CAULERPA TAXIFOLIA: A POTENTIAL THREAT TO U.S. COASTAL WATERS

A PRELIMINARY REPORT PREPARED FOR: THE AQUATIC NUISANCE SPECIES TASK FORCE

BY

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PURPOSE

On October 19, 1998, over 100 research scientists joined efforts to alert the Secretary of the U.S. Department of the Interior (DOI) of a potential marine invader poised for introduction into U.S. coastal waters. The group recommended immediate action by the DOI to prevent this invader from entering U.S. coastal waters and consequently threatening the biodiversity of these ecosystems (Appendix A). In response, the DOI requested leadership from the U.S. Fish and Wildlife Service (Service).

The Service has initiated efforts to investigate the potential invader, including potential pathways of introduction and impacts to coastal waters, as well as existing authorities relevant to preventing species introductions. This report is being prepared in partial fulfillment of the Service's charge, and will be presented to the national Aquatic Nuisance Species (ANS) Task Force at their next meeting, November 17-18, 1998. The ANS Task Force is an intergovernmental body established by the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. The ANS Task Force provides an appropriate forum for further discussion and decision-making regarding recommendations to prevent the introduction of this potential marine invader. The information provided in this report is intended to assist the ANS Task Force in its decision-making process.

INTRODUCTION / BACKGROUND

The tropical green alga *Caulerpa taxifolia* (Vahl) C. Agardh (Ulvophyceae, Caulerpales) was first detected in the Mediterranean Sea in 1984 (Meinesz et al. 1993). Since its discovery, it has become widespread across the northern and western coasts of the Mediterranean and in Adriatic coastal regions, crossing the borders of five countries. Like many successful invasion species, *C. taxifolia* spreads rapidly, possessing life history features enhancing its ability to spread and take over coastal areas. When first detected off the coast of Monaco in 1984, it was believed to cover an area approximately 1m^2. By 1990, it was found off the coast of France and coverage was estimated at approximately 3 hectares. In 1992, it was detected in the coastal waters of both Spain and Italy, and coverage was estimated at 427 hectares. By 1994, coverage increased to approximately 1500 hectares, and in 1995 it was discovered in Croatia in the Adriatic Sea (Komatsu et al. 1997). Current estimates indicate coverage to have increased to over 4000 hectares.

C. taxifolia is believed to have been introduced into the Mediterranean as an aquarium release or escape. It is genetically identical to strains cultured and propagated in western European aquaria since the early 1970's (Jousson et al. 1998). The introduced *C. taxifolia* is believed to be a genetic clone of a single plant, exhibiting characteristics and tolerances different from its parent plant. The naturally occurring strain reproduces sexually. However, in the Mediterranean only male cells have been detected, leading researchers to the clone theory (Raloff 1998). This aquarium-bred plant exhibits vegetative or asexual reproduction (Komatsu et al. 1997; Meinesz et al. 1993). Small cuttings or plant fragments are capable of regenerating whole new plants. In the Mediterranean, these plants form dense meadows, covering the seafloor, reaching up to 75cm in height. In its native range, *C. taxifolia* grows in small isolated clumps and typically reaches approximately 25cm in height (Raloff 1998).

In addition to its reproductive strategy the Mediterranean strain of *C. taxifolia* exhibits a number of characteristics divergent from its parent plant, contributing to its success as an invasion species. The naturally occurring strain of *C. taxifolia* is a tropical species that can not tolerate the cold temperatures of the Mediterranean in the winter. In its native range *C. taxifolia* is not found in waters less than 20.0°C (Raloff 1998). However, winter water temperatures in the Mediterranean drop to approximately 12.8°C (Raloff 1998). Based on laboratory investigations, the Mediterranean strain exhibits a wider range of thermal tolerance relative to the naturally occurring strain, surviving between the isotherms of 10 - 31°C (Komatsu et al. 1997). At temperatures between 10 and 12.5°C, the plant survives, however no growth occurs. At 15°C new stolons develop, and at 17.5°C new fronds develop. Between 15 and 31°C, growth and development increase as a function of temperature with optimum growth observed between 20 and 30°C. Based on the temperature tolerances exhibited by this strain in the laboratory and average water temperatures in the Mediterranean, it is expected that *C. taxifolia* will be capable of expanding its range throughout the Mediterranean Sea. The highest northern latitude at which a population has been confirmed is 45°N in Croatia, Adriatic Sea (Komatsu et al. 1997).

C. taxifolia is apparently able to adapt to a wide range of habitat conditions including substrate, light intensity, and water quality. This invasive has been collected from various substrate types including mud, sand, cobble, rock, and dead *Posidonia* meadows (Ceccherelli and

Cinelli 1998; Report 1998). Maximum colonization occurs at depths between 2 and 6m, however dense beds have been found at depths down to 50m (Bellan-Santini et al. 1996; Report 1998). The maximum depth reported is 99m (Bellan-Santini et al. 1996). Likely contributing to its success in deep-water habitats, *C. taxifolia* is capable of adapting to very weak light intensities (Komatsu et al. 1997). This invader is also apparently tolerant of poor water quality, growing in areas of both clean and polluted waters (Report 1998).

The Caulerpales in general synthesize toxic or repellent secondary metabolites as a strategy against herbivory and epiphytism (Ferrer et al. 1997). *C. taxifolia* synthesizes nine such toxic substances (Report 1998). The most active and abundant toxin synthesized by *C. taxifolia* is caulerpenyne, a toxin specific to and produced by all the Caulerpales (Ferrer et al. 1997; Lemée et al. 1993). However, it is more abundant in *C. taxifolia* than in other tropical species of *Caulerpa* (Ferrer et al. 1997; Guerriero et al. 1992). Increased production of this toxin likely contributes to its success as an invasion species by reducing herbivory, epiphytism, and negatively affecting indigenous seagrasses.

PATHWAYS:

The biology of *C. taxifolia* and its ability to adapt to a wide variety of environments enhance its ability to successfully expand its range and establish new populations. This algal species reproduces asexually through fragmentation. This is a critical life history feature important to predicting potential pathways of introduction as well as potential control alternatives. Expansion would likely be expected to continue in the Mediterranean based on the direct movement of plant fragments by currents. The introduction of nonindigenous species into new ecosystems is, however, often related to anthropogenic activities. The unintentional movement of species can be associated with international, national, regional, or local activities. In the case of *C. taxifolia* each of these types of activities could play an important role in its continued expansion to new areas.

C. taxifolia has been shown to foul commercial fishing gear (Komatsu et al. 1997). Other activities such as anchoring, dredging, and storm events can disrupt populations. Due to its successful reproductive strategy, the plant fragments disrupted and subsequently moved by such activities can establish new populations. Likewise, the attempt to reduce populations by mechanical removal tends to only expand the population (Medwaves 1997; Raloff 1998). Plant fragmentation due to commercial fishing activities and anchoring is believed to be the primary cause for continued expansion in the Mediterranean (Raloff 1998).

The transport and introduction of nonindigenous species in the ballast water of transoceanic vessels has been associated with many introductions in U.S. waters. If plant fragments can survive ballast tank conditions, this mechanism of transport could pose a significant global threat to coastal waters. Climatic and ocean currents could also play a role in the movement of *C. taxifolia* across the geographic barrier of the Atlantic Ocean. Ocean currents in the equatorial zones off the coast of Africa could disperse this invader. The probability of this type of transport resulting in the establishment of *C. taxifolia* is low. A number of condition factors would have to be met, including the establishment of *C. taxifolia* in the coastal waters of Africa. The threat posed by this mechanism of transport is minimal relative to other pathways of introduction.

As of this date, *C. taxifolia* has not been detected in any coastal waters of the U.S. However, it has been observed in an aquarium in Hawaii (Raloff 1998). Currently, there are no restrictions on the aquarium industry preventing the importation and distribution of *C. taxifolia* for use in public or private aquariums. Other countries, including France, Spain, and Australia have already banned the possession, transport, or sale of *C. taxifolia* to reduce associated risks. The importation and distribution of this species through the aquarium trade poses a risk to U.S. coastal waters as escape or release is likely inevitable. In addition to aquarium imports, fishery products imported for the fresh seafood market may also pose a risk to U.S. waters. Many fishery products are packaged in seaweed for importation. Again, the ability of this species to regenerate new plants from plant fragments enhances its potential for successful establishment through this pathway.

POTENTIAL RANGE

In an attempt to predict the potential range of *C. taxifolia* in U.S. waters, thermal tolerance was selected as a key factor contributing to colonization potential. *C. taxifolia* exhibits a wide range of thermal tolerance, surviving between the isotherms of 10 – 31°C (Komatsu et al. 1997). However, in laboratory investigations, *C. taxifolia* survived for short periods at colder temperatures, a potentially important characteristic relative to spread potential. After 10 days at 7°C or 7 days at 6°C, growth of *C. taxifolia* resumed as temperatures were gradually increased (Komatsu et al. 1997). When maintained at 9°C, *C. taxifolia* did not survive beyond two months (Komatsu et al. 1997). The lower lethal temperature for *C. taxifolia* is estimated to be between 9 and 10°C, as survival for longer periods of time (3 months) was not observed at temperatures less than 10°C (Komatsu et al. 1997). The upper lethal temperature for *C. taxifolia* has been defined as between 31.5 and 32.5°C (Komatsu et al. 1997).

To predict the potential range of *C. taxifolia* if introduced into U.S. coastal waters based on thermal regimes, average monthly water temperatures recorded at fixed locations (NOAA weather buoys) were examined. Data was retrieved from buoys on both the Atlantic and Pacific coasts to determine the potential northern limits of *C. taxifolia* in U.S. waters. Based on these estimates, the northern limit on the Atlantic coast is likely in the vicinity of Virginia Beach, Virginia. According to data collected between 1990 and 1993, the lowest monthly average temperature occurs in March, when water temperatures average 9.6°C (Virginia Beach Buoy #44014; latitude 36° 34' 59" longitude 74° 50' 01") (www.nws.fsu.edu/buoy). This temperature is within the lower lethal range of *C. taxifolia*, however as mentioned above, survival is possible at temperatures less than 10°C for short periods of time. Buoy data collected from the Pacific coast indicate greater vulnerability in terms of thermal regimes relative to the Atlantic coast. Warmer water temperatures were recorded at more northern latitudes. Based on average monthly water temperatures recorded in 1991 through 1993, the potential northern limit of *C. taxifolia* is estimated to be in the vicinity of Stonewall Bank, Oregon (Stonewall Bank Buoy #46050; latitude 44° 37' 01" longitude 124° 31' 04") (www.nws.fsu.edu/buoy). The lowest temperatures recorded at this location occurred in January, when the average monthly temperature was 9.9°C. Again, due to the ability of *C. taxifolia* to survive short periods of time at temperatures less than 10°C, expansion into these areas can not be ruled out. The upper lethal temperature tolerance of *C. taxifolia* is not likely to limit its distribution in U.S. coastal waters. Buoy data from the Gulf of Mexico was examined from two sites. According to recorded average monthly water temperatures off the coasts of Mississippi and Texas, water temperature will not be an impediment to the survival and growth of *C. taxifolia* in terms of either cold or warm water tolerance levels. (OTP-Biloxi Buoy - Mississippi #42007; latitude 30° 05' 24" longitude 88° 46' 12" and Eileen Buoy – Texas #42020; latitude 26° 54' 59" longitude 96° 42'

00") (www.nws.fsu.edu/buoy). Buoy data collected from the coastal waters of Hawaii were also examined (Southwestern Hawaii Buoy #51002; latitude 17° 11' 27" longitude 157° 49' 39") (www.nws.fsu.edu/buoy). Again, temperatures in these waters would not hinder the growth and survival of *C. taxifolia*. Temperature ranges in the Gulf of Mexico and off the coast of Hawaii would allow for year-round growth of *C. taxifolia*.

Based on these estimates, the potential range of *C. taxifolia* in U.S. coastal waters is significant. Its range could include coastal areas south of Virginia Beach, Virginia on the Atlantic coast, areas south of Stonewall Bank, Oregon on the Pacific coast, the Gulf of Mexico, Hawaii, Puerto Rico, the U.S. Virgin Islands, Guam, and the Solomon Islands. In the Mediterranean, *C. taxifolia* has been observed at depths ranging from the shore down to 99m. U.S coastal waters providing unique or critical habitat areas would be threatened by the introduction of *C. taxifolia*.

IMPACTS

The introduction and establishment of nonindigenous species can alter and drastically affect the indigenous biota of the receiving ecosystem. Changes associated with invading species are most often irreversible, as the invader usually becomes a permanent member of the community. The introduction of *C. taxifolia* into the Mediterranean coastal waters threatens the biodiversity of this region. Continued expansion of this species within the Mediterranean and its potential dispersal to other waters threaten global biodiversity. Ecological consequences can be translated to socio-economic impacts, especially when it, directly or indirectly, affects commercially valuable species, human activities (commercial or recreational), or human health risks.

Ecological Impacts

The invasion of *C. taxifolia* has altered both the flora and fauna of the coastal waters of the Mediterranean, reducing biodiversity. The ability of this species to outcompete native species for light and space contributes to its success as an invader. Through competitive interactions, indigenous flora are reduced or eliminated leading to monocultural stands of *C. taxifolia* (Boudouresque et al. 1992; Ferrer et al. 1997). For example, *C. taxifolia* is known to adversely affect the native Mediterranean seagrasses, *Posidonia oceanica* and *Cymodocea* *nodosa* (de Villle and Verlaque 1995; Ceccherelli and Cinelli 1997). Although the range of environmental conditions tolerated by *C. taxifolia* is a key factor to its competitive advantage, other biological characteristics also contribute to its ability to reduce indigenous floral species. As previously discussed, *C. taxifolia* synthesizes toxins as a defense against herbivory and epiphytism. This defense mechanism provides an effective competitive advantage to *C. taxifolia*. In addition, these toxic secondary metabolites are believed to be released by *C. taxifolia* into the surrounding water (Ferrer et al. 1997; Giannotti et al. 1994; Merino et al. 1994). The release of these toxins further allows this species to proliferate through chemical interactions. For example, the productivity of some macroalgae species is negatively impacted through direct physical contact with *C. taxifolia* or by contact with plant extracts alone (Ferrer et al. 1997). Observed maximum interspecific effects coincide with the maximum growth periods of *C. taxifolia* (Bellan-Santini et al. 1996; Ferrer et al. 1997). Similar impacts have been observed on various species of phytoplankton. Toxins released by *C. taxifolia* inhibit or delay the proliferation of some planktonic algae, with maximum effects observed in the summer (Lemée et al. 1997). Additionally, the metabolites released by *C. taxifolia* are toxic to sea urchin eggs (Lemée et al. 1993), ciliates (Dini et al. 1994), and bacteria (Giannotti et al. 1994). Several species of sea urchin, including *Lytechinus variegatus* and *Paracentrotus lividus*, are also affected through a reduction in food intake (Ferrer et al. 1997; McConnell et al. 1982).

C. taxifolia establishes dense mats with up to 215m of stolons and up to 5000 fronds per square meter of seafloor (Raloff 1998). This coverage can directly affect the benthic fauna of invaded areas. Bellan-Santini et al. (1996) compared benthic invertebrates from invaded and non-invaded areas, specifically examining species richness and abundance of molluscs, amphipods, and polychaetes. In general, species composition or richness was only slightly reduced, with amphipods being the most affected. However, species abundance was reduced in all three groups. Maximum reduction was observed in March. Habitat modification, spatial competition, and the production of toxins all may contribute to changes in invertebrate populations.

Changes in benthic invertebrates could be associated with subsequent changes in ichthyofauna. Population structure of fish assemblages has changed in areas invaded by *C. taxifolia*. Both the number of individuals and fish biomass have declined significantly (Francour et al. 1995; Harmelin-Vivien et al. 1996). Declines in fish could be related to invertebrate, macrophyte, and phytoplankton population changes through food web dynamics or habitat modification affecting important spawning or nursery areas. Fish parasites that require specific invertebrate hosts have also been affected by the invasion of *C. taxifolia*. Digenean parasites of the fish species, *Symphodus ocellatus*, have nearly disappeared in areas invaded by *C. taxifolia* (Bartoli and Boudouresque 1997). In addition to the declining number of invertebrates, the synthesis and release of toxins by *C. taxifolia* may be contributing to this loss of parasites (Bartoli and Boudouresque 1997). It is unknown whether these toxins can be accumulated through food web interactions.

Economic Impacts

The introduction of *C. taxifolia* into U.S. waters could result in economic impacts affecting a variety of important industries. Generally, invasion species expand rapidly, often exponentially. The receiving systems typically lack the natural control mechanisms (i.e. predators) that maintain population levels in an organism's native range. The rapid expansion of a species such as *C. taxifolia* could affect the commercial fishery (including groundfish and shellfish), tourism (including beaches, SCUBA diving, coral reef touring, and other recreational activities), and possibly power plants associated with coastal waters.

Impacts to the fishery may be evidenced by direct changes in fish abundances or distribution. The ability of *C. taxifolia* to overgrow large areas of the bottom, outcompeting indigenous species for space, may reduce or eliminate some species and force others to migrate to sub-optimal habitats. Impacts to the fishery may also be caused indirectly by this overgrowth, if prey species are reduced or eliminated, or if critical spawning and nursery areas are unavailable. In addition, fouling of commercial fishing gear has been implicated as a problem in the Mediterranean. Increases in costs due to cleaning time and the potential need for additional gear will also affect the fishery. In 1996 and 1997, the total harvest of flounder in U.S. waters was valued at $154 million and $131 million, respectively (O'Bannon 1998). In addition to groundfish, U.S. coastal waters support an important shellfish industry. It is unknown whether this potential invader could overgrow and eliminate highly valuable shellfish beds. In 1996, the harvest of oysters and blue crabs in the U.S. was valued at $115 million and $159 million, respectively. In 1997, these harvests were valued at $111 million and $171 million, respectively

(O'Bannon 1998).

Previous invasions such as the Asiatic clam (*Corbicula spp.*), zebra mussel (*Dreissena polymorpha*) and a hydroid already cost the electric power and other industrial water users tens to hundreds of millions of dollars annually. Invasion of U.S. waters by the *C. taxifolia* clone could further increase power and other industry costs.

Impacts to tourism have been indicated in the Mediterranean due to the loss of aesthetics (Raloff 1998). Recreational activities and tourism provide substantial sources of income supporting many local U.S. economies. The natural beauty of coral reefs in many U.S. coastal waters could be threatened by the introduction of *C. taxifolia*, as well as the revenues generated by SCUBA diving, boat tours (glass bottom boats, etc.), and other recreational activities. Fragments washed onto recreational beaches could reduce use and increase maintenance costs.

Efforts to prevent the introduction of *C. taxifolia* into U.S. waters should include restricting its importation for use in aquariums. Prohibiting imports would likely have a limited impact on the aquarium industry by preventing the sale of this species.

CONTROL

Like most invasion species, control or eradication of *C. taxifolia* is not likely once the species becomes established. If its invasion is detected early, before the species covers significant amounts of seafloor, there may be a brief window of opportunity to control and possibly eradicate this invader. Generally, three types of control are considered when developing a control plan for nonindigenous species: physical, chemical, and biological. Implementation of control alternatives in the Mediterranean has experienced limited success.

Physical control is the only alternative that has successfully slowed the spread *of C. taxifolia*. Manual uprooting by trained divers can be conducted in small areas of minimal infestation, typically measuring only a few square meters. Eradication is generally not achieved immediately because re-growth occurs. However, repeated removal can eventually eliminate the population. This approach successfully eliminated populations in the Balearic Islands and at Port-Cros (Medwaves 1997). Once the population establishes vast coverage, this approach is no longer feasible. The use of mechanical devices to plow or uproot *C. taxifolia* is more likely to contribute to population expansion as the disruption caused by this practice results in the dispersal of plant fragments. Additional alternatives that have been investigated include air suction, ultrasound, and hot water jets (Medwaves 1997). All of these methods were unsuccessful.

Chemical control alternatives are often avoided due to public perceptions and possible risks to public health and safety. Several chemical control options have been investigated including copper electrodes, cross-ionic dialysis, and dry ice (Medwaves 1997). None of these alternatives have proven successful.

Biological control has been suggested as a possible alternative. Two molluscs, native to the Caribbean, are being investigated. The sea slugs, *Oxynoe azuropunctata* and *Elysia subornata*, reportedly feed exclusively on *Caulerpa* (Raloff 1998). Several species of sea slugs indigenous to the Mediterranean also feed exclusively on other species of *Caulerpa*, however, these native slugs avoid *C. taxifolia*. The synthesis of higher amounts of toxins by *C. taxifolia* is thought to be related to this avoidance (Raloff 1998). A number of concerns have been expressed regarding the use of these species as a control alternative. The first involves issues of general ethics. *C. taxifolia* is an invasive species that is rapidly spreading throughout the Mediterranean. Introducing another species to control this invader may initiate new problems. Understanding how the control invader will respond in its new environment can not be predicted. In some cases the targeted prey item is not consumed due to the presence of alternative prey items. If the invading species is unique to its new environment, the probability of successfully introducing another highly specific species for control purposes may be higher. However, three species of *Caulerpa* are present in and native to the Mediterranean. In addition, another species of *Caulerpa* has recently invaded the Mediterranean, *C. racemosa* (Report 1998). The presence of several *Caulerpa* species precludes the uniqueness of *C. taxifolia* to its new environment. It is possible that the introduction of these sea slugs could render a greater threat to native *Caulerpa* species. Also, there is some indication that *C. racemosa* is preferred by most sea slugs feeding on *Caulerpa* (Raloff 1998). Further complicating this issue, both sea slugs being investigated do not actually consume plant parts. Rather it consumes the mucilagenous matrix (liquid nutrients) of the fronds, thereby leaving plant parts to regenerate new plants.

Early detection of population expansion is critical to control success. Efforts should focus on increasing public awareness to enhance monitoring capabilities and spread prevention. Despite the efforts of governmental or organizational surveillance programs, the public is often the first to report population expansions of invading species. Education initiatives should target boaters, commercial and recreational fishers, SCUBA divers, and other coastal water users. Education initiatives should include information about *C. taxifolia* and its impacts in the Mediterranean, how to identify the species, and prevention strategies that water users can implement to prevent its spread. Industrial water users should also be targeted, as economic impacts could be relevant.

LEGISLATIVE AUTHORITIES

Currently, the importation of *C. taxifolia* into the U.S. is not prohibited. Other countries, including France, Spain, and Australia have banned the possession, transport, or sale of *C. taxifolia* to reduce the risk of introduction and/or spread. The U.S. has several existing legislative authorities that through the amendment process could enact rules banning the importation of *C. taxifolia*. Existing legislation includes the Federal Noxious Weed Act, the Nonindigenous Aquatic Nuisance Prevention and Control Act, and the Lacey Act. A memo, drafted by the Service's Nonindigenous Species Coordinator outlines several strategies of action based on these legislative authorities (Appendix B).

The Service has already initiated contact with the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS). This agency is responsible for enforcing the Federal Noxious Weed Act. APHIS is considering adding *C. taxifolia* to its noxious weeds list, thereby prohibiting its importation into the U.S. This strategy may be the most efficient action and should be pursued. In addition, other suggested strategies include implementation of the prevention provisions of the Nonindigenous Aquatic Nuisance Prevention and Control Act and encouraging state government agencies within the potential range of *C. taxifolia* to enact laws or promulgate regulations prohibiting the importation, transport, or possession of this species. Action by the states will reinforce federal activities, highlighting their commitment to preventing the spread of nonindigenous aquatic species and promoting healthy ecosystems.

RECOMMENDATIONS:

1) **A.** Implement strategies outlined by the Executive Secretary of the Aquatic Nuisance Species Task Force in the memo dated October 25, 1998. These strategies include the implementation of existing legislative provisions, the enactment of amendments to legislative statutes, and the enactment of state regulations banning the import, transport, and possession of *C. taxifolia*.

   B. Continue to work with U.S. Department of Agriculture, Animal and Plant Health Inspection Service to list *C. taxifolia* under the Federal Noxious Weed Act.

2) Conduct a complete review of relevant legislative authorities to determine additional appropriate legislative alternatives.

3) Assess potential range of *C. taxifolia* in U.S. and North American waters based on biological and environmental tolerances in addition to temperature regimes. Specifically, salinity tolerance should be assessed to determine potential dispersal in brackish and freshwater systems.

4) **A.** Identify unique or critical habitat areas in U.S. coastal waters that could be threatened by the invasion of *C. taxifolia*. Develop and implement prevention strategies to protect these areas.

   B. Identify unique, threatened, and endangered flora and fauna indigenous to U.S. coastal waters that could be threatened by the invasion of *C. taxifolia*.

   C. Develop and implement strategies to protect indigenous flora and fauna.

5) Develop and implement surveillance programs to provide early detection of an invasion, utilizing existing programs when possible. Focus on identified unique or critical habitat areas.

6) Investigate community resistance to the direct impacts of *C. taxifolia* as well as resistance to the effects of toxins released by this invader.

7) Review shipping activities between the U.S. and invaded areas of the Mediterranean and Adriatic Seas. Identify U.S. ports at risk to invasion of *C. taxifolia* through shipping activities. Investigate the likelihood of survival of *C. taxifolia* in ballast water tank conditions.

8) Conduct research to identify potential control alternatives. Focus immediate research goals on short-term control strategies to eliminate founder populations. Develop long-

term control alternatives.

9) Coordinate with international partners to reduce or minimize the global threats posed by *C. taxifolia* invasions.

10) Develop and implement education/outreach programs targeting all potentially affected coastal water users, federal, state, local, and tribal government agencies, and private and public organizations. Focus education initiatives on identification, handling, dispersal pathways, potential impacts, and prevention strategies that can be implemented by all water users.

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