Rachel Woodfield

Caulerpa

Caulerpa taxifolia

Caulerpa taxifolia is an invasive marine alga that is widely used as a decorative plant in aquaria. Although unicellular, Caulerpa develops pseudo organs similar to roots, shoots, and leaves of more complex plants. The plant consists of a horizontal, stem-like rhizome that produces a series of colorless, root-like rhizoids that extend downward, anchoring the plant to the sea floor and absorbing food, water, and nutrients. Branch-like structures that shoot upward from the rhizome compose the recognizable feather-like fronds, which are the photosynthetic component of the plant. Typically 5 to 25 centimeters long in shallow water, fronds lenthen with depth and low light conditions, averaging 60 to 80 centimeters in very deep water. In Caulerpa patches, frond density ranges from 5,100/m2 to 14,000/m2, with the highest densities occurring in the summer.

NATIVE AND INVASIVE RANGE

Caulerpa taxifolia is native to northern Australia, the Indian Ocean, the east African coast, the western Pacific, Indonesia and the southwest Pacific, Hawaii, and the Caribbean. The potential for *Caulerpa* to invade the Gulf, southern Atlantic, and California coasts is high, due to its ability to tolerate a wide range of conditions and effective methods of dispersing into new areas.

In 1984 the aquarium strain of *Caulerpa taxifolia* was accidentally released from the Oceanographic Museum in Monaco. Its subsequent invasion of the Mediterranean Sea has gained significant attention over the past decade. By 2001 the aquarium strain of *Caulerpa* covered over 30,000 acres of Mediterranean seafloor off the coasts of France, Spain, Italy, Croatia, and Tunisia.

Several outbreaks of the aquarium strain have occurred in southeastern Australia. Eradication efforts have failed, and *Caulerpa* is spreading through coastal areas in a pattern similar to that of the Mediterranean invasion. In some areas off Australia, hybridization with native populations is possible.

WEST COAST DISTRIBUTION

In 2000 the aquarium strain of *Caulerpa* was first identified in Agua Hedionda Lagoon and Huntington Harbor in southern California. These colonies were genetically identified as the aquarium strain.

Aggressive eradication efforts were undertaken. Patches of *Caulerpa* were covered with tarps, and chlorine was pumped underneath. It is believed that eradication was successful, and extensive monitoring continues to ensure the absence of *Caulerpa* from both systems.

ECOLOGY

Life cycles and migration patterns

In native populations, reproduction is primarily sexual, although reproduction can also occur through asexual fragmentation when small sections of *Caulerpa* break off and float to a new location, where they develop into a viable clone of their parent plant. The aquarium strain reproduces by fragmentation only; invasive populations are clones of this distinct strain.

Habitat and food webs

Caulerpa defends against herbivory and epiphytism by using toxic secondary metabolites that prevent predation. When *Caulerpa* comes into contact with certain species, it releases toxins into the water column, which can have a negative effect on adjacent floral communities.

How *Caulerpa* got to the United States

Releases of *Caulerpa* from personal aquaria are the likely source for the introduction of the aquarium strain of the plant to marine environments.

How *Caulerpa* spreads

Caulerpa often spreads locally by vegetative asexual fragmentation, a process accelerated by water currents and disturbance from boat anchors, fishing gear, and other human activities. These factors have aided *Caulerpa*'s spread across the Mediterranean.

ECOLOGICAL IMPACTS

The aquarium strain exhibits several characteristics that are different from native strains. In addition to its reproduction by vegetative fragmentation, the aquarium strain has the ability to adapt to a wide variety of environmental conditions. This strain is more resistant to cold temperatures, and it can survive multiple days out of water. It grows on a variety of substrates at a wide range of depths, including sheltered bays, soft or sandy bottoms, polluted muddy harbors, rocky reefs, and high-current capes. Perhaps most importantly, the aquarium strain grows astoundingly fast and as dense monoculture beds.

Caulerpa invasions have caused major ecological damage in the Mediterranean ecosystem, through competition and habitat modification. *Caulerpa* competes with other species for space and light, grows rapidly, and emits toxins into the water column. These characteristics result in the displacement of native communities and the creation of dense, uniform mats that persist throughout the year.

Considered a major threat to marine biodiversity, dense mats of *Caulerpa* alter the physical structure of the environment (i.e., habitat for other animals), affecting benthic communities and eliminating important fish habitat for spawning and feeding (Williams and Schroeder 2004). Major reductions in fish population and distribution have been associated with the displacement and/or removal of native communities and habitat. When *Caulerpa* takes over their habitat, fish cannot find shelter, space to reproduce, or food.

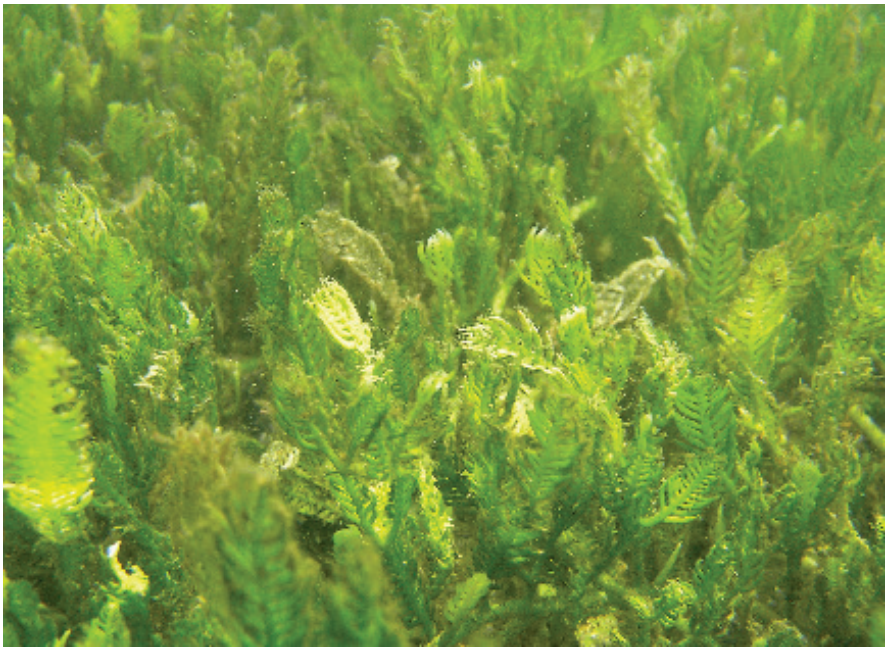
ECONOMIC IMPACTS

Economic damages from *Caulerpa* are difficult to estimate, but negative impacts on commercial and recreational fishing, as well as tourism and scuba diving, have been substantial. As *Caulerpa* spreads, economic damages will continue to increase.

Prevention and eradication measures have been expensive in Australia and the United States; costing the U.S. alone $ 7 million as of June 2006.

Dana Burfeind

The plant consists of a horizontal, stem-like rhizome that produces a series of root-like rhizoids that extend downward. Branch-like structures that shoot upward compose the recognizable, feather-like fronds.



Linda Walters

In Caulerpa *patches, frond density ranges from 5,100/m² to 14,000/m².*

CULTURAL SIGNIFICANCE

Loss of recreational opportunities and biodiversity are a culturally damaging and disturbing phenomenon in affected areas. However, *Caulerpa* is a popular commercial and domestic aquarium plant, due to its attractive appearance and rapid growth.

LAWS CURRENTLY IN PLACE

United States law: It is illegal to import or transport *Caulerpa taxifolia* aquarium strain across state lines, including via Internet sales.

California State law: It is illegal to possess, transport, transfer, release alive, import, or sell *Caulerpa taxifolia, Caulerpa sertularioides, Caulerpa mexicana, Caulerpa ashmeadii, Caulerpa scalpelliformis, Caulerpa racemosa* (and all varieties of *C. racemosa*), *Caulerpa cupressoides, Caulerpa verticillata,* and *Caulerpa floridana.*

City of San Diego law: It is illegal to possess, sell, and transport any *Caulerpa* species within city limits.

MANAGEMENT STRATEGIES

- Scientists once believed that since *Caulerpa taxifolia* was a tropical alga, it would die during the cold winter months in the Mediterranean.
- Unsuccessful attempts were made to eradicate *Caulerpa taxifolia* from certain portions of the Mediterranean infestation, but biomass was too extensive throughout the invaded areas. The new goal is to maintain "*Caulerpa*-free sanctuaries."
- In the United States, the Aquatic Nuisance Species Task Force has developed a prevention and eradication program for *Caulerpa taxifolia*. Any new discoveries will be aggressively and quickly treated with bleach to ensure eradication. Prevention in the United States has focused on vector control by prohibiting international trade of the aquarium strain of *Caulerpa*. Public education about proper disposal of aquarium species aims to prevent the risk of introduction. Other potential vectors of introduction must also be addressed.

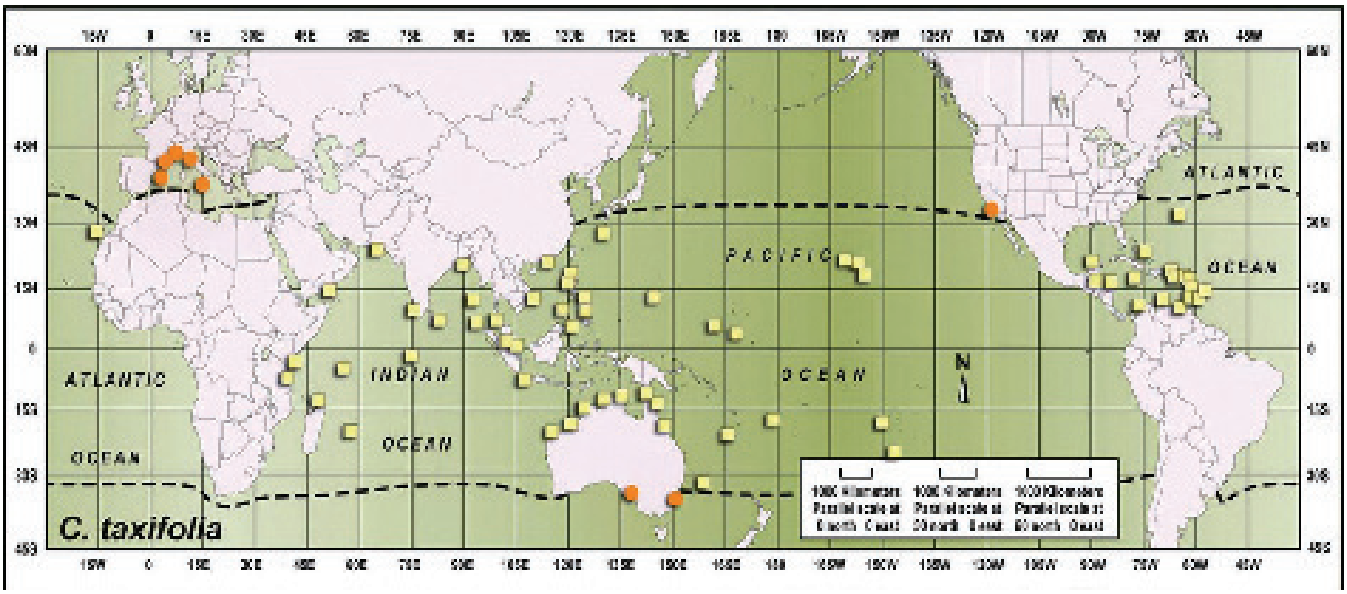
WHAT YOU CAN DO

Alternatives to releasing aquarium plants and pets:

- Give them to a responsible aquarium or pet store
- Give them to a responsible hobbyist
- Freeze *Caulerpa* for a minimum of 24 hours and then place it in the trash
- Contact an aquarium or pet store for guidance on humane animal disposal

INFORMATION GAPS

- Biocontrol research has focused on a variety of mussels and sea slugs. Few organisms eat *Caulerpa*, due to its toxicity, and no effective biocontrols have yet been discovered and approved for widespread implementation.
- Further experimentation with alternative herbicides is needed to identify a substance less toxic than chlorine to eradicate *Caulerpa*.



Worldwide distribution of Caulerpa taxifolia. *Yellow squares = native range. Orange circles = invasive populations of* Caulerpa taxifolia. *Dashed line = 15˚C average winter sea-surface temperature. Modeled after Verlaque et al. 2000.*

REFERENCES

Anderson, Lars WJ. 2007. "Control of Invasive Seaweeds." *Botanica Marina* 50:418–437.

NOAA. 2003. "Facts about *Caulerpa taxifolia*." National Marine Fisheries Service. Southwest Regional Office.

Keppner, Sandra M. and Russel T. Caplen. 1999. "A Prevention Program for the Mediterranean Strain of *Caulerpa taxifolia*." US Fish and Wildlife Service. Aquatic Nuisance Species Task Force.

ISSG Global Invasive Species Database. 2006. *Caulerpa taxifolia*. www.issg.org/database/species/ecology.asp?si=115&fr=1&sts=sss

Pierre, M. and Y. Maricela. 2005. "Literature Review of *Caulerpa taxifolia*." *BUFUS Newsletter*. No. 31.

Wiedenmann, J, A. Baumstark, T. L. Pillen, A. Meinesz, and W. Vogel. "DNA fingerprints of *Caulerpa taxifolia* provide evidence for the introduction of an aquarium strain into the Mediterranean Sea and its close relationship to an Australian population."

Williams, Susan L. and Stephanie L Schroeder. 2004. "Eradication of the invasive seaweed *Caulerpa taxifolia* by chlorine bleach." *Marine Ecology Progress Series* 272:69–76.

ADDITIONAL RESOUCES

Australia: "Eradicating and preventing the spread of the invasive alga *Caulerpa taxifolia* in NSW." Gives a long discussion of different control methods. ~~www.deh.gov.au/coasts/imps/caulerpa-taxifolia/index.html~~

Video on *Caulerpa taxifolia*:
Deep Sea Invasion. NOVA/PBS, 1 hr, grade level 4+. ISBN 1-57807-980-2. Available online from NOVA for $19.95 plus s/h. www.pbs.org/wgbh/nova/algae/

Killer Algae, The True Tale of Biological Invasion By Alexandre Meinesz. 1999. Translated by Daniel Simberloff. The University of Chicago Press, 360 pages.