SPECIES: Arundo donax

Choose from the following categories of information.

INTRODUCTORY

SPECIES: Arundo donax

James H. Miller, USDA Forest Service, www.forestryimages.org

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AUTHORSHIP AND CITATION:
McWilliams, John D. 2004. Arundo donax. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2007, September 24].

FEIS ABBREVIATION:
ARUDON

SYNONYMS:
None

NRCS PLANT CODE [92]:

ARDO4

COMMON NAMES:
giant reed
arundo grass
donax

TAXONOMY:
The currently accepted scientific name of giant reed is *Arundo donax* L. (Poaceae) [13,36,49,52,53,58,59,65,73,99,101,103]. One variation of giant reed is recognized in the literature:

Arundo donax L. var. *versicolor* (P. Mill) Stokes [49,103].

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:
Giant reed occurs in a wide belt in riparian areas across the southern United States from Maryland and West Virginia westward to California. Wunderlin [103] recognizes the variety *versicolor* as occurring in Florida and Jones and others [49] 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 [2,57,78,94]. Giant reed is likely present in other areas of Mexico.

In Europe, giant reed was probably cultivated as far back as the 1600s [21]. Giant reed is native to the countries surrounding the Mediterranean Sea. From this area it has become widely dispersed, mostly through intentional introductions [45]. Bell (personal communication in [25]) states it was introduced to the Mediterranean area from the subcontinent of India. It was intentionally introduced to California from the Mediterranean in the 1820s in the Los Angeles area [45].

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 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 [67] 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 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 [34]:
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 [56] 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 [28]:
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 [81]:
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. Zembal [106] provides a list of plants giant reed is known to displace in southern California riparian habitats. In coastal southern California the stream-side habitat often includes willow (*Salix* spp.) dominated with local stands of Fremont cottonwood (*Populus fremontii*), black cottonwood (*P. balsamifera* ssp. *trichocarpa*) and white alder (*Alnus rhombifolia*) (more abundant at higher elevations now), and mixed woodlands of oaks (*Quercus* spp.), especially coast live oaks (*Q. agrifolia*) and California sycamore (*Platanus racemosa*) on the higher terraces. Willow communities include arroyo willow (*S. lasiolepis*), red willow (*S. laevigata*), narrowleaf willow (*S. exigua*), Goodding willow (*S. gooddingii*), and mule's fat (*Baccharis salicifolia*) [106].

Dick-Peddie [20] lists giant reed as a plant occurring in riparian areas of floodplains and plains and riparian areas of arroyos in New Mexico. Giant reed occurs with plant associations in floodplains that are dominated by cottonwoods *(Populus*
spp.). In the southern part of New Mexico cottonwoods commonly share dominance with Goodding willow; farther north, peachleaf willow (*S. amygdaloides*) occasionally shares dominance with cottonwoods. Understory layers may be dominated by stretchberry (*Forestiera pubescens* var. *pubescens*), skunkbush sumac (*Rhus trilobata*), rabbitbrush (*Chrysothamnus* spp.), and sandbar willow (*S. interior*). Saltcedar (*Tamarix* spp.) associations are common on both floodplain and plains habitat. From Albuquerque north, Russian-olive

(*Elaeagnus angustifolia*) replaces saltcedar. 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*) [20].

Riparian areas where giant reed occurs in arroyos in the northwestern quarter of New Mexico are usually dominated by black greasewood (*Sarcobatus vermiculatus*). A common arroyo dominant of the northern two-thirds of the state is green rabbitbrush (*C. nauseosus* var. *graveolens*). This variety tends to be displaced in the northwest by rubber rabbitbrush (*C. n.* var. *bigelovii*). In the southern third of the state lower portions of arroyos, where the beds widen, are 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 [20].

In riparian woodlands within the Chihuahuan desert, Hendrickson and Johnston [41] 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. [36,49,52,53,58,59,65,73,99,101,103]). Giant reed and common reed can be difficult to distinguish. Common reed is a native grass distributed across most of the United States. It is essential to be certain of the proper identification of giant reed before beginning any control measures [21].

Giant reed is a perennial [25]. It is the largest member of the genus and among the largest of grasses, growing to a height of 26.2 feet (8 m) [11]. The culms reach a diameter of 0.4 to 1.6 inches (1-4 cm) and commonly branch during the 2nd 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 4.7 to 11.8 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 [70]. Giant reed uses "prodigious" amounts of water, as much as 2,000 L/meter of standing giant reed to supply its rate of growth [11,46,70]. Under optimal conditions it can grow more than 2 inches (5 cm) per day [70]. Giant reed has large plume-like panicles. Spikelets are several-flowered with upper florets successively smaller [29].

Giant reed growth can be seriously retarded by lack of moisture during its 1st year, but drought causes no great damage to patches 2 to 3 years old. When dormant it is able to survive very low temperatures but is subject to serious damage by frosts that occur after initiation of spring growth [70].

Once established, giant reed tends to form large, continuous, clonal root masses, sometimes covering several acres. These root masses can be more than 3.3 feet (1 m) thick [11].

Although giant reed has been widely cultivated for a long time, little information on its biology and ecology has been published [45]. As of this writing (2004), more research is needed to understand the biology and ecology of giant reed.

RAUNKIAER [74] LIFE FORM:
Hydrophyte

REGENERATION PROCESSES:
Very little information about the reproductive biology of giant reed is available in the literature. Importance of sexual reproduction, as well as seed viability, dormancy, germination and seedling establishment have yet to be studied and published [45]. Much research is needed in these areas.

Much of the cultivation of giant reed throughout the world is initiated by planting rhizomes which root and sprout easily [45].

Breeding system: No information is available on this topic.

Pollination: No information is available on this topic.

Seed production: Seeds produced by giant reed in North America are seldom, if ever, fertile [11]. Perdue [70] states giant reed does not produce viable seed in most areas where it is apparently well adapted.

Seed dispersal:
The hairy, light-weight disseminules (individual florets with the enclosed grain) are wind-borne [29].

Seed banking: No information is available on this topic.

Germination: No information is available on this topic.

Seedling establishment/growth:
Establishment of giant reed appears to be from fragmented rhizomes that take root [11]. Seedlings have not been observed in the field [25]. In a southern California study, Rieger and Kreager [76] 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 for in the 1st 40 days and 1 inch (2.67 cm) per day in the 1st 150 days.

Asexual regeneration:
Giant reed is well adapted to the high disturbance dynamics of riparian systems since it spreads vegetatively. Floods break up clumps of giant reed and spread pieces downstream. Fragmented stem nodes and rhizomes can take root and establish as new plant clones [11]. 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 [44] 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 [87]. In a greenhouse experiment, Motamed [64] determined giant reed stem fragments rooted throughout the growing season. Rhizomes buried under 3.3 to 9.9 feet (1-3 m) of alluvium readily resprout (R. Dale personal communication in Dudley [25]).

SITE CHARACTERISTICS:
Giant reed tolerates a wide variety of ecological conditions. Giant reed is best developed in "poor", sandy soil and in sunny situations [21] but is reported to flourish in all types of soils from heavy clays to loose sands and gravelly soils. It produces most vigorous growth in well-drained soils where abundant moisture is available [70]. Giant reed survives in areas with annual precipitation of 11.8 to 157.5 inches (300-4,000 mm) and pH values between 5 and 8.7 [21]. There is no information about temperature requirements for establishment and growth available in the literature.

Giant reed is a hydropyhte, growing along lakes, streams, drains and other wet sites [11]. Giant reed grows well where water tables are close to or at the soil surface [75]. In South Carolina it has invaded abandoned rice fields and grows in water described as "brackish" [82]. It tolerates excessive salinity and periods of excessive moisture [70]. In a greenhouse experiment designed to test the tolerance of giant reed to salt stress, Peck [69] determined giant reed can grow in saline conditions and may be able to invade and persist salt marshes. Giant reed can spread from the water's edge up the banks and far beyond the zone previously occupied by woody riparian vegetation [21,25,98].

In southern California giant reed reaches peak abundance downstream along major rivers in coastal basins. It has generally not spread up the steep, narrow canyons that characterize lower montane areas [83]. It is apparently restricted to low elevations, primarily below 1,640 feet (500 m) [43] and requires "well-developed" soils to become established [83]. However, Perdue [70] reports it grows at altitudes to 8,000 feet (2,438 m) in the Himalayas.

Altitudes reported in other states include:

Nevada-2,500 to 4,000 feet (760-1,220 m) [52]
New Mexico-4,000 to 4,500 feet (1,220-1,370 m) [58]
Utah-2,790 to 4,100 feet (850-1,250 m) [99]

SUCCESSIONAL STATUS:
Within its introduced range, giant reed is an aggressive competitor. It dramatically alters the ecological/successional processes of riparian ecosystems, making them essentially fire-driven communities, and ultimately moves most riparian habitats toward pure stands of giant reed [10]. Giant reed will expand at the expense of native vegetation until a climax community of giant reed is formed [91].

SEASONAL DEVELOPMENT:
Information on the phenology of giant reed in the literature is depauperate. In southern California giant reed goes dormant during the fall and winter months [95].

Flowering dates for giant reed in some states are:

State	Time of flowering	Reference
California (southern)	late summer	[11]
Carolina, North and South	September-October	[73]
Florida	all year	[103]
New Mexico	June to September	[58]

FIRE ECOLOGY

SPECIES: Arundo donax

FIRE ECOLOGY OR ADAPTATIONS:

Fire adaptations:

Giant reed is highly flammable throughout most of the year and appears highly adapted to "extreme" fire events [80]. Giant reed rhizomes respond quickly after fire, sending up new shoots and quickly outgrowing native

species that might have otherwise taken root or sprouted in a burned site [11].

Fire regimes:

In southern California, natural wildfires are usually ignited by rare lightning storms in late fall, winter, and early spring. Under these conditions moist green vegetation of riparian areas would normally act as a fire break. Human-caused wildfires often occur during the driest months of the year, July through October. Drier conditions in riparian areas at this time of year make them more likely to burn and more vulnerable to fire damage. Since giant reed is extremely flammable, once established in a riparian area it can change the fire regime of a site by increasing the probability of wildfire occurrence and intensity. If giant reed becomes abundant it can change riparian forests from a flood-defined to a fire-defined community. For example, this has happened on the Santa Ana River in Riverside, California, where monocultures of giant reed burn more often and more intensely than the native plant community [11].

The following table provides some fire regime intervals for ecosystems in which giant reed may occur. Giant reed may also occur within riparian or wetland areas included in these ecosystems. For further information, see the FEIS summary on the dominant species listed below

Community or Ecosystem	Dominant Species	Fire Return Interval 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 [97]
California chaparral	*Adenostoma* and/or *Arctostaphylos* spp.	< 35 to < 100 [68]
bluestem prairie	*Andropogon gerardii* var. *gerardii-Schizachyrium scoparium*	< 10 [55,68]
Nebraska sandhills prairie	*Andropogon gerardii* var. *paucipilus-Schizachyrium scoparium*	< 10
bluestem-Sacahuista prairie	*Andropogon littoralis-Spartina spartinae*	< 10 [68]
silver sagebrush steppe	*Artemisia cana*	5-45 [42,72,102]
sagebrush steppe	*Artemisia tridentata/Pseudoroegneria spicata*	20-70 [68]
basin big sagebrush	*Artemisia tridentata* var. *tridentata*	12-43 [77]
mountain big sagebrush	*Artemisia tridentata* var. *vaseyana*	15-40 [5,15,62]
Wyoming big sagebrush	*Artemisia tridentata* var. *wyomingensis*	10-70 (40**) [96,105]
coastal sagebrush	*Artemisia californica*	< 35 to < 100
saltbush-greasewood	*Atriplex confertifolia-Sarcobatus vermiculatus*	< 35 to < 100 [68]
mangrove	*Avicennia nitida-Rhizophora mangle*	35-200 [66]
desert grasslands	*Bouteloua eriopoda* and/or *Pleuraphis mutica*	5-100 [68]
plains grasslands	*Bouteloua* spp.	< 35
blue grama-buffalo grass	*Bouteloua gracilis-Buchloe dactyloides*	< 35 [68,102]
grama-galleta steppe	*Bouteloua gracilis-Pleuraphis jamesii*	< 35 to < 100
blue grama-tobosa prairie	*Bouteloua gracilis-Pleuraphis mutica*	< 35 to < 100 [68]
cheatgrass	*Bromus tectorum*	< 10 [71,100]

California montane chaparral	*Ceanothus* and/or *Arctostaphylos* spp.	50-100 [68]
sugarberry-America elm-green ash	*Celtis laevigata-Ulmus americana-Fraxinus pennsylvanica*	< 35 to 200 [97]
paloverde-cactus shrub	*Cercidium microphyllum/Opuntia* spp.	< 35 to < 100 [68]
curlleaf mountain-mahogany*	*Cercocarpus ledifolius*	13-1,000 [6,79]
mountain-mahogany-Gambel oak scrub	*Cercocarpus ledifolius-Quercus gambelii*	< 35 to < 100 [68]
Atlantic white-cedar	*Chamaecyparis thyoides*	35 to > 200 [97]
blackbrush	*Coleogyne ramosissima*	< 35 to < 100
Arizona cypress	*Cupressus arizonica*	< 35 to 200
northern cordgrass prairie	*Distichlis spicata-Spartina* spp.	1-3 [68]
beech-sugar maple	*Fagus* spp.-*Acer saccharum*	> 1,000 [97]
California steppe	*Festuca-Danthonia* spp.	< 35 [68,85]
black ash	*Fraxinus nigra*	< 35 to 200 [97]
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 [68]
cedar glades	*Juniperus virginiana*	3-22 [39,68]
creosotebush	*Larrea tridentata*	< 35 to < 100
Ceniza shrub	*Larrea tridentata-Leucophyllum frutescens-Prosopis glandulosa*	< 35 [68]
yellow-poplar	*Liriodendron tulipifera*	< 35 [97]
Everglades	*Mariscus jamaicensis*	< 10
melaleuca	*Melaleuca quinquenervia*	< 35 to 200 [66]
wheatgrass plains grasslands	*Pascopyrum smithii*	< 5-47+ [68,72,102]
southeastern spruce-fir	*Picea-Abies* spp.	35 to > 200 [97]
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 [68]
Mexican pinyon	*Pinus cembroides*	20-70 [63,88]
shortleaf pine	*Pinus echinata*	2-15
shortleaf pine-oak	*Pinus echinata-Quercus* spp.	< 10 [97]
Colorado pinyon	*Pinus edulis*	10-400+ [32,37,54,68]
slash pine	*Pinus elliottii*	3-8
slash pine-hardwood	*Pinus elliottii*-variable	< 35
sand pine	*Pinus elliottii* var. *elliottii*	25-45 [97]
South Florida slash pine	*Pinus elliottii* var. *densa*	1-5
longleaf-slash pine	*Pinus palustris-P. elliottii*	1-4 [66,97]
longleaf pine-scrub oak	*Pinus palustris-Quercus* spp.	6-10 [97]

pitch pine	*Pinus rigida*	6-25 [14,40]
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 [97]
galleta-threeawn shrubsteppe	*Pleuraphis jamesii-Aristida purpurea*	< 35 to < 100
eastern cottonwood	*Populus deltoides*	< 35 to 200 [68]
mesquite	*Prosopis glandulosa*	< 35 to < 100 [60,68]
mesquite-buffalo grass	*Prosopis glandulosa-Buchloe dactyloides*	< 35
Texas savanna	*Prosopis glandulosa* var. *glandulosa*	< 10 [68]
mountain grasslands	*Pseudoroegneria spicata*	3-40 (10**) [3,4]
California oakwoods	*Quercus* spp.	< 35 [4]
oak-hickory	*Quercus-Carya* spp.	< 35 [97]
oak-juniper woodland (Southwest)	*Quercus-Juniperus* spp.	< 35 to < 200 [68]
oak-gum-cypress	*Quercus-Nyssa*-spp.-*Taxodium distichum*	35 to > 200 [66]
southeastern oak-pine	*Quercus-Pinus* spp.	< 10 [97]
coast live oak	*Quercus agrifolia*	2-75 [38]
white oak-black oak-northern red oak	*Quercus alba-Q. velutina-Q. rubra*	< 35 [97]
canyon live oak	*Quercus chrysolepis*	<35 to 200
blue oak-foothills pine	*Quercus douglasii-P. sabiniana*	<35 [4]
northern pin oak	*Quercus ellipsoidalis*	< 35 [97]
Oregon white oak	*Quercus garryana*	< 35 [4]
bear oak	*Quercus ilicifolia*	< 35 >[97]
California black oak	*Quercus kelloggii*	5-30 [68]
bur oak	*Quercus macrocarpa*	< 10 [97]
oak savanna	*Quercus macrocarpa/Andropogon gerardii-Schizachyrium scoparium*	2-14 [68,97]
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 [97]
interior live oak	*Quercus wislizenii*	< 35 [4]

cabbage palmetto-slash pine	*Sabal palmetto-Pinus elliottii*	< 10 [66,97]
blackland prairie	*Schizachyrium scoparium-Nassella leucotricha*	< 10
Fayette prairie	*Schizachyrium scoparium-Buchloe dactyloides*	< 10 [97]
little bluestem-grama prairie	*Schizachyrium scoparium-Bouteloua* spp.	< 35
tule marshes	*Scirpus* and/or *Typha* spp.	< 35 [68]
redwood	*Sequoia sempervirens*	5-200 [4,31,86]
southern cordgrass prairie	*Spartina alterniflora*	1-3 [68]
baldcypress	*Taxodium distichum* var. *distichum*	100 to > 300
pondcypress	*Taxodium distichum* var. *nutans*	< 35 [66]
eastern hemlock-yellow birch	*Tsuga canadensis-Betula alleghaniensis*	> 200 [97]
western hemlock-Sitka spruce	*Tsuga heterophylla-Picea sitchensis*	> 200 [4]
elm-ash-cottonwood	*Ulmus-Fraxinus-Populus* spp.	< 35 to 200 [24,97]

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

POSTFIRE REGENERATION STRATEGY [84]:
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:
Giant reed is top-killed by fire (Joyce, personal observation in [91]), [11,45].

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

PLANT RESPONSE TO FIRE:
Giant reed rhizomes respond quickly after fire by sending up new shoots [11,50]. In an environmental assessment of a plan to remove giant reed from San Francisquito and Soledad canyons in southern California, fire was not considered a viable option because "Fire does not destroy the rhizomes significantly and is ineffective in eradication of giant reed due to its ability to resprout from damaged rhizomes. In some instances this method may actually promote growth of giant reed and deter growth of native riparian vegetation." [91]

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:
Joyce (personal observation in [91]) states a fire burned through about 5 acres (2.0 ha) of National Forest land in Soledad Canyon in southern California in January, 1991. Due to drier-than-normal conditions produced by prolonged drought, and presence of dried stands of giant reed, the fire burned aggressively through the riparian vegetation. Most willow, mule's fat, and aquatic plants were burned and many cottonwoods were scorched. The giant reed colonies also burned, but because of their extensive rhizome system, giant reed plants resprouted 1 week after the fire. Many sprouts were over 2 feet (0.6 m) tall within 2 weeks even though January is normally the dormant period for giant reed in southern California. Fire gives giant reed the competitive advantage over native riparian plants because it resprouts so rapidly; and dominance of giant reed in the area has increased dramatically (Joyce, personal observation in [91]).

FIRE MANAGEMENT CONSIDERATIONS:
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. Use of flame throwers or weed burning devices as spot treatments for giant reed is only appropriate during the wet season because of its potential to ignite unwanted fires during the dry season (Jones/Stokes (1984) in [45]).

Large areas of giant reed infestations may be burned to remove the standing plants [45]. However, broadcast burning of large areas infested with giant reed will not prevent resprouting. Burning is best followed by 1) herbicide treatment of stumps, 2) subsequent burning to exhaust underground food reserves, and/or 3) revegetation with fast growing native species [45].

In California, giant reed has changed riparian areas from barriers that prevent the spread of fire into wicks that carry fires into housing developments [7,26]. Giant reed thickets are highly flammable and known to carry wildfire up and down riparian corridors [18,26,80]. Scott [80] states that 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.

Prescribed fire, or burning piles of stacked biomass, is the most effective way of removing giant reed biomass as long as it does not threaten native vegetation or other resources [11].

MANAGEMENT CONSIDERATIONS

SPECIES: Arundo donax

IMPORTANCE TO LIVESTOCK AND WILDLIFE:
All evidence indicates giant reed provides neither food nor habitat for native species of wildlife [11]. Bell [11] speculated 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 noxious chemicals, including silica [47,70], triterpines, sterols [17], cardiac glycosides, curare-mimicking indoles [35], hydroxamic acid, and numerous other alkaloids which probably protect it from most native insects and grazers (Bell [11] and references therein).

Giant reed is not very palatable to cattle but they will eat it during drier seasons [45,104]. Domestic goats will also eat it [19,45].

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 [70,104]. This ability to concentrate phosphorus is documented in the following table by Wynd and others [104]. The authors analyzed the nutritional content of giant reed. Results are an average of 2 samples for each category and are presented as percentages of oven-dry weight:

	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 taken over by giant reed are largely depauperate of wildlife [9,11,50]. Additionally, a study by Chadwick and Associates [16] 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 [9,16].

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 [106]. For example, the southwestern willow flycatcher, an endangered species, has not been reported nesting in any vegetation patches dominated by giant reed. Giant reed does not produce small forked branches for southwestern willow flycatcher nest building [93]. Only a small number of bird species have been observed using giant reed for nest sites and dramatic reductions (50% or more) in abundance and diversity of invertebrates were documented in giant reed thickets in southern California compared with those found in native willow/cottonwood vegetation [26]. Giant reed's most observed use as cover has been by feral pigs [106].

OTHER USES:
Giant reed has been planted extensively as an erosion control agent for drainage canals and was also used for thatching roofs of sheds, barns and other buildings [45]. 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 [21].

Wynd and others [104] report giant reed can be used to stabilize sand dunes.

Giant reed is used to make reeds for a variety of musical instruments including bagpipes [11,70]. 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 [70].

Even before giant reed was used in musical instruments, 5,000 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 [70].

IMPACTS AND CONTROL:

Impacts: Bell [11] considers giant reed to be the greatest threat to southern California's remaining riparian corridors. Since giant reed is extremely flammable, once established in a riparian area it can alter the fire regime of a site by increasing the probability of wildfire and increasing the severity of wildfire when it occurs, as discussed in Fire Ecology.

Once established, giant reed often forms monocultural stands that physically inhibit growth of other plant species [11,76]. For example, Douthit [23] 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.

Giant reed does not provide a canopy structure like that of native vegetation. This lack of stream-side canopy structure may result in increased pH in the shallower sections of rivers due to high algal photosynthetic activity [9,16]. 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].

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 [22]. Giant reed growing in flood control channels necessitates constant removal tactics. It can form debris dams against flood control and transportation structures such as bridges and culverts [26,33]. 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 [95].

Iverson [46] provides insight into the economics of giant reed's impact on water use. He estimates giant reed transpires 52,000 acre-feet of water per year on the Santa Ana River or enough water to serve a population of about 280,000 people. If that amount of untreated water was purchased from the Metropolitan Water Association it would cost approximately $18,000,000 in 1993 dollars [46].

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 the root mass [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 [95].

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 stakeholders' direct role and responsibility [95].

Prevention:

No information is available on this topic.

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. If this happens many follow-up treatments must be

made, which negates any initial savings in herbicide and greatly increases labor costs [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. Glyphosate was selected because it has full registration for aquatic habitats and has proven effective against grasses. 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 in controlling giant reed with glyphosate than foliar sprays [30].

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].

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. Giant reed continues to resprout in the treatment area, but comprises 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 [45]. 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 [25]). 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% and may interfere with re-establishment of native plants [45]. Mechanical eradication of giant reed is extremely difficult, even with the use of a backhoe, as rhizomes buried under 3.3 to 9.9 feet (1-3 m) of alluvium readily resprout (R. Dale personal communication in [25]).

Fire: See Fire Management Considerations.

Biological: Tracy and DeLoach [89] provide an exhaustive summary of the search for biological control agents for giant reed in the United States. Areas taken over by giant reed in North America are essentially devoid of wildlife. This means native flora and fauna do not offer any significant control measures [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 [27], and aphids [61] 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 [90]. 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 [104]. In many areas of California the use of Angora and Spanish goats is showing promise as a control agent for giant reed [19].

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 which 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]) However, Finn and others [30], as noted above, conclude cut-stem treatments to be more effective than foliar sprays. Bell [11], Hoshovsky [45], and Jackson [48] 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 expands 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 [93].

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