

The Cost to Manage Invasive Aquatic Weeds in the California Bay-Delta

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Invasive aquatic weeds have become an increasing problem in the California Bay-Delta, with Brazilian waterweed and water hyacinth being particular problems. In 2014 and 2015, large mats of water hyacinth began to choke Delta waterways, increasing control costs of a variety of public agencies and marinas. Between 2013 and 2016, these groups spent about \$46 million to manage all invasive aquatic weeds.

The California Bay-Delta (Delta) is an inland delta system at the confluence of the Sacramento and San Joaquin rivers. It supports a complex ecosystem with diverse economic activities. About two-thirds of California salmon move through the Delta and the endangered Delta smelt calls it home. Agricultural crops grown on Delta islands have a value added of over \$1 billion. Water from the Delta is pumped south and used for agriculture in the San Joaquin Valley, valued at \$33.4 billion in 2015, and for millions of other urban and rural users in Californian homes and businesses.

Over the past decade, there has been a growing problem with invasive aquatic weeds in the Delta. Invasive weeds can either be floating aquatic weeds, where the plant floats on the surface and roots dangle in the water; or submerged aquatic weeds, where the plant roots at the bottom of the water body and grows from there. Two weeds of particular ecological and economic concern in the mid-2010s were Brazilian waterweed (*Egeria densa*) and water hyacinth (*Eichhornia crassipes*). Brazilian waterweed is a shallow, water-submerged weed with foliage floating on the surface of the water. Water hyacinth is a floating weed with broad, shiny, green leaves, purple flowers, and bulbous stalks with feathery, free hanging

roots. Water hyacinth prefers lakes and slow-running water. As a result, water hyacinth spread and grew rapidly into dense mats throughout the Delta during the drought years in 2014 and 2015. These mats shaded out Brazilian waterweed and other submerged plants, reducing their impact on the environment, but threatened the viability of different activities on the Delta.

Widespread invasions of aquatic weeds may cause significant damage to fish habitat by lowering the level of oxygen in the water; displacing or shading out submerged native habitat upon which native aquatic species thrive; interrupting commercial shipping and recreational boating; endangering the ability of federal and state agencies to pump water to the California aqueduct system; and increasing the costs to manage mosquito populations to reduce the risk of the spread of West Nile Virus.

To prevent these effects, several public agencies control aquatic weeds, including the California Division of Boating and Waterways, the U.S. Bureau of Reclamation, the Port of Stockton, county weed control districts, and private marinas. Following are the budgetary costs for managing all invasive weeds provided by these agencies and marinas. Marina owners or harbor masters were interviewed. Each interview included questions on whether there was a problem with invasive weeds at their facility; if they had a problem with weeds, did they manage it, and if they managed weeds, how did they manage them—including materials, labor and costs.

The Division of Boating and Waterways (DBW)

The public agency responsible for area-wide management of invasive weeds is the California Division of Boating and

Waterways (DBW). This agency is part of the California Department of Parks and Recreation. It is the only agency that can legally treat infestations using chemical controls such as herbicides, or mechanical controls such as harvesters. However, under special circumstances, the DBW can authorize another agency to complete weed management.

Area-wide management of invasive weeds must adhere to a rigorous set of environmental criteria, including limits on the months when herbicides can be applied in different treatment zones. There are four zones on the Delta. In three of the zones, treatments cannot begin until March 1. In the fourth zone, treatments cannot begin until June 1. These environmental restrictions (due to fish movements and breeding periods) allow weeds to grow until they can be treated with herbicides.

In 2015, DBW began using harvesting equipment for early-season treatments in select areas to keep the growth and spread of invasive weeds low until more effective herbicide treatments could occur. Frequently, these were “nursery” sites—those sites which are a particular source of infestation for other sites. This helps to keep the weeds from spreading, infesting other areas, and increasing the costs of control several months later when herbicides are available for use.

Budgetary costs to manage invasive aquatic weeds increased from \$7.124 million in 2013, to \$7.625 million in 2014, and \$13.718 million in 2015 (Table 1). In particular, 2015 saw very large infestations early on due to the mild winter. Typically, the large mats of water hyacinth will die off over the winter. Not everything will die off, so there will still be some plant material, especially in Delta nursery sites. However, the winter of 2015 was milder and dryer than most.

Table 1. Cost of Invasive Weed Control: California Bay Delta (in \$1000)

	2013	2014	2015	2016	Total
	-----dollars-----				
CA Division of Boating and Waterways	7,124	7,625	13,718	12,545	41,012
Bureau of Reclamation	343	833	921	658	2,755
Marinas	169	576	943	310	1,999
Port of Stockton	51	306	168	0	524
Weed Control District - San Joaquin County	223	73	37	155	488
Weed Control District - Contra Costa	74	0	0	0	74
Total	7,984	9,413	15,787	13,668	46,852

More plant material was seen earlier than previous years. With early control constrained by environmental regulations on the timing of herbicide applications, water hyacinth mats increased exponentially, causing control costs to increase rapidly. In 2016 budgetary costs fell to \$12.545 million.

During this time, DBW also began a collaborative project with the Delta Regional Areawide Aquatic Weed Project (DRAAWP) to improve management of invasive aquatic weeds, such as the use of satellite images of weed infestations. This reduced plant material, along with a colder and rainier winter, and lower infestation of water hyacinth. With improved management and better climatic conditions in 2016, the water hyacinth crisis abated and budgetary costs fell.

The U.S. Bureau of Reclamation

The U.S. Bureau of Reclamation (BOR) is one of the agencies responsible for operating a facility that pumps water from the Delta into the California aqueduct system. Before that water can be pumped, debris, weeds, and fish must be removed. This is done at the Tracy Fish Collection Facility. A series of screens and diversions are used to remove the objects and capture the fish.

With no control, large mats of water hyacinth will accumulate and “dam” the screens. A mechanical arm is used to sweep the weeds into an area where a crane then removes the weeds, puts them into a truck, and the truck disposes them on BOR property to dry out

and decompose.

At the height of the drought in 2014 and 2015 when water hyacinth infestations were greatest, multiple cranes were needed and operations were being completed around the clock. Since then, with better area-wide weed management, more rain, and stronger currents, infestations of water hyacinth have declined. Extra efforts are still required during the fall when weed mats break up, but fewer cranes are needed to clear out the debris and keep water flowing.

Costs by the BOR associated with changes in aquatic weed management increased from \$343,085 in 2013, to \$832,803 in 2014, and \$921,000 in 2015 (Table 1). In 2016 costs fell to \$657,664.

Marinas

Over 88 active marinas are found up and down the rivers of the Delta that allow for recreational activities such as boating and fishing. Without control, floating aquatic weeds gather around docks, grow, and will eventually shut down access to slips. Submerged aquatic weeds can block the entrance to marinas and get tangled up in ships’ rudders, motors, etc., causing damage.

Marina owners and managers cannot spray herbicides to treat weeds or use harvesters, but can use a variety of other means to keep weeds managed. For small infestations of floating weeds, marinas will have people physically remove plants from the water. For larger infestations, small boats will be used to push the weeds out into the main

channel of the river. In some cases, and with permission from the Army Corps of Engineers, booms can be placed across a marina opening to prevent floating weeds from entering. For submerged aquatic weeds, divers can pull weeds out of the riverbed. However, pulling weeds causes plants to break and spreads the infestation.

Marinas incur costs to remove weeds, and lose slip fees if infestations grow large enough to block boat slips. In 2014 invasive weeds cost marinas \$170,500 in Brazilian waterweed control and lost business, and \$405,676 for water hyacinth control and lost business. In 2015 the total costs due to the presence of Brazilian waterweed fell to \$103,218, but increased to \$198,670 in 2016. Conversely, the costs to marinas due to the presence of water hyacinth increased to \$840,109 in 2015, but fell to \$111,821 in 2016. Large mats of water hyacinth shade the plants underneath them, including Brazilian waterweed, and affect their growth. As populations of water hyacinth declined in 2016, costs to treat it also declined. The decline in water hyacinth growth; however, caused Brazilian waterweed populations to increase, along with marinas’ costs to manage it.

Weed Control Districts

The still water in water hyacinth mats provide enough habitat for mosquitoes to breed. When on-going disease-monitoring activities by local mosquito control districts show that West Nile Virus is a threat to human health, mosquitoes will need to be treated in water hyacinth as part of an area-wide mosquito management program.

Mosquito control costs in water hyacinth mats were highest in 2013 at \$233,000, and 2016 at \$155,000. During years when infestations of water hyacinth were greatest, mosquito control costs were lowest—\$73,000 in 2014 and \$37,000 in 2015. This is probably due to the drier, drought conditions in 2014 and 2015, which kept overall mosquito

populations low, even though there was more weed habitat in the Delta.

The Port of Stockton and Daylight-Only Navigation on the Delta

Deep water channels in the Delta from Oakland to Sacramento and Stockton allow commercial shipping through the Delta on container ships. The Port of Stockton is responsible for keeping public docks open to ships. Large mats of water hyacinth can prevent container ships from docking and unloading their cargo.

To keep the Port of Stockton clear, the port authority, under an agreement with DBW, will remove weeds using a harvester and truck them to a nearby disposal location. Costs incurred by the Port of Stockton to manage water hyacinth were \$51,000 in 2013 (Table 1). This increased to \$306,000 in 2014 and then decreased to \$168,000 in 2015. In 2016 the Port of Stockton did not need to do any supplemental treatments.

In addition, large mats of water hyacinth can interfere with commercial shipping by shutting down night time navigation on the deep-water channel between Oakland and Stockton. The San Francisco Bar Pilots association determines when weed infestations are so dense that they interfere with a pilot's ability to navigate the river.

When a container ship arrives at the Port of Oakland, a local pilot goes on board to navigate the ship up the river. When traveling the deep-water channel at night, these pilots rely on navigation pylons that ping when the radar hits them. When weed mats are so dense that they obscure the pylons from radar, the pilots are unable to safely determine where the river turns and where banks are. At that point, they shift to a "Daylight-Only Transfer" (DOT) protocol when pilots can visually see where the pylons are. Once a DOT is established, it remains in effect until weed mats have broken up and dissipated. To date, DOT protocols due to invasive weeds have

Table 2. Costs Incurred by Marinas Due to the Presence of an Invasive Aquatic Weed (IAW)

	2014		2015		2016	
	Brazilian Water Weed	Water Hyacinth	Brazilian Water weed	Water Hyacinth	Brazilian Water Weed	Water Hyacinth
Number of marinas surveyed	58	58	50	50	57	57
Percent of marinas that managed an IAW	22%	65%	22%	50%	14%	42%
Management expenditures	\$145,500	\$353,245	\$50,218	\$534,199	\$193,420	\$80,821
Average cost per marina that managed an IAW	\$12,125	\$9,812	\$4,565	\$21,368	\$21,491	\$3,368
Marinas that reported lost business due to an IAW	1	7	4	9	1	2
Total cost of lost business	\$25,000	\$52,431	\$53,000	\$305,910	\$5,250	\$31,000
Total costs	\$170,500	\$405,676	\$103,218	\$840,109	\$198,670	\$111,821

occurred between Oct. 26, 2014, and Jan. 30, 2015, as well as between Oct. 20, 2015, and Feb. 19, 2016.

No costs occurred due to DOT protocols because most of the costs to ship are fixed, such as the boat leasing, crew costs, etc. Losses would occur only if the closures prevented the ship from making its next pickup, and no evidence suggests that the five to six hours during which ships cannot navigate the deep-water channel at night resulted in a ship missing the next cargo pickup.

Total Costs of Managing Invasive Aquatic Weeds

Total costs to treat invasive weeds by all agencies and marinas were \$7.984 million in 2013, \$9.413 million in 2014, and \$15.787 million in 2015. In 2016 costs declined, equaling \$13.668 million. Total costs over all four years were \$46.852 million. DBW had the largest expenditures, followed by BOR, then the marinas (Table 1).

Costs to treat invasive weeds peaked in 2015 due to the peak infestations of water hyacinth in 2014 and 2015. While budgetary costs for DBW were relatively higher in 2015 and 2016 compared to previous years, the increased control of water hyacinth resulted in lower costs of control for other agencies, especially the Port of Stockton and marinas. By keeping infestations down in key areas and increasing management in others, there was less material for other players

to manage. Furthermore, with better control throughout the year, there was less plant material available the following year. This, combined with better climatic conditions, resulted in lower costs in 2016.

During 2014–2015, the severe drought caused water hyacinth populations to grow rapidly in the relatively slow current. With better management practices and more rain, populations of water hyacinth have not reached the heights of that time. With the decline in water hyacinth mats, different invasive aquatic weeds are now threatening Delta ecological and economic systems. Pennywort (*Hydrocotyle ranunculoides*), in particular, is spreading into areas once dominated by water hyacinth. In addition, the lack of water hyacinth mats in the river allowed more sunlight to pass through the water, causing increased growth of Brazilian waterweed.

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