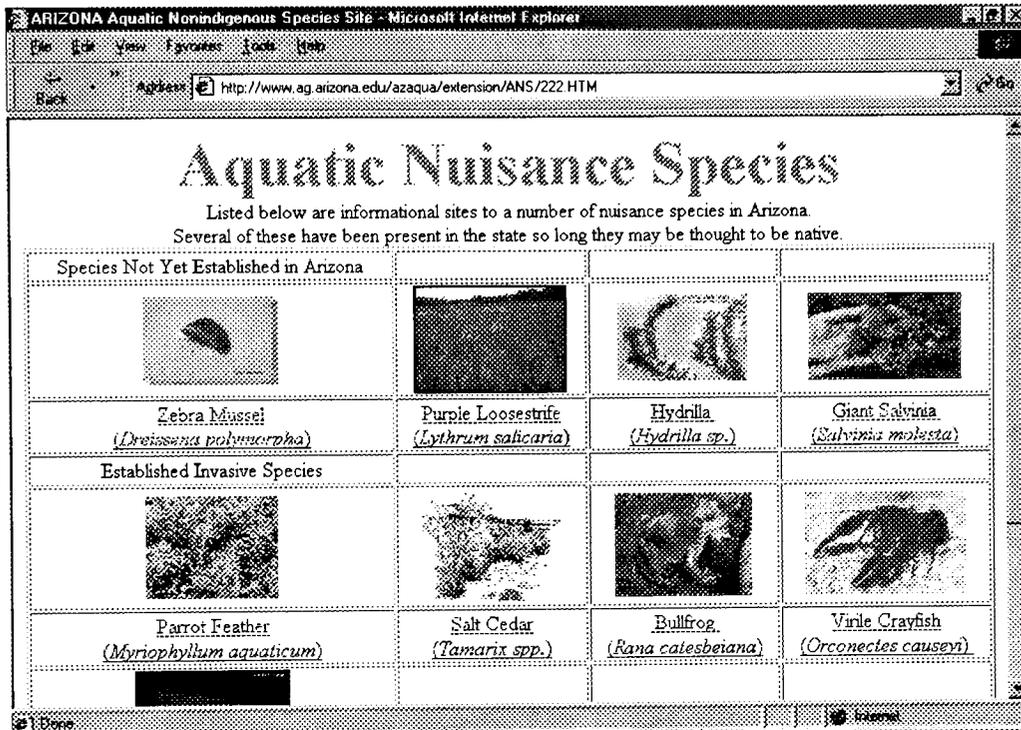


Figure 3: Links to Other Management Plans and Areas

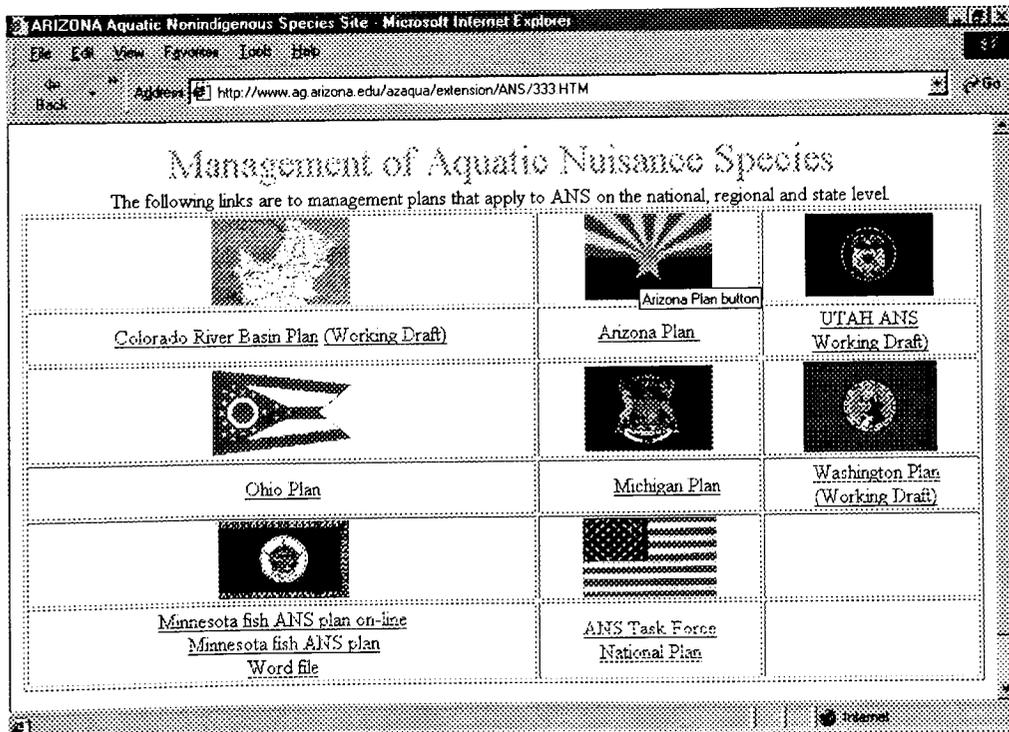


Figure 4: Links to Entities Across the U.S. Involved in Nuisance Species

ARIZONA Aquatic Nonindigenous Species Site - Microsoft Internet Explorer

File Edit View Favorites Tools Help

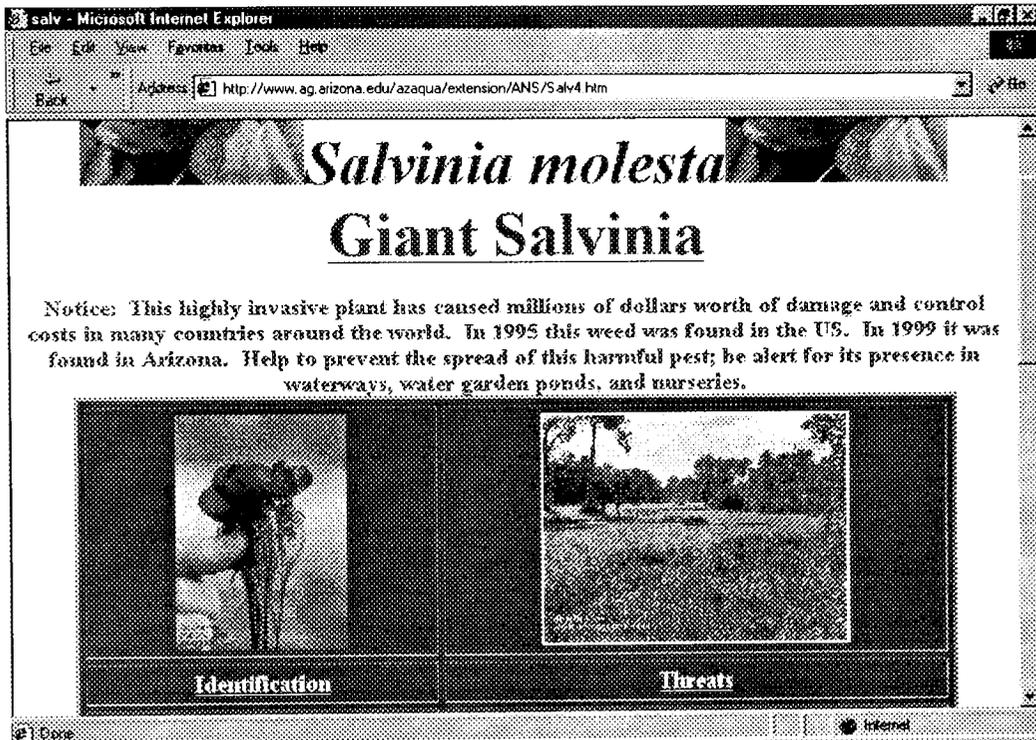
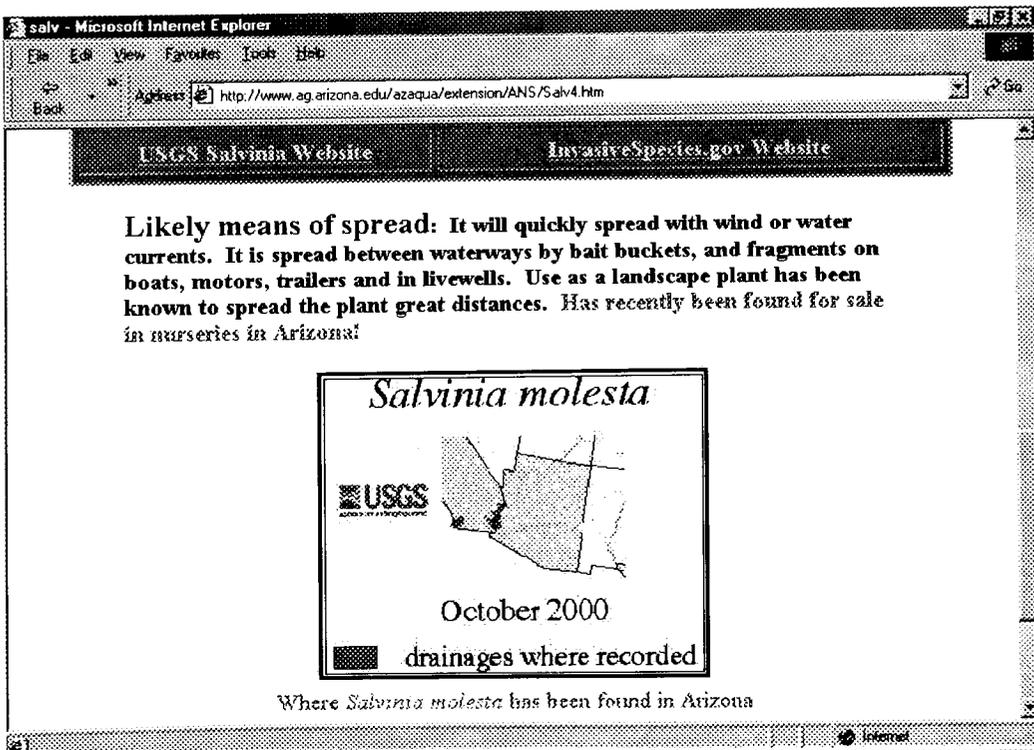
Address http://www.ag.arizona.edu/azaqua/extension/ANS/4.HTM

## Organizations Involved in Management of ANS

These links include other organizations acting to control the spread of ANS or provide sources of information to increase awareness of the problem of ANS.

		
<a href="#">Sea Grant site</a>	<a href="#">USGS Non-indigenous Aquatic Species Site</a>	<a href="#">National Biological Information Infrastructure Site</a>
		
<a href="#">Western Regional Panel on ANS</a>	<a href="#">Southwest Exotic Plant Mapping Program</a>	<a href="#">Aquatic Plant Management Society</a>
	<a href="#">America's Least Wanted</a>	

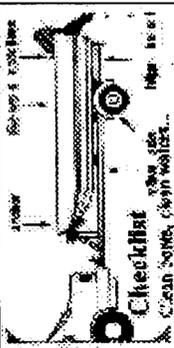
Done Internet

Figure 5.1: First half of *Salvinia molesta* LinkFigure 5.2: Second Half of the *Salvinia molesta* Link

**APPENDIX B**

**ANS Flyer: Brochure for Distribution to Increase Public Awareness**





Checklist

- ✓ Clean bowls, clean water, clean air.
- ✓ Remove plants and animals from your boat, miller, and necessary equipment before leaving the water access area.
- ✓ Drain your livewells, bilge water, and bait trays before leaving.
- ✓ Empty your bait bucket on land, never in the water. Never fill your bait or minnow bucket from the lake or river water in it from another. And never dump any fish from the water body into other waters.
- ✓ Wash your hat, waders, downriggers, and trailer with hot water when you get home. Flush water through your motor's cooling system and other boat parts that cannot be get out. If possible, let everything dry for three days before reintroducing your boat to another body of water.

What if you have these organisms look like (at least those you can see)? You suspect a new infestation of an exotic plant or animal, report it to:

**Control:**  
 For recommendations and permits before you try to control or eradicate an exotic "pest" organism, contact "pest" specialists on their website. Do-it-yourself control measures often make matters worse and can hurt native species.

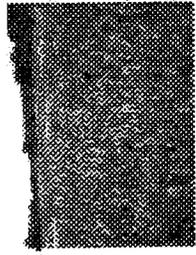


Zebra Mussel  
*Dreissena polymorpha*

- \* Adult size: 1 1/2 to 1 inch
- \* Not just in Arizona, but specimens have been found to pass through the state on boats entering California.
- \* Should look for a massive exfoliating of native freshwater mussels.
- \* Use the power to shut down electrical outlets and byproducts clinging onto boat pipes expected to cross 55 billion if caught by the year 2002.

Zebra mussel's egg sacs are a size of a quarter of a centimeter. They have a sticky coating and they stimulate native mussel species. Female zebra mussels can produce as many as 1 million eggs per year. These develop into microscopic, free-swimming larvae called veligers that quickly begin to form shells. As they grow, the sand grains they filter out settle and attach to any free surface using "byssal threads".

They will cover rock, gravel, metal, rubber, wood, crevices, native mussels, and such other likely means of spread. Microscopic larvae may be carried to new water bodies. Adults are usually in boats or boating equipment that sit in the water.



Purple Loosestrife  
*Lythrum salicaria*

- \* Adult height: 2-7 feet tall, in Arizona
- \* Purple loosestrife stems consist of 1/3 to 1/2 inch diameter, and they produce up to 2 million seeds per plant per year.
- \* Identified as an ornamental, this exotic plant is in all states and all Canadian border provinces.
- \* Purple loosestrife creates marshes and lakeshores, including streams and other wetland plants. The plant can form dense, impenetrable stands that are unmanageable to cover, abate, or mow.
- \* Many are and are being used in wetland plant and animal research.
- \* Several European insects that prey attack purple loosestrife are being tested as a possible long-term biological control of purple loosestrife in North America.
- \* Likely results of spread: Needs escape from garden and nurseries into wetlands, lakes, and rivers. Once in aquatic systems, seeds are easily spread by moving water and wetland animals.

South Carolina's... This plant has spread through most of the riparian areas of the state and is currently spreading to other plants. It may also alter or eliminate the habitat of other species such as the Texas pupfish, blackchin shiner, white crappie, and yellow billed cuckoo.



Fishhead smelt

- \* Introduced from Arizona's Salt River in 1977
- \* Lives for 20 years in rivers and reaches a length of four feet with a weight of 70 pounds.
- \* Unlike other smelts, the fishhead smelt is not a winter sport in water. It feeds on other fish, decreasing populations of native species.
- \* Depleted riparian streams in riparian areas both the endangered Colorado squawfish and the recovery of the Colorado squawfish and other endemic and native species.
- \* Because of the species' success in riparian areas, the state has begun a program to eradicate the species in the upper Colorado River basin.

South Carolina's... This plant has spread through most of the riparian areas of the state and is currently spreading to other plants. It may also alter or eliminate the habitat of other species such as the Texas pupfish, blackchin shiner, white crappie, and yellow billed cuckoo.

South Carolina's... This plant has spread through most of the riparian areas of the state and is currently spreading to other plants. It may also alter or eliminate the habitat of other species such as the Texas pupfish, blackchin shiner, white crappie, and yellow billed cuckoo.

## APPENDIX C

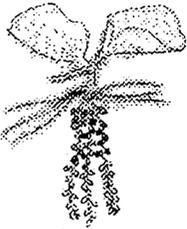
ANS WATER BILL INSERT: Created for Salt River Project Mailings and AZ Game and Fish Boat Manuals

### *Salvinia molesta* (Giant Salvinia)

#### Arizona's Newest Aquatic Nuisance Species

**Impacts:** *Salvinia molesta* populations can double weekly, produce a mat of growth over the water up to 2 feet thick, block off light to plant growth below, and reduce the exchange of oxygen into the water. It can clog boat propellers and engine intakes, ruin fishing and skiing, clog irrigation and municipal water pipes and impact migrating birds.

**Identification:** A free floating aquatic fern, made up of pairs of oval leaves, green to brown leaves that are up to 1 ½" long, connected by a horizontal stem. Each leaf has many tiny hair-like structures, that split then rejoin at the tips to form an egg beater-like structure. Root-like structures containing infertile spores hang below each plant segment.



Copyright 2008, University of Texas  
 Center for Aquatic and Wetland Research

**Likely means of spread:** It will quickly spread with wind or water currents. It is spread between waterways by bait buckets, and fragments on boats, motors, trailers and in livewells. The plant also escapes from water gardens, often carried by birds.



## APPENDIX D

### Lesson Plans to Inform Students of ANS

#### **Unit: Aquatic Nuisance Species (ANS)**

#### **Lesson: Finding alien invasions in our state.**

Grade: 6-9

Group size: 15-25 students

Cooperative Learning Groups of 3-4 students

Background Knowledge: Assumes students have studied plants (especially growth and reproduction), ecosystems and some ecology, and endangered species. However, should also work fine as a stand alone unit.

#### Objectives:

1. The students will be able to name three of the 5 main plants threatening AZ
2. The students will be able to distinguish at least 2 characteristics of plants that could make them invasive.
3. The students will be able to design a method of testing the waters of AZ for ANS

#### Anticipatory Set:

Introduce the zebra mussel problem by using the slide show at:

<http://www.science.wayne.edu/~jram/zmussel.htm#slide2> also show the animated dispersion map found at

<http://www.nationalatlas.gov/zmussels1.html> to demonstrate the rate of spread of this species.

Explain the difference between native species and exotics. Also define the terms alien species, aquatic nuisance species, nonindigenous species, invasive species.

#### Body

1. What makes a plant an invading alien?
  - a. List what students know about plants, focusing on reproduction and dispersion. Ask questions such as: What are ways plants can reproduce? What do plants use to reproduce? How do weeds take over a garden if they are not pulled?
  - b. Give each group of students information on the plant species that are invading or threatening to invade AZ. This information can be found on the ANS homepage at: <http://ag.arizona.edu/azaqua/extension/ANS/222.HTM> .
    1. Give them five minutes to look it over suggesting each student in the group chose one aspect of the plant
    2. Give them several minutes to discuss what they found, with one writing down their ideas for why this plant is an invading alien
    3. Ask them to share their findings about the basics of each plant species with the class.
    4. Open a discussion on why they think these plants are invading new areas
2. How do ANS spread?
  - a. Ask each group to draw three ways they think their plant could disperse.
  - b. Post the drawings in the front of the room, ask for explanations.
  - c. Draw out any other methods of spread through directive questioning
3. How do we know where ANS are now?

- a. Referring to a map or overhead with a map of AZ (one such as the Arizona Water map with its emphasis on bodies of water is recommended) point out where water is in the state. Emphasize where people live in relation to the areas the water is or goes through.
- b. Ask what some of the problems might be with trying to figure out where ANS are.
- c. Assign to each group the task of designing a plan for monitoring waterways in the state. Requirements are that each group figures out who, where, and how checks will be done. Plan must be written up as an action plan that is detailed enough to be started tomorrow.

#### Closure

1. Information popcorn: Pose one question and have one from each group answer it for their plant, one for the group to their right and one for the group to the left.
  - a. Name an ANS.
  - b. What makes it an ANS.
  - c. How can it spread.

2. Reiterate homework assignment. Take any questions on it.

#### Assignment:

Design a plan for monitoring waterways in the state. Requirements are that each group figures out who, where, and how checks will be done. Plan must be written up as an action plan that is detailed enough to be started tomorrow.

#### References:

Note websites listed in the lesson plan.

**Unit: ANS****Lesson: How does your ANS grow?**

## Objectives:

1. The students will be able to list four examples of potential harm due to the spread of ANS.
2. The students will be able to determine the time until various sized lakes are covered by *Salvinia molesta* at optimum growth rates at 80% accuracy
3. The students will be able to analyze ANS case studies in small groups and determine a plan of action for each.

## Anticipatory Set

One of the main concerns with ANS is the rapid rate at which they reproduce and cover bodies of water, especially slow moving water. Since a picture may be worth a thousand words, here are links to 5 pictures of the aquatic weed *Salvinia molesta* as found in states from North Carolina to Texas to Hawaii. As students look at these pictures, ask them to think of what kind of harm these plants may cause, and ask each to write down 3 questions of their own that come to mind when they see these pictures.

[http://nas.er.usgs.gov/plants/sa\\_molesta/images/nc/cape\\_fear\\_nc\\_2.jpg](http://nas.er.usgs.gov/plants/sa_molesta/images/nc/cape_fear_nc_2.jpg)

[http://nas.er.usgs.gov/plants/sa\\_molesta/images/alwake.jpg](http://nas.er.usgs.gov/plants/sa_molesta/images/alwake.jpg)

[http://nas.er.usgs.gov/plants/sa\\_molesta/images/harris.jpg](http://nas.er.usgs.gov/plants/sa_molesta/images/harris.jpg)

[http://nas.er.usgs.gov/plants/sa\\_molesta/images/enchlk.jpg](http://nas.er.usgs.gov/plants/sa_molesta/images/enchlk.jpg)

[http://nas.er.usgs.gov/plants/sa\\_molesta/images/bird.jpg](http://nas.er.usgs.gov/plants/sa_molesta/images/bird.jpg)

Discuss the student questions, seeing if the students can answer some of them. Then list on a board or overhead the potential harmful effects of these weeds that students came up with.

## Body:

1. In waters with adequate nutrient levels, *Salvinia molesta* has been observed to double in size in as little as 3 days. To get the students thinking about how fast this can be, first give them a piece of graph paper and have them mark off 16 equal sized boxes. Have them shade in one of the boxes, identifying this as the infested area of their square or rectangular pond. Assuming that nutrient conditions are right, the weeds will double in 3 days, how long until the whole pond is covered. Instruct the students to shade in as they go, showing the space covered each time the plants double.
2. Once the students have determined that their ponds will be covered in 12 days, give them the approximate square footage of the room. Suggest the room is a pond, and a 1 sq ft infestation of *salvinia* has become established. How long until the whole room/pond could be covered?
3. Now that it is more clear as to some of the dangers of the spread of ANS, and the extreme rate of the spread, its time to look at some case studies of circumstances that

are very similar to ANS cases in the state of Arizona and around the world. Working in groups of 3-4, each of these case studies should be examined. One person in the group should take the position of the person who has been found with an ANS in their possession, one person should take the position of a person who enjoys fishing and boating in Arizona waters, one person should take the position of the state department of agriculture (which is in charge of controlling exotic weeds), and if there is a fourth person, they should take the role of mediator. The goal is for each group to come up with a plan of action to take that will make all sides happy, and hopefully get rid of the weed. This can include who should pay, how should the weed be removed, and what can be done to prevent this from happening in the future.

#### CASE STUDIES:

1. A nursery imports many species of plants to meet the demands of gardeners who like to grow a variety of plants, especially unusual exotic species in their water pond gardening. One day, someone who works for the Arizona Department of Agriculture goes into the nursery and finds giant salvinia growing in among other plants that are for sale. The owner claims it sometimes comes in among other ornamental plants he buys from Brazil. He knows its been growing in his display pond for years, but fiercely claims it hasn't been doing any harm, even if it is on a list of weeds that aren't allowed to be shipped into the state. He does say he has sold it to several gardeners in the area. What should be done?
2. You are starting working at a pet store as an after school job. One of your first jobs is to clean out the fish tanks. The owner showed you where they usually dump the dirty water, right of the back porch and into a small stream. "Keeps our wild fish friends happy," said the owner when he showed you. As you clean out the tanks you notice bits and pieces of hydrilla and elodea are accumulating in the wastewater. When you step out back to dump the water, you notice hydrilla and bits of elodea are growing around the slow-moving pools along the edge of the stream. What should you do? What should be done to fix the problem?
3. The states of California and Arizona find Giant salvinia growing in an irrigation ditch that carries wastewater from the irrigation district back to the lower Colorado River. The infestation definitely started in the drainage ditch, but nobody knows how.. The ditch itself is actually owned by the irrigation district which is made up by all the farmers in the area. Since the ANS is in the drainage ditch, it doesn't affect the flow of water to the agriculture fields. The water has been found to have carried the salvinia miles downstream, where it has spread into several national parks and recreational areas. The cost to ensure that all of the salvinia is removed from the ditch is nearly \$750,000. What should be done to solve the problem?
4. Zebra mussels have caused millions of dollars of damage in the Great Lakes area of the US and Canada. They continue to spread at a rapid rate westward, upstream in rivers that flow to the Mississippi. So far they have not yet been

found in any rivers that flow west. Many irrigation districts are concerned about what may happen if zebra mussels infest the reservoirs where the water is drawn off. The costs to keep the water intakes and pumping mechanisms clean of zebra mussels are estimated to be in the several million dollar range if this should happen. Since Arizona has such a warm climate, many boaters bring their boats with them from northern mussel infested waters. Several of these boats have been found in Arizona with zebra mussels on the sides. What should be done to stop this method of spreading a devastating ANS to uninfected areas?

5. Many of the trout and catfish that are in the rivers of Arizona have been brought into the state from rivers that flow into the Mississippi. These fish can now survive in Arizona because of the dams that have been built. The deep water that builds up behind the dams becomes cold before it is released downstream. This cold water is perfect for the nonnative trout, but it slows down the native fish, especially some suckers and chubs, which aren't sport fish that are good for eating. Several of these native fish are now in danger of going extinct. Many fishermen don't want anything to happen to the trout, and some environmentalists think that all the nonnative fish should be removed. What should be done?

#### Conclusion:

If students have had enough time, they can give a short report on the situation they looked at, and what their solution was. A short explanation of how they came up with this solution would be helpful. A time for questions would be beneficial to address any questions the class may have for each group.

#### Assignment:

Assign some questions from the attached worksheet to strengthen their understanding of the time it takes for *salvinia molesta* to spread. Each group should prepare a write up on their proposed plan of study. Each group member should answer one of the following questions:

1. Give an overview of your situation in your own words.
2. In one paragraph explain your plan of action.
3. List people who would be affected by the problem in your scenario, and give pros and cons from your solution as viewed by each of these people (you must have at least three people and one or more pros and cons for each).
4. Name at least four harms that could be caused if the problem in your scenario was not fixed. If you can't think of four for your scenario, you may add to your list harms by any ANS.
5. What do you think are some of the reasons that it is hard to solve the problem of ANS rapidly? Explain in one paragraph.

#### References:

Note websites referenced in the lesson plan and the accompanying practice worksheet.

**Unit: ANS****Lesson 3: Spread the word, not the weed**

## Objectives:

1. The students will be able to create ways to clearly communicate potential harm to the public as caused by ANS by making some form of media conveying a convincing message about prevention, control or eradication of ANS.
2. The students will be able to demonstrate persuasive letter writing skills and knowledge of ANS by writing a letter to a public official encouraging them to focus on taking care of ANS.

## Anticipatory Set

Brainstorm session: If the goal is to stop the spread of all aquatic nuisance species, to control them where they have already started growing and to eradicate them whenever possible, what should be done to accomplish these three goals?

If we want to accomplish these goals, who needs to know about ANS (the people who ANS will directly affect are known as stakeholders)?

One example of something that has been done for giant salvinia is the printing of several brochures. One of these can be seen at:

[http://nas.er.usgs.gov/plants/sa\\_molesta/docs/salvinia.pdf](http://nas.er.usgs.gov/plants/sa_molesta/docs/salvinia.pdf)

<http://www.dcr.state.va.us/dnh/fslysa.pdf> a flyer for purple loosestrife

<http://www.nationalatlas.gov/zmussels1.html> an animated map of the spread of zebra mussels. Requires Shockwave, which can be downloaded for free at:

<http://sdc.shockwave.com/shockwave/download/frameset.fhtml?>

## Body:

1. Over the past several lessons it has become obvious how rapidly nuisance species can take over natural habitat and interfere with many activities that humans value from water bodies. Despite this potential storm of invaders that are waiting to invade many natural areas, news of these invaders is trickling out very slowly. Your first goal for this class is to produce some means of getting information out to the public. Working in pairs, each group should pick one group from the stakeholders list who they want to inform. A plan for getting information out to them must then be created. This can be in the form of ads, flyers, posters, etc.. The plan should also explain how or where the information will be spread, giving some justification as to why this is a valid way.
2. As well as the public getting involved, people in the government also need to be involved to ensure that the state receives funds for taking care of ANS. Still working with your partner, compose a letter to the governor or one of the legislators for your area to persuade them to focus some of their energies on solving this growing problem

<http://www.azleg.state.az.us/members/members.htm> links to contact your legislators

<http://www.az.gov/index.html> link to contact Gov. Hull

3. Each group should exchange their letter with another group for a proofreading, making any suggestions for changes and returning it to its original group for revisions.
4. Groups should prepare to present their public awareness project to the class with an explanation of who their target audience is and where they suggest putting their information.

**Conclusion:**

Students will present their public awareness project to the class as a whole in one minute or less.

**Assignment:**

Groups will type and print out their letters and have them prepared for mailing tomorrow.

**References:**

See websites in the lesson plan.

APPENDIX E  
*Salvinia molesta* and Aquatic Weed Management Area

Figure 6: Distribution of *Salvinia molesta*

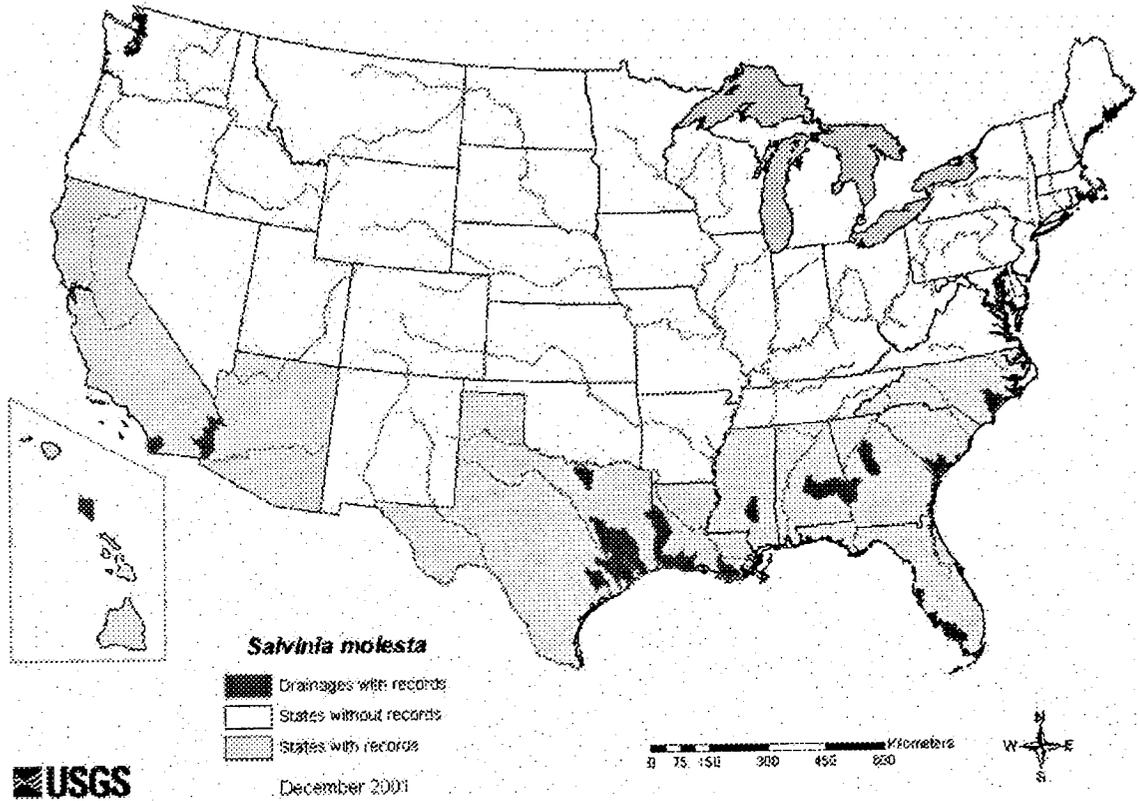


Figure 7: Aquatic Weed Management Area, Arizona: Dark areas in central part of the state represent the management area, geographically aligned around .

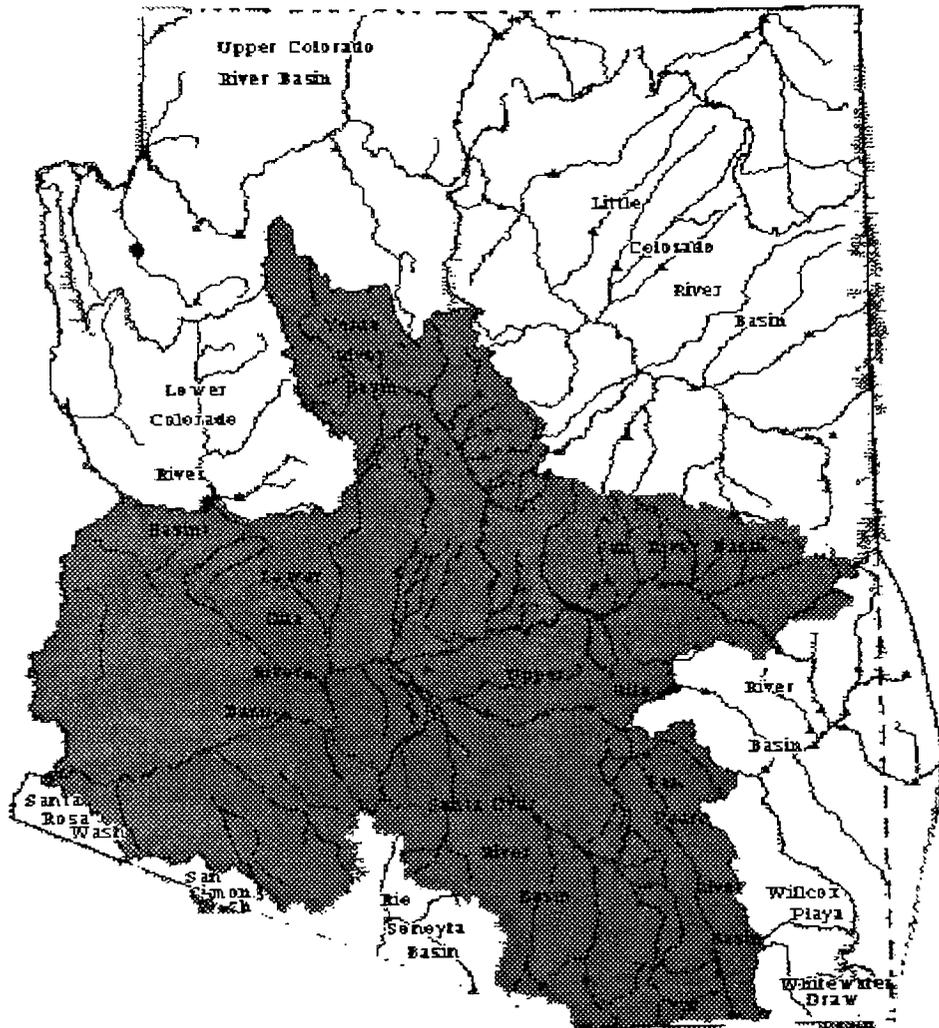
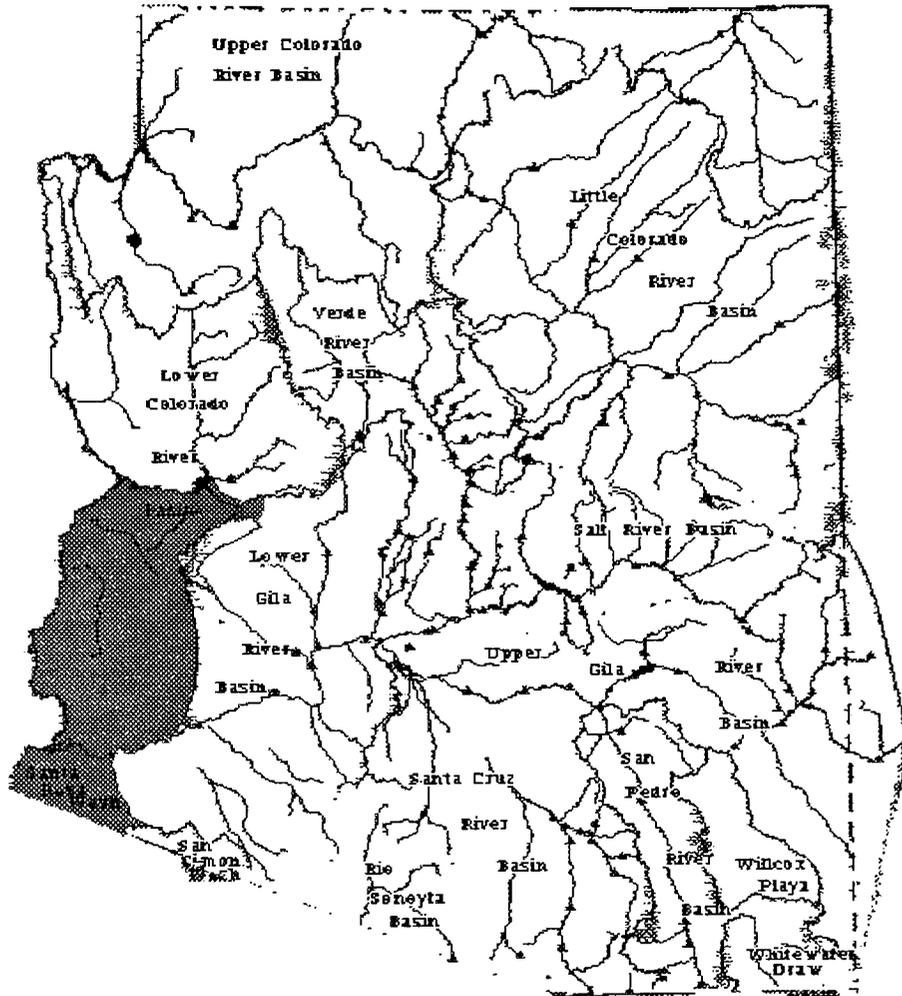


Figure 8: *Salvinia molesta* Weed Management Area, Arizona: Dark areas in southwest part of the state represent the management area.



## REFERENCES

- The Aquatic Nuisance Species Taskforce. (2002). Online.  
(<http://anstaskforce.gov/moreimpacts.htm#>)
- Biology web team. (2000). Department of the Interior. U.S. Geological Survey. Online  
(<http://biology.usgs.gov/pr/newsrelease/1995/8-16.html>).
- Cary, Peter R. and Weerts, Peter G.J. (1983). Growth of *Salvinia molesta* as Affected by Water Temperature and Nutrition II. Effects of Phosphorus Level. *Aquatic Botany*. 17: 61-70.
- Carmichael, G.J., Hanson, J.N., Schmidt, M.E., and D.C. Morizot. (1993). in Cox, George W. *Alien Species in North America and Hawaii*. Island Press, Covelo, CA.
- Cox, George W. (1999). *Alien Species in North America and Hawaii*. Island Press, Covelo, CA.
- Crawford, C.S., Ellis, L.M., and M.C. Molles, Jr. (1996). in Cox, George W. *Alien Species in North America and Hawaii*. Island Press, Covelo, CA.
- Crosby, Alfred (1986). in Cox, George W. *Alien Species in North America and Hawaii*. Island Press, Covelo, CA.
- Foy, C.L., Forney, D.R. and W.E. Cooley. (1983). in Cox, George W. *Alien Species in North America and Hawaii*. Island Press, Covelo, CA.
- Jacono, C.C. (2002). Department of Interior, U.S. Geological Survey. Online  
([http://salvinia.er.usgs.gov/html/news\\_and\\_notes.html](http://salvinia.er.usgs.gov/html/news_and_notes.html)).
- Loope, L.L. and D. Mueller-Dombois (1989). in Cox, George W. *Alien Species in North America and Hawaii*. Island Press, Covelo, CA.
- Minckley W.L., Marsh, P.C., Brooks, J.E., Johnson, J.E., and B.L. Jensen. (1991). in Cox, George W. *Alien Species in North America and Hawaii*. Island Press, Covelo, CA.
- Mitchell, D. S. (1979). Aquatic weeds in Papua New Guinea. *Science in New Guinea* 6:154-160.
- Mitchell, D. S., Petr, T. and Viner, A. B. (1980). The water fern *Salvinia molesta* in the Sepik River, Papua New Guinea. *Environmental Conservation* 7:115-122.

- The Nature Conservancy (2001). National Biological Information Infrastructure. Online.  
(<http://www.invasivespecies.gov/profiles/main.shtml>).
- Pimentel, D., Lack, L., Zuniga, R. and Morrison, D. (2000). Environmental and economic costs of nonindigenous species in the United States. BioScience 50 (1): 53-65.
- Rejmanek, M. (1991). in Cox, George W. *Alien Species in North America and Hawaii*. Island Press, Covelo, CA.
- Room, P. M. (1986b). Biological control is solving the world's *Salvinia molesta* problems. In: Proceedings EWRS/AAB 7th Symposium on Aquatic Weeds 1, pp. 271-276. European Weed Research Society, Loughborough.
- Room, P.M. (1990). Ecology of a Simple Plant-Herbivore System: Biological Control of *Salvinia*. TREE. 5(3).
- Room, P.M. and Julien, M.H. (1994). Population-biomass dynamics and the absence of  $-3/2$  self-thinning in the clonal weed *Salvinia molesta*. Australian Journal of Ecology. 19: 26-34.
- Simberloff, D. (1996). Impacts of introduced species in the United States. Consequences 2: 13-23.
- Thomas, P. A. and Room, P. M. (1986b). Taxonomy and control of *Salvinia molesta*. Nature 320:581-584.
- [TNC] The Nature Conservancy. (1996). America's least wanted: alien species invasions of US ecosystems. Arlington (VA): The Nature Conservancy.
- Department of the Interior.(2001). U.S. Geological Service. Online  
(<http://nas.er.usgs.gov>)
- Whiteman, J.B., and Room P.M. (1991). Temperatures lethal to *Salvinia molesta* Mitchell. Aquatic Botany. 40:27-35.
- Wilcove, D.S., Rothstein D., Dubow, J., Phillips, A. and Losos E. (1998). Quantifying threats to imperiled species in the United States. BioScience 48: 607-615.
- Williamson, M. and A. Fitter (1996). in Cox, George W. *Alien Species in North America*

*and Hawaii.* Island Press, Covelo, CA.