Invasive Plant *Arundo donax*: Mapping and Prioritizing Its Eradication in the Bay-Delta Region of Northern California

Abstract

The invasive plant *Arundo donax* has become widespread in California. In Southern California some riparian habitat has been reduced to monotypic stands, devastating native species locally. Eradication has been extensive and costly. In Northern California, Arundo infestations are less widespread. However, eradication efforts began later and have been occurring piecemeal as individual organizations fight local infestations. It is generally accepted by the invasive plant control community that there is not enough funding to eradicate all problem weeds, and the work of invasive species control must be strategically focused. To support this work, Team Arundo del Norte, a collaboration of organizations working on the control of Arundo, is mapping the distribution of Arundo in the San Francisco Bay and Delta Regions and recommending eradication priorities based on the value of the threatened habitat. We began by integrating available mapping data from disparate organizations, field mapping critical gaps, and combining all data into a single GIS layer. To determine eradication priorities, habitat suitability data for a suite of representative riparian species are combined with Federal and State threat indices to derive a multi-species conservation value index. At a given location, this index suggests the eradication priority for any threatening Arundo.

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Key Words: *Arundo donax*, Invasive Species, Eradication, Environment and Conservation, Habitat Valuation, California, San Francisco Bay Estuary, Sacramento San Joaquin River Delta, Team Arundo del Norte, CalFed, Arundo Eradication and Coordination Program.

Introduction

Arundo donax in California

Introduced to California two to three centuries ago and planted widely for a variety of uses, the invasive plant *Arundo donax* is now in the landscape spread phase of the four phase invasion process (Theoharides et al. 2007). In the ‘at risk’ riparian habitat it threatens, further colonization is occurring frequently and with apparent high success. Arundo out-competes native riparian plant species, consumes much more water, does not provide nesting or foraging needed by animal species, increases bank erosion during flood events and increases fire severity. (Bell 1993. Hoshovsky 1989. Jackson 1993. Di Tomaso 1998.)

In the early 1990s, a group of stakeholders in the Santa Ana watershed formed Team Arundo. This voluntary organization has shown a successful model for mapping, monitoring education, fund raising, long term strategy planning and eradication project implementation (Vartanian, 1998).

Objectives of Team Arundo del Norte AECP

Following the Team Arundo model, Team Arundo del Norte was formed in the mid 1990s to support and foster Arundo control activities in the San Francisco Bay and all rivers that flow into it. The *Arundo* Eradication and Coordination Program (AECP) is a project funded by Calfed to address many needs of the *Arundo* control community.

AECP objectives:

- Eradicate *Arundo* and restore riparian and aquatic habitat in eight Bay-Delta watersheds where restoration will contribute to recovery of sensitive species, habitat and ecosystem processes.
- Coordinate and consolidate support to partners in areas of information management, contracting and permitting, and technical expertise.
- Conduct needed research in efficacy of different eradication methodologies.
- Use information gained through monitoring and research to increase eradication efficacy, reduce costs, reduce herbicide load, and toward improved restoration of ecological function.
- Create a comprehensive map of *Arundo* infestations in San Francisco Bay and Delta Regions.
- Establish eradication priorities based on *Arundo*'s threat to sensitive species and habitats.
- Provide for outreach and support to organizations in areas threatened by Arundo invasion.

AECP Mapping Task objectives:

- Develop a catalog of *Arundo* location data. Identify all organizations doing or having done Arundo mapping. Publish metadata for organizations and their results on a public access server.
- Create an *Arundo* distribution map. Collect GIS data from the above organizations, consolidate into single map, and publish data for use by others on a public access server.
- Create an eradication priority map for California's Bay/Delta region and recommend priorities for funding future eradication efforts. Base recommendation on value of habitat threatened.

Methods and Materials

The project strategy was as follows:

- Collect and consolidate all available mapping data on *Arundo*. Publish information found on all organizations involved in mapping *Arundo* and their results on a public map server.
- Aggregate contributed data, identify critical gaps and use field mapping and/or imagery analysis to fill them. Consolidate all into a current distribution map and publish on a public map server.
- Collect mapping data on riparian habitat and habitat suitability and threat level data for riparian species. Derive an ecological or habitat valuation from these and use that valuation to rank threats to riparian habitat from current *Arundo* infestations. These suggested eradication priorities will be useful to CalFed in decision making on funding future eradication projects.

Arundo Distribution Mapping

Geographic Scope and Mapping Coverage Decisions

Our project defined the geographic scope as the CalFed San Francisco Bay Estuary and Delta regions. These two regions extend from the Golden Gate Bridge and the Petaluma River watershed in Marin County in the west, the Napa River in the north, Coyote Creek (Santa Clara County) in the south and the headwaters of the Cosumnes River (El Dorado County) in the east. This covers parts of 16 counties and contains 18,929 km^2 (7,308 mi^2).

Later in the data acquisition phase gaps were identified in the aggregated data and it was evident that there was an enormous unmapped area. Prioritization was necessary because it could not all be exhaustively mapped. The decision was made to complete Arundo mapping on rivers and streams which had been classified by NMFS as Salmonid Critical Habitat. Therefore, in the San Francisco Bay region no effort was expended in the urban dominated counties of San Francisco, San Mateo and Alameda. Critical mapping gaps did exist in Marin and Sonoma counties. In the Delta region, San Joaquin County had 2 critical gaps that were mapped: the Lower Calaveras and Lower Stanislaus Rivers.

In the Sierra Nevada no data, hard or anecdotal, suggested *Arundo* exists above the 'dam' line of Sierra foothill reservoirs. Our current understanding of *Arundo's* habitat requirements suggested it wasn't likely to be successful at colonization and establishment there even if transported there. No effort was expended above the 'dam' line.

Data Collection and Field Mapping

The project began with a wide search of online libraries on *Arundo* and related topics: California Invasive Plant Council (Cal IPC), California Environmental Resources Evaluation System (CERES), the National Biological Information Infrastructure (NBII), the Natural Resources Projects Inventory (NRPI) and the University of California Library system (Melvyl). Contact lists were developed through our nine AECP partners, US Fish and Wildlife Service, California Invasive Plants Council (Cal IPC), Resource Conservation Districts (CARCD), Weed Management Areas (WMA), UC Cooperative Extensions (UCANR), and Sonoma Ecology Center's (SEC) Restoration Program staff. We solicited geo-referenced *Arundo* data and further referrals from each contact. The solicitation process continued with each referral received. Each data contributor gave permission for SEC to publish their metadata and mapping data in a consolidated *Arundo* distribution dataset on a public map server. In the final edition, spatial datasets collected from 9 AECP partners and 12 other organizations were used (Table 1). *Arundo* occurrences were recorded in 22 counties in central and northern California.

Table 1. Contributors to Consolidated Arundo Distribution Dataset and counties mapped.

Data Source	County
AECP Partners	
Butte County Agricultural Commissioner's Office	Butte
California State University, Chico Research Foundation	Butte
Lake County Dept. Public Works, Water Resources Division	Lake
Napa County Flood Control and Water Conservation District	Napa
Putah Creek Streamkeeper and Solano County Water Agency	Solano, Yolo
Sacramento Weed Warriors	El Dorado, Placer, Sacramento
San Francisquito Creek Watershed Council	San Mateo, Santa Clara
San Joaquin River Parkway and Conservation Trust	Fresno, Madera
Sonoma Ecology Center	Calaveras, Marin, San Joaquin, Sonoma, Stanislaus
Other Organizations	
CA Dept. of Fish and Game, Vegetation Classification and Mapping Program	Contra Costa, Sacramento, San Joaquin, Solano
CA Dept. of Parks & Recreation, Gold Fields District	El Dorado, Placer
CA Dept. of Water Resources and Suisun Resource Conservation District	Solano, Fresno, Madera
CA Dept. of Water Resources and US Bureau of Reclamation	Merced
Center for Spatial Technologies & Remote Sensing	Contra Costa, Merced, Sacramento, San Joaquin, Solano, Stanislaus
Circuit Rider Productions, Inc.	Mendocino, Napa, Sonoma
Contra Costa County Community Development Department, Citizen Monitoring Program	Contra Costa
East Bay Municipal Utilities District	Sacramento, San Joaquin
Laurel Marcus Associates	Napa, Solano
Santa Clara Valley Water District	San Benito, San Mateo, Santa Clara
Solano Resource Conservation District	Solano, Yolo
Western Shasta Resource Conservation District	Shasta

Imagery Analysis. Analysis of aerial imagery was initially expected to be a feasible method for identifying *Arundo* on a large scale in areas where no mapping data existed. However, our large geographic scope combined with budget limitations required us to rely on free imagery sources: state DOQQ and National Agriculture Imagery Program (NAIP). 3 band color NAIP from 2005 was the highest quality available with coverage over entire study area. A trial of auto classification with NAIP imagery and Object Based Image Analysis (OBIA) software from Ecognition revealed limitations using that method for our application. NAIP's 1 meter resolution is coarse enough that *Arundo* vegetation appears fairly featureless except at some edges with darker groundcover below. The weed was also difficult to differentiate from willow and similar canopy. Significant spectral variations between flight lines were common; which would force significant ground-truthing to be done as part of the analysis. Further reducing the effectiveness of remote sensing methods is the fact that *Arundo* is commonly obscured by tall tree canopy, which occurred frequently in our study area. We concluded the imagery would be useful for navigation purposes and identification of suspect *Arundo* patches; but field mapping would be required to obtain high confidence data.

Field Mapping. Field mapping was limited to the identified critical gaps. The field mapping done in Marin and Sonoma counties was a combination of windshield surveys and on-foot coverage via available streamside trails. In reaches where the target watercourses passed thru urban areas, there was adequate street access to ensure that mapping coverage was thorough. In some rural areas however, access was quite limited due to private property and consequently we were only able to partially map them.

In San Joaquin County, survey teams mapped the Lower Calaveras River over a period of 3 days using a combination of windshield survey and observations recorded from kayak. The Lower Stanislaus River was mapped over a period of 3 days by survey teams in boat or kayak.

This mapping approach yielded fairly thorough results along the waterways themselves and where canopy was light. However these rivers have heavy tree canopy along much of their length and it is likely some *Arundo* patches not visible from the river evaded discovery. Undetected infestations are a risk inherent in discovery-level mapping. If a stream or river is later selected for eradication work, more rigorous use-level mapping is recommended. This will require a thorough search of the entire floodplain requiring landowner permission for access to ensure thorough search for all *Arundo* patches.

For our discovery-level mapping purpose we developed a light weight application that runs on a PDA under ArcPad 7.0. At various times a Trimble Recon or a GPS enabled Xplore IX104C3 Tablet PC were used. For backup, a Garmin or Magellan recreational GPS was carried. Upon return to the office the data was uploaded to PC, where minor adjustments and corrections were applied using ArcMap. Offset point locations were 'snapped' to NAIP imagery. Questionable or missing patch size attributes were corrected using NAIP. Metadata was created in ArcCatalog documenting methods used.

Data Consolidation. The data from all contributors and our own mapping efforts were consolidated into a single spatial data set. A standard attribute list (Table 2) was developed based on the California Weed Mapping standard and the North American Weed Mapping Association (NAWMA) standard. One attribute holds a link to the contributor's metadata record at California Environmental Information Catalog (CERES); so that the contributor can be contacted directly for further questions about the original source data.

Table 2. Standard attributes in Consolidated Arundo Distribution dataset

Attribute	Definition
Spec_Name	Scientific name of the species.
Spec_Code	Taxonomic code for the record.
Code_Sys	Taxonomic code system used, such as PLANTS or ITIS.
Obsrv_Date	Date of observation (YYYY-MM-DD)
Observer	Name of person making observation.
Metadata	URL for CERES metadata for original dataset
DataSource	Organization contributing data
Program	Specific program or name of survey under which this observation was made.
Aggregator	Name of the data aggregator that collated this set of observation points.
Country	The country or major political unit from which the observation was made.
State	The state, province, or region from which the observation was made.
County	The county, shire, or next level under province from which the observation was made.
Obs_Basis	The basis of the observation.
Gross_Area	Overall area referred to by this observation.
GA_Units	Units of measurement of gross area.
Infst_Area	The area that is actually infested by the weed.
IA_Units	Units of infested area measurement.
Perc_Cover	The percentage canopy cover of the weed in the infestation.
Site_ID	Unique identification number or code for this observation within original contributed dataset
Locality	The locality description from which the observation was made.
Loc_Precsn	The precision of the location of the observation
Lat_WGS84	The latitude of the observation, in the WGS84 datum.
Long_WGS84	The longitude of the observation, in the WGS84 datum.

The following steps of data standardization were done in ArcMap. Datasets were converted to ESRI shapefile format if not already so. Observations of plants other than *Arundo donax* were excluded. If source data geometry was polygon or polyline, it was converted to a point location using ArcToolBox, Feature to Point tool. The point was constrained to fall within the original polygon or on the original polyline.

Attributes in contributed data were mapped to the standard attributes list, starting with the URL link to the contributor's metadata record at CERES. Data were used "as is". If doubt existed about the match between contributed attribute and standard attribute, the contributed attribute value was not used. Data records that lacked date of observation were omitted. No attempt was made to identify possible duplicate records within each contributed dataset. No attempt was made to "interpret" percent canopy, infested area unit of measure, or gross area unit of measure attributes: measurements not fully documented by the contributor were assigned a value of "not available", and only the date and location fields were populated. Final steps of the consolidation process were done in in ArcMap using a geoprocessing model to re-project all constituent shapefiles to the WGS 1984 coordinate system, merge them into a single shapefile, and populate remaining attribute fields (Country, State, County).

Habitat Valuation

A primary project objective was to recommend eradication priorities based on the value of the habitat threatened. While other factors certainly play into prioritization, habitat value was the key factor we wanted to develop.

We planned to locate and acquire publically available riparian habitat maps but soon learned neither a standard definition nor region/state wide maps exist. While species range maps are available, detailed habitat suitability data far less common.

Species Decisions and Data Used

Root, et al (Root, 2003) describe a methodology for developing a multispecies conservation value metric. This method combines maps of habitat suitability for selected species into a single GIS layer of a multispecies conservation value, the Index-based Multispecies Conservation Value (IMCV). For each species the habitat suitability is weighted with endangerment indices (threat risk). This results in greater habitat value being assigned to species at risk. Following this method, our habitat valuation plan was developed as follows:

- Select a suite of 15 umbrella species (3 species each from 5 taxa- amphibian, bird, fish, mammal and reptile).
- Base habitat suitability scores on species' usage of riparian habitat for reproduction phases of lifecycle only (versus all or other phases of species life).
- Derive the IMCV metric for this suite of species via the published methodology.

Species Selection. The 3 fish species were selected due to the availability of habitat suitability data from NMFS. Remaining species were selected based on California Wildlife Habitat Relationships (CWHR) descriptions of reproduction habitat requirements. 3 species each from available amphibians, birds, mammals and reptiles were selected (Table 3).

Table 3. Selected Riparian Habitat Species				
CWHR Index	Common Name	Scientific Name	Taxa	Listing Status
	Cal. Central Coast ESU Steelhead	*Oncorhynchus mykiss*	Fish	FT
	Cal. Central Valley ESU Steelhead	*Oncorhynchus mykiss*	Fish	FT
	Central Valley Spring Run ESU Chinook	*Oncorhynchus tshawytscha*	Fish	FT, CT
A007	California Newt	*Taricha torosa*	Amphibian	
A039	Pacific Tree Frog	*Hyla regilla*	Amphibian	
A043	Foothilll Yellow Legged Frog	*Rana Boylei*	Amphibian	
R004	Western Pond Turtle	*Clemmys marmorata*	Reptile	
R039	Western Whiptail	*Cnemidophorus tigris*	Reptile	
R058	Common Kingsnake	*Lampropeltis getulus*	Reptile	
B467	Yellow-breasted Chat	*Icteria virens*	Bird	CSC
B505	Song Sparrow	*Melospiza melodia*	Bird	
B476	Blue Grosbeak	*Passerina caerulea*	Bird	
M112	Beaver	*Castor canadensis*	Mammal	
M139	Muskrat	*Ondatra zibethicus*	Mammal	
M163	River Otter	*Lutra canadensis*	Mammal	

Data Used. The following usable sources of habitat suitability data were identified:

- CA GAP Analysis (Davis, et al. 1998) is only source found for region/state-wide habitat suitability data. It is covers the 644 species in CWHR, all terrestrial; no fish, no plants. It is based on Cal-Veg polygons; so it has relatively coarse minimum mapping units (uplands: 100 hectares or 247 acres and wetlands 40 hectares or 99 acres).
- NOAA NMFS Salmonid Critical Habitat is the only available fish habitat suitability data. It currently exists for 3 Evolutionary Significant Units: California Central Coast Steelhead, California Central Valley Steelhead and Central Valley Spring Run Chinook Salmon. Fortunately this data covered our geographic scope.
- Point Reyes Bird Observatory Conservation Science has developed riparian bird habitat suitability data for CDFG under the Landowner Incentive Program. Currently it covers only the central valley. At a future date it may be available for the San Francisco Bay area as well. When complete, it will be desirable to incorporate this more complete dataset as an upgrade to and replacement for CGAP data for riparian birds.

Methodology of Valuation Ranking

Habitat Suitability Scores. For each species in CGAP, data consists of a single score (0 thru 5) for each habitat polygon. The score represents the predicted amount and suitability of habitat for reproduction contained in that polygon (Table 4). The GIS data is in ESRI polygon format; the selected species habitat suitability data is in Dbase format and is joined to the polygons in ArcMap.

Table 4. CGAP Predicted Habitat Suitability

Habitat Criteria	Score
>50% of area is High Suitability	5
>50% of area is Medium or High Suitability	4
>50% of area is Low, Medium or High Suitability	3
50% < area of Low, Medium or High Suitability but >0%	2
Suitable Habitat in wetland/riparian habitats only (no areal estimate)	1
No suitable habitat	0

The NMFS Salmonid Critical Habitat data contains habitat suitability data by stream reach. It is in ESRI poly-line format. Using ArcMap, 500 meter buffers (total width) were created from these streamlines. Buffering was necessary because no suitable maps defining riparian habitat or corridors were found and buffered streamlines were a commonly used method. Habitat suitability data are in text form. Separate scores for spawning and rearing were transformed (Table 5) to a format compatible with CGAP methods and then averaged to derive a single reproduction score.

Table 5. Derive CGAP compatible score from NMFS SPAWN/NATAL data

SPAWN UTILIZATION NATAL UTILIZATION	+ SPAWN QUALITY + NATAL QUALITY	→ Spawn Habitat Score → Natal Habitat Score
Blank	blank	0
No	Not suitable	0
Probable, undocumented	Periodic, Poor	2
Probable, undocumented	Periodic, Fair	2
Probable, undocumented	Periodic, Good	3
Probable, undocumented	Consistent, Poor	2
Probable, undocumented	Consistent, Fair	3
Probable, undocumented	Consistent, Good	4
Yes	Periodic, Poor	2
Yes	Periodic, Fair	3
Yes	Periodic, Good	4
Yes	Consistent, Poor	3
Yes	Consistent, Fair	4
Yes	Consistent, good	5

Endangerment Indices. We used Federal and State threat listings as the basis for the endangerment indices. Species' listing status determined a weighting factor for its habitat suitability. Table 6 shows weighting factors used

Table 6. Conversion of listing status to endangerment index				
Federal Listing level	Federal Endangerment Index		State Listing level	State Endangerment Index
Endangered	3		Endangered	3
Threatened	2		Threatened	2
			Special Concern	1.5
none	1		none	1

Final Data Format. Due to complexities of merging data resident in disjoint polygons and polylines the weighted habitat suitability data for each species were converted to raster format to simplify the calculation of IMCV. This was done using the ArcMap, Convert Features to Raster Tool. The grid cell size is 100 meters; rather large but smaller cell sizes are not appropriate with source data of 1:100,000 mapping scale.

Calculation of IMCV. The Index-Based Multispecies Conservation Value (IMCV) is calculated for each grid cell by the following formula:

$$\text{iMCV}_j = \frac{\sum_{i=1}^{n} (S_{ij} \times E_i)}{\sum_{i=1}^{n} E_i},$$

where n is the number of species, S_{ij} is the habitat suitability for species *i* at location *j*, and E_i is the endangerment index value for species *i*.

Using the ArcMap raster calculator, the weighted habitat suitability data for the 3 species in a taxonomic group were summed into a taxon layer. This simplifies creation of different IMCV metrics based on subsets of the species list, if desired. The final calculation was summing the 5 taxon layers and dividing that intermediate result by the summed taxon endangerment indices (Figure 1).

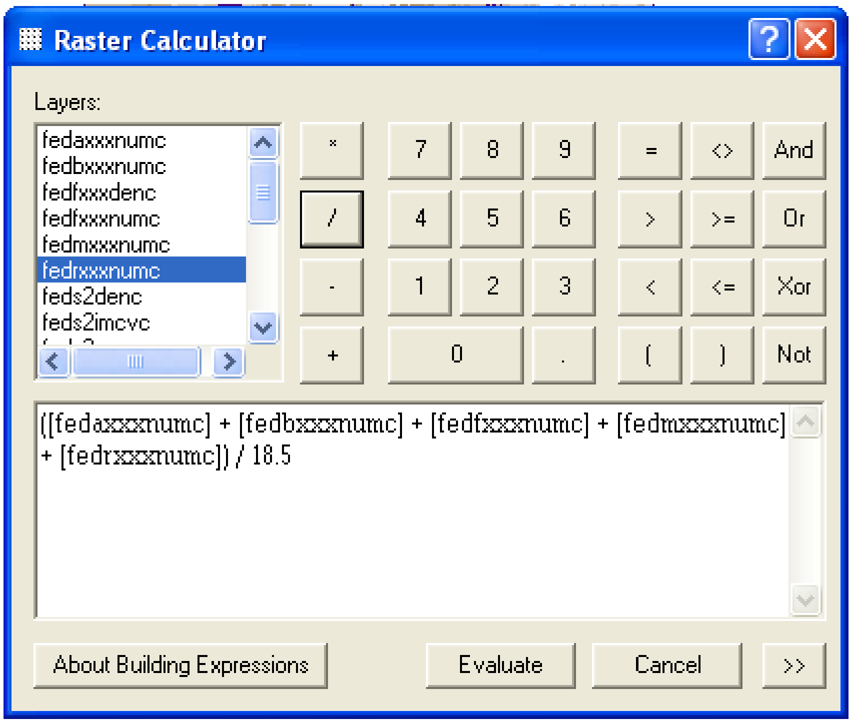
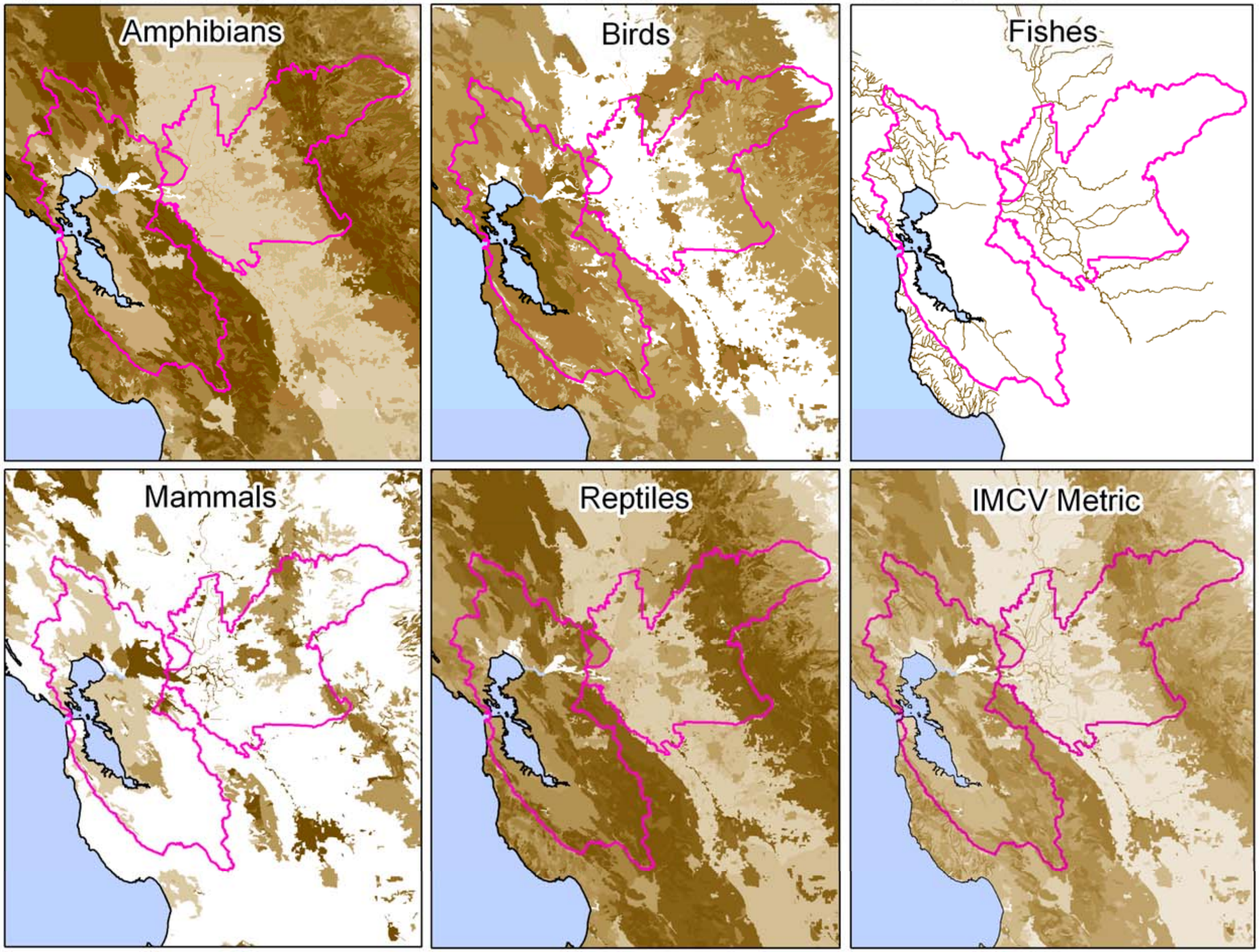


Figure 1. Calculating Federal listing weighted IMCV

Results were two IMCV layers based on identical habitat suitability data but one is weighted by federal threat listings as the endangerment index and the other weighted by state threat listings as the endangerment index. These products were developed with coverage of the entire state of California. Figure 2 shows examples of riparian habitat suitability for our study area.

Figure 2. Riparian habitat suitability for the Bay/Delta by taxon and final IMCV (weighted by federal listing status). Darker areas have higher habitat value.



Eradication Prioritization

The IMCV layer was then used to provide a habitat value attribute for each *Arundo* infestation. This is done in ArcMap using the Hawth's Tools, Point Intersect Tool. It populates the habitat value attribute of each *Arundo* point with the value of the IMCV metric obtained from the grid cell in which it is geographically located.

Figure 3 shows suggested *Arundo* eradication priorities based on the federal listing IMCV metric. The threat level of each Arundo infestation is determined by the conservation value of the immediately surrounding habitat.

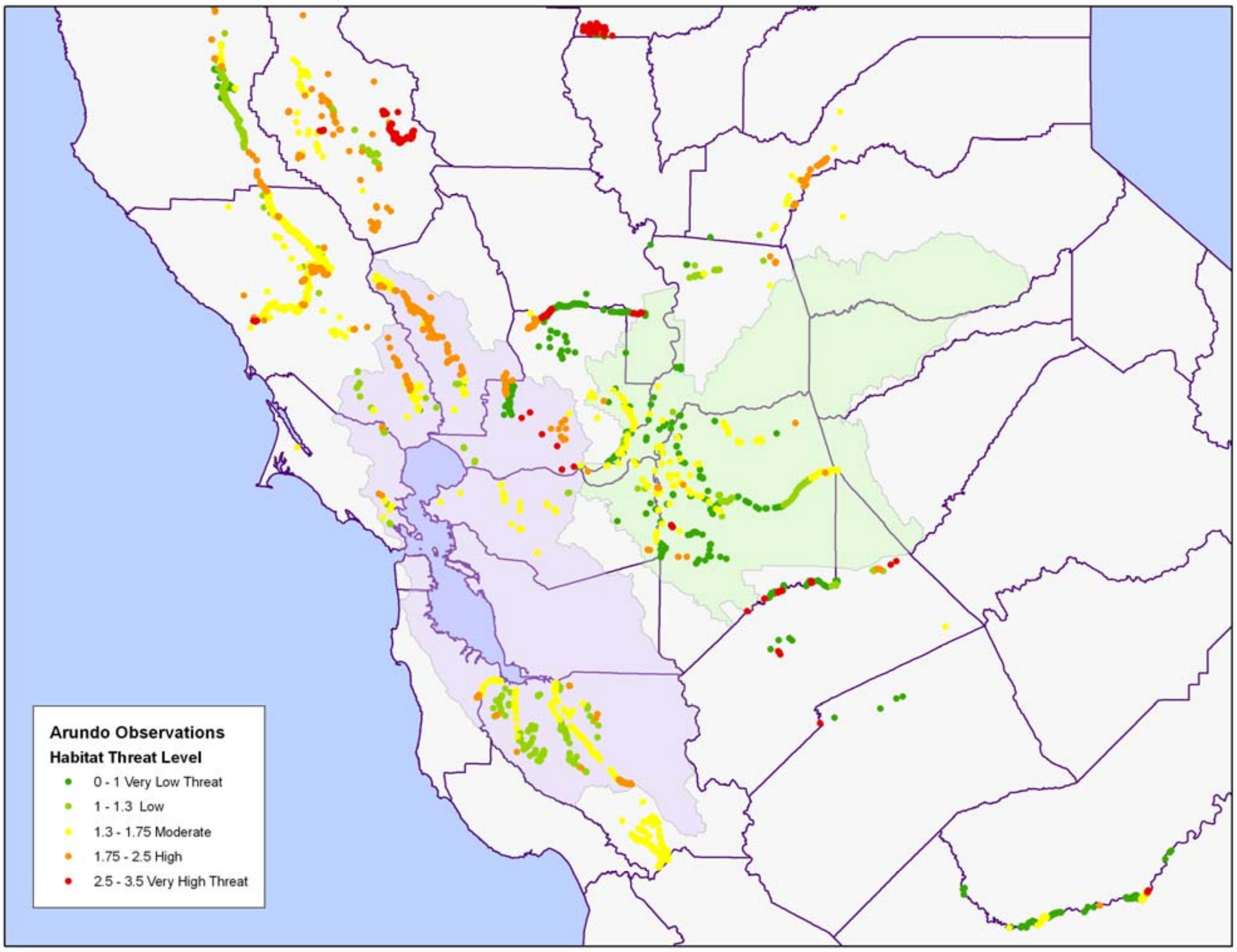


Figure 3. Eradication Priorities based on federally weighted IMCV.

In order to emphasize the value of larger habitat patch size we calculated neighborhood statistics for a 3x3 grid cell neighborhood. This yields a map with some visible differences in priorities (Figure 4).

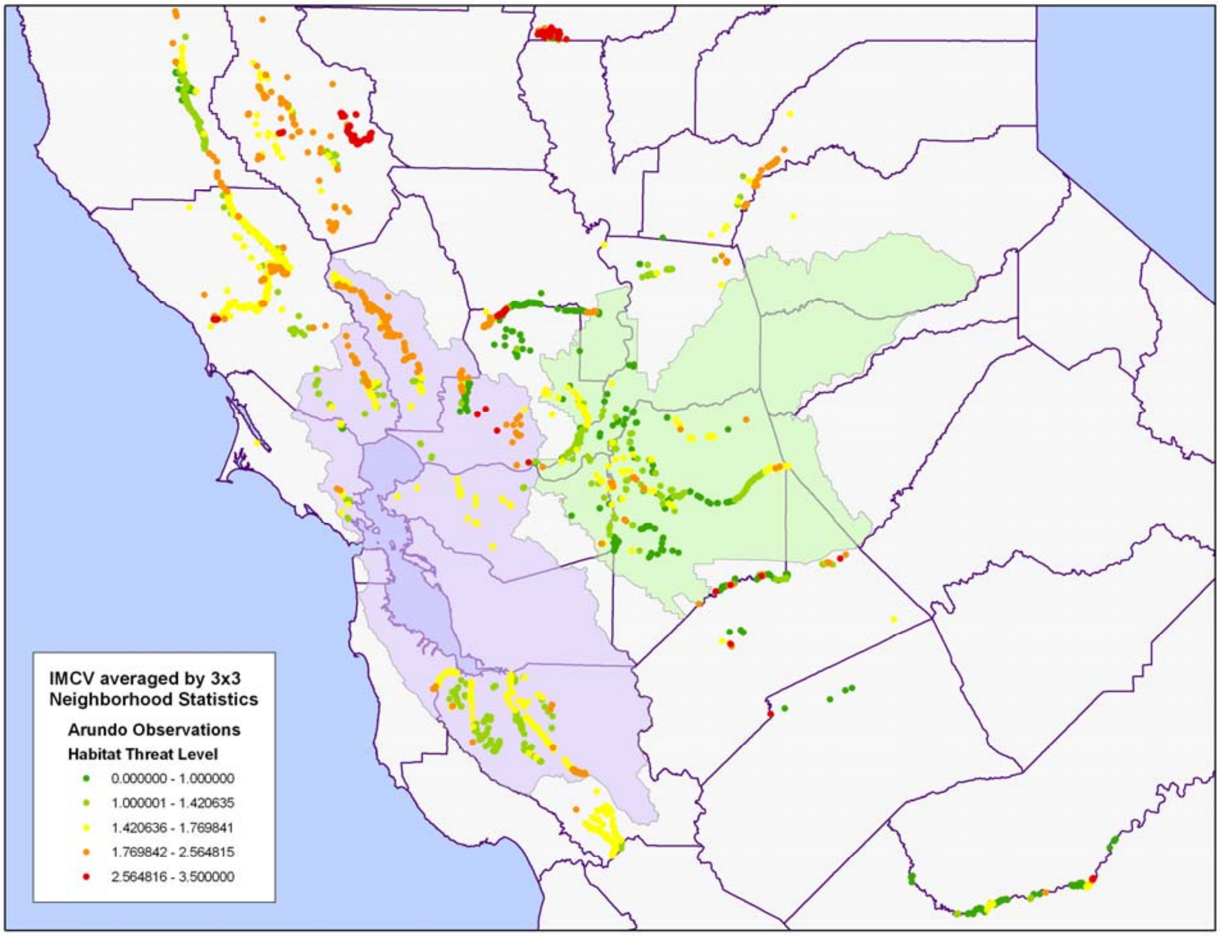


Figure 4. Eradication priorities based on 3x3 neighborhood statistics calculation of IMCV.

Data Sharing

One of the objectives of our Arundo data consolidation project was to share the results, making data available that was previously unknown and inaccessible to the weed eradication community. Data received from other organizations were contributed in several formats and geometries; we received point, polyline, and polygon data as ESRI shapefiles and geodatabases, and one Access database with point coordinates. Accompanying metadata (information on source, methods and data content) about the contributing organizations and their results varied from complete to non-existent. If a dataset was not received with FGDC-compliant metadata, a minimal metadata record was created from information supplied by contributor. Metadata records for all contributed datasets were uploaded into the Team Arundo del Norte metadata library in California Environmental Information Catalog at CERES (http://gis.ca.gov/catalog/BrowseCatalog.epl?id=105).

Figure 5 shows the top of the TAdN metadata Catalog, and the top portion of a metadata record for an individual contributor is shown in Figure 6.

A preliminary version of the consolidated *Arundo* distribution dataset was published in 2007 on the California Dept of Fish and Game's Biogeographic Information and Observation System (BIOS) map server and on National Biological Information Infrastructure (NBII) CRISIS Maps. Figure 7 shows the Preliminary dataset displayed in BIOS. Figure 8 displays CRISIS Maps' Arundo data, which includes both our project's Arundo locations and all other Arundo observations in their database.

Links to the public map servers are:

- CDFG BIOS: http://imaps.dfg.ca.gov/viewers/biospublic/app.asp?zoomtoBookmark=1053
- NBII CRISIS Maps: http://cain.ice.ucdavis.edu/cgi-bin/mapserv?map=../html/cain/crisis/crisismaps/crisis.map&mode=browse&layer=state&layer=county

After field mapping was completed a second data consolidation effort resulted in a final version of the Consolidated Arundo Distribution dataset, which is being submitted to BIOS and CRISIS at the time of this writing. The final version contains 11,659 records in 22 counties, obtained from 21 contributors. Figure 9 shows the final version of the data.

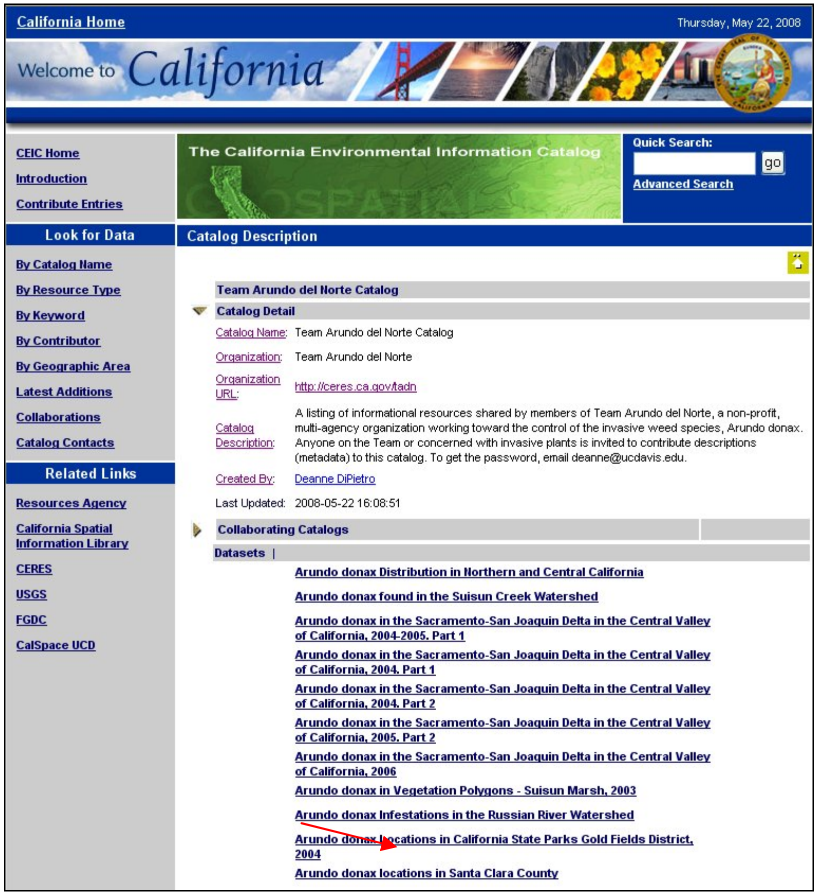


Figure 5. TAdN Metadata Catalog in CERES

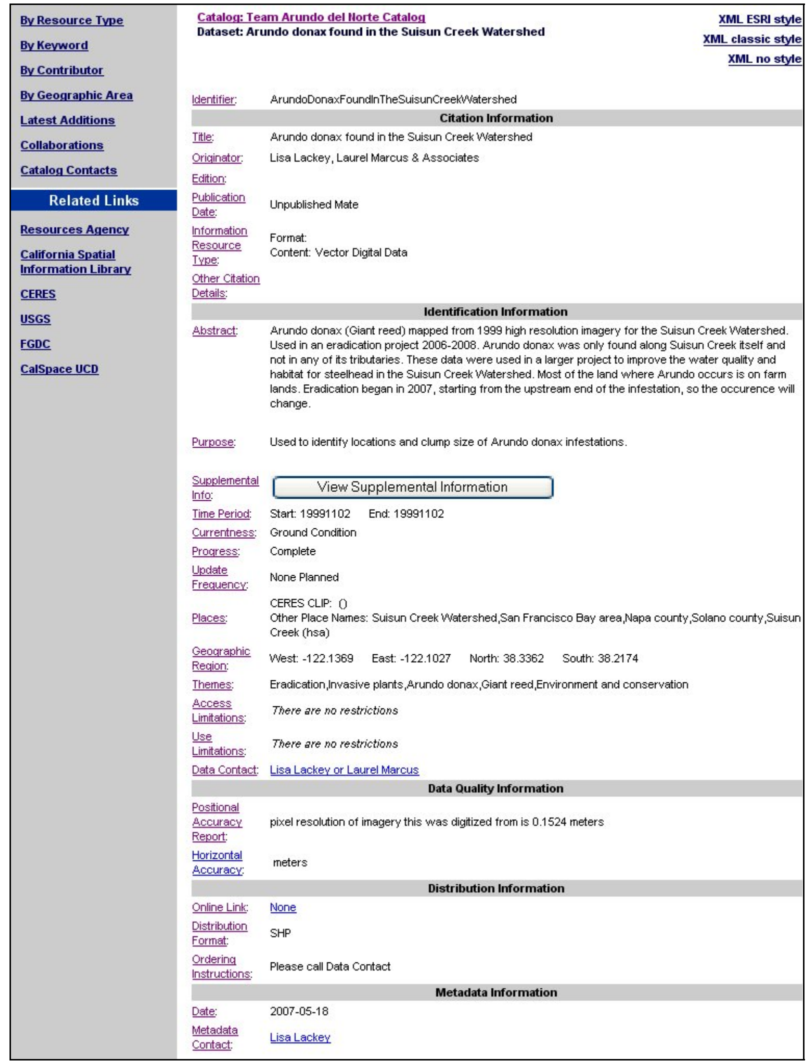


Figure 6. Metadata record for a data contributor

Figure 7. Preliminary version of consolidated *Arundo* distribution dataset in BIOS, 2007

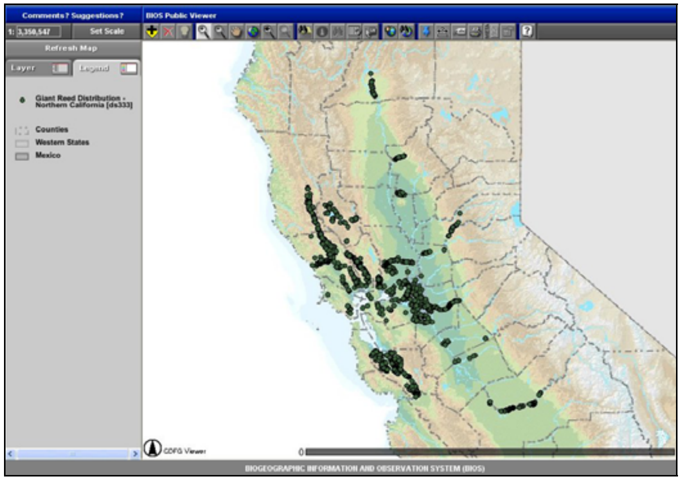


Figure 8. Preliminary version of consolidated *Arundo* distribution dataset in CRISIS Maps, 2007

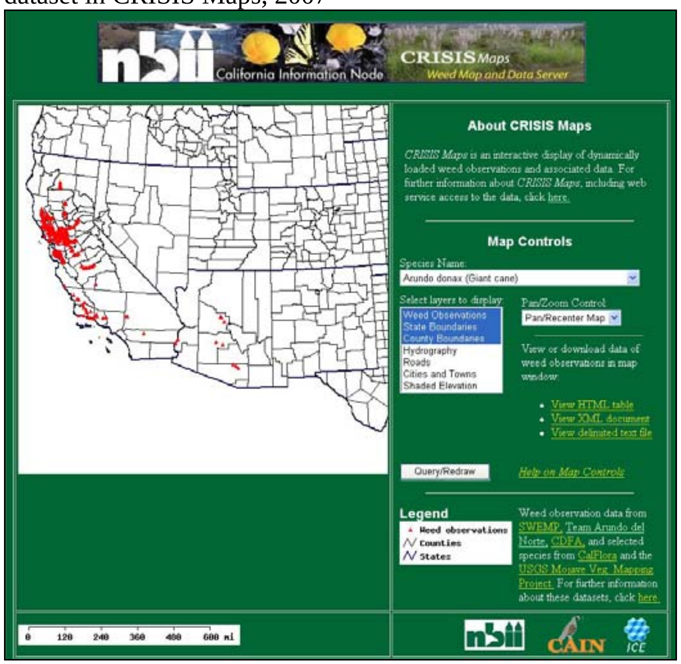
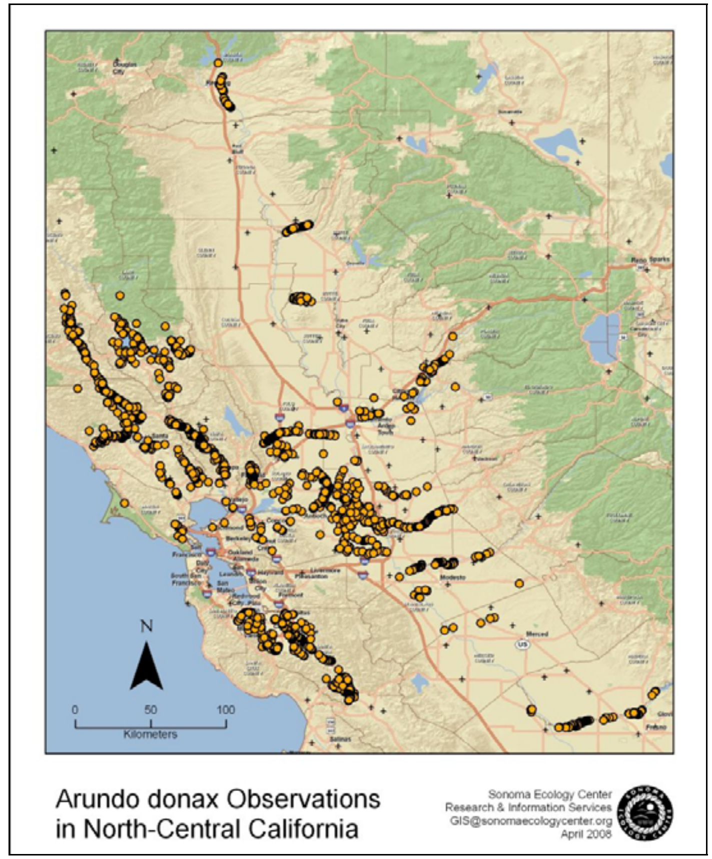


Figure 9. Final version of consolidated *Arundo* distribution dataset, 2008



Results and Discussion

Eradication Priority Presentation and Use

The eradication priorities shown in figures 9 and 10 identify areas where sensitive habitats are threatened by *Arundo*. The practical use of this information necessitates that it be delivered in a manner that is helpful to the invasive plant control community.

CalFed's use of the priority map will likely be to examine the region-wide threat of *Arundo* donax and determine needed action from a funding agency's point of view. A ranking of watersheds most threatened by *Arundo* may be the most effective presentation for serving this need.

The work of eradication will be done by various groups conducting invasive plant control at a local level, such as the partners of Team Arundo del Norte. In areas where there are as yet no TAdN partners there will need to be appropriate lead organizations identified. The invasive plant control community can be reached through groups known as Weed Management Areas (WMAs), which are typically associated with counties and receive funding from the California Department of Food and Agriculture. In order to utilize this mechanism for outreach, the priority areas will be listed by county, with stream names as an added grouping. These lists can be distributed to the WMAs for their consideration as part of their overall strategies for approaching weed control in their area. It may be helpful to use the GIS layers and techniques described here to analyze the threat to habitat by other locally relevant weed species, thereby creating a more comprehensive planning tool. It is only necessary to have the observation data in order to extend this approach further in that manner. A proposal requesting funding to eradicate Arundo would be strengthened by using this information to target the high-priority watersheds from a regional perspective and targeting the high-priority streams within them.

Once this information is in the hands of eradication practitioners, it important to recognize that a number of additional factors will need to be considered. Other necessary factors include:

- Known legal and permitting obstacles.
- Presence of other impairments that are likely to compromise restoration success.
- Presence of capable and willing local partners to perform actual eradication work.
- Permission to perform eradication work from private landowners or public land managers.
- Hazards caused by presence of Arundo, such as flooding and fire.
- Local expert opinion about Arundo infestation size and invasion rates, propagule sources, and stream dynamics.

Implications of Data Sharing

The reasons for documenting and sharing data with others are compelling. It is through data sharing that each project can contribute to the common knowledge and management of the natural environment. Project costs are greatly reduced when data acquisition can be done quickly and appropriate use of data evaluated efficiently. Environmental management decisions, policy, and research would benefit enormously from the availability of data and information from previous projects.

In practice, obtaining usable data from others is usually problematic. Projects are not typically planned with a data documentation and sharing component and so the data products are lost to the greater community. The data acquisition phase of this project is a typical example of the painstaking effort that is often undertaken to obtain data before a project can even begin. A time-consuming effort was made to contact data owners and then convince them to make their data openly available.

This project strives to provide an example of good data management and the value of data sharing and documentation in the hope of changing this trend. Data standardization, documentation, cataloging, and posting were carried out for the participating data contributors. This process of educating the weed data community was an intentional part of the project. The result of the consolidation of the disparate data sources into a single standardized dataset was intended to provide a target structure for future similar weed mapping efforts. This data layer serves not only as a valuable dataset in itself but also as a spatial index to the individual datasets and, while we did not post the original data, to the source of those data where it may be obtained if needed. Posting on BIOS and CRISIS Maps provides access to the data and metadata for the California weed management community and the national community, respectively. It is our hope that the data will be useful to future projects like ours and serve to inspire others to add to the collective knowledge about the distribution, spread, and eradication of *Arundo donax* in California.

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