Arundo donax

INTRODUCTORY

SPECIES: Arundo donax


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ARUDON

SYNONYMS:
None

NRCS PLANT CODE [96]:
ARDO4

COMMON NAMES:
giant reed
arundo grass
donax

TAXONOMY:

The currently accepted scientific name of giant reed is *Arundo donax* L. (Poaceae) [13,40,53,56,57,62,63,69,77,103,105,107]. One variety of giant reed is recognized in the literature:

Arundo donax L. var. *versicolor* (P. Mill) Stokes [53,107].

LIFE FORM:
Graminoid

FEDERAL LEGAL STATUS:
No special status

OTHER STATUS:
Giant reed is listed as a noxious weed in Texas, an exotic plant pest in California, an invasive weed in Hawaii, and as an invasive, exotic pest in Tennessee. See the Invaders or Plants databases for more information.

DISTRIBUTION AND OCCURRENCE

SPECIES: Arundo donax

- GENERAL DISTRIBUTION
- ECOSYSTEMS
- STATES/PROVINCES
- BLM PHYSIOGRAPHIC REGIONS
- KUCHLER PLANT ASSOCIATIONS
- SAF COVER TYPES
- SRM (RANGELAND) COVER TYPES
- HABITAT TYPES AND PLANT COMMUNITIES

GENERAL DISTRIBUTION:
Though accounts in the literature vary, a review by Bell [11] indicates giant reed is thought to be native in eastern Asia, and it has been cultivated throughout Asia, southern Europe, northern Africa and the Middle East for thousands of years. In North America, it was intentionally introduced from the Mediterranean to the Los Angeles area in California in the early 1800s (Robbins and others 1951, as cited in [49])[28], and has been widely planted throughout the warmer states as an ornamental and for erosion control along drainage canals [49,74]. It has escaped cultivation as far north as Virginia and Missouri, and abundant wild populations occur along the Rio Grande River [74] and along ditches, streams, and seeps in arid and cis montane regions of California (Robbins and others 1951, as cited in [49]).

According to Bell [11], giant reed is invasive throughout the warmer coastal freshwaters of the United States from Maryland westward to northern California. Wunderlin [107] recognizes the variety *versicolor* as occurring in Florida, and Jones and others [53] describe that variety as a cultivar. The literature contains specific references to the occurrence of giant reed in the 4 provinces of Mexico listed below [2,61,82,98]. Giant reed is likely present in other areas of Mexico.

Plants database provides a state distribution map of giant reed in the United States.

The following lists include North American ecosystems, habitat types, and forest and range cover types in which giant reed is known or thought to be invasive, as well as some that may be invaded by giant reed following disturbances in which vegetation is killed and/or removed and/or soil is disturbed (e.g. cultivation, fire, grazing, herbicide application, flooding). Giant reed is a hydrophyte and riparian areas or wetlands within these habitats could be subject to invasion by giant reed even if the habitat itself is not considered a wetland. For example, Nixon and Willett [71] list giant reed as a plant found within the Trinity River Basin in Texas. Habitats within the basin include cross timbers and prairies, blackland prairies, post oak (*Quercus stellata*) savannah, pineywoods, and Gulf prairies and marshes.

These lists are not necessarily exhaustive. More information is needed regarding incidents and examples of particular ecosystems and plant communities where giant reed is invasive.

ECOSYSTEMS [38]:
FRES12 Longleaf-slash pine
FRES13 Loblolly-shortleaf pine

FRES14 Oak-pine
FRES15 Oak-hickory
FRES16 Oak-gum-cypress
FRES17 Elm-ash-cottonwood
FRES27 Redwood
FRES28 Western hardwoods
FRES29 Sagebrush
FRES30 Desert shrub
FRES31 Shinnery
FRES32 Texas savanna
FRES33 Southwestern shrubsteppe
FRES34 Chaparral-mountain shrub
FRES35 Pinyon-juniper
FRES36 Mountain grasslands
FRES37 Mountain meadows
FRES38 Plains grasslands
FRES39 Prairie
FRES40 Desert grasslands
FRES41 Wet grasslands
FRES42 Annual grasslands

STATES/PROVINCES: (key to state/province abbreviations)
UNITED STATES

AL	AZ	AR	CA	FL	GA
HI	IL	KS	KY	LA	MD
MS	MO	NV	NM	NC	OK
SC	TN	TX	UT	VA	WV
PR	VI				

MEXICO

Chih.	Coah.	Son.	Tamps.

BLM PHYSIOGRAPHIC REGIONS [12]:
3 Southern Pacific Border
4 Sierra Mountains
6 Upper Basin and Range
7 Lower Basin and Range
11 Southern Rocky Mountains
12 Colorado Plateau
13 Rocky Mountain Piedmont
14 Great Plains

KUCHLER [60] PLANT ASSOCIATIONS:
K006 Redwood forest
K009 Pine-cypress forest
K023 Juniper-pinyon woodland
K027 Mesquite bosques
K031 Oak-juniper woodland
K032 Transition between K031 and K037
K033 Chaparral
K034 Montane chaparral
K035 Coastal sagebrush
K036 Mosaic of K030 and K035
K037 Mountain-mahogany-oak scrub
K038 Great Basin sagebrush
K039 Blackbrush
K040 Saltbush-greasewood
K041 Creosote bush
K042 Creosote bush-bur sage

K043 Paloverde-cactus shrub
K044 Creosote bush-tarbush
K045 Ceniza shrub
K048 California steppe
K049 Tule marshes
K053 Grama-galleta steppe
K054 Grama-tobosa prairie
K057 Galleta-threeawn shrubsteppe
K058 Grama-tobosa shrubsteppe
K059 Trans-Pecos shrub savanna
K060 Mesquite savanna
K061 Mesquite-acacia savanna
K062 Mesquite-live oak savanna
K065 Grama-buffalo grass
K069 Bluestem-grama prairie
K070 Sandsage-bluestem prairie
K071 Shinnery
K072 Sea oats prairie
K074 Bluestem prairie
K076 Blackland prairie
K077 Bluestem-sacahuista prairie
K078 Southern cordgrass prairie
K079 Palmetto prairie
K080 Marl everglades
K082 Mosaic of K074 and K100
K083 Cedar glades
K084 Cross Timbers
K085 Mesquite-buffalo grass
K086 Juniper-oak savanna
K087 Mesquite-oak savanna
K088 Fayette prairie
K089 Black Belt
K090 Live oak-sea oats
K091 Cypress savanna
K092 Everglades
K098 Northern floodplain forest
K100 Oak-hickory forest
K105 Mangrove
K111 Oak-hickory-pine
K112 Southern mixed forest
K113 Southern floodplain forest
K114 Pocosin
K115 Sand pine scrub
K116 Subtropical pine forest

SAF COVER TYPES [32]:
40 Post oak-blackjack oak
42 Bur oak
43 Bear oak
46 Eastern redcedar
51 White pine-chestnut oak
52 White oak-black oak-northern red oak
53 White oak
57 Yellow-poplar
58 Yellow-poplar-eastern hemlock
59 Yellow-poplar-white oak-northern red oak
60 Beech-sugar maple
61 River birch-sycamore
63 Cottonwood
64 Sassafras-persimmon
65 Pin oak-sweetgum

66 Ashe juniper-redberry (Pinchot) juniper
67 Mohrs (shin) oak
68 Mesquite
69 Sand pine
70 Longleaf pine
71 Longleaf pine-scrub oak
72 Southern scrub oak
73 Southern redcedar
74 Cabbage palmetto
75 Shortleaf pine
76 Shortleaf pine-oak
78 Virginia pine-oak
79 Virginia pine
80 Loblolly pine-shortleaf pine
81 Loblolly pine
82 Loblolly pine-hardwood
83 Longleaf pine-slash pine
84 Slash pine
85 Slash pine-hardwood
87 Sweetgum-yellow-poplar
88 Willow oak-water oak-diamondleaf (laurel) oak
89 Live oak
91 Swamp chestnut oak-cherrybark oak
92 Sweetgum-willow oak
93 Sugarberry-American elm-green ash
94 Sycamore-sweetgum-American elm
95 Black willow
96 Overcup oak-water hickory
97 Atlantic white-cedar
98 Pond pine
100 Pondcypress
101 Baldcypress
102 Baldcypress-tupelo
103 Water tupelo-swamp tupelo
104 Sweetbay-swamp tupelo-redbay
105 Tropical hardwoods
106 Mangrove
110 Black oak
111 South Florida slash pine
221 Red alder
222 Black cottonwood-willow
232 Redwood
235 Cottonwood-willow
239 Pinyon-juniper
240 Arizona cypress
241 Western live oak
242 Mesquite
243 Sierra Nevada mixed conifer
246 California black oak
249 Canyon live oak
250 Blue oak-foothills pine
255 California coast live oak

SRM (RANGELAND) COVER TYPES [85]:
201 Blue oak woodland
202 Coast live oak woodland
203 Riparian woodland
204 North coastal shrub
205 Coastal sage shrub
206 Chamise chaparral
207 Scrub oak mixed chaparral

208 Ceanothus mixed chaparral
209 Montane shrubland
210 Bitterbrush
211 Creosote bush scrub
212 Blackbush
213 Alpine grassland
214 Coastal prairie
215 Valley grassland
216 Montane meadows
217 Wetlands
401 Basin big sagebrush
402 Mountain big sagebrush
403 Wyoming big sagebrush
405 Black sagebrush
406 Low sagebrush
408 Other sagebrush types
409 Tall forb
410 Alpine rangeland
411 Aspen woodland
412 Juniper-pinyon woodland
413 Gambel oak
414 Salt desert shrub
415 Curlleaf mountain-mahogany
416 True mountain-mahogany
417 Littleleaf mountain-mahogany
418 Bigtooth maple
419 Bittercherry
420 Snowbrush
421 Chokecherry-serviceberry-rose
422 Riparian
501 Saltbush-greasewood
502 Grama-galleta
503 Arizona chaparral
504 Juniper-pinyon pine woodland
505 Grama-tobosa shrub
506 Creosotebush-bursage
507 Palo verde-cactus
508 Creosotebush-tarbush
509 Transition between oak-juniper woodland and mahogany-oak association
601 Bluestem prairie
604 Bluestem-grama prairie
605 Sandsage prairie
611 Blue grama-buffalo grass
701 Alkali sacaton-tobosagrass
702 Black grama-alkali sacaton
703 Black grama-sideoats grama
704 Blue grama-western wheatgrass
705 Blue grama-galleta
706 Blue grama-sideoats grama
707 Blue grama-sideoats grama-black grama
708 Bluestem-dropseed
709 Bluestem-grama
710 Bluestem prairie
711 Bluestem-sacahuista prairie
712 Galleta-alkali sacaton
713 Grama-muhly-threeawn
714 Grama-bluestem
715 Grama-buffalo grass
716 Grama-feathergrass
717 Little bluestem-Indiangrass-Texas wintergrass
718 Mesquite-grama

719 Mesquite-liveoak-seacoast bluestem
720 Sand bluestem-little bluestem (dunes)
721 Sand bluestem-little bluestem (plains)
722 Sand sagebrush-mixed prairie
723 Sea oats
724 Sideoats grama-New Mexico feathergrass-winterfat
725 Vine mesquite-alkali sacaton
726 Cordgrass
727 Mesquite-buffalo grass
728 Mesquite-granjeno-acacia
729 Mesquite
730 Sand shinnery oak
731 Cross timbers-Oklahoma
732 Cross timbers-Texas (little bluestem-post oak)
733 Juniper-oak
734 Mesquite-oak
735 Sideoats grama-sumac-juniper
801 Savanna
802 Missouri prairie
803 Missouri glades
804 Tall fescue
805 Riparian
806 Gulf Coast salt marsh
807 Gulf Coast fresh marsh
808 Sand pine scrub
809 Mixed hardwood and pine
810 Longleaf pine-turkey oak hills
811 South Florida flatwoods
812 North Florida flatwoods
813 Cutthroat seeps
814 Cabbage palm flatwoods
815 Upland hardwood hammocks
816 Cabbage palm hammocks
817 Oak hammocks
818 Florida salt marsh
819 Freshwater marsh and ponds
820 Everglades flatwoods
821 Pitcher plant bogs
822 Slough

HABITAT TYPES AND PLANT COMMUNITIES:
Information about giant reed and associated plant communities is sparse. Most accounts discuss riparian and wetland habitat types without delineating species that occur with giant reed. In the absence of giant reed, coastal southern California riparian habitat is typically dominated by willow (*Salix* spp.) with local stands of Fremont cottonwood (*Populus fremontii*), black cottonwood (*P. balsamifera* ssp. *trichocarpa*), and white alder (*Alnus rhombifolia*); and mixed woodlands of oak (*Quercus* spp.), especially coast live oak (*Q. agrifolia*), and California sycamore (*Platanus racemosa*) on the higher terraces. Willow communities may include arroyo willow (*S. lasiolepis*), red willow (*S. laevigata*), narrowleaf willow (*S. exigua*), Goodding willow (*S. gooddingii*), and mule's fat (*Baccharis salicifolia*) [110].

Dick-Peddie [23] lists giant reed as a plant occurring in riparian areas of floodplains, plains, and arroyos in New Mexico. These floodplains are often dominated by cottonwoods (*Populus* spp.). Cottonwoods commonly share dominance with Goodding willow in the southern part of New Mexico, and with peachleaf willow (*S. amygdaloides*) in the north. Understory layers may be dominated by stretchberry (*Forestiera pubescens* var. *pubescens*), skunkbush sumac (*Rhus trilobata*), rabbitbrush (*Chrysothamnus* spp.), and/or sandbar willow (*S. interior*). Nonnative tamarisk (*Tamarix* spp.) associations are common on both floodplain and plains habitat. From Albuquerque north, nonnative Russian-olive (*Elaeagnus angustifolia*) often dominates riparian communities. Riparian thickets on the Rio Grande River in the southern portion of the state are often composed of screwbean mesquite (*Prosopis pubescens*) with skunkbush sumac, mule's fat, wolfberry (*Lycium* spp.) and arrowweed (*Pluchea sericea*). Arroyos in the northwest part of New Mexico are usually dominated by black greasewood (*Sarcobatus vermiculatus*). Green rabbitbrush (*C. nauseosus* var. *graveolens*) and rubber rabbitbrush (*C. n.* var. *bigelovii*) are also common dominants on arroyos. In the southern part of the state, lower portions of arroyos, where the beds widen, are often dominated by singlewhorl burrobrush (*Hymenoclea monogyra*), Apache plume (*Fallugia paradoxa*), littleleaf sumac (*R. microphylla*), and splitleaf brickellbush (*Brickellia laciniata*). Mule's fat occurs in all areas [23].

In riparian woodlands within the Chihuahuan desert, Hendrickson and Johnston [45] list giant reed as occurring with saltcedar (*T. ramosissima*) and occurring with and displacing Gooding willow, desert willow (*Chilopsis linearis*), honey mesquite (*Prosopis glandulosa*), screwbean mesquite, Fremont cottonwood, velvet ash (*Fraxinus velutina*), common reed (*Phragmites australis*) and mule's fat.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Arundo donax

GENERAL BOTANICAL CHARACTERISTICS:
The following description of giant reed provides characteristics that may be relevant to fire ecology, and is not meant for identification. Keys for identification are available (e.g., [40,53,56,57,62,63,69,77,103,105,107]). Giant reed and common reed, a native grass distributed across most of the United States, can be difficult to distinguish. Proper identification of giant reed is essential before implementing control measures [24].

Giant reed is a tall, erect, perennial graminoid. It is the largest member of the genus and among the largest of grasses, growing 6 to 30 feet (2-8 m) tall [11,28,74]. The culms reach a diameter of 0.4 to 1.6 inches (1-4 cm) and commonly branch during the second year of growth. Culms are hollow, with walls 2 to 7 mm thick and divided by partitions at the nodes. The nodes vary in length from 5 to 12 inches (12-30 cm). Leaves are conspicuously 2-ranked, 2 to 3.2 inches (5-8 cm) broad at the base and tapering to a fine point. Bases of the leaves are cordate and more-or-less hairy-tufted, persisting long after the blades have fallen [74]. Giant reed has large plume-like panicles. Spikelets are several-flowered with upper florets successively smaller [33].

Giant reed has thick, knotty rhizomes [103] and deeply penetrating roots [74]. Once established, it tends to form large, continuous, clonal root masses, sometimes covering several acres. These root masses can be more than 3 feet (1 m) thick (review by [11]).

Although giant reed has been widely cultivated for centuries, little information on its biology and ecology has been published. As of this writing (2004), more research is needed to understand the biology and ecology of giant reed.

RAUNKIAER [78] LIFE FORM:
Hydrophyte

REGENERATION PROCESSES:
The reproductive biology of giant reed is not well studied. As of this writing (2004), information on the importance of sexual reproduction, seed viability, dormancy, germination and seedling establishment is not available.

Giant reed reproduces vegetatively by sprouting from rhizomes and stem nodes (reviews by [11,28,49]).

Breeding system: No information is available on this topic.

Pollination: No information is available on this topic.

Seed production: Although giant reed is well adapted in many parts of North America, it rarely, if ever, produces viable seed here (reviews by [11,74])[47].

Seed dispersal: The hairy, light-weight disseminules (individual florets with the enclosed grain) are dispersed by wind [33].

Seed banking: No information is available on this topic.

Germination: No information is available on this topic.

Seedling establishment/growth: Seedlings of giant reed have not been observed in the field [28]. Establishment of giant reed is from fragmented rhizomes or stem nodes that take root (see Asexual regeneration, below).

Giant reed grows very rapidly. In a southern California study, Rieger and Kreager [80] cut an established giant reed community and measured its growth after cutting. Growth rates from established rhizomes averaged 2.5 inches (6.25 cm) per day in the first 40 days and 1 inch (2.67 cm) per day in the first 150 days. Under optimal conditions (i.e., cultivation) giant reed is reported to grow 1.5 to 4 inches (4-10 cm) per day (review by [74]).

Asexual regeneration: Population expansion of giant reed in North America is through vegetative reproduction. This occurs either via underground rhizome extension or from plant fragments carried downstream (review by [28]). Giant reed is well adapted to the high disturbance dynamics of riparian systems, as floods break up clumps of giant reed and spread pieces downstream where they can take root and establish new clones [11,28]. Anecdotal accounts suggest that rhizomes buried under as much as 3 to 10 feet (1-3 m) of alluvium can "readily resprout" (R. Dale, personal communication in [28]).

Much of the cultivation of giant reed throughout the world is initiated by planting rhizomes which root and sprout easily [48,49]. A 1949 joint publication by the U.S. Forest Service and the California Department of Natural Resources, Division of Forestry, describing recommended plants for erosion control [48] states pieces of giant reed rhizomes can be buried to establish the plant. A 1988 paper describes giant reed as a planted rhizome which "performs well" as an understory plant in riparian zones in New Mexico [91]. In a greenhouse experiment, Motamed [68] determined that giant reed stem fragments rooted throughout the growing season.

SITE CHARACTERISTICS:
Although giant reed has a wide distribution in North America, details about site characteristics where it is invasive are limited. Most available information on its biology and ecology in North America comes from reviews and studies in California.

Giant reed is a hydrophyte, and grows best where water tables are near or at the soil surface [79]. Giant reed growth may be retarded by lack of moisture during its first year, but drought causes no serious damage in patches 2 to 3 years old [74]. In California, it typically grows along lakes, streams, drains and other wet sites [11]. It is well adapted for establishment and spread in riparian areas with regular flood cycles (see Asexual regeneration). In California, it is most commonly associated with waterways with altered hydrologic regimes (e.g., dams) and/or disturbed riparian vegetation, but can also establish in the understory of native riparian vegetation [28]. In southern California giant reed reaches peak abundance downstream along major rivers in coastal basins, and has generally not spread up the steep, narrow canyons that characterize lower montane areas [87]. It establishes primarily on streamside microsites, but can spread beyond the zone occupied by native riparian vegetation [24,28,102], and can occur on dry riverbanks far from permanent water [28]. A study along the San Luis Rey River in San Diego County found the highest concentration of giant reed colonies within 24 feet (7.3 m) of the river. The authors suggest frequency and magnitude of river flow contribute to this pattern of distribution [80].

Giant reed tolerates excessive salinity and periods of excessive moisture [74]. In South Carolina, it has invaded abandoned rice fields and grows in brackish water [86]. In a greenhouse experiment designed to test the tolerance of giant reed to salt stress, Peck [73] determined giant reed can grow in saline conditions and may be able to invade and persist in salt marshes.

Reviews (e.g., [24,28,49,74]) report that giant reed grows on a variety of soil types including coarse sands, gravelly soil, heavy clays, and river sediments; however, the sources and context of this information are unclear. Stephenson and Calcarone [87] suggest that it requires "well-developed" soils to become established, while DiTomaso [24] indicates that giant reed is "best developed in poor, sandy soil and in sunny situations," and survives in areas with pH values between 5 and 8.7. Purdue [74] states that its growth is most vigorous in well-drained soils where moisture is abundant.

Giant reed occurs in areas with annual precipitation ranging from 12 to 158 inches (300-4,000 mm) [24]. According to Purdue [74], it is a warm-temperate or subtropical species, and is able to survive very low temperatures when dormant, but is subject to serious damage by frosts that occur after initiation of spring growth.

In California, giant reed is apparently restricted to elevations below 1,640 feet (500 m) [47]. However, Perdue [74] reports it grows at altitudes to 8,000 feet (2,438 m) in the Himalayas.

Elevation ranges reported for giant reed in other areas include:

Nevada: 2,500 to 4,000 feet (760-1,220 m) [56]
New Mexico: 4,000 to 4,500 feet (1,220-1,370 m) [62]
Utah: 2,790 to 4,100 feet (850-1,250 m) [103]

SUCCESSIONAL STATUS:
Giant reed can establish and spread in communities of various successional stages, acting as an early-successional pioneer species, and a late-successional dominant.

According to reviews by Bell [11] and Dudley [28], giant reed is well adapted to the high disturbance dynamics of riparian systems, as floods break up clumps of giant reed and spread pieces downstream where they can take root and establish new clones. In California, it is most common along waterways with altered hydrologic regimes (e.g., dams) and/or disturbed riparian vegetation, but can also establish in the understory of native riparian vegetation [28]. However, establishment of giant reed in dense, mature riparian vegetation may be limited [80].

Once established, giant reed grows quickly [74,80] and spreads vegetatively, often forming monocultural stands that physically inhibit growth of other plant species [11,26,80]. Invaded habitats may thus become pure stands of giant reed [10,80,95].

Although evidence is limited and anecdotal, some authors (e.g., [9,84]) note changes in fuels, fire characteristics, and postfire plant community response that are suggestive of an invasive grass/fire cycle perpetuated by giant reed invasion in southern California riparian areas. Because giant reed produces abundant biomass (i.e., fuel), is "extremely flammable", and responds with rapid growth from sprouting rhizomes after top-kill, it may alter fire regime characteristics and successional processes of invaded riparian ecosystems (see Fire regimes).

SEASONAL DEVELOPMENT:
Information on the phenology of giant reed in the literature is sparse. In California, culms may remain green throughout the year, but can fade during semi-dormancy during the winter months or in drought [28,99]. According to Bell [11] in an assessment of optimal timing of herbicide application, giant reed plants actively translocate nutrients to the rootmass in preparation for winter dormancy around mid-August to early November.

Flowering dates for giant reed by location	
State	Time of flowering
California (southern)	late summer [11]
Carolina, North and South	September-October [77]
Florida	all year [107]
New Mexico	June to September [62]

FIRE ECOLOGY

SPECIES: Arundo donax

- FIRE ECOLOGY OR ADAPTATIONS
- POSTFIRE REGENERATION STRATEGY

FIRE ECOLOGY OR ADAPTATIONS:
Fire adaptations: As of this writing (2004), information on fire adaptations of giant reed are limited to anecdotal accounts and assertions based on known biological attributes. Giant reed's extensive rhizomes are likely to survive and sprout after fire removes top growth. Reviews (e.g., [11,28,95]) provide anecdotal evidence that indicates that sprouts emerge from rhizomes of giant reed soon after fire and grow quickly. Rieger and Kreager [80] observed rapid sprouting and growth of giant reed after removing top-growth by cutting (see Growth).

Fire regimes: With the exception of California, almost no published information is available that describes the types of plant communities in which giant reed is invasive, although giant reed generally occurs in riparian and wetland areas throughout its wide distribution. Characteristics of riparian zones and wetlands vary substantially throughout this range, and fire regimes are not well described for many of these communities. A review by Dwire and Kauffman [30] discusses how differences in topography, microclimate, geomorphology, and vegetation may lead to differences in fire behavior and fire effects between riparian areas and surrounding uplands. Riparian areas may act as a fire barrier or a fire corridor, depending on topography, weather, and fuel characteristics [30]. Recovery of riparian vegetation depends on fire severity and postfire hydrology [22].

Dwire and Kauffman [30] indicate that riparian microclimates are generally characterized by cooler air temperature, lower daily maximum air temperature, and higher relative humidity than the adjacent uplands, contributing to higher fuel moisture content and presumably lowering the intensity, severity, and frequency of fire in riparian areas compared to adjacent uplands. Similarly, Bell [11] suggests that fire is uncommon in riparian areas in southern California, and that native riparian species are not well adapted to frequent or severe fire. In this area, lightning-ignited wildfires usually occur in late fall, winter, and early spring when riparian vegetation is typically moist and green and would act as a fire break [11]. In southern California, riparian areas invaded by giant reed often occur within grasslands or chaparral shrublands. The limited available research from such ecosystems suggests longer fire return intervals and lower-severity burns in riparian areas relative to adjacent upland vegetation [30]. Human-caused wildfires often occur during the dry months of the year (July through October) in southern California, when drier conditions make riparian vegetation more vulnerable to fire damage [11].

Information regarding the effects of giant reed on fuels and fire regime characteristics in plant communities in which it is invasive in North America is limited to accounts from southern California. Although evidence is entirely anecdotal, several accounts (e.g., [11,20,29,84,95]) describe changes in fuels, fire characteristics, and/or postfire plant community response in southern California riparian areas invaded by giant reed that are suggestive of an invasive grass/fire cycle. Because giant reed grows quickly and produces large amounts of biomass [74] in dense stands described as having "large quantities of dry material" [95], it is conceivable that its invasion introduces novel fuel properties to the invaded ecosystem. It thus has the potential to alter fire behavior and the fire regime (*sensu* [14,19]). Giant reed is among the most productive of plant communities and can produce over 20 tons of aboveground biomass per hectare under some conditions [74]. Scott [84] observes that in the Santa Ana Basin in southern California, the invasion of giant reed into riparian corridors has doubled and in some areas tripled the amount of fuels available for wildfire.

According to Bell [9,11] giant reed is "extremely flammable" throughout most of the year, and once established increases the probability of wildfire occurrence and the intensity of fires that do occur. This observation is upheld by manager and newspaper accounts of intense wildfires fueled by giant reed in Riverside County (as cited in [95]), the Santa Ana River drainage (J. Wright, personal communication in [87]), and the Russian River further north [29]. For example, a fire in Soledad Canyon in January 1991 was said to have "burned aggressively through the riparian vegetation" due to dry conditions from a prolonged drought coupled with the presence of dried stands of giant reed (Joyce, personal observation cited in [95]). Dudley [29] describes destructive fires fueled by continuous, 15-foot-high colonies of giant reed along the Santa Ana River, noting that "such flammable vegetation is now changing riparian corridors from barriers to the spread of fires into wicks that carry fire up and downstream, into highway bridges or crowns of native, fire-sensitive trees". See Fire hazard potential for more information on this topic.

As of this writing (2004) no research is available on postfire response of giant reed; however, observations indicate that in most circumstances fire cannot kill the underground rhizomes and probably favors giant reed regeneration over native riparian species (e.g., Gaffney and Cushman 1998, cited in [28]). One week after a fire in Soledad Canyon in January 1991, for example, burned giant reed colonies were sprouting from their extensive rhizomes. Many sprouts were over 2 feet (0.6 m) tall within 2 weeks after the fire, even though January is normally the dormant period for giant reed. Most willow, mulefat, and aquatic plants were also burned, and many cottonwoods were scorched. The aquatic plants in the stream were the only plants other than giant reed that were recovering within the first few weeks of burning. In this way, fire gives giant reed an advantage over native riparian plants, and its dominance in the area has increased dramatically (Joyce, personal observation in [95]). In this sense, Bell [11] suggests that riparian communities invaded by giant reed can change from "flood-defined" to "fire-defined" communities, as has occurred on the Santa Ana River. This grass/fire cycle would thus result in river corridors dominated by stands of giant reed with little biological diversity [11].

As mentioned above, there is little research regarding fire regimes and fire return intervals in riparian areas. However, riparian communities may be influenced by the fire regimes of adjacent and surrounding plant communities. The following table provides fire return intervals for plant communities and ecosystems where riparian vegetation may include giant reed, though its invasiveness in many of these communities has not yet been demonstrated. For further information on fire regimes in these communities, see the FEIS summary on the dominant species listed below.

		Fire Return Interval

Community or Ecosystem	Dominant Species	Range (years)
silver maple-American elm	*Acer saccharinum-Ulmus americana*	< 35 to 200
sugar maple	*Acer saccharum*	> 1,000
sugar maple-basswood	*Acer saccharum-Tilia americana*	> 1,000 [101]
California chaparral	*Adenostoma* and/or *Arctostaphylos* spp.	< 35 to < 100 [72]
bluestem prairie	*Andropogon gerardii* var. *gerardii-Schizachyrium scoparium*	< 10 [59,72]
Nebraska sandhills prairie	*Andropogon gerardii* var. *paucipilus-Schizachyrium scoparium*	< 10
bluestem-Sacahuista prairie	*Andropogon littoralis-Spartina spartinae*	< 10 [72]
silver sagebrush steppe	*Artemisia cana*	5-45 [46,76,106]
sagebrush steppe	*Artemisia tridentata/Pseudoroegneria spicata*	20-70 [72]
basin big sagebrush	*Artemisia tridentata* var. *tridentata*	12-43 [81]
mountain big sagebrush	*Artemisia tridentata* var. *vaseyana*	15-40 [5,16,66]
Wyoming big sagebrush	*Artemisia tridentata* var. *wyomingensis*	10-70 (40**) [100,109]
coastal sagebrush	*Artemisia californica*	< 35 to < 100
saltbush-greasewood	*Atriplex confertifolia-Sarcobatus vermiculatus*	< 35 to < 100 [72]
mangrove	*Avicennia nitida-Rhizophora mangle*	35-200 [70]
desert grasslands	*Bouteloua eriopoda* and/or *Pleuraphis mutica*	5-100 [72]
plains grasslands	*Bouteloua* spp.	< 35
blue grama-buffalo grass	*Bouteloua gracilis-Buchloe dactyloides*	< 35 [72,106]
grama-galleta steppe	*Bouteloua gracilis-Pleuraphis jamesii*	< 35 to < 100
blue grama-tobosa prairie	*Bouteloua gracilis-Pleuraphis mutica*	< 35 to < 100 [72]
cheatgrass	*Bromus tectorum*	< 10 [75,104]
California montane chaparral	*Ceanothus* and/or *Arctostaphylos* spp.	50-100 [72]
sugarberry-America elm-green ash	*Celtis laevigata-Ulmus americana-Fraxinus pennsylvanica*	< 35 to 200 [101]
paloverde-cactus shrub	*Cercidium microphyllum/Opuntia* spp.	< 35 to < 100 [72]
curlleaf mountain-mahogany*	*Cercocarpus ledifolius*	13-1,000 [6,83]
mountain-mahogany-Gambel oak scrub	*Cercocarpus ledifolius-Quercus gambelii*	< 35 to < 100 [72]
Atlantic white-cedar	*Chamaecyparis thyoides*	35 to > 200 [101]
blackbrush	*Coleogyne ramosissima*	< 35 to < 100
Arizona cypress	*Cupressus arizonica*	< 35 to 200
northern cordgrass prairie	*Distichlis spicata-Spartina* spp.	1-3 [72]
beech-sugar maple	*Fagus* spp.-*Acer saccharum*	> 1,000 [101]
California steppe	*Festuca-Danthonia* spp.	< 35 [72,89]
black ash	*Fraxinus nigra*	< 35 to 200 [101]
juniper-oak savanna	*Juniperus ashei-Quercus virginiana*	< 35
Ashe juniper	*Juniperus ashei*	< 35
western juniper	*Juniperus occidentalis*	20-70
Rocky Mountain juniper	*Juniperus scopulorum*	< 35 [72]
cedar glades	*Juniperus virginiana*	3-22 [43,72]
creosotebush	*Larrea tridentata*	< 35 to < 100
Ceniza shrub	*Larrea tridentata-Leucophyllum frutescens-Prosopis glandulosa*	< 35 [72]
yellow-poplar	*Liriodendron tulipifera*	< 35 [101]

Everglades	*Mariscus jamaicensis*	< 10
melaleuca	*Melaleuca quinquenervia*	< 35 to 200 [70]
wheatgrass plains grasslands	*Pascopyrum smithii*	< 5-47+ [72,76,106]
southeastern spruce-fir	*Picea-Abies* spp.	35 to > 200 [101]
Engelmann spruce-subalpine fir	*Picea engelmannii-Abies lasiocarpa*	35 to > 200
pine-cypress forest	*Pinus-Cupressus* spp.	< 35 to 200 [4]
pinyon-juniper	*Pinus-Juniperus* spp.	< 35 [72]
Mexican pinyon	*Pinus cembroides*	20-70 [67,92]
shortleaf pine	*Pinus echinata*	2-15
shortleaf pine-oak	*Pinus echinata-Quercus* spp.	< 10 [101]
Colorado pinyon	*Pinus edulis*	10-400+ [36,41,58,72]
slash pine	*Pinus elliottii*	3-8
slash pine-hardwood	*Pinus elliottii*-variable	< 35
sand pine	*Pinus elliottii* var. *elliottii*	25-45 [101]
South Florida slash pine	*Pinus elliottii* var. *densa*	1-5
longleaf-slash pine	*Pinus palustris-P. elliottii*	1-4 [70,101]
longleaf pine-scrub oak	*Pinus palustris-Quercus* spp.	6-10 [101]
pitch pine	*Pinus rigida*	6-25 [15,44]
pocosin	*Pinus serotina*	3-8
pond pine	*Pinus serotina*	3-8
eastern white pine	*Pinus strobus*	35-200
eastern white pine-eastern hemlock	*Pinus strobus-Tsuga canadensis*	35-200
loblolly pine	*Pinus taeda*	3-8
loblolly-shortleaf pine	*Pinus taeda-P. echinata*	10 to < 35
Virginia pine	*Pinus virginiana*	10 to < 35
Virginia pine-oak	*Pinus virginiana-Quercus* spp.	10 to < 35
sycamore-sweetgum-American elm	*Platanus occidentalis-Liquidambar styraciflua-Ulmus americana*	< 35 to 200 [101]
galleta-threeawn shrubsteppe	*Pleuraphis jamesii-Aristida purpurea*	< 35 to < 100
eastern cottonwood	*Populus deltoides*	< 35 to 200 [72]
mesquite	*Prosopis glandulosa*	< 35 to < 100 [64,72]
mesquite-buffalo grass	*Prosopis glandulosa-Buchloe dactyloides*	< 35
Texas savanna	*Prosopis glandulosa* var. *glandulosa*	< 10 [72]
mountain grasslands	*Pseudoroegneria spicata*	3-40 (10**) [3,4]
California oakwoods	*Quercus* spp.	< 35 [4]
oak-hickory	*Quercus-Carya* spp.	< 35 [101]
oak-juniper woodland (Southwest)	*Quercus-Juniperus* spp.	< 35 to < 200 [72]
oak-gum-cypress	*Quercus-Nyssa*-spp.-*Taxodium distichum*	35 to > 200 [70]
southeastern oak-pine	*Quercus-Pinus* spp.	< 10 [101]
coast live oak	*Quercus agrifolia*	2-75 [42]
white oak-black oak-northern red oak	*Quercus alba-Q. velutina-Q. rubra*	< 35 [101]
canyon live oak	*Quercus chrysolepis*	<35 to 200
blue oak-foothills pine	*Quercus douglasii-P. sabiniana*	<35 [4]
northern pin oak	*Quercus ellipsoidalis*	< 35 [101]
Oregon white oak	*Quercus garryana*	< 35 [4]

bear oak	*Quercus ilicifolia*	< 35 >[101]
California black oak	*Quercus kelloggii*	5-30 [72]
bur oak	*Quercus macrocarpa*	< 10 [101]
oak savanna	*Quercus macrocarpa/Andropogon gerardii-Schizachyrium scoparium*	2-14 [72,101]
shinnery	*Quercus mohriana*	< 35
chestnut oak	*Quercus prinus*	3-8
post oak-blackjack oak	*Quercus stellata-Q. marilandica*	< 10
black oak	*Quercus velutina*	< 35
live oak	*Quercus virginiana*	10 to< 100 [101]
interior live oak	*Quercus wislizenii*	< 35 [4]
cabbage palmetto-slash pine	*Sabal palmetto-Pinus elliottii*	< 10 [70,101]
blackland prairie	*Schizachyrium scoparium-Nassella leucotricha*	< 10
Fayette prairie	*Schizachyrium scoparium-Buchloe dactyloides*	< 10 [101]
little bluestem-grama prairie	*Schizachyrium scoparium-Bouteloua* spp.	< 35
tule marshes	*Scirpus* and/or *Typha* spp.	< 35 [72]
redwood	*Sequoia sempervirens*	5-200 [4,35,90]
southern cordgrass prairie	*Spartina alterniflora*	1-3 [72]
baldcypress	*Taxodium distichum* var. *distichum*	100 to > 300
pondcypress	*Taxodium distichum* var. *nutans*	< 35 [70]
eastern hemlock-yellow birch	*Tsuga canadensis-Betula alleghaniensis*	> 200 [101]
western hemlock-Sitka spruce	*Tsuga heterophylla-Picea sitchensis*	> 200 [4]
elm-ash-cottonwood	*Ulmus-Fraxinus-Populus* spp.	< 35 to 200 [27,101]

*fire return interval varies widely; trends in variation are noted in the species review
**mean

POSTFIRE REGENERATION STRATEGY [88]:
Rhizomatous herb, rhizome in soil
Geophyte, growing points deep in soil
Ground residual colonizer (on-site, initial community)
Initial off-site colonizer (off-site, initial community)

FIRE EFFECTS

SPECIES: Arundo donax

- IMMEDIATE FIRE EFFECT ON PLANT
- DISCUSSION AND QUALIFICATION OF FIRE EFFECT
- PLANT RESPONSE TO FIRE
- DISCUSSION AND QUALIFICATION OF PLANT RESPONSE
- FIRE MANAGEMENT CONSIDERATIONS

IMMEDIATE FIRE EFFECT ON PLANT:
Anecdotal evidence cited in reviews (e.g., [11,28,95]) indicates that giant reed is top-killed by fire, and in most circumstances underground rhizomes survive fire.

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:
No additional information is available on this topic.

PLANT RESPONSE TO FIRE:

As of this writing (2004) no research is available on postfire response of giant reed; however, observations indicate that in most circumstances fire cannot kill the underground rhizomes. One week after a fire in Soledad Canyon in January 1991, for example, burned giant reed colonies were sprouting from their extensive rhizomes. Many sprouts were over 2 feet (0.6 m) tall within 2 weeks after the fire, even though January is normally the dormant period for giant reed (Joyce, personal observation in [95]).

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:
No additional information is available on this topic.

FIRE MANAGEMENT CONSIDERATIONS:
Postfire colonization potential: The limited information available on the postfire colonization potential of giant reed indicates that wherever it is present in or adjacent to burned areas, managers should expect it to persist and possibly spread in the postfire environment.

Fire as a control agent: While prescribed burning alone is unlikely to control giant reed or prevent sprouting, infestations may be broadcast burned to remove standing plants and/or prepare for other control methods such as herbicide treatments or revegetation with fast growing native species [49]. However, no information is available in the literature on the efficacy of such approaches. A review by Dudley [28] suggests that in most circumstances burning of live or chemically treated giant reed should not be attempted, as it cannot kill the underground rhizomes and probably favors giant reed regeneration over native riparian species. Additionally, burning giant reed infestations includes risks of uncontained fire, potential damage of desirable species, and difficulties of promoting fire through patchily distributed stands [28].

A review by Hoshovsky [49] suggests that a flame thrower or weed burner device can be used as a spot treatment to heat-girdle stems at the base of giant reed plants. This method is only appropriate when the potential to ignite unwanted fires is negligible (Jones/Stokes 1984, cited in [49]).

It is recommended that stems and roots of pulled plants or cut stems of giant reed be removed or burned on site to avoid re-rooting. Burning is suggested as the most cost-effective way of removing this biomass as long as it does not threaten native vegetation or other resources [11,84].

Fire hazard potential: Managers in Riverside county are concerned that allowing giant reed to continue to grow and spread in San Francisquito and Soledad canyons increases the threat of wildfire in the area (also see Fire regimes), possibly threatening life and property. They suggest that removal of giant reed is the most feasible alternative to reduce the risk of wildfire. Wildfire is common in the chaparral vegetation surrounding riparian areas of these canyons; however, the presence of large, dense stands of giant reed in riparian areas creates a novel fire hazard that is cumulative to the fire hazard from native chaparral vegetation, and thus increases the threat to life and property (review by [95]).

Firefighting in giant reed thickets may have a substantial impact on fire management resources (J. Wright, Riverside County Fire Dept.; R. Hawkins, Cleveland NF, personal communications in [87]).

MANAGEMENT CONSIDERATIONS

SPECIES: Arundo donax

IMPORTANCE TO LIVESTOCK AND WILDLIFE:
Available evidence indicates giant reed provides neither food nor habitat for native species of wildlife [11]. Bell [11] speculates that insects are sparse in sites dominated by giant reed because of abundant chemical defense compounds produced by the plant.

Palatability/nutritional value: Giant reed stems and leaves contain a wide array of chemicals that probably protect it from most native insects and grazers. These chemicals include silica [51,74], triterpines, sterols [18], cardiac glycosides, curare-mimicking indoles [39], hydroxamic acid, and numerous other alkaloids (Bell [11] and references therein).

Giant reed is not very palatable to cattle, but they will eat it during dry seasons [49,108]. Domestic goats will also eat it [21,49].

Giant reed is low in protein but has a comparatively high concentration of phosphorus in the upper portions even when grown on soils with an extremely low concentration of this mineral [74,108].

Nutritional content of giant reed. Results are an average of 2 samples for each category and are presented as percentages of oven-dry weight [108]:

	Old plant		Young plant	
	Lower half	Upper half	Lower half	Upper half
Total nitrogen	0.63	1.10	0.50	1.96
Protein (total N x 6.25)	3.94	6.88	3.13	12.25
Phosphorus	0.082	0.114	0.105	0.152
Calcium	0.52	0.67	0.30	0.43
Magnesium	0.25	0.32	0.12	0.19
Potassium	2.04	2.42	3.09	3.19
Carbohydrate	23.2	21.7	20.0	20.7

Cover value: Areas dominated by giant reed are largely depauperate of wildlife [9,11,54]. Additionally, a study by Chadwick and Associates [17] suggests giant reed also lacks the canopy structure to provide shading of bank-edge river habitats, resulting in warmer water than would be found with a native gallery of willows and cottonwoods. In the Santa Ana River system in California, this lack of streambank structure and shading has been implicated in the decline of native stream fishes including the arroyo chub, three-spined stickleback, speckled dace, and the Santa Ana sucker [9,17].

Giant reed has no structural similarity to any dominant riparian plant it replaces and offers little useful cover or nest placement opportunities for birds. Main stems are vertical with no horizontal structure strong enough to support birds [110]. For example, the southwestern willow flycatcher, an endangered species, has not been reported nesting in any vegetation patches dominated by giant reed [97]. Only a few of bird species have been observed using giant reed for nest sites. Dramatic reductions (50% or more) in abundance and diversity of invertebrates were also documented in giant reed thickets in southern California compared with those found in native willow/cottonwood vegetation [29]. Giant reed's most observed use as cover has been by feral pigs [110].

OTHER USES:
Giant reed has been planted extensively for erosion control along drainage canals [49]. Wynd and others [108] report it can also be used to stabilize sand dunes. It is also used for thatching roofs of sheds, barns and other buildings [49]. Mexican campesinos use new tillers of giant reed for roofing and construction materials. It is the most important construction material in the Juamave region of Mexico [2]. Giant reed makes a good quality paper, and in Italy it is used in the manufacture of rayon [24].

Giant reed is used to make reeds for a variety of musical instruments including bagpipes [11,74]. Reeds for woodwind musical instruments are still made from the culms of giant reed, and no satisfactory substitutes have been developed. The basis for the origin of the most primitive pipe organ, the Pan pipe or syrinx, was made from giant reed [74].

Five thousand years ago Egyptians used giant reed to line underground grain storage bins, and mummies from the 4th century A.D. were wrapped in giant reed leaves. Additional uses include basket-making, fishing rods, arrows, and ornamental plants. Medicinally, giant reed's rhizome has been used as a sudorific, a diuretic, an antilactant, and in the treatment of dropsy [74].

IMPACTS AND CONTROL:
Impacts: Bell [11] considers giant reed to be the greatest threat to southern California's remaining riparian corridors. It is so widespread and problematic in this area that more than 20 public and private organizations came together to form the Santa Ana River Arundo Management Task Force, also known as Team Arundo [54].

Once established, giant reed often forms monocultural stands that physically inhibit growth of other plant species [11,80]. For example, Douthit [26] describes a 1993 preliminary riparian assessment of the Santa Ana River basin where in the Riverside West Quad, 762 acres (308 ha) of 1,116 acres (470 ha) of riparian vegetation are impacted by giant reed. Of the impacted acres, 535 acres (217 ha) are monospecific stands of giant reed.

Although evidence is entirely anecdotal, several accounts (e.g., [11,20,29,84,95]) describe changes in fuels, fire characteristics, and/or postfire plant community response in southern California riparian areas invaded by giant reed that are suggestive of an invasive grass/fire cycle. The result of such cycle is loss of native riparian species, and continued dominance and spread of giant reed. See Fire ecology for more details.

Canopy structure of giant reed colonies differs from that of native vegetation, resulting in changes in water quality and wildlife habitat. The lack of stream-side canopy structure may result in increased pH in the shallower sections of rivers due to high algal photosynthetic activity [9,17]. In turn, high pH facilitates conversion of ammonium (NH_4^+) to toxic ammonia (NH_3), which further degrades water quality for aquatic species and for downstream users [9]. Several species listed as endangered are further threatened by giant reed invasion and control efforts in San Francisquito Canyon including least Bell's vireo, unarmored threespine stickleback, and Nevin's barberry (*Mahonia nevinii*) [95].

Giant reed is becoming a major biological pollutant of river estuaries and beaches. It is often ripped out of the soft bottoms of rivers during storms and washed downstream into flood control channels [25]. Giant reed growing in flood control channels necessitates constant removal. It can form debris dams against flood control and transportation structures such as bridges and culverts [29,37]. Because the rhizomes of giant reed grow close to the surface, they break off during floods. When the root mass breaks away during these floods the riverbanks are destabilized. Destabilization of riverbanks is the leading cause of flooding in southern California [99].

Iverson [50] provides insight into the economics of giant reed's impact on water use. He estimates giant reed transpires 56,200 acre-feet of water per year on the Santa Ana River, compared to an estimated 18,700 acre-feet that would be consumed by native vegetation - the difference being enough water to serve a population of about 190,000 people. If that amount of untreated water (37,500 acre-feet) was purchased from the Metropolitan Water Association it would cost approximately $12,000,000 in 1993 dollars [50].

Control: A suite of methods is needed to control giant reed depending on presence or absence of native plants, size of the stand, amount of biomass involved, terrain, and season. The key to effective treatment of established giant reed is killing or removing the rhizomes [11].

To be successful, a program to eliminate a riparian invasive plant like giant reed must start at the uppermost reaches of the watershed and work down stream. This means there must be coordination with all of the landowners and land managers, top to bottom, in a watershed. Regulatory agencies must provide technical assistance and required permits, and private landowners must provide work crews access to land [99].

To adequately coordinate removal of giant reed in a watershed, 3 programs need to be operating: 1) create a functional mapped database that contains hydrology, land ownership/use, infestations, project sites, etc.; 2) coordination with regulatory agencies to plan mitigation project sites to fit within other current projects; 3) regular meetings of stakeholders to share information regarding threats from giant reed, control techniques, funding opportunities, and each stakeholder's direct role and responsibility [99].

Prevention: Grading and construction can spread giant reed [80]. Care must therefore be taken in areas where it occurs such that soil disturbance and movement of plant parts is minimized.

Integrated management: A popular approach to treating giant reed has been to cut the stalks and remove the biomass, wait 3 to 6 weeks for the plants to grow about 3.3 feet (1 m) tall, then apply a foliar spray of herbicide solution. The chief advantage to this approach is less herbicide is needed to treat fresh growth compared with tall, established plants, and coverage is often better because of the shorter and uniform-height plants. However, cutting the stems may result in plants returning to growth-phase, drawing nutrients from the root mass. As a result there is less translocation of herbicide to the roots and less root-kill. Additionally, cut-stem treatment requires more time and personnel than foliar spraying and requires careful timing. Cut stems must be treated with concentrated herbicide within 1 to 2 minutes of cutting to ensure tissue uptake. This treatment is most effective after flowering. The advantage of this treatment is that it requires less herbicide and the herbicide can be applied more precisely. It is rarely less expensive than foliar spraying except on very small, isolated patches or individual plants [11].

An investigation to test the effectiveness of glyphosate for control of giant reed was conducted in southern California by Caltrans, the state transportation agency. Results indicate cut-stem treatments, regardless of time of application (May, July, or September), provided 100% control with no resprouting. In contrast, virtually all plants that were left untreated following cutting resprouted vigorously. Foliar treatments produced highly variable results with top die-back varying from 10 to 90% and resprouting ranging from 0 to 100% at various sites. The authors conclude treatment of cut stems appears more effective than foliar spraying in controlling giant reed with glyphosate [34].

In 1995, a full-scale project for control of giant reed was initiated in San Francisquito Canyon in the Angeles National Forest. The standing giant reed was mulched in place, using a hammer flail mower attached to a tractor, and then glyphosate was applied to the resprouts. Initial mulching occurred in October and November, 1995. Resprouts in spring, 1996, were treated with a solution of glyphosate in April, May, July, and August. Resprouts were treated again in June and September, 1997. In 1998, giant reed continued to resprout in the treatment area, but comprised only 1% of vegetative cover, as compared to 30% to 80% prior to treatment [8]. No information is provided about the composition of the plant community posttreatment.

Physical/mechanical: Minor infestations of giant reed can be eradicated by manual methods, especially where sensitive native plants and wildlife might be damaged by other methods. Hand pulling works with new plants less than 6.6 feet (2 m) in height, but care must be taken that all rhizomes are removed [49]. This may be most effective in loose soils and after rains have loosened the substrate. Giant reed can be dug using hand tools and in combination with cutting plants near the base. Stems and roots should be removed and burned on site to prevent rerooting. The fibrous nature of giant reed makes using a chipper difficult (R. Dale personal communication in [28]). For larger infestations on accessible terrain, heavier tools (rotary brush cutter, chainsaw, or tractor-mounted mower) may facilitate biomass removal followed by rhizome removal or chemical treatment. Such methods may be of limited value on complex or sensitive terrain or on slopes over 30%. These methods may also interfere with re-establishment of native plants [49]. Mechanical eradication of giant reed is extremely difficult, even with the use of a backhoe, as rhizomes buried under 3 to 10 feet (1-3 m) of alluvium readily resprout (R. Dale personal communication in [28]).

Cut material is often burned on site, subject to local fire regulations, because of the difficulty and expense involved in collecting and removing or chipping all material. Stems and roots must be removed, chipped, or burned on site to avoid re-rooting (Dale, personal communication in [28]).

Fire: See Fire Management Considerations.

Biological: Tracy and DeLoach [93] provide an exhaustive summary of the search for biological control agents for giant reed in the United States. Areas dominated by giant reed in North America are essentially devoid of wildlife. This means native flora and fauna do not offer any significant control potential [11]. It is uncertain what natural controlling mechanisms for giant reed are in its countries of origin, although corn borers (Eizaguirre and others 1990 in [11]), spider mites [31], and aphids [65] have been reported in the Mediterranean. A sugar cane moth-borer in Barbados is reported to attack giant reed, but it is also a major pest of sugar cane and is already found in the United States in Texas, Louisiana, Mississippi, and Florida [94]. A leafhopper in Pakistan utilizes giant reed as an alternate host but attacks corn and wheat [1].

In the United States a number of diseases have been reported on giant reed, including root rot, lesions, crown rust, and stem speckle, but none seem to have seriously impacted advance of this weed [11].

Giant reed is not very palatable to cattle, but during the drier seasons they will graze the young shoots, followed by the upper parts of the older plants [108]. In many areas of California the use of Angora and Spanish goats is showing promise for controlling giant reed [21].

Chemical: Application of herbicides on giant reed is most effective after flowering and before dormancy. During this period, usually mid-August to early November in southern California, the plants are actively translocating nutrients to the root mass in preparation for winter dormancy. This may result in effective translocation of herbicide to the roots [11]. Comparison trials on the Santa Margarita River in southern California indicate foliar application during the appropriate season results in almost 100% control, compared with only 5 to 50% control using cut-stem treatment. Two to 3 weeks after foliar treatment the leaves and stalks brown and soften creating an additional advantage in dealing with the biomass. Cut green stems might take root if left on damp soil and are very difficult to cut and chip. Treated stems have little or no potential to root and are brittle (Omori 1996 in Bell [11]). Bell [11], Hoshovsky [49], and Jackson [52] provide detailed information on specific herbicides and concentrations used to treat giant reed.

In the proceedings from a workshop on giant reed control published online, Bell [11] asserts pure stands of giant reed (>80% canopy cover) are most efficiently and effectively treated by aerial application of an herbicide concentrate, usually by helicopter. Helicopter application can treat at least 124 acres (50 ha) per day. In areas where helicopter access is impossible and giant reed makes up the understory, where patches are too small to make aerial application financially efficient, or where giant reed is mixed with native plants (<80% canopy coverage), herbicides must be applied by hand.

Cultural: Giant reed appears to be insensitive to flood regime. It survives and spreads through vegetative propagation during long periods without flooding but spreads during flood events as well. Because it does not reproduce sexually, giant reed is not affected by the timing of spring flows, but can establish any time that flood flows carry and deposit stem fragments or rhizomes. It thrives along edges of reservoirs, irrigation canals, and other structures where timing of drawdowns is incompatible with maintenance of native species [97].

Conversely, native riparian species and communities depend on natural flood regimes for maintenance and reproduction. If natural flood dynamics are maintained as part of an integrated management approach, native species may have a better chance of competing with giant reed in the long term [11].

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