ERDC/TN EMRRP-SI-37
December 2017

Rapid Assessment of Invasive Riparian Trees for Planning and Implementing USACE Ecosystem Restoration Projects

by Michael P. Guilfoyle and Richard A. Fischer

PURPOSE: This Technical Note (TN) was developed by the U.S. Army Engineer Research and Development Center- Environmental Laboratory (ERDC-EL), to provide an introduction to rapid assessment methods that can be used to provide a quantitative index to the abundance and distribution of invasive riparian trees found on U.S. Army Corps of Engineers (USACE) project lands. The USACE Ecosystem Management and Restoration Research Program (EMRRP) is supporting a nationwide effort to address the impacts of invasive tree species that affect decision making and the ultimate success of ecosystem restoration efforts. This research project has four objectives: (1) identify the suite of invasive woody riparian trees that are most problematic to USACE ecosystem restoration efforts, (2) develop guidelines that suggest thresholds for when and where on the landscape funds should be spent to control invasive trees, (3) determine the most efficient and ecologically-effective spatial configuration for woody invasive riparian plant removal on Corps-managed lands, and (4) investigate how faunal communities respond to various spatial control methods for invasive tree removal in densely vegetated riparian habitats.

Guilfoyle and Fischer (2016) provide an introduction to invasive riparian trees found on USACE project lands that may impact USACE restoration efforts. This TN follows that effort by: (1) detailing approaches USACE personnel can employ to rapidly assess the abundance and distribution of invasive riparian trees and other plants on project lands, (2) to use these data to make decisions about degree of control needed to protect or restore important native riparian communities, (3) to introduce other methods to intensively survey and manage invasive populations and assess restoration success, (4) identify the best locations where cost-effective approaches to riparian habitat restoration is most likely to be successful, and (5) to provide guidance on the best removal or control spatial configurations that will yield the best restoration outcomes.

BACKGROUND: Efforts to eradicate, control and monitor invasive plant species can impose significant economic and environmental costs in North America (Pimentel et al. 2000; Pimentel et al. 2005). Invasive plant species often negatively impact native plant communities with nearly 400 native plants listed as threatened and endangered due to interaction with invasive plants (Pimentel et al. 2000; Hayes and Holzmueller 2012). Surveys of invasive plants on USACE project lands can provide important information for identifying and prioritizing efforts to control these species and in guiding the planning and implementation of riparian ecosystem restoration. While cataloging all non-indigenous plants on USACE project lands is desirable for planning and management decisions, this TN focuses on those tree species that have become invasive and are

Approved for public release; distribution is unlimited.

therefore, expanding and/or having a significant impact on native plant and/or wildlife communities (Rew and Pokorny 2006).

In areas with significant alterations to local hydrological regimes, conditions may not be suitable for native plant communities. Restoration of pre-settlement hydrologic functions for an area may be cost prohibitive and may minimize capacity of future restoration of the native plant community. In other areas, hydrologic regimes may be suitable for native plant restoration, but the extent and dominance of invasive trees may require cost-prohibitive eradication and control, such that ecosystem restoration may not be cost-effective. In areas with both suitable hydrologic conditions and relatively low invasive tree densities, decisions need to be made on how to best configure invasive tree removal and control efforts while creating areas suitable for reestablishment of the native riparian plant community. The effort to remove large patches of invasive riparian trees may also need to be balanced with efforts to ensure that suitable habitat and structure remain to support native vertebrate communities (Sogge et al. 2008; Stromberg et al. 2009; Fischer et al. 2012; Guilfoyle and Fischer 2016). Moreover, after rapid assessment of invasive tree abundance and distribution, and after restoration of native plant community, USACE personnel will need to perform post-project monitoring to measure success of restoration efforts, while also engaging in post-project control of invasive trees to ensure that invasive species do not become reestablished in restored areas. Some restoration efforts may result in a mosaic of native and non-native plant communities. Post-project monitoring will be needed to ensure that goals of the restoration effort are achieved in such mosaic landscapes. Finally, USACE efforts to restore native riparian plant communities should provide detailed reports on both successes and failures in ecosystem restoration. Successful efforts need to transfer the approaches and knowledge gained to increase likelihood of success on different project lands, while restoration efforts that fail to meet objectives need to provide detailed information to minimize future mistakes.

REASONS FOR ASSESSING USACE PROJECT LANDS FOR INVASIVE SPECIES: Management of USACE project lands requires efforts to identify and protect numerous wildlife and plant species, including species listed by state and federal agencies as threatened, endangered, or rare and sensitive (Martin et al. 2006). Moreover, all federal lands, including lands managed by USACE, are also required to coordinate and effectively prevent and control the spread of invasive species under the *Nonindigenous Aquatic Nuisance Prevention and Control Act* (1990), *National Environmental Policy Act* (1969), *Federal Plant Pest Act* and *Executive Order* 13112 (Presidential Documents, Federal Register 1999). The USACE is a national leader in initiating extensive ecosystem restoration efforts national-wide, ranging from small bank stabilization projects to large riparian ecosystem restorations (Fischer 2003). Since presence of invasive riparian trees may indicate need for reestablishment of hydrologic function in an area/region, plus significant control and/or removal efforts, USACE Districts and specific project lands are encouraged to initiate inventories or site specific surveys to estimate and predict abundance and distribution of invasive species. Often, riparian habitats exhibiting significant degradation, including the presence of invasive species, are the areas selected for restoration efforts (Stromberg 2000). In order to assess restoration potential and to assist in determining cost estimates that may require control and/or eradication of invasive riparian trees, numerous federal and state agencies have developed methods and approaches for rapid assessment of abundance and distribution of invasive plants (e.g., Rew and Pokorny 2006; Rawlins et al. 2011; U.S. Fish and Wildlife Service [USFWS] 2016).

An early approach to rapid assessment of invasive plants can be found in the *Federal Interagency Committee for the Management of Noxious and Exotic Weeds* (FICM-NEW) (FICM-NEW 2003). The U.S Fish and Wildlife Service (USFWS), including the National Wildlife Refuge System (NWRS), follow national data standards established by the North American Invasive Species Management Association (NAISMA) (Welch et al. 2012; NAISMA 2014; USFWS 2016). These data standards can be used in a rapid assessment approach to document the specific invasive species present, provide an estimate on abundance, and to map the distribution of invasive species on USACE project lands. These data can be standardized and entered into a national database that will help facilitate the scientific communities' knowledge concerning the extent of invasive riparian trees, and other invasive plant species nation-wide.

RAPID ASSESSMENT AND OTHER METHODS TO DETERMINE ABUNDANCE/ DISTRIBUTION OF INVASIVE RIPARIAN TREES ON USACE PROJECT LANDS: Methods for rapid assessment of invasive riparian trees on USACE project lands assume that presence and/or extent of invasive species on a specific project site is either unknown or poorly understood. Therefore, these approaches generally represent the first effort to assess status and distribution of invasive species. This effort may be a part of a USACE project manager's effort to conduct natural resource inventories for current and future management planning (Martin et al. 2006), or it may be part of an effort to identify and target areas specifically for restoration (Guilfoyle and Fischer 2006; 2016). Setting goals and objectives for rapid assessment is imperative to effectively use data to assist in subsequent management decisions (Guilfoyle and Fischer 2006; Rew and Pokorny 2006; USFWS 2016). Before on-the-ground surveys are conducted, managers should complete some preliminary research to determine which invasive species are in their region and likely to be in the vicinity of the project lands; plus specific attributes of the target species so that correct identification can be made (Guilfoyle and Fischer 2016). Topographic maps or a hand-held Global Positioning Satellite (GPS) unit can be used to provide precise locations on the distribution of invasive species on the project land (Rawlins et al. 2011; USFWS 2016). Data on relative abundance of invasive species and their locations can permit creation of detailed maps showing their current extent (USFWS 2016), and data can be entered into modeling programs to predict the future spread on the landscape (Rawlins et al. 2011). Following an assessment of the abundance and distribution of invasive species, decisions on the best areas for restoration and or control/eradication can be made (FICM-NEW 2003; Rew and Pokorny 2006; Rawlins et al. 2011; Welch et al. 2012; USFWS 2016).

1) Aerial/Satellite Imagery and Arc-Geographic Information System (GIS) Analysis. This approach requires little to no field work, except to verify presence and location of invasive trees on the project land. This approach may be preferable if the area to be surveyed is very large (e.g., $\geq$ 1,000 ha) (Welch et al. 2012). Application of this approach requires procurement of high resolution (1 m to 4 m) aerial or satellite imagery and may require an experienced GIS technician. Imagery must be brought into ArcGIS (ESRI, Redlands, CA) or similar software program and geo-rectified to the appropriate UTM coordinate system. The analysis can use Feature Analyst 4.0 (or most current version) to extract coverage estimates of specific invasive trees on project lands (see Fischer et al. 2012 for application of the approach). Image data brought into Feature Analyst can be used to train the software to identify the specific multispectral signatures of the invasive tree foliage. After ground-truthing the locations, specific areas used as training sets can be digitized to produce the "ideal" features to be extracted by the program (Fischer et al. 2012). In addition, the learning algorithms of the program incorporates other information from the imagery, including texture, patch shape, spatial context, patch size and extent of coverage to further define features to be extracted that will provide an estimation of the extent and distribution of invasive species on the project lands. With the appropriate imagery, software, and experienced GIS technician, this approach can provide a good estimate of the extent and distribution of invasive species in about two to three days. Although there can be errors in the ArcGIS extracted features, this approach may be just as accurate as the mapping approach recommended by Rawlins et al. (2011) and the USFWS (2016). This approach may be the best rapid assessment method on very large project lands, and can also be used in conjunction with spot surveys and/or transect surveys described below to provide more accurate maps of invasive species abundance and distribution for planning and management. This approach is recommended on large project areas when sufficient high-resolution aerial or satellite imagery, computer capabilities, and qualified GIS technical personnel are available.

2) Exploratory/Spot Surveys. This approach involves randomly identifying areas on project lands and searching as much land as possible for the presence of invasive species. All possible survey areas can be assigned a numeric identifier that can be randomly selected through a generated random number table. Often, this approach represents the first effort to determine presence of invasive tree species, and generally reflects the Early Detection and Distribution Mapping System (Rawlins et al. 2011). Similar approaches are used by the National Invasive Species Council (NISC 2003), USFWS (USFWS 2016), the U.S. Geological Survey (USGS) (Welch et al. 2012), and the U.S. Department of Agriculture (USDA) (Rew and Pokorny 2006). To survey an area for invasive species, the observer stands at a predetermined location and records all invasive trees detected and their general location within the area of view (Figure 1). The purpose of spot surveys is to collect data rapidly, with small projects (e.g., ≤ 400 ha) surveyed in as little as one day, while larger project areas (e.g., ≥ 1,000 ha) may require three or more days. While collecting data from spot surveys, location data can be recorded using hand-held Geographic Positioning (GPS) units, and abundance and location data can be used to generate maps according to the approach recommended by Rawlins et al. (2011), NAISMA (2014) and the USFWS (2016). This approach is recommended as a first attempt to document and describe invasive species on USACE project lands, especially if high-resolution imagery, sufficient computer capability, and/or GIS technical support are not available.

3) Transect Surveys/Intensive Randomized Plot Surveys. Transect surveys, or intensive randomized plot surveys, can provide the best information on the abundance and distribution of invasive species on project lands (USFWS 2016). However, the approach may require much more time and manpower; and therefore, is not an approach for rapid assessment. In terms of land covered by the sampling, and the type of data collected, this approach is analogous to intensive sampling of randomly or systematically random established plots on the land (Rew and Pokorny 2006; Welch et al. 2012, USFWS 2016). This approach may be used after spot survey and/or other preliminary mapping approaches have been used (Rew and Pokorny 2006). However, if time and funding permit, the data collected from this approach can provide more precise and accurate data on the abundance and extent of invasive species on project lands. This method also is useful as a standard approach for long-term monitoring (Rew and Pokorny 2006; Welch et al. 2012; USFWS 2016). The use of transects has been standardized by the USFWS in wildlife refuges in the Northeast Region (USFWS 2016). As with the spot survey approaches, this approach can be used with aerial/satellite imagery or using mapping approaches detailed by Rawlins et al. (2011) and the USFWS (2016). This approach is recommended on those project lands where good information on the presence of invasive species and their extent and distribution are well known. This approach is also recommended for before, during, and post-project completion to assess success of restoration efforts and/or invasive species control efforts.

To establish line transects, grid systems are laid over a map of the area, and line transects are mapped through the area to cover as much area as possible (USFWS 2016) (Figure 2). Spacing between transects is generally dependent upon the visibility in the habitat and the perceived density of invasive species. Open grassland areas, or areas with a low density of invasive species can space transects farther apart through the project area. In large managed areas (e.g., ≥ 1,000 ha), it may be more cost-effective to subsample by intensively sampling smaller areas (e.g., ≤ 30 ha) on the project land that provide the information that can be extrapolated over the entire area (USFWS 2016). During pre- or post-restoration and/or invasive species control efforts, care will need to be taken to ensure that suitable areas subjected to management actions, along with non-impacted areas as controls, are included in the sampling approach. Sampling plots along transects may be established randomly or with systematic random intervals to provide the best coverage based on time and funding availability (Welch et al, 2012).

Figure 1. Random placement of spot surveys for rapid assessment of abundance and distribution of invasive trees on USACE project lands.

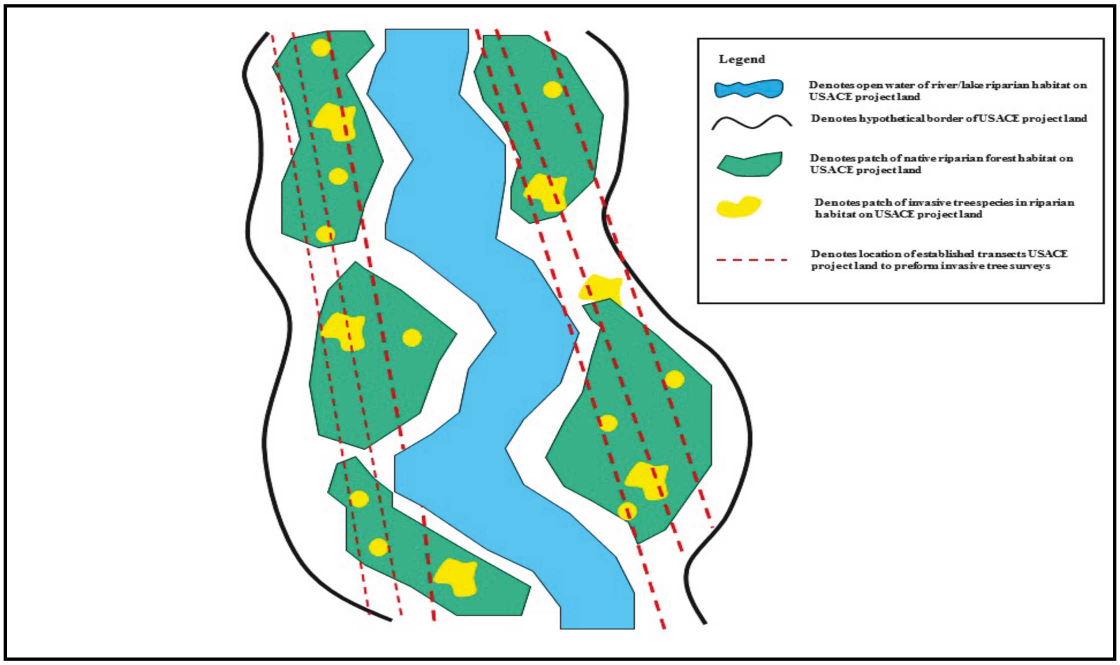

Figure 2. Placement of transects for intensive inventory and monitoring of invasive trees on USACE project lands.

DATA ANALYSIS AND INTERPRETATION: There are numerous analytical approaches to statistically analyze vegetation collected in randomly established plots and/or sampling stations along transects (summarized by Giessler 2012). For rapid assessment purposes, the final product is usually a coverage map that provides a visual tool to assess the abundance and distribution of invasive trees on the project area. From this map, there are usually three scenarios on the landscape that may be present and may require action:

1) Low presence of invasive species. Areas where invasive species have been found, either in low abundance (e.g., small isolated patches of trees ≤ 0.05 to 0.3 ha), or even isolated single trees, represent the usefulness of the Early Detection and Distribution Mapping System (Rawlins et al. 2011). It is in the best interest of the project manager to, as much as possible, prevent the establishment and spread of invasive species on project lands. Therefore, upon the discovery of areas with low abundance, the recommended management action is to remove the invasive species as quickly as possible to prevent the establishment and spread of the species. For most species, a combination of mechanical or herbicide removal may be necessary to fully eradicate invasive species (Guilfoyle and Fischer 2016). Early detection is critical to prevent establishment of species on any USACE managed property. Post-action monitoring is needed to ensure that invasive trees do not become reestablished in the area.

2) Moderate abundance of invasive species. Areas with moderate abundance (e.g., multiple scattered patches of invasive trees ≥ 0.4 ha) of invasive species may present a good opportunity for extraction and habitat restoration. In these areas, costs of removal may be significantly lower than areas dominated by invasive species. Moreover, persistence of native species in the area may help provide seedbank sources that will facilitate reestablishment of the native habitat during restoration efforts. Managers will still need to consider the costs of invasive species removal, any engineering necessary to restore hydrologic function, and costs associated with post-project monitoring. Again, post-action monitoring is needed to assess success of restoration and/or control efforts and to ensure that invasive trees do not become reestablished in the area.

3) High abundance/dominance of invasive species. Often, the most degraded areas are the areas selected for restoration efforts. Areas with high abundance of invasive trees may support dozens to hundreds of hectares of invasive tree monocultures (e.g., Russian olive (*Elaegnus angustifolia*) in southeast Washington; Fischer et al. 2012). Selecting such areas may be reasonable if invasive species can be removed effectively and if native plant communities can be reestablished in the area. In some cases, high removal/eradication costs, necessary engineering to restore hydrologic function, plus significant post-project monitoring and action costs, may derail restoration efforts and/or limit potential success of the restoration effort (Guilfoyle and Fischer 2016). However, such high-risk restoration efforts may provide high rewards if the efforts are planned and funded appropriately. To save costs, complete eradication of invasive trees may not be necessary, nor even possible (Stromberg et al. 2009; Fischer el al. 2012; Guilfoyle and Fischer 2016). Strategically removing invasive trees in smaller patches, sufficiently large enough to reestablish native plant communities, may provide an approach to successfully restore native plant communities, while also increasing habitat availability and wildlife diversity in the area. In such cases, invasive species may be too dominant to ever be completely removed in a cost-effective manner (Guilfoyle and Fischer 2016); however, a resulting mosaic of native and invasive plant patches may be effective in meeting restoration goals. Fischer et al[1] are currently working on strategies for patch removal size and configuration in areas dominated by Russian olive. Results of this effort may be applicable to other western and southwestern habitats, including habitats dominated by saltcedar (*Tamarix ramosissima*). Considerably more research will be needed to address habitats in the northeast and southeast dominated by Chinese tallow (*Triadica sebiferum*) or privet (*Ligustrum* spp.) (Guilfoyle and Fischer 2016). Significant post-project monitoring and control will be needed to assess success and ensure restored native habitat patches are not reinvaded by invasive tree species from adjacent patches.

IDENTIFYING COST-EFFECTIVE APPROACHES TO RESTORATION OF RIPARIAN HABITAT ON USACE PROJECT LANDS: Specific considerations and planning must take place before restoration efforts on USACE project lands can proceed. Locating and planning for restoration efforts should occur once initial efforts to survey project lands for invasive trees (and other invasive plants) have been completed. Once knowledge of the abundance and distribution of invasive trees has been determined, several considerations should be addressed before finalizing restoration plans:

1. **Amount of funding available for desired restoration effort.** Areas with moderate to high levels of invasive trees will require more funds to successfully eradicate. Restoration success may be limited, or may fail, if costs of removal are not accurately predicted. Moreover, complete eradication may remove vital habitat for some sensitive or rare native species.

[1] Fischer, R. R., M. P. Guilfoyle, and S. S. Jackson. (In Prep). Environmental Management Research and Restoration Program (EMRRP): Impact and relationship of invasive species on ecosystem restoration: guidelines for spatial removal patterns of invasive woody vegetation in USACE riparian ecosystems 2013–2016.

2. **Potential need for engineering to restore hydrologic function.** In many areas in the southwest and western United States, significant changes to system hydrology can create conditions suitable for invasive species, such as saltcedar, while reducing conditions for native plant communities. Simply removing invasive species and planting native species may not be sufficient if conditions are not suitable for reestablishment of the native plant community. To improve likelihood of success, it is recommended to target areas with suitable conditions for native communities, or carefully plan and budget restoration efforts to restore habitat conditions, including hydrologic function and/or removal of invasives as needed.

3. **Amount of area to be restored.** High costs of invasive tree eradication and control may limit the size and success of restoration efforts (Guilfoyle and Fischer 2016). If funding is limited, it is recommended that managers target restoration efforts on portions of project lands with low to moderate levels of invasive trees, as these areas likely have a better probability of successful eradication and/or control.

4. **Size of invasive dominated area to be removed.** In areas with low abundance of invasive species, project managers may have the capability of targeting larger areas for restoration efforts. However, areas in which invasive species have extensive domination and a cover large proportion of land, carefully planning the removal of smaller patches in the landscape is recommended as a cost-effective approach for habitat restoration efforts (Guilfoyle and Fischer 2016).

Research has been conducted on removal patch size and configuration approaches within one hectare sized circular plots dominated by Russian olive[1]. Plots were surveyed for wintering and breeding bird communities under specific removal regimes, including areas with 50% removal (1/2 circle), 50% removal (hour-glass shaped cuts), and 40–60% random selection cut removal. Preliminary results have observed no significant differences in bird abundance for most species among the different treatments. However, selective removal cuts provided patches too small for reestablishment of native plants. Small selective removals were either too shaded for native plants to become established; or, the patches were quickly recolonized by Russian olive and reduced survivorship of native plantings. The small areas in selection cuts also have other drawbacks; the remaining Russian olive trees may still form dense thickets, which makes access to the smaller cut sites difficult for replanting and monitoring efforts. Moreover, removal of selective Russian olive trees weakens the remaining standing trees resulting in significant blow-over during periods of high wind. Trees that have blown over and are difficult to remove, increase the difficulty of access and can cause mortality of native plantings. Larger, 50% removal cuts, provided the best conditions and access for reestablishment of native plants, with no discernable impacts on bird community diversity or abundance. However, more research will be needed to assess any differences in reproductive success of birds in different treatments, including removal patches that may lead to higher rates of nest failure by breeding birds due to predation or parasitism by brown-headed cowbirds (*Molothrus ater*). Research is needed to determine if other sensitive vertebrates such as small mammals and reptiles and amphibians may be negatively impacted in larger removal areas.

---

[1] Fischer, R. R., M. P. Guilfoyle, and S. S. Jackson. (In Prep). Environmental Management Research and Restoration Program (EMRRP): Impact and relationship of invasive species on ecosystem restoration: guidelines for spatial removal patterns of invasive woody vegetation in USACE riparian ecosystems 2013–2016.

DISCUSSION: USACE land managers need to determine presence and extent of invasive species, including invasive riparian woody trees, on project lands. Once presence of invasive trees is documented, managers can initiate control and eradication efforts as needed. Identification and eradication of invasive riparian tree species before they become established on USACE project lands is the best, most cost-effective means of control. If invasive trees are found to be established and widely distributed, then a more labor intensive eradication program may be required. It is recommended that an initial rapid assessment approach be used to document presence, extent and distribution of invasive species on USACE project lands. When restoration or control efforts are planned, it is recommended that a more intensive monitoring approach be used to accurately assess pre- and post-control efforts conditions and to determine the success of these efforts. It is recommended that the establishment of line transects and/or intensive placement of randomly established survey plots for long-term monitoring of the invasive plant population, including the population of invasive species found on USACE project lands be used. More detail on these methods can be found in NISC (2003), Rew and Pokorny (2006), Rawlins et al. (2011), Welch et al. (2012), and USFWS (2016). These methods can be used in conjunction with conducting Level I and II surveys on project lands (Martin et al. 2006). Documenting and monitoring invasive species is required by the *Nonindigenous Aquatic Nuisance Prevention and Control Act* and knowledge gained should facilitate the planning and implementation of ecosystem restoration efforts. It is recommended that while documenting the presence, location, and distribution of invasive species on USACE projects, that managers also consider submitting these data to national databases to further extend knowledge and understanding of invasive plant populations (e.g., Rawlins et al. 2011). Developing collaborative relationships with other agencies near project lands including the USDA, the USGS, and the USFWS, may promote cost-effective opportunities to leverage control of invasive species by partnering with other ongoing efforts in specific regions.

When planning restoration efforts, it will be necessary to make decisions based on circumstances existing at specific localities. Funding for some restoration projects will not be sufficient for large scale eradication and control of invasive species. Additional costs may accrue if hydrologic function of the system is highly degraded. Restoration of hydrologic function of an area may be necessary to create conditions suitable for establishment of native plant communities. Locating areas within project lands that support low abundance of invasive species and require little to no hydrologic engineering, may be reasonable targets for ecosystem restoration. In areas with moderate to high abundance of invasive species, removal of relatively small patches (e.g., $\leq$2 to 4 ha) may be a cost-effective approach that permits areas suitable for establishing native plant communities, yet provides some remaining structure for forest dependent species (Sogge et al. 2009; Fischer et al. 2012). Resulting restored habitat may form a landscape mosaic of native and invasive plant community patches. The value of such habitat for the conservation and protection of native populations is poorly understood. Ongoing research on Russian olive dominated habitats in southeast Washington indicate that one hectare plots are benefited by a 50% removal approach that permits sufficient area for growth of planted native trees and better access for monitoring and control of the sites. However, the long-term capability of these areas to support sustaining native flora and faunal populations will require further long-term monitoring and assessment.

SUMMARY: All USACE project managers are required to monitor and assess the extent of invasive plant species on their lands. Knowledge of the abundance and distribution of invasive trees is necessary when planning and implementing ecosystem restoration efforts. Rapid assessments for invasive trees, including the use of satellite imagery on large areas, or the use of small spot surveys on projects lands, are useful approaches to rapidly assess abundance and distribution of invasive plants. These approaches have been used and standardized by numerous other agencies, including the USFWS, USGS and the USDA. The establishment of transects or randomly placed survey plots may be needed for long-term monitoring of invasive trees, to assess the success of eradication and control efforts, and to assess success of ecosystem restoration projects. Data on the abundance and distribution of invasive trees should be submitted to national databases to further knowledge of invasive populations and to aid in the control of these species. For restoration projects with limited funding, complete eradication of invasive plants may not be tenable, and engineering may be needed to restore hydrologic function to create conditions for native plant communities. With limited funding, USACE project managers may wish to utilize smaller cuts that will create a landscape of native plant community patches interspersed with patches of invasive plants. Long-term capability of such landscapes to support sustaining native flora and faunal populations will require further long-term monitoring and assessment.

ACKNOWLEDGEMENTS: Funding was provided by the Ecosystem Management and Restoration Research Program (EMRRP). The Technical Director for the ER Program is Dr. Al Cofrancesco. Technical reviews were provided by Dr. Jacob Jung and Darrell Evans, both of ERDC/EL.

POINTS OF CONTACT: For additional information, contact Dr. Michael P. Guilfoyle (601-634-3432; *Michael.P.Guilfoyle@usace.army.mil*), Dr. Richard A. Fischer (502-641-7824; *Richard.A.Fischer@usace.army.mil*), or the Program Manager of the Ecosystem Management and Restoration Research Program (EMRRP), Dr. Trudy Estes (601-634-2125; *Trudy.J.Estes@usace.army.mil*).

This technical note should be cited as follows:

Guilfoyle, M. P., and R. A. Fischer. 2017. *Rapid Assessment of Invasive Riparian Trees for Planning and Implementing USACE Ecosystem Restoration Projects*. EMRRP Technical Notes Collection. ERDC/TN EMRRP-SI-37. Vicksburg, MS. U.S. Army Engineer Research and Development Center. *http://el.erdc.usace.army.mil/emrrp/techran.html*

REFERENCES

Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICM-NEW). 2003. *A national early detection and rapid response for invasive plants in the United States.* Washington, DC. *https://www.fws.gov/ficmnew/FICMNEW_EDRR_FINAL.pdf*.

Fischer, R. A. 2003. *Riparian restoration and management needs in the arid and semi-arid western United States*. EMRRP Technical Notes Collection. ERDC TN-EMRRP-SI-03-1. Vicksburg, MS. U.S. Army Engineer Research and Development Center. *http://el.erdc.usace.army.mil/emrrp/techran.html*.

Fischer, R. A., J. J. Valente, M. P. Guilfoyle, M. D. Kaller, and S. B. Jackson. 2012. Bird community response to vegetative cover and composition in riparian habitats dominated by Russian olive (*Elaeagnus angustifolia*). *Northwest Science* 86:39–52.

Geissler, P. H. 2012. Chapter 8: Sampling and survey design. Pages 100-118 *in* B. A. Welch, P. H. Geissler, and P. Latham, Eds., *Early detection of invasive plants – principles and practices*. U.S. Geological Survey Scientific Investigation Report 201205162, 193. Pp. *http://pubs.usgs.gov/sir/2012/5162/pdf/sir2012-5162.pdf* (accessed August 1, 2016).

Guilfoyle, M. P., and R. A. Fischer. 2006. *Guidelines for establishing monitoring programs to assess the success of riparian restoration efforts in arid and semi-arid landscapes*. EMRRP Technical Notes Collection. ERDC TN-EMRRP-SR-50. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://el.erdc.usace.army.mil/emrrp/techran.html

Guilfoyle, M. P., and R. A. Fischer. 2016. *Review of invasive riparian trees that impact USACE ecosystem restoration projects*. EMRRP Technical Notes Collection. ERDC TN-EMRRP-SI-36. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://el.erdc.usace.army.mil/emrrp/techran.html

Hayes, S. J., and E. J. Holzmueller. 2012. Relationship between invasive plant species and forest fauna in eastern north America. *Forests* 3(3):840–852. doi:10.3390/f3030840

Martin, C. O., J. Krause, and D. N. Wiese. 2006. *Natural resources level one inventories: What are the needs and process for Corps projects?* EMRRP Technical Notes Collection. ERDC TN-EMRRP-EM-04. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://el.erdc.usace.army.mil/emrrp/techran.html

National Invasive Species Council (NISC). 2003. General guidelines for the establishment and evaluation of invasive species early detection and rapid response systems. Version 1. National Invasive Species Council, Department of the Interior.

North American Invasive Species Management Association (NAISMA). 2014. *North American Invasive Species Mapping Standards*. North American Invasive Species Management Association, Fargo, ND.

Pimentel, D. R., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. *BioScience* 50(1):53–65.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52:273–288.

Presidential Documents. (1999). Executive Order 13112 of February 3, 1999: Invasive Species. *Federal Register* 64:6183-6186.

Rew, L. J., and M. L. Pokorny. 2006. *Inventory and survey methods for nonindigenous plant species*. Montana State University, Bozman, MT. 78 pp.

Rawlins, K. A., J. E. Griffin, D. J. Moorhead, C. T. Bargeron, and C. W. Evans. 2011. *EDDMapS: Invasive Plant Mapping Handbook.* Center for Invasive Species and Ecosystem Health. The University of Georgia: Tifton, GA. BW-20011-02 3–3.

Sogge, M., K. Sferra, and E. Paxton. 2008. Saltcedar as habitat for birds: implications to riparian restoration in the southwestern United States. *Restoration Ecology* 16:146–154.

Stromberg, J. C. 2000. Restoration of riparian vegetation in the arid southwest: challenges and opportunities. *Arizona Riparian Council Newsletter* 13:1–7.

Stromberg, J. C., M. K. Chew, P. L. Nagler, and E. P. Glenn. 2009. Changing perceptions of change: the role of scientists in *Tamarix* and river management. *Restoration Ecology* 17:177–186.

U.S. Fish and Wildlife Service (USFWS). 2016. National Wildlife Refuge System: Managing Invasive Plants, https://www.fws.gov/invasives/stafftrainingmodule/index.html (accessed August 2, 2016).

Welch, B. A., P. H. Geissler, and P. Latham (eds.). 2012. Early detection of invasive plant – principles and practice. U.S. Geological Survey Scientific Investigation Report 201205162. http://pubs.usgs.gov/sir/2012/5162/pdf/sir2012-5162.pdf (accessed August 1, 2016).

NOTE: The contents of this technical note are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such products.