U.S. Fish and Wildlife Service
U.S. Department of the Interior

National Wildlife Refuge System

Regional Protocol Framework for the Inventory of Invasive Plants

North Atlantic-Appalachian Region

Version 0.9 **JANUARY 2021**

ON THE COVER
Oriental bittersweet (*Celastrus orbiculatus*) wrapping around quaking aspen (*Populus tremuloides*)
Photograph by: Nathan Bush

NWRS Survey Protocol Signature Page

Protocol Title: Regional Protocol Framework for the Inventory of Invasive Plants	
Version[1]: 0.9	
Station Name: [1]North Atlantic-Appalachian Region, Division of Natural Resource and Conservation Planning, [2]Stewart B. McKinney National Wildlife Refuge, [3]Back Bay National Wildlife Refuge, [4]Mississquoi National Wildlife Refuge	**Authors and Affiliations** [1]Nathan Bush, USFWS [1]Rachel Katz, USFWS [1]Laura Eaton, USFWS [2]Kris Vagos, USFWS [3]Lauren Mowbray, USFWS [4]Ken Sturm, USFWS

Approvals

Action	Appropriate Signature/Name	Date
Survey coordinator[2] Submitted by:	Nathan Bush	
Zone I&M[3] or equivalent Approval:		
Regional I&M[4] Approval:	Troy Wilson	
National I&M[5] Approval:		

Version[1]	Date	Author	Change Made	Reason for Change

[1] Version is a decimal number with the number left of decimal place indicating the number of times this protocol has been approved (e.g., first approved version is 1.0.; prior to first approval all versions are 0.*x*; after first approval, all minor changes are indicated as version 1. *x* until the second approval and signature, which establishes version 2.0, and so on). Only two signatures are required: one from the submitter (lead author)[2] one from the approving official, which is dictated by the scope of the protocol[3,4,5].

[2] Signature of station or I&M representative designated lead in development of a site-specific survey protocol.

[3] Signature signifies approval of a site-specific survey protocol.

[4] Signature by Regional I&M Coordinator signifies approval of a protocol framework to be used at multiple stations within a Region.

[5] Signature by National I&M Coordinator signifies approval of a protocol used at multiple stations from two or more Regions.

Summary

Invasive plant species affect more than 2.5 million acres of Department of Interior (DOI) U.S. Fish and Wildlife Service (USFWS) National Wildlife Refuge System (NWRS) lands, with managers ranking invasive plants one of the highest threats to achieving management objectives. A successful invasive management program requires several key elements, including baseline knowledge of the severity and location of invasive plant infestations, clear management objectives with species-specific targets, and ability to implement effective management strategies with continued monitoring. This regional protocol framework supports management by quantifying the baseline spatial distribution and infestation states of highest priority invasive plant species likely to threaten management objectives within priority habitats on Region 1 (IR1) North Atlantic-Appalachian Region (NAAR) USFWS NWRS lands.

The protocol framework provides standardized field methods and a regional data management system to facilitate conducting a rapid area search (census) to document current infestation states (e.g., percent cover categories) of target invasive plant species in highest priority areas selected by each refuge. Techniques described herein include identifying the appropriate sampling frame, creating a standardized grid for surveying, and using Environmental Systems Research Institute (Esri) ArcGIS Online (AGOL) and Collector application (with an iOS device) for data collection.

The inventory framework recommends selecting a subset of areas (e.g., habitats or management units) and target plants (e.g., 10 species) to inventory within 3-years based on the relative importance of invasive plants to achieving management objectives (e.g., native vegetation and Resource of Concern) and need for spatial information to implement management actions. Many refuges are too large to inventory all habitats and plants and some refuges may contain numerous non-native plants that are relatively innocuous and thus a low management priority. The framework suggests using the Invasive Plant Inventory and Early Detection Prioritization Tool (iPIP) and/or Invasive Plant Management Prioritization Tool (iPMP) to aid in selecting area and plants for inventory and associated management, respectively. If early detection, rapid response (EDRR) species are observed and treated during an inventory survey, management actions can also be recorded using this framework. The resulting spatially explicit data can be compiled for each refuge, across multiple refuges, or across all refuges to assess the extent of target invasive plants, aid in the development of strategic management targets and evaluation of strategies, and potentially lead to more specific monitoring surveys to evaluate management effectiveness as needed.

The content and structure of this protocol framework follows the USFWS's How to Develop Survey Protocols: A Handbook (Version 1.0) and the USFWS NWRS Protocol Template (Version 2.0). The eight elements addressed include: introduction, sampling design, field methods, data management and analysis, reporting, personnel requirements and training, operational requirements, and references. A series of standard operating procedures (SOPs) provide details on recommended methods and technical aspects of this protocol. This protocol framework and associated data management systems (AGOL, and USFWS Service Catalog) provide quick access to information by refuge biologists and managers, ensures long-term archives of survey information, and allows data to be integrated into national datasets (e.g., EDDMapS, FWSpecies). This protocol framework was developed as part of the USFWS NWRS

Inventory and Monitoring (I&M) Initiative. NAAR refuges are encouraged to use this protocol framework to develop site-specific surveys for conducting inventories and EDRR management. Although this protocol framework is to be used primarily by the NAAR's NWRS, the approach may be used by other DOI/USFWS regions and/or partners.

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We thank numerous Department of Interior North Atlantic-Appalachian Region (NAAR) U.S. Fish and Wildlife Service (USFWS) National Wildlife Refuge (NWR) staff for their engagement in developing and testing early versions of this protocol framework, including Stephanie Koch (Assabet River NWR), Kate O'Brien (Rachel Carson NWR), Kris Vagos (Stewart B. McKinney NWR) and Ken Sturm (Missisquoi NWR). These early adopters provided critical insights that informed the protocol's purpose and objectives, and greatly improved field and data collection methods. We acknowledge the foundational inventory surveys conducted at Assabet River NWR by Jeffrey Collins and Massachusetts's Audubon Society's Ecological Extension Service, which informed the development of infestation states used in this framework.

We are grateful to the numerous authors of the USFWS Midwest Regional Protocol Framework for the Inventory and Effectiveness Monitoring of Invasive Plants in Forests, which served as a foundation for this protocol framework. We especially thank Giselle Block (USFWS), Heather Olson (Utah State University) and Corey Ransom (Utah State University) for developing the Invasive Plant Inventory and Early Detection Prioritization Tool, as well as Jennifer Casey who lead the development of the Invasive Plant Management Prioritization Tool with the authors of this protocol framework (L. Eaton and R. Katz). These tools collectively assist refuges in selecting the sampling frame(s) (e.g. areas) and target invasive plants for inventory and provide a foundation for developing management strategies using inventory data.

We especially thank the data management network of the Division of Natural Resources and Conservation Planning, including Dave Zimmerman (USFWS) for providing a thoughtful review of the data management system, Erin King (USFWS) for assisting with organization of PRIMR and ServCat records, and Rick Schauffler (USFWS) for assisting with integration of resulting data with regional and national datasets. Thoughtful reviews by Scott Schwenk (Division of Natural Resource and Conservation Planning Chief), [insert Reviewer1], and [insert Reviewer2], and substantially improved this protocol framework.

Contents

Narrative

Element 1: Introduction

Background

Invasive plant species affect more than 2.5 million acres of Department of Interior (DOI) U.S. Fish and Wildlife Service (USFWS) National Wildlife Refuge System (NWRS) lands (USFWS 2013a). According to the National Invasive Species Management Strategy Team, managers ranked invasive plants as the highest threat to refuges, almost double of any other threat. Most refuges report that invasive plants interfere with their management objectives (USFWS 2003) and/or directly threaten habitat of federally or state threatened and endangered species. As a result, budgets for refuge staff to combat invasive species increased from $6 million in fiscal year 2004 to $15.8 million in fiscal year 2011 (USFWS 2013b), and increases are expected to continue to occur over the next decade. Although considered a top priority throughout the NWRS, there remains limited funding and staff to efficiently monitor and treat established infestations or prevent new infestations, and it is estimated that only about 10% of infested acres are treated annually (USFWS 2013a).

The Department of Interior North Atlantic-Appalachian Region (NAAR) NWRS protects a wide range of regionally significant ecosystems (e.g., salt marshes, beach and dunes, freshwater wetlands, mature upland forests, riverine bottomland forests, shrublands, and grasslands), with USFWS regional priorities focusing on connecting people with nature and implementing strategic conservation, including increasing aquatic connectivity, proactively conserving species and the habitats they depend on, and increasing coastal resiliency (USFWS 2016, USFWS 2019). Achieving these goals remains challenging because over half of refuges (37 of 76 stations) are located within or adjacent to large population centers and are repeatedly susceptible to invasion due to nearby high densities of roads, trails, waterways and other areas of increasing public access and visitation. As a result, refuges must consider managing multiple invasive plants across all stages of invasion (e.g., pre-arrival, invasion front, epidemic, and established) for long-term success.

Prevention, eradication, containment and long-term control are four main management strategies for invasive species and the selection of strategies depends on the extent of the area occupied by an invasive plant (Figure 1.1; DOI 2016). Prevention and eradication are recognized as the most cost-effective strategies, with a window for implementing early detection, rapid response (EDRR; Westbook 2004). By the time an invasive species has become widespread, eradication is rarely possible (Rejmánek and Pitcairn 2002), resulting in a containment or long-term control strategy to ensure valued resources are protected over time. In order to select the most appropriate management strategy, the distribution and severity of invasive plants considered for management must be reasonably known. It can be difficult for refuges to allocate staff time to inventory when the management need appears urgent, but conducting a baseline inventory ensures that infestations are accurately detected in relation to value resources and refuges will be informed about where treatments may be most effective, such as the eradication of small, localized populations (Moody and Mack 1998). Several policies recognize the need for inventorying invasive plants to inform cost-effective management, including DOI and USFWS Integrated Pest Management (IPM) Policies (517 DM1 and 569 FW1, respectively), Strategic

Habitat Conservation (SHC) Policy (SHC; 052 FW1), Habitat Management Plan (HMP) Policy (620 FW1), and Inventory and Monitoring Policy (701 FW 2), and Adaptive Management (AM) Implementation Policy (522 DM1).

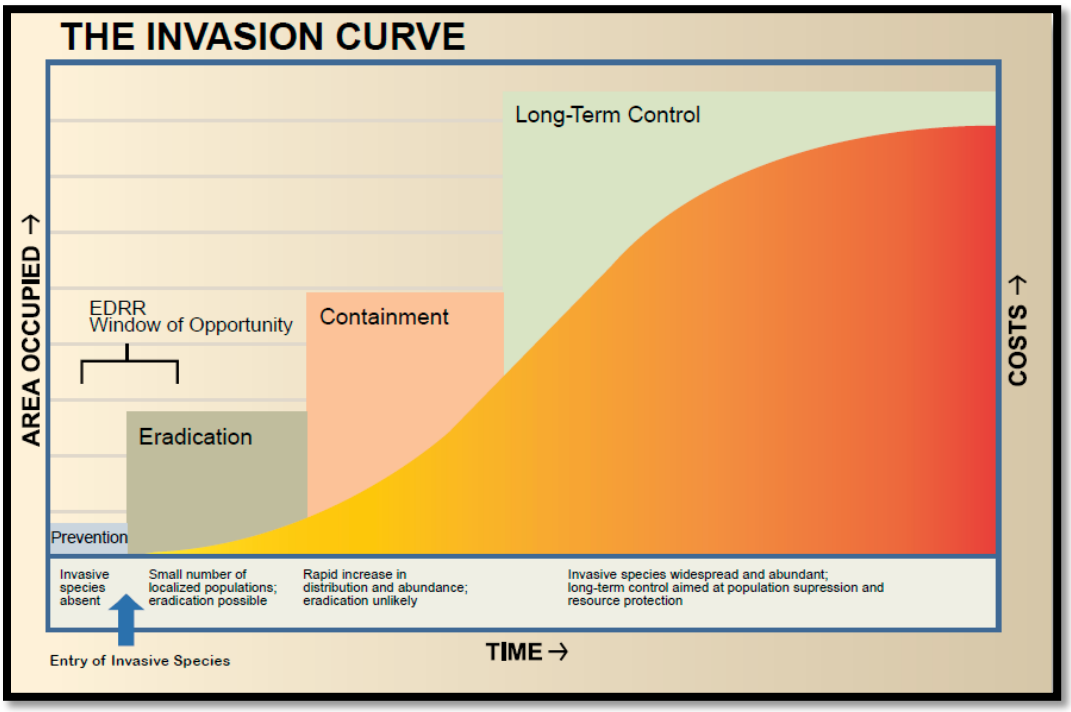

Figure 1.1 Four invasive management strategies (prevention, eradication, containment, and long-term control) corresponding to the extent of the area occupied by an invasive species and management costs, and a "EDRR Window of Opportunity" (lower costs and higher likelihood of eradication), taken from *Safeguarding America's land and water from invasive species: A national framework for early detection and rapid response* (DOI 2016).

Although inventorying invasive plants is an essential step in any strategic invasive plant management program, there are multiple pre- and post-inventory steps to consider that help ensure the inventory survey is designed and data are used to inform and evaluate management effectiveness. The NAAR NWRS used The Land Manager's Guide to Developing an Invasive Plant Management Plan (USFWS and CAIPC 2018) and the National Invasive Species Council (NISC 2003) to inform the development of an invasive plant management framework, which includes (but is not limited to) the following steps:

- Identify valued resources (e.g., priority resources of concern, infrastructure) sensitive to invasive plants and their location
- Create a list of known invasive plants on and near the boundaries of the refuge
- Select areas (habitats or management units) and plants for inventory in each
- Design and conduct an inventory survey
- Identify most appropriate management strategy (e.g., prevention, eradication, containment, long-term control) for each plant
- Develop SMART management targets for each plant (e.g., distribution and infestation level)

- Evaluate alternative threat reduction strategies using principles of IPM and decision analysis
- Develop and implement monitoring plan to evaluate success or effectiveness over time
- Implement selected threat reduction strategies
- Set a revision timeline (e.g., every 5-years) and revise targets and strategies, as needed

This protocol framework provides guidance on how to conduct a rapid baseline inventory of invasive plants for any refuge within NAAR following the guidelines for protocol development outlined by the Inventory and Monitoring Initiative (hereafter "I&M"; USFWS 2013c; USFWS 2018) in accordance with the I&M Policy (USFWS 2014). Previous efforts to inventory invasive plants within NAAR refuges were largely opportunistic and ad hoc, primarily driven by short-term refuge needs and focusing on pre-treatment monitoring to inform management contracts. Initially, field methods consisted of hand-delineating patches of focal species with limited standardization regarding survey design (e.g., where and how to look for patches) and attributes (e.g., presence, percent cover, stem density, relative abundance). This approach generally favors collecting information on species in the later stages of invasion (epidemic or established) and lacks information on low density species (pre-invasion and invasion front) that may be difficult to detect, avoids habitats difficult to survey (dense native understory), and concentrates search efforts near access points (roads, trails, and waterways). The resulting data were limited in spatial scope and thus provided a narrow scope of the invasive species management problem.

In 2006, Assabet River National Wildlife Refuge, in partnership with the Massachusetts Audubon Society's Ecological Extension Service, piloted a more comprehensive (spatially), standardized, rapid census grid-based approach in an attempt to standardize methods and provide a more complete assessment of all infestation states across larger management areas to better match the scale of planning and decision-making. This method used percent cover categories, which were slightly modified from the Braun-Blanquet cover class scale to allow for more rapid data collection (Collins 2007). Regional staff recommended this systematic grid approach as a standard operating procedure (Bush et al. 2018), which guided refuge scale inventories at Rachel Carson NWR in 2013 and John Heinz NWR in 2016.

As a result of the success of these previous efforts, this protocol framework recommends using a rapid area search within a defined sampling unit (e.g. square plot, also called "grid") across a defined sampling frame (e.g., management unit, habitat type, or refuge). Infestation states (i.e., percent cover category of 0, less than 1, between 1 and 10, between 10 and 25, between 25 and 60, or greater than 60) for a pre-defined target list of invasive plant species (typically 10 or less) are recorded within each sampling unit. Although it is ideal to inventory an entire refuge within a short time period (e.g. three years) to ensure management planning and implementation is based on a complete picture of invasive plants infestations, this is likely not feasible for most refuges due to resource limitations. Therefore, this framework recommends that each refuge select areas and a subset of plants that can be inventoried in no more than three years to ensure that data at the end of the survey period are still reasonably accurate and relevant to inform management strategies.

Selecting areas and plants for inventory can be challenging because of the large number of options, uncertainty related to their ecological impact and current distribution, and potential

effectiveness and costs of management. To assist refuges in selecting areas and plants for inventory, the Invasive Plant Inventory and Early Detection Prioritization Tool (iPIP) is a Microsoft Access database created by the USFWS and Utah State University (2019). iPIP was designed to harness information from existing ranking systems (e.g., NatureServe) and site-specific knowledge to help rank areas and plant species for inventory. Generally, areas are ranked based on a set of pre-defined characteristics, including the presence of valued resources, the ecosystem's resistance to invasion, potential invasion pathways, and the hypothesized current infestation levels and number of species. Species are ranked based on the characteristics of the plant (invasiveness), their impact on valued resources, the ability for the species to spread within the habitat, the importance of the species in the region to control, and the hypothesized current abundance and distribution (e.g., species that fall within the EDRR window). Although the tool and criteria have helps many refuges think through why certain areas and species should be higher priority than others, it lacked several practical management considerations, often (but not always) resulted in a re-ranking species to ensure species selected for inventory would also be appropriate for management. For example, refuges may want to consider the logistics of implementing treatments in terms of multiple methods or expertise required, as well as treatment efficacy and total costs (short and long-term) to ensure management actions can readily be implemented after the inventory is completed. These elements are outlined in the Invasive Plant Management Prioritization Tool (iPMP; Microsoft Excel; Casey et al. 2020), which can be used to prioritize management of species after refuges obtain inventory results. This protocol does not require the specific use of any selection tool, but does require that the selection process be transparent and defensible based on clearly stated criteria, the list of areas and plants considered, and rationale for why each species and area was ultimately selected for inventory prior to starting the inventory (see Element 5, Appendix C).

While conducting an inventory survey, refuges may also conduct management activities upon detecting small, localized infestations (e.g., EDRR). Such activities typically focus on early stages of invasion (pre-arrival and invasion front) and can be categorized as passive or active. Passive EDRR refers to detecting and treating species found haphazardly, potentially while conducting this inventory or performing other duties on the refuge. Active EDRR refers to purposefully re-occurring monitoring (annually or bi-annually) along pre-identified transport vectors (roads, streams, and other areas vulnerable to invasions) where new species are most likely to first arrive on a refuge and the potential for prevention and eradication is high. Although this protocol is not designed for active EDRR, surveyors conducting an inventory may choose to implement a management treatment (e.g., hand pulling) during a survey. This protocol provides guidance for how to record management actions to in order to maintain a complete record of invasive management activities, which can be used to inform Refuge Annual Performance Plan (RAPP) reporting (https://refuge-results.fws.doi.net/).

Objectives

There are three main types of objectives to consider when stepping down this protocol framework to a specific refuge survey: management objectives, survey objectives, and sampling objectives (USFWS 2013c; Reynolds et al. 2016). Overarching *management objectives* are typically developed during the HMP and used to evaluate the need to use this inventory protocol framework within the refuge's IMP. Management objectives guide the survey objective, data

collection, data analysis, and reporting processes, and are briefly discussed below. Survey objectives represent primary reasons for collecting and analyzing data, yet are often missing from survey instructions and designs, which can delay or prevent implementation of effective management using survey results. Sampling objectives are quantitative statements about how survey objectives will be achieved with a particular study design and sampling effort. Guidance on how to develop each is provided below, but each refuge should work with the regional data manager, the regional invasive coordinator, and invasive species experts to clarify the objectives of the inventory and modify this framework as needed. Regardless of the type of objective, all objective statements should follow the "SMART" model in terms of being specific, measurable, achievable, results-oriented, time-fixed (Adamcik et al. 2004, Powell and Casey 2019).

Management objectives

Refuge-scale management objectives are often developed during the HMP process and tier from a range of policies (Improvement Act of 1997 and NWRS Biological Integrity, Diversity, and Environmental Health (BIDEH) Policy; 601 FW 3), refuge purposes, and Comprehensive Conservation Plans, which reflect the following core conservation values (in no particular order of importance): sustaining migratory bird populations and associated habitats, recovering federal and state threatened and endangered species, benefiting priority resources of concern, and maintaining or restoring biological diversity and integrity, and environmental health. Non-biological management objectives may also be important to consider when selecting this protocol framework, including maintaining wildlife-depending uses (i.e., visitor services activities, aesthetics for visitors, access to trails) and/or refuge operations (e.g., infrastructure and road access). This protocol framework does not provide guidance on how to develop specific management objectives (often completed during HMP process), but the results of this inventory framework are intended to provide critical information to revise and develop invasive plant-specific management targets as a *means* to achieving these more fundamental biological, visitor services, or operational management objectives. Additional guidance for how to use inventory results to develop targets is in development and will be available after a refuge's inventory is completed. Due to the high likelihood of refuges to conduct invasive plant specific management actions during the implementation of this inventory framework (e.g., EDRR), this protocol provides guidance on how to accurately record invasive treatment actions (Element 4; SOP 6), but the objective of this protocol is not to evaluate effectiveness of specific actions.

Survey objectives

The primary purpose of this inventory protocol framework is to assess the spatial distribution and infestation states of targeted invasive plant species likely to threaten the ability to achieve management objectives, and to inform the development of invasive management targets as part of strategic IPM. The inventory is a rapid area search (e.g., visual total canopy percent cover category) within a defined set of sampling units (i.e., grid) across moderately sized sampling frames (e.g., multiple habitat types, management areas, a single refuge, or multiple refuges), in which the infestation state for targeted invasive plants (typically 10 or less species) is recorded (Element 2 and Element 3). The inventory is intended to be rapid and not exceed three years for each sampling unit (habitat or management unit). A 3-year timeframe was selected because it is a reasonable time frame to assume that infestation states within a given sampling frame will be *relatively* stable, resulting in reasonably accurate baseline inventory to aid in management planning. It is important to document how and why a refuge decided to (and not to) inventory

certain areas and how and why target invasive species were selected (see *Refuge final report*). After these decisions are made, survey objectives can be written. The survey objective contains the type of survey (in this framework, "inventory"), number of acres, focal habitat name(s), refuge or refuge complex name(s), start and end year, target invasive species (common names only; Appendix B), key attribute being measured (percent cover category), and the primary reason survey information is useful for management decisions. For example:

> Conduct an invasive plant inventory across six habitats (Salt Marsh, Maritime Forest, Rocky Shore, Mudflat, Dune Grassland and Beach, Maritime Forest/Shrubland, , Upland, Tidal and Freshwater Wetland, Early Successional) on Stewart B. McKinney NWR from 2018 to 2027 to understand the distribution and infestation states of 22 invasive plants. Baseline inventory results will be used to develop SMART management objectives, targets and strategies for the refuge's Habitat Management Plan. The inventory will include a total of 940 acres across 9 years, with each habitat completed within a 3-year timeframe, and target the following habitats and plants:
>
> - 534 acres of Salt Marsh (autumn olive, common reed, perennial pepperweed, princess tree, and spotted knapweed),
> - 226 acres of Maritime Forest (Mainland; burning bush, garlic mustard, honeysuckle, Japanese stiltgrass, and tree of heaven),
> - 90 acres of Maritime Forest/Shrubland (Island; Asiatic tearthumb, black swallowwort, garlic mustard, Japanese stiltgrass, and tree of heaven),
> - 62 acres of Rocky Shore, Mudflat, Dune Grassland and Beach (Island; black mustard, Japanese knotweed, jimsonweed, mugwort, and perennial pepperweed),
> - 9 acres of Rocky Shore, Mudflat, Dune Grassland and Beach (Mainland; Japanese knotweed, Japanese sedge, spotted knapweed, and tree of heaven),
> - 4 acres of Falkner Island Upland (bitter dock, black swallowwort, common reed, mugwort, tree of heaven),
> - 4 acres of Tidal and Freshwater Wetland (Asiatic tearthumb, common reed, Perennial pepperweed, and purple loosestrife), and
> - 8 acres of Early Successional Habitat (honeysuckle, Japanese honeysuckle, multiflora rose, mugwort, and porcelain berry).

In this example, the NWR selected several habitat and identified no more than 5 target species per unit, resulting in greater than 10 total target species across the entire NWR. This survey objective can be generalized into the following:

> Conduct an invasive plant inventory across *[insert number]* habitats *([insert habitat or management unit names]*) on *[insert NWR name]* NWR from *[insert start year]* to *[insert end year]* to understand the distribution and infestation states of *[insert total number of species to be inventoried]* invasive plants. Baseline inventory results will be used to develop SMART management objectives, targets and strategies for the *[select Habitat or Integrated Pest]* Management Plan (anticipated completion in *[insert year]*). The inventory will include a total of *[insert total]* acres across *[insert years]*, and the following habitats and plants:
>
> - *[insert value]* acres of *[insert habitat or management unit name]* (*[insert up to 10 target species]*) *[add if years vary per habitat type:* from *[insert start year]* to *[insert end year]],*

- *[insert value]* acres of *[insert habitat or management unit name]* (*[insert up to 10 target species]*) *[add if years vary per habitat type:* from *[insert start year]* to *[insert end year]]*,
- *[insert value]* acres of *[insert habitat or management unit name]* (*[insert up to 10 target species]*) *[add if years vary per habitat type:* from *[insert start year]* to *[insert end year]]*.

The survey objective statement should include all refuges, management units and/or habitats that were selected for inventory while and considering available resources or the ability to obtain resources and should be at the forefront of any reporting documentation of inventory results (Element 5: Refuge Final Report).

Sampling objectives

Sampling objectives provide key information that guide where the survey will be conducted (sampling frame and number of sample units; Element 2), and the main attribute(s) being measured and potential attribute values (Element 3), and include the time frame and statement of desired precision. The main attribute of this protocol is the infestation state of each target species within a pre-defined sampling unit (i.e., grid). Since the inventory is intended to be a rapid baseline assessment and completed within three years, infestation states are discretized into six categories based on percent cover (0 percent cover, less than 1 percent cover, 1 to 10 percent cover, 10 to 25 percent cover, 25 to 60 percent cover, and greater than 60 percent cover) to minimize sampling effort (survey time per grid). Percent cover categories were derived from the Braun-Blanquet cover class scales modified by the Massachusetts Audubon Society's Ecological Extension Service during a pilot inventory survey conducted at Assabet NWR (Collins 2007). This inventory aims to have high accuracy in recording presence versus absence (occupancy) of each species, with greater than 0.90 probability of grids determined to be occupied (at any infestation state) when the species is present and only a 0.10 probability of grids determined to clean (un-occupied) when the species was in fact present (detectability may vary by species, time of year, and surveyor). Additionally, this inventory aims to have high infestation state accuracy, with 0.90 probability of grids assigned to the correct infestation state and only a 0.10 probability of grids potentially being mis-classified as a higher or lower infestation state. Mis-classification errors are most likely to occur in in the less than one percent cover state when in fact percent cover is slightly higher (e.g. two to three percent).

Refuges should keep in mind that using infestation states, which is a discrete ordinal data type as opposed to a continuous interval data type of one percent cover intervals, may constrain the ability to detect and thus measure management effectiveness (if hypothesized effects and/or response time is slow and/or small). If this inventory protocol framework is intended to be used as year one of trend or effectiveness monitoring by refuges, or as pre-treatment data for a research study, the survey coordinator should consult a biometrician to evaluate the sampling objectives and associated sampling design (e.g., grid size, number of sampling units, survey frequency, and attribute data type) are appropriate to detect treatment responses.

Element 2: Sampling Design

This protocol framework was designed to balance the need for a comprehensive understanding of the spatial distribution of infestations and the feasibility of inventorying an entire refuge due to various constraints (staff time and access), while acknowledging that management actions may be ongoing or be triggered as a response to survey data in real time. To accommodate these competing activities, this framework recommends conducting inventories at smaller spatial scales (when needed) based on habitat or management units, and the ability of invasive species to occur in, or traverse through, multiple habitat types. It is also important to maintain the goal of inventorying all habitats with high conservation value (e.g., priority one habitats from Habitat Conservation Plans, or prioritized management areas/units from iPiP) that may be negatively affected by invasive plants. Inventories should not focus just on small areas known to have invasive species, or areas prone to invasive species movement (e.g., transport vectors such as roads, trails, and parking lots). These areas should be addressed with a more regularly occurring active EDRR monitoring survey framework which is currently under considered for future development by I&M staff) as part of a management plan to reduce the spread of invasive plants throughout a refuge or to critically sensitive areas.

Sample design

Baseline invasive plant inventories typically include recording a metric of relative abundance (percent cover in this protocol) for a subset of species within a pre-defined sampling area (e.g., sampling frame). This protocol framework uses a census sampling approach to understand the level of infestation of invasive plant species and their distribution to aid in management planning. Given budgetary and/or feasibility constraints (e.g., unsafe terrain), an inventory of the entire refuge and all invasive plants is likely not feasible. In order to maximize local understanding of invasive species to inform management, this protocol recommends defining several sampling frames to survey in rotation (see *Survey Objectives*) rather than subsampling. The intent of the protocol is to provide a comprehensive view of the invasive plant problem; thus, it is important to survey all areas in which management actions may be deployed. It is important not to "cherry pick" areas within a sampling frame based on previously known infestations as unoccupied areas may quickly become occupied with multiple invasive plants, and management resource allocation should consider both large known infestations and low levels of new infestations (single plant) in unexpected areas. Thus, this protocol framework focuses on multiple sampling frames, which are each small enough to inventory within three years and yet large enough to yield useful spatial information to guide management planning and implementation. If the sampling frame is large (i.e., > 3000 acres), subsampling may be required, and a biometrician should be consulted when considering a systematic or cluster sampling designs.

Sampling frame and units

The sampling frame is defined as the area of inference of survey results and may occur at multiple scales, including the entire refuge (largest frame), an ecosystem or habitat type (e.g., salt marsh or forest) within a refuge (moderate frame), or a focal management unit (smallest frame), and excludes areas that are inaccessible (permanently flooded wetlands and/or ponds, unexploded ordnance, unsafe terrain) or that are not applicable (buildings, parking lots, roads, etc.). For most refuges, multiple habitat types and/or focal management units will be selected as distinct sampling frames to accommodate feasibility of implementation and utility of data to

management planning. This may result in over five sampling frames for a small refuge, and over 20 distinct sampling frames for refuge complexes. For the purpose of this framework, it can be assumed that infestation states will not substantially vary within a three-year time frame (grids that are free from a species in year one will not have large infestations in year three), thus each sampling frame selected should be small enough to sample within three years. If this assumption is not reasonable for a habitat/unit or species, then the sampling frame should be smaller and/or subsampling may be considered.

To aid in determining the size of each sampling frame (not sample size), consider a 100-acre management unit using the standard large grid size (50 m x 50 m; see moderate and small grid size options below). Based the assumption that it takes approximately 10 to 20 minutes per grid (1-2 minute per target species per grid) and there are 160 grids across 100 acres, it should be expected that the survey should take 3.3 to 6.6 x 8-hour field-days (not including travel or breaks) to complete. As a rule of thumb, this protocol could therefore be completed on a 100-acre unit within 1-2 x 40-hr weeks with travel, training, and breaks. At the other extreme, a 3,000-acre sampling frame could be completed over 3 years only with approximately 3 months (10 x 40-hr weeks) of consistent surveying each year. If NWRs intent to inventory excessively large sampling frames (that would take more than 3 years to complete or more than 3 000 acres), then the refuge should estimate how many hours or weeks the inventory may take based on the guidance above and evaluate if an alternative sampling design (not census, sampling a subset of grids) is needed (Element 7). If so, a biometrician should be consulted to determine the most appropriate sampling size and selection process, such as a systematic sampling approach (select every 2nd, 3rd, 4th, or 5th grid) or stratified cluster sampling approach (clusters of grids are selected).

The sampling unit in this protocol is a square grid, which may vary in length from 12.5 meters to 50 meters based on the size and configuration of the sampling frame (Figure 2.1). A large grid (i.e., 50 meters x 50 meters; 2500 square-meters; 0.62 acres) is recommended for most NWRs and is selected when sampling frames are contiguous and moderately large (> 100 contiguous acres or multiple > 25 acre fragments) and when more detailed knowledge about distribution will not substantially affect development and implementation of broad-scale management strategies. A large grid is assumed to take approximately 10 to 20 minutes to survey (assuming 1-2 minute per target species and 10 target species within a moderately vegetated habitat). A moderate grid (i.e., 25 meters x 25 meters; 625 square-meters; 0.15 acres) is considered when the sampling frame is either less than 100 acres, contains only 5 to 25 acres of contiguous habitat (potentially fragmented by infrastructure), or has a linear configuration. A moderate grid size ensures that the inventory is restricted to areas of interest (a grid does not include neighboring habitats or paved areas such as roads) and ensures data are fine scale enough to inform management decisions. A small grid (i.e., 12.5 meters x 12.5 meters; 156.25 square-meters; 0.04 acres) is only selected when the sampling frame is very small (less than 5 acres) and is highly fragmented or has a linear configuration and is assumed to take approximately 5-10 minutes per grid. Note that GPS error (3 to 5 meters) may result in misclassifying a small grid's infestation state by assigning percent cover to a neighboring grid when located near the grid boundaries (e.g., within 5 meters). However, this can be mitigated by connecting to an external Global Navigational Satellite System (GNSS) receiver (see SM 1: Equipment Purchasing Guide).

At most refuges, the grid size will be large or moderate and not vary widely among the various sampling frames. For example, Fisherman Island NWR (2,175 contiguous acres) selected the large grid because it was tractable to complete the entire refuge and management strategies would not benefit from finer scale grid information. In contrast, Eastern Shore of Virginia NWR (2,091 acres total) selected a smaller sampling frame focused on only the maritime forest habitat (316 acres), with a moderate grid size. Moderate grid size was selected despite the area exceeding 100 acres (proposed threshold in Figure 2.1) because the area is composed of semi-contiguous blocks and larger grids would be difficult to arrange within the sampling frame, and because the refuge wanted to ensure more detailed distribution information was available to guide forest and invasive management prescriptions (Figure 2.2). It is important to ensure the sampling frame and associated sampling unit size are selected based on the management needs of each refuge and the rationale is documented in the refuge's prioritization results and final report (Element 5).

If a refuge aims to develop an effectiveness monitoring survey in addition to the baseline inventory survey (this framework), a biometrician should be consulted to assist developing the sampling frame, grid size (and potentially monitoring attributes), and frequency to ensure sufficient power to detect a treatment(s) effect. Detecting change from a large infestation state to a lower infestation may be challenging if treatments are not hypothesized to have large impacts because the percent cover categories are too large to detect small changes (i.e., between 1 and 10, between 10 and 25, between 25 and 60, or greater than 60). Conversely, detecting changes among low infestation states (0, less than 1, between 1 and 10) may be overshadowed by errors in detectability when plant abundances are low and require an additional detectability component of the survey to account for misclassifying low infestation states.

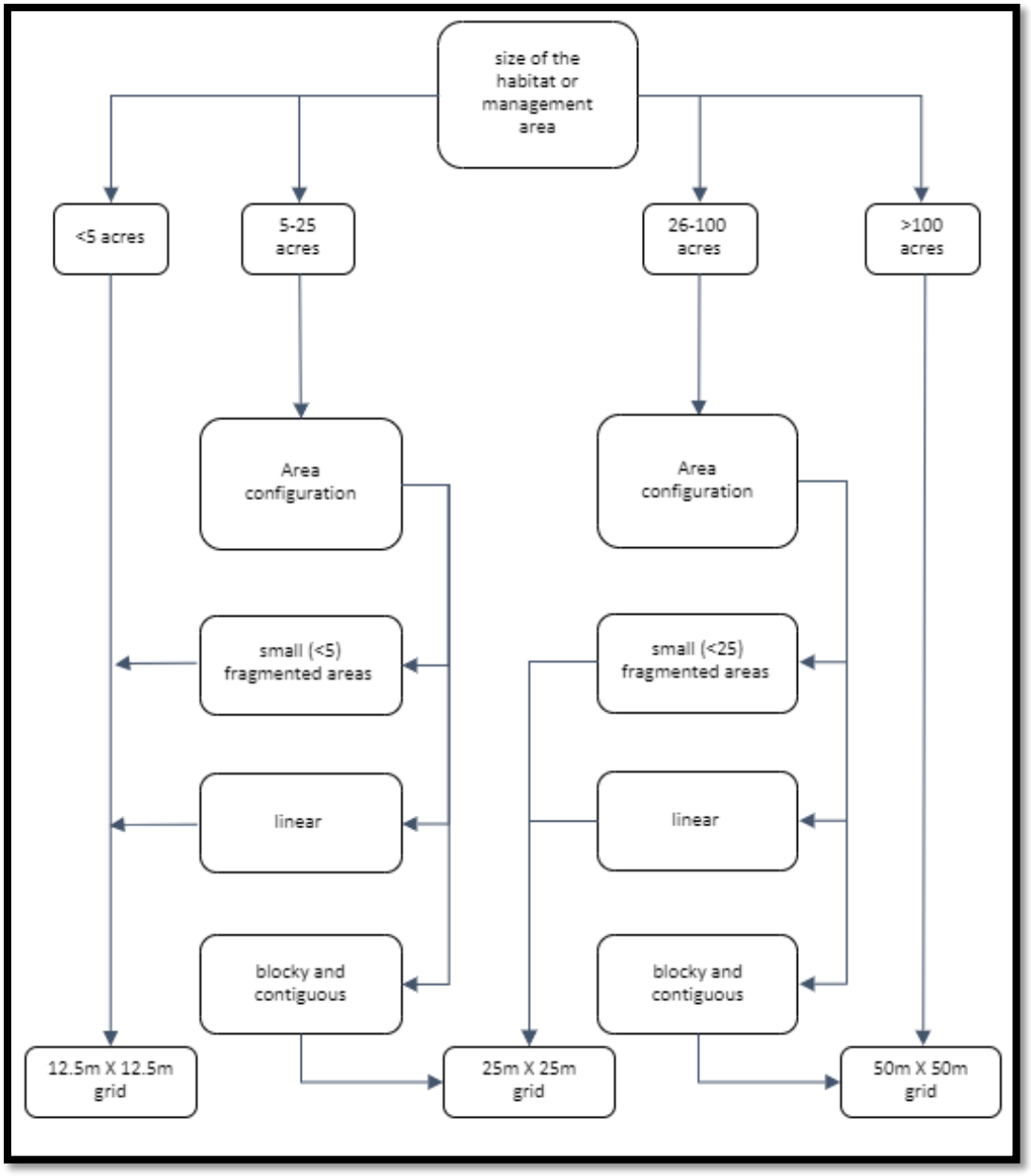

Figure 2.1 Flow chart to guide the selection of appropriate sampling unit (large grid = 50 meters x 50 meters, moderate grid = 25 meters x 25 meters, or small grid = 12.5 meters x 12.5 meters) based on the total acres of the sampling frame (habitat or management unit; less than 5 acres, 5 to 25 acres, 26 to100 acres, or greater than 100 acres), the landscape configuration of the sampling frame (small fragmented areas, linear, or blocky and contiguous). Note that most refuges will select large or moderate grids sizes because sampling frames are greater than 25 acres with blocky and contiguous configuration.

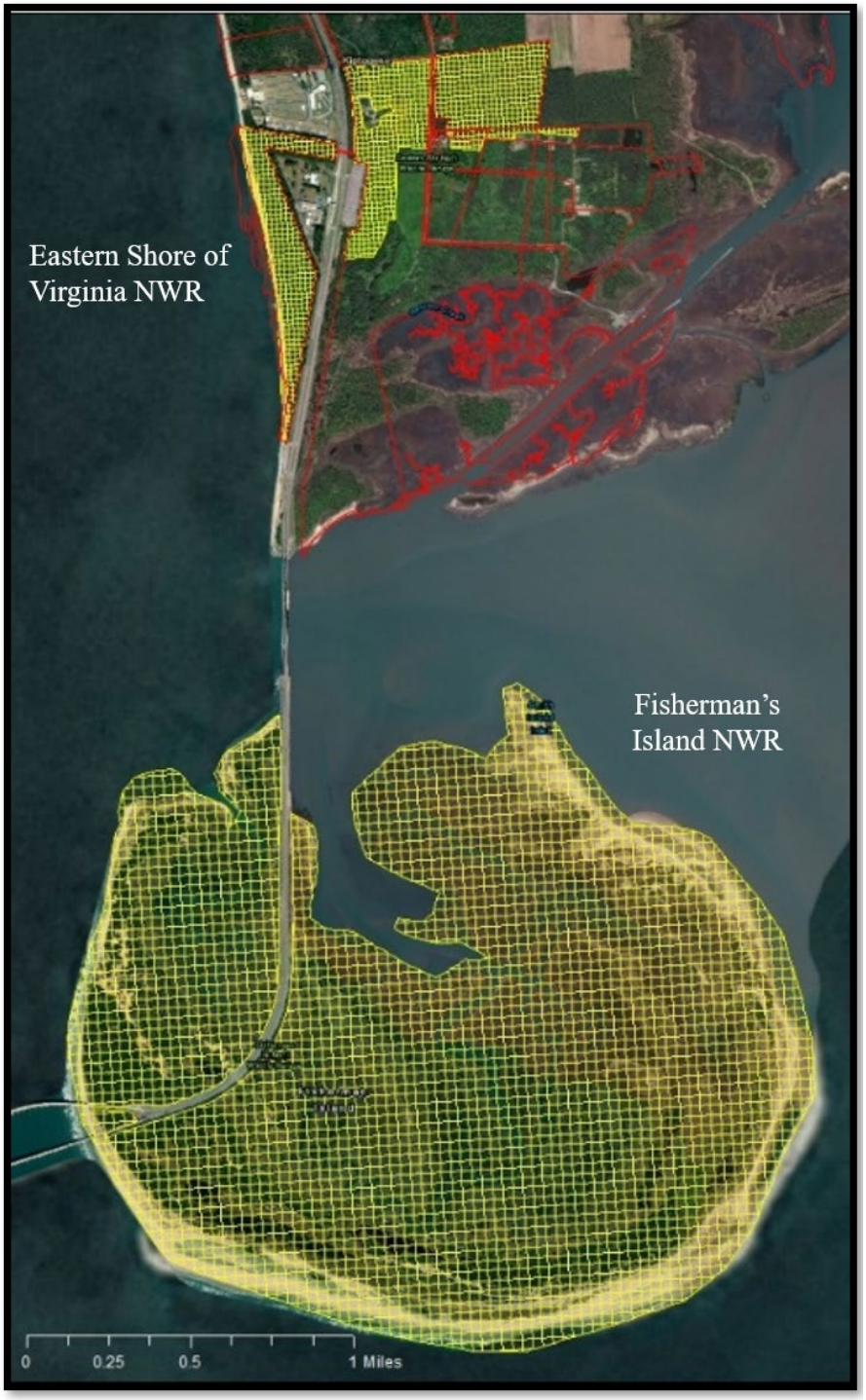

Figure 2.2 Two example sampling frames and associated sampling units for Fisherman Island NWR (entire NWR is 501 acres, contiguous block with 50 x 50-m grid size) and Eastern Shore of VA NWR (maritime forest unit is 316 acres linear, and contiguous block with 25 x 25-m grid).

Sample selection and size

Each refuge should aim to survey all sampling units within each sampling frame within 3 years (no sample selection process required). All grids in each sampling frame are surveyed (census), unless the habitat is impassible, visibility is highly obscured, or dangerous. As a result, a single refuge may have multiple sampling frames around specific habitats or sets of management units, and the order of sampling each frame should be pre-determined to ensure each frame does not exceed 3 years.

Survey timing and schedule

Surveys are conducted during the growing seasons for targeted invasive plants. Surveys should not be conducted when plants are difficult to observe, such as when they are newly emerging or senesced. This is especially important for herbaceous species, which may not be evident outside their growing season. Flowering plants will likely have higher detectability during their flowering season when they are more noticeable. Some plants have an extended growing season and so may be easier to detect early in the spring before native plants leaf out. Phenology will likely differ among target species, so surveys are timed to maximize detection across all target species (i.e., woody plants may be identified by buds or bark, while flowering plants may be identified based on leaf and flowers). The National Phenology Network created visualization tools for tracking changes in species' phenology that can aid in determining the optimal periods for conducting surveys during the year (i.e., calendar tool). If the sampling area is subject to flooding, burning, or other major disturbance, avoid surveying until vegetation has recovered. Conducting surveys during heavy rain or high winds should be avoided due to decreased detectability and survey efficiency. If surveys are halted to conduct treatment activities, the optimal treatment method and timing should be considered to maximize effectiveness and will vary by plant and treatment method (specific guidance not provided in this protocol).

Sources of error

Imperfect detection of invasive plants and misclassification of infestation states are the largest potential source of error during an inventory survey. Imperfect detection refers to the fact that not all observers will detect a species as present (e.g., record as clean, when in fact it was present) due to variations in observer skills (e.g., search image and search strategy within a grid), poor visibility due to dense vegetation, distance to target plant, asynchronous timing of visible plant characteristics (e.g., flowering period or highest ground biomass, which increases availability for detection), and low search effort (time), resulting in detection probabilities less than 100%. Detection probability is expected to approach 100% as search effort (time), plant size, and plant abundance increase (Garrard et al. 2008; Chen et al. 2009; Moore et al. 2011). For example, an experiment with Orange Hawkweed (*Hieracium aurantiacum*), an invasive perennial, herbaceous 25 to 50 cm-tall plant, indicated that detection probability increased when plants were found in groups of 3 or more (Moore et al. 2011). In a similar study, detection probability of Ute-ladies'-tresses Orchid (*Spiranthes diluvialis*), a perennial 20 to 50 cm-tall terrestrial orchid, ranged from 0.65 to 1.0 along a transect line and from 0 to 1.0 when observers were 5 meters away from the transect line (Colket and Church 2005). Flowering plants will also have higher detectability during their flowering season as they are more noticeable (Moore et al. 2011). Misclassification of an infestation state may also occur during an inventory survey. For this protocol, six broad infestation states are used, in part, to minimize mis-classification errors (i.e., classifying a plant as greater than 10 percent cover when in fact it was less than 60 percent

cover) within and among observers. This error can be minimized by ensuring proper training and consistency among observers and over time (Element 6). If multiple observers are used, the infestation state classification selected for each observer should be compared periodically throughout the survey, especially when new plants are detected or when surveying densely vegetated grids. Not only can infestation states be mis-classified, but target plants can be missed completely if there are species identification errors (i.e., a grid is recorded as clean when the species was present and not identified correctly). For example, native swamp rose and invasive multiflora rose are often confused given the species' similar growth form and rose-like characteristics. Proper training of field personnel and timing of surveys is essential to reducing mis-identification errors, especially when infestation states are low (i.e., less than 1 percent cover based on a single plant present) and may require additional search time.

Equipment error may result in recording invasive species infestations in one grid when the species was in fact present in another neighboring grid. This error may occur when the surveyor is traversing a grid and the majority of an infestation is on the edge of a grid because the internal GPS of the iOS, on average, has a spatial error of 3 to 5 meters. This GPS accuracy can decrease under dense tree canopy, varying terrain, and time of day (less satellites available to capture location), but can be mitigated by connecting to an external GNSS receiver (SM 1: Equipment Purchasing Guide).

As with the collection and processing of any field data, data entry errors can be reduced by ensuring surveyors are familiar with all survey attributes and to review and correct errors as soon as possible after collection (see Element 4). For this protocol, data entry via the Collector application for ArcGIS was created with pre-determined fields for each attribute and drop-down menus for several fields (e.g., date and infestation states) to help save time in the field, reduce data entry errors, and maintain standardization among surveys throughout the region.

Element 3: Field Methods

Pre-survey logistics and preparation

Planning for the first inventory survey should begin approximately six months (typically December) prior to the start of the first survey event (typically May; Element 6 and Element 7). Prior to conducting a survey, sampling frame (s) and target invasive species (typically no more than 10 per sampling frame) are identified (see Element 2), where results are uploaded to ServCat, and a survey record is created in the Planning and Review of Inventory & Monitoring Activities on Refuges database (PRIMR; Element 4). These activities ensure that regional staff are aware that the refuge will be conducting an inventory and can ensure resources are available to assist with implementation. Resources required to conduct the inventory (equipment, and number of interns, volunteers or staff available) are assessed and potential funding opportunities are identified (typically January or February). All equipment recommended for this protocol (e.g. iOS device, GNSS receiver, batteries, maps, plant identification guides, and protective gear; SOP 5) should be purchased and/or checked and updated as needed (see SM 1: Equipment Purchasing Guide)

After the sampling frame (habitats or management units) and sampling units (e.g., grid size and sample size) have been established (see *Sampling units and work areas*), the refuge-specific grids are merged to the IR-1 NWRS Invasive Survey layer on AGOL (SOP 1, SOP 2). Surveyors are identified and added to the appropriate group to access AGOL and Collector (SOP 3). Once surveyors have been hired, the survey coordinator ensures that all personnel are properly trained to identify target invasive, familiar with all field equipment and rare plant species, are aware of areas to avoid (e.g., due to safety concerns, or risk of causing unintentional harm to species or habitats), and how to use spread prevention techniques (see below). Since surveyors typically conduct the first survey event within 1 to 2 weeks of on-boarding (e.g., mid-May or June), multi-refuge trainings may be coordinated to increase training efficiency. It is recommended that new surveyors do not conduct the first few surveys alone, but instead are paired with trained staff or previously trained interns or volunteers to ensure the survey is executed well in the field.

Sampling units and work areas

Sampling units (grids) are established by the survey coordinator and regional data manager prior to the start of an inventory using inventory prioritization results (SOP 1 and 2). Work areas are a subset of grids downloaded to the iOS device to be inventoried while in the field, especially when there is limited or no Wi-Fi or cell service. Work areas are useful when the sampling frame as multiple fragmented grids and are used to assist surveyors with navigating, collecting, and syncing data to AGOL throughout the inventory (SOP 4). Work areas are created while connected to Wi-Fi (e.g., in the office) and are large enough to capture a least one work day (e.g., 50 x 50 meter grids), yet small enough to not consume much of the iOS device's internal memory (ideally 6-8mb). Each work area is considered a child version of the master version of sampling grids on the Esri cloud server. Overlapping work areas may occur if two surveyors are inventorying the same general area and collecting data within different grids. Generally, overlapping work areas should be avoided to minimize losing any data when syncing back to the cloud after the work area is completed (daily or weekly; SOP 4). A survey route (within a single work area or across multiple work areas) should be recommended by the survey coordinator, and consider access points, survey efficiency, difficult terrain, safety considerations, and potential for invasive species spread (see *Spread prevention techniques* below), strength and accuracy of GPS signals.

Data collection procedures (field)

During each survey event, the surveyor(s) locate and navigate to selected grid cells (sample units) with a work area using Collector on an iOS device. A single, trained surveyor is capable of conducting a survey, but it may be more efficient to work in pairs to ensure safety, accuracy, and efficiency. Once the selected grid cell is located, surveyor(s) walk a modified random "Z" or "V" pattern depending on terrain to rapidly search for each target species (SOP 5; Figure 5.3). For this protocol, the total search time for each grid 50-meter x 50-meter grid is approximately 10 to 20 minutes based on visibility and terrain. If two surveyors conducted a search, they should compare estimates of percent cover for each plant before recording the final data in Collector. If there is uncertainty in species identification, surveyors should consult and agree upon a single species name to use, take photos, and make a note in the comments and ensure data entered are corrected once the species is identified. This uncertainty should also be reported to the survey

coordinated upon return to the office or at the next check-in time. All attributes are entered into Collector (see Element 4 and SOP 5 for all survey attributes collected while in the field). Before moving to the next grid cell, data are reviewed by all surveyors present to ensure quality assurance and then the grid is marked as complete. Surveyors conducting EDRR or light management after completing a grid or set of grids should also record their management actions (see *Recording invasive treatments*).

Surveyor(s) should maintain the recommended survey route as best as possible. Survey routes may be altered to accommodate changes in other field work priorities. For example, surveyors may create a new route after consulting with the survey coordinator to conduct other biological surveillance or management activities unrelated to the invasive inventory. If the survey coordinator is concerned about surveyors not spending the minimum search time within each selected grid, or are deviating from the recommended route, the tracking layer can be turned on in Collector to record the actual route of the iOS device. The track log is not required for this protocol, but an option to assist in coordinating Surveyors. All personnel should review and adhere to the recommendations for limiting the spread of invasive species propagules during implementation of this protocol framework (see *Spread prevention techniques*).

Recording invasive treatments

Although developing and implementing management strategies are not specifically addressed in this protocol framework, invasive species may receive "light" or "on-the-spot" management (e.g., hand-pulling, herbicide) during the inventory survey year (a form of passive EDRR). Recording these treatments entails identifying where the action took place (the management area), the type of action (e.g., biological, burn, chemical, mechanical, or Integrated Pest Management), which are based on RAPP reporting categories (DOI 2018), the specific action implemented, the date it was implemented, and by whom (IR-1 Invasive Treatment layer; SOP 6). Although this protocol framework focuses on inventory (current infestation state) and is not necessarily an effective protocol for conducting treatment or research experiments (in which power to detect change due to a treatment is desired). Nonetheless, treatment information is foundational to understanding, interpreting, and hypothesizing changes in infestation over time and could be used to evaluate management effectiveness when paired with an altered sampling design (e.g., smaller grid size, additional target species such as native plants, primary measurement such as additional infestation states, continuous percent cover, abundance, or stem density, and sampling timing and frequency).

Spread prevention techniques

It is important that steps be taken throughout the implementation of the inventory protocol to minimize movement of invasive plant species (e.g., seeds). The following guidelines should be implemented to limit spread while conducting surveys (USFS 2001):

- Organize fieldwork and survey routes, if possible, to survey units with zero to low percent cover of invasive plants before surveying more infested units with anticipated higher percent cover, or survey sensitive areas first to avoid risk of unintentional spreading of plants.
- Do not walk directly through patches of invasive species of high concern when surveying a unit (walk around). Especially, restrict entry into highly infested areas when there is

high risk of spread (e.g., after seed set). When large infestations are detected, convey the location of the infestation to survey coordinator (if desired).

- Inspect clothing (e.g., boots, waders, gaiters, raincoats) and equipment to remove any dirt and seeds when moving between geographically isolated areas of the refuge, especially if travelling from an infested area to an un-infested area (at the end of the day). Use a boot brush/pick to remove mud or debris from shoe soles. This is especially important when small-seeded or clinging-seeded species, such as garlic mustard or Japanese stiltgrass, have been encountered. Ideally, propagules are removed, bagged, and incinerated. Shoes can be sterilized with a 10% bleach solution, if needed.
- Clean equipment (e.g., vehicles, field equipment) after being in an infested area of the sampling frame (at the end of the week). Be aware that parking lots or other staging areas for vehicles can concentrate invasive plant propagules and become sources of spread. Portable leaf blowers can be used to blow seeds and debris off vehicles before leaving a sampling area.
- While conducting management actions, be aware that opening up the canopy, disturbing the soil, or removing invasive species may create conditions conducive to the expression of other invasive species whose seeds are already at that site (seed bank). Where practical, revegetate with appropriate native species to avoid seeds from regenerating.

Photographing species for identification

Although all surveyors should be properly trained to identify target invasive plants (Element 6), identification is undoubtedly more challenging during the first couple of surveys and surveyors should ask for assistance when uncertain about plant identification. This protocol does not encourage the collection of invasive plant specimens for identification in order to minimize spread and/or accidental collection of rare plant species. Instead, take close up photos of key characteristics, such as the flower, whole plant, leaf arrangement, whole leaf, any fruit/seed present, and surrounding habitat for context. Habitat type, location (GPS and grid cell number), soil, light, and weather conditions should also be recorded to aid in identification. When photos are taken within Collector, they are automatically related to the grid where the picture was taken, and a default photo name is generated (SOP 5). If the plant is not able to be identified after consulting with others, multiple visits may be required to record various phenology stages (e.g., flower) to aid in identification.

End-of-season procedures

At the end of the season (typically late September), all field equipment (e.g., waders, boots, gaiters) are cleaned of all debris, sterilized with a 10 percent bleach solution, dried, and stored appropriately. Clean field equipment thoroughly if surveyors are and/or equipment is moving between geographically isolated areas of the refuge to avoid moving invasive plant propagules (e.g., seeds) to un-infested areas (see *Spread prevention techniques*). All electronic data collection and iOS devices are checked to ensure data have been uploaded and all errors resolved at the end of each year (Element 4). Regional annual reports will help identify data errors for each refuge to resolve (see *Regional annual report*) at the end of the year. All iOS devices are cleaned using the manufacturer's recommended cleaning solution and properly stored.

Element 4: Data Management and Analysis

The overall data management workflow of this protocol framework utilizes ArcGIS for creating sampling units, the Collector application for data access and data entry, the Esri Cloud Server and ArcGIS Online (AGOL) for data storage and visualizations, and the U.S. Fish and Wildlife Service Catalog (ServCat) and Planning and Review of Inventory & Monitoring Activities on Refuges (PRIMR) databases for archiving data, metadata, documents, and reports. The data workflow begins with creating sampling units (grids) in ArcGIS, which are then synced to the Esri Cloud Server and utilized for field data collection via Collector. Next, AGOL and R-markdown are used to create webmaps and reports for visualizing the data. Finally, the data layers are appended to regional and national layers for tracking monitoring locations, archived in ServCat, and linked to PRIMR (Figure 4.1).

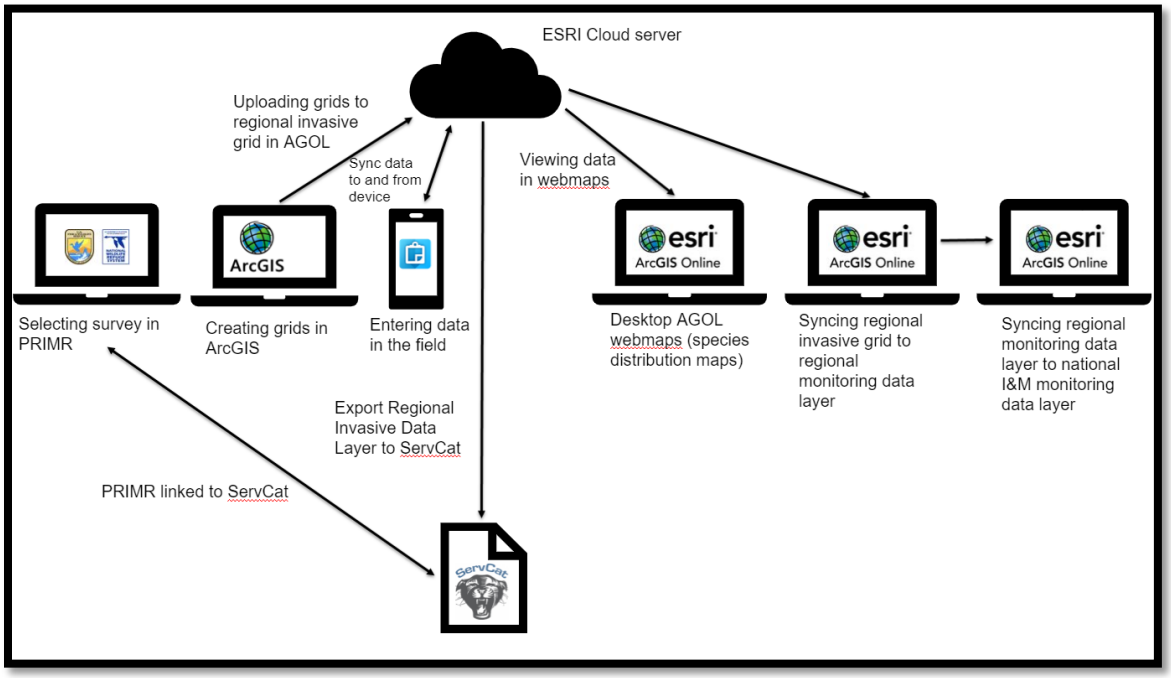

Figure 4.1 Generalized data management workflow, which utilizes the Esri Cloud Server, ArcGIS Online (AGOL), ArcGIS, Collector, ServCat, and PRIMR.

Data entry, verification, and editing

This protocol framework exclusively utilizes iOS devices, the Esri Collector application, and AGOL for entering, verifying, and editing survey data. Data from each refuge is compiled into a single IR-1 NWRS Invasive Survey layer and IR-1 NWRS Invasive Treatment layer, with each refuge maintaining data entry and editing permissions to their refuge-specific webmap. Using AGOL for data management will require setting up AGOL Groups and Member settings (SOP 3) and for users to learn how to use Collector and edit data (SOP 5). Additional instructions are available from Esri (see https://doc.arcgis.com/en/arcgis-online/manage-data/data-access-and-editing.htm).

Data quality control is primarily conducted at the refuge-level. After a single survey or set of surveys (e.g., daily, weekly, or by work area) are completed (SOP 5), data can be reviewed for potential errors within Collector before synchronizing to AGOL. Each record (all data fields corresponding to a specific grid cell) should be verified for accuracy and completeness. Data can still be edited after syncing to AGOL if needed. If AGOL editing occurs within an uncompleted work area, corrected data may be lost if the work area is synced again after it is completed (overwriting the corrected grids in AGOL with the data from Collector). Be sure to remove and re-download work areas to the iOS device to prevent the corrected data from being lost or overwritten by the uncorrected data (SOP 4). Missing and incomplete data records are a pervasive problem with any survey. Rapid identification of such errors along with close supervision by survey coordinators and proper training of surveyors resolve most of these data entry and editing issues and help maintain data integrity. Annually, data can be verified as complete at the regional level (typically during late fall/winter), and refuges will be informed to complete missing data or correct errors before archiving the regional annual report and associate dataset in ServCat (Appendix C).

Metadata

The longevity and utility of a dataset are greatly improved when accompanied by documentation of the background, assumptions, processes, and conditions surrounding its collection. Collectively, metadata describes a dataset, including details about what, where, when, why, and by whom data were collected and information about the reliability and scope of the data to aid future users in understanding limitations of the dataset. By implementing metadata standards, future users of the data (e.g., refuge biologist, managers, researchers) will have access to information such as field definitions, the purpose of data collection, and any restrictions to avoid misinterpretation of the data.

Attribute metadata, geospatial metadata, and survey metadata are critical for implementing this protocol framework. Attribute metadata includes a list of the main survey attributes and domains, definitions of each, and their data types (e.g., date, integer, character, etc.) for the IR-1 NWRS Invasive Survey layer (Table 4.1, Table 4.2, Table 4.3, and Table 4.4) and IR-1 NWRS Invasive Treatment layer (Table 4.4, Table 4.5, and Table 4.6). The I&M program data standard for species names is the FWSpecies Taxonomy Database. The primary source of information for that database is the Integrated Taxonomic Information System (ITIS). For this protocol, all species common names are cross-walked to their Taxonomic Serial Number (TSN) number (Appendix B). For example, the TSN for Japanese stiltgrass (*Microstegium vimineum*) is 503829. Geospatial metadata for each data layer is entered in ArcMap using the ArcGIS metadata editor tool and Federal Geographic Data Committee's (FGDC) ISO 19115/-1 metadata standard format, and exported to an XML file for archiving (see *ServCat*). Geospatial metadata should be updated annually to reflect any additional inventories conducted throughout a given year. Guidance on creating and editing metadata can be found here: https://desktop.arcgis.com/en/arcmap/10.3/manage-data/metadata/creating-and-managing-fgdc-metadata.htm. Survey metadata (e.g., survey name, survey coordinator, partners, survey purpose, sampling frame and attributes, timing, effort, and any other deviations from this protocol framework) should be entered and maintained within existing USFWS databases (see *PRIMR* and *ServCat*) by the survey coordinator.

Table 4.1 IR-1 NWRS Invasive Survey layer attributes, brief description, data type (date, character/text, or integer/float), and if the attribute is required as part of this protocol framework. Refuge names are recorded as "ORGNAME", while complex names and LIT codes are added post-processing (see Appendix D). Infestation State corresponds with 8 domains (Table 4.2), Completion Status corresponds with 3 domains (Table 4.3), and target species names domains (Target Species Name 1-10; Table 4.4) will be replaced with 109 ITIS common name domain separated by an underscore (e.g., the attribute name for Alligator Weed is Alligator_Weed). Attributes populated by the regional data manager are indicated by an asterisk, with a single asterisk indicating the field is populated pre-data collection and a double asterisks indicating the field is populated post-data collection, and all other domains are entered during field data collection. Note this is also Table SOP 5.1.

Attribute	Brief Description	Data Type	Domain	Required
CMPXNAME**	NWR complex name	character/text	Appendix D	Yes
CMPX_LIT**	NWR complex literal code	character/text	Appendix D	Yes
ORGNAME*	NWR station name	character/text	Appendix D	Yes
LIT**	NWR station literal code	character/text	Appendix D	Yes
Management Unit*	NWR habitat or management unit	character/text		Yes
Survey ID**	PRIMR survey identification number	character/text		Yes
Feature ID*	Identification number of grid cell	integer		Yes
Survey Year**	Year of survey (yyyy) (derived from Survey Date)	integer	-	Yes
Survey Date	Select survey date (mm/dd/yyyy)	date	-	Yes
Surveyor Name	Enter surveyor name conducting the survey	character/text	-	Yes
Target Species Name 1	Select infestation state	integer	Infestation State	Yes
Target Species Name 2	Select infestation state	integer	Infestation State	Yes
Target Species Name 3	Select infestation state	integer	Infestation State	Yes
Target Species Name 4	Select infestation state	integer	Infestation State	Yes
Target Species Name 5	Select infestation state	integer	Infestation State	Yes
Target Species Name 6	Select infestation state	integer	Infestation State	Yes
Target Species Name 7	Select infestation state	integer	Infestation State	Yes
Target Species Name 8	Select infestation state	integer	Infestation State	Yes
Target Species Name 9	Select infestation state	integer	Infestation State	Yes
Target Species Name 10	Select infestation state	integer	Infestation State	Yes
Other Species Name	Enter other invasive species common name (capitalize both genus and species)	character/text	-	No
Other Species State	Select infestation state	character/text	Infestation State	No
Comments	Enter comments	character/text	-	No
Picture	All photos are automatically assigned a to the grid in which they were taken	character/text	-	No
Completion Status	"Not Surveyed" is the default domain. Select "Complete" when the grid has been surveyed and data are entered, or "Not Complete" if a not all target species were surveyed.	character/text	Completion Status	Yes
Survey Acres**	Area of grid cell in units of acres	float	-	Yes

Table 4.2 Infestation state domains include 8 options (each with a unique Integer ID), including 6 infestation states (Integer ID 0 through 5) and two states indicated a species was not targeted (Integer ID 99) or the infestation state is unknown (Integer ID is 100). Note this is also Table SOP 5.2.

Integer ID	Data Entry Text	Brief Description
0	Clean	Species is absent (also referred to as "clean")
1	< 1%	Species is present with a single plant, or small patches, or widely scattered plants

2	1-10%	Species is present with several widely scattered plants or several small patches
3	10-25%	Species is present with many scattered plants or a few large patches or many small patches
4	25-60%	Species is present and co-dominating in tree canopy, sub-canopy, or ground cover
5	> 60%	Species is present and co-dominating to full canopy cover or blankets nearly all other vegetation
99	NOT TARGETED	Species was not targeted for inventory at a given NWR
100	UNKNOWN	Species' percent cover is unreported for a Target Species, Regional EDRR Species, or Other Species fields

Table 4.3 Completion status domains include Completed, Not Completed, and Not Surveyed corresponding character/text and brief description. Note this is also Table SOP 5.3.

Completion Status	Character/Text	Brief Description
Completed	Completed	Sampling unit has been sampled and is complete
Not Completed	Not Completed	Sampling unit has not been completed (inaccessible). Sampling unit is within the sample frame
Not Surveyed	Not Surveyed	Sampling unit has not been surveyed, but I expected to be sampled as part of the sampling frame

Table 4.4 Target species domains include all ITIS common names (see Appendix B for ITIS scientific name, and taxonomic serial number) separated by an underscore, and used to populate 10 fields (Target Species Name 1-10) in the IR-1 NWRS Invasive Survey Layer based on prioritization results for each refuge. Note this is also Table SOP 5.4.

Target Species	Target Species	Target Species	Target Species
alligator weed	common mullein	jimsonweed	South American waterweed
American lotus	common reed	johnson grass	spotted knapweed
amur honeysuckle	common tansy	kudzu	spurge
Asiatic tearthumb	common water hyacinth	large gray willow	swallowwort
autumn olive	creeping buttercup	marsh dewflower	sweet autumn virginsbower
barberry	crownvetch	mimosa	sweet fennel
bitter dock	curly pondweed	moneywort	swollen bladderwort
black locust	cypress spurge	morrows honeysuckle	tatarian honeysuckle
black mustard	English ivy	mugwort	thistle
black swallowwort	Eurasian water milfoil	multiflora rose	thorny olive
bog bulrush	European privet	narrowleaf bittercress	tree of heaven
border privet	fanwort	Norway maple	wall lettuce
broadleaf water milfoil	fig buttercup	Oriental bittersweet	water chestnut
buckthorn	flowering rush	pale swallowwort	weeping lovegrass
bull thistle	garlic mustard	paper mulberry	white clover
burningbush	giant hogweed	parrot feather	white poplar
callery pear	glossy buckthorn	perennial pepperweed	wild parsnip
Canada thistle	gray willow	porcelainberry	wild radish
cattail	honeysuckle	princess tree	wild rice
Chinese catalpa	hydrilla	privet	wineberry
Chinese lespedeza	Japanese barberry	purple loosestrife	yellow flag
Chinese privet	Japanese black pine	reed canary grass	yellow floating heart
Chinese wisteria	Japanese clover	reed mannagrass	yellow pond-lily
chocolate vine	Japanese honeysuckle	roundleaf chastetree	yellow sweetclover
coltsfoot	Japanese hop	rugosa rose	yellow toadflax
common barberry	Japanese knotweed	scots pine	
common buckthorn	Japanese sedge	shrubby lespedeza	
common frogbit	Japanese stiltgrass	smooth bedstraw	

Table 4.5 IR-1 NWR Invasive Treatment layer attributes, brief description, data type (date, character/text, or integer/float), and if the attribute is required as part of this protocol framework. All attributes are listed within AGOL layer. Target species corresponds with 109 domains (Table 4.4), action type corresponds with 5 domains (Table 4.6), and management action corresponds to the specific action taken. Attributes populated by the regional data manager are indicated by an asterisk, with a single asterisk indicating the field is populated pre-data collection and a double asterisks indicating the field is populated post-data collection, and all other domains are entered during field data collection.

Attribute	Brief Description	Date Type	Domain	Required
CMPXNAME**	NWR complex name	character/text	Appendix D	Yes
CMPX_LIT**	NWR complex literal code	character/text	Appendix D	Yes
ORGNAME*	NWR station name	character/text	Appendix D	Yes
LIT**	NWR station literal code	character/text	Appendix D	Yes
Surveyor Name	Enter surveyor name	character/text		Yes
Management Area Name	Enter the management area or habitat type name where the management action occurred or is planned to occur	character/text		Yes
Action Type	Select the type of action conducted	character/text	Action Type	Yes
Management Action	Select the primary management action	character/text	Management Action[1]	Yes
Target Species	Select the target invasive species of the management	character/text	Target Species	Yes
Management Description	Enter a brief description of the management action taken, such as the chemical solution used during herbicide treatment	character/text		Yes
PUPS_ID	Pesticide Use Protocol System identification number	integer		Yes
RAPP Year**	Fiscal year the management action was implemented (yyyy)	integer		Yes
Start Date	Select the start date of the management action (mm/dd/yyyy)	date		Yes
End Date	Select the end date of the management action (may be the same as start date) (mm/dd/yyyy)	date		Yes
Acres**	Area of treatment in units of acres	float		Yes
Comments	Enter comments about the management area or action taken, including any noticeable disturbance, such as evidence of spraying or other management. This attribute field may be used to record names and states of additional non-target invasive species or anything else of interest	character/text		No
Pictures	All photos are automatically assigned a to the polygon in which they were taken and given a name	character/text		No

[1]The management action domain is currently being revised by regional staff. Please contact if there are questions regarding which to management action to select.

Table 4.6 Action type domains include five categories: biological, burn, chemical, manual, mechanical, and Integrated Pest Management (see https://www.fws.gov/policy/569fw1.html). Four actions are RAPP treatment categories (DOI 2018; pg. 34), with the burn category added due to its broad application on refuges.

Action Type	Description
Biological	Using bio-control such as goats, or other bio-control for management

Burn	Using fire as a management strategy
Chemical	Using any combination of herbicide or other chemical agents
Manual	Using manual techniques such as hand –pulling as a strategy
Mechanical	The use of any saw, mower, or other mechanical device
Integrated Pest Management	Using a planned combination of techniques to achieve higher effectiveness

Data security and archiving

When data are entered into Collector, records are automatically (if connected to WiFi or cellular in the field) or manually (after a work area is completed) synced to AGOL and stored on the Esri cloud server (Figure 4.1). The Esri cloud server meets the Federal Information Security Management Act (FISMA) requirements under the Federal Risk and Authorization Management Program (FedRamp). The Regional Invasive Survey and IR-1 NWRS Invasive Treatment layer will be downloaded annually from AGOL as a geopackage and associated XML files on the USFWS Service Catalog (see *ServCat*; Appendix C). Each refuge's data layers are synced to the NWRS Invasive Species Dashboard App for rapid viewing of results (see *AGOL Webmaps*). Documenting all survey locations on NWRS lands is one of the priorities identified by the National Geospatial Advisory Committee; therefore, all data layers will be synced to the regional and national inventory and monitoring site datasets using the refuge's *PRIMR ID*.

FWSpecies

FWSpecies (https://ecos.fws.gov/FWSpecies/) documents the biodiversity of our National Wildlife Refuges by giving refuges a centralized location to build, manage, and share species lists and detailing each species' occurrence and status. These lists are easily accessible, revisable, expandable, and secure while providing standardized documentation of the species that occur on or near refuge lands for the availability of other Service programs, the public and partners. Before and after conducting this protocol for invasive plants, survey coordinators should review the species list for their refuge(s) in FWSpecies to ensure that inventoried species are reported. Inventoried species not already listed for a refuge in the FWSpecies database will be added progressively as they are found on the refuge. To gain editing access to FWSpecies, contact a regional data manager.

PRIMR

The Planning and Review of Inventory & Monitoring Activities on Refuges (PRIMR; https://ecos.fws.gov/primr/) is an online national information system database that allows refuges to easily document and catalog legacy, current, and future surveys. Maintaining these records preserves the institutional I&M knowledge for each station. The PRIMR database can be used by NWRs to identify protocols, such as this protocol framework, being implemented at other stations to increase collaboration and learning among stations and avoid duplicating protocol development efforts. In addition, PRIMR assists with development of I&M station and regional planning and implementation through various customized reports.

A unique *PRIMR ID* and survey record is created for each refuge implementing an invasive plant inventory using this protocol framework. Each refuge should select the "*Invasive Plant Inventory"* survey template and the name of the survey should remain *Invasive Plant Inventory* at each station (do not add "Monitoring" or "Survey" to the end of the survey name). The survey template will have many fields automatically populated to ensure accuracy in accordance with this protocol framework, which will aid in IMP development (e.g., fields contributing to creating

Table 1 and Survey Profile Tables). All remaining fields must be populated by the survey coordinator, including the ServCat link to associated products from this framework.

For example, the "Start Year" is the year in which data were first collected (e.g., 2020) and the "End Year" is the anticipated last year of the last inventory survey (e.g., 2022 if a single sampling frame is targeted for inventory and large enough to take three years to complete). The "End Year" should not remain "indefinite" for this inventory, as it was designed to be completed within a certain time frame to support strategic management. "Survey Frequency" should remain as "Occurs one time only", even if the station plans to re-inventory grids in future years (this would be a new inventory survey). Every year at the end of each survey season (e.g., November) the survey is marked as implemented (or not) for that year by selecting *Enter Annual Activity Survey* and selecting "Yes" or "No" in the *Data Collected?* field. If the survey was planned for a given year, but not implemented, the primary reason for a lack of implementation is entered to help identify and resolve barriers to implementing this protocol framework in subsequent years. If the station plans to use results from the *Invasive Plant Inventory* survey as year 1 data of trend or effectiveness monitoring survey, a second survey record is created to represent the monitoring portion of the survey (e.g., *Invasive Plant Monitoring)* because the associated metadata, SOPs (timing of re-survey, new grid size, and/or additional attributes such as native plant cover), analysis, and products may/will be different for a monitoring survey than for the inventory survey. A regional data manager can be consulted for assistance in implementing survey templates and finalizing the PRIMR survey record for this framework.

ServCat

The USFWS Service Catalog (ServCat; https://ecos.fws.gov/ServCat/) is a secure, national online database application designed to centralize and archive important documents, completed datasets, and associated metadata. ServCat records include protocol documentation elements, finalized data products, and reports (Element 5). These records should be marked open to the public (unless data include sensitive information). ServCat records may contain individual files or collections of files, and each record is assigned a long-term stable web link (Appendix C). Basic metadata are entered in ServCat for all protocol documents and data products associated with this protocol framework. Any supplemental paper datasheets, digital datasheets, or field notes generated during the inventory should reside with the survey coordinator and be archived to ServCat if deemed necessary.

All multi-refuge inventory and monitoring efforts of NAAR refuges (especially those using established protocol frameworks) are organized as ServCat *Programs*, with each participating refuge (or refuge complex) having its own invasive plant inventory *Project* for this framework (Figure 4.2). Following the national I&M ServCat guidance (USFWS 2019), each refuge's *Project* is cross referenced with their corresponding refuge-specific Inventory and Monitoring *Program*, which should include a list of all of the refuge's projects with surveys, datasets, and reports (especially IMP approved surveys). All refuge-specific documents used to implement this protocol framework, such as survey instructions, additional SOPs, training materials, interim and final reports (Element 5) are archived as *Products* under each refuge's *Project*, while all regional data and report *Products* are archived under the regional invasive plant inventory *Project* (Figure 4.2; Appendix C). The ServCat reference link for each survey *Product* should be copied into the "Survey Products" field of the corresponding survey record into PRIMR.

Products listed under the regional *Project* will include the IR-1 NWRS Invasive Survey layer and IR1 NWRS Invasive Treatment layer (e.g., each with a shapefile and corresponding XML geospatial metadata file), regional annual and final reports (.pdf and .docx files) and any code associated with creating data summaries (e.g., rcode, such as .R and .Rmd files). Regional *Products* and will be uploaded within six months of the final survey each year (approximately in January). All regional data layers will include the data layer name and year of the most recent survey across all refuges (e.g., Regional_Invasive_Survey_layer_2021.shp and Regional_Invasive_Survey_layer_2021.XML). Regional reports and any code (R or .Rmd) include the region (IR-1), protocol type (RPF) protocol framework name (InvasivePlantInventory), file type (RegionalAnnualReport or RefugeAnnualReport), and year. For example, files for the regional annual report may include: IR1_RPF_InvasivePlantInventory_RegionalAnnualReport_2021.pdf (final report) and IR1_RPF_InvasivePlantInventory _RegionalAnnualReport_2021.Rmd (code to generate final report), and IR1_RPF_InvasivePlantInventory _RegionalAnnualReport_DataSummary1_2021.R (source code for functions needed to generate final report).

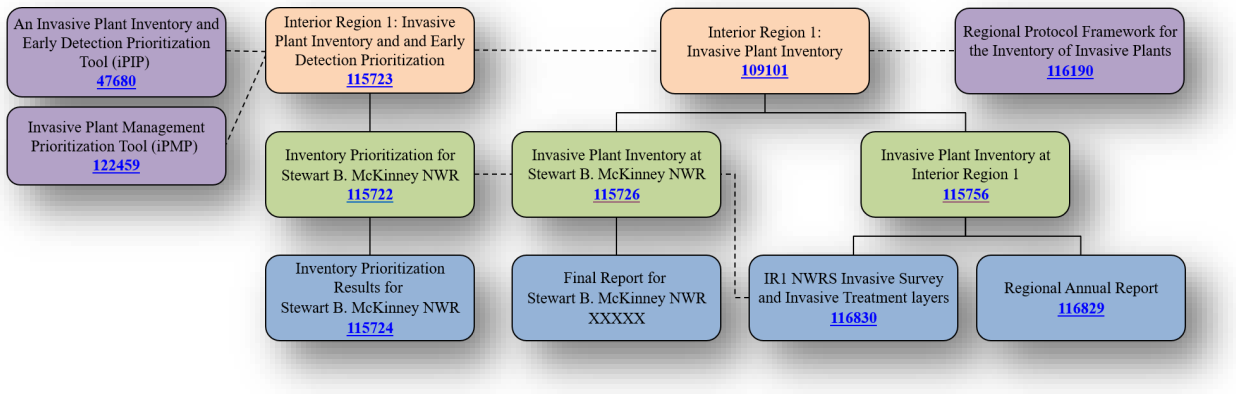

Figure 4.2 ServCat schema for this protocol framework includes Programs (orange), Projects (green), Products (blue) and Guiding Resources (purple). The protocol consists of the IRI Prioritization Program (with 1 Project and Product for each refuge that includes prioritization guidance and results), IR-1 Invasive Plant Inventory Program (with 1 Inventory Project and Product for each refuge that includes the Final Report), 1 Regional Project (with 2 Products that includes IR-1 NWRS Invasive Survey layer and IR-1 NWRS Invasive Treatment layer and Regional Annual Report), with the Regional Protocol Framework (this document) and Invasive Plant Prioritization Tools (iPIP and iPMP; purple) as a Guiding Resource. See Element 5 for details about reporting.

Analysis methods

Data may be summarized (after quality control) using a range of summary metrics to assess the spatial distribution and infestation severity of targeted invasive plant species (the survey objective). Data summaries are useful for developing management targets and strategies. Common summary metrics for reporting include total survey effort (e.g., acres completed), gross infestation (e.g., acres with at least 1 target species present), infestation severity (e.g., number of acres in each infestation state), EDRR species presence (e.g., detection of at least 1 regional EDRR species), and distribution (e.g., number and proximity of large, moderate, or small infested patches; see Table 5.1). Distribution metrics may be created to help identify

management targets and strategies (e.g., eradicate small patch species, contain moderate patch species, and tolerate large patch species).

Since this protocol framework was designed to be a rapid area search of all sample units in the sampling frame (census), it does not require any modeling or statistical approaches for broader inference to unsampled areas. If sub-sampling is required (see Sample Design) and thus inference to unsampled areas is needed, consult a biometrician for guidance on the most appropriate models to apply for broader inference. All summary metrics should be interpreted with caution in light of potential biases and errors (see Element 2). Important assumptions for consideration include: 1) only target plants were recorded (total acres infested of all invasive plants is likely grossly underestimated); 2) detection of target plants is likely imperfect (total acres infested of each target species is likely underestimated); 3) infestation states are subject to visual estimation errors and infestation states of 0, < 1 and 1-10 percent cover may be underestimated (number of clean areas, or the distribution of low density species, is over or underestimated). If the refuge is concerned about potential biases of surveyors and/or under- or overestimating infestation severity, a pilot study could be designed to quantify the probability of detection and misclassification rates (e.g., single season multi-state occupancy sample design and model), and then infestation states of each target species can be adjusted to provide a more realistic infestation severity estimates (or potential range).

Software

Before conducting an inventory, this protocol framework recommends that each refuge uses iPIP, a Microsoft Access platform to assist with prioritizing areas and plants for inventory and EDRR, and/or iPMP, a Microsoft Excel based decision tool to aid in selecting plants for management within pre-determined areas. Sampling units (grids) was created using a custom geoprocessing tool (model builder and Visual Basic code) in ArcMap 10.5 (SOP 1). The NWRS Invasive Species Dashboard App was created in ArcGIS Online (see *AGOL Webmaps*), and the Esri Collector application is used to collect and edit data. Data layers may be exported from ArcGIS Online for use in ArcMap (SOP 8). Regional and refuge reports (Element 5) can be created using Microsoft Word (or similar word processing software) and/or R, with a range of open-source packages (e.g., *tidyverse* for data wrangling and *markdown* for creating maps, graphs, and tables).

Element 5: Reporting

There are three broad types of reporting for this protocol framework: AGOL webmaps, regional annual reports, and refuge final reports. An inventory is not considered completed until both regional data layers are archived, and results are interpreted in regional annual reports, and refuge final reports are on ServCat (see Element 4; Appendix C). Additionally, the survey is not considered completed until it is marked as "historic" in PRIMR. Other products may be generated from survey results (e.g., story maps, fact sheets, or species lists) and should be catered to the target audience, distributed, and archived appropriately.

Implications and application

Invasive inventory reports serve multiple purposes, such as stating the survey objective and field methods, ensuring data accuracy and interpretation, documenting the severity of the invasive plant problem on each refuge, informing future management and monitoring, and documenting a

key information source used for developing management triggers and strategies. Significant findings within or across refuges, or across NWRS may be considered for publication in scientific journals or USFWS publications following the scientific integrity policy.

AGOL Webmaps

The NWRS Invasive Species Dashboard App (hereafter "App") is an AGOL webmap application to aid in displaying real-time inventory data collected across all refuges using this protocol framework (Figure 5.1). The App includes both primary datasets (IR-1 NWRS Invasive Survey layer and IR-1 NWRS Invasive Treatment layer) and allows users to view data by refuge and/or by target invasive species. The primary map displayed within the App will include a heat map of infestation states for each species. As a pilot (e.g., for 2021), the App will include at least the 5 most commonly detected invasive species to date (common reed, multiflora rose, Japanese stiltgrass, autumn olive), and 1 additional regional species of interest (perennial pepperweed). Over time, each species will be symbolized in the App based on the capacity of the GIS specialist. Note that refuges can always create their own maps for customized displays at any time (SOP 7). The symbology for each infestation state (i.e., percent cover class category) will be consistent across species and include grid boundaries (yellow), no fill color to represent grids not surveyed, green fill to represent a completed grid, and red fill color spectrum for each infestation state (clean grids have no fill, while < 1 percent cover has light pink to dart read for > 60 percent cover). The App also includes data summaries (e.g., total acres infested, total acres inventoried) that are customized to the user's view (region or refuge). Due to the AGOL data schema, limited customized maps and summaries are available within the online platform. If additional maps and summaries are desired by users to aid in data exploration and reporting (e.g., gross infestation or infestation hotspots), data layers can be downloaded from AGOL (SOP 8).

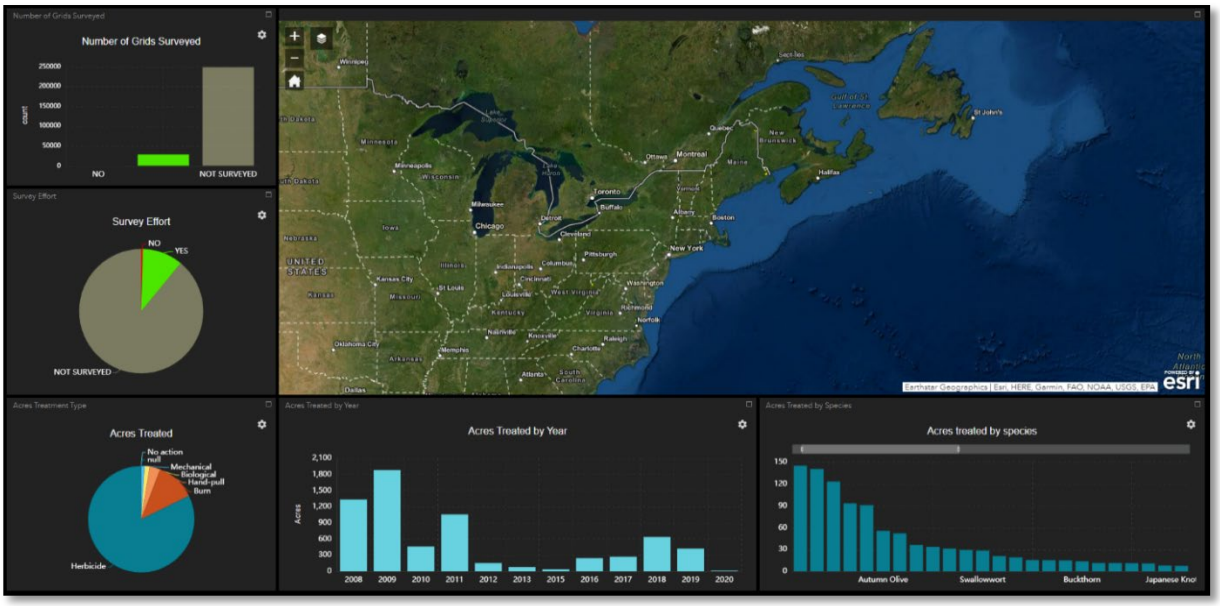

Figure 5.1 Example view of the NWRS Invasive Species Dashboard App scaled to NAAR NWRS (Virginia to Maine) with total survey effort of acres surveyed (upper pie chart), total acres treated (lower pie chart), acres treated by year (left lower bar chart), and acres treated by species (right lower bar chart).

Regional annual report

Objectives and methods

A regional annual report should allow all refuge staff (e.g., DNRCP Chief, I&M Coordinator, Invasive Network Team, Data Managers, Project Leaders and Biologists) to rapidly assess progress toward completing invasive plant inventories across the region. The report should contain a brief background with key information regarding protocol development and any major changes between years to aid in interpretation of results. The overall report objectives are to provide a snapshot of completed inventories that aids in future survey implementation (planning and field support) and to evaluate potential issues with data management (AGOL, PRIMR, ServCat). All reports should include names of the lead authors, reporting date range, reference files used to generate the report (including code and links to archived datasets) to ensure reproducibility and are the responsibility of the regional protocol team to complete (e.g., regional invasive coordinator and/or invasive biologist and regional data manager).

Summary of results

Regional annual reports should include results organized into several sections, including background, user summary, target invasive plant species and areas, survey effort, inventory results, treatment summary, PRIMR and ServCat, funding support, and discussion.

The background section should provide context for interpreting results and may include the following:

- brief status of the inventory protocol framework and major accomplishments (background)
- names of refuges (ORGNAME, LIT) that used this protocol in current and previous years with acres completed (user summary)
- target invasive plants (identified as highest priority to each refuge) and sampling frames (with acreage) for each refuge (target plants and areas)
- effort allocated toward conducting surveys (days) and number of volunteer effort (hours) (if applicable) (survey effort) for each refuge

Two sections will provide regional summaries of progress toward completing inventories for each refuge, most common target invasive plants detected and treatments deployed across the region and include the following:

- number of acres infested (across and by species) for each refuge with proper interpretation of results (i.e., not all target species are surveyed at every refuge and not all invasive plants present are recorded) (inventory results)
- number of acres and type of treatments implementing used during the inventory for each refuge and/or range of other management activities being conducted (treatment summary)

The report should provide a summary of the status of each survey's data and results in national databases, regional funds deployed to support inventories, such as a list of *PRIMR ID*s and status for each refuge conducting this protocol (current, future, historic), along with any additional field data, site-specific protocols, or reports uploaded to ServCat. I&M funds provided to refuge to support inventories and "light EDRR" treatments, and/or regional staff time spent supporting protocol implementation should also be reported. Fund allocation should be interpreted to ensure accurate understanding of the costs of conducting and supporting this inventory protocol.

Lastly, a discussion section should report important findings related to implementation of the inventory for the year, major highlights and accomplishments and/or future recommendations. Findings may include interesting or key results of the inventory (excessively high infestations or detection of regional EDRR species), insights regarding how the protocol was implemented and supported by the region (what worked well, what did not work well and why), and specific areas of improvement (planning, protocol element, data management, reporting, recording management actions) based on both field and regional perspectives.

Refuge final report

Objectives and methods

Refuge final reports are completed after all inventory surveys have been conducted and/or after 3 years (whichever comes first). Since the regional annual report and webmaps provide annual progress towards completing inventories at each refuge, refuge-specific annual reports are not required for this protocol framework. However, refuge may decide to generate a simple annual report to aid in workforce planning at the refuge scale (e.g., notes regarding volunteer trainings, hiring seasonal staff, budget expenditures). The objective of the final report is to allow current and future refuge staff, as well as other USFWS staff and the public, to rapidly understand why and how the inventory was conducted (citing this framework for the key methods) and the historical context of the survey (previous inventory or monitoring efforts). This should include the steps taken to plan, design, and complete the inventory (in lieu of a site-specific protocol), and interpret inventory results and potential auxillary data (additional data collected during the inventory that was not part of the regional protocol framework) in the context of future decision-making (e.g., results help assess the invasive problem, provide a baseline for developing management targets, and evaluation of potential management strategies). Each refuge manager may have additional objectives for the final report to ensure long-term data quality and interpretation. Include names of the lead authors, primary refuges being reported, date range (year to year), and reference files used to generate the report (including code and links to archived datasets) to ensure reproducibility.

Summary of results and important findings

Refuge final reports include a *brief* synopsis of the background, methods, inventory results, treatments, database management system, operational budget, and discussion and cite this protocol framework when applicable. This protocol recommends content for each section below, with a list of potential tables and figures (Table 5.1). Note that the protocol framework and regional annual report will contain a substantial amount of information regarding purpose, methods, and results. Final reports are intended to highlight important deviations, results or findings outside of what could be interpreted with the data alone. Reports should be written so that a new wildlife biologist, manager, or other refuge staff understands why it was important to conduct the inventory, how it was conducted, and important insights for future management and monitoring.

Title Page

- Title: *Final Report for the Inventory of Invasive Plants at [insert NWR full name]*
- Authors list: Last Name, First Name, Affiliation, City, State
- Report date: YYYY-MM-DD

- Inventory date range: YYYY to YYYY
- Suggested citation: Last, First Initial. YYYY. *Final Report for the Inventory of Invasive Plant at [insert full refugename]*. [insert full refuge name], City, State. [insert ServCat link to report]

Background

- Brief history of invasive plant surveys on the refuge (or refuge complex)
- Rationale for conducting this invasive plant inventory and using this protocol framework
- HMP management objectives (if applicable) expected to benefit from knowledge gained from conducting the invasive plant inventory survey and rationale for why invasive plants are a major/minor threat to achieving each management objective
- Inventory survey objectives (see *Survey objectives*)

Methods

- Summary of the methods used (using this protocol framework or if your survey deviated from this framework, explain how and rationale), names of all surveyors and their affiliations (FWS staff, volunteers, or others)
- Description of each target sampling frame(s) (with acres and habitat description), with a short description of the prioritization process used and final rationale for each species and area selected
- Selection of grid size for each sampling frame with rationale
- List of primary measurements (e.g. infestation states in this framework) and any additional fields collected outside of this framework and rationale for each
- Start and end date of surveys per year, total number of survey days required to complete surveys, and number of unique surveyors involved in conducting surveys.
- Unique or noteworthy events during the inventory are described in detail sufficient that other surveyors and data analysts can interpret conditions under which data were collected (e.g. grids were not surveyed due to rare plant or presence of listed species, poor weather, or high canopy cover reducing satellite signals).

Results

- Total acres inventoried across the refuge and by sampling frame and year
- Total acres infested by target species and associated maps of infestation states for each
- List and map (if detected) of the five selected regional EDRR species detected
- Infestation hotspots (many grids close together with high infestation state for many species) with associated maps
- Total acres treated by target species and associated maps of treatment areas
- Although out of the scope of this framework, results from re-surveying pre- and post-treatment areas (effectiveness monitoring that goes beyond the inventory survey in this protocol framework) may also be included

PRIMR and ServCat

- The *PRIMR ID*(s) associated with this inventory, survey status (current, historic), and any PRIMR fields that have not been completed

- Links to ServCat records associated with this report (report link, data link, protocol link, etc.)
- List other databases in which the data were submitted or archived (e.g., EDDMaps, FWSpecies) and the process for sharing data, if applicable

Operational Summary

- List the funding received to conduct this survey (e.g., USFWS invasive funding, I&M funding, or other sources) and how these funds were deployed
- List and explain any additional costs associated with conducting this survey (e.g., equipment, total staff time)

Discussion

- Identify key findings of ecological or management significance, especially those that help with interpretation of results (e.g., plant detection or identification issues) and future surveys (phenology and detectability)
- Discuss any new or novel non-target invasive plant species encountered and their potential importance
- Document potential mental models or ecologic hypotheses regarding spread of target invasive plant species and vulnerable habitats, communities, or resources of concern
- General recommendations for management targets (eradicate, contain, control) for each species for consideration in future management plans

Table 5.1 Potential data summaries and maps to aid in reporting, some of which are provided by the regional webmap, regional or refuge reports.

Data Summaries
Total number of acres inventoried (completed grid; table and map) and target species for each area
Total acres infested (> 1 percent cover) by each target species (gross infestation; table and map)
Total acres uninfested (0 percent cover for all target species (with map)
Total acres with each infestation state by target species (infestation distribution)
Total number of regional EDRR species detected (with map)
Total acres with 1, 2, 3…10 target species present (invasive biodiversity hotspot)
Total acres with high infestation states (at least 1 target species with > 60 percent cover) (high infestation hotspots)
Total acres with low infestation states (all target species infestation states are < 10 percent cover) (candidate eradication areas)
Total acres treated by treatment category and target species
Start and end survey dates per year and total number of inventory days (effort)

Reporting schedule

Regional annual reports are produced at the end of the field season (see Element 7) or within 3 months of the last survey of the year (e.g. December) to ensure adequate time to make adjustment for the following field season (funding, support to the field). Refuge final reports are to be completed within 6 months of the last inventory survey year (e.g., March) and should include results from the entire inventory (up to 3 years per sampling frame). The NWRS Invasive Species Dashboard App and any associated refuge webmaps are updated "live" and have no reporting schedule. Specialized reports (e.g., single species, multi-refuge or by habitat type) may be produced as needed to inform regional or refuge-specific management strategies.

Report distribution

All reports are archived on ServCat, marked as "public" (as appropriate), and distributed via weblinks (Appendix C). Note that although reports (.pdf or .docx) are not searchable on data.gov, the regional data layers should be searchable. Refuge-specific report distribution may include refuge leadership (e.g., NWRS Senior Leadership Team, Project Leaders, Regional I&M Coordinator, and DNRCP Chief), as well as the National Invasive Species Coordinator, the National Integrated Pest Management Coordinator, the Invasive Species Inventory and Monitoring working group, the National Invasive Species and Integrated Pest Management Coordination team. Data may also be shared or uploaded to EDDMapS (https://www.eddmaps.org/), iMap (https://www.imapinvasives.org/) and/or FWSpecies (https://doimspp.sharepoint.com/sites/fws-FF09R00000-species-information). When a new species (invasive plant) is documented for the first time on a refuge, FWSpecies records may be updated using the ServCat reference code for the regional dataset (i.e., 116830).

Element 6: Personnel Requirements and Training

Roles and responsibilities

Implementing this protocol framework requires collaborations between the regional invasive coordinator (or regional invasive biologist), survey coordinators (e.g., refuge staff), surveyors (e.g., field crews), regional data manager (or GIS specialist) and the regional biometrician.

The **regional invasive coordinator** (or regional invasive biologist) is responsible for overseeing the implementation of the protocol framework at each refuge to ensure effective communication and consistency. The regional invasive coordinator (or regional invasive biologist) and regional data manager (or biometrician) may assist the survey coordinators in interpreting and stepping down this protocol framework to specific refuges (e.g. reviewing sampling objectives, sampling frame and target species, grid size selection, and AGOL and Collector application setup).

Each refuge that selects this protocol framework must appoint a **survey coordinator** (e.g., Refuge Biologist), who is responsible for all aspects of implementing the survey at the station maintaining overall data integrity. The survey coordinator oversees applying this framework to their specific refuge (or refuge complex), and steps down survey instructions for surveyors within for the final report, oversees data collection, management, and interpretation, and ensures timely final reporting. It is the responsibility of the survey coordinator to train surveyors and ensure proficiency in identification, data collection methodology, and use of necessary technology. The survey coordinator plans the survey route, which may consist of areas to be surveyed each day, week, or month with or without a direction or order of preference. Lacking an appointed survey coordinator, a station cannot engage effectively or maintain the level of data integrity necessary for participation in this protocol framework.

Surveyors are responsible for implementing the survey (including following survey routes, field safety, daily data collection and management), and reporting results as assigned by the survey coordinator. It is the responsibility of the surveyors to reach the desired level of proficiency in completing these tasks outlined by the survey coordinator.

The **regional data manager** (or GIS specialist) is responsible for managing data workflows and content on AGOL. Together, the regional invasive coordinator (or regional invasive biologist)

and data manager are responsible for enrolling stations into the protocol framework, helping survey coordinators upload existing data, overseeing regional data integrity, updating invasive species lists, and other tasks related to data management. The regional data manager will provide technical support to survey coordinators with creating and archiving their grid system, installing, running, and setting up Collector, as well as syncing data to regional data layers and creating webmaps in AGOL.

The **regional biometrician** may be consulted for technical assistant regarding sampling design, sampling frames, survey objectives, grid sizes, running regional reports (R scripts), as well as using the inventory framework for another survey purpose (trend or effectiveness monitoring, or research study).

Qualifications

This protocol framework should be implemented by survey coordinators (trained FWS Biologists at the participating refuge) with knowledge of invasive plant ecology, phenology, and identification, survey design, survey planning, coordination and implementation (multiple surveyors), effective treatment methods, and basic knowledge of data management systems, such as ArcGIS Online (AGOL, Collector) and USFWS databases (PRIMR, ServCat). The survey coordinator should be able plan and implement this protocol framework, in collaboration with surveyors, in accordance with the scientific integrity and scholarly conduct (212 FW 7.7).

The field portion of the protocol is implemented by surveyors (e.g. who could be the survey coordinator, intern, biological technician, or volunteer) with knowledge of invasive plant identification (especially target plants of the inventory and rare plant communities, if applicable), basic survey techniques and equipment (GPS and iPad), field navigation, data entry and management (Collector), and oral and written communication skills. Surveyors may be asked to walk long distances, over several hours in inclement weather and uneven terrain, and navigate through a variety of habitats. Volunteers of less physical capability can survey less challenging areas as defined by the survey coordinator. Personnel must be able to accurately record data using the Collector application. Basic GIS and AGOL skills may be needed if surveyors are expected to prepare the survey grid in conjunction with the regional data manager.

The regional invasives coordinator (or regional invasives biologist) should be an expert in invasive plant ecology and identification, survey design, effective treatment methods, and should be well trained in this protocol framework, able to coordinate and manage implementation across the region, and have a basic understanding of the principles of survey design and data management (for protocol implementation).

The regional data manager should be an expert in tabular and geospatial data management with a knowledge of data science and database administration, as well as working knowledge of survey design (or consult regional biometrician), field data collection, basic data analysis and visualizations, and be able to assist with setting up and troubleshooting the Collector application and data workflows.

Training

Training materials (e.g. invasive plant identification materials) were not developed as part of this protocol framework because over 100 invasive plant species will be targeted across refuges (Appendix B), and regional variations in plant phenology and habitats will require refuge-specific training materials. Additionally, training materials for Collector are available via ESRI and other online sources available to the public. Refuges are encouraged to develop their own training materials (e.g., slide shows with photos of species and identifying characteristics organized by growth form) and share with other refuges by uploading materials to their refuge's ServCat Project (Appendix C).

This framework recommends approximately 16 hours (approximately 2 days) of training for surveyors before conducting the field portion of the survey. This framework recommends all surveyors complete 4 hours of classroom training (1 session) in invasive plant identification and data entry with Collector, coupled with 12 hours of field training (3 x 4 hrs sessions) in field identification, survey techniques (Collector), and safety. More or less training time may be required based on the skill sets of surveyors (especially volunteers). If needed, personnel may be given the opportunity for eight hours of self-study and practice.

Classroom training may use prepared slide shows to review basic botany, plant families, and target species (invasive, native, or rare communities of interest to the survey coordinator), emphasizing diagnostic characteristics to distinguish invasive species from other similar plants based on growth form and habitats (e.g., native honeysuckle). The U.S. Department of Agriculture (USDA) provides a detailed description of more than 50 invasive species categorized by growth form in the northeast (Olson & Cholewa 2009; Miller et al. 2010), and other species descriptions may be found at http://www.bugwood.org and www.invasive.org. It is recommended that each refuge provide access to a plant field guide for reference and limit collecting new specimens for classroom identification training (see field training for identification or existing herbariums).

Field training should include visiting one or more sites (on or off refuge) where many, if not all, of the target species are known to occur *in situ*. To find sites, survey coordinators may consult regional invasive experts, or point- or county-level distribution data available from the Early Detection and Distribution Mapping System (EDDMapS; http://www.eddmaps.org). All personnel should be trained in procedures to minimize the risk of inadvertently transmitting invasive plant propagules between sampling areas, and demonstrations of techniques should occur during field training (see *Spread prevention techniques*).

A day of self-study should be made available to surveyors. Actual tasks may vary, depending on the survey coordinator and the experience of the field crew. Surveyors may use the day to do inside and outside review and develop their own "cheat sheets" to help them in the field. Alternatively, each of the surveyors may create a digital slide show with photographs and a brief description of a portion of the target species and likely habitat conditions.

All personnel should adhere to refuge-specific safety training measures. Surveyors should be trained on a variety of situations: answering questions from the public, encountering a crime or a private-citizen emergency, region specific field risks (e.g., encountering and removing ticks or

insects, avoiding venomous snakes and toxic plants), potential injuries in the field (e.g., heat exhaustion, bee stings, potential allergies) and management or stabilization, and emergency contact numbers and protocol. Prior to entering a new area, surveyors should consult with others who know the area to determine the appropriate dress and the equipment required.

Element 7: Operational Requirements

Budget

This framework is intended to be flexible to allow survey effort to fluctuate with budgets and priorities at each refuge in any given year. The costs associated with completing this protocol is shared between the region and the refuge. Regional costs are largely driven by staff time, including coordination time by the regional invasive coordinator (or regional invasive biologist) and regional data manager. Refuge costs will vary substantially and largely depend on the total acres targeted for inventory, as well as the selected grid size, number of target plants, site accessibility, and vegetation complexity that may decrease the ability to rapidly move from grid to grid. Refuge costs are largely driven by time (current staff and seasonal staff), with moderate to low (< $2000) equipment and maintenance costs. An example budget is provided by refuge staff experienced with conducting invasive plant inventories for a theoretical 617 acre target sampling area (1000 50 m x 50 m grids), with 10 target invasive species and 5 regional EDRR species, and moderate to easy access and minimal vegetation complexity (Table 7.1). Most stations will hire interns or biological technicians, or use volunteers with plant identification expertise, to conduct inventory surveys. For remote locations or areas with high vegetation complexity, two surveyors are recommended to ensure safety, although one person could undertake the surveys if familiar with the sampling area, landscape, and has superior navigation skills and safety awareness. Equipment costs are generally low and based on on-line retail prices (SM 1), and some stations will already own some of the needed equipment (e.g., iPad, vehicles, decontamination equipment). Costs are in 2020 dollars and annual inflation factors of 2 to 4% can be applied to quickly predict costs in subsequent years. Current prices of equipment should be obtained from vendors when applying for funding support.

Staff time

General estimates of staff time (weeks per year) required to implement this framework are provided for each primary role (Table 7.1). Planning, training, and grid set up may only occur within the first year of the inventory, while reporting occurs annually for regional staff and at the end of the inventory for survey coordinators. The regional coordinator consults with each refuge using this framework to ensure consistency in implementation of the protocol and assist with coordinating multi- refuge hires and equipment purchases and reviewing regional annual reports. The regional data manager assists refuges with setting up their grids, data archiving, maintaining the AGOL layers and webmaps and runs the regional annual report (with assistance from the regional biometrician). If 10 to 15 new refuge stations decided to set up inventories in a given year, the total regional staff time requirement would be approximately 0.4 to 0.6 FTE, split evenly among the survey coordinator and regional data manager. The survey coordinator steps down this framework, coordinates hiring, training, and supervision of surveyors, and oversees survey planning, implementation, data management, and reporting.

Table 7.1 Example budget to set up, conduct, and complete an inventory at a single refuge (or refuge complex) with a sampling frame consisting of approximately 1000 x 50 meter x 50 meter grid cells (617 acres), with 10 target invasive plant species. The actual time required to conduct the survey will depend on how easy it is to navigate among survey grid cells (which takes the most time in the field), species detection ability, and the overall level of infestation. All hours and prices are estimated from refuge staff that have previously conducted an inventory. Note that equipment totals may be a minimum (does not include field clothes, emergency phones, boot brushes, picks, or blowers used for preventing spread of plants) and many items may be a one-time purchase for the refuge to be used for multiple purposes and years.

	Staff Time (Week)								Operational Expenses ($)			Total
	Plan and Train	**Grid Set Up**	**Data Collection[5]**	**Data Archiving**	**Database Maintenance**	**Report**	**Total Weeks**	**Total FTE[6]**	**Staff**	**Fuel**	**Equipment[7]**	
Regional Staff												
Regional Coordinator[1]	0.4	-	-	0.2	-	0.2	0.8	0.02	$1,222	-	-	
Regional Data Manager[2]	-	0.2	0.1	0.2	0.4	0.1	0.9	0.02	$1,479	-	-	
Total per NWR	**0.4**	**0.2**	**0.1**	**0.4**	**0.4**	**0.3**	**1.8**	**0.04**	**$2,701**	**-**	**-**	**$2,701**
Station Staff												
Survey Coordinator[3]	0.6	0.4	0.4	0.4	-	1.0	2.8	0.05	$3,574	$100	$1,388	
Surveyors[4]	0.5	-	5.0	0.4	-	0.5	6.4	0.12	$4,679	-	-	
Total per NWR	**1.1**	**0.4**	**5.4**	**0.8**	**-**	**1.5**	**9.2**	**0.17**	**$8,253**	**$100**	**$1,388**	**$9,741**

[1]Regional Invasive Biologist (GS 9)
[2]Regional Data Manager (GS 11)
[3]Survey Coordinator (GS 9/11/12, assumed GS 11 for operational staff expenses)
[4]Surveyors (GS5, contractor, biotech, or volunteers)
[5]Data collection includes quality control activities prior to archiving
[6]Full time employee (FTE) or 52 weeks using 2020 GS Pay Table
[7]Includes iPad Pro ($1,099), AppleCare ($79), External Charger ($40), LifeProof Case ($170; SM 1: Equipment Purchasing Guide), but prevention equipment could also be added

Schedule

A typical schedule for conducting activities associated with the inventory component of this protocol is provided to aid in workforce planning (Table 7.2). This schedule is dictated by the growing seasons of the invasive plant species targeted for management and will be adjusted for each refuge. This cycle will occur each year until each inventory is completed across all select sampling frames (habitat or management units) on the refuge.

Table 7.2 Example annual schedule of activities based on station staff categories in Table 7.1. Note reporting will only be completed after the inventory is complete (not every year), and planning may be reduced after the first year.

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Plan Survey												
Train Surveyors												
Data Collection												
Data Archiving												
Report												

Coordination

Survey coordinators communicate with the regional invasive coordinator (and/or regional invasive biologist) throughout the course of inventory to ensure that the protocol framework is being implemented consistently, surveyors are being hired and trained in a timely manner, and data manager is aware of upcoming workload to assistant the field. Regional invasive coordinator should coordinate with the regional invasive network (including the regional data manager, I&M coordinator, DNRCP Chief, and Senior Leadership Team) on progress of inventories across the region and resources needed to support each refuge in implementing this protocol framework, and communicate how data collecting using this framework supports strategic habitat conservation for every refuge and across the NWRS.

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Appendices

Appendix A: Protocol Checklist

This framework includes several essential steps for completing the inventory protocol, which are described throughout the Elements and SOPs. To improve the ability for survey coordinators at each refuge station (often Refuge Biologists) to properly plan, implement, synthesize and archive data collected using this protocol, the following checklist was created as a general guide with important links to specific sections of the protocol for more information.

- ❑ Review CCP and/or HMP management objectives, priority habitats, priority ROCs, and management units (see *Management Objectives*).
- ❑ Decide if an invasive inventory survey (this protocol framework) is the most appropriate survey to meet the refuge's information needs for improving management (see Reynolds et al. 2016). If so, add to IMP and/or contact regional staff for assistance.
- ❑ Create list of potential sampling frames (see *Sampling frame and units*) and plants for inventory in each. Review current distribution maps (EDDMapS), and use a prioritization process (e.g., iPIP) to rank and select highest priority areas and plants.
- ❑ Write a survey objective statement using results from prioritization process (see *Survey Objectives*), and upload prioritization results with survey objective to the refuge's Invasive Plant Prioritization Project on ServCat (see *ServCat* and 115723). Contact regional staff for assistance.
- ❑ Consider alternative grid sizes (see Figure 2.1) based on inventory area and configuration, and contact regional data manager to establish grid system (SOP 1 and SOP 2).
- ❑ Evaluate field time and resources required to complete inventory over the next 3 years for at least one sampling frame by listing potential surveyors, developing a survey schedule, and assessing funding availability (see Element 7).
- ❑ Confirm with project leader that survey is a high priority and review resources needed to support the survey. Contact regional office if additional funding is needed (e.g., Invasive RFP).
- ❑ Select the *Invasive Plant Inventory* survey in PRIMR and update all metadata so the record is "complete" (see PRIMR).
- ❑ Review survey methods and evaluate equipment (SOP 5). Purchase additional or upgrade equipment if needed (SM 1) and hire additional staff (interns) or secure volunteers as surveyors, if needed.
- ❑ Set up Collector on the iPad, create collaborator accounts in AGOL, and add members to your project group (SOP 3).
- ❑ Train surveyors in spread prevention techniques, plant identification, and use of Collector (see *Training*).
- ❑ Plan the survey route and timing based on phenology, download work areas if cellular data plan is lacking (SOP 4), surveyors collect data in the field (invasive layer and treatment layer) (SOP 5). Record management actions in field, if applicable (SOP 6).
- ❑ Assess survey progress, quality control data, and visualize results in regional AGOL webmap or refuge maps (SOP 7; SOP 8), and fix data errors reported in regional annual report.
- ❑ Annually, communicate any concerns with protocol implementation to refuge and regional staff and update PRIMR each year to indicate the survey was completed (Select "Yes" or "No" under Surveys → "Enter Annual Activity" → "Data Collected?").
- ❑ When inventory is completed for a given sampling frame (or all sampling frames), write the refuge final report, upload to the refuge's Invasive Plant Inventory Project on ServCat (109101), and distribute results as needed.

Appendix B: Common Invasive Plant Species on NWRs

This appendix lists potential invasive plants for inventory on IR-1 NWRs (Table B.1). This list is not exhaustive, and a refuge may decide to include additional species. Note that all species should have a corresponding ITIS TSN number (https://www.itis.gov/).

Table B.1. ITIS common name, scientific name, and taxonomic serial number (TSN) for each common invasive plant species recently observed (e.g., 2015-2020) or anticipated to occur on NWRs, including 5 regional EDRR species in the IR-1 North Atlantic-Appalachian Region (asterisk).

ITIS Common Name	ITIS Scientific Name	ITIS TSN
alligator weed	*Alternanthera philoxeroides*	20770
American lotus	*Nelumbo lutea*	18398
amur honeysuckle	*Lonicera maackii*	35298
Asiatic tearthumb	*Persicaria perfoliata*	823774
autumn olive	*Elaeagnus umbellata*	27776
barberry	*Berberis spp*	18814
bitter dock	*Rumex obtusifolius*	20939
black locust	*Robinia pseudoacacia*	504804
black mustard	*Brassica nigra*	23061
black swallowwort	*Vincetoxicum nigrum*	523292
bog bulrush	*Schoenoplectus mucronatus*	507791
border privet	*Ligustrum obtusifolium*	32976
broadleaf water milfoil	*Myriophyllum heterophyllum*	27044
buckthorn	*Rhamnus spp*	28561
bull thistle	*Cirsium vulgare*	36428
bur chervil*	*Anthriscus caucalis*	29586
burningbush	*Euonymus alatus*	27946
callery pear	*Pyrus calleryana*	504706
Canada thistle	*Cirsium arvense*	36335
cattail	*Typha spp.*	42324
Chinese catalpa	*Catalpa ovata*	34314
Chinese lespedeza	*Lespedeza cuneata*	25898
Chinese privet	*Ligustrum sinense*	32979
Chinese wisteria	*Wisteria sinensis*	27023
chocolate vine	*Akebia quinata*	18857
coltsfoot	*Tussilago farfara*	38583
common barberry	*Berberis vulgaris*	18837
common buckthorn	*Rhamnus cathartica*	28573
common frogbit	*Hydrocharis morsus-ranae*	503098
common mullein	*Verbascum thapsus*	33394
common reed	*Phragmites australis*	41072
common tansy	*Tanacetum vulgare*	36328
common water hyacinth	*Eichhornia crassipes*	42623
creeping buttercup	*Ranunculus repens*	18642
crownvetch	*Securigera varia*	521245
curly pondweed	*Potamogeton crispus*	39007
cypress spurge	*Euphorbia cyparissias*	28061
elmleaf blackberry*	*Rubus ulmifolius*	504890
English ivy	*Hedera helix*	29393
Eurasian water milfoil	*Myriophyllum spicatum*	27039
European privet	*Ligustrum vulgare*	32980
fanwort	*Cabomba caroliniana*	18408
fig buttercup	*Ranunculus ficaria*	18603
flowering rush	*Butomus umbellatus*	38886
garlic mustard	*Alliaria petiolata*	184481
giant hogweed	*Heracleum mantegazzianum*	502954
giant reed*	*Arundo donax*	41450

ITIS Common Name	ITIS Scientific Name	ITIS TSN
glossy buckthorn	*Rhamnus frangula*	28579
gray willow	*Salix cinerea*	22519
honeysuckle	*Lonicera spp.*	35281
hydrilla	*Hydrilla spp.*	38973
Japanese barberry	*Berberis thunbergii*	18835
Japanese black pine	*Pinus thunbergii*	183390
Japanese clover	*Kummerowia striata*	503294
Japanese honeysuckle	*Lonicera japonica*	35283
Japanese hop	*Humulus japonicus*	503065
Japanese knotweed	*Fallopia japonica*	565897
Japanese sedge	*Carex kobomugi*	39406
Japanese stiltgrass	*Microstegium vimineum*	503829
jimsonweed	*Datura stramonium*	30520
johnson grass	*Sorghum halepense*	42111
kudzu	*Pueraria montana*	504683
large gray willow	*Salix atrocinerea*	520760
large-flower primrose-willow*	*Ludwigia grandiflora*	516152
marsh dewflower	*Murdannia keisak*	39145
mimosa	*Albizia julibrissin*	26449
moneywort	*Lysimachia nummularia*	23993
morrows honeysuckle	*Lonicera morrowii*	35299
mugwort	*Artemisia vulgaris*	35505
multiflora rose	*Rosa multiflora*	24833
narrowleaf bittercress	*Cardamine impatiens*	22798
Norway maple	*Acer platanoides*	28755
oriental bittersweet	*Celastrus orbiculatus*	506068
pale swallowwort	*Vincetoxicum rossicum*	523295
paper mulberry	*Broussonetia papyrifera*	19107
parrot feather	*Myriophyllum aquaticum*	503904
perennial pepperweed	*Lepidium latifolium*	503379
porcelainberry	*Ampelopsis brevipedunculata*	28632
princess tree	*Paulownia tomentosa*	33460
privet	*Ligusticum spp*	29523
purple loosestrife	*Lythrum salicaria*	27079
reed canary grass	*Phalaris arundinacea*	41335
reed mannagrass	*Glyceria maxima*	40846
roundleaf chastetree	*Vitex rotundifolia*	505725
rugosa rose	*Rosa rugosa*	24811
scots pine	*Pinus sylvestris*	183389
shrubby lespedeza	*Lespedeza frutescens*	515841
slender oat*	*Avena barbata*	41456
smooth bedstraw	*Cruciata laevipes*	506922
south american waterweed	*Egeria densa*	38972
spotted knapweed	*Centaurea stoebe*	780246
spurge	*Euphorbia spp*	28032
swallowwort	*Cynanchum*	500233
sweet autumn virginsbower	*Clematis terniflora*	18712
sweet fennel	*Foeniculum vulgare*	29509
swollen bladderwort	*Utricularia inflata*	34453
tatarian honeysuckle	*Lonicera tatarica*	35306
thistle	*Cirsium spp*	36334
thorny olive	*Elaeagnus pungens*	502223
tree of heaven	*Ailanthus altissima*	28827
wall lettuce	*Mycelis muralis*	503893
water chestnut	*Trapa natans*	27170
weeping lovegrass	*Eragrostis curvula*	502340
white clover	*Trifolium repens*	26206
white poplar	*Populus alba*	22451
wild parsnip	*Pastinaca sativa*	29795
wild radish	*Raphanus sativus*	23290

ITIS Common Name	ITIS Scientific Name	ITIS TSN
wild rice	*Zizania aquatica*	41319
wineberry	*Rubus phoenicolasius*	25016
yellow flag	*Iris pseudacorus*	43194
yellow floating heart	Nymphoides peltata	29998
yellow pond lily	*Nuphar advena*	18382
yellow sweetclover	*Melilotus officinalis*	26150
yellow toadflax	*Linaria vulgaris*	33216

Appendix C: ServCat Records

All guidance documents, datasets, and reports for this protocol framework are organized under the Interior Region 1: Invasive Plant Inventory Program (ServCat Reference Code: 109101), which includes prioritization of areas and target plants (Table C.1), protocol framework guidance and products (regional datasets and regional reports; Table C.2), and refuge specific projects (final reports with any additional datasets) associated with PRIMR surveys (Table C.3).

Table C.1. List of ServCat records for prioritizing areas and target invasive plants for inventory and EDRR. Each NWR implementing this protocol framework must upload the results from their prioritization process (e.g., iPIP and/or iPMP). Contact the regional office to set up a new ServCat Project for the refuge's prioritization results (and survey objectives).

Reference Type	Title	Brief Description	ServCat Link
Program	Interior Region 1: Invasive Plant Inventory and Early Detection Prioritization Program	IR1 Program to support prioritization of areas and plants for inventory and EDRR.	115723
Generic Dataset	An Invasive Plant Inventory and Early Detection Prioritization Tool (IPIEDPT; version 4.0)	Guidance document and Access database tool to assist with prioritizing areas and plants for inventory and associated EDRR.	47680
Generic Dataset	Invasive Plant Management Prioritization Tool (IPMPT; version 1.0)	Excel based tool to assist with prioritizing areas and plants for management.	122459
Project	Invasive Plant Inventory and Early Detection Prioritization at Stewart B. McKinney National Wildlife Refuge	Results from prioritization process (iPiP)	115722
Project	Invasive Plant Inventory and Early Detection Prioritization at Back Bay National Wildlife Refuge	Results from prioritization process	TBD
Project	Invasive Plant Inventory and Early Detection Prioritization at Missisquoi National Wildlife Refuge	Results from prioritization process	TBD
Project	Invasive Plant Inventory and Early Detection Prioritization at Eastern Shore of Virginia National Wildlife Refuge	Results from prioritization process (iPiP)	122416

Table C.2. List of ServCat records for regional protocol framework guidance, regional datasets, and regional reports.

Reference Type	Title	Brief Description	ServCat Link
Regional Protocol Framework	Regional Protocol Framework for the Inventory of Invasive Plants [In Review]	This protocol framework (version 0.9)	116190
Project	Invasive Plant Inventory in Interior Region 1 Project	The regional project that contains 2 regional product (Raster Dataset and Unpubished Report)	115756
Geospatial Dataset	IR1 NWRS Invasive Plant Inventory Protocol Regional Dataset	Annual upload of IR1 NWRS Invasive Survey layer and IR1 NWRS Invasive Treatment layer and metadata files.	116830
Unpublished Report	IR1 NWRS Invasive Plant Inventory Protocol: 2020 Regional Annual Report	Annual upload of Regional Annual report summarizing the list of NWRs that completed inventories that year.	116829

Table C.3. ServCat reference codes (ServCat ID) for each NWR specific project, which will contain final reports and additional datasets associated with each NWR's PRIMR survey, with the NWR's current IMP Status (None, Draft w/ Selected Survey, Draft w/o Selected Survey, Approved w/ Selected Survey, Approved w/o Selected Survey) and Inventory Status (None Planned, In Progress, Not Started, Completed). A dash indicates that project has not yet been created in ServCat and should be created when a NWR has an inventory report, training materials, survey instructions, or additional data available to archive. A list of all Department of Interior Region 1 National Wildlife Refuge Inventory and Monitoring ServCat Programs can be found here: https://ecos.fws.gov/ServCat/Collection/Profile/1317.

Title	IMP Status	Inventory Status[1]	ServCat ID
Invasive Plant Inventory at Back Bay National Wildlife Refuge	Draft w/ Selected Survey	In Progress	109102
Invasive Plant Inventory at Canaan Valley National Wildlife Refuge	None	In Progress	-
Invasive Plant Inventory at Cape May National Wildlife Refuge	None	Not Started	-
Invasive Plant Inventory at Chesapeake Marshlands National Wildlife Refuge Complex	None	None Planned	-
Invasive Plant Inventory at Chincoteague National Wildlife Refuge	None	In Progress	-
Invasive Plant Inventory at Coastal Delaware National Wildlife Refuge Complex	None	In Progress	-
Invasive Plant Inventory at Eastern Massachusetts National Wildlife Refuge Complex	None	In Progress	116263
Invasive Plant Inventory at Eastern Shore of Virginia and Fisherman's Island National Wildlife Refuges	None	In Progress	-
Invasive Plant Inventory at Eastern Virginia Rivers National Wildlife Refuge Complex	None	In Progress	-
Invasive Plant Inventory at Edwin B. Forsythe National Wildlife Refuge	None	None Planned	-
Invasive Plant Inventory at Erie National Wildlife Refuge	None	In Progress	-
Invasive Plant Inventory at Great Dismal Swamp National Wildlife Refuge	None	In Progress	-
Invasive Plant Inventory at Iroquois National Wildlife Refuge	None	In Progress	-
Invasive Plant Inventory at John Heinz National Wildlife Refuge	None	Completed	-
Invasive Plant Inventory at Lenape National Wildlife Refuge Complex	None	Not Started	-
Invasive Plant Inventory at Long Island National Wildlife Refuge Complex	None	None Planned	-
Invasive Plant Inventory at Maine Coastal Islands National Wildlife Refuge	Approved; Selected Survey	In Progress	-
Invasive Plant Inventory at Missisquoi National Wildlife Refuge	None	In Progress	-
Invasive Plant Inventory at Montezuma National Wildlife Refuge	None	In Progress	-
Invasive Plant Inventory at Northern Maine National Wildlife Refuge Complex	None	In Progress	-
Invasive Plant Inventory at Ohio River Islands National Wildlife Refuge Complex	None	None Planned	-
Invasive Plant Inventory at Parker River National Wildlife Refuge (includes Great Bay NWR)	None	In Progress	-
Invasive Plant Inventory at Patuxent Research Refuge	Approved w/ Selected Survey	Not Started	-
Invasive Plant Inventory at Potomac River National Wildlife Refuge Complex	Draft w/ Selected Survey	In Progress	114744
Invasive Plant Inventory at Rachel Carson National Wildlife Refuge	Approved w/ Selected Survey	Completed	109439

Invasive Plant Inventory at Rhode Island National Wildlife Refuge Complex	Draft w/ Selected Survey	In Progress	111477
Invasive Plant Inventory at S.O. Conte National Fish and Wildlife Refuge	None	In Progress	-
Invasive Plant Inventory at Stewart B. McKinney National Wildlife Refuge	None	In Progress	115726
Invasive Plant Inventory at Umbagog National Wildlife Refuge	None	None Planned	-

[1]Inventory status is based on knowledge of regional staff and last updated in October 2020.

Appendix D: NWR Complex and Station Names

Table D.1. NWR complex and station names (CMPXNAME, ORGNAME, respectively) with corresponding literal (LIT) codes (CMPX_LIT and LIT) for 75 NWR stations eligible to conduct this protocol. Names and codes help locate surveys in PRIMR and ServCat and aid in annual reporting.

CMPXNAME	CMPX_LIT	ORGNAME	LIT
BACK BAY NATIONAL WILDLIFE REFUGE	BKB	BACK BAY NATIONAL WILDLIFE REFUGE	BKB
CANAAN VALLEY NATIONAL WILDLIFE REFUGE	CAV	CANAAN VALLEY NATIONAL WILDLIFE REFUGE	CAV
CAPE MAY NATIONAL WILDLIFE REFUGE	CPY	CAPE MAY NATIONAL WILDLIFE REFUGE	CPY
CHESAPEAKE MARSHLANDS NATIONAL WILDLIFE REFUGE COMPLEX	CMC	BLACKWATER NATIONAL WILDLIFE REFUGE	BLK
CHESAPEAKE MARSHLANDS NATIONAL WILDLIFE REFUGE COMPLEX	CMC	EASTERN NECK NATIONAL WILDLIFE REFUGE	ESN
CHESAPEAKE MARSHLANDS NATIONAL WILDLIFE REFUGE COMPLEX	CMC	MARTIN NATIONAL WILDLIFE REFUGE	MRN
CHESAPEAKE MARSHLANDS NATIONAL WILDLIFE REFUGE COMPLEX	CMC	SUSQUEHANNA NATIONAL WILDLIFE REFUGE	SSQ
COASTAL DELAWARE NATIONAL WILDLIFE REFUGE COMPLEX	CDC	PRIME HOOK NATIONAL WILDLIFE REFUGE	PMH
COASTAL DELAWARE NATIONAL WILDLIFE REFUGE COMPLEX	CDC	BOMBAY HOOK NATIONAL WILDLIFE REFUGE	BMH
CHINCOTEAGUE NATIONAL WILDLIFE REFUGE COMPLEX	CHN	WALLOPS ISLAND NATIONAL WILDLIFE REFUGE	WAL
CHINCOTEAGUE NATIONAL WILDLIFE REFUGE COMPLEX	CHN	CHINCOTEAGUE NATIONAL WILDLIFE REFUGE	CHN
CHINCOTEAGUE NATIONAL WILDLIFE REFUGE COMPLEX	CHN	FISHERMAN ISLAND NATIONAL WILDLIFE REFUGE	FSH
CHINCOTEAGUE NATIONAL WILDLIFE REFUGE COMPLEX	CHN	EASTERN SHORE OF VIRGINIA NATIONAL WILDLIFE REFUGE	ESV
EASTERN MASSACHUSETTS NATIONAL WILDLIFE REFUGE COMPLEX	EMC	ASSABET RIVER NATIONAL WILDLIFE REFUGE	ASR
EASTERN MASSACHUSETTS NATIONAL WILDLIFE REFUGE COMPLEX	EMC	GREAT MEADOWS NATIONAL WILDLIFE REFUGE	GRM
EASTERN VIRGINIA RIVERS NATIONAL WILDLIFE REFUGE COMPLEX	EVC	JAMES RIVER NATIONAL WILDLIFE REFUGE	JSR
EASTERN VIRGINIA RIVERS NATIONAL WILDLIFE REFUGE COMPLEX	EVC	PLUM TREE ISLAND NATIONAL WILDLIFE REFUGE	PTI
EASTERN VIRGINIA RIVERS NATIONAL WILDLIFE REFUGE COMPLEX	EVC	PRESQUILE NATIONAL WILDLIFE REFUGE	PRS
EASTERN VIRGINIA RIVERS NATIONAL WILDLIFE REFUGE COMPLEX	EVC	RAPPAHANNOCK RIVER VALLEY NATIONAL WILDLIFE REFUGE	RPP
EASTERN MASSACHUSETTS NATIONAL WILDLIFE REFUGE COMPLEX	EMC	MASHPEE NATIONAL WILDLIFE REFUGE	MHP
EASTERN MASSACHUSETTS NATIONAL WILDLIFE REFUGE COMPLEX	EMC	MONOMOY NATIONAL WILDLIFE REFUGE	MNY
EASTERN MASSACHUSETTS NATIONAL WILDLIFE REFUGE COMPLEX	EMC	MASSASOIT NATIONAL WILDLIFE REFUGE	MSA
EASTERN MASSACHUSETTS NATIONAL WILDLIFE REFUGE COMPLEX	EMC	NANTUCKET NATIONAL WILDLIFE REFUGE	NAT
EASTERN MASSACHUSETTS NATIONAL WILDLIFE REFUGE COMPLEX	EMC	NOMANS LAND ISLAND NATIONAL WILDLIFE REFUGE	NLI
EASTERN MASSACHUSETTS NATIONAL WILDLIFE REFUGE COMPLEX	EMC	OXBOW NATIONAL WILDLIFE REFUGE	OXB
EDWIN B. FORSYTHE NATIONAL WILDLIFE REFUGE	EBF	EDWIN B. FORSYTHE NATIONAL WILDLIFE REFUGE	EBF
ERIE NATIONAL WILDLIFE REFUGE	ERE	ERIE NATIONAL WILDLIFE REFUGE	ERE
IROQUOIS NATIONAL WILDLIFE REFUGE	IRQ	IROQUOIS NATIONAL WILDLIFE REFUGE	IRQ
GREAT DISMAL SWAMP NATIONAL WILDLIFE REFUGE	DIS	GREAT DISMAL SWAMP NATIONAL WILDLIFE REFUGE	DIS
NANSEMOND NATIONAL WILDLIFE REFUGE	NAS	NANSEMOND NATIONAL WILDLIFE REFUGE	NAS
JOHN HEINZ NATIONAL WILDLIFE REFUGE AT TINICUM	TCM	JOHN HEINZ NATIONAL WILDLIFE REFUGE AT TINICUM	TCM
LENAPE NATIONAL WILDLIFE REFUGE COMPLEX	LNP	CHERRY VALLEY NATIONAL WILDLIFE REFUGE	CHV
LENAPE NATIONAL WILDLIFE REFUGE COMPLEX	LNP	GREAT SWAMP NATIONAL WILDLIFE REFUGE	GRS
LENAPE NATIONAL WILDLIFE REFUGE COMPLEX	LNP	WALLKILL RIVER NATIONAL WILDLIFE REFUGE	WLK
SHAWANGUNK GRASSLANDS NATIONAL WILDLIFE REFUGE	SGL	SHAWANGUNK GRASSLANDS NATIONAL WILDLIFE REFUGE	SGL
LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	LIC	AMAGANSETT NATIONAL WILDLIFE REFUGE	AMG
LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	LIC	CONSCIENCE POINT NATIONAL WILDLIFE REFUGE	CNP
LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	LIC	ELIZABETH ALEXANDRA MORTON NATIONAL WILDLIFE REFUGE	MOR

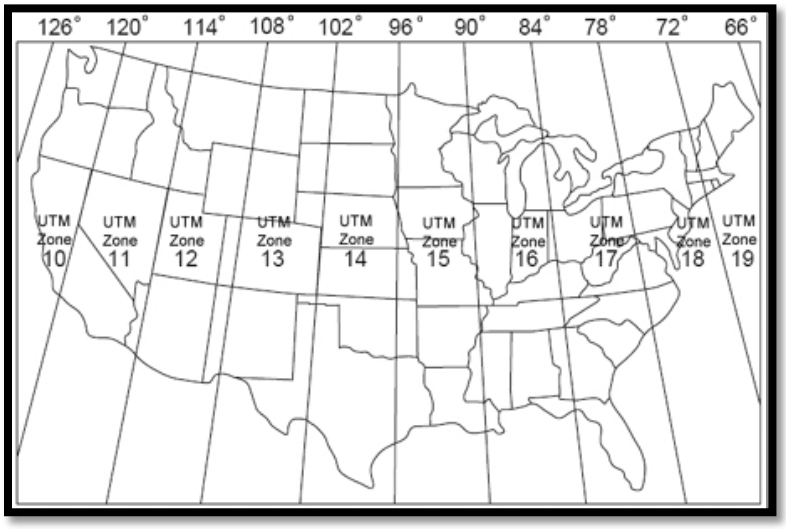
LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	LIC	LIDO BEACH WILDLIFE MANAGEMENT AREA	CLB
LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	LIC	OYSTER BAY NATIONAL WILDLIFE REFUGE	OYS
LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	LIC	SEATUCK NATIONAL WILDLIFE REFUGE	STK
LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	LIC	TARGET ROCK NATIONAL WILDLIFE REFUGE	TGR
LONG ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	LIC	WERTHEIM NATIONAL WILDLIFE REFUGE	WRT
MAINE COASTAL ISLANDS NATIONAL WILDLIFE REFUGE COMPLEX	MEC	CROSS ISLAND NATIONAL WILDLIFE REFUGE	CRI
MAINE COASTAL ISLANDS NATIONAL WILDLIFE REFUGE COMPLEX	MEC	FRANKLIN ISLAND NATIONAL WILDLIFE REFUGE	FID
MAINE COASTAL ISLANDS NATIONAL WILDLIFE REFUGE COMPLEX	MEC	SEAL ISLAND NATIONAL WILDLIFE REFUGE	SIS
MAINE COASTAL ISLANDS NATIONAL WILDLIFE REFUGE COMPLEX	MEC	PETIT MANAN NATIONAL WILDLIFE REFUGE	PMN
MAINE COASTAL ISLANDS NATIONAL WILDLIFE REFUGE COMPLEX	MEC	POND ISLAND NATIONAL WILDLIFE REFUGE	PIS
MISSISQUOI NATIONAL WILDLIFE REFUGE	MSQ	MISSISQUOI NATIONAL WILDLIFE REFUGE	MSQ
MONTEZUMA NATIONAL WILDLIFE REFUGE	MNT	MONTEZUMA NATIONAL WILDLIFE REFUGE	MNT
NORTHERN MAINE NATIONAL WILDLIFE REFUGE COMPLEX	NMC	AROOSTOOK NATIONAL WILDLIFE REFUGE	ARO
NORTHERN MAINE NATIONAL WILDLIFE REFUGE COMPLEX	NMC	CARLTON POND WATERFOWL PRODUCTION AREA	CPW
NORTHERN MAINE NATIONAL WILDLIFE REFUGE COMPLEX	NMC	MOOSEHORN NATIONAL WILDLIFE REFUGE	MSH
NORTHERN MAINE NATIONAL WILDLIFE REFUGE COMPLEX	NMC	SUNKHAZE MEADOWS NATIONAL WILDLIFE REFUGE	SNK
OHIO RIVER ISLANDS NATIONAL WILDLIFE REFUGE	ORI	OHIO RIVER ISLANDS NATIONAL WILDLIFE REFUGE	ORI
PARKER RIVER NATIONAL WILDLIFE REFUGE	PKR	PARKER RIVER NATIONAL WILDLIFE REFUGE	PKR
GREAT BAY NATIONAL WILDLIFE REFUGE	GTB	GREAT BAY NATIONAL WILDLIFE REFUGE	GTB
THACHER ISLAND NATIONAL WILDLIFE REFUGE	TIS	THACHER ISLAND NATIONAL WILDLIFE REFUGE	TIS
WAPACK NATIONAL WILDLIFE REFUGE	WPC	WAPACK NATIONAL WILDLIFE REFUGE	WPC
PATUXENT RESEARCH REFUGE	PWR	PATUXENT RESEARCH REFUGE	PWR
POTOMAC RIVER NATIONAL WILDLIFE REFUGE COMPLEX	PRC	FEATHERSTONE NATIONAL WILDLIFE REFUGE	FRS
POTOMAC RIVER NATIONAL WILDLIFE REFUGE COMPLEX	PRC	MASON NECK NATIONAL WILDLIFE REFUGE	MSN
POTOMAC RIVER NATIONAL WILDLIFE REFUGE COMPLEX	PRC	OCCOQUAN BAY NATIONAL WILDLIFE REFUGE	OCQ
RACHEL CARSON NATIONAL WILDLIFE REFUGE	RHC	RACHEL CARSON NATIONAL WILDLIFE REFUGE	RHC
RHODE ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	RIC	BLOCK ISLAND NATIONAL WILDLIFE REFUGE	BLI
RHODE ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	RIC	JOHN H. CHAFEE NATIONAL WILDLIFE REFUGE	JHC
RHODE ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	RIC	NINIGRET NATIONAL WILDLIFE REFUGE	NGR
RHODE ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	RIC	TRUSTOM POND NATIONAL WILDLIFE REFUGE	TPD
RHODE ISLAND NATIONAL WILDLIFE REFUGE COMPLEX	RIC	SACHUEST POINT NATIONAL WILDLIFE REFUGE	SPT
SILVIO O. CONTE NATIONAL FISH AND WILDLIFE REFUGE	SOC	JOHN HAY NATIONAL WILDLIFE REFUGE	JHY
SILVIO O. CONTE NATIONAL FISH AND WILDLIFE REFUGE	SOC	SILVIO O. CONTE NATIONAL FISH AND WILDLIFE REFUGE	SOC
SILVIO O. CONTE NATIONAL FISH AND WILDLIFE REFUGE	SOC	STEWART B. MCKINNEY NATIONAL WILDLIFE REFUGE	SBM
SUPAWNA MEADOWS NATIONAL WILDLIFE REFUGE	SPM	SUPAWNA MEADOWS NATIONAL WILDLIFE REFUGE	SPM
UMBAGOG NATIONAL WILDLIFE REFUGE	LKU	UMBAGOG NATIONAL WILDLIFE REFUGE	LKU

Standard Operating Procedures (SOP)

SOP 1: **Creating Grid and Sampling Units**

The inventory is conducted within a grid overlaid on the selected sampling frame defined during the prioritization process. This SOP details how to create the grid using ArcGIS and is commonly completed by the regional data manager in consultation with the survey coordinator. Prior to creating a grid, the inventory prioritization process should be completed and an appropriate study design (sampling frame and appropriate grid cell size) should be selected. Survey coordinators will need the following information for this SOP: boundary of the sampling frame (e.g. habitat or area of inference as a single shapefile, or separate shapefiles for each sampling frame if grid cell sizes and species differ), and the invasive grid geoprocessing tool (Template_Grid.zip available at https://ecos.fws.gov/ServCat/Reference/Profile/116190).

- Open a new empty map in ArcMap
- Set the projection and units for data frame by selecting the View menu option and then Data Frame Properties.
- Select the General tab in the Data Frame Properties pop-up box and select Meters for both Map and Display in the Units box. Click Apply.
- Select the Coordinate System tab and expand the Projected Coordinate System folder. In the directory, navigate to UTM > NAD 1983 > [your UTM zone]. See the figure below to determine which zone your NWR is in. Click Apply and OK.



- Add the area boundary shapefile to the data frame (this layer must be a shapefile within the same spatial coordinate system). If grid size differs for each inventory area, repeat this step.
- Open ArcCatalog. Navigate to the folder location where the invasive grid geoprocessing tool is stored. Expand the toolbox and double click on the inventory model to open the tool. Select the area boundary as the Input Feature. Select the NWR from the drop-down list. Name the management unit, habitat type, or resource area (if no management name or habitat type exists, type “Area 1”, or another unique name). Enter the target invasive species (typically 10 or less) using common names in the dialog boxes: Species One

through Species Ten. Define the grid size (in meters) in the Grid Size dialog box. Click OK to run the tool. If you don't have ten species, than fill in the remaining species dialog boxes with "A", "B", or "C", etc.

- The tool will automatically output a new grid in the "Template_Grid" geodatabase within the invasive grid tool folder. The new feature class will be named by concatenating the NWR name + management unit name + Inventory_Grid (e.g. "EASTERN_SHORE_OF_VIRGINIA_ NATIONAL_WILDLIFE_REFUGE Southern Tip Inventory_Grid".
- In Microsoft Windows Explorer, compress the shapefile and the associated files into a zipped folder and place in the "Invasive Grid Data Transfer" SharePoint site here: https://doimspp.sharepoint.com/sites/fws-FF05R02000-invasive-species/Shared%20Documents/Forms/AllItems.aspx?newTargetListUrl=%2Fsites%2Ffws%2DFF05R02000%2Dinvasive%2Dspecies%2FShared%20Documents&viewpath=%2Fsites%2Ffws%2DFF05R02000%2Dinvasive%2Dspecies%2FShared%20Documents%2FForms%2FAllItems%2Easpx&viewid=5b09e712%2Ddbc7%2D47c2%2Dac99%2Df6ffd1e413fd&id=%2Fsites%2Ffws%2DFF05R02000%2Dinvasive%2Dspecies%2FShared%20Documents%2FInvasive%20Grid%20Data%20Transfer

SOP 2: **Uploading Grid to ArcGIS Online for Collector**

This SOP details how to upload grid maps to ArcGIS Online (AGOL) for use in Collector and is commonly completed by the regional data manager. All U.S. Fish & Wildlife Service employees have an AGOL account that requires either a PIV card or an active directory username and password to access. Survey coordinators will need "Publishing" rights to create a feature service to upload data to AGOL, which can be obtained by the National IRTM GIS Coordinator and will need to be added as an owner of the data layer to complete this SOP (access can be requested here: https://doimspp.sharepoint.com/sites/fws-gis/SitePages/FWS-ArcGIS-Online-Publisher-Request.aspx). SOP 1 created the grid as a shapefile and exported as a zipped folder (.zip), which is then appended to the IR-1 NWRS Invasive Survey layer in AGOL using the steps below.

1. Locate the IR-1 NWRS Invasive Survey layer in AGOL
2. Navigate to the "Data" tab on the upper right of page, between "Overview" and "Visualization"
3. Click the "Options" tab located at the top-right of the data table and choose "Append Data to layer"
4. Use the "Choose File" to locate the zipped folder containing the newly created grid (must be a zipped shapefile).
5. Once zipped folder is chosen, click "Upload and Continue"
6. If the field names in the input file do not exactly match the fields in the layer, click Show field matching to map the fields from the file to the fields in the layer. Click apply to finish.
7. Go back to the Overview tab of the IR-1 NWRS Invasive Survey layer in AGOL https://fws.maps.arcgis.com/home/item.html?id=fc34c61be8e8474d930a7c526bf07de6. Click Open in Map Viewer.. Click Save Map and enter "[LITCODE] National Wildlife Refuge Grid (Collector)". This serves as the Refuge Invasive Webmap. Enter "Invasive" in tags, and add a brief summary. Click OK.
8. Click Basemap > choose Imagery. Any other layers you add to the map must be enabled for offline use. It is recommended that only the grid and the IR-1 NWRS Invasive Treatment layer (see SOP 5 for attributes collected) be added to the map while inventorying. Click Share and check U.S. Fish and Wildlife Service, and check any groups that you wish to share this map. Click OK.
9. Under the IR-1 NWRS Invasive Survey layer in the table of contents in your map, click "More Options"
10. Ensure that the map is offline enable. Go My Content > click on the map you created > Settings. Under Offline, check Enable offline mode. Click Save.

SOP 3: **Creating ArcGIS Online Collaborators and Surveyor Roles**

This SOP details how to create ArcGIS Online (AGOL) groups, add group members, and establish member roles. This is helpful for allowing Surveyors to access maps and feature services, along with restricting accessibility. Creating groups is a common method to provide a simple level of data security. Since AGOL does not allow for subfolders within a group, all projects related to the NWR will be stored within the group, including the survey associated with this inventory protocol framework. If the NWR group already exists, proceed to step 8.

1. Open AGOL in the a web browser https://fws.maps.arcgis.com/home/index.html.
2. Click "Sign in" with Enterprise Account. Enter "FWS" in the dialog box to finish the organization account URL. Click using U.S. FISH AND WILDLIFE SERVICE.
3. Go to the Groups tab and click Create Group. Most NWRs already have a group created. Check before attempting to create a new group (if so, go to step 8).
4. Each section with a red asterisk must be filled-in. Provide a simple group name. This protocol relies on the NWR literal followed by "Projects" (e.g., PRK_Projects). Provide a brief summary of the group and the group's intent (e.g. this group was created to store projects related to Parker River NWR". Enter simple tags (e.g., invasive, NWRS, Parker River NWR) to increase searchability within AGOL.
5. Under "Who can view this group?", check "People in the organization (U.S. Fish & Wildlife Service)".
6. Under the "Who can join this group?" section, check "Those who request membership and are approved by a group manager".
7. Under the "Who can contribute content to the group?" section, "Group members" should be checked. This restricts any outside content to be added to the group.
8. Click the Create Group tab.
9. Within the Group page, users can be invited by clicking the Invite Users tab. Type the name of the person to give access to the group and click search. If they are registered in AGOL, their name will appear in the Users box below. Click the user's name to add them to the Invitation List. If the user is a member of your organization, check the box "Add members of the organization immediately, without requiring confirmation". Click Send Invitation. This will automatically add them to the group. If they are outside partners, than you will need to send the invitation, and the user will have to respond to the invitation within AGOL.
10. If the user does not belong to an AGOL Organization, a FWS employee must input a collaborator (Non-FWS Person) information below in order to have a collaborator account created. Survey coordinators must vet the collaborator and ensure that it is necessary they have access to the FWS AGOL Account as the survey coordinator is sponsoring the collaborator. Collaborators will only be able to Join Organizational Groups, edit existing features, and share within the organization. To register, fill out the form here: https://fishnet.fws.doi.net/projects/gisnew/Lists/Publisher_Collaborator_Pro_Form/Item/newifs.aspx?List=1ba4ff31-665c-48de-bf77-5fcd068cba13&RootFolder=&Web=d3156e04-03c1-48c4-a667-07307f9c1a43. For additional guidance about collaborator accounts: https://fishnet.fws.doi.net/projects/gisnew/Lists/Publisher_Collaborator_Pro_Form/Item/

newifs.aspx?List=1ba4ff31-665c-48de-bf77-5fcd068cba13&RootFolder=&Web=d3156e04-03c1-48c4-a667-07307f9c1a43

11. Once members have been added to the group, click the Members tab. This will display all members of the group. Check the box next to the member whom you would like to make the group manager or group member click “Update Member’s Group Role”. Choose Group Manager or Group Member. Group Manager has the rights to add and or delete users and content, Group Members can only add content.
12. The survey coordinator notifies the FWS AGOL administrators (Paul Hoeffler) when a collaborator account is no longer needed. Administrators will remove the account from the FWS AGOL Organization when the collaborator’s work with the FWS is completed.

SOP 4: **Preparing Offline Work Areas in Collector**

This SOP details how to prepare offline work areas in Collector before conducting a survey. Work areas are typically created in anticipation of being off Wi-Fi and/or cellular service when conducting the inventory. If the NWR has good Wi-Fi and/or cellular service, than you can enter data directly without creating work areas. Creating offline work areas allows Surveyors to enter data when Wi-Fi and/or cellular service is unavailable and to ensure proper synchronizing of data to ArcGIS Online (AGOL). Surveyors must establish and download distinct work areas that contain all grids for a single survey (1 surveyor, 1 day), multiple surveys (1 surveyor, multiple days or multiple Surveyors, 1 or multiple days). A work area is a uniquely defined area designated by the survey coordinator and downloaded from the Refuge Invasive Webmap "[LITCODE] National Wildlife Refuge Grid (Collector)", which was created in SOP 2, to the iOS device's internal memory. Each work area should be large enough to capture at least a full day's work (1 survey), yet small enough to not consume too much of the iOS device's internal memory (ideally 6-8mb).When downloading the work area, all layers including the treatment layer, are downloaded within the map. Although a particular work area may take several days to complete, its best practice to synchronize any offline data collection and edits to AGOL daily, as the downloaded work area is considered a child version of the master version on the Esri cloud server. To perform this SOP, the survey coordinator must open the Apple Store application on the iOS device, search for "Collector for ArcGIS", and download the application. Note, there is a "Classic" version of Collector, which is NOT intended for use with this protocol.

To create and download work areas:

1. Turn on the iOS device, ensure it is connected to a Wi-Fi source or cellular data (if purchased), and open Collector.
2. Both ArcGIS Online and ArcGIS Enterprise will appear, choose ArcGIS Online.
3. Select Enterprise login, enter "FWS" in the text window, and press Continue.
4. Select "USING YOUR U.S. FISH AND WILDLIFE SERVICE ACCOUNT".
5. Enter your USFWS active directory username and password.
6. Once Collector opens, a series of accessible webmaps will be visible, click on the Refuge Invasive webmap named "[LITCODE] National Wildlife Refuge Grid (Collector)" to open.
7. To create and download a work area, press the 3-dots icon and select the Add Offline Area tab to identify the offline work area. If you have cellular data access in the field, remember you do not have to download work areas to avoid overlapping work areas.
8. After the Add Offline Area icon is selected, a map opens up to a window where to define the work area. Pan and zoom to the extent of the offline work area. Note that if two Surveyors are creating separate offline work areas, overlapping work areas should be avoided at all cost (see below).
9. Use the "level of detail" tab to change the size of your offline area. Once at the desired scale (Room, Rooms, Small Buildings, etc.), press the Download Area tab to download the map to the iOS device.
10. After the map has downloaded, you may (not required) change the name of the work area (default is "Area 1", "Area 2", etc.) by clicking the 3-dots icon. If you have many offline work areas, naming each work area differently can help keep track of

which have been complete, as a single inventory (across multiple years) will often require several work areas.

11. Click on the map to open, zoom out to see the full extent of the work area. Notice how the features (i.e., grids) are "clipped" to the work area. Features may extend past the work area because the clipping captures all features touching the bounding box of the work area.

Avoid overlapping work areas

If multiple surveyors are surveying in the same area, but not the same grids, Surveyors must avoid creating overlapping offline work areas to maintain proper data synchronizing with AGOL. For example, two Surveyors (surveyor 1 and surveyor 2) define two separate offline work areas (A and B, respectively). Each surveyor has a small section of overlapping work area (C). Surveyor 1 collected data (or edited previously collected data) in the overlapping work area (C), while surveyor 2 did not collect any data in the overlapping area. At the end of the work day, surveyor 1 synced data to the master version on AGOL at 4:00 PM, while surveyor 2 synced data at 4:05 PM. Surveyor 2 would overwrite surveyor 1 data for grids in the overlapping work areas, resulted zero data being saved to AGOL from surveyor 1 (Figure SOP 4.1). To avoid overlapping areas, the survey coordinator can request the regional data manager to help create pre-defined work areas as small acreages of overlap are important to avoid. However, this would limit the survey coordinator's ability to define custom work areas. This can be completely avoided if, while in the field, you are connected to the cloud via your cellular data plan. If so, there is no need to download work areas.

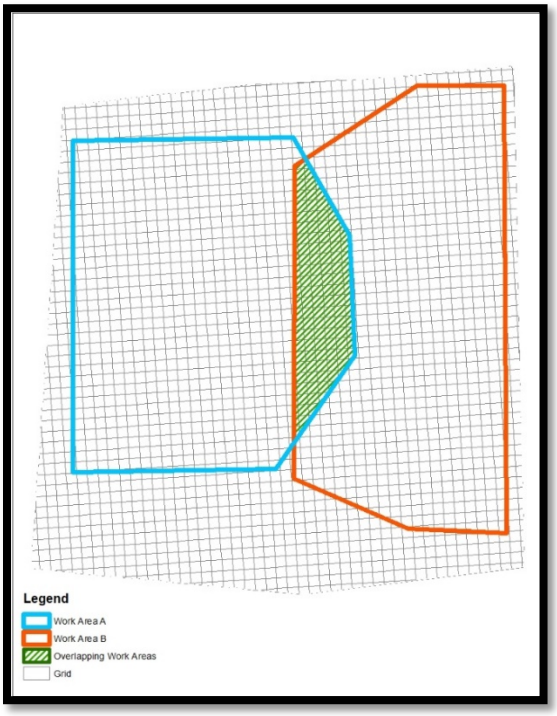


Figure SOP 4.1 Example of overlapping offline work areas (green area) from two surveyor's individual work areas (surveyor 1 = work area A, blue, surveyor 2 = work area B, orange), which should be avoided.

SOP 5: **Conducting a Survey**

This SOP details how to use Collector to prepare, collect, and enter data. These steps are commonly completed by the surveyor, in collaboration with the survey coordinator. Details about purchasing equipment can be found in SM1.

Gather equipment and supplies

- Handheld iOS device (e.g., iPad, iPhone) with Collector installed and a waterproof case;
- Portable GNSS receiver (to enhance Collector accuracy) (optional);
- Spare batteries and/or portable charger for all electronic devices;
- Maps with areas (grid cells) to be surveyed and the preferred survey route;
- Field references for plant identification (e.g., field guides or cheat sheet cards);
- Camera to photograph unknown plants (e.g., iOS device can take photos via Collector);
- Plastic bags and paper towels for unknown specimen collection (optional);
- Phone (e.g., tract phone for roving crews) in weatherproof case for emergencies;
- Water supply, sunscreen, bug spray;
- Boots, waders, gaiters, and/or raincoat (optional);
- Boot bush and/or pick for cleaning shoe soles (optional);
- Potable leaf blower for removing seeds/propagules from vehicles/field equipment (optional).

Navigate to starting grid

1. Open Collector on the iOS device, and open the appropriate offline work area (if applicable; SOP 4).
2. Turn on any additional layers that may be helpful (e.g., NWR boundaries, Management Units), along with setting the preferred basemap.
3. Use the work area, navigate to the starting grid.
4. Select a corner of the grid to start (the next grid will start at the opposite corner; Figure SOP 5.1).
5. A blue dot with an arrow within it will appear and represent the iOS device's current location. The arrow is the currently traveling direction, not a navigation direction to the start grid. Orient the blue arrow to start grid and navigate to the grid location.
6. Upon arrival at the start grid, click on the grid in the map. The bottom panel will open, click the pencil to edit the plot attributes. DO NOT press the PLUS button because it will add activate the polygon for the IR-1 NWRS Invasive Treatment layer (see SOP 6 when ready to enter treatment data); if you do press it, just hit cancel to return to the previous screen.
7. Click the edit tab and enter "Survey Date", "Surveyor Name" (Table SOP 5.1).
8. The surveyor walks a slow modified "Z" route throughout the grid and ends at the opposing side of the next grid (Figure SOP 5.1), searching for approximately 1 minute for every target species (e.g., approximately 10 to 20 minutes total per grid given 10 target species and a 50-m x 50-m grid size). Increased search time is expected during early surveys to calibrate accurate plant identification. If two surveyors are present, each can walk each grid and visually estimate infestation states independently and enter a consensus infestation state. Do not count each individual vine for species such as bittersweet or Japanese honeysuckle but focus instead on the amount of area covered by

each species. Note that cover is the portion of the ground obscured by a species' aboveground leaves and stem, percent is the unit of measure. Use Figure SOP 5.2 examples as a guide for visually assessing percent cover and converting to infestation state.

9. The surveyor mentally tracks estimates of percent cover for each target plant, while navigating the route using the Collector map and using navigation arrow to ensure the lead surveyor stays within the focal grid.
10. Once the surveyor reaches the end of the grid, the infestation state for each target species and regional EDRR species (Table SOP 5.1; Table SOP 5.2; Table SOP 5.4) is entered into Collector.
11. If there is another species detected (not target or regional EDRR) and the survey coordinator wants to record it, enter information for "Other Species Name" and "Other Species State" (drop-down menu of percent covers). These columns are optional.
12. Select "Complete" once infestation states for each target and regional EDRR species has been entered. If the grid cell cannot be completed due to access, choose "Not Complete". The default is "Not Surveyed" (Table SOP 5.3).
13. Record any noteworthy comments about the grid in the "Comments" field, such as noticeable disturbance or evidence of management. Since "Comments" is a text field, it may also be used to record names and infestation states of additional non-target EDRR invasive species within the observed area and/or anything of interest to the surveyors or survey coordinator.
14. Click "Take Photo" to take photos (optional) of plants within the gird using the using the Collector application's in-app camera or accessing the iPad's camera.
15. After all attributes are entered into Collector for the grid, click the "Submit" tab in the upper right corner.
16. The surveyor should be at the start of the next grid, repeating steps 7-15 until all grids have been surveyed in the work area for the day or week.
17. If working offline, at the end of the survey (daily or weekly) data should be checked for data entry errors before syncing with AGOL using a strong Wi-Fi source (preferably at the office), even if not all grids in the offline work area were completed. Click the 3-dots and choose Sync to begin synchronizing. If working online, data should be checked for data entry errors periodically (and especially before the end of the season and before the regional annual report) for errors.
18. After the syncing process is completed and all grids have been surveyed in the offline work area, click the "Remove Area" tab to remove the offline work area from the iOS device. Upload a new offline work area for the next survey (SOP 4).
19. If additional data entry errors are observed after syncing, open the layer in AGOL and edit the records as appropriate or contact the regional data manager for assistance.
20. Final editing of layers should be conducted prior to finalizing the regional annual report and the regional data manager will notify survey coordinators of any errors to correct before archiving the data layers and annual report.

Figure SOP 5.1 Example modified “Z” routes through each grid following a linear survey route across multiple grids.

Table SOP 5.1 IR-1 NWRS Invasive Survey layer attributes, brief description, data type (date, character/text, or integer/float), and if the attribute is required as part of this protocol framework. Refuge names are recorded as “ORGNAME”, while complex names and LIT codes are added post-processing (see Appendix D). Infestation State corresponds with 8 domains (Table 4.2), Completion Status corresponds with 3 domains (Table 4.3), and target species names domains (Target Species Name 1-10; Table 4.4) will be replaced with 109 ITIS common name domain separated by an underscore (e.g., the attribute name for Alligator Weed is Alligator_Weed). Attributes populated by the regional data manager are indicated by an asterisk, with a single asterisk indicating the field is populated pre-data collection and a double asterisks indicating the field is populated post-data collection, and all other domains are entered during field data collection. Note this table is the same as Table 4.1.

Attribute	Brief Description	Data Type	Domain	Required
CMPXNAME**	NWR complex name	character/text	Appendix D	Yes
CMPX_LIT**	NWR complex literal code	character/text	Appendix D	Yes
ORGNAME*	NWR station name	character/text	Appendix D	Yes
LIT**	NWR station literal code	character/text	Appendix D	Yes
Management Unit*	NWR habitat or management unit	character/text		Yes
Survey ID**	PRIMR survey identification number	character/text		Yes
Feature ID*	Identification number of grid cell	integer		Yes
Survey Year**	Year of survey (yyyy) (derived from Survey Date)	integer	-	Yes
Survey Date	Select survey date (mm/dd/yyyy)	date	-	Yes
Surveyor Name	Enter surveyor name conducting the survey	character/text	-	Yes
Target Species Name 1	Select infestation state	integer	Infestation State	Yes
Target Species Name 2	Select infestation state	integer	Infestation State	Yes
Target Species Name 3	Select infestation state	integer	Infestation State	Yes

Target Species Name 4	Select infestation state	integer	Infestation State	Yes
Target Species Name 5	Select infestation state	integer	Infestation State	Yes
Target Species Name 6	Select infestation state	integer	Infestation State	Yes
Target Species Name 7	Select infestation state	integer	Infestation State	Yes
Target Species Name 8	Select infestation state	integer	Infestation State	Yes
Target Species Name 9	Select infestation state	integer	Infestation State	Yes
Target Species Name 10	Select infestation state	integer	Infestation State	Yes
Other Species Name	Enter other invasive species common name (capitalize both genus and species)	character/text	-	No
Other Species State	Select infestation state	character/text	Infestation State	No
Comments	Enter comments	character/text	-	No
Picture	All photos are automatically assigned a to the grid in which they were taken	character/text	-	No
Completion Status	“Not Surveyed” is the default domain. Select “Complete” when the grid has been surveyed and data are entered, or “Not Complete” if a not all target species were surveyed.	character/text	Completion Status	Yes
Survey Acres**	Area of grid cell in units of acres	float	-	Yes

Table SOP 5.2 Infestation state domains include 8 options (each with a unique Integer ID), including 6 infestation states (Integer ID 0 through 5) and two states indicated a species was not targeted (Integer ID 99) or the infestation state is unknown (Integer ID is 100). Note this table is the same as Table 4.2.

Integer ID	Data Entry Text	Brief Description
0	Clean	Species is absent (also referred to as “clean”)
1	< 1%	Species is present with a single plant, or small patches, or widely scattered plants
2	1-10%	Species is present with several widely scattered plants or several small patches
3	10-25%	Species is present with many scattered plants or a few large patches or many small patches
4	25-60%	Species is present and co-dominating in tree canopy, sub-canopy, or ground cover
5	> 60%	Species is present and co-dominating to full canopy cover or blankets nearly all other vegetation
99	NOT TARGETED	Species was not targeted for inventory at a given NWR
100	UNKNOWN	Species’ percent cover is unreported for a Target Species, Regional EDRR Species, or Other Species fields

Table SOP 5.3 Completion status domains include Completed, Not Completed, and Not Surveyed corresponding character/text and brief description. Note this table is the same as Table 4.3.

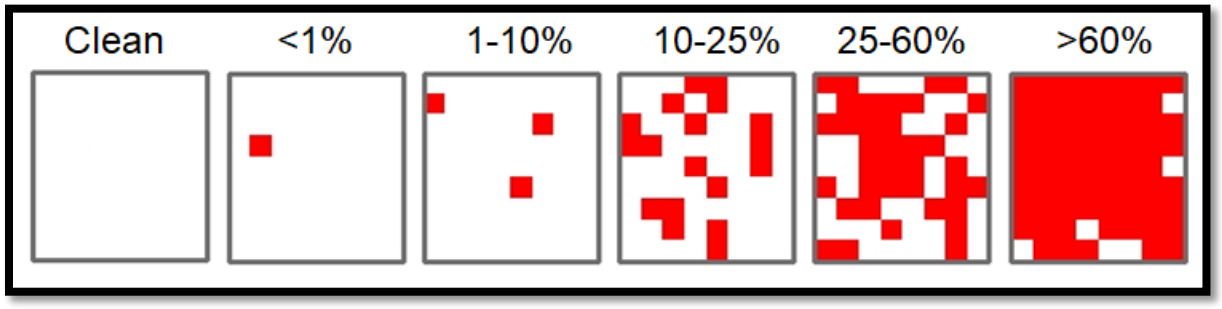
Completion Status	Character/Text	Brief Description
Completed	Completed	Sampling unit has been sampled and is complete
Not Completed	Not Completed	Sampling unit has not been completed (inaccessible). Sampling unit is within the sample frame
Not Surveyed	Not Surveyed	Sampling unit has not been surveyed, but I expected to be sampled as part of the sampling frame

Table SOP 5.4 Target species domains include all ITIS common names (see Appendix B for ITIS scientific name, and taxonomic serial number) separated by an underscore, and used to populate 10 fields (Target Species Name 1-10) in the IR-1 NWRS Invasive Survey Layer based on prioritization results for each refuge. Note this table is the same as Table 4.4.

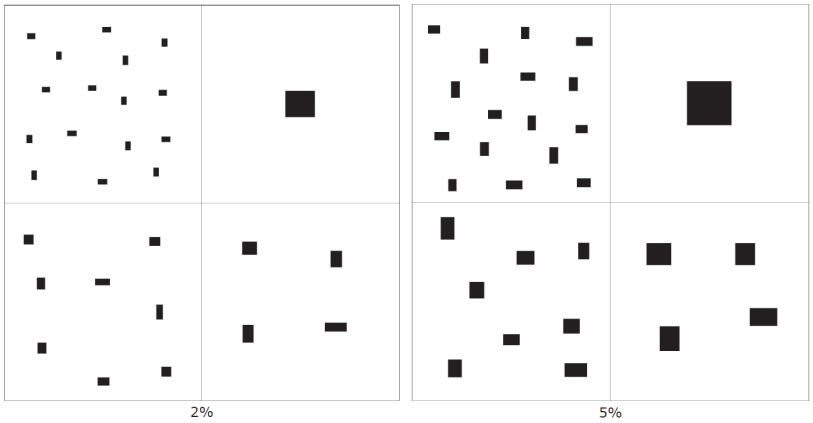
Target Species	Target Species	Target Species	Target Species

alligator weed	common mullein	jimsonweed	South American waterweed
American lotus	common reed	johnson grass	spotted knapweed
amur honeysuckle	common tansy	kudzu	spurge
Asiatic tearthumb	common water hyacinth	large gray willow	swallowwort
autumn olive	creeping buttercup	marsh dewflower	sweet autumn virginsbower
barberry	crownvetch	mimosa	sweet fennel
bitter dock	curly pondweed	moneywort	swollen bladderwort
black locust	cypress spurge	morrows honeysuckle	tatarian honeysuckle
black mustard	English ivy	mugwort	thistle
black swallowwort	Eurasian water milfoil	multiflora rose	thorny olive
bog bulrush	European privet	narrowleaf bittercress	tree of heaven
border privet	fanwort	Norway maple	wall lettuce
broadleaf water milfoil	fig buttercup	oriental bittersweet	water chestnut
buckthorn	flowering rush	pale swallowwort	weeping lovegrass
bull thistle	garlic mustard	paper mulberry	white clover
burningbush	giant hogweed	parrot feather	white poplar
callery pear	glossy buckthorn	perennial pepperweed	wild parsnip
Canada thistle	gray willow	porcelainberry	wild radish
cattail	honeysuckle	princess tree	wild rice
Chinese catalpa	hydrilla	privet	wineberry
Chinese lespedeza	Japanese barberry	purple loosestrife	yellow flag
Chinese privet	Japanese black pine	reed canary grass	yellow floating heart
Chinese wisteria	Japanese clover	reed mannagrass	yellow pond-lily
chocolate vine	Japanese honeysuckle	roundleaf chastetree	yellow sweetclover
coltsfoot	Japanese hop	rugosa rose	yellow toadflax
common barberry	Japanese knotweed	scots pine	
common buckthorn	Japanese sedge	shrubby lespedeza	
common frogbit	Japanese stiltgrass	smooth bedstraw	

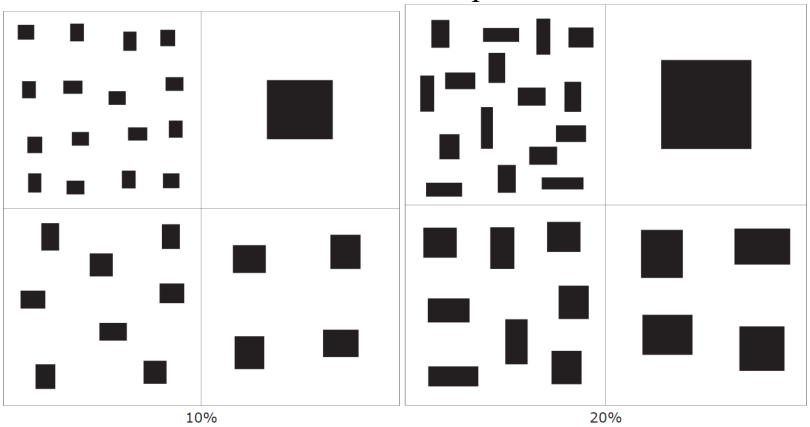
Figure SOP 5.2 Examples of 6 infestation states, with corresponding visualization of percent cover, including 0 percent cover (the grid cell is free from target invasive species, also called “clean”), less than 1 percent cover (invasives range from a single plant to small patches or widely scattered plants), between 1 and 10 percent cover (several widely scattered plants and or several small patches), between 10 and 25 percent cover (any scattered plants, or few large or extensive small patches), between 25 and 60 percent cover (co-dominating in the tree canopy, sub-canopy, or ground cover), and greater than 60 percent cover (co-dominating to full canopy cover or blankets nearly all other vegetation). Additional examples 4 infestation states (between 1 and 10, between 10 and 25, between 25 and 60, and greater than 60) with corresponding visualization of percent cover demonstrating variation within infestation sates (modified from Miscellaneous Chapter, 7.1-7.9, Schoeneberger et al. 2012).



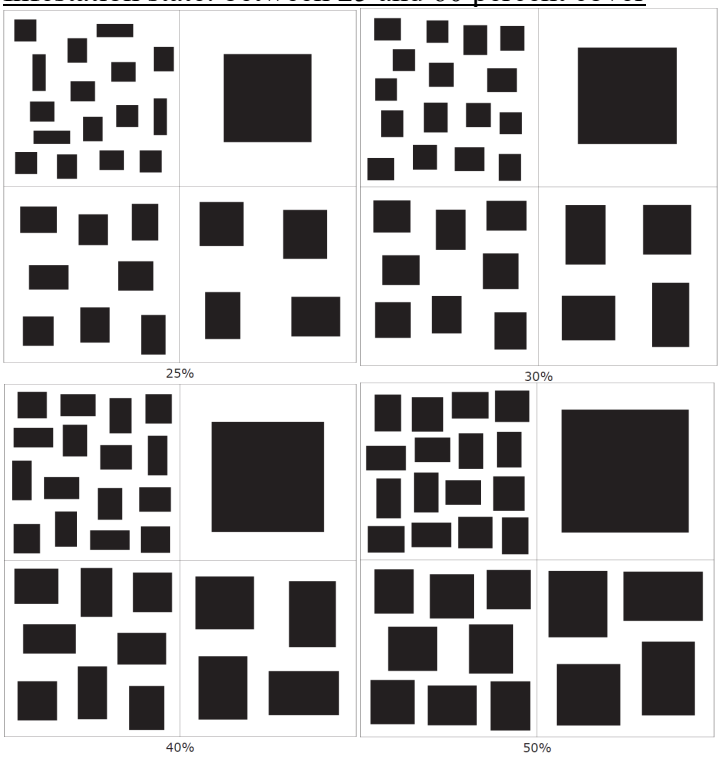
Infestation state: between 1 and 10 percent cover



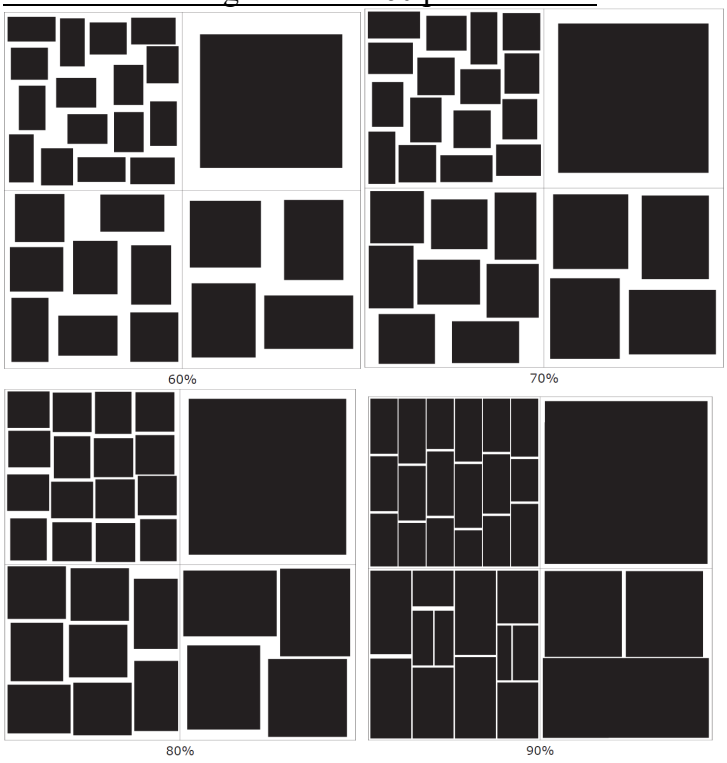
Infestation state: between 10 and 25 percent cover



Infestation state: between 25 and 60 percent cover



Infestation state: greater than 60 percent cover



SOP 6: **Recording Treatment Management Areas**

This SOP details how to delineate and record invasive treatment management actions while conducting an inventory survey. Surveyors may detect a species (which may or may not be on the target species list) and decide to take immediate action (e.g., hand pulling or herbicide) in order to more effectively eradicate and/or reduce spread rate. It is imperative that refuges properly document any management actions as part of their annual reporting (e.g., acres treated in RAPP) and to aid in interpreting change over time and management effectiveness. Treatments are recorded using the Regional Invasive Treatment layer within AGOL and Collector. This layer is used to record where, what, when, and who conducted a treatment during the inventory and summaries can be easily exported for RAPP reporting. Note that the treatment data layer is the same data layer used to record all other invasive-related management actions on a given refuge and includes actions implemented within and outside the sampling frame or during non-inventory survey periods.

Using the iOS device's internal GPS receiver, the surveyor navigates to the desired management area in Collector. Using the IR-1 NWRS Invasive Treatment layer, a polygon is drawn around the boundary of the management area (e.g., polygon feature class). This can be accomplished by either enabling the streaming polygon feature and walking the perimeter of the area or referencing the aerial imagery to digitize the polygon. This area should represent the entire area that the surveyor is intending to conduct a treatment and should include all patches and/or individual plants that will be treated within the management area. For single-species hand pulling (e.g., one plant is removed within several neighboring grids), a polygon is delineated around the plant as a polygon (no point data types are permitted within the data layer). Once the management area is delineated, the surveyor records attributes to describe and document the action implemented (Table SOP 6.1 and Table SOP 6.2). Each management area (i.e., polygon) is added as an individual record within the attribute table of the invasive treatment layer.

To record a treatment:

1. Open Collector on the iOS device, and the appropriate offline work area (SOP 4).
2. To delineate a management area, press the PLUS sign.
3. Choose the action type conducted from a pre-determined list (Table SOP 6.1), then select the specific management action that best describes the action taken from the drop-down menu[1].
4. Click Add Point to delineate your management area point-by-point by viewing the aerial basemap image. Optional, you can use the Start Streaming tool to walk the perimeter of your management area.
5. Press each tab to enter management details (Table SOP 6.2). Once finished click Submit.
6. At the end of the survey (daily or weekly), data must be pushed to AGOL using a strong Wi-Fi source (preferably at the office), even if not all management in the offline work has been completed. Click the 3-dots and choose Sync to begin synchronizing.
7. After the syncing process is completed and management areas have been created in the offline work area, click the Remove Area tab to remove the offline work area from the iOS device.

[1]Note that the list of management actions is currently being revised by regional staff. Please contact if there are questions regarding which to management action to select.

Table SOP 6.2 Action type domains include five categories: biological, burn, chemical, manual, mechanical, and Integrated Pest Management (see https://www.fws.gov/policy/569fw1.html). Four actions are RAPP treatment categories (DOI 2018; pg 34), with the burn category added due to its broad application on refuges.

Action Type	Description
Biological	Using bio-control such as goats, or other bio-control for management
Burn	Using fire as a management strategy
Chemical	Using any combination of herbicide or other chemical agents
Manual	Using manual techniques such as hand –pulling as a strategy
Mechanical	The use of any saw, mower, or other mechanical device
Integrated Pest Management	Using a planned combination of techniques to achieve higher effectiveness

Table SOP 6.1 IR-1 NWR Invasive Treatment layer attributes, brief description, data type (date, character/text, or integer/float), and if the attribute is required as part of this protocol framework. All attributes are listed within AGOL layer. Target species corresponds with 109 domains (Table 4.4), action type corresponds with 5 domains (Table 4.6), and management action corresponds to the specific action taken. Attributes populated by the regional data manager are indicated by an asterisk, with a single asterisk indicating the field is populated pre-data collection and a double asterisks indicating the field is populated post-data collection, and all other domains are entered during field data collection.

Attribute	Brief Description	Date Type	Domain	Required
CMPXNAME**	NWR complex name	character/text	Appendix D	Yes
CMPX_LIT**	NWR complex literal code	character/text	Appendix D	Yes
ORGNAME*	NWR station name	character/text	Appendix D	Yes
LIT**	NWR station literal code	character/text	Appendix D	Yes
Surveyor Name	Enter surveyor name	character/text		Yes
Management Area Name	Enter the management area or habitat type name where the management action occurred or is planned to occur	character/text		Yes
Action Type	Select the type of action conducted	character/text	Action Type	Yes
Management Action	Select the primary management action	character/text	Management Action[1]	Yes
Target Species	Select the target invasive species of the management	character/text	Target Species	Yes
Management Description	Enter a brief description of the management action taken, such as the chemical solution used during herbicide treatment	character/text		Yes
PUPS_ID	Pesticide Use Protocol System identification number	integer		Yes
RAPP Year**	Fiscal year the management action was implemented (yyyy)	integer		Yes
Start Date	Select the start date of the management action (mm/dd/yyyy)	date		Yes
End Date	Select the end date of the management action (may be the same as start date) (mm/dd/yyyy)	date		Yes
Acres**	Area of treatment in units of acres	float		Yes
Comments	Enter comments about the management area or action taken, including any noticeable disturbance, such as evidence of spraying or other management. This attribute field may be used to record names and states of	character/text		No

	additional non-target invasive species or anything else of interest			
Pictures	All photos are automatically assigned a to the polygon in which they were taken and given a name	character/text		No

[1]The management action domain is currently being revised by regional staff. Please contact if there are questions regarding which to management action to select.

SOP 7: **Creating Maps in ArcGIS Online**

This SOP details how to create refuge-specific species distribution maps within ArcGIS Online (AGOL). Creating new services (publishing) of existing GIS data is not covered in this SOP since publishing permissions are not granted to all FWS employees. Species distribution maps are useful for visualizing spatial distribution and the infestation level of invasive species within the inventory area beyond the regional webmap. Distribution maps are also used to develop management targets and guide where and which plants to manage.

1. Go to AGOL https://fws.maps.arcgis.com/home/index.html and click on the "Sign In" tab in the upper right corner.
2. Select the Enterprise login and/or click on the "U.S. Fish and Wildlife Service" tab.
3. Click on the "Organization" tab in the navigation bar, and search for "Regional Invasive Survey". Be sure to press enter after typing "Regional Invasive Survey" into the search bar to see the full search results.
4. Create a species distribution webmap by clicking on the three dots in the bottom right of the IR-1 NWRS Invasive Survey layer feature service and select "Add to new map". If you already have the feature service open, then click "Open in Map Viewer".
5. Click Save, and select Save As. Then enter a title for your map (e.g *[Insert Refuge Name]* Invasive Species Distribution Map), select the Biota/Invasives category, and enter keyword as tags (e.g. invasives), and a brief summary of the content within the map. Click OK.
6. Your new map will automatically open. Click the Add button, search for layers by going to My Organization, then type the name of the layer (IR-1 NWRS Invasive Survey and/or IR-1 NWRS Invasive Treatment) and click the PLUS sign next to the layer to add the layer to the Contents panel.
7. Click the layer in the contents panel (you may have to click on details first) to display the options. Click the Change Style icon. Choose the species you want to display under the Choose an attribute to show.
8. Select Count and Amount (Color) under Select drawing style. Then click the Options button that appears in the middle of the icon.
9. Check Classify Data, Using Natural Breaks, with seven classes. Then click the Symbols icon and choose a color ramping.
10. Click Legend. To change the class labels or colors click on the label or color square. Change the Classes (0-0 to "zero" and change color to no fill, >0-1 to "<1%", >1-2 to "1-10%", >2-3 to "10-25%", >3-4 to "25-60%", >4-5 to ">60%", >5-99 to "NOT TARGETED" and change color to no fill or gray). Click OK.
11. The resulting map should look similar to the map on the right, and can be repeated for each species.

SOP 8: **Exporting Data from ArcGIS Online**

This SOP details how to export inventory data from ArcGIS Online (AGOL) for use in ArcMap or ArcPro. When a the entire inventory is partially or fully completed (e.g., all grids are complete or 3 years, whichever comes first) and the survey coordinator aims to conduct analysis that requires software other than AGOL, a zipped folder containing all data layers (IR1 NWRS Invasive Survey layer, Invasive Treatment layer) must be download from Esri cloud server to a geospatial database file.

To download inventory data:

1. Go to the Content page on AGOL.
2. Click on the layer of interest to download and view the layer's Overview page.
3. Click the Export Data tab on the right and choose FGDB (file geodatabase).
4. Enter a title, add a tag, provide a brief summary, and choose the location on ArcGIS Online to save the feature. Note that all sections must be filled in before the export tab is available to click.
5. A new browser window will appear. Click the Download button on the right and a .zip file will be downloaded. Unzip the file to access the data in ArcMap.

Supplemental Materials (SM)

SM 1: Equipment Purchasing Guide

This equipment purchasing guide was created by David Zimmerman (regional data manager) and located here: https://doimspp.sharepoint.com/sites/fws-FF05R02000-gis-dm/Shared%20Documents/GIS%20Resources/NAAR%20DNRCP%20GPS%20Purchase%20Guide_2019.pdf (Accessed 2020-09-09).

North Atlantic-Appalachian Region (IR-1) Biology GPS Purchase Recommendations (2019)
(with material adapted from the August 2018, USFWS Geospatial Services Newsletter)

Purpose
This document provides guidance for provisioning stations with GPS equipment to support data collection for I&M projects.

Base Device
To best support I&M survey work, stations will need to purchase an Apple mobile device (e.g., iPad Pro, iPad Mini, or iPhone). These devices all accept IRTM MaaS360 Mobile Device Management Software and have been capable performers in the field. Various devices are available to suit different needs, but the IR-1 DNRCP Data Network has identified the following as an example of the best suited device and accessories for most I&M applications:

Unit and components	Price (2019)
Apple iPad Pro (11 inch) Wi-Fi + Cellular, 256 GB*	$1,099.00
2-Year AppleCare+ for iPad (S4745LL/A)	$79.00
ANKER PowerCore 15000 (A1242011)	$39.99
LifeProof Nüüd for iPad Pro	$170.00
Total Cost:	**$1,387.99**

Purchase a device that has cellular enabled (even if you don't purchase a data plan). This will ensure your device has a GPS chipset (receives signal from the GPS constellation).

Network Adapters
To facilitate quick data transfers and device maintenance, we recommend outfitting your device to connect to your local ethernet network in the refuge office. For that capability you'll need an RJ45 (ethernet cable) adapter to plug into the device. An example for a device with lightning connector (iPhones, some iPads, iPad minis): ENBIA RJ45 Ethernet LAN Network Adapter for Phone Pad, Phone Ethernet Adapter, 3.3ft/1m Cable, 10/100Mbps High Speed,Plug and Play. An example for a device with USB-C connector (iPad Pro): Anker USB C to Ethernet Adapter, Portable 1-Gigabit Network Hub, 10/100/1000 Mbps. There are also adapter options with ports for both power and Ethernet cables. These can be found on the Apple store or through other online retailers like Amazon.

Accessories for greater positional accuracy

When an approved protocol requires accuracy to less than within 3 to 5 meters (e.g., shoreline survey), the IR-1 DNRCP Data Network recommends purchasing the following equipment to use as accessories with the aforementioned Apple mobile device:

Unit and components	Price (2019)
Eos Arrow 100 GNSS Receiver Kit (1) Arrow 100 receiver with Arrow Smart Battery Pack (1) Single-Frequency GNSS / LBand Precision Antenna (2) Antenna Cables, 1.5m (1) Soft hat for Antenna (1) Nylon Carrying Case (belt-clip & shoulder strap) (1) 12V International Power Supply for Arrow Smart Battery (1) USB Data Cable	$2995
Eos Arrow Receiver Pole mounting system	$245
Eos Arrow 2-Piece Carbon Fiber Rangepole	$225
Total Cost:	**$3465**

The Arrow device is an option that has been tested and used successfully in the field by other programs in the NWRS. We are recommending it based on that experience, however, other options do exist. You can review the details and a quote for one such option, the Geneq GiSXBlue II, here: https://doimspp.sharepoint.com/:b:/r/sites/fws-FF05R02000-gis-dm/Shared%20Documents/GIS%20Resources/QUOTE%20396637.PDF?csf=1&e=j7p26I. Although we do not know of FWS users of Geneq GiSXBlue II, it did receive many positive reviews online from industry professionals writing on the subject. If the protocol calls for survey grade/RTK equipment, please contact region staff to discuss further and for more information and assistance with borrowing/using DNRCP equipment.

Purchasing

Purchasing is coordinated through the NWRS Budget Division and IT support. Complete an Acquisition Request using FWS Form 3-2109. Work with your Property Officer and Budget Specialist to complete the form in order to ensure that the device is delivered to the appropriate location and accounted for by the property office before placing it into use. If you will not be purchasing a cellular data plan, enter the following justification at the bottom of the Detailed Description section: "The device will be used as a data recorder without a cellular data plan but must be cellular capable to ensure it has a GPS chipset to support the GPS use requirement." Once the AR is approved, use the information on the AR form to complete a new service request on the Cellular Request SharePoint site: https://fishnet.fws.doi.net/projects/home/mdm/cellrequests/default.aspx. The national mobile device procurement staff will call to discuss if a data plan is needed. Data plans are not required to use Collector or Survey 1,2,3 and are at the discretion of the refuge management.

Note that although this protocol framework is providing this guidance, it is the responsibility of refuge staff to purchase and maintain the equipment needed for refuge operations. If cost is an impediment and the equipment is primarily to support I&M related projects, then refuges might consider including the cost in their related RFP submission with supporting justification (e.g., needed to support the I&M survey and no devices (or too few) are currently at the station to accomplish the work proposed in the RFP).

Configuration

Your device will be configured to USFWS policy in advance. If your device is going to be used only as a field data collection device, ask your IT for the “No email Policy”. This removes Bison Connect from the device and gives you a 15 minute screen time out over the standard 5 minute screen time out. Another perk to the no email policy, is the ability to share the iPad with others, like volunteers.

Apple ID account management

To best support many users who may share a device at your location, use the refuge group e-mail to acquire an Apple ID to use for all of your group mobile devices.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