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I. Abstract

Non-native invasive species are very aggressive, able to establish without co-evolved pests or pathogens and can also have a severe impact on native ecosystems also diverting funding for its management and control. Non-native invasive species are difficult to eradicate and must be managed for control. Parris Island Marine Recruit Depot has contracted Invasive Plant Control Inc. for herbicide treatments since 2001 for the control of the non-native invasive species that have been impacting their military training grounds. The principle non-native invasive species that have been prioritized for control are Chinese tallow (*Triadicasebifera*), Chinese privet (*Ligustrumsinense*), Chinaberry (*Meliaazedarach*) and tamarisk/saltcedar(*Tamarixramosissima*). This report investigates the effectiveness of past herbicide treatments, provides new priorities for management, and recommends new treatment options for control.
II. Introduction

Non-native invasive species are a significant threat to military training grounds and to natural ecosystems. Executive Order 13112 directs federal agencies, such as Parris Island Marine Corps Recruit Depot (MCRD), to “prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause.” Non-native invasive species (NNIS) are a severe threat to biological diversity by causing a decline in native species and result in ecosystem degradation [45]. NNIS has been identified by the Chief of the U.S. Forest Service as one of four largest threats to the forest ecosystem. A biological invasion has occurred when a species has established, proliferated and persisted in a geographical location in which it does not occur naturally [23].

The formal management of invasive plant species on Parris Island MCRD, in Beaufort County, South Carolina began in 2001. Invasive Plant Control Inc. (IPC) was contracted to survey and prescribe a management plan to control invasive plant species with the primary use of herbicides. IPC has applied herbicide treatments to high priority stands to control the NNIS infestations since 2002. NNIS on Parris Island not only have a direct impact on native vegetation and ecosystem health, but also impact recruit training because their ability to create dense, impenetrable stands that impede training priorities. NNIS can impede military operations in the following ways [44]:

- Eliminate realistic training or testing conditions and limit related activities
- Divert funding from other natural resource or operational priorities
- Act as a main cause of habitat destruction and biodiversity loss, further reducing training lands
• Pose security risks (e.g. creating visual screens) or lead to potentially life threatening situations (e.g. increasing the incidence and intensity of wildfires)

Species such as Chinese tallow (*Triadicasebifera* L.) are so widespread throughout Parris Island MCRD that it is not feasible for eradication. In such cases the priority of management is to slow the rate of spread and to reduce the impacts on recruit training and the natural ecosystem. Large scale invasions, such as these, can fundamentally change the successional trajectory of the forest ecosystem. A change of this kind could have far reaching implications for numerous plant and animal species that rely on native plant communities and their successional pathways [43].

Invasive tree species unlike other (e.g. herbaceous) plants are long-lived and relatively slow growing. Shade-tolerant tree species are able to colonize gradually by building up a dense and persistent sapling layer which achieves dominance through gap capture after disturbance [43].

Management for invasive species must be accomplished by using an Integrated Pest Management (IPM) approach. For an effective IPM plan, it must include the best available scientific information, be continuously monitored with updated information on the target population, and an evaluation of the effectiveness of past control methods. Methods of control can include cultural practices, restraining invasive species dispersal, mechanical removal of NNIS, the use of chemical control with herbicides, and the release of biological controls agents.

Effective IPM plans for NNIS must follow the prescribed tenets of adaptive management. According to Miller and Schelhas (2009), adaptive collaborative restoration is key to effectual invasive plant management. Management must be adaptive to learn from past control successes or failures; it must include collaborative efforts across ownership boundaries and among managers, and scientists; and it must be restorative because the goals of the plan are to restore a
sustainable system and the wildlife and cultural values associated with the natural ecological processes [25].

The following report is a review of the invasive species control work that has been prescribed on Parris Island MCRD since 2002. This report encompasses a complete survey of Parris Island MCRD including a review of past control effectiveness, priority of management at the stand level that is necessary for future NNIS control, and options/recommendations for control based on infestation level for each stand.

III. Historical Invasive Species Occurrence and Management

The initial invasive species survey was conducted on Parris Island Marine Corps Depot in 2001 by Invasive Plant Control Inc. (IPC). Although not included in the 2002 IPC management report, through dialog with Lee Patrick, VP of IPC, the survey was conducted by transect methodology using backpack GPS (Global Positioning System) devices. For their management purposes, invasive species were categorized by plant characteristics: tree, vine, herbaceous, or multi-stemmed species. This classification was chosen because it is helpful in choosing an appropriate method of application for applying herbicides. Invasive plant species were then categorized by their difficulty to control as experienced by IPC. Species that were either found on or in related proximity to Parris Island at the time of the survey included (ranked 1-10, with 10 being the most difficult) Chinese privet (difficulty rank= 4), tamarisk (difficulty rank= 5), Chinese tallow tree (difficulty rank= 9), and Chinaberry (difficulty rank= 11). Each site was then classified by species according to the level of infestation using a subjective scale of 1 (least infested) to 5 (most infested). Localized populations were valued as representative points with 1
as the highest level of management priority and 5 indicating the lowest level of management priority.

a. **Invasive Species Survey 2001: Species Occurrence and Abundance**

In the 2001 invasive species survey conducted by IPC, the following invasive species were found and mapped for management efforts (numerical value of average infestation level found on Parris Island): Chinese tallow tree (1), Chinaberry (5), tamarisk (3) and Chinese privet (1). Management priority was primarily assigned by forest stand level with localized populations singled out as areas with the highest level of priority.

Chinese tallow tree was indicated as the highest management priority species on Parris Island and was ranked with an average level of 5 for the Depot. Areas of higher infestation were found clustered around Page Field with all levels of Chinese tallow infestation intensity including level 5, and management priority point indications. Forest stands along the southern end of the golf course had an average infestation level of 4. Forest stands along St. Mihiel Road leading to Elliott’s Beach had average area intensity between 3 and 4.
Map 1: 2001 Management Priority areas
b. Management and Control Efforts

IPC has been conducting herbicide control treatments on Parris Island Marine Corps Recruit Depot since 2002, however, recorded data from Parris Island MCRD only reports back to 2006. Data sheets prior to 2009 only give stand numbers where herbicide was applied and not GPS location. Implication for treatment effectiveness is difficult due to the nature of the layout of stands at Parris Island MCRD, because they are often not contiguous and control efforts may have not been applied in all areas of the total stand area. This was revealed by the presence of mature trees in previously treated stands identified in the 2010 survey.

As evidenced in the data reports received from Parris Island MRCD the primary targeted species for herbicide control were Chinese tallow, Chinaberry, and Chinese privet. Chinese tallow due to its abundance was the most targeted species for control with herbicide.

The primary method of herbicide application was hack and squirt. Hack and squirt is an injection method in which a hatchet or ax is used to make downward cuts creating a cup into the stem of the tree. Herbicide is then squirted into the stem cuts and is translocated to the roots through the tree’s vascular system. Hack and squirt is a very selective method of herbicide application because it only affects the treated individual.
c. Herbicides

The following herbicides/products were used from 2006-2009 (Appendix: Herbicide data sheets and documentation):

**Garlon 4 Ultra herbicide:**

Garlon 4 Ultra is manufactured by Dow AgroSciences with the active ingredient triclopyr. It is non-petroleum, plant-derived methylated seed oil (MSO) solvent, which reduces environmental impact. Garlon 4 has broad spectrum control on brush and broadleaf trees with increased efficacy on woody species including mesquite, sweetgum and scotch broom.

**Garlon 3A herbicide:**

Garlon 3A is manufactured by Dow AgroSciences, its active ingredient in triclopyr. Garlon 3A is a broad-spectrum and broadleaf weed herbicide.

**Imazapyr E-Pro:**

Imazapyr E-Pro has the same active ingredients as Arsenal® (imazapyr), but is not manufactured by BASF.

**Accord®:**

Accord® is manufactured by Dow AgroSciences with the active ingredient glyphosate. It is a broad-spectrum control of a wide range of woody, broadleaf and grass species.

**Arsenal®:**

Arsenal® is manufactured by BASF with the active ingredient imazapyr. It is an herbicide that will control most annual and perennial grasses and broadleaf weeds in addition to brush and vine species.
Clearcast®:

Clearcast® began to be applied using hack and squirt methodology in 2009. Clearcast® was developed by BASF, and is now manufactured by SePro Products. Clearcast® was developed for submerged aquatic and wetland invasive and nuisance plant species with selective control of Chinese tallow tree in mixed hardwood/pine stands. In March of 2008, it received federal section 3 labeling. Clearcast® has no restrictions on fishing, swimming, and has exemption status from the US EPA. Clearcast® has not shown to impact important native species such as oak species (live, nuttall, water and willow), red maple, hickories, red mulberry, pecan, loblolly pine, sugarberry, southern red cedar, Baccharis, elm, hackberry, green ash and wax myrtle. Sensitivity such as leaf burning and browning can occur on species such as black cherry, hawthorn, sumac, sweetgum, willow, with full recovery.

Nu-Film:

Nu-Film is manufactured by Miller Chemical and Fertilizer Corporation. Nu-Film is a sticking agent that works with industrial herbicides that holds to foliage and reduces runoff after rainfall.

Bulls Eye Marking Dye:

Bulls Eye Marking Dye is a product that allows for thorough application of herbicide by providing a visual indicator of application.

Red River 90:

Red River 90 is a surfactant that is used for forestry, rights of way, utility, roadside, aquatic, agriculture and turf markets.

SUN-SPOT:
SUN-SPOT is used with industrial herbicides to form a sticky, elastic film that holds the herbicide on the plant foliage when applied by air or ground application. SUN-SPOT reduces the effects of ultra-violet light allowing for more effective herbicide by reducing herbicide degradation and increasing translocation.

Map 2 shows the geographic representation of the number of herbicide treatment days by stand level from 2006 through 2009. Data on herbicide treatments prior to 2006 were not on record at the Parris Island Natural Resource office so they are not included in this analysis. All herbicides that were applied are included in this map. The majority of the herbicide treatments occurred in the area surrounding Page Field. Page Field is highly utilized by marine recruit training with a high level of disturbance, and was the number one priority as designated by IPC.

Clearcast® retreatment at the forest stand level began in 2009 (Map 3), and as of the survey period appeared to have high mortality in treatment areas.
Map 2: Number of herbicide treatment days from 2006 to 2009.
Map 3: Clearcast® treatment stands in 2009.
Number of forest stands having herbicide treatment from 2006-2009 are shown in Table 1.

Table 1: Number of forest stands with herbicide treatment from 2006-2009

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Garlon® 4</th>
<th>Garlon® 3A</th>
<th>Imazapyr E-Pro</th>
<th>Accord®</th>
<th>Arsenal®</th>
<th>Clearcast®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Treated</td>
<td>22</td>
<td>26</td>
<td>10</td>
<td>5</td>
<td>32</td>
<td>11</td>
</tr>
<tr>
<td>Forest Stands</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IV. 2010 Survey of Invasive Species

a. Survey Methods

The invasive species survey for Parris Island Marine Corps Base was performed using a stratified, systematic random sample method of targeted transects through forest stands and along right of ways. This method required traveling the forest stand perimeters with transect lines perpendicular to the perimeter occurring approximately every 135 feet using pacing (Figure 1). Invasive species occurrences were recorded within approximately 20 feet of each transect line. Transect methods provide the most effective logistical survey of invasive species [32]. Invasive species found along the perimeter of the forest stand were also recorded. Transects would occur perpendicularly through the stand until the opposite side of the stand was reached in which the paced distance occurred along the opposite side perimeter.

Occurrences and populations were recorded using a Trimble Juno GPS device with

Figure 1: Example of survey methodology
ArcPad 7.1 (ESRI) and Weed Information Management System v. 3.0 (WIMS 3) software applications. WIMS 3 was created by The Nature Conservancy (TNC) as a Microsoft Access-based database for the purpose of managing invasive species data and mapping. The program allows for the mapping of invasive species occurrences as GPS point and polygon locations. Data outputs can be created for ArcGIS, Microsoft Excel, as well as charts and graphs created within the program.

Weed occurrences on Parris Island were mapped following the North American Invasive Plant Mapping Standards created by the North American Weed Management Association (NAWMA). These standards have been adopted by the United States National Park Service, U.S. Forest Service, U.S. Fish and Wildlife Service, Bureau of Land Management, and the U.S. Geological Survey. These standards were created to insure compatible information sharing among levels of management and agencies. The following basic standards were recorded of all invasive species occurrences: collection date, examiner (individual who collected the information), scientific name, common name, PLANTS database code (United States Department of Agriculture), infested area and unit of measure, land ownership, and location (UTM). Additional information not required for the NAWMA were recorded for the purposes of understanding the population dynamics, levels of infestation, management implications and priorities, and review of the effectiveness of the previous herbicide treatments.

Because Chinese tallow has been primarily targeted for control and is the species with the highest level of impact on Parris Island, individual occurrences were recorded with additional information regarding size and distribution. The following additional characteristics were recorded: seedling (less than 4.5 feet tall), number of seedlings (two or more seedlings per square meter), sapling (greater than 4.5 feet tall, less than 2 inches in DBH), number of saplings (two or
more saplings per square meter), advance regeneration (stump sprouts, root sprouts, stem sprouts), and mature tree sizes were recorded by DBH using an ocular measurement to the nearest inch. Advance regeneration recordings were taken for the purpose of determining herbicide effectiveness at the individual tree level. With this information, inference can be made at the stand level given all the data points taken. Management can also use this detailed point information to target specific individuals for immediate eradication.

b. GIS Methods

In order to determine the level of management necessary for control on Chinese tallow, information was recorded on location for individual occurrences. This allows for the analysis of the population by stand level using ArcGIS. Recorded data on life stage of Chinese tallow was translated into a numerical ranking by level of management priority. Mature trees with the ability to produce a high number of propagules are given a higher ranking for management, and should be targeted for immediate control efforts to reduce the likelihood of spread. The lower the representative ranking of the occurrence, the lower the management priority level based on the ability to reproduce. The following ranking system was applied to each recorded occurrence (Table 2):
Table 2: Ranking of Chinese tallow for GIS analysis

<table>
<thead>
<tr>
<th>Rank</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Seedling (Less than 4.5 feet tall)</td>
</tr>
<tr>
<td>2</td>
<td>Seedlings (The occurrence of more than 1 seedling per square meter)</td>
</tr>
<tr>
<td>3</td>
<td>Sapling (Greater than 4.5 feet tall, less than 2 inches in DBH)</td>
</tr>
<tr>
<td>4</td>
<td>Saplings (The occurrence of more than 1 sapling per square meter)</td>
</tr>
<tr>
<td>5</td>
<td>Advance Regeneration (Stump/stem/root sprouts)</td>
</tr>
<tr>
<td>6</td>
<td>Tree DBH 2-4 inches</td>
</tr>
<tr>
<td>7</td>
<td>Tree DBH 5 + inches</td>
</tr>
</tbody>
</table>

This visualization produces a map of Parris Island MCRD giving an overview of the population dynamics of Chinese tallow (Map 4).
Map 4: Ranked Chinese tallow point occurrences in 2010 survey
In order to make inference regarding the level of management by stand level, using ArcGIS the forest stand layer was spatially joined to the weighted Chinese tallow occurrence data. The spatial join calculated the average weighted point occurrences for the stand. The average by stand level was then ranked to determine level of management priority. The higher the average is to 7 (tree greater than 4 inches in DBH) the higher the management priority for the stand (Map 5).
Map 5: Management priority areas for Chinese tallow in the 2010 survey
c. Survey Results

The 2010 survey Of Parris Island MCRD was begun May 3rd and ended on July 17th. The completed survey collected 6,585 individual point occurrences, 59 polygon occurrences, and 12 line occurrences. NNIS that were documented included mimosa (*Albizia julibrissin*), autumn olive (*Elaeagnus umbellata*), glossy privet (*Ligustrum lucidum*), Chinese privet (*Ligustrum sinense*), honeysuckle (*Lonicera japonica*), Chinaberry (*Melia azedarach*), golden bamboo (*Phyllostachys aurea*), and tamarisk/saltcedar (*Tamarix ramosissima*) (Map6). The species with the largest occurrence and distribution was Chinese tallow (*Triadica sebifera*).
Map 6: Non-Chinese tallow invasive species occurrences from 2010 survey.
Mimosa (*Albizia julibrissin*) was found in three locations, with six individual point occurrences recorded on Parris Island MCRD. Its population size is not high for management priority; however there is the ability to target this species before it spreads to other locations and increases in abundance. Mimosa was found on 3rd Battalion Pond Road causeway as a single mature occurrence. Occurrences were also recorded on the Legends Golf Course next to the main building, on the firing range, and on Elliot’s Beach. These occurrences should be quickly targeted, and the species should be included in an EDRR program.

Autumn olive (*Elaeagnus pungens*) was recorded as five individual point occurrences, and 2 recorded polygon occurrences (0.05 total acres) on the Legends Golf Course next to the main building growing along the wooded edge, growing as a planted occurrence in Mainside, and along the edge of forest stand 60. Autumn olive should be quickly targeted as infestations could be easily managed, and the species should be included in an EDRR program.

Glossy privet (*Ligustrum japonicum*) was recorded as a large mature single occurrence in the wooded area along the sanitary landfill. Glossy privet has been categorized as a Category I species by the Florida Exotic Pest Council, and should be targeted immediately for management and included in an EDRR program. Florida considers a Category I species as an NNIS, “that are altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives” [6].

Chinese privet (*Ligustrum sinense*) was recorded with 128 individual point occurrences, 5 recorded polygon occurrences (1.86 total acres), and one recorded line occurrence. Locations include Legends Golf Course, forest stands: 3, 8, 9, 12, 13, 14, 25, 27, 33, 35, 38, 42, 43, 44, 45, 47, 49, 51, 52, 65, 157, 159, 170, and 173(Map 7). Chinese privet is considered a high priority species due to its abundance and ability to spread. Chinese privet is moderately salt tolerant and
will only have restricted growth in areas with direct salt spray. The majority of the Chinese privet infestations occurred along right-of-ways and on the exterior of forest stands. However, some minor populations did occur within the forest stands. Large stemmed individuals that should be targeted for immediate control were found within Page Field.
Map 7: Chinese privet management areas by stand level in 2010 survey.
Japanese honeysuckle (*Lonicera japonica*) was found throughout Parris Island MCRD; however occurrences were only recorded if they were having a significant impact on native vegetation. There were 24 recorded occurrences of Japanese honeysuckle. Areas with significant occurrences include: areas along Legends Golf Course, and forest stands: 3, 6, 7, 35, 38, 45, 123, 139, and 140.

Chinaberry (*Melia azedarach*) was recorded with 101 individual point occurrences, and four recorded polygons occurrences (3.24 total acres). Due to its infestation size and multiple population occurrences, Chinaberry should be targeted as a high priority for ongoing management. Areas with recorded occurrences include: the firing range, along roadsides, Legends Golf Course, forest stands: 2, 3, 9, 10, 12, 13, 25, 38, 53, 90, 91, 93, 118, 121, 147, and 157. High priority management areas for Chinaberry include forest stands 2, 3, 90 and 91 (Map8).
Map 8: Chinaberry management areas by stand level in 2010 survey.
Golden bamboo was recorded in two locations as two point occurrences and one polygon occurrence (0.03 acres), at Legends Golf Course along the main buildings and in forest stands 104. The infested locations are small and can be easily controlled by Parris Island MCRD maintenance crews. Golden bamboo should also be included on an EDRR program.

There were 34 recorded individual point occurrences of tamarisk (*Tamarisk ramosisima*), nine recorded polygon occurrences (41.23 total acres), and eight recorded line occurrences. Tamarisk or saltcedar is predominantly found along the causeways as it was planted there to prevent erosion. However, occurrences were found on the island off of Page Field, at the Ribaut monument, in forest stands 2 and 173, and in a marsh area on the backside of the old trailer park.

V. **Review of Effectiveness of Past Treatment Methods**

Map 9 represents the previous management priority survey data for Chinese tallow were complied in 2001 by IPC (*left*), the number of herbicide treatment days from 2006-2009 that was recorded by IPC (*center*) and the current management priority areas as surveyed in 2010 (*right*). Stands selected for treatment occurred primarily around Page Field, a significant recruit training area. Treatment areas along the eastern portion of Page Field that received six treatment days remain at a low priority in 2010 as they did in 2001. The southern portion of Page Field had a range of 1 to 7 treatment days with an increase in Chinese tallow management priority in areas with 4 or fewer treatment days. Forest stands along the western portion of Page Field received significant herbicide treatments with varied results. Results ranged from a reduction in management priority, suppression to historical 2001 levels, and an increase in management priority.
Chinese tallow without effective removal can result in greater density than non-treatment areas due to its ability to root, stem and stump sprout prolifically. There is notable re-sprouting of Chinese tallow in several treatment stands. There is evidence of mortality failure on Chinese tallow individuals where the hack and squirt method of herbicide application resulted in significant stump and stem sprouts. Unfortunately, these individuals still have the same reproductive capability as the original stem.

Map 10 shows the forest stands that have evidence of advance regeneration (stump, stem and root sprouts) following herbicide.
Map 10: Forest stands that have presence of advance regeneration (yellow) that were treated with herbicide from 2006-2009
Chinaberry was documented on the contractor data sheets with herbicide treatments in the following forest stands: 115, 147, 148, 149, and 151. Stands 147 and 157 were recorded with of Chinaberry in the 2010 survey.

Chinese privet was documented on the contractor data sheets with herbicide treatments in the following forest stands: 147, 148, 149, and 151. However, Chinese privet was not documented in the 2010 survey in forest stands that were recorded with herbicide treatments. The herbicide treatments on Chinese privet appear to have been effective in the stands that were treated.
VI. Recommendations for Management

For the effective management of NNIS populations, plans must be long-term and approached holistically. Treatment as an annual maintenance issue will generally perpetuate the target populations, and may even increase the vigor or spread of certain species [18]. Such short term applications will need to be repeated indefinitely. The management of NNIS must be prioritized due to budgetary, time and resource constraints. Prioritizations must concentrate on controlling those species having the largest impact on recruit training and natural ecological processes. Only a small portion of NNIS cause significant impacts. The prevention of NNIS is the most cost effective means of reducing invasions, it is however difficult to control across the landscape. Aggressive NNIS that are able to establish in undisturbed locations due to certain traits such as shade tolerance or alleopathy (i.e. Chinese tallow) require management which is equally as aggressive to prevent spread and persistence in the landscape [18].

The management of NNIS can be prioritized in several ways including focusing on managing areas with the largest populations, focusing on high quality habitats that are high risk for invasion or by concentrating on areas that are able to produce a high number of propagules contributing to the infestation. The infestation of Chinese tallow on Parris Island MCRD is severe enough that priorities must be made to concentrate management efforts. Management methods must be long-term to reduce NNIS seedbank for the promotion of native species. There was only one high quality natural area of note that management should be focused to prevent infestation. Forest stand 45 (center of stand) on Chicken Farm Road should be prioritized for early detection and rapid response (EDRR) because of its unique, high quality maritime forest habitat that is surrounded by high density Chinese tallow in forest stands 38, 41, 42, 44, and 49. Due to the intensity of Chinese tallow on the rest of the island, management efforts should be
made on forest stands where trees readily have the ability to produce propagules. With the
detailed point occurrence information provided by the 2010 survey, management could focus on
areas that there are trees greater than 4 inches. Consideration of prioritization should also be
made regarding Chinese tallow’s ability to produce seed in three years.

Parris Island MCRD may want to consider an active education program that involves the
land management workers and the resident community. Land management workers, either
civilian or military may be able to provide assistance in recognizing problems and identifying
unknown populations. By educating the resident community at Parris Island MCRD, volunteer
programs could be established as well as an increase in awareness and public support for control
programs. The Department of Defense has an online Invasive Species Outreach Toolkit available
for its managers (http://www.dodinvasives.org/). The U.S. Fish and Wildlife Service havealso
produced a website to aid in incorporating volunteers in to NNIS control and management

Biocontrol might be an effective form of invasive species management. It can be a long-
term management option that requires minimal labor and funding. The three categories of
biocontrol for NNIS include classical, and conservation, augmentation or inundation. Classical
biocontrol methods introduce a control agent that is native to the pest’s natural habitat.
Conservation method of biocontrol promotes the existing populations (native or non-native) that
could control the NNIS population. Inundation or augmentation is mass releases of control
agents already present that will target NNIS populations but that are not currently in adequate
numbers to control the NNIS. The use of abiocontrol is quite controversial, and classical
biocontrol releases could have unintended consequences on non-target species. These methods of
control require long intensive studies and may not have the desired effects on NNIS for many years, and for these reasons, they will not be considered for the purposes of this report.

Prescribed fire can achieve multiple management goals including the control of NNIS populations. Prescribed fire has the potential to control certain NNIS, restore natural disturbance regimes, reduce fuel loads, promote native vegetation, and increase training mobility in forest stands. Prescribed fire may not be applicable in all areas due to its impact on human residents or physical structures as well as certain requirements that must be met to effectively and safely prescribe a fire.

Parris Island MCRD is a maritime forest with the following historically occurring native tree species: live oak (*Quercus virginiana*), laurel oak (*Quercus laurifolia*), loblolly pine (*Pinus taeda*), and slash pine (*Pinus elliottii*). The live oak forest occurs in a mosaic of vegetation types. Where saline levels are high the maritime forest becomes dominated by palmettos. In fresh water wetlands the maritime forest contains blackgum (*Nyssa sylvatica*). Dryer sites are nearly pure live oak stands on exposed salt spray sand dunes. The maritime forest as classified by the U.S. Forest Service is a Fire Regime Group I, with frequent, light surface fires [13]. The Mean Fire Return Interval ranges from 2-26 years depending on topography and ignition source. Frequent fire areas, with a return interval of 2 to 5 years, have a bi-level structure with a nearly closed canopy level with a moderately developed grass layer. Less frequent fire interval areas of the maritime forest, with an interval of 5 to 7 years, typically have a shrub layer dominated by yaupon (*Ilex vomitoria*)[13]. Fire suppression in maritime forests may have helped lead to dense, multi-storied woody vegetation including the invasion of Chinese tallow. Re-introduction of a prescribed fire regime may help to promote native vegetation, reduce Chinese tallow and other NNIS impacts, and improve training conditions.
Fire can be used as an integrated part to NNIS management. Fire has been shown to be effective after herbicide treatments to reduce dead woody vegetation and stimulate native growth. Fire may also be used between herbicide treatments and serve as an additional method of control. In stands with high Chinese tallow, density mechanical treatment may be necessary to increase woody debris to perpetuate the ability of a prescribed fire to burn.

The restoration of native fast growing plant communities is an integral component to a comprehensive NNIS prevention and control program [27], and is often overlooked. Fast growing native vegetation may help to out-compete NNIS populations especially when the native vegetation is planted and given a head start.

The following section will describe by priority the species options for management for Parris Island MCRD. Methods of control may depend on vegetation characteristics of native and NNIS populations, and specifics will be given on recommended control types.

VII. Biological Characteristics and Recommendations for control

**Chinese tallow** (*Triadicaeberifera*)

**Biological Characteristics:**

Chinese tallow is a fast growing, highly successful invasive tree, with high fecundity (producing up to 100,000 seeds at maturity) and a broad ecological tolerance. It is believed that tallow is relatively short-lived, less than 100 years, with roots having the ability to live longer [21]. Once it is naturalized, Chinese tallow can form monotypic woodlands that result in little or no woody vegetation in the understory [4]. When damaged, tallow is able to reproduce vegetatively by root and stump sprouts. Chinese tallow flowers from April to June in the southeastern US with fruit production occurring from August through January [25] [29]. It can
start to reproduce when only three feet tall [14]. Chinese tallow may have a persistent soil seedbank [16]. Distribution of Chinese tallow is primarily restricted by frigid and/or arid conditions [22]. Dispersal of Chinese tallow seeds may be the greatest limiting factor to distribution where low temperatures are not extreme enough to inhibit growth and establishment [23].

Chinese tallow may promote its own growth through fast nutrient cycling resulting from large annual litter fall and rapid decomposition [8]. However, some chemicals resulting from decomposition may have inhibited the germination and seedling growth of loblolly pine [17]. Studies have detected tannins and other potentially allelopathic chemicals in Chinese tallow leaves and bark [7] [46] and its leaves are toxic to domesticated herbivores [33].

Previous studies on Chinese tallow have focused on the potential invasiveness and competitive ability, the ecotype differences between invasive and native host range plants, and the potential allelopathic effects on other plant species. Although a few studies have been conducted directly towards the control of Chinese tallow infestations, these studies have primarily focused on effects of individual treatments such as fire, herbicide or biological control agents. Integrated management methods have not been formally tested and reported. Moreover, most studies were conducted in Gulf Coastal prairies [4] [3]. We know little on how Chinese tallow invasion affects native plant communities and which control methods are most effective in terms of their efficacy and adverse impact on native plants in coastal forests.

Studies on prescribed fires in coastal prairie ecosystems indicated that growing season burns achieved a better control of Chinese tallow with greater long-term impacts and a weaker recovery of individuals than dormant season burns [15] [16]. All seedlings of Chinese tallow less than 4 inches (10cm) tall and 40% of seedlings between 4 inches and 3 feet (10 cm to 1 m) tall
were killed while larger Chinese tallow trees typically survive fire or re-sprout from underground parts after fire [15]. Prescribed burns appear to reduce germination probability of Chinese tallow [4]. However, established Chinese tallow stands can suppress herbaceous vegetation, and thus reduce the necessary fuels needed to carry a fire [15] [16]. As a result, other methods of control (e.g., mechanical or chemical) become necessary. For example, mowing at one to three year intervals has proven effective for maintaining native prairie vegetation in southern Texas [20]. Mulching may reduce seed germination and vegetative sprouting from roots and stumps. Mulch depths of little as 5 cm damped diurnal soil temperatures and significantly reduced Chinese tallow seedling emergence [11].

Methods Available for Chinese Tallow Control:
SeProaquatics and horticultural products manufacture recommends the following herbicide treatment they manufacture for the treatment of Chinese tallow (information taken from manufacture’s published literature):

- Foliar application with backpack sprayer: 2% v/v Clearcast® + MSO 1% v/v with 100% coverage
- Hack and squirt: 50% v/v Clearcast® with water and blue dye marker with a hack every 2 inches
- Frill and girdle: Clearcast® 50% with water carrier and blue dye marker. Girdled at breast height with the exposed cambium treated.
- Cut stump: Clearcast® 50% v/v with water carrier and blue dye marker to be treated immediately after cutting
Dow AgroSciences recommends any one of the following herbicide treatments they manufacture for the treatment of Chinese tallow (information taken from manufacture’s published literature):

Foliar Treatments (spray to wet, application should occur between full leaf and October)

- Application of a mixture of 5 percent to 8 percent Milestone® VM Plus specialty herbicide and 1 percent surfactant
- Application of a mixture of 2.5 percent Garlon® 4 Ultra specialty herbicide or 1.5 percent Forestry Garlon XRT and 1 percent surfactant
- Application of a mixture of 2.5 percent Accord® XRT II herbicide and 1.5 percent Arsenal® herbicide. (Arsenal® cannot be used where desired hardwood species are present)
- Application of a mixture of 2.5 percent Accord® Concentrate, 025 percent Arsenal® AC, and 1 percent surfactant
- Application of a mixture of 5 percent Accord® Concentrate and 1 percent surfactant in wetland areas, or where no soil residual activity is desired

Low-volume Basal Treatments (lower density infestations, selective)

- Garlon® 4 for basal applications on Chinese tallow trees that are less than 6 inches in DBH
- Application of 20 percent to 25 percent Garlon® 4 Ultra in commercially available basal oil, using a backpack sprayer using low pressure (20 psi)
  - Spray from the groundline to 12 to 15 inches above the groundline in a solid band around the trunk
  - On multiple stemmed trees basal application must be applied to all stems
• Pathfinder® 2 specialty herbicide is a ready-to-use basal formulation which does not require mixing

• Annual follow up should allow for maximum growth the following growing season before re-application. Re-growth or any sprouting maybe slowed from herbicide applications made the previous year.

Cut-stump Treatments (lower density infestations, selective)

• Application of a mixture of 50 percent Garlon® 3A with water

• Application of Milestone VM Plus undiluted

• Application of a mixture of 20 percent to 25 percent Garlon® 4 Ultra in commercially available basal oil

• Cut stem as close to the ground as possible, apply immediately in a complete circle where the inner stem contacts the bark

• On larger stumps, the outer 2 inches should have herbicide applied

DuPont recommends the following herbicide treatment they manufacture for the treatment of Chinese tallow (information taken from manufacture’s published literature):

Foliar (aerial or ground application), Invert (emulsion) application systems, or cut stump (best results with a quality adjuvant):

• Application of a mixture of 25 ounces per acre Lineage™ Clearstand™ with water
Recommendations for Chinese Tallow Control for Parris Island MCRD

The level of infestation for Chinese tallow at Parris Island MCRD is at such a severe level that the current management using only ground crew application of herbicide appears to be ineffectual and may in turn be increasing the number stems per acre.

The recommendation for a species as aggressive as Chinese tallow requires aggressive management for control. The following recommendations have not been scientifically reviewed or studied, but they represent the best available management approach.

1. Year 1 (spring treatment): Mechanical treatment using a Gyrotrac® to mulch Chinese tallow trees and felling of large individual Chinese tallow trees with a chainsaw, with immediate cut stump herbicide application. Mulched debris will remain on the ground and may help to reduce seedling and advance regeneration re-growth.

2. Year 1 (late summer treatment): Herbicide application to target Chinese tallow re-growth from seedlings or advance regeneration. A highly selective herbicide such as Clearcast® is recommended as it can be applied as a broadcast foliar application without impact on native vegetation.

3. Year 2: Follow up herbicide application on any re-growth.

4. Year 3 (spring treatment): Application of a prescribed fire. The year 1 mechanical treatment resulting in ground layer mulch should be reduced and dry enough that it can carry a prescribed fire. A continued prescribed fire regime (every 3 to 4 years) should help to reduce Chinese tallow seedling and advance regeneration growth due to its poor ability to survive fire at early life stages.
**Chinaberry (Melia azedarach)**

**Biological Characteristics:**

Chinaberry is a prolific seed producer, is fast growing [6], with the ability to begin flowering in the seedling stage at three to four years of age [42] [9]. Seed dispersal occurs by animals, gravity and possibly water. Chinaberry likely has a short term seedbank. When above ground portions are damaged Chinaberry is able to produce sprouts by roots [37], or from stump sprouts [37] [1]. Chinaberry trees that are produced from vegetative sprouts may grow faster and reproduce earlier than trees that are produced from seed.

**Methods Available for Chinaberry Control:**

DuPont recommends the following for the treatment of Chinaberry (information taken from manufacture’s published literature):

Foliar (aerial or ground application), Invert (emulsion) application systems, or cut stump (best results with a quality adjuvant):

- Application of a mixture of 25 ounces per acre Lineage™ Clearstand™ with water

  Mechanical methods of treatment alone are not recommended for management due to Chinaberry’s ability to produce numerous root and stem sprouts.

  Herbicides such as a glyphosate or tricloyr would be effective for hack and squirt, girdle and frill or cut stump treatments.

**Recommendations for Chinaberry Control for Parris Island MCRD**

Chinaberry primarily occurs along with Chinese tallow and Chinese privet in heavily impacted NNIS stands. These stands should be managed as an entirety with all species targeted for control. Mechanical felling of the larger trees coupled with cut stump herbicide application is
recommended to remove the seed producing trees and to reduce the chance of hack and squirt failure. Smaller diameter individuals could be controlled with foliar or hack and squirt methods of herbicide applications.

**Tamarisk/Saltcedar** *(Tamarix ramosissima)*

**Biological Characteristics:**

Tamarisk creates very dense, impenetrable thickets along the planted causeways of Parris Island MCRD. Tamarisk can lower the water table and increase salinity of the upper soil levels due to its high water consumption.

Tamarisk may be able to flower within their first year of growth [41], with most beginning to flower in three growing seasons [35]. Seed dispersal occurs shortly after flowering from March to October [10]. Seeds are readily dispersed by the wind and water [35]. Tamarisk can produce seed throughout the growing season with increased fecundity when stressed or damaged [19]. Tamarisk seeds are short-lived and do not form a persistent seedbank [35]. Seeds can remain viable for up to 45 days in ideal conditions or for as little as 24 days when fully exposed to full sunlight and dry conditions [47].

**Methods Available for Tamarisk Control:**

Tamarisk is easily able to resprout after fire, making prescribed fire not an option for control. SePro recommends any one of the following herbicide treatments they manufacture for the treatment of tamarisk/saltcedar (information taken from manufacture’s published literature):

- Foliar application (non-selective): 64oz/A Habitat® + 32oz/A AquaPro (glyphosate) + 2qts/A MSO applied in the fall
Dow AgroSciences recommends any one of the following herbicide treatments they manufacture for the treatment of tamarisk/saltcedar (information taken from manufacture’s published literature):

Cut-stump application (Table 3) (immediate application, after 1 hour must apply an application of Garlon® 4 Ultra or Remedy® Ultra with an oil carrier)

Table 3: Cut-stump applications for Dow AgroSciences herbicides

<table>
<thead>
<tr>
<th>Product</th>
<th>Rate</th>
<th>Amount of product for 1 gallon mix</th>
<th>Amount of product for 3 gallon mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garlon® 3A</td>
<td>50% v/v in water</td>
<td>2 quarts</td>
<td>6 quarts</td>
</tr>
<tr>
<td>Garlon® 4 Ultra</td>
<td>50% v/v in water or oil</td>
<td>2 quarts</td>
<td>6 quarts</td>
</tr>
<tr>
<td>Remedy® Ultra</td>
<td>50% v/v in water or oil</td>
<td>1.2 quarts</td>
<td>3.6 quarts</td>
</tr>
</tbody>
</table>

Basal bark application (Table 4) (year round application, except when bark is wet, frozen or frost is present on the stem)

Table 4: Basal bark applications for Dow AgroSciences herbicides

<table>
<thead>
<tr>
<th>Product</th>
<th>Rate (oil as carrier)</th>
<th>Amount of product for 1 gallon mix</th>
<th>Amount of product for 3 gallon mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garlon® 4 Ultra</td>
<td>25% v/v</td>
<td>1 quart</td>
<td>3 quarts</td>
</tr>
<tr>
<td>Garlon® 4 Ultra</td>
<td>30% v/v</td>
<td>1.3 quarts</td>
<td>4 quarts</td>
</tr>
<tr>
<td>Remedy® Ultra</td>
<td>25% v/v</td>
<td>1 quarts</td>
<td>3 quarts</td>
</tr>
<tr>
<td>Remedy® Ultra</td>
<td>30% v/v</td>
<td>1.2 quarts</td>
<td>3.6 quarts</td>
</tr>
</tbody>
</table>
Foliar individual plant treatments (Table 5) (will damage non-target species, nonionic surfactant should be added at the rate of 0.25% v/v)

Table 5: Foliar application for Dow AgroSciences herbicides

<table>
<thead>
<tr>
<th>Product</th>
<th>Rate</th>
<th>Amount of product for 1 gallon mix</th>
<th>Amount of product for 3 gallon mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rodeo®</td>
<td>0.50% v/v</td>
<td>0.66 ounces</td>
<td>2 ounces</td>
</tr>
<tr>
<td>Arsenal®</td>
<td>0.50% v/v</td>
<td>0.66 ounces</td>
<td>2 ounces</td>
</tr>
</tbody>
</table>

DuPont recommends the following herbicide treatment they manufacture for the treatment of tamarisk (information taken from manufacture’s published literature):

Foliar (aerial or ground application), Invert (emulsion) application systems, or cut stump (best results with a quality adjuvant):

- Application of a mixture of 25 ounces per acre Lineage™ Clearstand™ with water

Recommendations for Tamarisk Control for Parris Island MCRD

Tamarisk was planted along the causeways to prevent erosion. Because of this it is necessary to re-plant fast growing, salt tolerant, native vegetation to replace the tamarisk after treatment. Recommended plants such as yaupon (*Ilex vomitoria*), waxmyrtle (*Morella cerifera*), and/or baccharis (*Baccharishalimifolia*) are native plants that would easily provide erosion control. Tamarisk should be targeted in the fall with a foliar herbicide with native vegetation planted in the early spring.
Chinese/Japanese privet (*Ligustrum spp.*)

**Biological Characteristics:**

Chinese privet and Japanese privet are an evergreen to semi-evergreen shrubs that are one of the most widespread NNIS in the Southeastern United States. Because it is so prevalent, controlling privet is difficult due to the magnitude of available seed source. It is able to form dense, impenetrable thickets which crowd out native vegetation and impede recruit training.

Chinese privet (*Ligustrum sinense*) produces 1-2 seeds per fruit, with Japanese privet (*Ligustrum japonicum*) only having one seed per fruit [39]. Mature privet trees can produce hundreds of fruit per year [2], with dispersal occurring from September to November in the Carolinas [29]. Seed dispersal typically occurs by wildlife, especially birds. Neither Chinese nor Japanese privets form seedbanks, with germination occurring in the first growing season following dispersal [28] [34]. Privets are able to reproduce asexual regeneration by root and stump sprouts [2] [38].

**Methods Available for Privet Control:**

Chinese privet can readily establish after fire. However, on some sites, repeated prescribed fire maybe able to control Chinese privet.

Dow AgroSciences recommends any one of the following herbicide treatments they for Chinese privet (information taken from manufacture’s published literature):

**Foliar Treatments:**

- Application of a mixture of 2 percent Accord® XRT II in a solution of water in a high-volume spray (spray-to-wet)
• Application of a mixture of 4 percent Accord® XRT II in a solution of water in a low-volume spray (spray-to-cover)

Low-volume Basal Treatments (low density infestations, selective):

• Stem should be less than 6 inches in DBH, and bark must be dry

• Application of a mixture of 20 percent to 25 percent Garlon® 4 Ultra in commercially available basal oil

• Application of 20 percent to 25 percent Garlon 4 Ultra in commercially available basal oil, using a backpack sprayer using low pressure (20 psi)
  
  o Spray from the groundline to 12 to 15 inches above the groundline in a solid band around the trunk
  
  o On multiple stemmed trees basal application must be applied to all stems

• Pathfinder® 2 specialty herbicide is a ready-to-use basal formulation which does not require mixing

• Annual follow up should allow for maximum growth the following growing season before re-application. Re-growth or any sprouting maybe slowed from herbicide applications made the previous year.

Cut-stump Treatments

• Application of a mixture of 50 percent Garlon® 3A with water

• Application of a mixture of 20 percent to 25 percent Garlon® 4 Ultra in commercially available basal oil
  
  o Advantage for treatments not immediately treated: Garlon® 4 Ultra specialty herbicide is an oil mix that enters the vascular system of the plant instead of through active movement that is necessary with Garlon® 3A
• Application of 50 percent Accord® XRT II with water
  o Not as effective as Garlon products for cut-stump applications

DuPont recommends the following herbicide treatment they manufacture for the treatment of Chinese privet (information taken from manufacture’s published literature):
Foliar (aerial or ground application), Invert (emulsion) application systems, or cut stump (best results with a quality adjuvant):
  • Application of a mixture of 25 ounces per acre Lineage™ Clearstand™ with water

**Recommendations for Privet Control for Parris Island MCRD**

Chinese privet on Parris Island MCRD is primarily in localized populations that could be managed if prioritized separately from the other NNIS populations. A dormant season foliar application of a glyphosate herbicide and water mix is recommended because selectivity from desired species since it is evergreen to semi-evergreen.
VIII. Acknowledgements

I would personally like to thank the United States Marine Corps via the United States Army Corps of Engineers for funding this project. Dr. Pat Layton and Dr. Vic Shelburne are deeply appreciated for their guidance on this project. The staff at Parris Island Natural Resources and Environmental Affairs Office, particularly John Holloway Jr. and Ron Kinlaw, were exceptionally supportive and were essential to the thoroughness of this report. Michael Broom and Tyler Jones provided some assistance in the field work. Tyler Brown and Dr. Larry Gering provided technical assistance with GPS and GIS software. Dr. Geoff Wang, Dr. Tom Waldrop, and Dr. Joan Walker helped to provide management and silvicultural recommendations. I would also like to thank Todd Horton from SePro who supplied technical assistance on SePro products (Clearcast® and Habitat®), and Charles Kemp from Marshfield Forest who provided a tour of herbicide treatments areas on Bulls Island, South Carolina.

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IX. References


