Farallon National Wildlife Refuge

Farallon Islands

2016 Invasive Plant Inventory

Final Report

December 20, 2016

Prepared by Barbara A. Holzman and Quentin Clark

San Francisco State University

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Table of Contents

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1.0 Introduction:

Invasive non-native plant species have become an increasing threat to biodiversity worldwide (Mack et al. 2000; Mooney & Hobbs 2000). Mediterranean climate regions are considered to be one of the more vulnerable ecosystems to invasive plants (Rejmánek & Randall 1994; Gaertner et al. 2009; Underwood et al. 2009), and islands even more so (Lloret et al. 2005; Kueffer et al. 2010). Islands have experienced extreme changes in land cover triggered by human settlement, contributing to ecological degradation and biotic invasion (Oppel et al. 2011). Human occupancy on most Californian islands has led to the introduction of non-native mammals such as sheep, rabbits, and rodents (McChesney and Tershy 1998) and plants. Introduced animals can decrease island vegetation by herbivory (e.g. Donlan et al. 2002), seed consumption (Smith et al. 2002; Jones & Golightly 2006), and soil erosion (Brumbaugh 1980; Johnson 1980; Pinter & Vestal 2005), leading to a reduction in native plant cover and diversity (Klinger et al. 1994) and an increase in invasion by non-native plants. Non-native plant invasion on islands have been correlated with a decline in habitat for seabirds. On the Islands of Firth in southeastern Scotland, a decline in the island's Atlantic puffin population was correlated with the spread of non-native *Malva arborea* throughout the islands (Harris et al. 2003, Leitch 2005 and Van der Wal et al. 2008). In southern Australia, the short-tailed shearwater population on Allthorpe Island was directly impacted by the presence of the toxic African boxthorn (Lawley et al. 2005). On Midway and Kure Atoll in the northwestern Hawaiian Islands, the invasive golden crownbeard (*Verbesina encelioides*) reduced available habitat for ground-nesting seabirds such as Laysan albatross, black footed albatross, Christmas shearwater and wedge-tailed shearwater (Feenstra and Clements 2008). Although there are no current studies of habitat loss on the Farallones, findings such as these indicate the potential for a relationship to exist between the seabird species and invasive plant communities on the South Farallon Islands. Land rehabilitation efforts on degraded islands are underway worldwide (Glen et al. 2013) including eradication of introduced animals and plants with active or passive ecosystem restoration (Beltran et al. 2014, and references therein).

The South Farallon Islands of central California are part of the Farallon National Wildlife Refuge (Refuge), managed by the U.S. Fish and Wildlife Service (USFWS). Ongoing seabird and marine mammal population and habitat studies as well as non-native vegetation management activities currently occur on the islands (USFWS 2009). These activities require baseline vegetation data to assess the efficacy of current and future management actions. To efficiently and effectively eradicate non-native plants and facilitate native vegetation regeneration in degraded areas, an understanding of the non-native plant communities is needed. This Invasive Plant Inventory Report provides the initial spatial data to assist in non-native species management of the Refuge to guide subsequent inventories and eradication efforts.

1.1 Study Area

The Farallon Islands are located in the Pacific Ocean approximately 48 km (30 mi) west of San Francisco, California and 32 km (20 mi) south of Point Reyes. They are comprised of four rocky island groups: Noonday Rock, North Farallones, Middle Farallon, and South Farallones. This study examines the South Farallon Islands. The South Farallones include Southeast Farallon Island (SEFI), the largest and only inhabited island, West End Island, and several adjacent rocks and islets (Figure 1). The 29-hectare (72-acre) Southeast Farallon Island (SEFI; 37°42’ N, 123°0’W) is characterized by a marine-cut terrace with several steep crags and talus slopes. The highest point is Lighthouse Hill that stands approximately 105m (343 feet) above sea-level. SEFI is separated from West End by the narrow Jordan Channel, making access to West End difficult.

The Refuge was established in 1909 as a preserve and breeding ground for seabirds and marine mammals, and originally included North and Middle Farallon Islands, with the South Farallones being added to the Refuge in 1969. The Farallon Islands host thirteen breeding seabird species with some 300,000 birds nesting annually (DeSante & Ainley 1980; Warzybok & Bradley 2011). Today, the USFWS has cooperative agreements with Point Blue Conservation Science (formerly Point Reyes Bird Observatory) to assist with wildlife monitoring, facilities management, and protection of the Refuge. Due to the steep rocky shoreline and sensitivity of wildlife, the Refuge remains closed to public access.

The parent material of the South Farallon Islands is primarily granitic with some quartz diorite (Hannah 1951; Schoenherr et al. 1999). On SEFI, minor soil layering occurs in the low-lying Marine Terrace, comprised of guano, granitic sand, bone fragments, and other decomposing detritus that can accumulate up to 20 cm thick (Vennum et al. 1994).

The temperature on the South Farallon Islands remains cool throughout the year, with average maximums of 14°C (58°F) in the summer and 12°C (54°F) in the winter, with warmest temperatures in early autumn (Schoenherr et al. 1999). Precipitation averages 63cm (25in.) annually and peaks over winter months. No standing or running fresh water occurs on the island with the exception of puddles and seepage areas during the rainy season. The California Current aids in blanketing the island in heavy fog throughout the summer that is not accounted for in precipitation measures.

The dominant plant species on Southeast Farallon Island is the native annual *Lasthenia maritima* (maritime goldfields, or, "Farallon weed"), an endemic to offshore seabird nesting islands and sea stacks from Central California to the northern tip of Vancouver Island, British Columbia (Ornduff 1961b; Ornduff 1966; Crawford et al. 1985; Vasey 1985). The peak of vegetative growth and flowering (March-April) coincides with the beginning of the seabird breeding season when *L. maritima* is collected by cormorants and gulls for ground nest building material (Ainley & Boekelheide 1990). The senesced debris is later utilized as hiding cover for gull chicks (USFWS 2009). Vegetation on Southeast Farallon Island is entirely herbaceous with the exception of two *Hesperocyparis macrocarpa* (Monterey cypress) trees and several *Malva arborea* (tree mallow) shrubs originally planted for landscaping near the living quarters. A single specimen of *Pinus radiata* (Monterey pine) and two *Coprosma repens* (creeping mirrorplant) shrubs also persist on the island, with origins unknown.

Rapid changes in land use and the introduction of non-native plant and animal species began in the late 1700s (White 1995), when an influx of people, supplies and livestock enabled accidental and intentional introductions of many non-native plants. A feral European rabbit population decimated native vegetation (Pinney 1965) until its eradication in 1975 (White 1995). Several ornamentals were planted as garden varieties and some grasses were likely transported within

animal feed (Coulter 1971). As a result, the number of introduced species outnumbers natives 3:1 today, and invasions prevail in disturbed and ruderal portions of the island, most markedly on the Marine Terrace and south-facing slopes of Lighthouse Hill.

Invasive plants are considered one of the primary threats to natural resources of the refuge. Invasive plant management was initiated at SEFI in the late 1980s, primarily in response to the establishment and spread of two non-native plants, New Zealand spinach (*Tetragonia tetragonioides*) and cheeseweed (*Malva parviflora*). New Zealand spinach was first recorded on SEFI in 1968 by Malcom Coulter (Coulter and Irwin 2005) and has since spread to several parts of the island (USFWS 2004, Coulter and Irwin 2005). Cheeseweed was first recorded on SEFI in 1991 (Coulter 1991). Although many other non-native plant species have been recorded on the refuge (Coulter and Irwin 2005), New Zealand spinach and cheeseweed have been the main focus of invasive plant management efforts because of the direct impact they have on nesting seabird species. These plant species form dense stands that prevent seabird access to nest burrows (Gerry McChesney, personal communication). Other plants of concern on the refuge are non-native grasses (such as *Avena fatua*, *Bromus diandrus*, and *Hordeum murinum*) and plantain (*Plantago coronopus*). Thick mats of these species may hinder burrowing by nesting auklets and compete with native plants (USFWS 2009).

The first weed management plan for the Refuge was prepared in 2004 and updated in 2008 (USFWS 2008). The Farallon National Wildlife Refuge Weed Management Plan (Irwin & Buffa 2004, unpubl.) outlines an adaptive management protocol for the removal and control of primary invasive species *Tetragonia tetragonioides* (New Zealand spinach), *Malva parviflora* (cheeseweed), and several secondary non-natives. The primary tool for managing these two species on SEFI was a mid-late summer application of glyphosate-based herbicides and intensive hand pulling ((Irwin & Buffa 2004, unpubl.). In 2013, the refuge added a second glyphosate treatment (in late March) in addition to its annual summer treatment. Due to budgetary and staffing constraints treatment intensity varies and eradication is far from complete. In 2016 the Refuge began a more intensive summer campaign with one eradication specialist on the island the entire summer implementing spot treatments where necessary.

No baseline or consistent monitoring of invasive plants currently occurs on the Refuge, although prior to and during the biannual spraying, locations of invasives targeted for spraying are identified. Qualitative Refuge observations suggested spring treatments have reduced the abundance of mature, seed-producing plants (McChesney, pers. obs.). In 2013, the Refuge piloted the use of imazapyr (tradename Habitat) to control invasive plants. Qualitative refuge observations suggest imazapyr is not effective at controlling target species and limits colonization by native plants for at least 2 years following application (creating 'dead zones'). Qualitative refuge observations also suggest that the native *Lasthenia maritima*, and non-native grasses (such as *Bromus diandrus, Avena barbata, A. fatua*), are the primary species that colonize invasive plant removal areas. There are no current treatment studies or assessments of efficacy of treatments being conducted. Nor have any quantitative assessments of invasive plant management efficacy been conducted at Farallon NWR.

1.2 Management Objectives

The Refuge was established to protect seabirds and marine mammals (USFWS 2009). The following natural resources also have high conservation importance: *Lasthenia maritima* is the dominant native plant and important nest building material for cormorants and gulls. Two presumed endemic species: the Farallon Arboreal Salamander (*Aneides lugubris farallonensis*) and the Farallon camel cricket (*Farallonophilus cavernicolus*) are also found on SEFI.

Details about the ecology and history of Refuge conservation priorities and associated Refuge management goals can be found in the Refuge Comprehensive Conservation Plan (CCP) (USFWS 2009) and more recent Refuge reports and publications.

The CCP identified several threats to Refuge conservation priorities and included objectives and strategies aimed at reducing or eliminating these threats. Invasive plants are considered a priority threat to natural resources of the Refuge. Invasive plant management was initiated at SEFI in the late 1980s, primarily in recognition of the establishment and spread of two non-native plants mentioned above. The first Refuge weed management plan was prepared in 2004 and updated

in 2008 (USFWS 2008) reference the following objectives related to reducing the threat of invasive plants on the Refuge found in the CCP include:

Objective 2.3: Within one year after the CCP's approval, continue to implement and annually update the Refuge's Weed Management Plan with the goal of decreasing the abundance and extent of target invasive species by 50 percent, primarily on the Marine Terrace and south-facing slope of Lighthouse Hill.

Objective 2.3 Strategy: Reduce the percent cover of New Zealand spinach and cheeseweed by 50 percent within 10 years of plan initiation and develop a strategy for eradication of 95 percent of these non-native plants on SEFI annually by hand-spraying herbicide, manual pulling, and other potential methods. Conduct herbicide application in mid-August as needed and follow up application in September or October. Hand-pull vegetation intermittently from November through early January, conduct intensive hand-pulling from late January through mid-March.

Objective 2.4: Within one year of the CCP's approval, initiate annual assessment of weed management strategies by assessing percent cover and distribution of key weed species, correlating any changes in wildlife nesting that may have occurred in those areas.

This inventory provides a quantitative baseline so that work on the objectives and further eradication can be quantitatively assessed to guide future management procedures and efforts.

2.0 Material and Methods

In order to initiate and plan for this invasive species inventory on the South Farallon Islands, a workshop was held at the Don Edwards San Francisco Bay National Wildlife Refuge Complex on January 19-20, 2016 (Block 2016, in Appendix A). The workshop's goals were to 1) prioritize invasive plant species and areas for management and 2) identify optimal methods for evaluating the distribution and abundance of priority invasive plant species. Although the Refuge CCP objectives focus on the two aforementioned species, the Refuge recognized the need to expand

its consideration to other species that cause harm to its conservation priorities. From this workshop, it was clear that the overarching invasive plant management objective was to prevent introduction of new and harmful invasive plant species and to reduce or eliminate established priority invasive plant species. Species of priority concern for inventory (and subsequent management) were identified during the workshop (Block 2016).

2.1 Inventory Objective

The objective of the Refuge Invasive Plant Inventory is to document the presence, spatial distribution, and abundance (percent cover) of priority invasive plant species in terrestrial areas of Southeast Farallon Island and West End Island. Area and species prioritization processes are noted below.

2.2 Area Prioritization

During the prioritization workshop, the Refuge was subdivided into six distinct areas based on topography, vegetation assemblage (Hawk & Holzman unpublished), area use, and trail access (the Refuge currently does not recognize distinct management units except for the individual islands that make up the Farallon NWR) (Figure 2). Once identified, the **areas** were prioritized for inventory using the Invasive Plant Inventory and Early Detection Prioritization Tool (IPIEDPT) (USFWS 2015) and the following characteristics:

- Ecological integrity
- Innate resistance of the environment to non-native plant invasions
- Importance of the area to federally listed species and other natural resources of concern
- Density and type of vectors and vector pathways
- Current perceived status of invasive plants

These criteria were applied to each area defined for the project scope. Areas with high ecological integrity, low resistance to invasion, high importance to conservation priorities, high density of vectors or vector pathways, and low perceived abundance of invasive plants were a higher priority for inventory. Areas in order of priority were North End, Marine Terrace, South Slope,

West End Island, Corm Blind Hill and Perimeter (Table 2). All areas were inventoried in the 2016 survey.

2.3 Species Prioritization

Ten individual species and four species groups were targeted for inventory (Table 1). These species targets were identified during the January 2016 workshop using the IPIEDPT (USFWS 2015). The IPIEDPT used the following characteristics to prioritize **species** for inventory:

- invasiveness or level of harm to natural resources considered at refuge and larger landscape scales
- proximity of the species to the project scope; perceived current abundance in the project scope
- potential for further spread (habitat suitability)
- observed ecological impacts and larger landscape importance (for example, species listed on local early detection list)

Species with high invasiveness, close proximity, low abundance, high potential for spread, observed ecological impacts, and those that are a priority for management within the larger landscape were a higher priority for inventory. Inherent in the IPIEDPT tool is a natural bias towards species that would be considered "early detection rapid response" targets.

A list of 51 non-native plant species that at some time had been noted on the Farallon NWR dating back to 1892 were considered. Fifteen (29%) of these species are listed as invasive by the Cal-IPC inventory (Cal-IPC 2006) and an additional seven species are on the Cal-IPC invasive species watch list (Cal-IPC 2015). During the workshop, the project team reviewed the species list and decided to remove five species from inventory consideration due to their absence on the island, or presence as a single tree (*Pinus radiata*) or several trees (*H. macrocarpa*). The remaining 46 species were prioritized for inventory using the IPIEDPT tool. Following prioritization, 22 species were selected for inventory in 2016 (Table 1). Ten species were to be mapped individually, while twelve of the 22 species were mapped as part of four specific 'species groups'. It was determined to be more efficient to map some species as groups rather than

individuals. Species were grouped into 'species groups' if they had similar ecology and would be managed using similar methods. Species groups include 1) *Malva spp. (Malva parviflora, M. neglecta and M. pseudolavatera, but not M. arborea), 2) Sonchus spp. (Sonchus asper and Sonchus oleraceus), 3) Rumex spp.* (*Rumex acetosella* and *Rumex crispus*) and 4) all non-native annual grasses (*Avena fatua, Avena barbata, Bromus diandrus, Hordeum murinum, Poa annua, and Vulpia bromoides*, excluding *Ehrharta erecta* which was to be mapped individually).

All species noted were targeted during the spring survey. An additional survey during July of 2016 targeted *T. tetragonioides, Chenopodium murale, Plantago coronopus, Ehrharta erecta,* and the *Malva, Sonchus,* and annual grass species groups.

The highest priority species was *Ehrharta erecta*, a species not previously a focus of Refuge management but known to be highly invasive. Species that had been a focus of management, *T. tetragonioides* and *Malva* species, were also among the top species selected by the project team as inventory targets.

2.4 Survey Timing

Timing of the inventory was based on a period that would increase target species detectability, occur before the Refuge applies herbicides in the spring (planned), and minimize seabird and pinniped disturbance. To assist with making this decision we examined the bloom period of each target species using data from Calflora (www.calflora.org) (Figure 3). The project team selected late March to early April as the spring inventory period. Although not all species will likely be in bloom, all of the target species were detectable. A follow-up survey in July targeted species that might be missed in the spring due to late emergence or flowering.

The spring inventory occurred from March 19 until April 6, 2016. There was an additional summer follow up trip conducted July 23-29, 2016. During the spring survey, all of the targeted species were identifiable, with many in flower (see Phenology results). This timing was also advantageous as few seabirds had begun nesting, minimizing possible disturbance to breeding birds.

The summer survey was conducted during the latter portion of the seabird breeding season. While many areas were accessible, others were not to avoid disturbing nesting seabirds. The main goal of the July survey was to improve detection and cover estimation of species with greater summer growth, such as *T. tetragonioides, Chenopodium murale, Plantago coronopus*. These species (especially *T. tetragonioides*) are also subjected to summer herbicide treatments, which greatly reduce cover in fall through spring. However, the July inventory survey was conducted after substantial treatment of much of the island's *T. tetragonioides* and *Malva*, limiting detection of these species to untreated areas. The July survey also permitted cursory surveys from a small boat of otherwise inaccessible areas, such as portions of West End Island and the surrounding islets. Any green plants observed during this time would be target invasive species.

The field crew was in frequent contact with staff from USFWS or Point Blue Conservation Science present on the island when surveying, and discussed daily mapping efforts and targeted areas to determine whether any special precautions or limitations to entering the area were required. Efforts were made to minimally disturb marine mammals, nesting birds or burrows while mapping in a certain area. Any accidental flushing of marine mammals was recorded and relayed to Point Blue Conservation Science for their daily journal. Any changes to methodology needed in the field was communicated to Refuge staff.

2.5 Data Collection Procedures

Methods were adapted from Anderson and Dewey (2007) and Elwood *et al.* (2013) and modified to meet objectives of the Refuge and accommodate accessible locations, topographic characteristics and wildlife considerations on the island. The complete protocol is located in Appendix B.

Defining invasive plant features

Field crews conducted a complete search of SEFI and West End for target species. Locations of targeted plants were recorded using GNSS receivers and mapped as buffered points (patches),

linear features or polygons. A patch was defined as a single individual plant or a group of plants comprised of a single species or species group target. The patch separation resolution (PSR) for the Refuge inventory was 10m. Clusters of plants separated by a distance that was more than the PSR were recorded as separate features. Plants separated by less than the PSR were considered a single patch. The Minimum Detection Target Size (MDTS) was $4m^2$ (0.0001ac). The MDTS represents a patch size large enough to be detected with >90% confidence within the inventory scope; but small enough so that any missed patches smaller than the MDTS could still feasibly be eradicated (Anderson and Dewey 2007).

Search procedures and detection confidence

See Appendix B for the detailed protocol. Initially surveyors walked along a series of parallel transects that covered all but the Perimeter Inventory Area on SEFI and West End Island. Where feasible, transects were oriented along contour lines on slopes and perpendicular to trails in flatter areas. Areas where transect lines were not feasible were traversed as systematically as possible. Transects were separated by 20m, giving a 10m effective detection swath width (EDSW). The EDSW is defined as the maximum width of a linear swath in which a walking observer is confident of detecting an acceptable percentage of all target species of the minimum detection target size (MDTS) (Anderson and Dewey, 2007). The EDSW is based on a number of environmental conditions such as visibility (weather, density of vegetation) and detectability of target species. The confidence of detecting target species at an EDSW of 10m was estimated to be 90%. The EDSW was reduced if the detection confidence was estimated to be below 90%.

Initially two to three surveyors walked along the center line of each transect and searched for target species on each side (10m width). During the survey it was found that walking back and forth between the transects produced a better coverage of the area and provided higher confidence so the method was modified slightly. First, each transect line was walked by one crew member to provide a track log of each area searched (Appendix C), and then a more refined search along each transect was conducted to provide a finer, more detailed map with a high detection confidence rate of 90 to 100 percent for most targets. Areas where transect lines were not feasible were also tracked in the log provided (Appendix C). Because a few species

(*Chenopodium murale*, *Plantago coronopus* and *Tetragonia tetragonioides*) were just beginning to emerge, an additional survey in July was undertaken to provide a more accurate survey for those species.

Visual surveys were conducted for sections of the study area that were inaccessible due to terrain instability, or the presence of protected seabirds and marine mammals. Visual surveys were completed from accessible locations using binoculars to scan the search area for target species. A target species identified during a visual survey was recorded using a GNSS receiver. Attribute variables were assessed to the best of a surveyor's ability. All visually surveyed features were logged as offset points and then converted to buffered points in the GIS environment. Offset points require a calculation of horizontal distance, vertical height, and azimuth angle of the feature relative to the position of the surveyor. Distance, height, and angle measurements are then applied to the receiver's built-in offset function with positions established according to input values.

It was unreasonable based on time and resources available for surveyors to find every single plant of every targeted species. A minimum detection target size (MDTS) of $4m^2$ was chosen as reasonable and repeatable. Any single plant or patch smaller than the MDTS was not mapped. When a target species of the MDTS was detected, the surveyor assessed the spatial extent of the patch, and used this information to decide if the patch would be mapped as a buffered point, buffered line, or polygon as defined below:

Buffered point: a non-linear patch of target species $>4m^2$. In general, per inventory protocol occurrences less than $4m^2$ were not mapped (Appendix B). Using a Trimble GNSS receiver, a point was recorded while standing at the approximate center of the patch and the average radius of the patch was estimated using a digital range finder. The patch perimeter was not walked. Buffered points were converted to **patch features** (circle polygons) in the GIS representing the approximate area of individual patches. Buffered points provide a visual representation of the size of the patch and its location (Christensen et al. 2011). It does not however, accurately represent the actual perimeter of a patch.

Buffered line: a linear patch (such as along roads, trails, or waterways). If the patch was more linear, such as those found directly along roads or trails, the patch was recorded in the GNSS receiver as a **linear feature** (a series of points) and the average width of the linear patch was recorded and mapped as a buffered line.

Polygon: a large non-linear patch of target species. If the perimeter of a patch was not visible from the designated center, then a polygon feature was created, or if there were several patches within close proximity the entire area infested was mapped as a polygon feature. In this case, the perimeter was walked by the surveyor, logging positions in the GNSS receiver at major vertex points along the polygon. Terrain variability resulted in multiple instances where polygons were created with smaller total areas than patch features.

Mapping attributes

A data dictionary file (.ddf) was created for the inventory using the Data Dictionary Editor wizard in GPS Pathfinder Office (version 5.70), and was transferred to Terrasync (version 5.81) for use on the GNSS receivers utilized during data collection. Data dictionary details are located in Appendix D. Attribute information for each patch, line or polygon (collectively called features) included: spatial coordinates, date, (MM/DD/YYYY) observer (initials), species name or species group (scientific name (ITIS) from pull down menu), inventory area, measured radius (for points) or width (for lines) from rangefinder, estimated percent cover class of feature (from pulldown menu), species phenology of the majority of the feature at time of survey (from pulldown menu) as well as any additional comments about the area.

Feature location data were spatially referenced using the NAD83 UTM Zone 10 projection. A digital range finder was used to record radius (for points) or width (for lines) features.

Canopy cover classes were noted for the majority of the feature as follows: 1) Scarce <1%, 2) Poorly represented: 1-10%, 3) Well represented: 11-25%, 4) Abundant: 26-60% and 5) Very High: > 61% (reference p. 279-280 of the RLGIS Data Dictionary, 2006).

Phenology was visually evaluated and growth stages of the majority of the feature was placed in the following categories: 1. Basal rosette (plant emergent with no buds or flowers present), 2. Pre flowering (flower stalk emergent, none to few buds); 3. Flowering (buds or flowers present); 4. Post flowering (seeds present or plant drying); (These codes were simplified for efficiency from reference p. 264 of the RLGIS Data Dictionary).

2.6 Data Management and Analysis

Data management

Spatial coordinates and attribute information for each invasive plant feature/occurrence was recorded in a custom data dictionary in Terrasync (Appendix D). Daily inventory routes were recorded using the tracklog feature on the GNSS unit. Areas searched (as a feature class) and track logs are provided (see Figures 4 and 6 and Appendix C). All data recorded each day was downloaded onto a computer each night and backed up on a separate hard drive. Each evening the downloaded data were mapped using ArcGIS (version 10.3.1) and checked to ensure that all surveyed area data for that day were included in the GIS and on the digital draft map. A detailed accuracy assessment procedure was completed once all areas had been surveyed and is described below.

Metadata

Metadata is reported with descriptions of data files, data fields and nature of attribute values in Appendix E. All point, line and polygon features are stored in one geodatabase as separate feature classes with metadata stored with each feature class. Metadata adheres to the standards recommended for the USFWS (Federal Geographic Data Committee, https://www.fgdc.gov/metadata/geospatial-metadata-tools).

Data Analysis and Processing

Data collected as point and line features were converted to polygons by buffering (using ArcGIS toolset) each point or line to its associated radius or length derived from field measurements. Buffered points, lines, polygons and search area feature attributes were used to calculate percent area inventoried and percent area infested.

In addition to maps, non-native plant occurrence data were summarized in total and by each inventory area in the text and tables that follow. They include:

- total area surveyed on the islands and percent of islands surveyed
- total area of each inventory area surveyed
- percentage of inventory area surveyed
- total area of non-natives inventoried by species with average canopy cover
- total area of non-natives inventoried by species with phenology
- the number of patches identified by species, total number of features
- adjusted area of targeted species by inventory area.

Adopted from Elwood et al. (2013) and modified to fit the needs of this inventory, an adjusted area procedure was used to reduce the potential for generating numbers that could be an over-representation of the area infested (ha) by invasive plant species. The procedure was executed within the GIS environment (ArcMap version 10.3.1) and was comprised of two major geoprocessing steps. Step one identified all like geospatial features from the inventory (buffered patches, buffered lines and/or polygons) that possess the same desired attribute, i.e. the same species or location within a given inventory area, and merged them into a single feature class. Step two locates all overlapping features within that newly formed feature class and dissolves them into a single, stand-alone feature. The area values of dissolved features (ha) were then calculated alongside the area values of non-dissolved features (ha) to establish the final adjusted area (ha).

All values representing area infested (ha) in this inventory are a result of this adjustment procedure. The procedure has been employed in two separate instances, producing two mutually exclusive results. Values representing area infested (ha) per target species are a result of the merger and dissolving of all plant features that belong to each individual target species or species group across the entire study area. Values representing hectares infested (ha) per inventory area are a result of the merger and dissolving of all invasive plant features found within a given

inventory area. The results from the inventory area specific adjustments are therefore lower than the results calculated from the individual species/species group adjustments.

Software: Data collection was performed with Trimble GNSS units, post-processed with Trimble Pathfinder Office (version 5.70) and Terrasync (version 5.81) and transferred to ArcGIS 10.3.1 for data management. Maps were created using ArcGIS 10.3.1 and Adobe Illustrator CC. Data analyses were performed using ArcGIS 10.3.1 and MS Excel 2016.

Accuracy Assessment

For both spring and summer surveys, an assessment was conducted to analyze the accuracy of the inventory. The assessment was conducted by randomly selecting ten percent of the features mapped on SEFI from the field type (patches, lines, polygons) (West End accuracy was not assessed because it was no longer accessible to the surveyor). The randomly selected features were located in the field and an assessment was made as to whether the species information was correct. Results of the accuracy assessment are noted below.

2.7 Plant specimen collection

Specimens of plant species surveyed were collected in the field and provided to California Academy of Sciences for archival storage. Each specimen was identified by species and included information on date collected, location and brief description of plant and name of collector.

2.8 Boat Survey

A circumnavigation of the study area was conducted via a USFWS research vessel stationed at the Refuge on 28 July 2016. The circumnavigation allowed for a visual inspection of portions of both SEFI and West End Island that were inaccessible to survey crews during the spring and summer inventories (Figures 4a & 4b). Track logs were established for the boat survey and can be found in Figure 6c. Three survey crew members took part in the circumnavigation; each crew member was outfitted with a pair of binoculars for surveying and either an inclinometer, digital

range finder, or GNSS receiver for mapping locations of target species. Target features were recorded and mapped using the visual inspection search procedure as outlined in Section 2.5.

3.0 Results

Results are presented in two parts, the first part discusses results summarizing the total island areas and each targeted species on SEFI and West End, the second part describes results for each inventory area. For the purpose of this report, amounts, unless otherwise noted, are adjusted values (see above for detailed explanation of area adjusting procedure).

As noted, the initial inventory was conducted from March 26 to April 2, 2016 with a follow-up survey completed July 23-29th. A total of 38.694ha of SE Farallon Island and West End Island were physically or visually surveyed for the invasive target species noted in Table 1. This represented nearly 100% of the two island areas (Table 3a & 3b, Figure 4a & 4b). One hundred transect lines were drawn pre-survey to guide the inventory (Figure 5). Searchable areas were limited along the Perimeter and on West End Island due to wildlife disturbance concerns. Where direct surveying was limited, observation with binoculars was able to yield further confirmation of the presence or absence of non-native plants. Track logs were created and mapped for both surveys (Figure 6a-c, Appendix C). During the spring inventory a total of 54.07 km were tracked with an average of 6.75km per day of tracking for the eight days that logs were recorded. In the summer survey 25.09 km were tracked over six days for an average of 4.2km/day.

During the spring survey, six crew members in two teams surveyed for six days (average 8 hrs. /day) with an additional 2 hrs. /day for two crew members for post-processing the data. One crew member stayed an additional week to do follow-up on survey areas that were not surveyed and perform an accuracy assessment and analysis (approximately 30 hours). Survey and mapping required approximately 342-person mapping hours in total for spring. Summer follow-up survey consisted of 4 crew in two teams spending approximately 8 hours/day in surveying or post-processing for 6 days, a total of an additional 192 hours.

3.1 Inventory Areas

Crews from the combined spring and summer surveys were able to map all six inventory areas where non-native target species were present. These included 28.934ha of the Southeast Farallon Island and 9.760ha of West End Island, representing 100% of the two islands (94% in spring, 100% in summer survey (which included those areas surveyed by boat).

The spring crews physically surveyed and mapped the six inventory areas noted above including: 100% of North End, 100% of South Slope, 100% of the Marine Terrace, 100 % of Corm Blind Hill, 78% of the Perimeter of the Island, and 11% of West End Island. The remaining areas were visually observed (using binoculars) (Table 3a). Summer surveys were able to survey 100% of each area with a combination of physical and visual surveys (Table 3b). In the spring, physical area searches were limited on the Perimeter and West End Island Inventory Areas due to wildlife disturbance concerns, such as the possibility of flushing marine mammals or nesting seabirds that were present in the area. Where direct surveying was limited, observation with binoculars was able to yield further confirmation of the presence or lack of non-natives. Visual observations through binoculars were more frequent during the summer when access to certain areas was not permitted or limited due to wildlife presence (Table 3a & 3b). Crew members were confident in detecting at least 90% of all target species in patches at least $4m^2$ in size.

3.2 Total Area Inventory

A total of 1,067 targeted species features were mapped, including 996 patches; 41 linear; and 30 polygon features (Table 4a). The spring survey included a total of 686 features, or non-native plant areas mapped with targeted species. This included 626 buffered points (patches), 38 linear areas, and 22 larger polygons (Table 4b). Summer survey mapped an additional 381 features (370 patches, 3 linear and 8 polygon areas) of the seven summer targeted species surveyed (Table 4c). Non-native species were found on 9.145ha of the islands, representing 24% of the islands (Table 5a).

As noted above, for the purpose of this report, areas infested represent a dissolving of overlapping species distribution. For example, if *T. tetragonioides* and annual grass infest the same area, the adjusted infested value is the dissolving of *T. tetragonioides* and annual grass patches where they overlapped. When listing specific species separately for the island or a given area, the adjusted infested value is the dissolving of overlapping features belonging to the same species or species group. Because of the differences in these processes, the summation of infested area for all target species found within a given inventory area (Table 10-15) may total more than searched hectares in some cases.

3.2.1 Target Invasive Species

Of the 10 targeted non-native species, nine species: *Chenopodium murale, Coprosma repens, Ehrharta erecta, Malva arborea, Oxalis pes-caprae, Plantago coronopus, Senecio vulgaris, Sisymbrium orientale , Tetragonia tetragonioides* and the four species groups : *Rumex* species *(Rumex crispus* and *R. acetosella),* annual grasses (including *Avena fatua, A. barbata, Bromus diandrus, Hordeum murinum, Poa annua,* and *Vulpia bromoides), Malva* species *(Malva neglecta, M. parviflora and M. pseudolavatera)* and *Sonchus species (Sonchus asper and S. oleraceus)* were documented on SEFI or West End Island (Table 6a-c, Figure 7). *Rubus bifrons* (Himalayan blackberry) had been previously listed as found on the island and because of its invasive potential, it was listed as a target species, however, no blackberry was documented on the island during the survey. This species may have been found only once and noted on a previous plant list but was thought to have been removed (Brian White *pers comm.*). However, *R. bifrons* was found in a recent assessment of the island's seedbank (Chasey 2016). Even so, at this time this species does not appear to be a species that should be of further management concern.

Approximately 24% (9.145ha) of the island areas were mapped as infested (Table 5a). The spring survey mapped 6.787ha of non-overlapping target species (Table 5b) and the summer survey added an additional 2.359ha not previously detected (Table 5c). Examining all targeted species mapped on the island using the combined spring and summer surveys; T. *tetragonioides* covered the largest area with 449 recorded features found on 4.876ha covering ~13% of the islands, the

annual grasses group covered the next largest area, with 174 features covering 4.094ha or ~10.6% of the islands (Table 4a-c and 6a). *Plantago coronopus* accounted for 6% of the infested area, with the *Malva spp.* group at 2.8%, *Chenopodium murale* accounted for about 2.5% of the area, with all other species at less than 2% (Table 6a-c).

Table 7a notes the total area of infestation detected for each species by inventory area for spring and summer combined. Table 7b notes the spring inventory results and Table 7c shows the additional areas mapped in summer for the seven species targeted in the follow-up inventory.

Species Cover

For each feature recorded, average canopy cover was noted in five classes. The majority (70%) of patches, linear features and polygons were recorded within cover classes 2 (1-10%) and/or 3 (10-25%) (Table 8a & b). Each targeted species (with the exception of *Coprosma repens*) had greater than 60% of features in those two cover classes. Because *Coprosma repens* was a shrub, (present in two locations), the patches were composed of the entire shrub and the cover class was designated as 6 (high >60%) at its locations. The lower canopy percentages for individual species does not indicate a sparseness of vegetation, but merely reflects that in many patches there were a combination of several invasive species or invasive and native species. Figures 14-26 are maps of each species with cover classes noted for each feature.

Phenology

Tables 9a and 9b present phenology data for spring and summer surveys. For each feature the phenology of the species was recorded. During the spring survey 43% of all species mapped were flowering and very few individuals had gone to seed. Phenology was variable based on species. Greater than 50% of all features with Annual grasses, *Chenopodium murale*, *Coprosma repens, Ehrharta erecta*, *Malva arborea*, *Oxalis pes-caprae*, *Rumex spp.* group, *Senecio*, *Sisymbrium orientale* or *Sonchus spp.* group were recorded as flowering. Species with the majority of individuals in the feature noted as rosette or pre-flower were *Tetragonia tetragonioides*, *Plantago coronopus*, and the *Malva spp.* group. These species along with *Chenopodium murale,*

Ehrharta erecta, Sonchus spp. group and annual grasses were reassessed in July to be certain that features were accurately mapped, as newly emergent species are often difficult to detect. The summer survey did prove useful in identifying additional patches of these later emerging species.

3.3 Inventory Areas

The inventory area with the highest infestation of non-native target species was the South Slope Inventory Area with greater than 74% of the area infested (See Table 5a). The area with the fewest non-natives present was the Perimeter Inventory Area with approximately 2.5% of the area with targeted species. However, much of the Perimeter area was highly disturbed by pinniped activity before and during the time of the survey, and a larger than normal percent of the area (especially adjacent to the Marine Terrace) was completely denuded of vegetation due to high pinniped activity. This area was revisited in the summer follow-up inventory to note any late emergence of target species. The area should be visited in other years if pinniped use returns to more typical levels in order for the area to be resurveyed.

3.3.1. North End

The inventory area called North End included the north slope of SEFI (Figure 8). This area of the island is closed to most access to protect this largely undisturbed habitat. Other than West End Island, this area tends to be the least visited area of SEFI. The area is covered primarily by *Lasthenia maritima*, a native plant on the island.

One hundred percent of the inventory area designated as North End was physically inventoried. Of the 4.99ha surveyed, 1.455ha or 29.11% of the area was infested (see Table 5a, Figure 8). Nine target species or groups were discovered in this area (Table 10a-c). *T. tetragonioides* was the most abundant, accounting for almost 25% (1.24ha) of the inventory area. Annual grasses were found on 0.16ha (3%) of North End. Seven additional species or species groups were found in this area. In order of greatest abundance they were: *Ehrharta erecta* (0.08ha), *Malva* sp. group (0.05ha), *Sonchus* sp. group (0.024 ha), *Chenopodium murale* (0.024ha), *Coprosma repens* (0.006ha), *Plantago coronopus* (0.003ha), and one small patch of O*xalis pes-caprae* (0.001ha) located at the far east side of this area. *Malva arborea, Rumex sp., Senecio vulgaris* and

Sisymbrium orientale were not documented in the North End Area. The only two individual mirrorplant (*Coprosma repens)* located on the island are present on North End.

During the summer survey a large area of *T. tetragonioides* was discovered that was not detected during the spring survey, along with smaller patches of *Ehrharta* grass*, Plantago coronopus, Chenopodium murale* and *Sonchus* (Table 10c).

3.3.2 South Slope

One hundred percent (3.333ha) of the inventory area designated as South Slope was physically surveyed. This is the area most frequently used by island personnel. It has a history of use for many decades including current and former living quarters, several former naval and U.S. Coast Guard buildings and other infrastructure, as it includes the trail to the lighthouse, bird blinds, and nest boxes. It was the area most infested with invasive plants. Of the total area surveyed, nearly 75% (2.47ha) were documented infested (see Table 5a, Figure 9). Seven of the 14 targeted species or groups were documented in this area (Table 11a-c). *T. tetragonioides* made up the largest percentage of the invasives with 2.16ha (65%) of the area. Annual grasses covered an additional 0.96ha (29%) of the surveyed area. Both these species were found throughout the inventory area. The additional five target species or species groups detected in this area in order of greatest abundance were: *Ehrharta* grass (0.31ha), *Malva spp.* group (0.08 ha), *Sonchus spp.* group (0.05ha), *Plantago coronopus* (0.015ha), and *Chenopodium murale* (0.009ha). The *Malva spp.* group was mostly found on the upper slopes while *Plantago coronopus* was found near trails (Figure 9). *Coprosma repens*, *Malva arborea*, *Oxalis pes caprae*, *Rumex* sp., *Rubus bifrons, Senecio vulgaris* and *Sisymbrium orientale* were not detected in this area.

The summer survey was able to detect an additional 0.49ha of target species, primarily *T. tetragonioides* and *Ehrharta erecta* (Table 11c).

3.3.3 Marine Terrace

The Marine Terrace area included 7.85ha surveyed. One hundred percent of the area was physically surveyed. Of the total area surveyed, nearly 55% (4.35ha) was documented infested

(Figure 10). Eleven of the 14 targeted species or species groups were documented in this area (Table 12a). Annual grasses made up the largest percentage of the invasives with 2.40ha (38%) of the area. *Plantago coronopus* was also present covering 2.23ha (20%) of the area. These two species were found throughout this inventory area. The additional nine target species or species groups in this area in order of greatest abundance were: *T. tetragonioides* (0.94ha), *Malva spp.* group (0.88ha), *Chenopodium murale* (0.53ha), *Sonchus spp.* group (0.37ha), *Malva arborea* (0.15ha),) *Rumex spp.* group (0.09ha), *Senecio vulgaris* (0.011ha), *Oxalis pes-caprae* (0.002ha) and *Sisymbrium orientale* (0.002ha). *T. tetragonioides* was found primarily on the western side of this area, while the *Malva spp.* group was mostly on the eastern and central parts. Several large patches of *Chenopodium murale*, were detected in the summer survey in areas that were occupied or denuded by marine mammals during the spring. *Ehrharta* grass, *Rubus bifrons* and *Coprosma repens* were not found in this area (Table 12a-c).

The summer survey detected additions to all seven targeted species in the inventory mapping 2.3ha of additional patches not captured in the spring survey (Table 12c).

3.3.4 Corm Blind Hill

The Corm Blind Hill area included 1.633ha that was physically surveyed during the spring, representing 100% of the area. During the summer only 29% was physically surveyed, the remainder was visually surveyed. Of the total area surveyed, 6.5% (0.106 ha) was infested (Table 5a, Figure 11). Four of the 14 targeted species or group were detected in this inventory area (Table 13a). *T. tetragonioides* made up the largest percentage accounting for 0.103ha (6.3%) of the area. The additional target species or groups in this area in order of greatest abundance were: *Ehrharta* grass (0.009 ha), *Sonchus spp.* group (0.004ha), and *Chenopodium murale* (0.003ha). Although a smaller patch of annual grass was present, it did not meet our minimum mapping unit requirement and was not included. Most of these species were found near the trail or bird blind area. *Coprosma repens*, *Malva arborea*, *Malva* sp. group, *Oxalis pes-caprae*, *Plantago coronopus*, *Rubus bifrons, Rumex spp.* group, *Senecio vulgaris* and *Sisymbrium orientale* were not detected in this area.

Primarily visual surveys during the summer added several small patches of *T. tetragonioides* (0.043ha) to this inventory (Table 13c)

3.3.5 Perimeter

About 97% of the Perimeter inventory area was surveyed in the spring (Table 5b). Much of the time this area was covered with resting pinnipeds and was found to be severely denuded when they returned to the water. Less than 3% (0.273ha) of this area was infested (Table 5a, Figure 12). Six of the 14 targeted species or groups were documented in this area (Table 14a-c). *T. tetragonioides* made up the largest percentage of the invasives with (0.171ha) 1.5% of the area infested. Additional target species documented included: *Chenopodium murale* (0.078ha), *Malva spp.* group (0.02ha), *Sonchus spp.* group (0.013ha), *Plantago coronopus* (0.003 ha) and annual grasses (0.007ha). *Coprosma repens*, *Ehrharta erecta*, *Malva arborea, Oxalis pes-caprae*, *Rubus bifrons*, *Senecio*, *Sisymbrium orientale* and the *Rumex spp.* group were not detected in this area.

The summer survey noted a small amount (0.118ha) of additional *T. tetragonioides* and *Chenopodium murale* features (Table 14c).

3.3.6 West End Island

West End Island was difficult to get to and because of presence of resting pinnipeds only 78% (7.76 ha) of the island was mapped in the spring survey. The area physically surveyed was the area with previously known evidence of infestation (Gerard McChesney pers com). During the summer survey, the entire island was visually surveyed by boat along the perimeter of the island. West End is highly disturbed by pinnipeds and seabirds most of the year. Of the 9.76ha of West End surveyed only 0.49ha (5%) were documented as infested (Table 5a, Figure 13). Six of the 14 targeted species or group were documented in this area (Table 15a). *Chenopodium murale* made up the largest area of invasives with 0.31ha or 3% of the area. *T. tetragonioides* covered an additional 0.26ha (2.7%) of the area. The additional four target species or groups in this area in the order of greatest abundance were: *Sonchus spp.* group (0.162ha), *Malva spp.* group (0.05ha), *Rumex spp.* group (0.001ha) and annual grasses (0.001ha). Most of these patches were located

on the eastern side of the island. *Coprosma repens*, *Rubus bifrons*, *Ehrharta erecta*, *Malva arborea*, *Oxalis pes-caprae, Plantago coronopus*, *Senecio vulgaris* and *Sisymbrium orientale* were not detected in this area.

The completely visual summer survey added only 0.064ha of *T. tetragonioides* that was not previously detected (Table 15c).

3.4 Accuracy Assessment

An assessment was conducted to analyze the accuracy of the inventory. Of the 79 patches selected, one was found to be incorrect (no species was in the database). Of the 4 linear features selected, no inaccuracies in species were identified. Of the 3 polygon features, no inaccuracies in species were identified. This gave a 98.7 % accuracy in mapping target species.

4.0 Discussion and Recommendations

This inventory documents the presence, abundance, and spatial distribution of targeted invasive species on Southeast and West End Island of the Farallon National Wildlife Refuge. The inventory can support wildlife managers at the Refuge by providing baseline mapping and data for further terrestrial plant management activities. These data can support the invasive plant management strategies and decisions by:

1. Documenting areas 'clean' from target invasive plants (no Features documented).
2. Identifying small and outlier populations for eradication.
3. Providing increased understanding about the patterns of invasion.
4. Providing a baseline for evaluating invasive plant management success over time.
5. Providing a baseline for developing SMART invasive plant management objectives (specific, measureable, achievable, results-oriented, and time-bound).

The data collected in spring and summer of 2016 documents locations and abundance of targeted species on the Refuge. These data provide valuable information for implementing and modifying

the current integrated pest management plan. By noting areas free of invasives, management can actively monitor and rapidly react in these areas to maintain native species. Of the 38.694ha physically or visually searched on the island, non-native target species (that occupied >.001ha) were not documented on 75% of the island. These areas included areas occupied by native species or rocky and/or steep areas where no plants were located.
Keeping clean areas free of non-native species is the most economically feasible and ecologically beneficial approach when resources are limiting.

By understanding patterns of invasion, combined with environmental features (such as soil, topography, infrastructure), the Refuge will understand how invasion may progress in the future, and what actions are needed to prevent future spread. Although this study does not look at spatial patterns per se, this inventory can be used in conjunction with other studies to model invasives occurrence on the islands and provide valuable information on ways to limit spread and future introductions. This inventory examines one spring and summer season in time, but this inventory coupled with additional future inventories can help us understand change in invasive species presence, abundance, and distribution over time. Doing so will provide the Refuge with a better understanding and documentation of management techniques that are working and those that are not.

By doing the work to prioritize and target species of most concern in the inventory the Refuge can begin to assess their efforts in eradicating non-native species. By separating the Refuge into inventory or management areas, the Refuge is able to see how non-native species inhabit the island differently in different areas.

Starting with the targeted species that are of most concern, to those of least concern this section discusses the presence and possible considerations for each of the targeted species or groups. For more information on these species, ecology and treatment we recommend the Cal-IPC website found at http://www.cal-ipc.org/. This site provides information on the description of many invasive species as well as its ecology and research on methods of control or eradication.

Ehrharta grass: The Refuge should pay serious attention to the presence of *Ehrharta erecta* (Veldt grass). This genus is noted as invasive by Cal-IPC and has been observed to spread rapidly in wildland areas within northern California (Cal-IPC 2015). The species was noted on South Slope and starting to invade near the summit and down into the North End (Figure 14). It was also documented in the Corm Blind Hill area. The summer survey located additional patches of this invasive grass on South Slope and North End. This species should be a priority in eradication as the population is still relatively small in extent and manageable. Its presence on North End could, if not eradicated, further encroach into the area considered wilderness and become quite difficult to control. On Corm Blind Hill it is also present close to the trail in two patches. Removal by chemical and manual means should be pursued. It can spread by seed or vegetatively. Manual removal requires complete removal of the root stock to prevent resprouting; disturbance by manual removal may stimulate germination by dormant seeds (Cal-IPC 2006). Education on and strict adherence to using the boot brushes can be useful in curbing further spread into Corm Blind Hill and North End areas. It is recommended that all researchers and interns on the island be educated in the identification of this species so if they come across it they can remove it. A handout describing this species that should be posted in both houses on SEFI is located in Appendix G.

New Zealand Spinach: *T. tetragonioides (NZ spinach)* and annual grasses are the non-native species that cover the largest areas of the Refuge. NZ spinach was detected on approximately 13% of the total area surveyed (primarily on SEFI). This species was found on all inventory areas of the island, particularly the South Slope, North End and the western Marine Terrace (Figure 15) and it will take a significant effort to eradicate. It was sparsely distributed on West End, Corm Blind Hill and the Perimeter Inventory Areas and these may be areas where it can be eliminated with less effort and protected from further introductions. Concentrated efforts in the areas where the species is sparse should be prioritized to minimize spread in these locations. This species has been a target of control efforts by the Refuge for several years. Current efforts include annual or bi-annual spraying (early spring and summer) and more limited manual removal. The initial vegetation monitoring plots (Holzman, unpublished) that had previously been excluded from the spraying program for three years have now been included in the eradication efforts.

This Inventory can be used to provide a new baseline for future assessments. Quantitative assessment of eradication efforts should be initiated biannually prior to spraying to assess control progress. Photo-monitoring plots should be continued for a visual assessment of large areas.

Annual grasses: Annual grasses including *Avena fatua, A. barbata, Bromus diandrus, Hordeum murinum, Poa annua,* and *Vulpia bromoides,* are all non-native grasses common on the mainland. These grasses are present primarily on the Marine Terrace and South Slope Areas, with moderate infestation on the North End and minimal patches on West End, the Perimeter and Corm Blind Hill Areas (Figure 16). The author (Holzman) has observed variable densities and distribution over the years, hence a one-year inventory of their distribution is likely to be highly variable and less useful in a prescription for removal. The largest areas of invasive plants are on the eastern Marine Terrace which has likely been disturbed by wildlife and humans since they visited the island. Manual removal is likely to further disturb these areas leading to continued germination and abundance of grasses and other invasive species. The native perennial grass, *Bromus maritimus* (Maritime brome) is also present in many of these areas, so chemical spraying could lead to a decrease in its abundance unless great care were taken to protect these plants. Areas with minimal invasives should be targeted for removal to prevent additional infestations or increasing their distribution in those areas. Further research and discussion of the effect of non-native grasses on nesting birds and native plant species should be initiated before a full scale attempt at eradication is pursued.

Plantain: *Plantago coronopus* was found primarily on the marine terrace in largely disturbed areas (Figure 17). It has been recorded as invasive in California, forming dense mats which can displace native vegetation (Weber, 2003). There are a few patches on the upper slope of South slope and North end inventory areas which should be removed to prevent further spreading in the area. The best strategy for this species may be to concentrate on removing it from peripheral areas to prevent spread and contain it to the marine terrace if possible.

Cheeseweed: The Malva group includes three species; *Malva neglecta, Malva parviflora* and *Malva pseudolavatera.* The largest areas of invasive plants occur throughout the Marine Terrace, and South Slope primarily near trails (Figure 18). There are small patches in the other inventory

areas including West End Island that could be targeted for removal and provide successful eradication in these areas. We suggest that these areas with minimal patches be targeted with maximum effort to eliminate these species from those areas and minimize seed source, and that monitoring and rapid removal be performed once these plants are eradicated to protect these areas from re-introduction. Invasive plants on South Slope seems to have spilled over the top to North End so it will be important to remove the species from the summit and the spill over areas to eliminate further introductions on North End. Minimizing additional infestations may be the most effective and economical way to treat this species. Invasive plant occurrence on the Marine Terrace is widespread.

Nettleleaf goosefoot: *Chenopodium murale* (nettleleaf goosefoot) was found in scattered areas throughout the island (Figure 19). It has a large presence on West End. It is often found in disturbed environments. It reproduces via seeds, so removing this plant prior to seed set is important. This plant appears to occur in areas where marine mammals tend to haul out, although further study on this relationship would be warranted.

Sowthistle: There are two species of Sonchus that occur on the island, *Sonchus asper* (spiny sowthistle) and *Sonchus oleraceus* (common sowthistle). Since both species will be treated the same they were combined into a species group for this inventory. *Sonchus spp.* were detected scattered throughout the island include West end (Figure 20). It tends to occur in disturbed areas near trails. These species reproduce from seeds and can be prolific. Surface seeds do not seem to last beyond a year, so catching them before they get into the seed bank is the best method. Once in the seed bank they can remain dormant for several years. There is some research that suggest these species can easily become resistant to herbicides (Widderick & Walker 2012).

Rumex: Two species of Rumex were found on the Refuge*, Rumex acetosella (common sheep sorrel)* and *Rumex crispus* (curly dock). It was detected on the Marine Terrace and on West End Island (Figure 21). The West End population is small (0.001ha) and could be removed manually. The 0.09ha on the terrace is scattered and occurs alongside other non-natives, particularly the *Malva spp.*, annual grasses and *Plantago coronopus*. The California Invasive Plant Council

classifies common sheep sorrel's potential impact on native systems as moderate and curly dock's potential impact as limited (Calflora 2016). Sheep's sorrel can reproduce by seed or vegetatively while curly dock reproduces mainly by seed. It can flower year round. Both species are common in disturbed areas. These *Rumex spp.* have limited distribution on the island during the year of the survey. It may be more abundant during wet years as it prefers wet environments.

Groundsel and Hedge mustard: *Senecio vulgaris and Sisymbrium orientale* were only found on the Marine Terrace in areas of high traffic and anthropogenic disturbance (Figures 22 and 23). While *Senecio vulgaris* does not appear to be problematic, *Sisymbrium orientale* could be. The author has watched this species increase on the terrace on the north and south side of the Carpenter shop. Although it occurs in patches is still minimal, it is a species that is highly invasive and can spread easily. As such, when it is located it should be removed. Similar to our recommendation for *Ehrharta erecta*, managers, researchers and interns should be educated in identification of this species, so when it is observed it can be pulled throughout the year. A description of this species is also included in Appendix G.

Tree Mallow: *Malva arborea* is an upright woody species whose presence on the Marine Terrace has increased in both locations, between the houses and near the Carpenter shop (personal observation) (Figure 24). As it is a species attractive to invertebrates and song birds, its presence is thought of as increasing habitat for those species. This species does tend to increase and its presence should be carefully watched to avoid further distribution beyond these two locations.

Bermuda buttercup: *Oxalis pes–caprae* was found in two discrete areas, on North End and the Marine Terrace (Figure 25). This species can divide and reproduce easily asexually and should be watched. If removing, the bulbs need to be completely removed to prevent further infestation. This species can also be eradicated chemically. This species is found to rapidly invade on the mainland and should be considered a target for removal. As burrowing birds, such as auklets populate these areas the risk of spreading will increase. Since it's occurrence on the island is currently limited, it could easily be eradicated.

Mirror plant: *Coprosma repens* (creeping mirror plant) is a flowering perennial shrub native to New Zealand and found in two locations on the North End (Figure 26). This introduced shrub provides some roosting sites for birds. It can grow from seed or hardwood cutting. It is considered a weed in California and Hawaii, but it doesn't appear to be a rapid invader on the Farallones. Should the Refuge decide to eradicate this species it would not be difficult to do as its distribution is very limited. Since it appears to be favorable for songbirds who visit the area (Russell Bradley pers com), allowing this species to remain with careful monitoring should not present an invasion issue.

Summary: From this Inventory it is evident that the Marine Terrace and South Slope are highly infested areas, this will be of no surprise to the Refuge Manager and staff. These areas are also well travelled by staff, researchers and wildlife. Most of the trails are also located in these areas. While full scale assault on these areas may yield some appreciable reduction in non-natives' presence, eradication in peripheral areas may be more advantageous in containing invasives to these two areas. By removing smaller population, monitoring, and rapidly responding to reappearances in these areas, the Refuge may be better able to get a handle on further incursion by non-natives outside these core use areas (South Slope and Marine Terrace) and create larger areas for protection. Enhancing the occurrence and use of boot brushes to prevent movement of seeds into the less infested areas would be helpful. Education and identification of plants targeted for rapid detection and removal by all on the island would provide more eyes on the ground to assist in removal. An annual walkthrough assessment for rapid detection of all target species may enhance protection. The South Slope and Marine Terrace will probably be continuously subjected to future introductions due to trails, as well as movement and soil disturbance from wildlife throughout these areas. Effective containment and minimization of distribution of non-native species in these areas would appear to be the most logical and economical management practice for South Slope and the Marine Terrace. The Refuge will need to establish a protocol for best management practices for treating invasive species as well as prevention methods to limit future re-introductions or new introductions of additional invasive species.

North End and West End Island seem to be minimally impacted by invasive species. Care should be taken to monitor the area to prevent further introductions. *E. erecta* was detected on North End possibly representing a new incursion from the south slope. Its removal should be a top priority to prevent any further spread. NZ spinach seems to have increased in these areas, targeted removal efforts here may be able to control spread and limit distribution. Given the right timing and access, it may be possible to eradicate invasive species from West End Island. Targeting *Chenopodium murale, T. tetragonioides* and *Sonchus spp*. would be the highest priority for this inventory area to prevent increasing the seedbank. Once clear of non-natives, extra precaution and/or limiting personnel movement in this area may limit re-occurrence. It is possible that wildlife may also be contributing to reintroductions of invasive plants.

Future monitoring and mapping: It will be extremely useful for the Refuge to continue monitoring and mapping these invasive species every few years to be able to ascertain variable emergence of species as well as document the effects of their control and eradication efforts. This will allow them to adapt management techniques to use the most effective means to meet their invasive species management goals. Understanding the effects of such efforts on the elimination of targeted species as well as the reestablishment of natives will help future restoration efforts.

5.0 Conclusion

This Invasive Plant Inventory provides information on the location and spatial distribution of targeted non-native species on the South Islands of the Farallon Islands National Wildlife Refuge. It provides maps and statistical data on each inventory area and each targeted species detected on the Refuge and where they were found during the spring and summer surveys of 2016. One year of data will not provide a complete view of the totality of non-native species found on the Islands as variable germination requirements and current climate may limit certain species from appearance in a given year. This Inventory can be used as a baseline and be updated with future monitoring and mapping. Our hope is that this inventory can provide useful information to current and future managers of the Refuge to effectively and efficiently manage the Refuge to maximize habitat and protection of our nation's flora and fauna.

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TABLES

Table 1. Priority invasive plant species and species groups for inventory at the Refuge.

Scientific Name (IT IS)	Common Name
Chenopodium murale	nettle-leaf goosefoot, nettleleaf goosefoot
Coprosma repens	creeping mirrorplant
Ehrharta erecta	panic veldt grass, erect veldt grass
Malva arborea	tree mallow
Oxalis pes-caprae	Bermuda buttercup, buttercup oxalis
Plantago coronopus	Plantain
Rubus bifrons	Himalayan berry, Himalaya blackberry
Senecio vulgaris	old-man-in-the-spring, common groundsel
Sisymbrium orientale	Indian hedge-mustard
Tetragonia tetragonioides	New Zealand spinach
SPECIES GROUPS	
Annual Grasses	
Avena fatua	wild oat, wild oats, flax grass, oatgrass, wheat oats
Avena barbata	slender oat, slender oats, slender wildoat
Bromus diandrus	ripgut brome
Hordeum murinum	mouse barley, bulbous barley
Vulpia bromoides	brome fescue
Rumex Species	
Rumex acetosella	sheep sorrel, field sorrel, red sorrel
Rumex crispus	curly dock, narrowleaf dock, sour dock
Sonchus Species	
Sonchus asper	spiny sowthistle, prickly sow thistle,
Sonchus oleraceus	common sowthistle, sow-thistle
Malva Species	
Malva neglecta	cheeseweed, common mallow, dwarf mallow
Malva parviflora	small-whorl mallow, cheeseweed,
Malva pseudolavatera	Cretan mallow

Table 2. Inventory Areas

Total Hectares per Inventory Area	
Inventory Area	**Total Hectares**
North End	4.999
South Slope	3.333
Marine Terrace	7.851
Corm Blind Hill	1.633
Perimeter	11.118
West End Island	9.760
Total	**38.694**

SEFI = 28.934ha, WEI =9.760ha

Table 3a. Survey Coverage

Survey Coverage per Inventory Unit: Spring 2016					
Inventory Area	**Physically Surveyed Area (ha)**	**Visually Surveyed Area (ha)**	**Area Not Surveyed (ha)**	**Total Area Surveyed (ha)**	**Total Area Surveyed (%)**
North End	4.999	0.000	0.000	4.999	100.00
South Slope	3.333	0.000	0.000	3.333	100.00
Marine Terrace	7.851	0.000	0.000	7.851	100.00
Corm Blind Hill	1.633	0.000	0.000	1.633	100.00
Perimeter	8.623	2.221	0.274	10.844	97.90
West End Island	1.063	6.538	2.159	7.601	77.88
Total	**27.502**	**8.759**	**2.433**	**36.261**	**93.71**

Table 3b. Survey Coverage

Survey Coverage per Inventory Unit: Summer 2016				
Inventory Area	**Physically Surveyed Area (ha)**	**Visually Surveyed Area (ha)**	**Total Area Surveyed (ha)**	**Total Area Surveyed (%)**
North End	3.668	1.331	4.999	100.00
South Slope	3.308	0.025	3.333	100.00
Marine Terrace	5.956	1.895	7.851	100.00
Corm Blind Hill	0.475	1.158	1.633	100.00
Perimeter	0.532	10.586	11.118	100.00
West End Island	0.000	9.760	9.760	100.00
Total	**13.939**	**24.755**	**38.694**	**100.00**

Table 4a. Inventory Features Mapped

Feature Types Mapped per Species: Total Features				
Scientific Name	**Patches**	**Linear**	**Polygon**	**Total**
Annual grasses group	126	5	12	**143**
Chenopodium murale	117	7	1	**125**
Coprosma repens	2	0	0	**2**
Ehrharta erecta	101	1	0	**102**
Malva arborea	15	0	0	**15**
Malva spp. group	140	13	3	**156**
Oxalis pes-caprae	3	0	0	**3**
Plantago coronopus	39	4	5	**48**
Rumex spp. group	11	0	0	**11**
Senecio vulgaris	8	1	0	**9**
Sisymbrium orientale	3	0	0	**3**
Sonchus spp. group	128	8	0	**136**
Tetragonia tetragonioides	302	2	9	**313**
Total	**996**	**41**	**30**	**1,067**

Table 4b. Inventory Features Mapped

Feature Types Mapped per Species: Spring 2016				
Scientific Name	**Patches**	**Linear**	**Polygon**	**Total**
Annual grasses group	115	5	9	**129**
Chenopodium murale	75	5	0	**80**
Coprosma repens	2	0	0	**2**
Ehrharta erecta	38	1	0	**39**
Malva arborea	15	0	0	**15**
Malva spp. group	131	13	3	**147**
Oxalis pes-caprae	3	0	0	**3**
Plantago coronopus	10	4	2	**16**
Rumex spp. group	11	0	0	**11**
Senecio vulgaris	8	1	0	**9**
Sisymbrium orientale	3	0	0	**3**
Sonchus spp. group	108	8	0	**116**
Tetragonia tetragonioides	106	1	8	**115**
Total	**626**	**38**	**22**	**686**

Table 4c. Inventory Features Mapped

Feature Types Mapped per Species: Features Added by Summer Survey				
Scientific Name	**Patches**	**Linear**	**Polygon**	**Total**
Annual grasses group	11	0	3	**14**
Chenopodium murale	42	2	1	**45**
Ehrharta erecta	63	0	0	**63**
Malva spp. group	9	0	0	**9**
Plantago coronopus	29	0	3	**32**
Sonchus spp. group	20	0	0	**20**
Tetragonia tetragonioides	196	1	1	**198**
Total	**370**	**3**	**8**	**381**

Table 5a. Target Plant occurrence in Area by Inventory Area from Spring and Summer Surveys

Hectares Infested per Inventory Area: Total Area[1]			
Inventory Area	**Total Area Surveyed (ha)**	**Inventory Area Infested (ha)[2]**	**Inventory Area Infested (%)[3]**
North End	4.999	1.455	29.11
South Slope	3.333	2.470	74.11
Marine Terrace	7.851	4.349	55.39
Corm Blind Hill	1.633	0.106	6.49
Perimeter	11.118	0.273	2.46
West End Island	9.760	0.492	5.04
Total	**38.694**	**9.145**	**23.63**

[1]Total area infested (ha) according to spring and summer 2016 surveys.
[2]Features merged and dissolved to eliminate overlapping data.
[3]Ratio of infested area (ha) to total area (ha) surveyed per inventory area.

Table 5b. Target plant occurrence in Area by Inventory Area from Spring Survey

Hectares Infested per Inventory Area: Spring 2016			
Inventory Area	**Total Area Surveyed (ha)**	**Inventory Area Infested (ha)[1]**	**Inventory Area Infested (%)[2]**
North End	4.999	0.552	11.04
South Slope	3.333	2.195	65.86
Marine Terrace	7.851	3.385	43.12
Corm Blind Hill	1.633	0.063	3.86
Perimeter	10.844	0.147	1.36
West End Island	9.760	0.444	4.55
Total	**36.261**	**6.787**	**18.71**

[1]Features merged and dissolved to eliminate overlapping data per inventory area.
[2]Ratio of infested area (ha) to total area surveyed (ha) per inventory area.

Table 5c. Additional area detected in Summer Survey

Hectares Infested per Inventory Area: Area Added by Summer Survey	
Inventory Area	**Summer Survey Additions (ha)**
North End	0.903
South Slope	0.275
Marine Terrace	0.964
Corm Blind Hill	0.043
Perimeter	0.126
West End Island	0.048
Total	**2.359**

Table 6a. Area per Target Species from Spring and Summer Surveys

Hectares Infested per Target Species: Total Area[1]		
Species Name	**Infested Area (ha)[2]**	**Infested Area (%)[3]**
Annual grasses group*	4.094	10.58
*Chenopodium murale**	0.955	2.47
Coprosma repens	0.006	0.02
*Ehrharta erecta**	0.398	1.03
Malva arborea	0.145	0.37
*Malva spp. group**	1.081	2.79
Oxalis pes-caprae	0.003	0.01
*Plantago coronopus**	2.355	6.09
Rumex spp. group	0.092	0.24
Senecio vulgaris	0.010	0.03
Sisymbrium orientale	0.002	0.01
*Sonchus spp. group**	0.616	1.59
*Tetragonia tetragonioides**	4.876	12.63

[1]Total area infested (ha) from combined spring and summer 2016 surveys.
[2]Features merged and dissolved to eliminate overlapping data.
[3]Ratio of infested area (ha) to total area (38.694ha) surveyed.
*Values represent additional Features noted in the targeted summer survey.

Table 6b. Area per Target Species from Spring Survey

Hectares Infested per Target Species: Spring 2016		
Species Name	**Infested Area (ha)[2]**	**Infested Area (%)[3]**
Annual grasses group*	3.524	9.72
*Chenopodium murale**	0.465	1.28
Coprosma repens	0.006	0.02
*Ehrharta erecta**	0.198	0.55
Malva arborea	0.145	0.40
*Malva spp. group**	1.010	2.79
Oxalis pes-caprae	0.003	0.01
*Plantago coronopus**	1.654	4.56
Rumex spp. group	0.092	0.25
Senecio vulgaris	0.010	0.03
Sisymbrium orientale	0.002	0.01
*Sonchus spp. group**	0.467	1.29
*Tetragonia tetragonioides**	3.075	8.48

[1]Features merged and dissolved to eliminate overlapping data.
[2]Ratio of infested area (ha) to total area (36.261ha) surveyed.

Table 6c: Additional area per Target Species detected in Summer Survey.

Hectares Infested per Target Species: Area Added by Summer Survey	
Species Name	**Summer Survey Additions (ha)**
Annual grasses group	0.570
Chenopodium murale	0.490
Ehrharta erecta	0.200
Malva spp. group	0.070
Plantago coronopus	0.701
Sonchus spp. group	0.149
Tetragonia tetragonioides	1.801
Total	**3.981**

Table 7a. Area per Target Species per Inventory Area from Spring and Summer Inventories

Hectares Infested per Target Species per Inventory Area: Total Area[1]							
Species Name	**North End**	**South Slope**	**Marine Terrace**	**Corm Blind Hill**	**Perimeter**	**West End Island**	**Total**
Annual grasses group*	0.157	0.956	2.973	0.000	0.007	0.001	**4.094**
*Chenopodium murale**	0.024	0.009	0.533	0.003	0.078	0.308	**0.955**
Coprosma repens	0.006	0.000	0.000	0.000	0.000	0.000	**0.006**
*Ehrharta erecta**	0.080	0.309	0.000	0.009	0.000	0.000	**0.398**
Malva arborea	0.000	0.000	0.145	0.000	0.000	0.000	**0.145**
*Malva spp. group**	0.046	0.076	0.889	0.000	0.020	0.050	**1.081**
Oxalis pes-caprae	0.001	0.000	0.002	0.000	0.000	0.000	**0.003**
*Plantago coronopus**	0.003	0.015	2.334	0.000	0.003	0.000	**2.355**
Rumex spp. group	0.000	0.000	0.090	0.000	0.000	0.001	**0.092**
Senecio vulgaris	0.000	0.000	0.010	0.000	0.000	0.000	**0.010**
Sisymbrium orientale	0.000	0.000	0.002	0.000	0.000	0.000	**0.002**
*Sonchus spp. group**	0.024	0.047	0.366	0.004	0.013	0.162	**0.616**
*Tetragonia tetragonioides**	1.240	2.158	0.944	0.103	0.171	0.261	**4.877**

[1]Total area infested (ha) per species per inventory area according to spring and summer 2016 surveys. Features merged and dissolved to eliminate overlapping data according to target species or species group.

*Values represent additional Features of targeted species in the summer survey.

Table 7b. Area per Target Species per Inventory Area from Spring Inventory

Hectares Infested per Target Species per Inventory Area: Spring 2016[1]							
Species Name	**North End**	**South Slope**	**Marine Terrace**	**Corm Blind Hill**	**Perimeter**	**West End Island**	**Total**
Annual grasses group	0.157	0.952	2.407	0.000	0.007	0.001	**3.524**
Chenopodium murale	0.018	0.005	0.059	0.003	0.072	0.308	**0.465**
Coprosma repens	0.006	0.000	0.000	0.000	0.000	0.000	**0.006**
Ehrharta erecta	0.047	0.142	0.000	0.009	0.000	0.000	**0.198**
Malva arborea	0.000	0.000	0.145	0.000	0.000	0.000	**0.145**
Malva spp. group	0.046	0.076	0.819	0.000	0.020	0.050	**1.010**
Oxalis pes-caprae	0.001	0.000	0.002	0.000	0.000	0.000	**0.003**
Plantago coronopus	0.001	0.001	1.649	0.000	0.003	0.000	**1.654**
Rumex spp. group	0.000	0.000	0.090	0.000	0.000	0.001	**0.092**
Senecio vulgaris	0.000	0.000	0.010	0.000	0.000	0.000	**0.010**
Sisymbrium orientale	0.000	0.000	0.002	0.000	0.000	0.000	**0.002**
Sonchus spp. group	0.022	0.044	0.222	0.004	0.013	0.162	**0.467**
Tetragonia tetragonioides	0.336	1.858	0.566	0.060	0.059	0.197	**3.075**

[1]Total area infested (ha) per species per inventory area according to spring 2016 survey. Features merged and dissolved to eliminate overlapping data according to target species or species group.

Table 7c. Additional Areas noted in Summer Inventory for Seven Targeted Species by Inventory Area

Hectares Infested per Target Species per Inventory Area: Area Added by Summer Survey							
Species Name	**North End**	**South Slope**	**Marine Terrace**	**Corm Blind Hill**	**Perimeter**	**West End Island**	**Total**
Annual grasses group	0.000	0.004	0.566	0.000	0.000	0.000	**0.570**
Chenopodium murale	0.006	0.004	0.474	0.000	0.006	0.000	**0.490**
Ehrharta erecta	0.033	0.167	0.000	0.000	0.000	0.000	**0.200**
Malva spp. group	0.000	0.000	0.070	0.000	0.000	0.000	**0.070**
Plantago coronopus	0.002	0.014	0.685	0.000	0.000	0.000	**0.701**
Sonchus spp. group	0.002	0.003	0.144	0.000	0.000	0.000	**0.149**
Tetragonia tetragonioides	0.904	0.300	0.378	0.043	0.112	0.064	**1.801**
Total	**0.947**	**0.492**	**2.317**	**0.043**	**0.118**	**0.064**	**3.981**

Table 8a. Canopy Cover detected in Spring Inventory

Canopy Cover Classifications per Target Species: Spring 2016							
Species Name	**Infested Area (ha)**	**Total Features[1]**	**Canopy Cover Classes (# of Features per Class)**				
			1: < 1 %	**2: 1-10 %**	**3: 10-25 %**	**4: 25-60%**	**5: > 60%**
Annual grasses group	3.524	160	0.00	27.50	37.50	25.63	9.38
Chenopodium murale	0.465	91	4.40	49.45	31.87	13.19	1.10
Coprosma repens	0.006	2	0.00	0.00	0.00	0.00	100.00
Ehrharta erecta	0.198	45	2.22	40.00	31.11	24.44	2.22
Malva arborea	0.145	15	0.00	6.67	46.67	40.00	6.67
Malva spp. group	1.010	164	1.83	51.22	30.49	12.80	3.66
Oxalis pes-caprae	0.003	3	0.00	33.33	33.33	33.33	0.00
Plantago coronopus	1.654	31	3.23	35.48	45.16	16.13	0.00
Rumex spp. group	0.092	13	23.08	38.46	23.08	15.38	0.00
Senecio vulgaris	0.010	9	0.00	44.44	55.56	0.00	0.00
Sisymbrium orientale	0.002	3	33.33	33.33	33.33	0.00	0.00
Sonchus spp. group	0.467	149	4.70	61.74	24.16	6.71	2.68
Tetragonia tetragonioides	3.075	251	1.99	45.02	31.87	14.34	6.77
Total	**10.650**	**936**	**2.67**	**44.76**	**32.05**	**15.49**	**5.02**

[1]Summation of all feature types: patches, lines and polygons.

Table 8b. Canopy Cover Detected in Summer Inventory

Canopy Cover Classifications per Target Species: Summer 2016							
Species Name	**Infested Area (ha)**	**Total Features[1]**	**Canopy Cover Classes (% of Total Features)**				
			1: < 1 %	**2: 1-10 %**	**3: 10-25 %**	**4: 25-60%**	**5: > 60%**
Annual grasses group	2.172	50	2.00	38.00	48.00	12.00	0.00
Chenopodium murale	0.512	54	5.56	66.67	24.07	3.70	0.00
Ehrharta erecta	0.268	107	4.67	55.14	20.56	17.76	1.87
Malva spp. group	0.120	32	6.25	75.00	12.50	3.13	3.13
Plantago coronopus	2.290	41	4.88	68.29	21.95	4.88	0.00
Sonchus spp. group	0.180	40	7.50	77.50	12.50	2.50	0.00
Tetragonia tetragonioides	2.614	299	9.70	48.16	25.42	11.04	5.69
Total	**8.156**	**623**	7.22	54.74	24.56	10.27	3.21

[1]Summation of all feature types: patches, lines, and polygons.

Table 9a. Phenology for Species Mapped in Spring Inventory

Phenology Classifications per Target Species: Spring 2016							
Species Name	**Infested Area (ha)**	**Total Features[1]**	**Phenology Classes (% of Total Features)**				
			Rosette	**Pre-Flower**	**Flowering**	**Post-Flower**	**Senesced**
Annual grasses group	3.524	160	1.88	0.63	97.50	0.00	0.00
Chenopodium murale	0.465	91	6.59	16.48	76.92	0.00	0.00
Coprosma repens	0.006	2	0.00	0.00	100.00	0.00	0.00
Ehrharta erecta	0.198	45	0.00	4.44	95.56	0.00	0.00
Malva arborea	0.145	15	6.67	40.00	53.33	0.00	0.00
Malva spp. group	1.010	164	49.39	45.73	4.27	0.61	0.00
Oxalis pes-caprae	0.003	3	33.33	0.00	66.67	0.00	0.00
Plantago coronopus	1.654	31	51.61	6.45	41.94	0.00	0.00
Rumex spp. group	0.092	13	23.08	7.69	53.85	15.38	0.00
Senecio vulgaris	0.010	9	0.00	0.00	100.00	0.00	0.00
Sisymbrium orientale	0.002	3	0.00	0.00	100.00	0.00	0.00
Sonchus spp. group	0.467	149	28.19	17.45	53.69	0.67	0.00
T. tetragonioides	3.075	251	84.46	14.34	1.20	0.00	0.00
Total	**10.650**	**936**	**39.00**	**17.52**	**43.06**	**0.43**	**0.00**

[1]Summation of all feature types: patches, lines, and polygons.

Table 9b. Phenology for Seven Targeted Species mapped in Summer Inventory

Phenology Classifications per Target Species: Summer 2016							
Species Name	**Infested Area (ha)**	**Total Features[1]**	**Phenology Classes (% of Total Features)**				
			Rosette	**Pre-Flower**	**Flowering**	**Post-Flower**	**Senesced**
Annual grasses group	2.172	50	0.00	0.00	0.00	0.00	100.00
Chenopodium murale	0.512	54	0.00	1.85	98.15	0.00	0.00
Ehrharta erecta	0.268	107	0.93	2.80	7.48	81.31	7.48
Malva spp. group	0.120	32	3.13	21.88	56.25	9.38	9.38
Plantago coronopus	2.290	41	0.00	0.00	68.29	21.95	9.76
Sonchus spp. group	0.180	40	0.00	0.00	97.50	2.50	0.00
T. tetragonioides	2.614	299	4.01	80.60	7.69	1.67	6.02
Total	**8.156**	**623**	**2.25**	**40.45**	**27.13**	**16.85**	**13.32**

[1]Summation of all feature types: patches, lines, and polygons.

Table 10a. North End: Infestation per Species from Spring and Summer Inventories

Hectares Infested - North End: Total Area[1]		
Species Name	**Infested Area (ha)[2]**	**Infested Area (%)[3]**
Annual grasses group*	0.157	3.14
*Chenopodium murale**	0.024	0.48
Coprosma repens	0.006	0.12
*Ehrharta erecta**	0.080	1.60
*Malva spp. group**	0.046	0.92
Oxalis pes-caprae	0.001	0.02
*Plantago coronopus**	0.003	0.06
*Sonchus spp. group**	0.024	0.48
*Tetragonia tetragonioides**	1.240	24.80

[1]Total area infested (ha) combined from spring and summer 2016 surveys.
[2]Features merged and dissolved to eliminate overlapping data.
[3]Ratio of infested area (ha) to total area (ha) surveyed in North End.
*Values represent additional Features noted in the targeted summer survey.

Table 10b. North End: Infestation per Species from Spring Inventory

Hectares Infested - North End: Spring 2016		
Species Name	**Infested Area (ha)[1]**	**Infested Area (%)[2]**
Annual grasses group	0.157	3.14
Chenopodium murale	0.018	0.36
Coprosma repens	0.006	0.12
Ehrharta erecta	0.047	0.94
Malva spp. group	0.046	0.92
Oxalis pes-caprae	0.001	0.02
Plantago coronopus	0.001	0.02
Sonchus spp. group	0.022	0.44
Tetragonia tetragonioides	0.336	6.72

[1]Features merged and dissolved to eliminate overlapping data.
[2]Ratio of area infested (ha) to total area (ha) surveyed in North End during spring 2016 inventory.

Table 10c. North End: Additional Infestation noted in Summer for 7 targeted species

Hectares Infested - North End: Area Added by Summer Survey	
Species Name	**Summer Survey Additions (ha)**
Chenopodium murale	0.006
Ehrharta erecta	0.033
Plantago coronopus	0.002
Sonchus spp. group	0.002
Tetragonia tetragonioides	0.904
Total	**0.947**

Table 11a. South Slope: Infestation per Species from Spring and Summer Inventories

Hectares Infested – South Slope: Total Area[1]		
Species Name	**Infested Area (ha)[2]**	**Infested Area (%)[3]**
Annual grasses group[*]	0.956	28.68
Chenopodium murale[*]	0.009	0.27
Ehrharta erecta[*]	0.309	9.27
Malva spp. group[*]	0.076	2.28
Plantago coronopus[*]	0.015	0.45
Sonchus spp. group[*]	0.047	1.41
Tetragonia tetragonioides[*]	2.158	64.75

[1]Total area infested (ha) according to spring and summer 2016 surveys.
[2]Features merged and dissolved to eliminate overlapping data.
[3]Ratio of infested area (ha) to total area (ha) surveyed in South Slope.
[*]Values represent additional Features noted in the targeted summer survey.

Table 11b. South Slope: Infestation per Species from Spring Inventory

Hectares Infested – South Slope: Spring 2016		
Species Name	**Infested Area (ha)[1]**	**Infested Area (%)[2]**
Annual grasses group	0.952	28.56
Chenopodium murale	0.005	0.15
Ehrharta erecta	0.142	4.26
Malva spp. group	0.076	2.28
Plantago coronopus	0.001	0.03
Sonchus spp. group	0.044	1.32
Tetragonia tetragonioides	1.858	55.75

[1]Features merged and dissolved to eliminate overlapping data.
[2] Ratio of infested area (ha) to total area (ha) surveyed in South Slope during spring 2016 inventory.

Table 11c. South Slope: Additional Infestation noted in Summer for 7 targeted species

Hectares Infested – South Slope: Area Added by Summer Survey	
Species Name	**Summer Survey Additions (ha)**
Annual grasses group	0.004
Chenopodium murale	0.004
Ehrharta erecta	0.167
Plantago coronopus	0.014
Sonchus spp. group	0.003
Tetragonia tetragonioides	0.300
Total	**0.492**

Table 12a. Marine Terrace: Infestation per Species from Spring and Summer Inventories

Hectares Infested - Marine Terrace: Total Area[1]		
Species Name	**Infested Area (ha)[2]**	**Infested Area (%)[3]**
Annual grasses group[*]	2.973	37.87
Chenopodium murale[*]	0.533	6.79
Malva arborea	0.145	1.85
Malva spp. group[*]	0.889	11.32
Oxalis pes-caprae	0.002	0.03
Plantago coronopus[*]	2.334	29.73
Rumex spp. group	0.090	1.15
Senecio vulgaris	0.010	0.13
Sisymbrium orientale	0.002	0.03
Sonchus spp. group[*]	0.366	4.66
Tetragonia tetragonioides[*]	0.944	12.02

[1]Total area infested (ha) according to spring and summer 2016 surveys.
[2]Features merged and dissolved to eliminate overlapping data.
[3]Ratio of infested area (ha) to total area (ha) surveyed in Marine Terrace.
[*]Values represent additional Features noted in the targeted summer survey.

Table 12b. Marine Terrace: Infestation per Species from Spring Inventory

Hectares Infested - Marine Terrace: Spring 2016		
Species Name	**Infested Area (ha)[1]**	**Infested Area (%)[2]**
Annual grasses group	2.407	30.66
Chenopodium murale	0.059	0.75
Malva arborea	0.145	1.85
Malva spp. group	0.819	10.43
Oxalis pes-caprae	0.002	0.03
Plantago coronopus	1.649	21.00
Rumex spp. group	0.090	1.15
Senecio vulgaris	0.010	0.13
Sisymbrium orientale	0.002	0.03
Sonchus spp. group	0.222	2.83
Tetragonia tetragonioides	0.566	7.21

[1]Features merged and dissolved to eliminate overlapping data.
[2] Ratio of infested area (ha) to total area (ha) surveyed in Marine Terrace during spring 2016 inventory.

Table 12c. Marine Terrace: Additional Infestation noted in Summer for 7 targeted species

Hectares Infested - Marine Terrace: Area Added by Summer Survey	
Species Name	**Summer Survey Additions (ha)**
Annual grasses group	0.566
Chenopodium murale	0.474
Malva spp. group	0.070
Plantago coronopus	0.685
Sonchus spp. group	0.144
Tetragonia tetragonioides	0.378
Total	**2.317**

Table 13a. Corm Blind Hill: Infestation per Species from Spring and Summer Inventories

Hectares Infested - Corm Blind Hill: Total Area[1]		
Species Name	**Infested Area (ha)[2]**	**Infested Area (%)[3]**
Chenopodium murale	0.003	0.18
Ehrharta erecta	0.009	0.55
Sonchus spp. group	0.004	0.24
Tetragonia tetragonioides	0.103	6.31

[1]Total area infested (ha) according to spring and summer 2016 surveys.
[2]Features merged and dissolved to eliminate overlapping data.
[3]Ratio of infested area (ha) to total area (ha) surveyed in Corm Blind Hill.
[*]Values represent additional Features noted in the targeted summer survey.

Table 13b. Corm Blind Hill: Infestation per Species from Spring Inventory

Hectares Infested - Corm Blind Hill: Spring 2016		
Species Name	**Infested Area (ha)[1]**	**Infested Area (%)[2]**
Chenopodium murale	0.003	0.18
Ehrharta erecta	0.009	0.55
Sonchus spp. group	0.004	0.24
Tetragonia tetragonioides	0.060	3.67

[1]Features merged and dissolved to eliminate overlapping data.
[2]Ratio of infested area (ha) to total area (ha) surveyed in Corm Blind Hill during spring 2016 inventory.

Table 13c. Corm Blind Hill: Additional Infestation noted in Summer for 7 targeted species

Hectares Infested – Corm Blind Hill: Area Added by Summer Survey	
Species Name	**Summer Survey Additions (ha)**
Tetragonia tetragonioides	0.043
Total	**0.043**

Table 14a. Perimeter: Infestation per Species from Spring and Summer Inventories

Hectares Infested - Perimeter: Total Area[1]		
Species Name	**Infested Area (ha)[2]**	**Infested Area (%)[3]**
Annual grasses group	0.007	0.06
Chenopodium murale	0.078	0.70
Malva spp. group	0.020	0.18
Plantago coronopus	0.003	0.03
Sonchus spp. group	0.013	0.12
Tetragonia tetragonioides	0.171	1.54

[1]Total area infested (ha) according to spring and summer 2016 surveys.
[2]Features merged and dissolved to eliminate overlapping data.
[3]Ratio of infested area (ha) to total area (ha) surveyed in Perimeter.
[*]Values represent additional Features noted in the targeted summer survey.

Table 14b. Perimeter: Infestation per Species from Spring Inventory

Hectares Infested - Perimeter: Spring 2016		
Species Name	**Infested Area (ha)[1]**	**Infested Area (%)[2]**
Annual grasses group	0.007	0.06
Chenopodium murale	0.072	0.66
Malva spp. group	0.020	0.18
Plantago coronopus	0.003	0.03
Sonchus spp. group	0.013	0.12
Tetragonia tetragonioides	0.059	0.54

[1]Features merged and dissolved to eliminate overlapping data.
[2]Ratio of infested area (ha) to total area (ha) surveyed in Perimeter during spring 2016 inventory.

Table 14c. Perimeter: Additional Infestation noted in Summer for 7 targeted species

Hectares Infested - Perimeter: Area Added by Summer Survey	
Species Name	**Summer Survey Additions (ha)**
Chenopodium murale	0.006
Tetragonia tetragonioides	0.112
Total	**0.118**

Table 15a. West End Island: Infestation per Species from Spring and Summer Inventories

Hectares Infested - West End Island: Total Area[1]		
Species Name	**Infested Area (ha)[2]**	**Infested Area (%)[3]**
Annual grasses group*	0.001	0.01
*Chenopodium murale**	0.308	3.16
*Malva spp. group**	0.050	0.51
Rumex spp. group	0.001	0.01
*Sonchus spp. group**	0.162	1.66
*Tetragonia tetragonioides**	0.261	2.67

[1]Total area infested (ha) according to spring and summer 2016 surveys.
[2]Features merged and dissolved to eliminate overlapping data.
[3]Ratio of infested area (ha) to total area (ha) surveyed on West End Island.
*Values represent additional Features noted in the targeted summer survey.

Table 15b. West End Island: Infestation per Species from Spring Inventory

Hectares Infested - West End Island: Spring 2016		
Species Name	**Infested Area (ha)[1]**	**Infested Area (%)[2]**
Annual grasses group	0.001	0.01
Chenopodium murale	0.308	4.05
Malva spp. group	0.050	0.66
Rumex spp. group	0.001	0.01
Sonchus spp. group	0.162	2.13
Tetragonia tetragonioides	0.197	2.59

[1]Features merged and dissolved to eliminate overlapping data.
[2]Ratio of infested area (ha) to total area (ha) surveyed on West End Island during spring 2016 inventory.

Table 15c. West End Island: Additional Infestation noted in Summer for 7 targeted species

Hectares Infested - West End Island: Area Added by Summer Survey	
Species Name	**Summer Survey Additions (ha)**
Tetragonia tetragonioides	0.064
Total	**0.064**

FIGURES

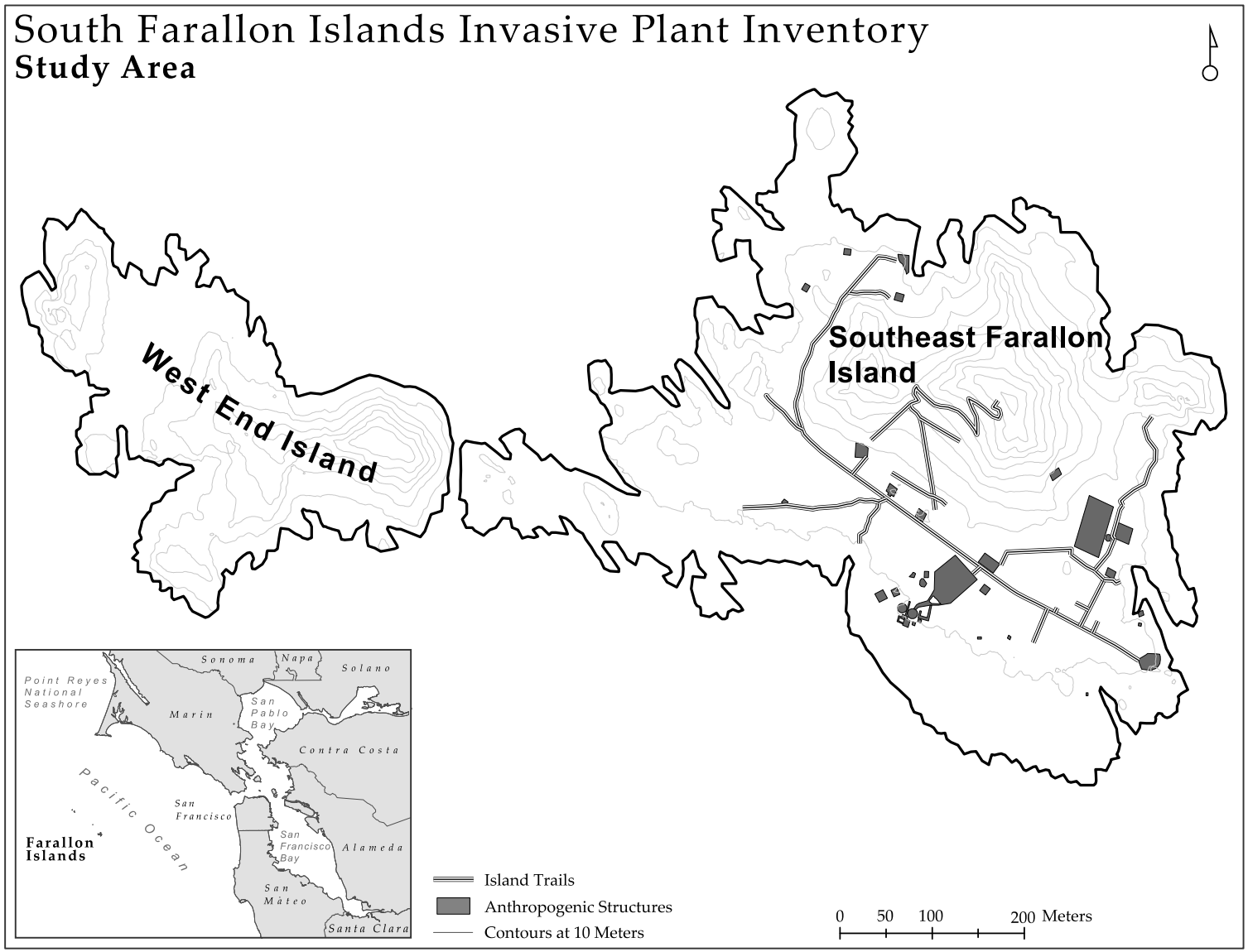

Figure 1 : Map of South Farallon Islands.

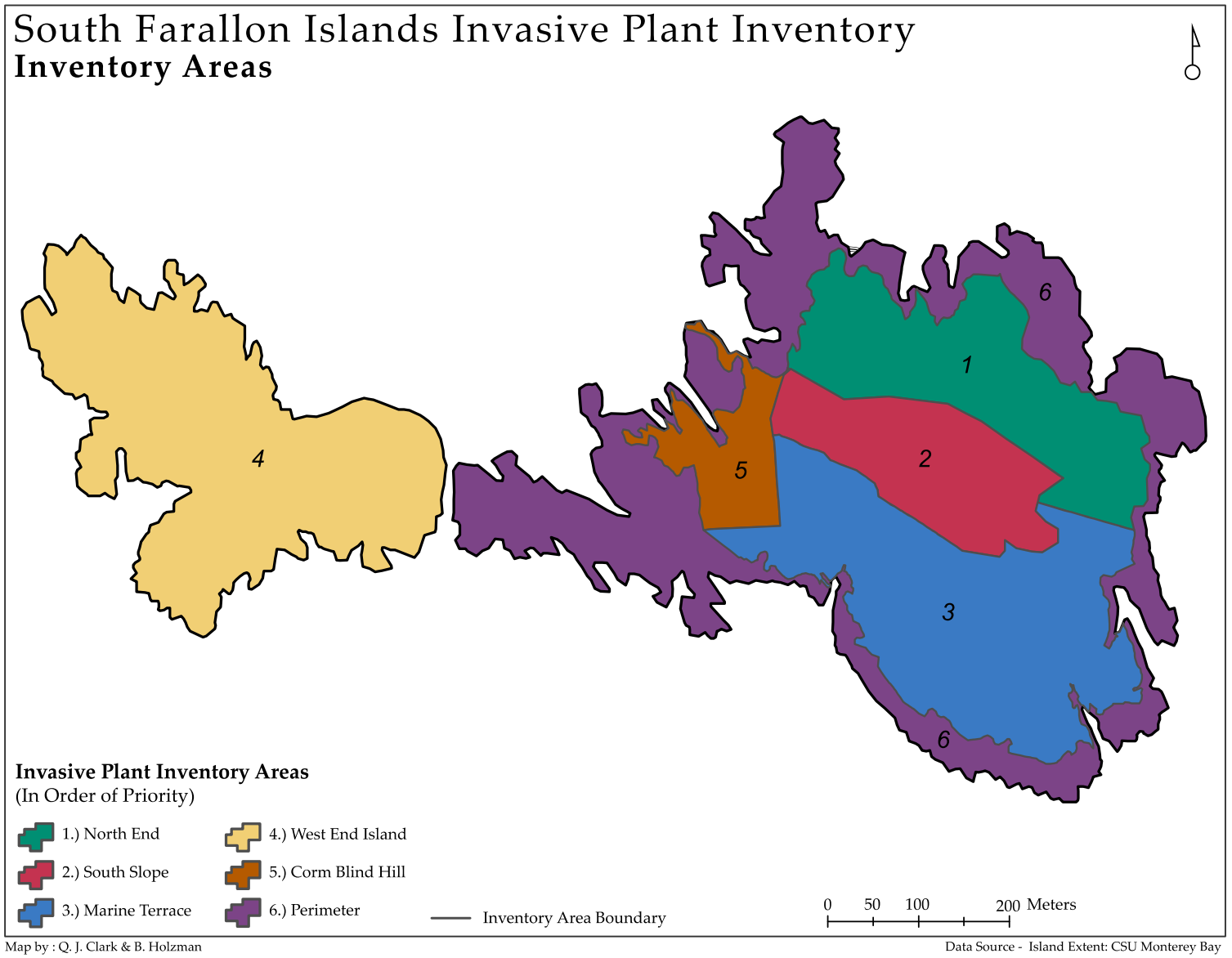

Figure 2 : Map of inventory areas used during survey with priority noted.

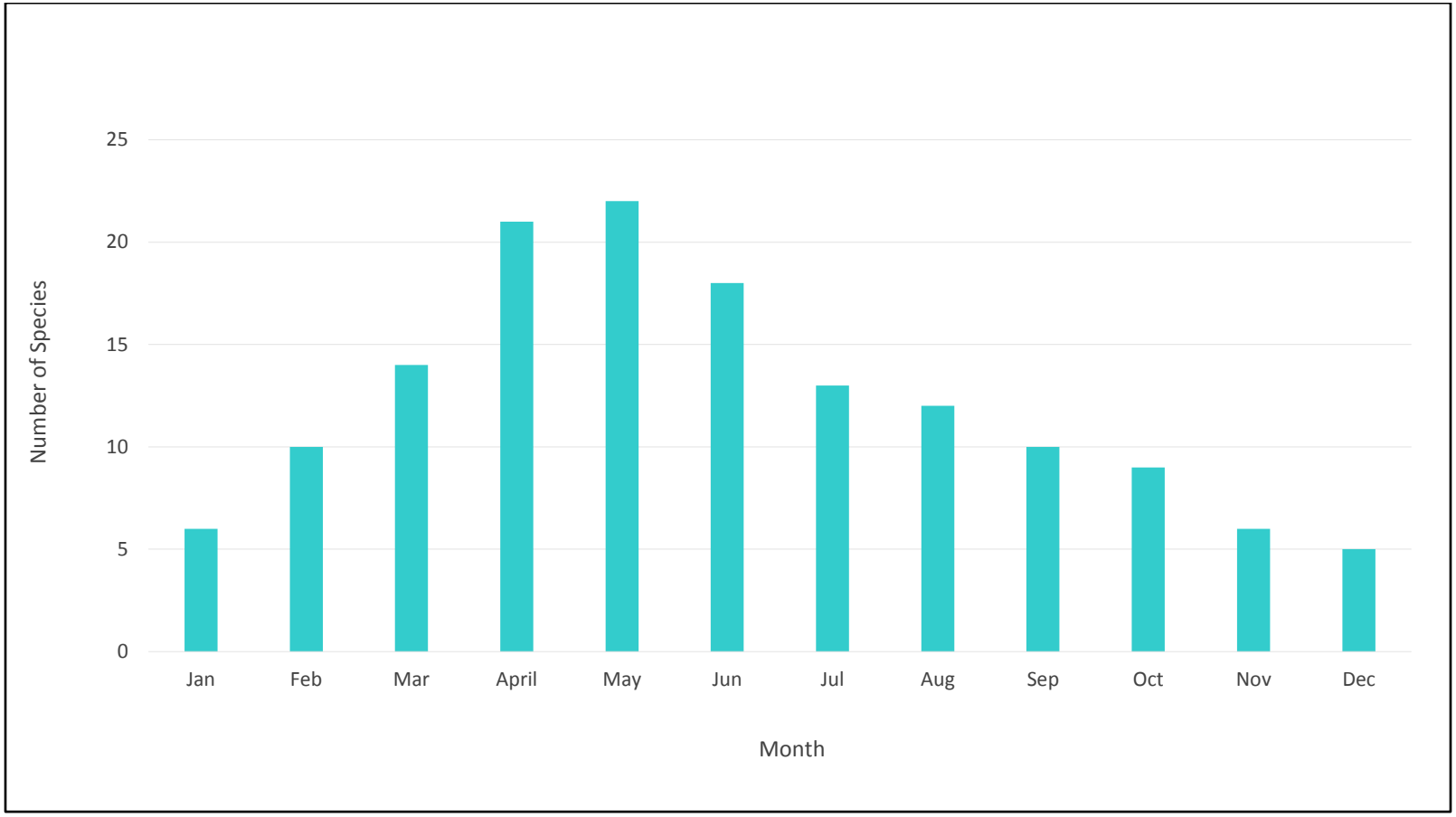

Figure 3. Number of Farallon National Wildlife Refuge invasive plant inventory species likely to be in bloom by month. Based on data from Calflora (www.calflora.org; Block 2016).

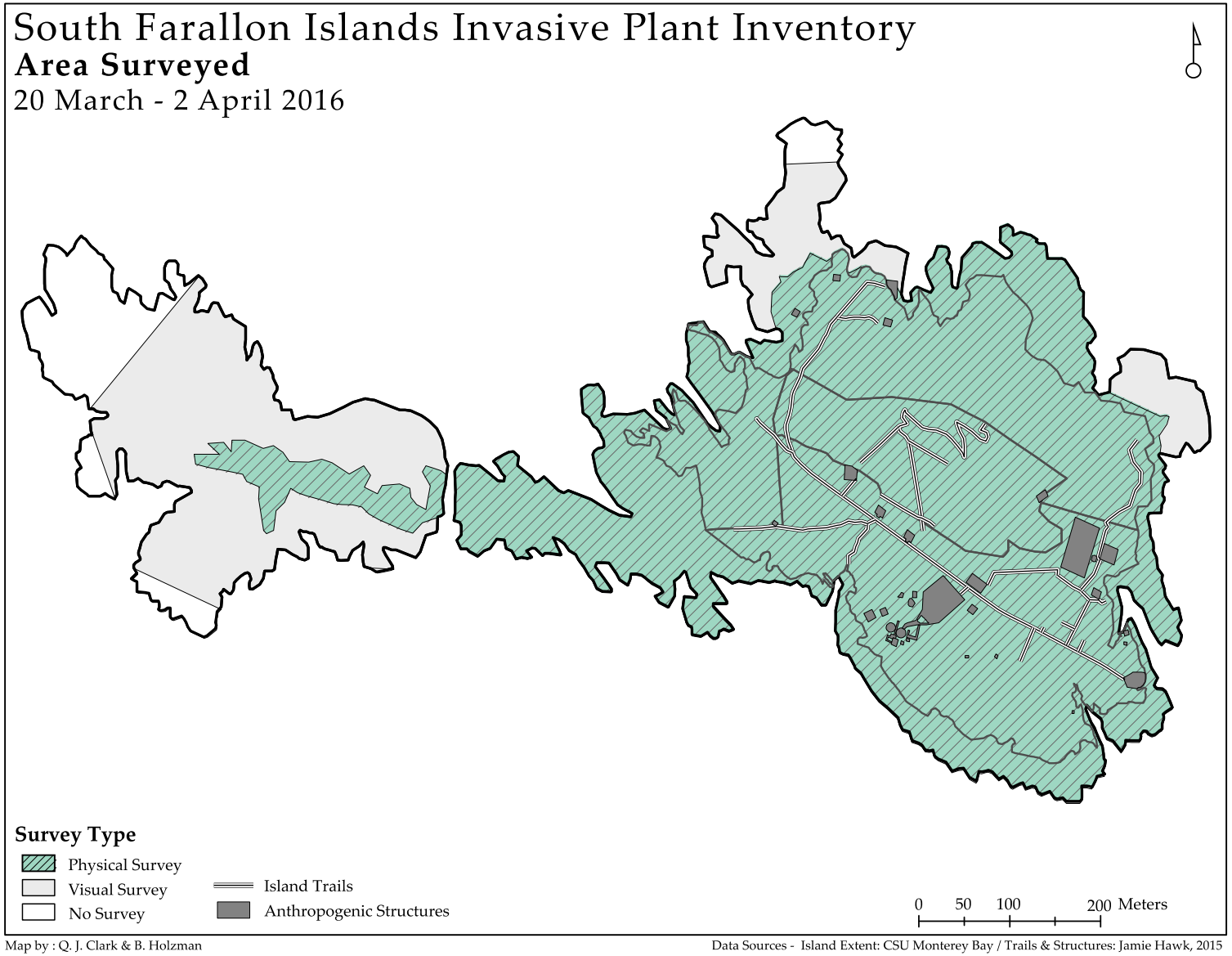

Figure 4a: Map of areas physically and visually inspected during spring 2016 survey.

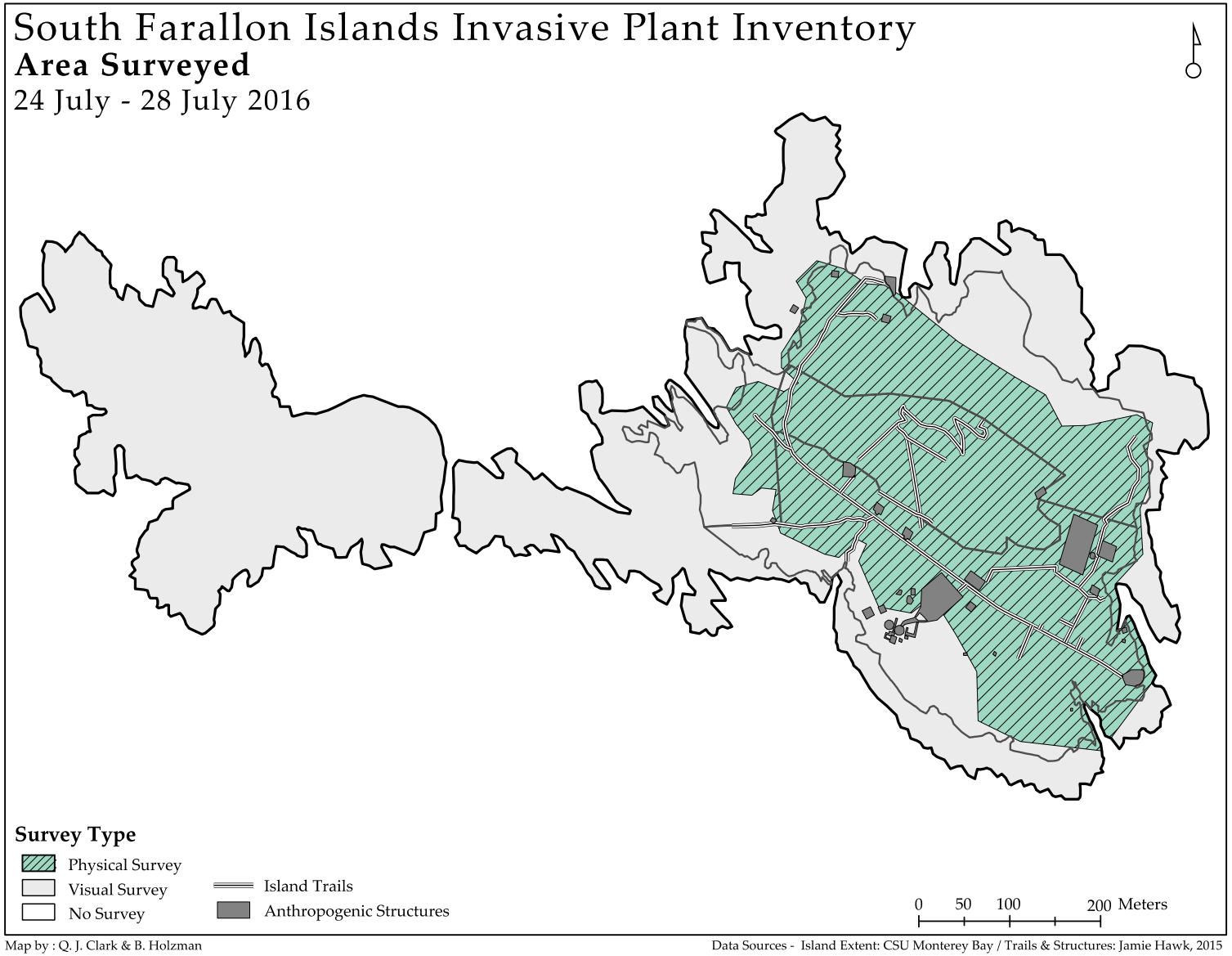

Figure 4b: Map of areas physically and visually inspected during summer 2016 survey.

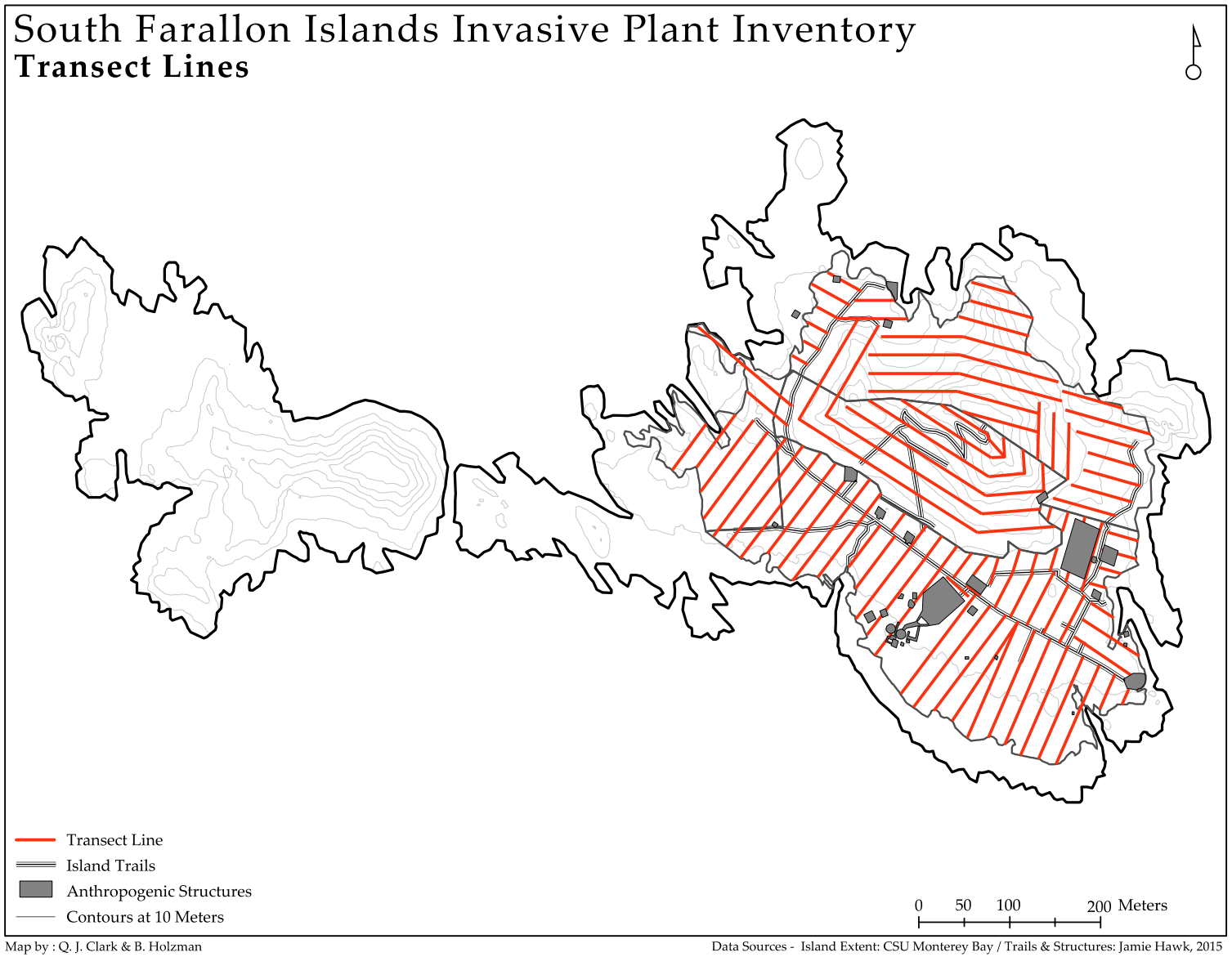

Figure 5: Map of preloaded transect lines used for inventory.

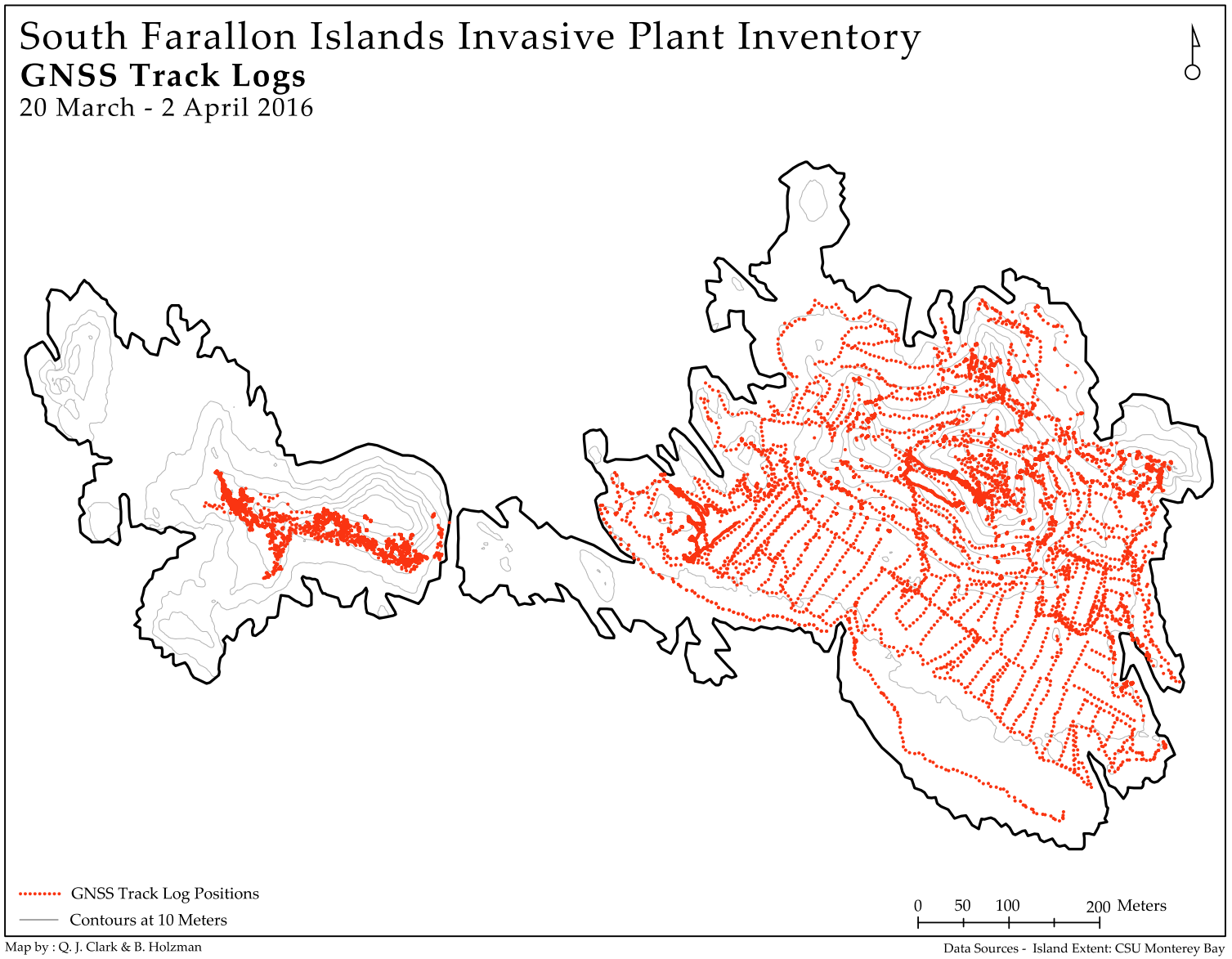

Figure 6a: Map of GNSS track logs from spring 2016 survey.

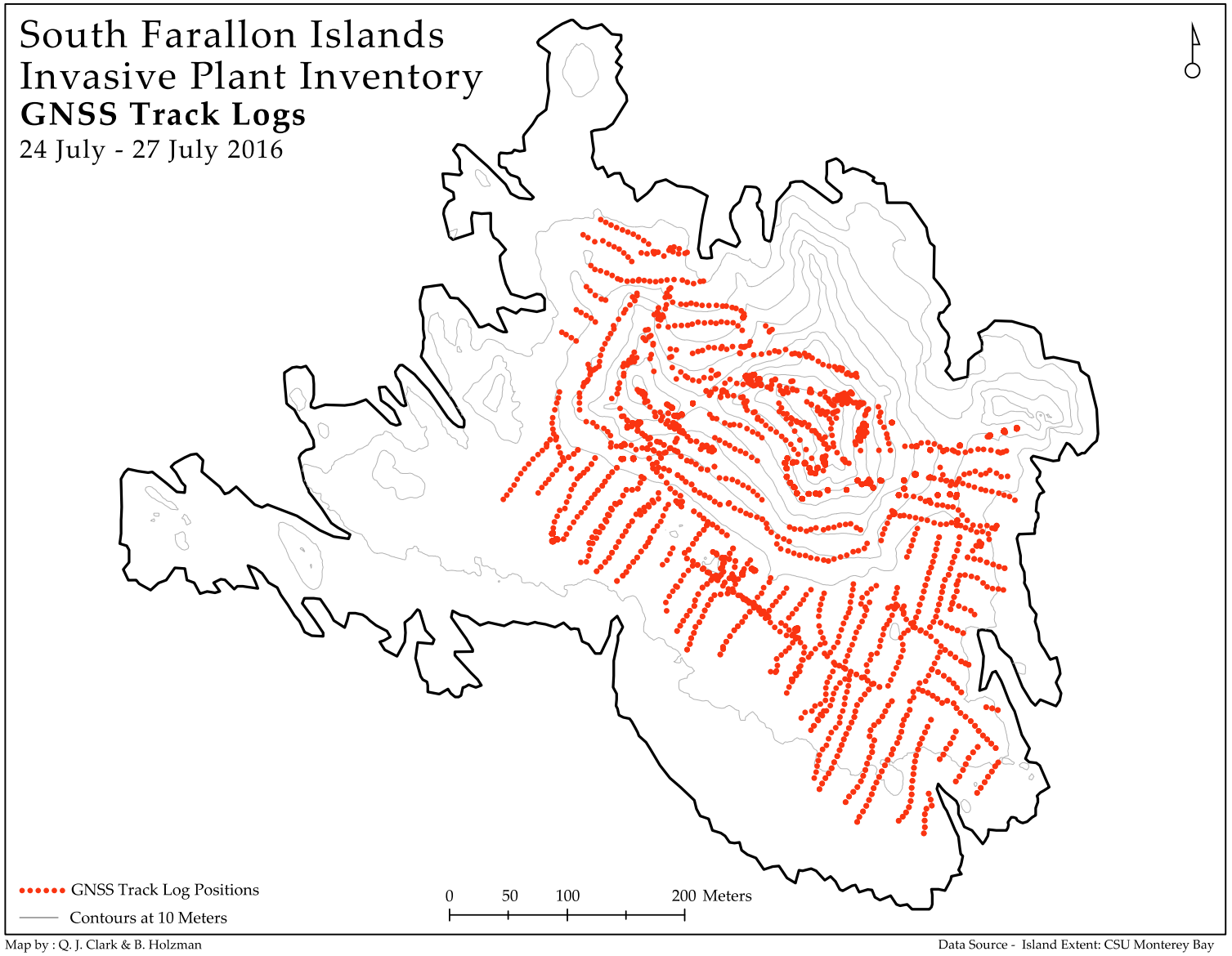

Figure 6b: Map of GNSS track logs from summer 2016 survey.

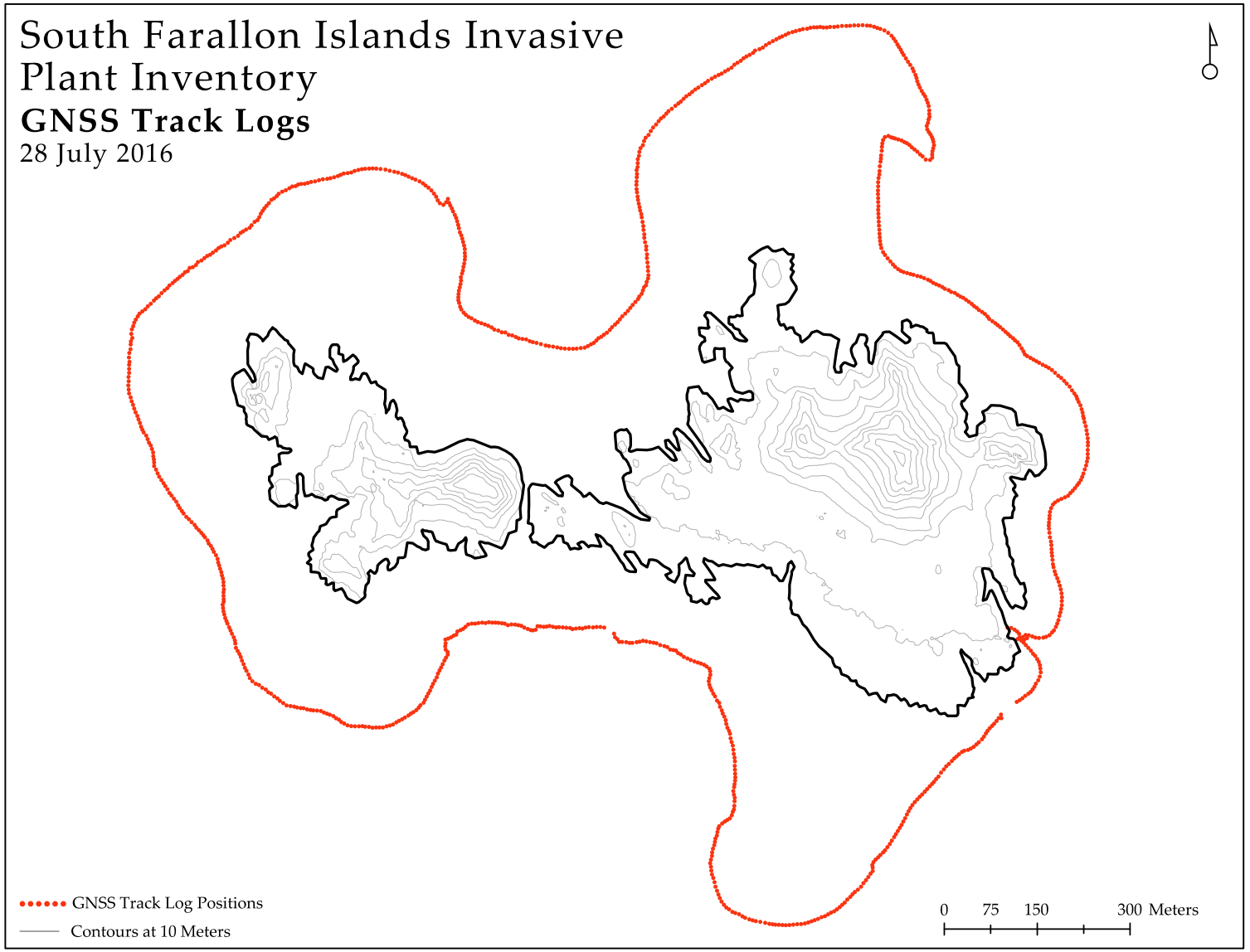

Figure 6c: Map of GNSS track logs from circumnavigation by boat for visual survey of unreachable areas on 28 July 2016.

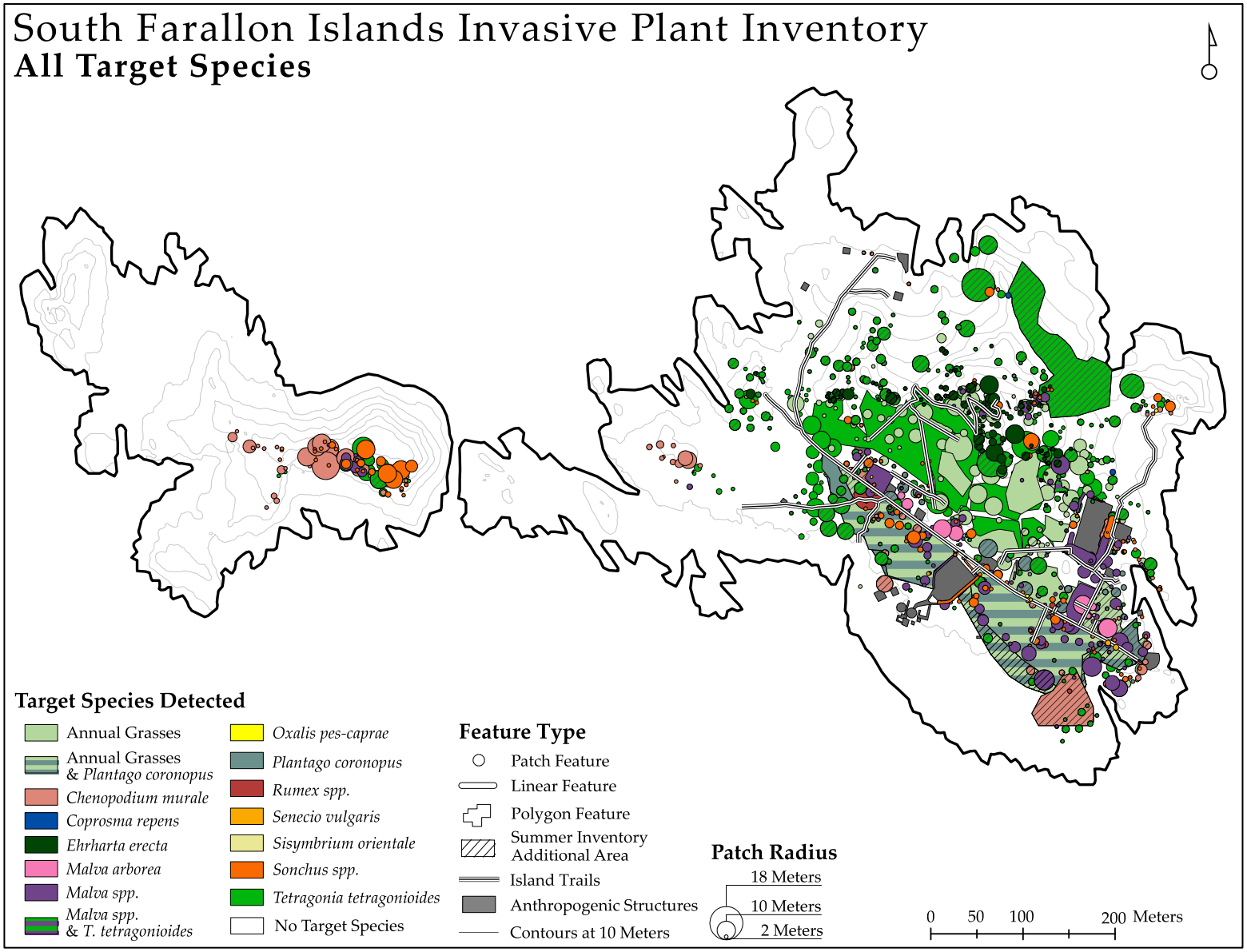

Figure 7: Map of all target species surveyed spring and summer surveys combined.

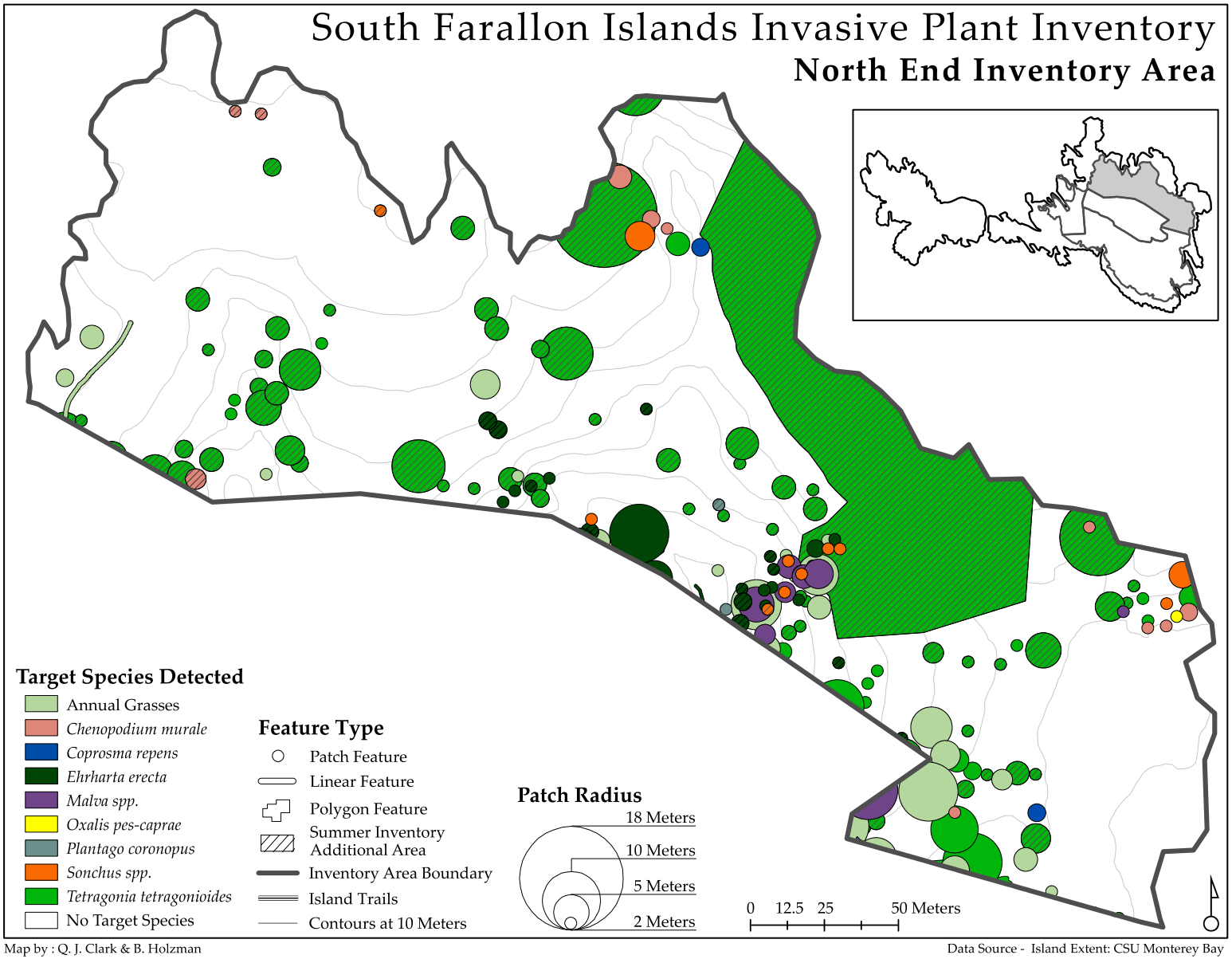

Figure 8: Map of North End inventory area and all species detected.

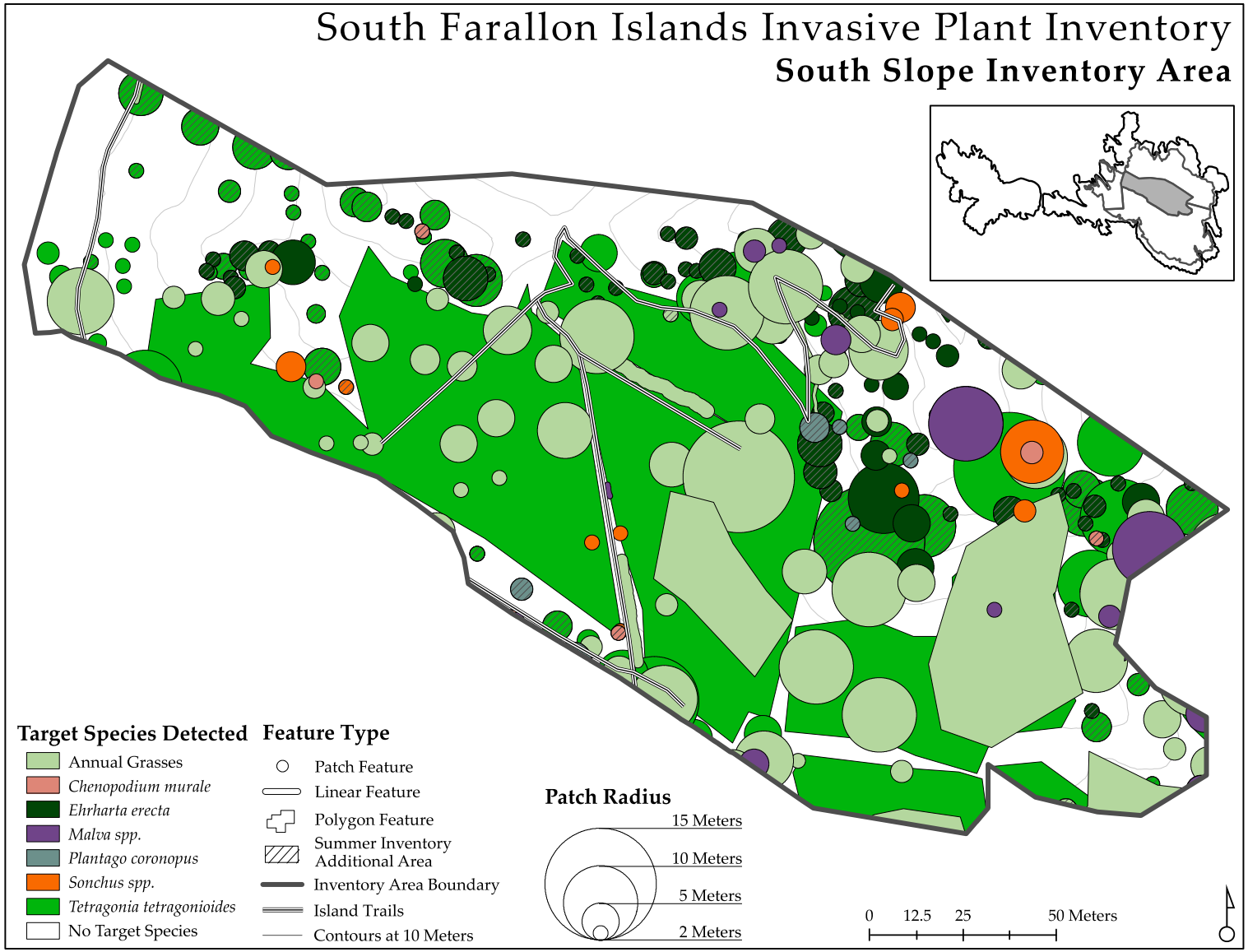

Figure 9: Map of South Slope inventory area and all species detected.

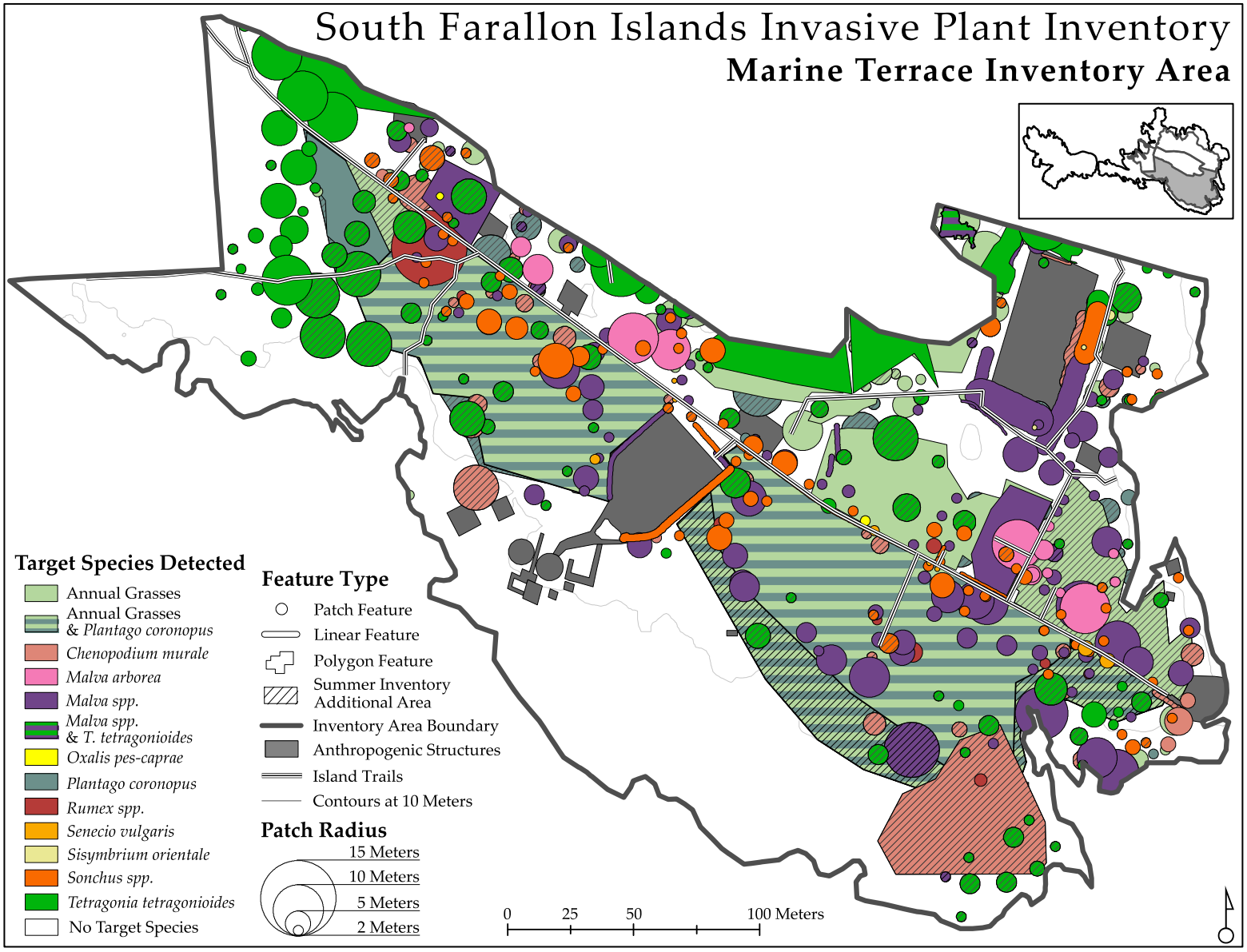

Figure 10: Map of Marine Terrace inventory area and all species detected.

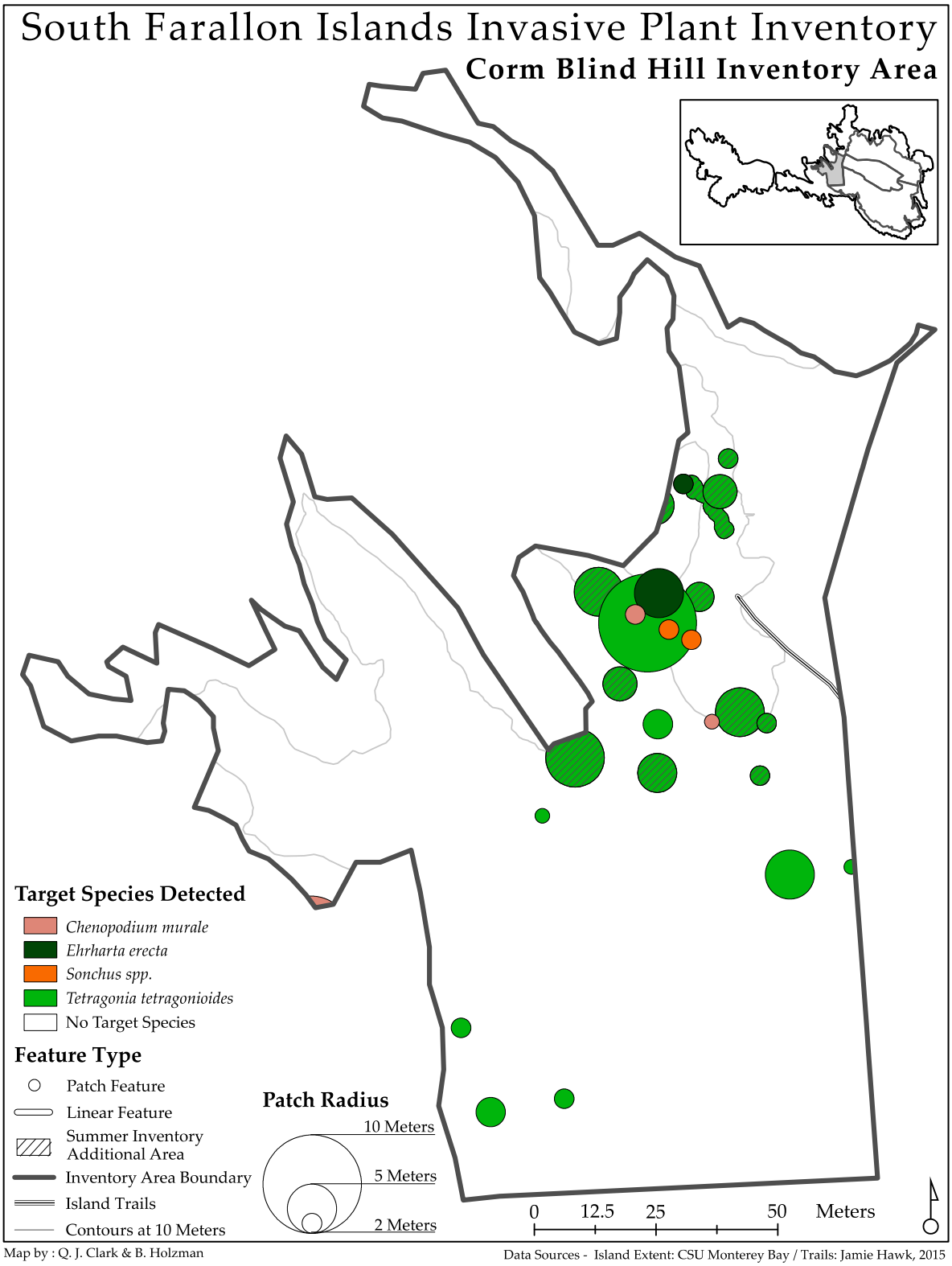

Figure 11: Map of Corm Blind Hill inventory area and all species detected.

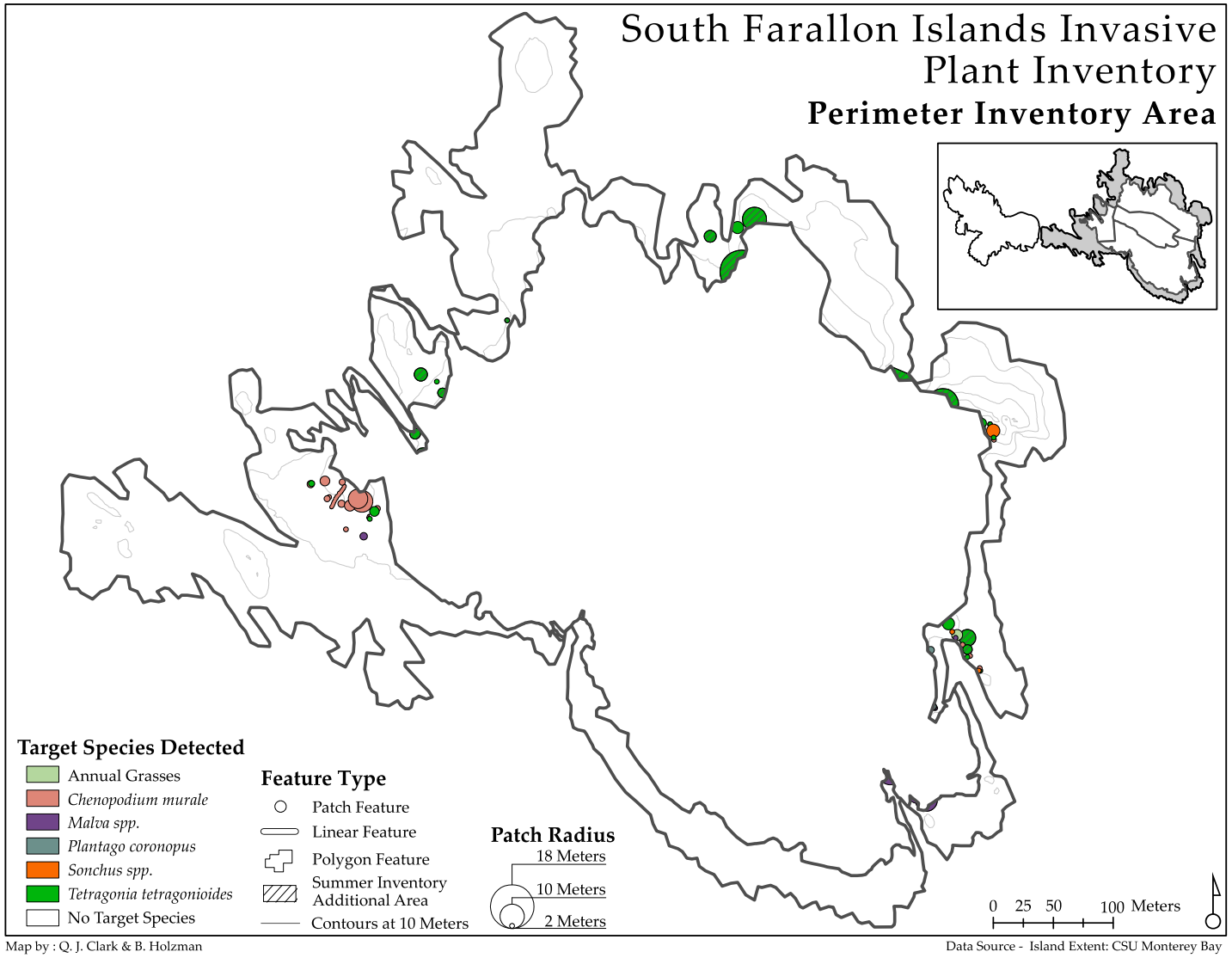

Figure 12: Map of Perimeter inventory area and all species detected.

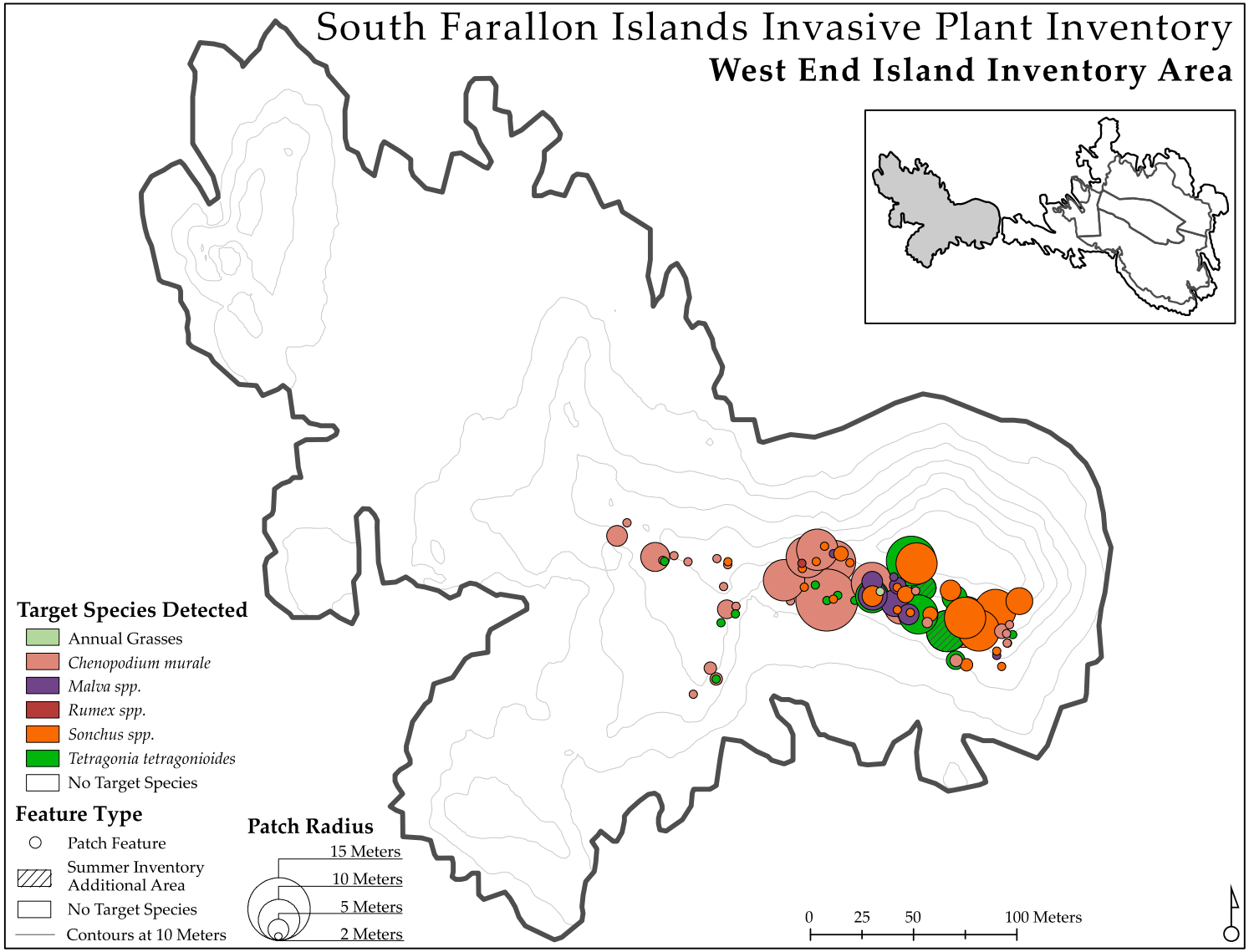

Figure 13: Map of West End Island inventory area and all species detected.

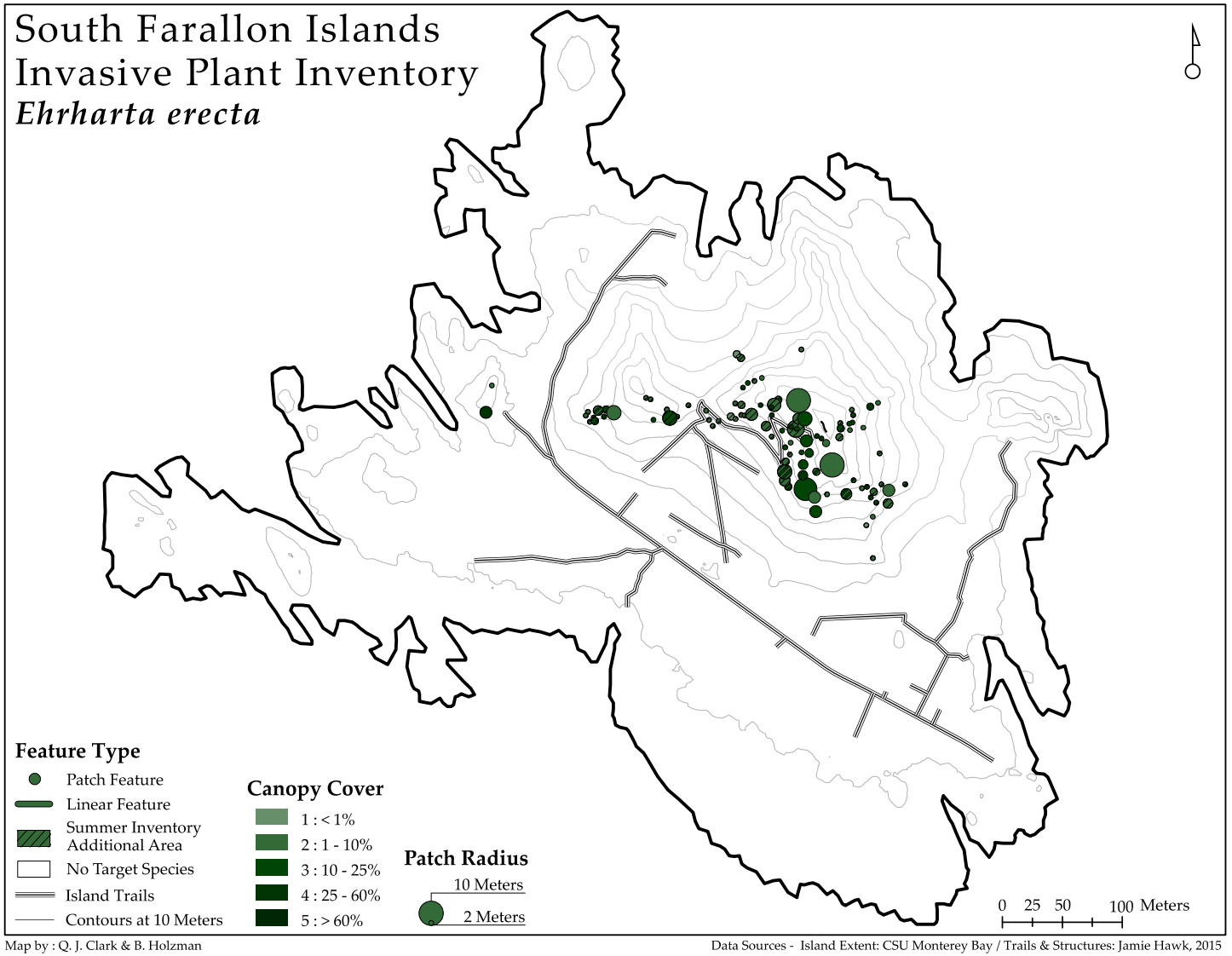

Figure 14: Map of Ehrharta erecta detected on South Farallon Islands. No Ehrharta was detected on West End Island (not shown).

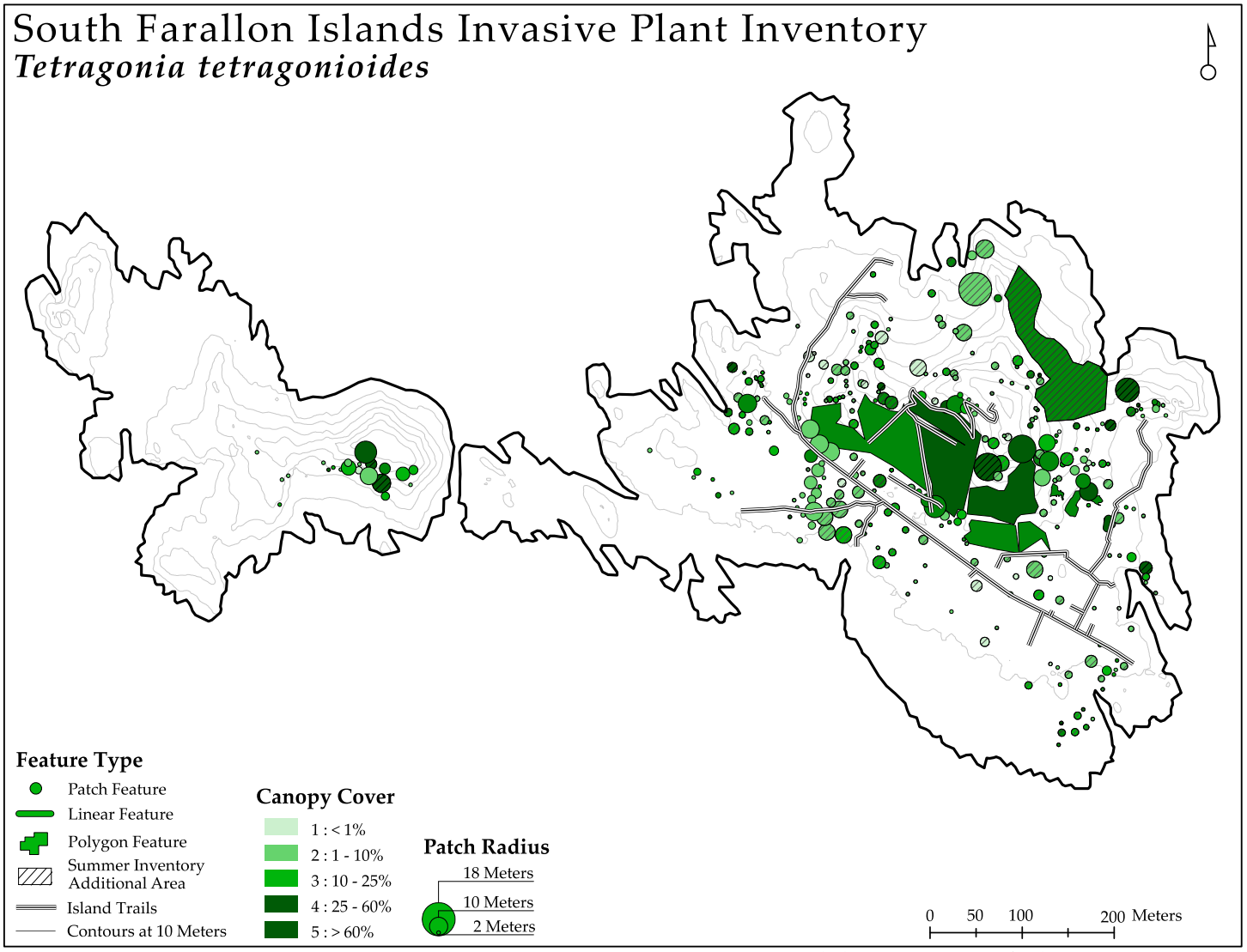

Figure 15: Map of Tetragonia tetragonioides detected on South Farallon Islands.

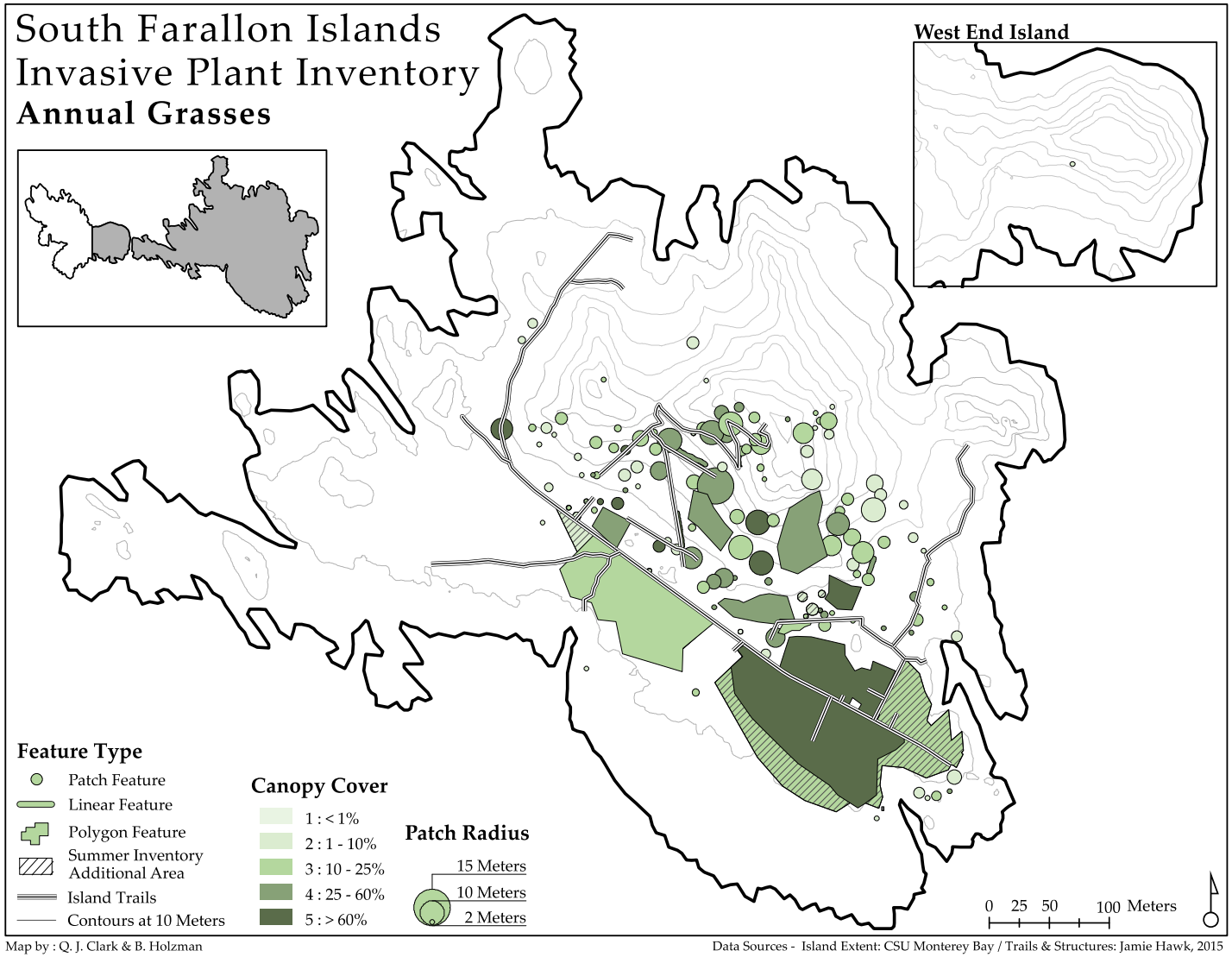

Figure 16: Map of annual grasses detected on South Farallon Islands. Annual grasses detected on West End are shown in the inset.

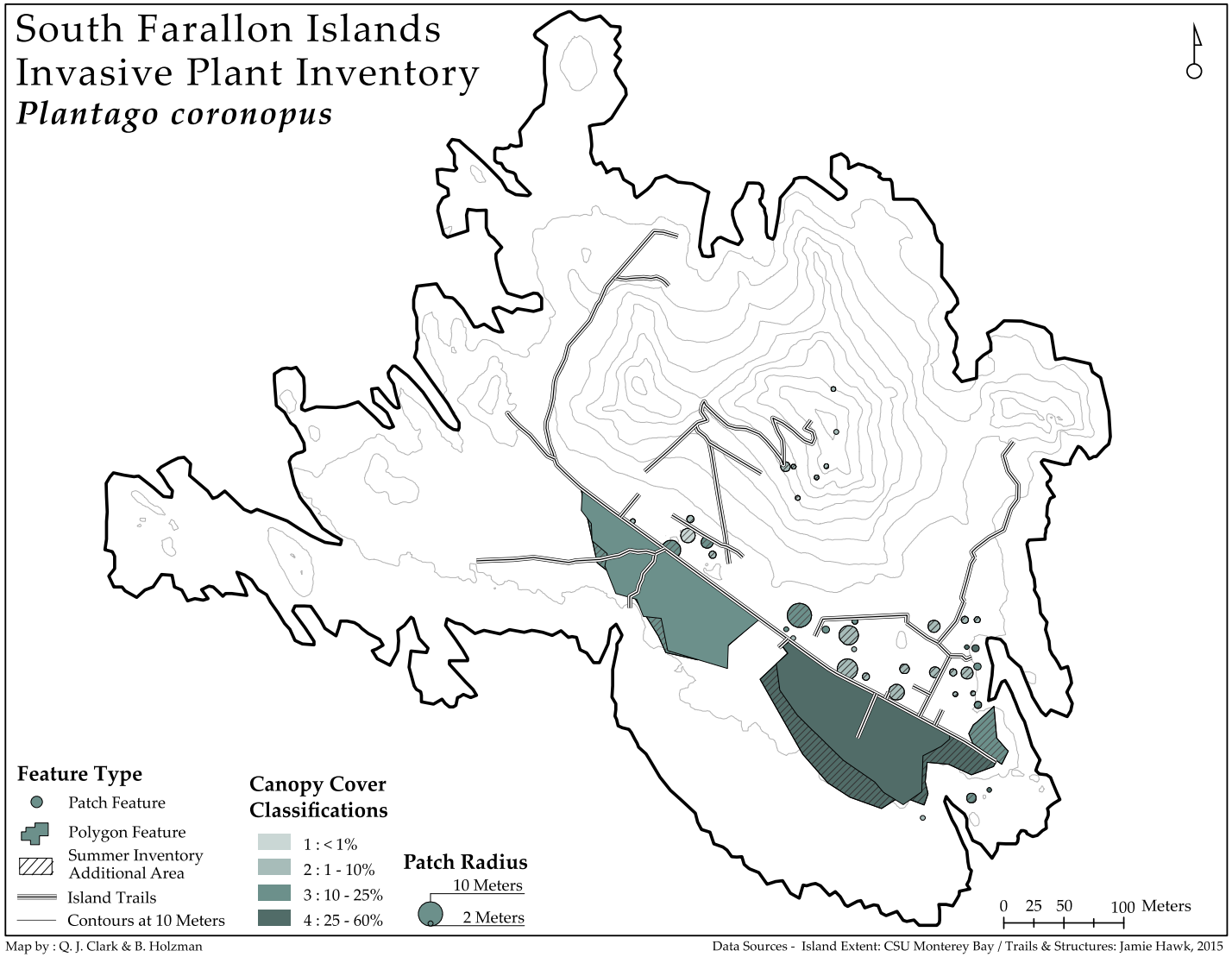

Figure 17: Map of Plantago coronopus detected on South Farallon Islands. No Plantago was detected on West End Island (not shown).

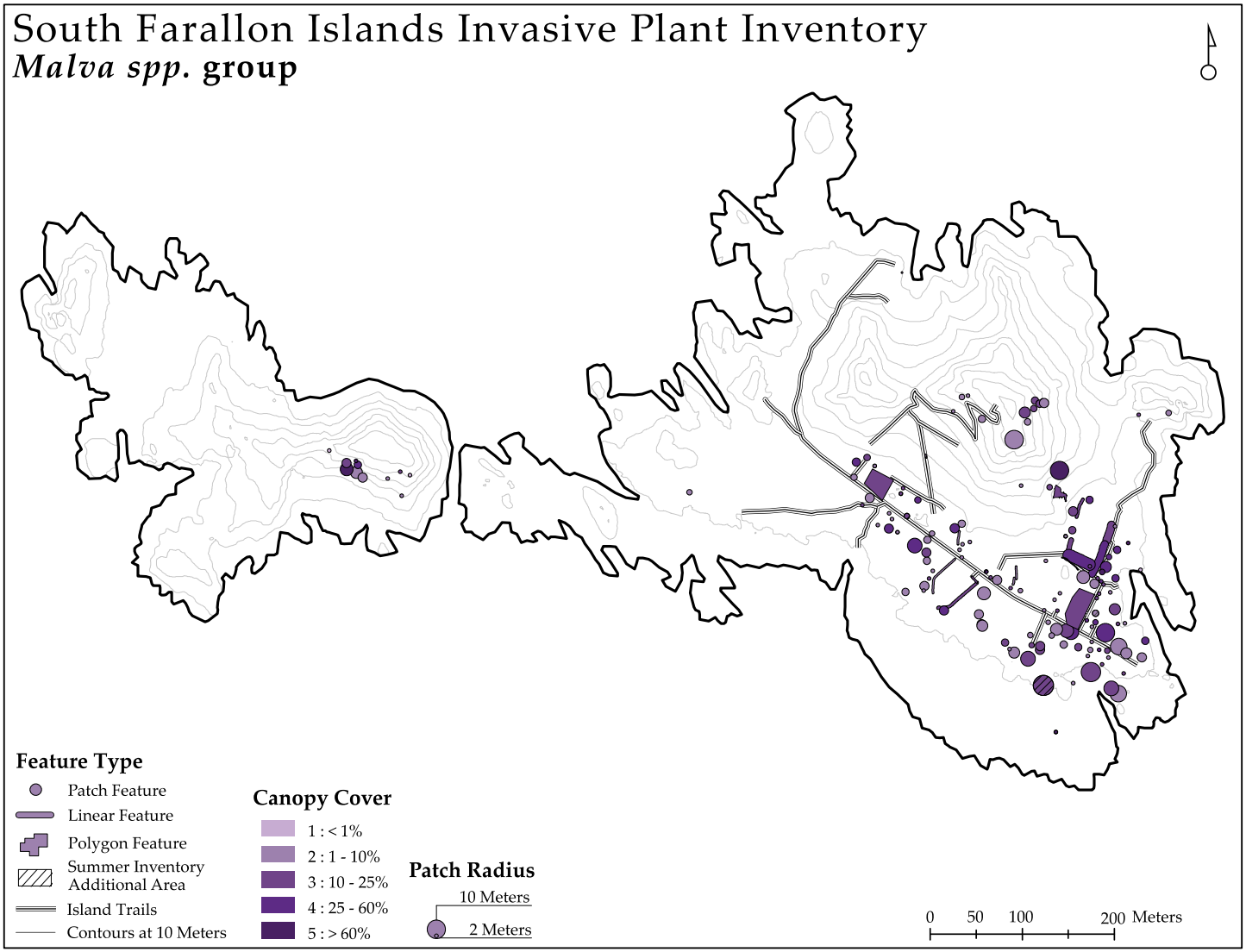

Figure 18: Map of Malva spp. group detected on South Farallon Islands.

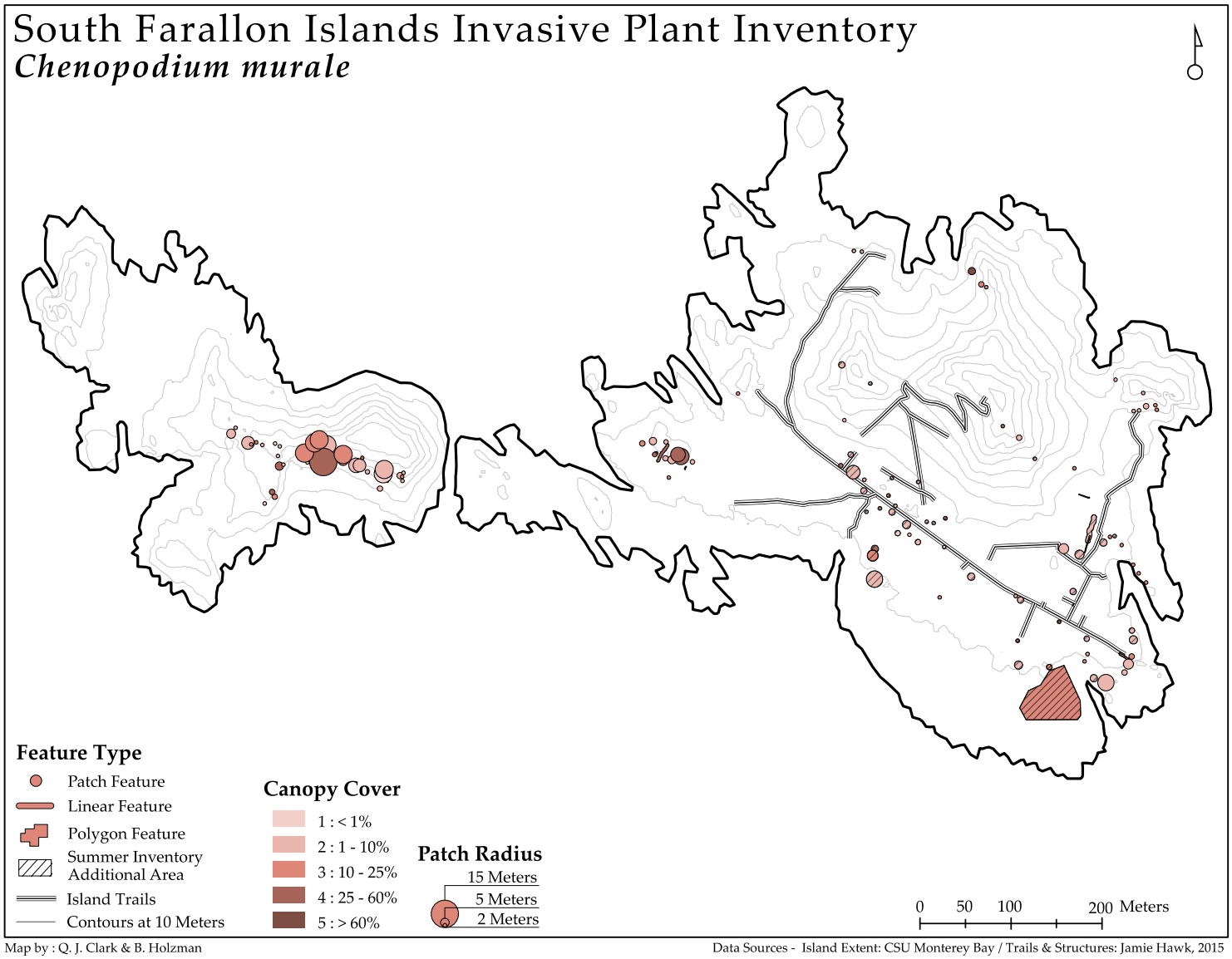

Figure 19: Map of Chenopodium murale detected on South Farallon Islands.

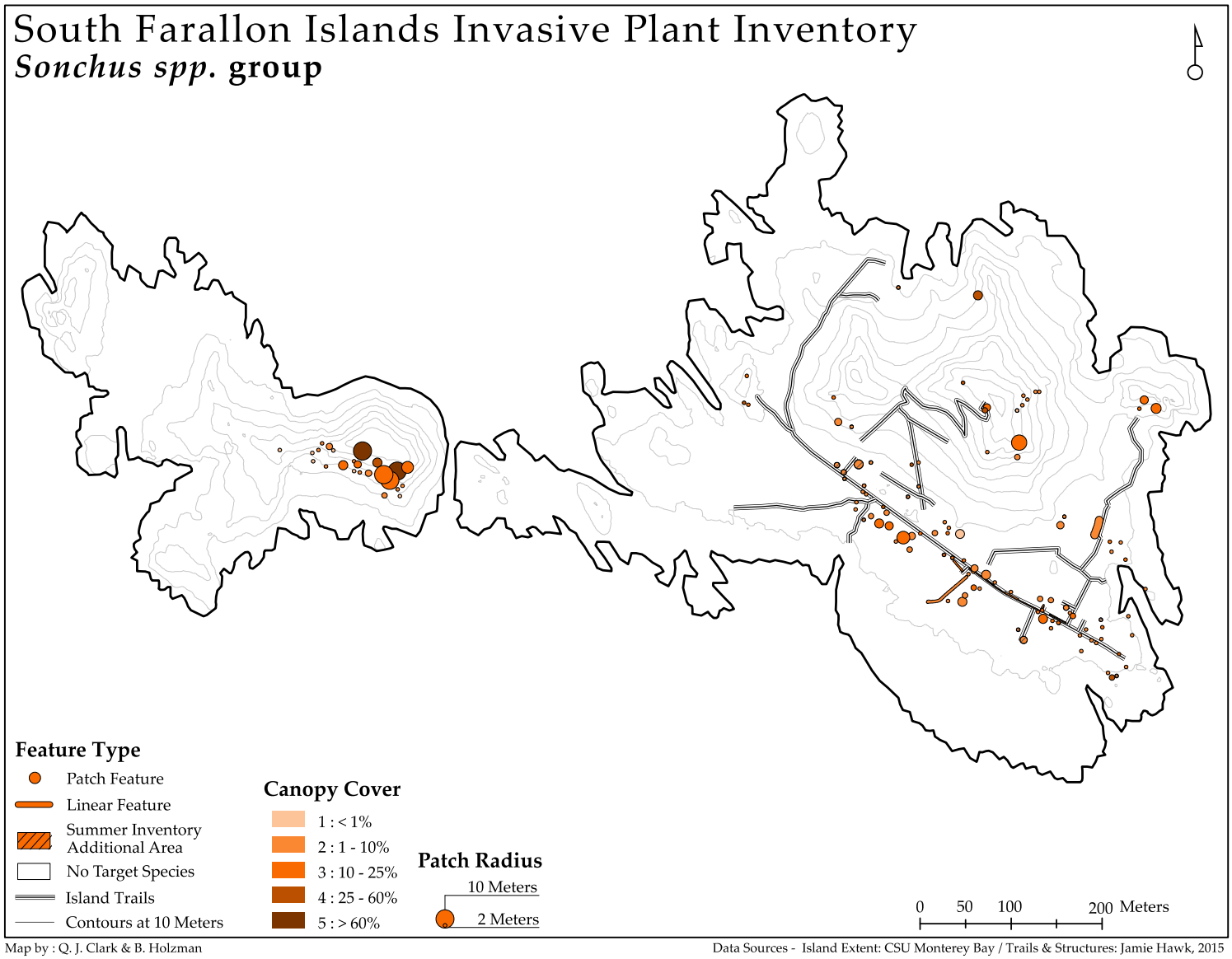

Figure 20: Map of Sonchus spp. group detected on South Farallon Islands.

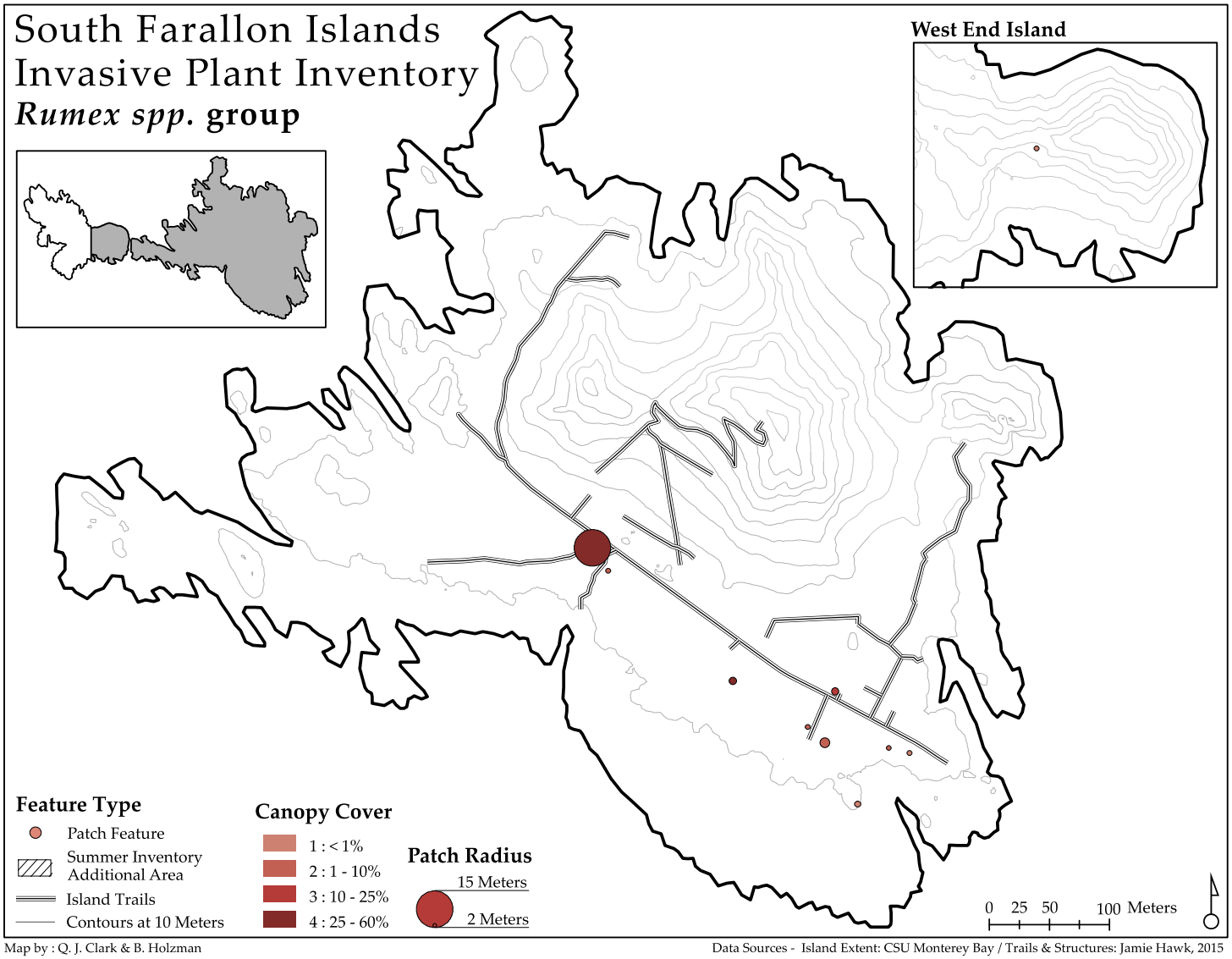

Figure 21: Map of Rumex spp. group detected on South Farallon Islands. Rumex spp. detected on West End are shown in the inset.

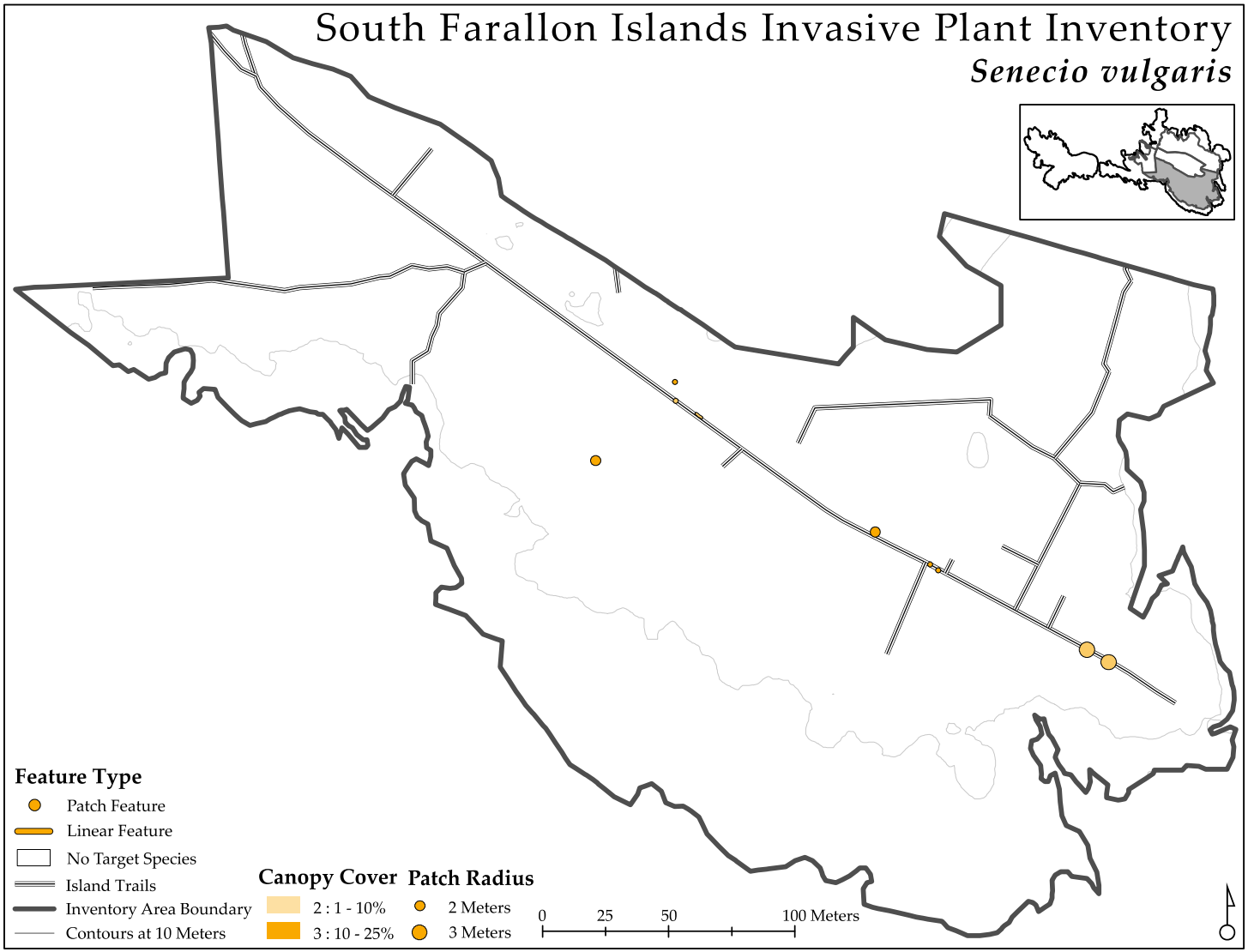

Figure 22: Map of Senecio vulgaris detected on South Farallon Islands. This species was only detected on the Marine Terrace.

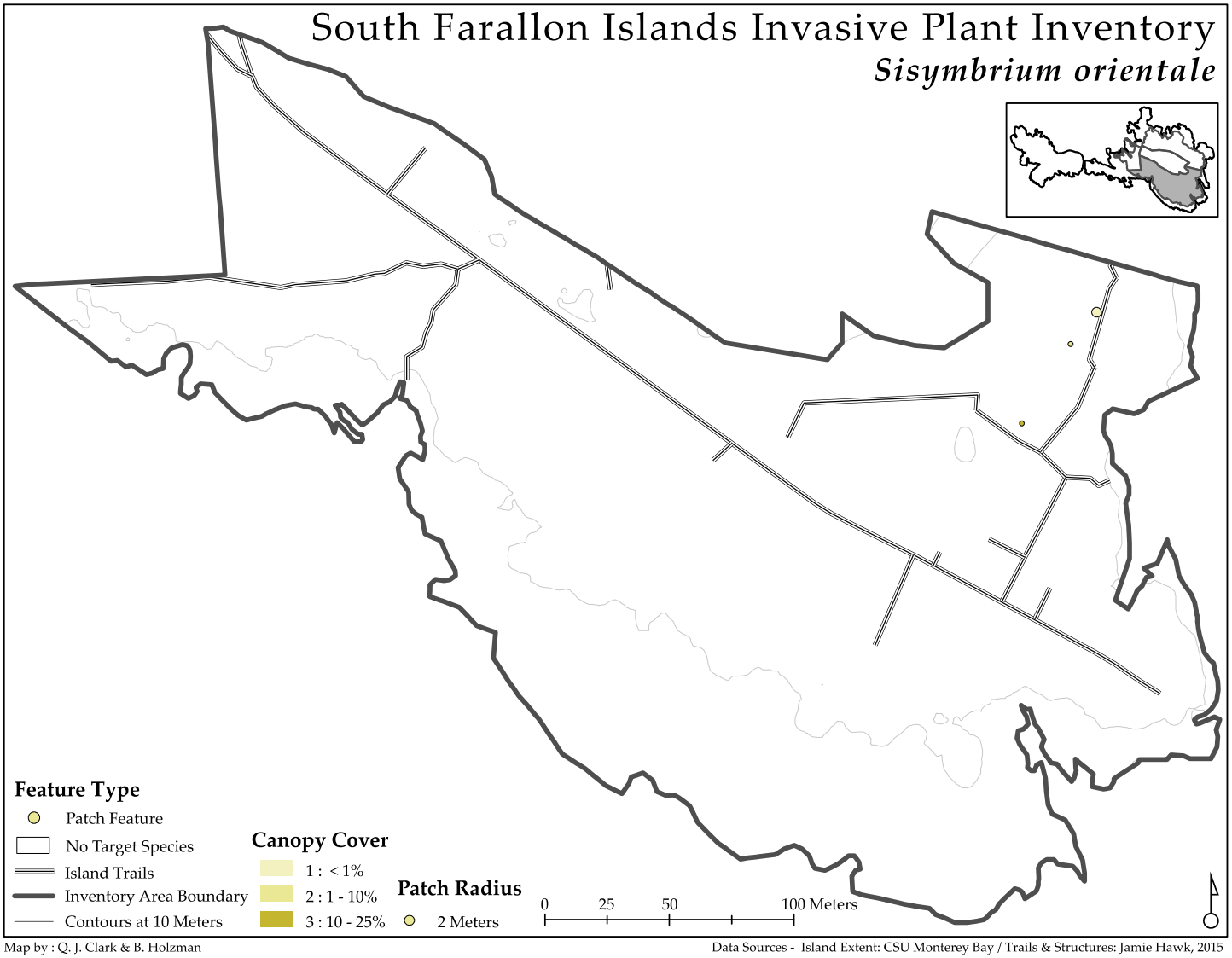

Figure 23: Map of Sisymbrium orientale detected on South Farallon Islands. This species was only detected on the Marine Terrace.

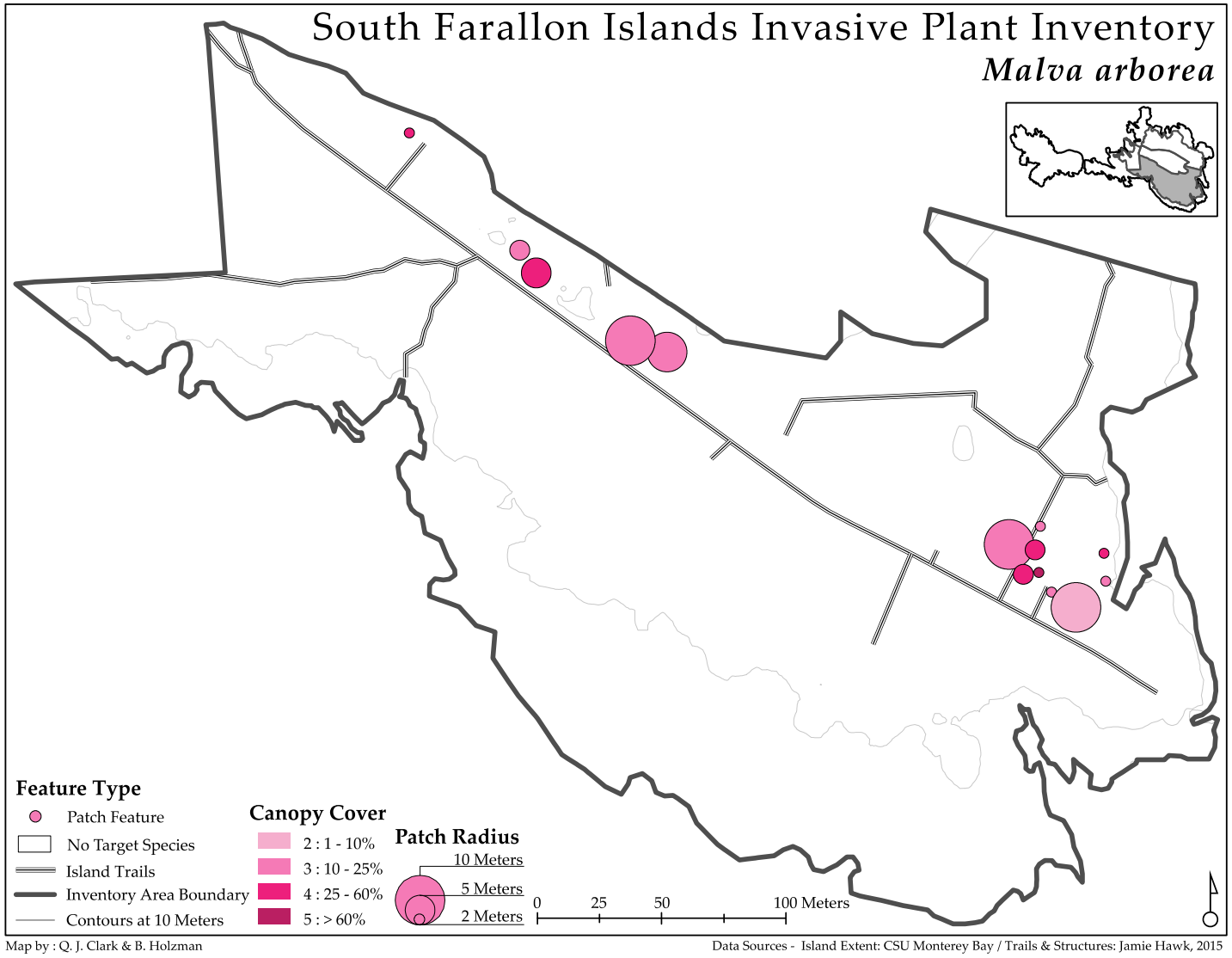

Figure 24: Map of Malva arborea detected on South Farallon Islands. This species was only detected on the Marine Terrace.

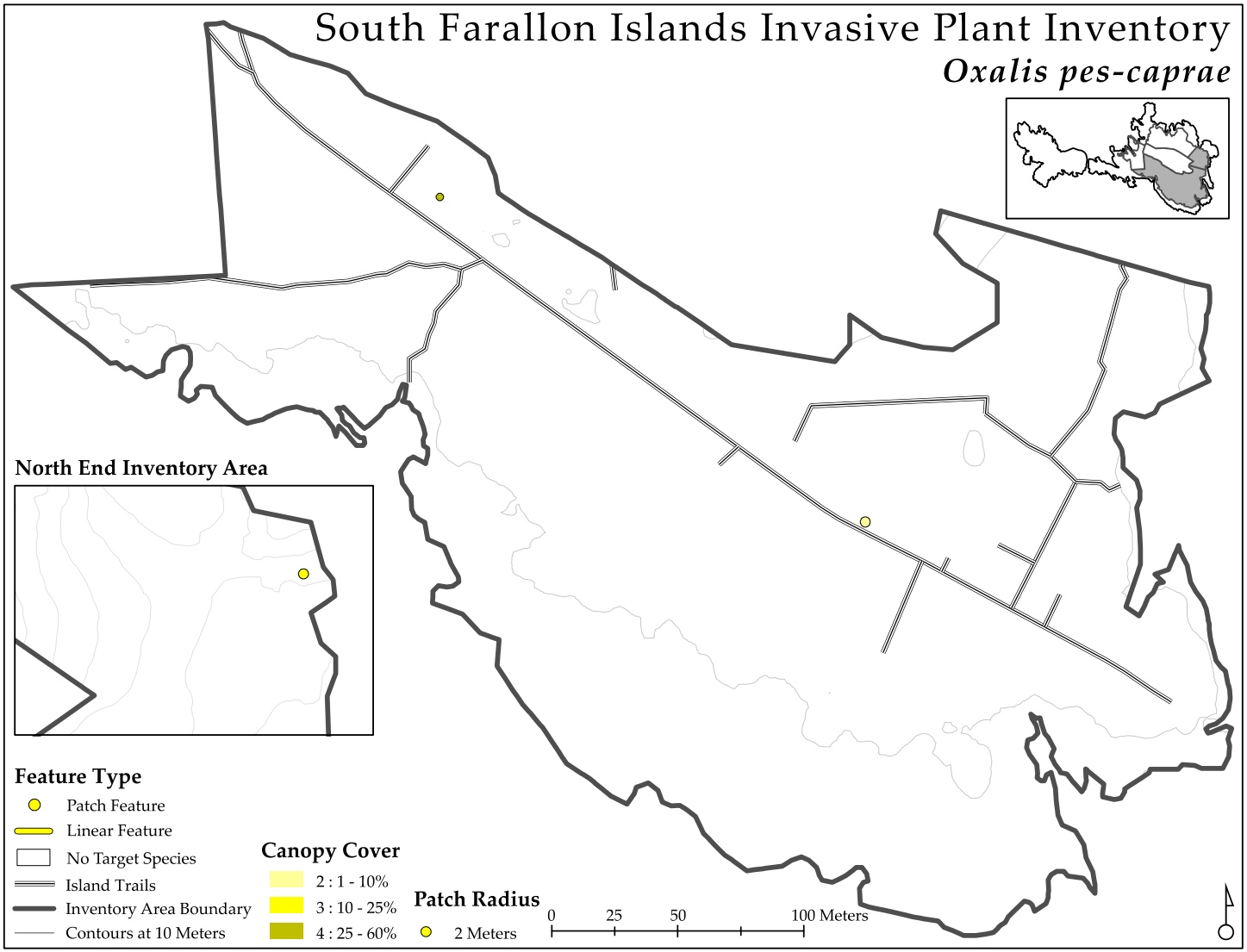

Figure 25: Map of Oxalis pes caprae detected on South Farallon Islands. This species was only detected on the Marine Terrace and North End (North End seen in inset map).

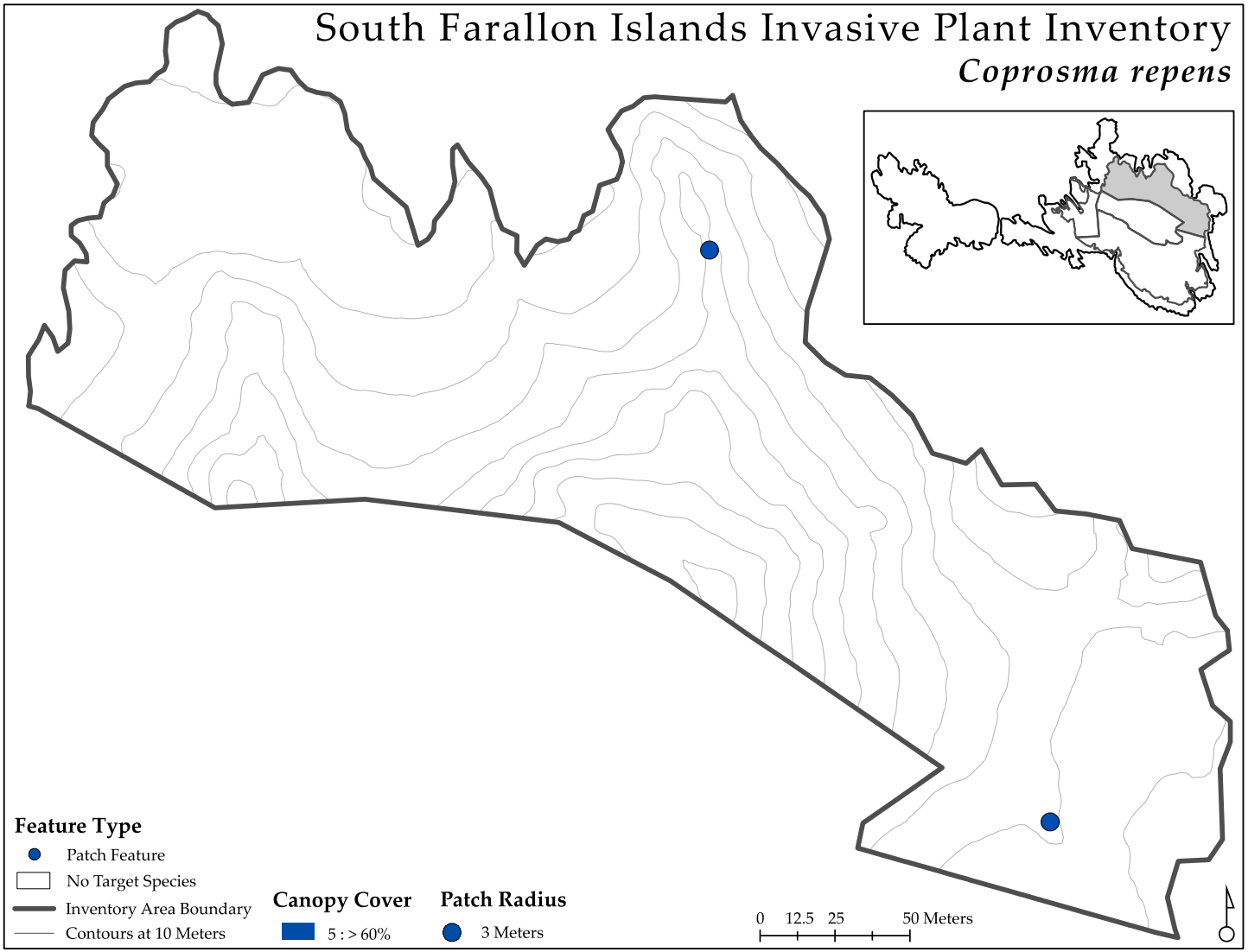

Figure 26: Map of Coprosma repens detected on South Farallon Islands. This species was only detected on the North End.

APPENDICES

LIST OF APPENDICES

Appendix A: Prioritization Process and Results

Invasive Plant Inventory Workshop: Farallon National Wildlife Refuge

Prepared by

Giselle Block, USFWS

February 2016

Table of Contents

1.0 Introduction

1.1 Purpose and Need

Invasive plants are one of the most pervasive threats to biological integrity, diversity, and environmental health in the National Wildlife Refuge System. Invasive plants can alter ecosystem function and structure and change the distribution, abundance and diversity of native species. Many refuges report that invasive plants are a top threat to refuge natural resources and managing them consumes a large proportion of their annual budget (USFWS 2003, USFWS 2013). Costs for staff and resources to combat invasive plants are increasing each year. In fiscal year 2011, the NWRS spent $15.8 million directly on invasive plants management (USFWS 2013). Further, many federally-listed threatened and endangered species are increasingly stressed by invasive species.

Although considered top priority for many National Wildlife Refuge (NWR, refuge) managers, there is limited funding and staff to control established infestations or prevent new infestations. The high cost of managing invasive plants combined with decreasing budgets emphasizes the need to be highly efficient and effective. This means that we prioritize our work, we use science to inform our strategies, we assess our progress (based on specific, measureable, and **results-oriented** objectives), and we learn and adapt our strategies as needed (figure 1).

Inventory is an essential part of invasive plant management. Often, in the face of temporal, budgetary, and personnel constraints, **managers plan their management strategies with little to no *a priori* information as to the nature of the infestations that they are managing**. This paradoxical dilemma is difficult to overcome, as many managers feel the need to use limited resources to control invasive plants rather than "waste" those resources on inventories or monitoring. However, **effective management is dependent upon credible inventory and monitoring data**. Inventories should be conducted before prioritizing and adopting specific management strategies (Dewey and Andersen 2004). The following analogies illuminate the error of well-meaning managers who conduct treatments prior to diagnosing the problem:

- A doctor treating a patient prior to diagnosing the illness
- A firefighter fighting a wildland fire without aerial reconnaissance mapping: (where is the fire boundary? Where are the satellite hot spots?)

Lastly, without any record of progress there is no legacy of information for those who come after us – did the strategies implemented in the past work or not? Should we be doing the same thing?

Identifying which invasive species should be a focus of our limited resources (and where) is an important first step in invasive plant management (figure 1). This principle is based on the assumption that **managing all non-native species is impractical and unnecessary** (Hiebert and Stubbendieck 1993, Randall 2000, Skurka Darin et al. 2011). Once priorities are identified, we then invest in inventory[1] or early detection[2]. The data is then used to develop measureable, results-oriented management objectives, inform development of efficient and effective management strategies, and provides a foundation for evaluating management effectiveness (figure 1). Since 2012, the Pacific Southwest Region Inventory and Monitoring Initiative has been assisting refuges with planning and conducting invasive plant inventories. These efforts begin with a two-day workshop where the objectives are to:

[1] An inventory is a survey that documents the presence, relative abundance, status, and/or distribution of abiotic resources, species, habitats, or ecological communities at a particular time.

[2] Early detection is a type of survey focused on the detection of highly invasive species that are not yet established but have a high likelihood of establishment or occur in small isolated populations within a defined spatial scope.

1. Review refuge natural resource conservation priorities, refuge management goals and objectives, and invasive plant management history
2. Define the invasive plant inventory spatial scope and objective(s)
3. Prioritize inventory targets: plant species and areas
4. Decide when and how inventory should be conducted
5. Discuss inventory safety and logistics

A workshop was held on January 19-20, 2016 to prepare for an invasive plant inventory at Farallon NWR in spring 2016. This report summarizes the workshop process and the results that will guide the 2016 invasive plant inventory.

1.2 Refuge Establishment and Conservation Priorities

Created in 1909 by President Theodore Roosevelt, Farallon National Wildlife Refuge was established to protect seabirds and marine mammals (USFWS 2009). The refuge comprises four island groups located within the boundaries of San Francisco City and County. These groups are Noonday Rock, the North Farallons, Middle Farallon, and South Farallon Islands (SFI). SFI consists of West End, Southeast Farallon Island (SEFI), and adjacent outcrops and islets. South Farallon Islands is the largest island group at 70 acres and was added to the refuge in 1969. Congress designated these islands, excepting Southeast Farallon Island, as the Farallon Wilderness Area in 1974. The Farallon islands are also designated as a State Ecological Reserve and a Golden Gate Biosphere Reserve. Southeast Farallon is the only island that supports structures from earlier times, several of which have been maintained or renovated for refuge management purposes. Although the focus of refuge conservation is on seabirds and marine mammals, the following natural resources are also have conservation importance:

- Maritime goldfields (*Lasthenia maritima*) (figure 1)– endemic to rocky shorelines of California; dominant native plant on the Refuge and important nest building material for cormorants and gulls
- Farallon Arboreal Salamander (*Aneides lugubris farallonensis*) (figure 2)
- Farallon camel cricket (*Farallonophilus cavernicolus*)

Details about the ecology and history of refuge conservation priorities can be found in the refuge comprehensive conservation plan (CCP) (USFWS 2009) and more recent refuge reports and publications.

Figure 1. Maritime goldfields (Lasthenia maritima), ©2013 Robert Steers/NPS.

Figure 1. Farallon arboreal salamander (Aneides lugubris farallonensis), Point Blue Conservation Science.

1.3 Refuge Invasive Plant Management History

Invasive plants are considered one of the primary threats to natural resources of the refuge. Invasive plant management was initiated at SEFI in the late 1980s, primarily in response to the establishment and spread of two non-native plants, New Zealand spinach (*Tetragonia tetragonioides*) (figure 3) and cheeseweed (*Malva parviflora*). New Zealand spinach was first recorded on SEFI in 1968 by Malcom Coulter (Coulter and Irwin 2005) and has since spread to several parts of the island (USFWS 2004, Coulter and Irwin 2005). Cheeseweed was first recorded on SEFI in 1996. Although many other non-native plant species have been recorded on the refuge (Coulter and Irwin 2005), New Zealand spinach and cheeseweed have been the focus of invasive plant management efforts because of the direct impact they have on nesting seabird species. These species form dense stands that prevent seabird access to nest burrows (Gerry McChesney, personal communication). Other plants of concern on the refuge are non-native grasses (such as *Avena fatua*, *Bromus diandrus*, and *Hordeum murinum*) and plantain (*Plantago coronopus*). Thick mats of these species may hinder burrowing by nesting auklets and compete with native plants (USFWS 2009).

The first refuge weed management plan was prepared in 2004 and updated in 2008 (USFWS 2008). The plan focuses solely on SEFI and highlights New Zealand spinach and cheeseweed as priorities for management. Since the late 1980s, the primary tool for managing these two species on SEFI has been a mid-late summer application of glyphosate-based herbicides and hand pulling (National Wildlife Refuge System Pesticide Use Proposal System [2008-present], refuge personal communication [1980s-2008]). In 2013, the refuge added a 2nd spring glyphosate treatment (late March) in addition to its annual summer treatment. Qualitative refuge observations suggest spring treatments have reduced the abundance of mature, seed-producing plants. In 2013, the refuge piloted the use of imazapyr (tradename Habitat) to control invasive plants. Qualitative refuge observations suggest imazapyr is not effective at controlling target species and limits colonization by native plants for at least 2 years following application (creates 'dead zones'). Qualitative refuge observations also suggest that the native Lasthenia maritima, and non-native grasses (such as *Bromus diandrus, Avena barbata, A. fatua*), are the primary species that colonize invasive plant removal areas. No quantitative assessment of invasive plant management efficacy has been conducted at Farallon NWR.

The refuge CCP contains the following objectives and strategies related to the management of invasive plants:

- **CCP Objective 2.3**: Within one year after the CCP's approval, continue to implement and annually update the Refuge's Weed Management Plan with the goal of decreasing the abundance and extent of target invasive species by 50 percent, primarily on the Marine Terrace and south-facing slope of Lighthouse Hill
- **CCP Objective 2.3** (*listed as a strategy under this objective*): Reduce the percent cover of New Zealand spinach and cheeseweed by 50 percent within 10 years of plan initiation and develop a strategy for eradication of 95 percent of these nonnative plants on SEFI annually by hand-spraying herbicide, manual pulling, and other potential methods. Conduct herbicide application in mid-August as needed and follow up application in September or October. Hand-pull vegetation intermittently from November through early January, conduct intensive hand-pulling from late January through mid-March
- **CCP Objective 2.4**: Within one year of the CCP's approval, initiate annual assessment of weed management strategies by assessing percent cover and distribution of key weed species, correlating any changes in wildlife nesting that may have occurred in those areas

Figure 3. New Zealand spinach (Tetragonia tetragonioides), © 2013 Jean Pawek

2.0 Methods

2.1 Project Team and Workshop

Persons involved in the planning or implementation of the 2016 invasive plant inventory at Farallon NWR (project team) are identified in table 1. The project team met on January 19-20 to define the inventory scope, define the inventory objective(s), identify priority species and areas for inventory, and decide on inventory methods. In advance of the workshop, the project team gathered the following information:

- Refuge spatial data: boundary, infrastructure (roads, trails, structures), sensitive natural resource data locations (such as seabird nesting sites, rare plants), topography/elevation
- Reports with refuge plant information
- Recent reports about refuge conservation targets (location, abundance, trends, habitat associations)
- Non-native plant species list(s): documented and undocumented
- Conservation plans: comprehensive conservation plan, weed management or integrated pest management plan

This information was used to help the project team come to a collective understanding about refuge conservation priorities and invasive management history, create a comprehensive non-native plant list, define inventory objectives, and select species and areas for inventory.

Table 1. Persons involved in the planning and implementation of the 2016 invasive plant inventory at Farallon National Wildlife Refuge.

Organization	*Name, Title*	*Inventory Project Role*
San Francisco State University	Dr. Barbara Holzman, professor,	Botanical advisor, protocol development, data collection
	Quentin Clark, graduate student), dept. geography and environment	Map production, protocol development, data collection
	Richard Chasey, graduate student, dept. geography and environment	Botanical advisor
U. S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex	Gerry McChesney, Farallon Islands National Wildlife Refuge, refuge manager	Planning, product review
	Jonathan Shore, Farallon Islands National Wildlife Refuge, refuge operations specialist	Planning, data collection, product review
	Joy Albertson, complex supervisory refuge biologist	Planning, product review
U. S. Fish and Wildlife Service, Pacific Southwest Region, Inventory and Monitoring Initiative	Giselle Block, coastal zone biologist	Workshop facilitator, protocol development, product review
	Tessa Turner, biological science technician	Planning

2.2 Prioritizing Inventory Targets: Species and Areas

We used the invasive plant inventory and early detection prioritization tool (IPIEDPT) to identify which non-native plant species and areas of the Refuge are priorities for inventory (USFWS 2015). The IPIEDPT uses several criteria and associated scores to rank areas and species for inventory. The IPIEDT is a Microsoft Access database in which the user responds to questions in a "yes/no/unknown" format or chooses from a list of states or conditions that best describe the situation. Each descriptive answer correlates to a numerical value that is used to generate scores and rank the area and species targets. The tool is comprised of three main sections: 1) Area Prioritization, 2) Species Prioritization, and 3) Area-Species Link which ranks species within specified areas rather than on a refuge-wide scale. Only the first two sections (area prioritization and species prioritization) were completed for Farallon NWR.

2.2.1 Area Prioritization

In advance of using the IPIEDPT, the project team subdivided the Refuge into distinct *areas* for inventory. The areas considered for inventory were defined by geographical and thematic factors including perceived ecological integrity, dominant vegetation types (figure 4), level of human disturbance, hydrology, topography, and accessibility. The refuge currently does not recognize distinct management units except for the individual islands that make up the Farallon NWR. The IPIEDPT uses the following characteristics to prioritize areas for inventory:

- Ecological integrity
- Innate resistance of the environment to non-native plant invasions
- Importance of the area to federally listed species and other natural resources of concern
- Density and type of vector[3]s and vector pathways
- Current perceived status of invasive plants

These criteria are applied to each area defined for the project scope.

Areas with high ecological integrity, low resistance to invasion, high importance to conservation priorities, high density of vectors or vector pathways, and low perceived abundance of invasive plants are a higher priority for inventory.

Ideally all areas would be inventoried in 2016. In the event that the entire refuge cannot be inventoried, higher priority areas will be inventoried first followed by lower priority areas. Lower priority areas would be inventoried in subsequent years.

[3] Vector (aka transport vector). The conveyance (e.g., wind, water, animal, human, mechanical, etc.) that moves a non-native propagule to its novel location (Lockwood et. al. 2007); vector pathway (aka transport pathway). The route between the non-native propagule source and release location (Lockwood et. al. 2007).

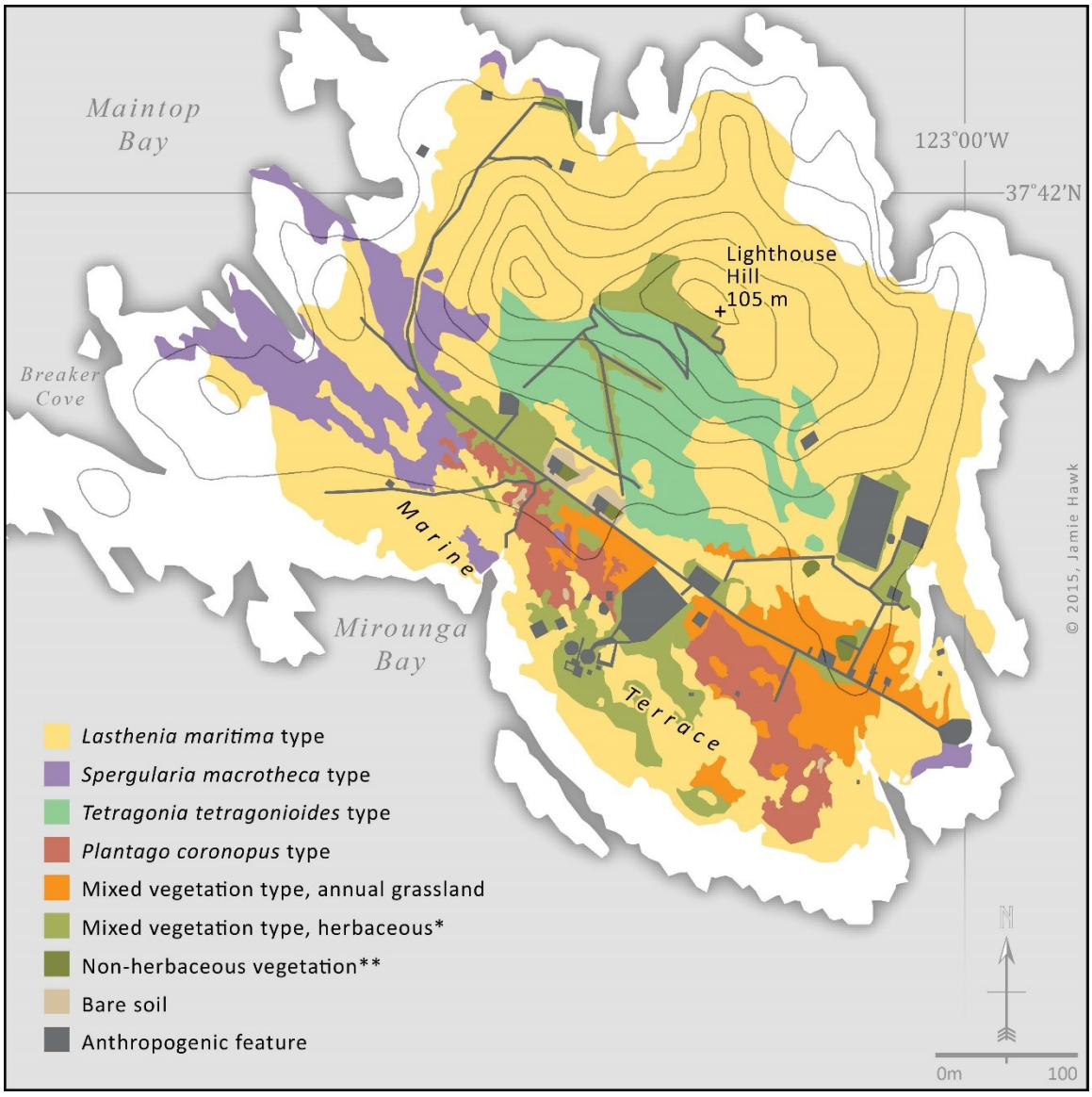

Figure 4. Vegetation map of Southeast Farallon Island (California). Map borrowed from Hawk (2015).

2.2.2 Species Prioritization

Prior to the workshop, we created a comprehensive list of non-native plant species of Farallon NWR. The list was constructed from the refuge CCP and website, refuge staff non-native plant list (December 2015), a 2015 Master's thesis, non-refuge staff documented species lists, and project team expert opinion (Blankinship and Keeler 1892, Coulter 1978, Coulter and Irwin 2005, USFWS 2004, Hawk 2015). We then standardized plant scientific names using the integrated taxonomic information system (IT IS). The species list was then crosswalked to the California Invasive Plant Council Inventory (CAIPC Inventory) and Watchlist to identify species that are considered harmful to wildlands in California (CAIPC 2006, CAIPC 2015). The CAIPC Inventory categorizes plants as *High, Moderate, or Limited*, reflecting the level of each species' negative ecological impact in California. Although the impact of each plant varies regionally, its rating represents cumulative impacts statewide. A plant whose statewide impacts are categorized as Limited may have more severe impacts in a particular location.

Conversely, a plant categorized as having a High cumulative impact across California may have very little impact in some areas of California. CAIPC's Watchlist compiles information on non-native plant species that have been reported by land managers as spreading into California wildlands but are not yet on the CAIPC Inventory list. We also reviewed the National Wildlife Refuge System Pesticide Use Proposal System (PUPS) to identify which species have been treated in the past on the Refuge with pesticides.

The IPIEDPT uses the following characteristics to prioritize species for inventory:

- Invasiveness or level of harm to natural resources. Considered at refuge and larger landscape scales
- Proximity of the species to the project scope
- Perceived current abundance in the project scope
- Potential for further spread (habitat suitability)
- Observed ecological impacts
- Larger landscape importance (for example, species listed on local early detection list)

Species with high invasiveness, close proximity, low abundance, high potential for spread, observed ecological impacts, and are a priority for management within the larger landscape are a higher priority for inventory. Inherent in the tool is a natural bias towards species that would be considered "early detection rapid response" targets.

3.0 Results

3.1 Inventory Scope

The scope of the 2016 refuge invasive plant inventory is approximately 121 acres and encompasses the terrestrial portions of Southeast Farallon Island and West End Island (figure 5).

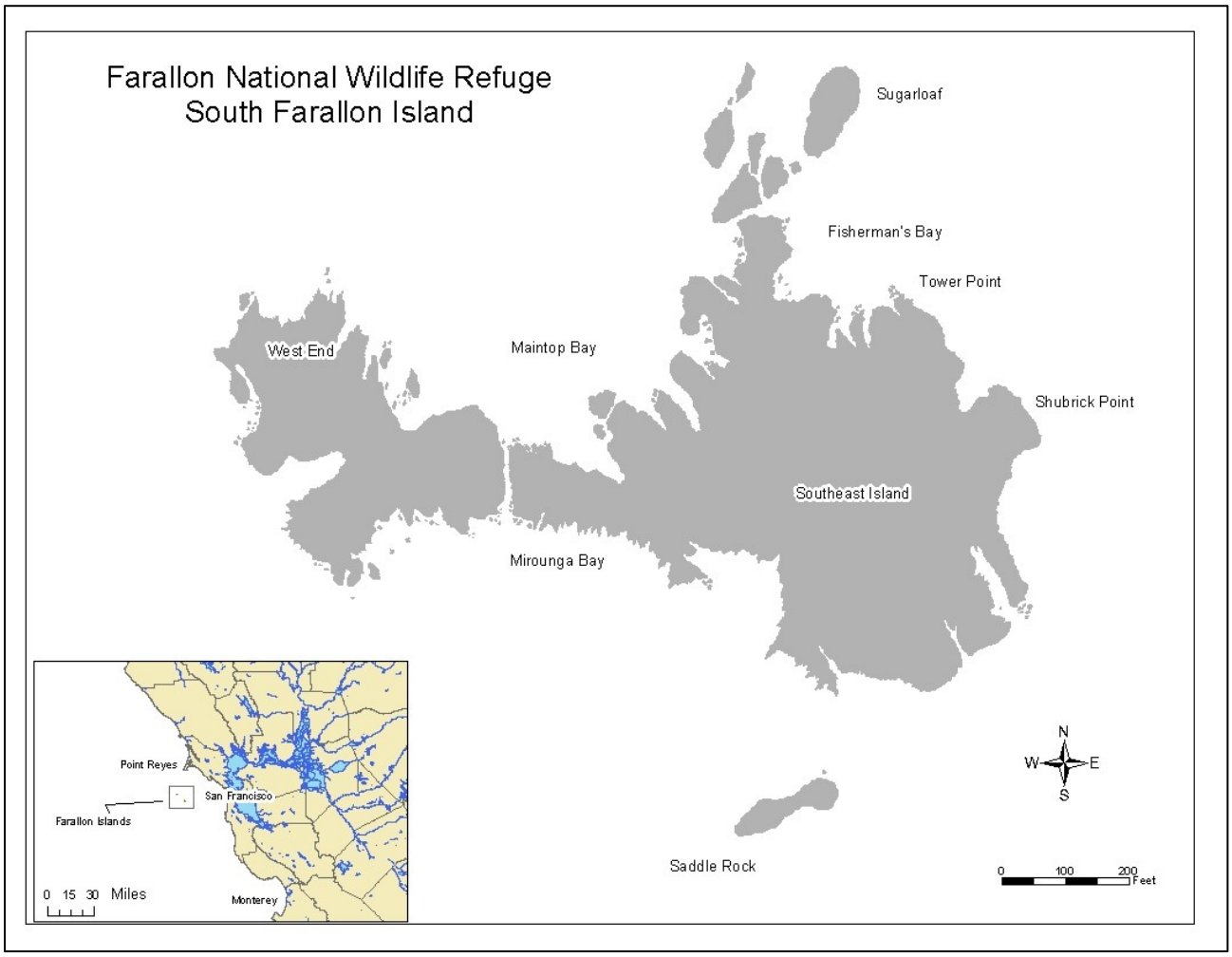

Figure 5. Map depicting the location of the Farallon National Wildlife Refuge, California.

3.2 Inventory Objective

Following workshop discussions about Refuge conservation targets, invasive plant management history, and future management needs, the project team defined the following survey objective for the 2016 invasive plant inventory:

Document the presence, spatial distribution, and abundance (percent cover) of priority invasive plant species in terrestrial areas of Southeast Farallon Island and West Island

Priority invasive plant species are identified in Section 3.4 and table 4 of this report.

3.3 Area Prioritization

The project team defined 6 areas for inventory (figure 6). The area priority scores ranged from a high of 5.4 for the *North End* area to a low of 4.0 for Corm Blind Hill (table 2). The project team generally agreed with the area rankings although they decided to switch the priority of Corm Blind Hill and Southeast Farallon Perimeter. The project team felt it was important to tackle the top of the island before moving into the perimeter area. The perimeter area is composed primarily of steep cliffs and intertidal areas. These areas will be difficult to inventory and similarly, will require a unique set of strategies to manage invasive plants. The project team also felt it was

important to focus on areas where invasive plants cause the greatest stress to their conservation targets, seabirds on the island tops.

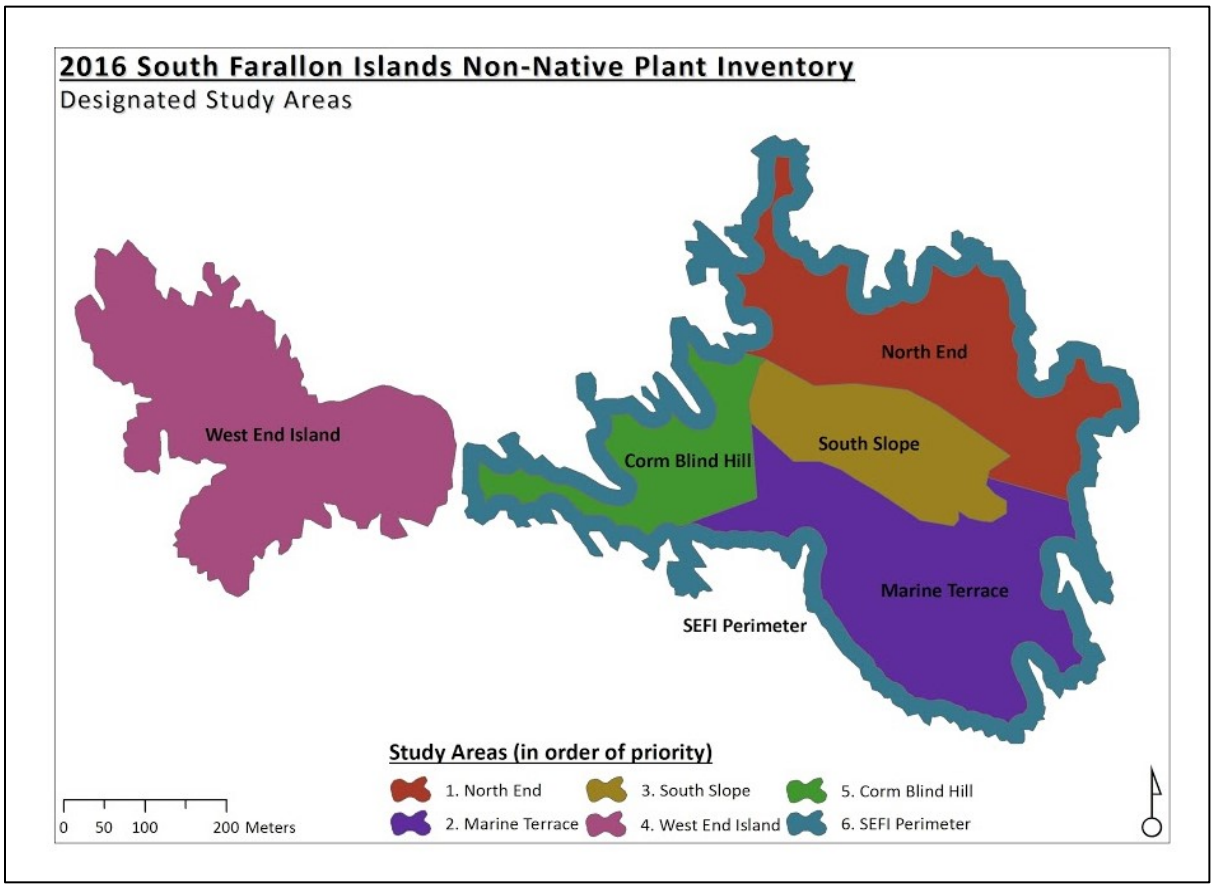

Figure 6. Farallon National Wildlife Refuge invasive plant inventory areas. Map prepared by Quentin Clark, San Francisco State University.

Table 2. List of prioritized areas for inventory at Farallon National Wildlife Refuge.

Area Name	Dominant Vegetation Type (s)	IPIEDPT Total Score	Final Priority
North End	*Lasthenia maritima* type	5.43	6
Marine Terrace	*Lasthenia maritima* type, mixed herbaceous, mixed annual grassland, *Plantago coronopus*	5.07	5
South Slope	*Tetragonia tetragonioides* type	5.07	4
West End Island	Not defined	4.98	3
Corm Blind Hill	*Lasthenia maritima* type, *Spergularia macrotheca* type	**4.00**	**2**
Southeast Farallon Perimeter	Not defined	**4.62**	**1**

3.4 Species Prioritization

We compiled a list of 51 non-native plant species for the Farallon NWR dating back to 1892 (table 3). Fifteen (29%) of these species are listed as invasive by the CAIPC inventory and an additional 15 species are on the CAIPC invasive species watch list. During the workshop, the project team reviewed the species list and decided

to remove 5 species for inventory consideration. These were *Brassica oleracea, Callitropsis macrocarpa, Elymus repens, Pinus radiata, Lycopersicon esculentum*. *P. radiate and B. oleracea* are believed to be extinct. *E. repens* was misidentified (actually *Ehrharta erecta*), and *C. macrocarpa* and *P. radiata* exists as single trees that do not pose no threat to refuge resources. The remaining 46 species were prioritized for inventory using the IPIEDPT tool (table 4). Following prioritization, 21 species were selected for inventory in 2016. Eleven of the 21 species will be mapped as part of a 'species group':

- Annual grasses: *Avena fatua, Avena barbata, Bromus diandrus, Hordeum murinum, Vulpia bromoides, Vulpia myuros*
- Sonchus species: *Sonchus asper, Sonchus oleraceus*
- Malva species: *Malva neglecta, Malva parviflora*

The project team believe that mapping species as part of a group will increase mapping efficiency. Species were grouped if they had similar ecology and would be managed in a similar way. The remaining 10 species will be mapped as individual species. The highest priority species was *Ehrharta erecta*, a species not previously a focus of refuge management. Species that have been a focus of management, *Tetragonia tetragonioides* and *Malva* species, were among the top 50% for inventory and were selected by the project team as inventory targets.

Table 3. Non-native plant species of Farallon National Wildlife Refuge: 1892-2015. Nomenclature follows the integrated taxonomic information system (IT IS).

Scientific Name (IT IS)	Other Scientific Names Used	Common Name (IT IS)	Other Common Name Used	PUPs Database	Most Recent Year Documented	CAIPC Rating	Observation Notes
Anagallis arvensis		scarlet pimpernel			2015	Watchlist	
Avena barbata		slender oat			2015	Moderate	
Avena fatua		wild oat			2001	Moderate	
Brassica oleracea		cabbage			2001	Watchlist	Believed to be extinct
Bromus diandrus		ripgut brome		X	2015	Moderate	
Cakile maritima		European searocket	sea rocket		2001	Limited	May occur in intertidal areas
Callitropsis macrocarpa	*Cupressus macrocarpa*	Monterey cypress					
Cerastium glomeratum		sticky chickweed			2001		
Chenopodium murale		nettle-leaf goosefoot	pigweed	X	2015		Throughout refuge in low densities
Coprosma repens		creeping mirrorplant	burning bush		2015	Watchlist	Two plants known to exist
Cotula australis		Australian waterbuttons			2015		Throughout 'terrace' area
Cotula coronopifolia		brass buttons			2015	Limited	
Cymbalaria muralis		Kenilworth ivy [English]			1978		Believed to be extinct
Ehrharta erecta		panic veldt grass			2015	Moderate	
Elymus repens	*Elytrigia repens*	quackgrass				Watchlist	misidentified - actually *Ehrharta erecta*
Erodium cicutarium		Red-stem stork's bill	storksbill		2015	Limited	
Erodium moschatum		musky stork's bill	storksbill		2015	Watch list: evaluated not listed	
Geranium molle		awnless geranium			1978	Watch list: evaluated not listed	Believed to be extinct
Hordeum murinum ssp. leporinum		leporinum barley	foxtail barley		2015	Moderate	
Leontodon saxatilis		hairy hawkbit			1978		May be extinct

Scientific Name (IT IS)	Other Scientific Names Used	Common Name (IT IS)	Other Common Name Used	PUPs Database	Most Recent Year Documented	CAIPC Rating	Observation Notes
Lepidium didymum	*Coronopus didymus*	lesser swinecress			2015		
Lycopersicon esculentum		garden tomato					Added by project team during workshop
Malva arborea		tree mallow			2015		Refuge allows this species to persist in a limited area for land bird use - per Point Blue request
Malva neglecta		common mallow			2015		
Malva parviflora		small-whorl mallow	cheeseweed	X	2015		
Medicago polymorpha		bur clover			1978	Limited	
Melilotus indicus		annual yellow sweetclover			2001	Watch list	May be extinct
Oxalis pes-caprae		African woodsorrel			2015	Moderate	
Pinus radiata		Monterey pine			2015		
Plantago coronopus		buckhorn plantain	plantain	X	2015	Watch list	
Poa annua		annual blue grass	annual bluegrass	X	2015	Watch list	On the trail toward the 'north landing'. Limited control options
Polycarpon tetraphyllum		fourleaf manyseed	four- leaved allseed		2015	Watch list	
Polygonum aviculare ssp. depressum		common knotweed			1892	Watch list	Believed to be extinct
Polypogon monspeliensis		annual rabbit's-foot grass			2015	Limited	
Portulaca oleracea		common purslane			2001		
Pseudognaphalium luteoalbum		Jersey cudweed			2001		
Raphanus sativus		cultivated radish	radish		2005	Limited	Last observed and pulled by refuge volunteers in 2011; may be extinct
Rubus bifrons	*Rubus ammeniacus*	Himalayan berry	Himalayan blackberry			High	Added by project team during workshop; believed to be extinct
Rumex acetosella		sheep sorrel			2015	Moderate	
Rumex crispus		curly dock		X	2015	Limited	

Scientific Name (IT IS)	Other Scientific Names Used	Common Name (IT IS)	Other Common Name Used	PUPs Database	Most Recent Year Documented	CAIPC Rating	Observation Notes
Senecio vulgaris		old-man-in-the-spring			2015	Watch list	
Sisymbrium orientale		Indian hedge-mustard			2015		
Sonchus asper		spiny sowthistle	prickly sow thistle		2015	Watch list: evaluated not listed	
Sonchus oleraceus		common sowthistle		X	2015	Watch list	
Spergularia media		media sandspurry			2015		
Stellaria media		chickweed		X	2015		On terrace and trail by 'north landing'
Tetragonia tetragonioides		New Zealand spinach		X	2015	Limited	
Urtica urens		burning nettle	stinging nettle		2015		
Vulpia bromoides	*Festuca bromoides*	brome fescue			2015	Watch list: evaluated not listed	
Vulpia myuros	*Festuca myuros*	rat-tail fescue			2001	Moderate	
Zantedeschia aethiopica		calla lily			2015	Limited	Less than a handful of plants; near structures

Table notes:

- All species were ranked using the invasive plant inventory and early detection prioritization tool (IPIEDPT) except *Brassica oleracea,* ***Callitropsis macrocarpa,*** *Elymus repens, Pinus radiata, Lycopersicon esculentum*
- PUPs database = U. S. Fish and Wildlife Service pesticide use proposal and reporting system
- CA IPC Rating = California Invasive Plant Council Invasive Plant Inventory level of harm to wildlands (limited, moderate, high). Watchlist = species is on the California Invasive Plant Council 'watchlist'. The watchlist compiles information on plants that land managers have reported escaping in wildlands and are in need of evaluation. Watchlist: evaluate not ranked = some of these plants were previously evaluated for inclusion in the CAIPC Inventory but were not added to the Inventory due to lack of information or limited distribution within California. For more information, go to www.cal-ipc.org
- Observation notes: comments by the project team during the 2016 workshop about species presence, location or distribution on the Refuge
- Most Recent Year Documented = the last year a record was recorded for the species (observer, date, location, species)

Table 4. Prioritized list of non-native plant species for inventory at Farallon National Wildlife Refuge in 2016.

Scientific Name ITIS	*IPIEDPT Scores*				*Selected as 2016 inventory target*	*Inventory Notes*
	Invasiveness Score	*Status Score*	*Impacts Score*	*Total Score*		
Ehrharta erecta	1.5	3	2.8	7.3	Yes[M]	Map as single species
Avena fatua	1.5	2.7	2.8	7	Yes[M]	Map as 'non-native annual grass' group target
Oxalis pes-caprae	1.5	2.7	2.8	7	Yes[M]	Map as single species
Rubus bifrons	3	1.2	2.8	7	No[H]	Assumed to be extirpated from island several years ago
Rumex acetosella	1.5	2.7	2.8	7	Yes[M]	Map as 'Rumex species' group target
Avena barbata	1.5	2.4	2.8	6.7	Yes[M]	Map as 'non-native annual grass' group target
Bromus diandrus	1.5	2.4	2.8	6.7	Yes[M]	Map as 'non-native annual grass' group target
Sonchus asper	1.5	2.3	2.8	6.6	Yes	Sonchus grouping
Sonchus oleraceus	1.5	2.3	2.8	6.6	Yes	Sonchus grouping
Tetragonia tetragonioides	0.3	2.1	4	6.4	Yes[L]	
Hordeum murinum	1.5	2	2.8	6.3	Yes[M]	Map as 'non-native annual grass' group target
Sisymbrium orientale	0.3	3	2.8	6.1	Yes	
Coprosma repens	0.3	2.7	2.8	5.8	Yes	2 plants known
Malva neglecta	0.3	2.7	2.8	5.8	Yes	Map as 'Malva species' group target
Rumex crispus	0.3	2.7	2.8	5.8	Yes[L]	Map as 'Rumex species' group target
Chenopodium murale	0.3	2.3	2.8	5.4	Yes	map in future effort, not 2016
Malva parviflora	0.3	2.3	2.8	5.4	Yes	Map as 'Malva species' group target
Plantago coronopus	0.3	2.3	2.8	5.4	Yes	Map as single species
Vulpia myuros	1.5	3	0.4	4.9	Yes[M]	Map as 'non-native annual grass' group target
Senecio vulgaris	0.3	3	1.2	4.5	Yes	
Erodium cicutarium	0.3	2.7	1.2	4.2	No[L]	map in future effort, not 2016
Stellaria media	0.3	2.4	1.2	3.9	No	map in future effort, not 2016
Urtica urens	0.3	2.3	1.2	3.8	No	map in future effort, not 2016
Vulpia bromoides	0.3	3	0.4	3.7	Yes	Map as 'non-native annual grass' group target

Scientific Name ITIS	*IPIEDPT Scores*				*Selected as 2016 inventory target*	*Inventory Notes*
	Invasiveness Score	*Status Score*	*Impacts Score*	*Total Score*		
Anagallis arvensis	0.3	2.7	0.4	3.4	No	
Cerastium glomeratum	0.3	2.7	0.4	3.4	No	
Cotula australis	0.3	2.7	0.4	3.4	No	
Cotula coronopifolia	0.3	2.7	0.4	3.4	No[L]	
Lepidium didymium	0.3	2.7	0.4	3.4	No	
Malva arborea	0.3	2.7	0.4	3.4	Yes	
Polycarpon tetraphyllum	0.3	2.7	0.4	3.4	No	
Polypogon monspeliensis	0.3	2.7	0.4	3.4	No[L]	
Erodium moschatum	0.3	2.4	0.4	3.1	No	
Poa annua	0.3	2.3	0.4	3	No	
Raphanus sativus	0.3	1.5	1.2	3	No[L]	
Zantedeschia aethiopica	0.3	2.3	0.4	3	No[L]	
Geranium molle	0.3	1.2	1.2	2.7	No	
Leontodon saxatilis	0.3	1.2	1.2	2.7	No	
Medicago polymorpha	0.3	1.2	1.2	2.7	No[L]	
Melilotus indicus	0.3	1.2	1.2	2.7	No	
Portulaca oleracea	0.3	1.2	1.2	2.7	No	
Pseudognaphalium luteoalbum luteoalbum	0.3	1.2	1.2	2.7	No	
Spergularia media	0.3	2	0.4	2.7	No	
Cakile maritima	0.3	1.2	0.4	1.9	No[L]	
Cymbalaria muralis	0.3	0.8	0.4	1.5	No	

Table notes:
IPIEDPT = invasive plant inventory and early detection prioritization tool.
Field = Selected as Inventory Target: California invasive plant council invasive plant invasiveness rank is denoted with a superscript if the species is on the CAIPC list (L = limited invasiveness, M = moderately invasive, H = highly invasive)

3.5 Inventory Methods

Prior to the workshop, Dr. Barbara Holzman (San Francisco State University) developed a draft protocol for invasive plant inventory on the refuge. The protocol is based on methods adapted from Anderson and Dewey (2007) and Elwood *et al.* (2013). The project team reviewed the protocol and refined several protocol elements (table 5). Of particular interest was the selection of an inventory period that would increase target species detectability, occur before the refuge applies herbicides in the spring (planned), and minimize seabird disturbance. To assist with making this decision we examined the bloom period of each target species using data from Calflora (www.calflora.org) (figure 7). The project team selected late March to early April as the inventory period. Although not all species will likely be in bloom, Dr. Holzman believes all of the target species would be detectable. Dr. Holzman will refine the protocol based on workshop discussions and provide a new protocol for review in late February 2016.

Table 5. Farallon National Wildlife Refuge invasive plant inventory protocol details discussed during a January 2016 workshop.

Protocol Element	***Project Team Decision(s)***
Invasive plant mapping details: minimum detection target size, inter-patch distance (also known as patch separation resolution), effective detection swath widths, minimum patch size, detection confidence	Minimum detection target size = adult plants; inter-patch distance = 10m; effective detection swath width = 20m (10m on each side of search path); minimum patch size = 4m^2. In cases where there are distinct differences in plant cover within a patch, the inter-patch distance rule may be overruled (a separate patch will be delineated). Detection confidence is set at 90% = 90% confident that all patches containing adult plants that are ≥4m^2 will be detected. Dr. Holzman will examine detection confidence of each target species during the inventory
Mapping patch perimeters (average radius)	Exact patch perimeters will not be mapped. Surveyors will locate patch center and patch edges and then record patch center (point) and average patch radius (point attribute). Surveyors will always conduct reconnaissance to identify patch edges if they are not visible from the patch center. Patch center point and average radius will be used to generate polygons in ArcMap (point buffered on radius)
Mapping features: points, lines, polygons	Features will be mapped using points (<4m^2), buffered points (>4m^2), and buffered lines (used when target follows a linear feature such as a trail). Buffered points and lines will be used to generate polygons
Documenting invasive plants in the island perimeter area	Subdivide island perimeter into polygons and record species presence and abundance (%cover) rather than mapping individual patches
How to survey hard to access areas or areas where risk of harm to seabirds as a result of survey disturbance is high	The inventory crew will use boats and binoculars to survey hard to access areas (island perimeter) or areas where a high level of seabird disturbance would occur
Documenting search areas	Search areas will be documented using GPS track logs
Data collection tools	Trimble GPS with Terrasync
Inventory crew	4-5 people
Inventory timing	Inventory window = March 19 to March 27, 2016; consider making a 2nd visit in late summer (*Lasthenia* very thick in spring and may reduce detectability of some target species)
Inventory training	Dr. Holzman will ensure that all surveyors are trained to ID target species and on the inventory methodology
Methods for preventing spread of invasive plants during the inventory	Surveyors will use boot brushes and bleach. Gear (such as boots, clothes, backpack) will be cleaned upon arrival to the islands and before moving into new inventory areas

Invasive plant vouchers	A voucher specimen of each target species will be collected and stored at the California Academy of Sciences

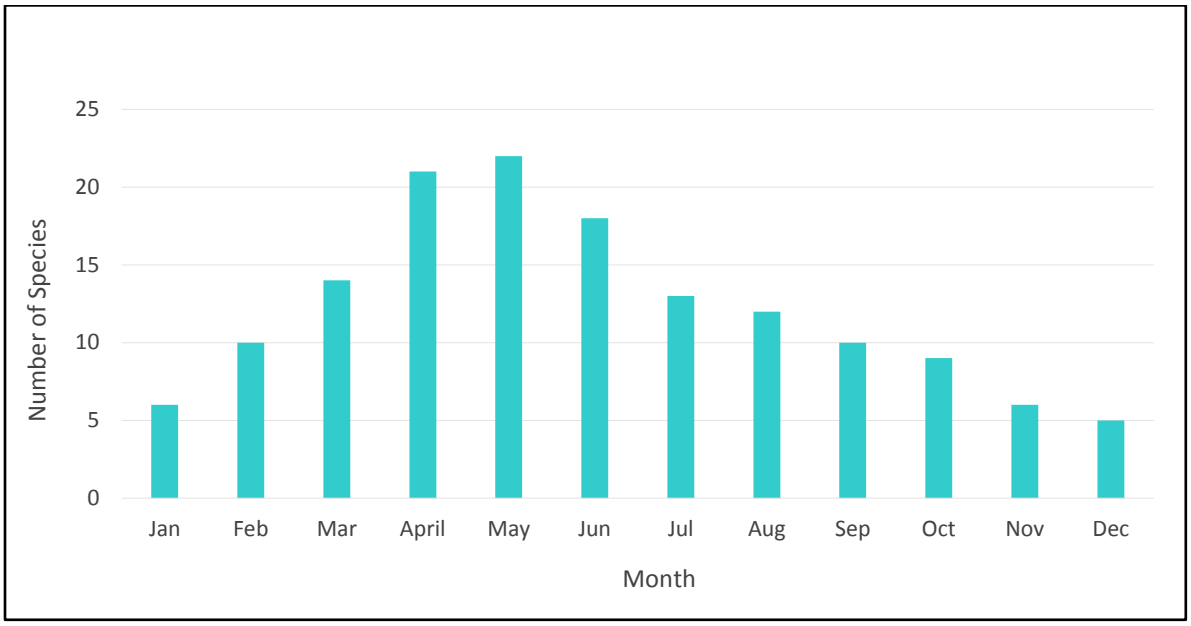

Figure 7. Number of Farallon National Wildlife Refuge invasive plant inventory species likely to be in bloom by month. Based on data from Claflora (www.calflora.org).

Conclusion

The Farallon NWR invasive plant inventory workshop provided a unique opportunity for refuge staff and botanical experts to collectively review the history of invasive plant management on the refuge, discuss the ecology of non-native plants that have been documented on the Refuge, and plan the first invasive plant inventory of the Refuge. The information generated from the inventory will be critical to refining the Refuge weed management strategy as well as provide a foundation for assessing progress and adaptive management. The workshop, and the work leading up to it, provided the refuge with a comprehensive list of non-native plant species observed on the Refuge since 1892. Application of the IPIEDPT tool provided an objective, transparent, and ecological approach to deciding which species should be a focus of inventory and where. Many of the same species selected for inventory will likely be a focus of future management, the degree to which this is true will depend on the inventory results. Lastly, the workshop provided the Refuge, the Inventory and Monitoring Initiative, and San Francisco State University with an opportunity to discuss the details of the invasive plant inventory and development of a documented protocol. The protocol will provide Refuge staff with a scientifically sound and repeatable method for assessing invasive plant status at on the Refuge.

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Appendix B: Farallon Island Wildlife Refuge Invasive Species Inventory Protocol

Protocol for Invasive Species mapping of the South Farallon Islands, Farallon National Wildlife Refuge, California

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Inventory Protocol Summary

This protocol describes the process and rationale for evaluating abundance and distribution of invasive[4] plant species at Farallon National Wildlife Refuge (Refuge). The survey involves collection, analysis, and summary of spatially referenced invasive plant distribution and abundance information. Data produced from this survey will be used to refine the Refuge weed management plan and provide a basis for evaluating invasive plant management progress over time.

Element 1: Introduction

Background

Invasive plant species, which affect approximately 2.4 million acres of U.S. Fish and Wildlife Service (USFWS) National Wildlife Refuge System (NWRS) lands, are ecologically and economically costly (Leung et al. 2002). As mandated by the NWRS Improvement Act of 1997 and subsequent policy, the NWRS is to be administered to ensure the maintenance of the biological integrity, diversity, and environmental health (BIDEH) of the System. The BIDEH Policy states that where it is feasible and supports the Refuge purposes, the NWRS will be managed for historic conditions that were present prior to substantial human-related changes to the landscape. Most Refuges report that invasive plants interfere with their wildlife management objectives (USFWS 2003), but control with cost-effective and publicly acceptable methods is a challenge. Refuge managers rank invasive plants the highest threat to the NWRS, scoring almost double that of any other threat. Costs for staff and resources to combat invasive plants are exponentially increasing each year. In fiscal year 2011, the NWRS spent $15.8 million directly on invasive plant management (USFWS 2013). Further, many federally-listed threatened and endangered (T&E) species are increasingly impacted by exotic species. Although considered top priority for most National Wildlife Refuge (NWR) managers, there is limited funding and staff to control established infestations or prevent new infestations.

The Refuge was established in 1909 as a preserve and breeding ground for seabirds and marine mammals, and originally included North and Middle Farallon Islands, with the South Farallones being added to the Refuge in 1969. The Farallon Islands host thirteen breeding seabird species

[4] Invasive species" means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health (1999; EO 13112: http://www.gsa.gov/portal/content/101587)

with some 300,000 birds nesting and roosting on Southeast Farallon Island annually (DeSante & Ainley 1980; Warzybok & Bradley 2011). Today the USFWS has a cooperative agreement with Point Blue Conservation Science (formerly Point Reyes Bird Observatory) to assist with wildlife monitoring, facilities management, and protection of the Refuge. Due to the steep rocky shoreline and sensitivity of wildlife, the Refuge remains closed to public access.

Farallon National Wildlife Refuge

The Farallon Islands are located in the Pacific Ocean approximately 48 km (30 mi) west of San Francisco, California and 32 km (20 mi) south of Point Reyes. They are comprised of four rocky island groups: Noonday Rock, North Farallones, Middle Farallon, and South Farallones. The South Farallon group includes Southeast Farallon Island, the largest and only inhabitable island, West End (or, Maintop) Island, and adjacent rocks and islets (Figure 1). The 49-hectare (120-acre) Southeast Farallon Island (37°42’ N, 123°0’ W) is characterized by a marine-cut terrace with several steep crags and talus slopes. The highest point is Lighthouse Hill that stands approximately 105 m (343 feet) above sea-level. Southeast Farallon Island is separated from West End by the narrow Jordan Channel.

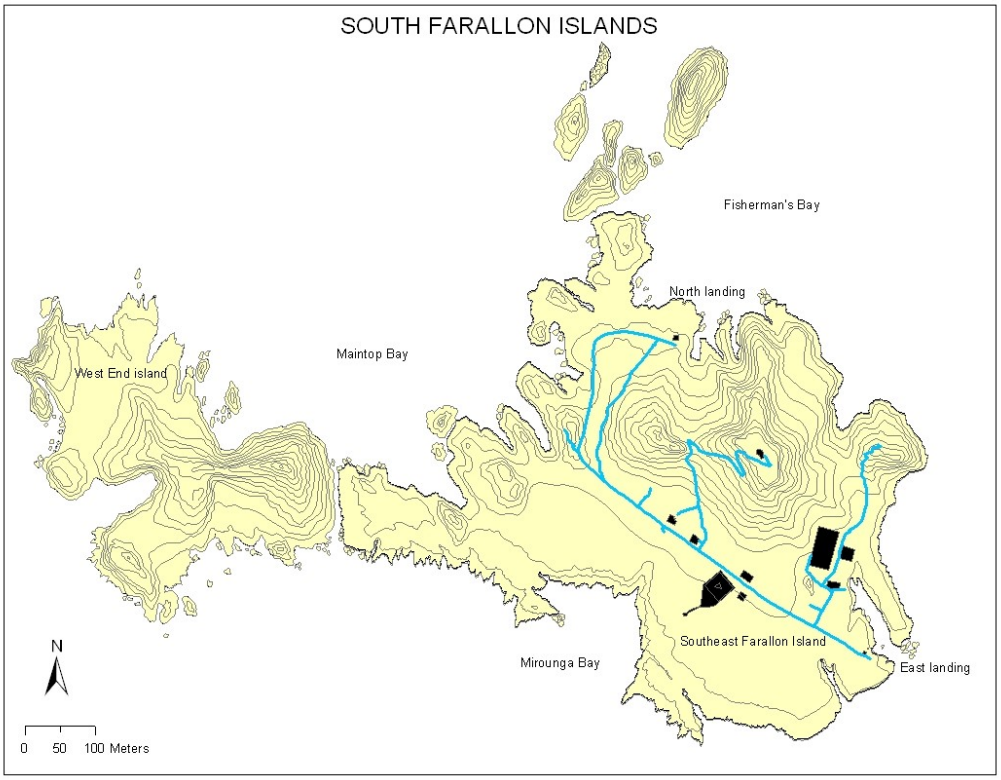

Figure 0-1. Map of the South Farallon Islands, Farallon National Wildlife Refuge including Southeast Farallon and West End islands. Black polygons represent existing buildings and other structures; blue lines are trails.

Objectives

The Refuge was established to protect seabirds and marine mammals (USFWS 2009). The following natural resources also have high conservation importance:

- Maritime goldfields (*Lasthenia maritima*) – dominant native plant and important nest building material for cormorants and gulls
- Farallon Arboreal Salamander (*Aneides lugubris farallonensis*)
- Farallon camel cricket (*Farallonophilus cavernicolus*)

Details about the ecology and history of Refuge conservation priorities and associated Refuge management goals can be found in the Refuge comprehensive conservation plan (CCP) (USFWS 2009) and more recent Refuge reports and publications.
The CCP identified several threats to Refuge conservation priorities and contains objectives and strategies aimed at reducing or eliminating these threats. Invasive plants are considered a priority threat to natural resources of the Refuge. Invasive plant management was initiated at SEFI in the late 1980s, primarily in recognition of the establishment and spread of two non-native plants, New Zealand spinach (*Tetragonia tetragonioides*) and cheeseweed (*Malva parviflora*). The first Refuge weed management plan was prepared in 2004 and updated in 2008 (USFWS 2008). The plan focuses solely on SEFI and highlights New Zealand spinach and cheeseweed as priorities for management. Objectives related to reducing the threat of invasive plants on the Refuge are found only in the CCP:

- **Objective 2.3**: Within one year after the CCP's approval, continue to implement and annually update the Refuge's Weed Management Plan with the goal of decreasing the abundance and extent of target invasive species by 50 percent, primarily on the Marine Terrace and south-facing slope of Lighthouse Hill
- **Objective 2.3 Strategy**: Reduce the percent cover of New Zealand spinach and cheeseweed by 50 percent within 10 years of plan initiation and develop a strategy for eradication of 95 percent of these nonnative plants on SEFI annually by hand-spraying herbicide, manual pulling, and other potential methods. Conduct herbicide application in mid-August as needed and follow up application in September or October. Hand-pull vegetation intermittently from November through early January, conduct intensive hand-pulling from late January through mid-March
- **Objective 2.4**: Within one year of the CCP's approval, initiate annual assessment of weed management strategies by assessing percent cover and distribution of key weed species, correlating any changes in wildlife nesting that may have occurred in those areas

Element 3: Sampling Design

Survey objectives

The overall objective of the Refuge Invasive Plant Inventory is to document the presence, spatial distribution, and abundance (percent cover) of priority invasive plant species (hereafter referred to as targets) in terrestrial areas of Southeast Farallon Island and West Island (Figure 1). The objectives of the invasive plant inventory are:

1. Document the location and abundance of targeted non-native plant species on the Refuge

2. Document areas free from targeted non-native plants on the Refuge
3. Provide a dataset and report of inventory results to Farallon National Wildlife Refuge for refinement of the Refuge weed management plan, specifically its objectives and strategies (such as prevention, early detection, eradication).

Rationale for inventory objectives

Inventory is an essential part of invasive plant management. Managers of National Wildlife Refuges, and most other land managers, have an established need for cost-effective informational tools to properly plan, prioritize, manage, and understand non-native invasive plant infestations. Often, in the face of temporal, budgetary, and personnel constraints, managers plan their management strategies with little to no a priori information as to the nature of the infestations that they are managing. This paradoxical dilemma is difficult to overcome, as many managers feel the need to use limited resources to control invasive plants rather than "waste" those resources on invasive plant inventories. However, effective management is dependent upon reliable vegetation monitoring data and area-wide invasive species inventories should be conducted before prioritizing and adopting specific management strategies (Dewey and Andersen 2004). The following analogies, a doctor treating a patient prior to diagnosing an illness and firefighters fighting a wild land fire without aerial reconnaissance mapping, illuminate the error of well-meaning managers who conduct treatments prior to diagnosing the problem.

Besides the logical reasoning for inventorying first, there are plenty of legal reasons to do so as well. Department of Interior and Fish and Wildlife Service policies (517 DM1, 30 AM 12, 7 RM 14, and 620 FW1) instruct Refuges to adopt integrated pest management (IPM) as a strategy for managing invasive species. These policies also relate directly to the Biological Integrity Policy (601 FW 3) which mandates the use of IPM strategies. The USFWS Integrated Pest Management guidance for preparing and implementing IPM strategies states that monitoring and mapping are critical components of successful IPM programs and should be completed prior to any pest management action (USFWS 2004). Inventories should be conducted as a "first step" in an integrated pest management strategy with the objective of creating accurate species-distribution maps that will be used in priority setting and management strategy selection.

In order for an inventory to be effective certain critical data must be acquired, this includes: identifying which invasive species are present, their location, and their relative abundance (or level of infestation). Invasive species monitoring often focuses on presence only data, however, the collection of true absence data gives greater value to the data set and allows the use of traditional statistical methods (Li et. al 2011). True absence data is essential to producing accurate assessments within any species distribution model (Vaclavik and Meentemeyer 2009).

Inventory Targets

A workshop was held at the Don Edwards San Francisco Bay National Wildlife Refuge Complex on January 19-20, 2016 to plan an invasive plant inventory at Farallon National Wildlife Refuge. Workshop goals were to 1) prioritize invasive plant species and areas for inventory and 2) identify optimal methods for evaluating the distribution and abundance of priority invasive plant species. Results of this workshop are presented in the report '*Invasive Plant Inventory Workshop: Farallon*

National Wildlife Refuge' (Block 2016). We used the invasive plant inventory and early detection prioritization tool (IPIEDPT) to identify inventory target species and areas (USFWS 2015). The IPIEDPT uses several criteria and associated scores to rank areas and species for inventory.

Plant species

A comprehensive list of non-native plant species documented on the Refuge was compiled from the Refuge CCP, site-specific reports containing plant information, and plant species lists provided by Refuge staff. Plant species were prioritized for inventory using the IPIEDT.

The IPIEDPT uses the following characteristics to prioritize species for inventory:

- Invasiveness or level of harm to natural resources. Considered at refuge and larger landscape scales
- Proximity of the species to the project scope
- Perceived current abundance in the project scope
- Potential for further spread (habitat suitability)
- Observed ecological impacts
- Larger landscape importance (for example, species listed on local early detection list)

Species with high invasiveness, close proximity, low abundance, high potential for spread, observed ecological impacts, and are a priority for management within the larger landscape are a higher priority for inventory. Inherent in the tool is a natural bias towards species that would be considered "early detection rapid response" targets.

Ten individual species and four species groups were selected for inventory (Table 1). Some species were grouped into 'species groups' for inventory if they had similar ecology and would be managed using similar methods. It was determined that it would be more efficient to map some species as groups rather than individuals. Species groups include 1) *Malva spp (except M. arborea), 2) Sonchus spp, 3) Rumex spp.* and 4) all non-native annual grasses (except *Ehrharta erecta*).

Table 1. South Farallon Islands invasive plant inventory target species and groups.

Scientific Name (ITIS)	Common Name
Chenopodium murale	nettle-leaf goosefoot, nettleleaf goosefoot
Coprosma repens	creeping mirrorplant
Ehrharta erecta	panic veldt grass, panic veldt grass, erect veldt grass
Malva arborea	tree mallow
Oxalis pes-caprae	African woodsorrel, Bermuda buttercup, buttercup
Plantago coronopus	Plantain
Rubus bifrons	Himalayan berry, Himalaya blackberry
Senecio vulgaris	old-man-in-the-spring, common groundsel
Sisymbrium orientale	Indian hedge-mustard
Tetragonia tetragonioides	New Zealand-spinach, New Zealand spinach
SPECIES GROUPS	
Annual Grasses	
Avena fatua	wild oat, wild oats, flax grass, oat grass, wheat oats
Avena barbata	slender oat, slender oats, slender wildoat
Bromus diandrus	ripgut brome
Hordeum murinum	mouse barley, bulbous barley
Vulpia bromoides	brome fescue
Rumex Species	
Rumex acetosella	sheep sorrel, field sorrel, common sheep sorrel
Rumex crispus	curly dock, narrowleaf dock, sour dock
Sonchus Species	
Sonchus asper	spiny sowthistle, prickly sow thistle
Sonchus oleraceus	common sowthistle, sow-thistle, pualele
Malva Species	
Malva neglecta	buttonweed, cheeseplant, cheeseweed, common mallow, dwarf mallow, roundleaf mallow
Malva parviflora	small-whorl mallow, cheeseweed
Malva pseudolavatera	Cretan mallow

Inventory areas

The island was subdivided into six logical mapping areas (inventory areas) based on factors such as island (Southeast Farallon or West End), aspect, slope, dominant plant community composition (vegetation type), or other habitat variables (Figure 2). The IPIEDT was then used to prioritize areas for inventory.

The IPIEDPT uses the following characteristics to prioritize areas for inventory:

- Ecological integrity
- Innate resistance of the environment to non-native plant invasions
- Importance of the area to federally listed species and other natural resources of concern
- Density and type of vector5s and vector pathways
- Current perceived status of invasive plants

These criteria are applied to each area defined for the project scope.

Areas with high ecological integrity, low resistance to invasion, high importance to conservation priorities, high density of vectors or vector pathways, and low perceived abundance of invasive plants are a higher priority for inventory. Ideally all areas would be inventoried in 2016. In the event that the entire refuge cannot be inventoried, higher priority areas will be inventoried first followed by lower priority areas. Lower priority areas would be inventoried in subsequent years.

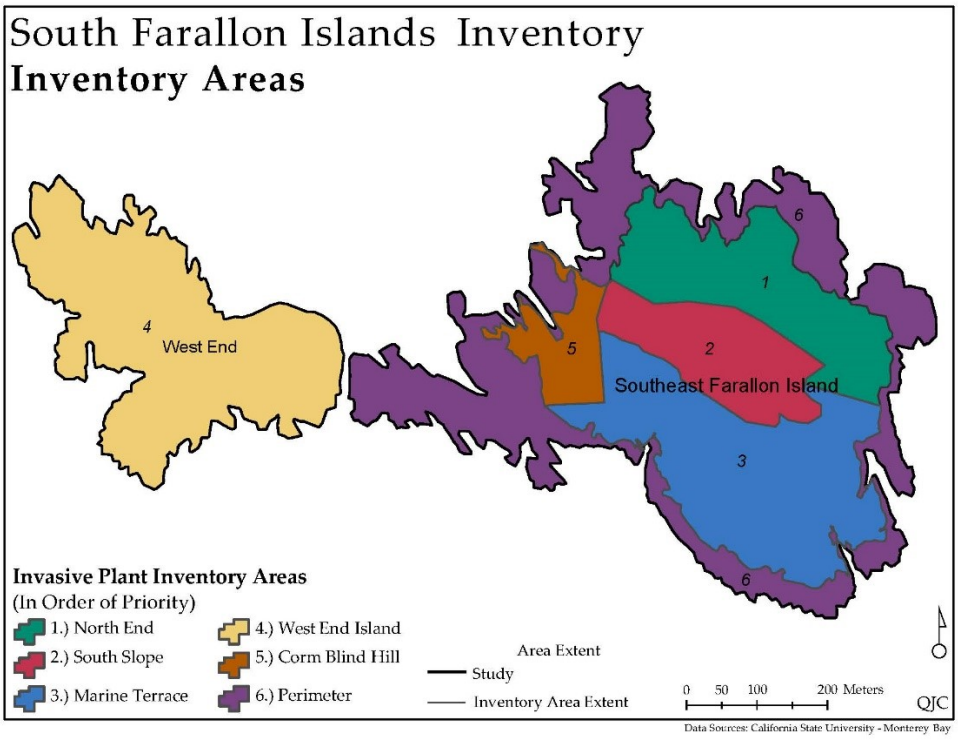

Figure 0-1: Map showing invasive plant inventory areas of South Farallon Islands. Areas are numbered in order of priority

[5] Vector (aka transport vector). The conveyance (e.g., wind, water, animal, human, mechanical, etc.) that moves a non-native propagule to its novel location (Lockwood et. al. 2007); vector pathway (aka transport pathway). The route between the non-native propagule source and release location (Lockwood et. al. 2007).

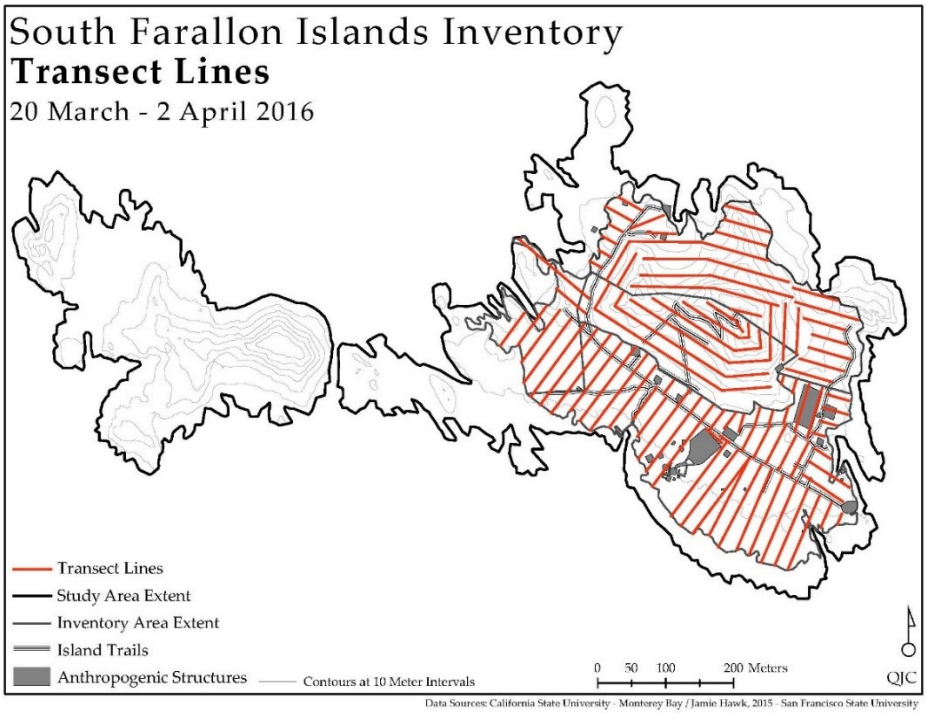

Figure 0-2: Transect Map for SE Farallon Island

Survey timing

Inventory will occur in spring 2016 (late March to early April), when many targeted plant species are expected to flower (figure 4). Because of the cycles of marine mammals and bird breeding on the Refuge, the timing window for inventory to take advantage of the blooming cycle without presenting major disruptions to the wildlife on the refuge is limited. The March survey date was established to coincide with plant blooming but to occur after seal pupping and before gull breeding. Some target species may not be full grown or in bloom and time of survey. Careful search under taller plants will be necessary to located small individuals of target species, specifically *T. Tetragonioides*, and *Malva* species and some *Plantago* individuals. The survey will also need to occur prior to the spring herbicide spraying by USFWS Spinach eradication team.

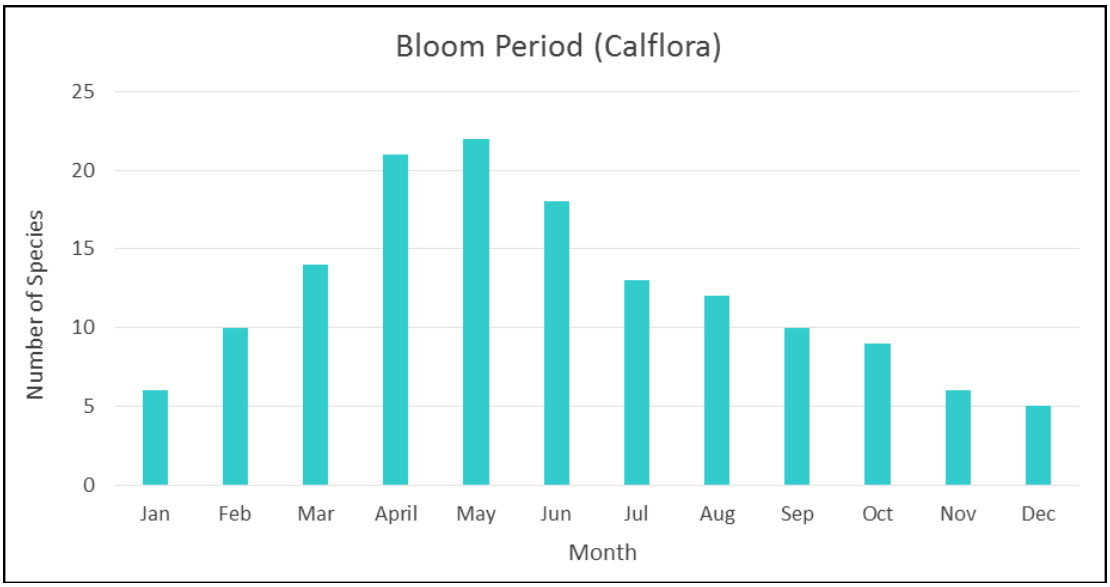

Figure 0-3. Number of invasive plant species targeted for inventory at South Farallon Islands that are expected to be in bloom by month. Data source: www.calflora.org.

Sources of error

Plant detection: Non-detection of new plants under larger native (*L. maritima*) or Non-natives (*B. diandrus*) is possible. The process of walking through the plot areas allows us to detect these individuals, but some may still be missed. A late season (late July) additional survey when *L. maritima* has senesced will allow better detection.

GPS satellite connectivity: In some areas the GPS units will not establish satellite connections due to location (this can happen on North slope) or weather conditions. Hand mapping of area will be required. This would involve using closest known locations and measuring distance and compass direction to invasive feature.

Access: Access to certain areas due to steep slope or possible bird disturbance may not be possible, these areas will be visually scanned using binoculars.

Variability in plant identification and mapping skills

Prior to the inventory, crew members will be given a list of target species to learn or review. Surveyors will be in teams of 2 or more. Crews will consist of at least one person with GIS/GPS expertise and the other with knowledge of plant identification and familiarity with the target species. Each crew member will be tested on knowledge of the target species prior to mapping commences. A binder with every species known to be on the island will also be available for reference during the inventory.

Element 3: Field Methods and Sampling Processes

Pre-survey logistics and preparation

For the Spring 2016 survey a total of six crew will be needed. Surveys are done in two teams with one member of each group handling the larger GPS unit, an additional member using a smaller, Trimble Juno unit to record track logs and a third member surveying the area to detect target

species. All members of the team are instructed in identification of target species and were also involve in detection.

Jonathan Shore and Gerry McChesney of USFWS will communicate with Dr. Barbara Holzman (SF State) regarding transportation to and from the island. Transportation to and from the refuge will be scheduled by USFWS staff. Housing will be provided by USFWS on the refuge. Safety instructions on the boat and on the refuge will be communicated to all crew members by Refuge manager. Communication on the refuge is via hand held radios. Each team will have two radios to enable among and within team communication. A USFWS permit was obtained for previous vegetation mapping efforts and extended to cover invasive mapping. Training materials consists of a copy of the protocol provided to each crew member for review. A complete list and descriptions of all plant species found on the refuge will be available for crew to review. Field crew will be trained at SF State under the direction of the PI.
The first day of the survey the crew and PI will go over all instructions and procedures and the crew will be trained in target species identification, use of GNSS devices for mapping and creating tracking logs. Daily am meetings will be held to discuss areas to be mapped, special circumstances and plan of attack. Evening meetings will be held to discuss any deviations from protocol that were necessary, the findings of the day, any instructions for GIS mapping and any problems encountered.

Equipment

- GNSS units Trimble GeoExplorer 2008 and Trimble Juno SB for track logs
- Data Dictionary preloaded to GNSS units: Trimble Pathfinder Office 5.70
  Preprogrammed with popup menus for species, features
- Paper maps of inventory area and Refuge
- Maps of island with place names for easy communication
- Binoculars
- Sunto clinometer
- Rangefinder (Insight 1000LH by Opti-Logic)
- Radio (Walkie-Talkie)
- Field notebook/pen
- Stakes with flagging
- Compass
- 2 meter tapes per team
- Camera
- Hat
- Sunscreen
- Computer with Software: Data collection will be performed with Trimble GNSS units, post-processed with Trimble Pathfinder Office (version 5.70) and Terrasync (version 5.81) and transferred to ArcGIS 10.3.1 for data management. Maps will be created using ArcGIS

10.3.1 and Adobe Illustrator CC. Data analyses will be performed using ArcGIS 10.3.1 and MS Excel 2016.

- Plant identification books (Jepson, 2013)
- Plants species on SEFI Binder (Holzman & Kalchmayr, 2016)

Communication

Any changes to methodology needed in the field will be communicated to Refuge staff and included in final report. Also, any other problems encountered, disturbances to wildlife or habitats, or personnel injuries will be reported to USFWS Refuge staff as soon as possible, and included in daily journals recorded by Point Blue staff.

Inventory transects will be created before the survey begins. Transects will be placed 20 meters about and where possible perpendicular to trails. Each GNSS device will have transect locations preloaded. Transect lines will be included in the completed GIS provided to the USFWS for future monitoring efforts.

Environmental restrictions and safety

Field crew will be in constant contact with staff from USFWS or Point Blue Conservation Science present on the island when surveying to notify them of the day's mapping area and to determine whether any special precautions or limitations to entering the area are required. Efforts will be made not to disturbed marine mammals, nesting birds or burrows while mapping in a certain area.

Data collection procedures

Data collection methods were adapted from Anderson and Dewey (2007) and Elwood *et al.* (2013) and modified to meet inventory objectives and accommodate accessible locations, topographic characteristics and wildlife considerations on the island. Field crews will conduct a complete search of South Farallon Islands for targeted invasive plant species (table 1).

Defining invasive plant patches/features

Individual plants or groups of plants will be mapped (using GPS) as patches. A patch can be a single individual plant or a group of plants comprised of a single species or species group target. The minimum detection target size (MDTS) for a patch is 0.0004ha ($4m^2$) (.001 ac) (Figure 3). The MDTS represents a patch size large enough to be detected with >90% confidence within the inventory scope; but small enough so that any missed patches smaller than the MDTS could still feasibly be eradicated (Anderson and Dewey 2007). The patch separation resolution (PSR) for the Refuge inventory is 10m (Figure 4). Clusters of plants separated by a distance that is more than the PSR are recorded as separate patches. Plants separated by less than the PSR are considered a single patch or polygon.

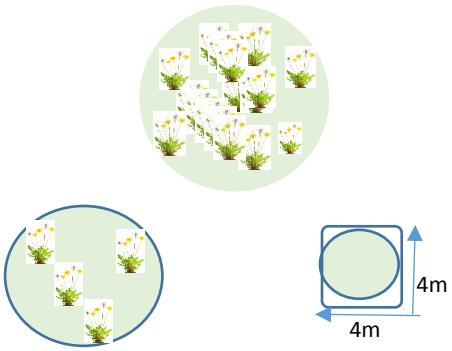

Figure 3. Minimum Detection Target Size (MDTS) or minimum patch size was $4m^2$

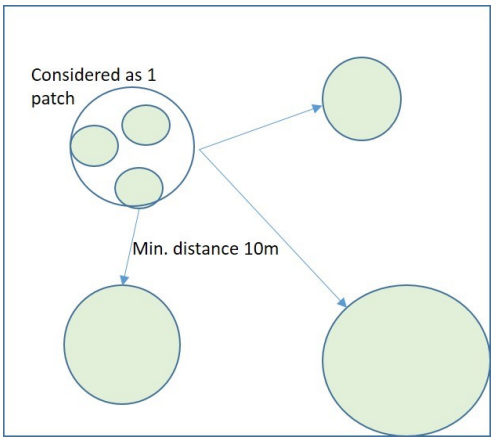

Figure 4. Patch Separation Resolution (PSR) Minimum distance between patches was 10m.

Search procedures and detection confidence

Surveyors searched for target plant species by walking along a series of parallel transects that cover the South Farallon Islands. Transects are separated by 20m, known as the effective detection swath width (EDSW) (Figure 3). Transects are oriented along contour lines on slopes and perpendicular to trails in flatter areas. Transect locations are preloaded onto GPS units and used to guide the inventory. Transect starting point and 10 meter widths on each side of the transect are flagged for reference. Surveyors walk along the center line of each transect and search for target species on each side (10m width). If 10m distance between transects do not allow for an accurate assessment the area between transects are be traversed to locate targeted species (this was the case in Spring 2016). The EDSW can vary based on a number of environmental conditions such as visibility (weather, density of vegetation) and detectability of target species. The confidence of detecting target species at an EDSW of 20m is estimated to be 90%. The EDSW will be reduced if the detection confidence is below a set percent. When detection confidence for target species is rated below 90% it will be noted in the GPS as Low (1to 50%) or Medium (51 to 89%). The goal is 90% detection confidence. However, if lower confidence is achieved for certain species due to vegetation structure or growth stage a follow-up visit in early summer is needed to improve detection rates for those species.

Mapping invasive plant features

At the start of each survey, one GPS with log tracking capability will be turned on. Each preloaded transect will be walked to provide a track log of each area surveyed. From these transects the search for invasive species will begin.

When a target species is detected, the surveyor will Trimble Pathfinder Office mark his/her location along the transect, assess the spatial extent of the patch, and use this information to decide if the patch will be mapped as a buffered point (patch), buffered line (linear), or polygon feature:

- ***Buffered point***: non-linear feature of target species >4m^2 will be recorded using a Trimble GPS. Each point will be recorded while standing at the approximate center of the invasive species patch and the average radius of the patch will be estimated using a digital range finder (radius will be rounded to 0.5m). The patch perimeter will not be mapped. Buffered points will be converted to polygons representing the approximate area of individual patches. Buffered points will provide a visual representation of the size of infestation and its location. It will not however accurately represent the actual perimeter of an infestation. These will be called linear features.
- ***Buffered line***: linear feature (such as along roads, trails, or waterways). If the patch is more linear, such as those found along roads or trails, the patch will be recorded as a line feature (a series of points) and the average width of the linear feature will be recorded. These will be called polygon features.
- **Polygon**: The perimeter of non-circular features covering large areas or irregularly shaped will be recorded as polygons. Polygons are mapped using vertices.
- **Track logs**: Logs of all transects surveyed will be mapped using a handheld Trimble Juno. One crew member will walk the entire transect with the Juno recording points at 5 meter intervals. The device will be paused after the transect is walked until the next transect is encountered.

Feature attributes

A data dictionary file (.ddf) will be created for the inventory using the Data Dictionary Editor wizard in GPS Pathfinder Office (version 5.70), and transferred to Terrasync (version 5.81) for use on the GPS receivers utilized during data collection. Attribute information for each patch, line or polygon (collectively called features) included: spatial coordinates (location data will be spatially referenced using the NAD83 UTM Zone 10 projection) that will be created from GPS and entered into GIS post-survey, date (MM/DD/YYYY), observer (initials of crew members doing the inventory), species name or species group (scientific name preloaded in a pull down menu), inventory area, measured radius (for points) or width (for lines) using a digital range finder, estimated percent cover class of feature (reference p. 279-280 of the RLGIS Data Dictionary) noted in Table 3 below and preprogrammed into a pull down menu, and species phenology at time of survey (noted in Table 4 below) preprogrammed into a pull down menu, phenology codes were simplified for efficiency, and any additional comments about the area.

Table 3: Canopy Cover values

Coded Value	Description
1	<1% - Scarce
2	1-10% - Poorly Represented
3	11-25% - Well Represented
4	26-60% - Abundant
5	>61% - Very High

Table 4: Phenology codes (modified from p. 264 of the RLGIS Data Dictionary)

Coded Value	Description
Rosette (R) or seedling	Basal Rosette
Pre-Flowering (PrF)	Buds present
Flowering (F)	Flowering
Post-Flowering (PoF) /Senescent	Post-Flowering or seeds present

Element 4. Data Management and Analysis

Data Management

Location and attribute information for each invasive plant patch/feature will be recorded in a custom data dictionary in Terrasync. Attribute information will include: date, observer, species name (scientific), inventory area name, vegetation type being invaded (from Hawk 2015), measured patch radius (for points) or feature width (for lines), estimated percent cover class of feature, and species phenology at time of survey. Daily inventory routes will be recorded using the tracklog feature on the GPS unit. Data collected each day will be downloaded onto a laptop computer each night and backed up on a separate hard drive. Each evening the downloaded data will be mapped using ArcGIS and checked to be sure all surveyed area data for that day were included in the GIS and on the digital draft map. Metadata will be reported with descriptions of data files, data fields and nature of attribute values. All point, polygon and line features will be stored in one file geodatabase as separate feature classes with metadata stored with each feature class. Metadata will adhere to the standards recommended for the USFWS (Federal Geographic Data Committee, https://www.fgdc.gov/metadata/geospatial-metadata-tools). Data will be provided to USFWS for storage and archiving. Any paper data sheets will be scanned and also provided. End of week report will be provided to Point Blue Conservation Science to be included in their daily/weekly logs on the island.

Analysis Methods

Data Analysis and Processing:

Data collected as point and line features will be converted to polygon features by buffering (using ArcGIS toolset) each point or line to its associated radius or length derived from field measurements. Buffering will allow for area calculations and increase visibility on maps. Point, line, polygon area feature attributes will be used to calculate percent area inventoried and percent area infested.

Additional data post survey will include: Total area surveyed, percentage of area surveyed, total area infested, area of infestation by species for total area surveyed, percent of area infested, area of infestation by species per inventory area, percent of area infested by inventory area and species, number of features; patches, linear features and polygons by total area and each inventory unit.

Mapping: using ArcGIS and Adobe Illustrator maps of area surveyed, track logs, targeted species documented in total area and within each inventory area and targeted species maps of the surveyed area will be created.
In addition to maps, non-native plant occurrence data will be summarized in total and by each inventory area in the text and tables. They include:

- total area surveyed on the islands and percent of islands surveyed
- total area of each inventory area surveyed
- percentage of inventory area surveyed
- total area of non-natives inventoried by species with average canopy cover
- total area of non-natives inventoried by species with phenology
- the number of features identified by species and total number of features
- adjusted area of targeted species by inventory area.

Adopted from Elwood et al. (2013) and modified to fit the needs of this inventory, an adjusted area procedure will be used to reduce the potential for generating numbers that could be an over-representation of the area infested (ha) by invasive plant species. The procedure will be executed within the GIS environment (ArcMap version 10.3.1) and be comprised of two major geoprocessing steps. Step one identified all like geospatial features from the inventory (buffered patches, buffered lines and/or polygons) that possess the same desired attribute, i.e. the same species or location within a given inventory area, and merged them into a single feature class. Step two locates all overlapping features within that newly formed feature class and dissolves them into a single, stand-alone feature. The area values of dissolved features (ha) will be calculated alongside the area values of non-dissolved features (ha) to establish the final adjusted area (ha).
All values representing area infested (ha) in this inventory will be a result of this adjustment procedure. The procedure will be employed in two separate instances, producing two mutually exclusive results. Values representing area infested (ha) per target species will be the result of the merger and dissolving of all plant features that belong to each individual target species or species group across the entire study area. Values representing hectares infested (ha) per inventory area will be a result of the merger and dissolving of all invasive plant features found within a given inventory area. The results from the inventory area specific adjustments will therefore be lower than the results calculated from the individual species/species group adjustments.

Voucher specimen collection. A specimen will be collected for each initial discovery of a target species. Specimens will include the following information: family, genus, species, subspecies/variety, date, collector's name, location (Refuge, unit), description of environment (e.g., slope, marine terrace), brief description of plant, plant frequency at collection location (e.g. abundant, common, uncommon, rare). Specimens will be delivered to California Academy of Sciences for archiving.

Element 5: Reporting

The report will include the following:

- methods used and any modifications to the protocol in the field.
- total area surveyed on the islands and percent of islands surveyed
- total area of each inventory area surveyed
- percentage of inventory area surveyed
- total area of non-natives inventoried by species with average canopy cover
- total area of non-natives inventoried by species with phenology
- the number of features identified by species and total number of features
- adjusted area of targeted species by inventory area.
- maps of total Refuge and all target species detected
- maps of each inventory area with all target specie detected
- maps of individual target species and where they were detected on the Refuge with canopy classes noted

Report will be distributed to USFWS- Farallon Refuge, Point Blue Conservation Science. Inventory reports should be catalogued in ServCat and data.gov

Element 6: Personnel Requirements and Training

Crew includes individuals with expertise in mapping, using GNSS devices and or plant identification/botany. It is important to have members of team with both expertise to accurately inventory the area. Expertise in GIS and familiarity with statistics using Excel or some platform is needed for post-processing the data. Each crew member should be training in using the GNSS device as well as be familiar with all target species. It is helpful to have a botanist on board to identify other species on the island in case of new introductions as well as review and test crew for properly identification. The plant identification binder should be available to crews on the island to help in plant identification.

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Appendix C. Track Logs

C1: Track logs for Spring surveys

(see Figure 6a-c for map and attached CD for GIS data file).

Spring Survey Log: 20-31 March 2016			
Date	**Surveyors**	**Inventory Areas Surveyed**	**Distance Walked (Km)**
20-Mar	BH, QC, KK, RC, LS, GM	NE, MT	2.29
21-Mar	BH, QC, KK, RC, LS, GM	NE, MT	6.06
22-Mar	BH, QC, KK, RC, LS	NE, MT	4.8
23-Mar	BH, QC, KK, RC, LS	SS, MT	8.09
24-Mar	BH, QC, KK, RC, LS, GM	WEI, NE	8.48
25-Mar	BH, QC, KK, RC, LS	MT, CBH, SS, NS	2.76
30-Mar	QC	NE, P, CBH	4.48
31-Mar	QC	NE, MT, P	7.11
Surveyors			
BH = Barbara Holzman			
QC = Quentin Clark			
KK = Kerstin Kalchmayr			
RC = Richard Chasey			
LS = Lauren Scheinberg			
GM= Gerard McChesney			
Inventory Areas			
NS = North End			
SS = South Slope			
MT = Marine Terrace			
WEI = West End Island			
CBH = Corm Blind Hill			
P = Perimeter			

C2: Track logs for Summer survey

Summer Survey Log: 23 – 29 July,2016			
Date	**Surveyors**	**Inventory Areas Surveyed**	**Distance Walked (Km)**
24-July	QC, JB, SF, RT	MT	5.27
25-July	QC, JB, SF, RT	MT	3.23
26-July	QC, JB, SF, RT	SS	4.17
27-July	QC, JB, SF, RT	NE, SS, P	4.67
28-July	QC, JB, SF, RT	NE, WEI, P	7.50
29-July	QC	CBH, P	0.25
Surveyors			
QC = Quentin Clark			
JB = Jeffrey Blumenthal			
SF = Sarah Fiori			
RT = Rob Thoms			
Inventory Areas			
NS = North End			
SS = South Slope			
WEI = West End Island			
MT = Marine Terrace			
CBH = Corm Blind Hill			
P = Perimeter			

Appendix D: Inventory Data Dictionary

Inventory Data Dictionary:
A data dictionary file (.ddf) was created the inventory using the Data Dictionary Editor wizard in GPS Pathfinder Office (version 5.70), and was transferred to Terrasync (version 5.81) for use on the GPS receivers utilized during data collection. The .ddf contained four unique features: 'Non_native_plant' point feature, 'Non_native_plant' line feature, 'Non_native_plant' polygon feature and 'Non_Target_Species' point feature.

The 'Non_native_plant' point feature was used for collecting positions of invasive plant features that were classified as patches. The feature consisted of the following attribute fields: 'Observer_Name', 'Collection_Date', 'Time', 'Unit_Name', 'Scientific_Name', 'Canopy_Cover', 'Phenology', 'Patch_radius', 'Native_Vegetation' and 'Comments'. The 'Non_native_plant' line feature was used for collecting positions of invasive plant features that were classified as linear features. The feature was comprised of the same attribute fields as the 'Non_native_plant' point feature, with a 'line_width' field in place of the 'patch_radius' field as the only exception. The 'Non_native_plant' polygon feature was used for collecting positions of invasive plant features that were classified as polygons. The feature contained an identical set of attribute fields as the other two 'Non_native_plant' features, however it did not contain a field for either patch radius or line width. The 'Non_Target_Spcies' point feature was used for collecting positions of any non-target non-native species that were discovered during the inventory. The feature was comprised of the same attribute fields as the 'Non_native_plant' point feature. For all four features in the .ddf, an entry for each attribute field, except for 'Native_Vegetation' and 'Comments', was required before a feature could be closed and a final feature position logged.

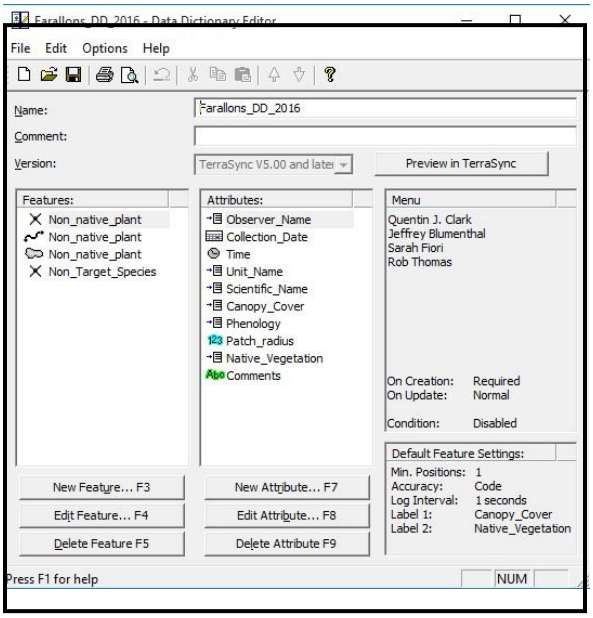

Figure D.1: Screen shot of data dictionary file developed for the 2016 South Farallon Islands Inventory.

Appendix E: Inventory GIS Metadata

2016 South Farallon Islands Invasive Plant Inventory- Metadata

1. Anthropogenic Structures

- Summary: Series of polygon features representing anthropogenic structures on Southeast Farallon Island, California.
- Credits: Hawk, J.L. 2015. Classification, vegetation-environment relationships, and distribution of plant communities on Southeast Farallon Island, California. M.A. thesis, San Francisco State University, San Francisco, CA, US.
- Author: Jamie Hawk
- Coordinate System: NAD 1983 UTM Zone 10 North
- Linear Unit: Meters
- Hardware Used: Trimble GeoXH 6000 GNSS Unit
- Software Used: Terrasync (version 5.4), Pathfinder Office (version 5.4), ArcGIS (version 10.1).
- Fields:
    i. OBJECTID – Internal feature number
    ii. Shape – Feature geometry
    iii. Zone_Desc – A text string fully describing each mapping unit code (aka zone column).
    iv. Comment – Text string with general comments and field notes.
    v. Shape_Length – Length of feature in internal units.
    vi. Shape_Area - Area of feature in internal units squared.

2. Island Trails

- Summary: Series of linear features representing trails of Southeast Farallon Island, California.
- Credits: Hawk, J.L. 2015. Classification, vegetation-environment relationships, and distribution of plant communities on Southeast Farallon Island, California. M.A. thesis, San Francisco State University, San Francisco, CA, US.
- Author: Jamie Hawk
- Coordinate System: NAD 1983 UTM Zone 10 North
- Linear Unit: Meters
- Hardware Used: Trimble GeoXH 6000 GNSS Unit
- Software Used: Terrasync (version 5.4), Pathfinder Office (version 5.4), ArcGIS (version 10.1).
- Fields:
    i. OBJECTID – Internal feature number
    ii. Shape – Feature geometry
    iii. Shape_Length – Length of feature in internal units.

3. Contours 10 meters

- Summary: Series of linear features representing the terrestrial elevation of South Farallon Islands, California.
- Credits: B.A Holzman, Clark, Q.J. Farallon National Wildlife Refuge: 2016 Invasive Plant Inventory. U.S. Fish and Wildlife Service, 2016.
- Author: Quentin J. Clark
- Coordinate System: NAD 1983 UTM Zone 10 North
- Linear Unit: Meters
- Software Used: ESRI ArcGIS (version 10.3.1)
- Fields:
    i. OBJECTID – Internal feature number
    ii. Shape – Feature geometry
    iii. Contour – Values representing elevation above mean sea level on the South Farallon Islands. Units are in meters.
    iv. Shape_Length – Length of feature in internal units.

4. Inventory Areas

- Summary: Series of polygons representing arbitrarily delineated inventory areas used for an invasive plant survey conducted on the South Farallon Islands, California in 2016.
- Credits: B.A Holzman, Q.J. Clark, Farallon National Wildlife Refuge: 2016 Invasive Plant Inventory. U.S. Fish and Wildlife Service, 2016.
- Author: Quentin J. Clark
- Coordinate System: NAD 1983 UTM Zone 10 North
- Linear Unit: Meters
- Software Used: ESRI ArcGIS (version 10.3.1)
- Fields:
    i. OBJECTID – Internal feature number
    ii. Shape – Feature geometry
    iii. Study_Area – Provides the arbitrarily defined title for the delineated inventory areas used in the 2016 South Farallon Islands invasive plant inventory. Inventory area titles have been established solely for this inventory and do not represent official titles used by the U.S. Fish and Wildlife Service. Inventory area titles are: North End, South Slope, Marine Terrace, West End Island, Corm Blind Hill, Perimeter.
    iv. Priority Value - Whole numbers defining the features priority level according to the IDEPT (Olson et al. 2015) and research personnel. Value range is from 1 - 6, with 1 representing the highest priority level and 6 the lowest. Factors considered for prioritization include the following: presence of invasive plant species, presence of native plant species, dominant plant assemblages (native vs. invasive), invasive plant species richness, vectors available to invasive plant species, and accessibility for research staff.
    v. Inventory_Area – Area of feature in internal units squared. Units are in hectares.
    vi. SHAPE_Length – Length of feature in internal units.

vii. SHAPE_Area – Area of feature in internal units squared.

5. Inventory Areas (Topology)
    - Summary: Topology classification for Inventory Areas feature class.
    - Credits: Credits: B.A Holzman, Clark, Q.J. Farallon National Wildlife Refuge: 2016 Invasive Plant Inventory. U.S. Fish and Wildlife Service, 2016.
    - Author: Quentin J. Clark
    - Coordinate System: NAD 1983 UTM Zone 10 North
    - Linear Unit: Meters
    - Software Used: ESRI ArcGIS (version 10.3.1)
    - Topology Type: Full Planar Graph

6. South Farallon Islands Shoreline

- Summary: Shoreline of South Farallon Islands as determined by mean high tide.
- Credits: Teale Data Center, US Geological Survey (2001) 1:24 000 topographic map series.
- Author: Teale Data Center, US Geological Survey (2001)
- Coordinate System: NAD 1983 UTM Zone 10 North
- Linear Unit: Meters
- Software Used: ESRI ArcGIS (version 10.3.1)
- Fields:
    i. OBJECTID – Internal feature number
    ii. Shape – Feature geometry
    iii. Shape_Length – Length of feature in internal units.

7. Transect Lines

- Summary: Dataset containing one feature class comprised of linear features representing transect lines walked by San Francisco State University research personnel during the 2016 South Farallon Island invasive plant survey.
- Credits: B.A Holzman, Clark, Q.J. Farallon National Wildlife Refuge: 2016 Invasive Plant Inventory. U.S. Fish and Wildlife Service, 2016.
- Author: Quentin J. Clark
- Coordinate System: NAD 1983 UTM Zone 10 North
- Linear Unit: Meters
- Software Used: ArcGIS (version 10.3.1)
- Fields:
    i. OBJECTID – Internal feature number
    ii. Shape – Feature geometry
    iii. Line_ID – Alphanumeric identifier established for each feature.
    iv. Shape_Length – Length of feature in internal units.

8. Track Logs

- Summary: Dataset containing two feature classes representing areas physically travelled by San Francisco State University personnel during the 2016 South Farallon Island invasive plant inventory.
- Credits: B.A Holzman, Clark, Q.J. Farallon National Wildlife Refuge: 2016 Invasive Plant Inventory. U.S. Fish and Wildlife Service, 2016.
- Author: Quentin J. Clark
- Coordinate System: NAD 1983 UTM Zone 10 North
- Linear Unit: Meters
- Hardware Used: Trimble Juno SB GNSS Unit
- Software Used: Terrasync (version 5.81), Pathfinder Office (version 5.70), ArcGIS (version 10.3.1)
- Fields:
    i. OBJECTID – Internal feature number
    ii. Shape – Feature geometry
    iii. GPS_Date – Date feature was collected (mm/dd/yyyy). Field generated automatically at time of collection.
    iv. GPS_Time – Time feature was collected (hh:mm:ss). Field generated automatically at time collection.

9. 2016 South Farallon Islands Invasive Plant Inventory Data Dictionary

- Summary: A data dictionary file (.ddf) used for data collection of invasive plant features during 2016 South Farallon Islands invasive plant inventory. Data dictionary used on Trimble GeoExplorer 2008 Series and Trimble Juno SB GNSS units.
- Credits: B.A Holzman, Clark, Q.J. Farallon National Wildlife Refuge: 2016 Invasive Plant Inventory. U.S. Fish and Wildlife Service, 2016.
- Author: Quentin J. Clark, San Francisco State University
- Software used: Pathfinder Office (version 5.70)
- Fields:
    i. Observer_Name – Name of person who collected feature position.
    ii. Collection_Date – Date when feature was collected (mm/dd/yyyy). Field generated automatically at time of collection.
    iii. Time – Time when feature was collected (hh:mm:ss). Field generated automatically at time of collection.
    iv. Unit_Name – Name of inventory area where feature was collected. Inventory area names are: North End, South Slope, Marine Terrace, West End Island, Corm Blind Hill, or Perimeter.
    v. Scientific – Scientific name (ITIS) of a feature. Annual_grasses = annual grasses species group, Chenopodium_murale = *Chenopodium murale*, Coprosma_repens = *Coprosma repens*, Ehrharta_erecta = *Ehrharta erecta*, Malva_arborea = *Malva arborea*, Malva_spp. = *Malva spp.* group, Oxalis_pes-caprae = *Oxalis pes-caprae*, Plantago_coronopus = *Plantago coronopus,* Rumex_spp. = *Rumex spp.* group, Senecio_vulgaris = *Senecio vulgaris*, Sisymbrium_orientale = *Sisymbrium orientale*,

Sonchus_spp. = *Sonchus spp*. group and T_tetragonioides = *Tetragonia tetragonioides.*

vi. Canopy_Cover – Canopy cover of a feature. Values are coded using positive whole numbers. 1 = < 1 % canopy cover, 2 = 1 - 10 % canopy cover, 3 = 10 - 25 % canopy cover, 4 = 25 - 60 % canopy cover and 5 = > 60 % canopy cover.

vii. Phenology – Phenology classification of a feature. Field generated manually by collector. Values are coded using alpha characters. R = Rosette, PrF = PreFlower, F = Flowering, PoF = PostFlower, S = Senesced.

viii. Patch_radius – Radius of point feature. Radius determined using a digital range finder (Opti-Logic Insight 1000 LH). Minimum mapping unit is 2-meter radius.

ix. Native_Vegetation – Native vegetation present at time of collection. No data is an applicable submission. Lasthenia_maritima = *Lasthenia maritima*, Spergularia_macrotheca = *Spergularia macrotheca*, Claytonia_perfoliata = *Claytonia perfoliata*, Lasthenia/Spergulria mix = Mixture of *Lasthenia maritima* and *Spergulria macrotheca*, Lasthenia/Claytonia mix = Mixture of *Lasthenia maritima* and *Claytonia perfoliata* and Bare_soil/rocky = bare soil or exposed rock with no vegetation.

x. Comments – Additional comments regarding feature. No data is an applicable submission.

10. Invasive Plant Features (Inventory Area)

- Summary: A dataset containing a collection of feature classes that represent all invasive plant features collected on the South Farallon Islands across both the spring and summer 2016 inventories. Feature classes are classified according to inventory area.
- Credits: B.A Holzman, Clark, Q.J. Farallon National Wildlife Refuge: 2016 Invasive Plant Inventory. U.S. Fish and Wildlife Service, 2016.
- Author: Quentin J. Clark
- Coordinate System: NAD 1983 UTM Zone 10 North
- Linear Unit: Meters
- Hardware Used: Trimble GeoExplorer 2008 Series GNSS Unit & Trimble Juno SB GNSS Unit
- Software Used: Terrasync (version 5.81), Pathfinder Office (version 5.70) & ArcGIS (version 10.3.1)
- Fields:
    i. OBJECTID – Internal feature number
    ii. Shape – Feature geometry
    iii. Observer_N – Name of person who collected feature position. Field generated manually by collector.
    iv. Collection – Date when feature was collected (mm/dd/yyyy). Field generated automatically at time of collection.
    v. Time – Time when feature was collected (hh:mm:ss). Field generated automatically at time of collection.

vi. Unit_Name – Name of inventory area where feature was collected. Field generated manually by collector. Inventory area options are: North End, South Slope, Marine Terrace, West End Island, Corm Blind Hill, or Perimeter.

vii. Scientific – Scientific name (ITIS) of a feature. Field generated manually by collector. Annual_grasses = annual grasses species group, Chenopodium_murale = *Chenopodium murale*, Coprosma_repens = *Coprosma repens*, Ehrharta_erecta = *Ehrharta erecta*, Malva_arborea = *Malva arborea*, Malva_spp. = *Malva spp.* group, Oxalis_pes-caprae = *Oxalis pes-caprae*, Plantago_coronopus = *Plantago coronopus,* Rumex_spp. = *Rumex spp.* group*,* Senecio_vulgaris = *Senecio vulgaris*, Sisymbrium_orientale = *Sisymbrium orientale*, Sonchus_spp. = *Sonchus spp*. group and T_tetragonioides = *Tetragonia tetragonioides.*

viii. Canopy_Cov – Canopy cover of a feature. Field generated manually by collector. Values are coded using positive whole numbers. 1 = < 1 % canopy cover, 2 = 1 - 10 % canopy cover, 3 = 10 - 25 % canopy cover, 4 = 25 - 60 % canopy cover and 5 = > 60 % canopy cover.

ix. Phenology – Phenology classification of a feature. Field generated manually by collector. Values are coded using alpha characters. R = Rosette, PrF = PreFlower, F = Flowering, PoF = PostFlower, S = Senesced.

x. Native_Veg – Native vegetation present at time of collection. Field generated manually by collector. No data is an applicable submission. Lasthenia_maritima = *Lasthenia maritima*, Spergularia_macrotheca = *Spergularia macrotheca*, Claytonia_perfoliata = *Claytonia perfoliata*, Lasthenia/Spergulria mix = Mixture of *Lasthenia maritima* and *Spergulria macrotheca*, Lasthenia/Claytonia mix = Mixture of *Lasthenia maritima* and *Claytonia perfoliata* and Bare_soil/rocky = bare soil or exposed rock with no vegetation.

xi. Comments – Additional comments regarding feature. Field generated manually by collector. No data is an applicable submission.

xii. HA_Area – Area of buffered feature or polygon feature in hectares. Generated during post-processing.

xiii. Line_Width – Width of linear feature. Field generated manually by collector. Width determined using a digital range finder (Opti-Logic Insight 1000 LH). Values are positive real numbers. Minimum mapping unit is a width of 2 meters.

xiv. BUFF_DIST – Value used to create buffered features. Buffered features are both point and line features. Generated during post-processing. Values for buffered point feature is equivalent to patch radius value, value for buffered linear feature is equivalent to .5 of line width value.

xv. Patch_radi – Radius of point feature. Field generated manually by collector. Radius determined using a digital range finder (Opti-Logic Insight 1000 LH). Minimum mapping unit is 2-meter radius.

xvi. GNSS_Heigh – Height of patch feature above mean sea level (not applicable for line or polygon features). Units are in meters. Field generated automatically when position is collected.

11. Invasive Plant Features (Species Specific)

- Summary: A dataset containing a collection of feature classes that represent all invasive plant features collected on the South Farallon Islands across both the spring and summer 2016 inventories. Feature classes are classified according to species and/or species group.
- Credits: B.A Holzman, Clark, Q.J. Farallon National Wildlife Refuge: 2016 Invasive Plant Inventory. U.S. Fish and Wildlife Service, 2016.
- Author: Quentin J. Clark
- Coordinate System: NAD 1983 UTM Zone 10 North
- Linear Unit: Meters
- Hardware Used: Trimble GeoExplorer 2008 Series GNSS Unit & Trimble Juno SB GNSS Unit
- Software Used: Terrasync (version 5.81), Pathfinder Office (version 5.70) & ArcGIS (version 10.3.1)
- Fields:
    i. OBJECTID – Internal feature number
    ii. Shape – Feature geometry
    iii. Observer_N – Name of person who collected feature position. Field generated manually by collector.
    iv. Collection – Date when feature was collected (mm/dd/yyyy). Field generated automatically at time of collection.
    v. Time – Time when feature was collected (hh:mm:ss). Field generated automatically at time of collection.
    vi. Unit_Name – Name of inventory area where feature was collected. Field generated manually by collector. Inventory area options are: North End, South Slope, Marine Terrace, West End Island, Corm Blind Hill, or Perimeter.
    vii. Scientific – Scientific name (ITIS) of a feature. Field generated manually by collector. Annual_grasses = annual grasses species group, Chenopodium_murale = *Chenopodium murale*, Coprosma_repens = *Coprosma repens*, Ehrharta_erecta = *Ehrharta erecta*, Malva_arborea = *Malva arborea*, Malva_spp. = *Malva spp.* group, Oxalis_pes-caprae = *Oxalis pes-caprae*, Plantago_coronopus = *Plantago coronopus,* Rumex_spp. = *Rumex spp.* group*,* Senecio_vulgaris = *Senecio vulgaris*, Sisymbrium_orientale = *Sisymbrium orientale*, Sonchus_spp. = *Sonchus spp*. group and T_tetragonioides = *Tetragonia tetragonioides.*
    viii. Canopy_Cov – Canopy cover of a feature. Field generated manually by collector. Values are coded using positive whole numbers. 1 = < 1 % canopy cover, 2 = 1 - 10 % canopy cover, 3 = 10 - 25 % canopy cover, 4 = 25 - 60 % canopy cover and 5 = > 60 % canopy cover.
    ix. Phenology – Phenology classification of a feature. Field generated manually by collector. Values are coded using alpha characters. R = Rosette, PrF = PreFlower, F = Flowering, PoF = PostFlower, S = Senesced.
    x. Native_Veg – Native vegetation present at time of collection. Field generated manually by collector. No data is an applicable submission. Lasthenia_maritima = *Lasthenia maritima*, Spergularia_macrotheca = *Spergularia macrotheca*,

Claytonia_perfoliata = *Claytonia perfoliata*, Lasthenia/Spergulria mix = Mixture of *Lasthenia maritima* and *Spergulria macrotheca*, Lasthenia/Claytonia mix = Mixture of *Lasthenia maritima* and *Claytonia perfoliata* and Bare_soil/rocky = bare soil or exposed rock with no vegetation.

xi. Comments – Additional comments regarding feature. Field generated manually by collector. No data is an applicable submission.

xii. HA_Area – Area of buffered feature or polygon feature in hectares. Generated during post-processing.

xiii. Line_Width – Width of linear feature. Field generated manually by collector. Width determined using a digital range finder (Opti-Logic Insight 1000 LH). Values are positive real numbers. Minimum mapping unit is a width of 2 meters.

xiv. BUFF_DIST – Value used to create buffered features. Buffered features are both point and line features. Generated during post-processing. Values for buffered point feature is equivalent to patch radius value, value for buffered linear feature is equivalent to .5 of line width value.

xv. Patch_radi – Radius of point feature. Field generated manually by collector. Radius determined using a digital range finder (Opti-Logic Insight 1000 LH). Minimum mapping unit is 2-meter radius.

xvi. GNSS_Heigh – Height of patch feature above mean sea level (not applicable for line or polygon features). Units are in meters. Field generated automatically when position is collected.

Appendix F: Photos of 2016 inventory

Figure F-1: Spring 2016 Farallon Inventory Team: (from left to right) Kerstin Kalchmayr, Gerry McChesney, Barbara Holzman, Lauren Scheinberg, Richard Chasey and Quentin Clark.

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Figure F-2: Summer 2016 Farallon Inventory Team (from left to right) Sarah Fiori, Quentin Clark missing Jeff Blumenthal and Robert Thoms.

Figure F-3: Chenopodium murale
(Photo ©2005 Luigi Rignanese)

Figure F-4:Coposma repens
(Photo: http://www.esc.nsw.gov.au/living-in/about/our-natural-environment/introduced-plants-and-animals/weeds/weed-profiles/mirror-bush-coprosma-repens/Coprosma-repens2.jpg)

Figure F-5: Ehrharta erecta (Photo Quentin Clark)

Figure F-6: Malva arborea

Figure F-7: Oxalis pes-caprae

Figure F-8: Plantago coronopus

Figure F-9: Rubus bifrons (Photo http://weedwise.conservationdistrict.org/wp-content/uploads/sites/2/2013/05/photo-1-copy.jpg)

Figure F-9: Senecio vulgaris

Figure F-10: Sisymbrium orientale (Hedge mustard) center with Lasthenia maritima

Figure F-0-1: Tetragonia tetragonioides

Figure F-12: Avena fatua: part of the annual grass group (Photo ©2006 Louis-M. Landry)

Figure F-13: Avena barbata: part of the annual grass group (Photo ©2001 Steven Thorsted)

Figure F-14: Bromus diandrus, part of the annual grass group.

Figure F-16: Vulpia bromoides: part of the annual grass group. (Photo http://luirig.altervista.org/biology/

Figure F-15: Hordeum murinum, part of the annual grass group.

Figure F-17: Rumex crispus part of the Rumex spp. group

Figure F-18::Rumex acetosella part of the Rumex spp. group (Photo http://hasbrouck.asu.edu/imglib/seinet/

Figure F-19: Sonchus oleraceus part of the Sonchus spp. group

Figure F-20: Sonchus asper part of the Sonchus spp. group

Figure F-21: Malva neglecta, part of the Malva spp. group (Photo http://www.easterncoloradowildflowers.com/Malva%20neglecta.htm)

Figure F-22: Malva parviflora, part of the Malva spp. group

Figure F-23: Malva pseudolavatera, part of the Malva spp. group (Photo ©2006 Luigi Rignanese)

Figure F-24: Large patch of annual grass.

Figure F-25: Large and small swaths of annual grasses on the Marine terrace. Because each patch was in close proximity the area was mapped as a polygon.

Appendix G: Rapid response posters

BE ON THE LOOKOUT FOR THIS PLANT

Oriental hedge mustard (Sisymbrium orientale)

Oriental or Indian hedge mustard is an invasive plant on SEFI. If you see it take care to remove it along with its roots.

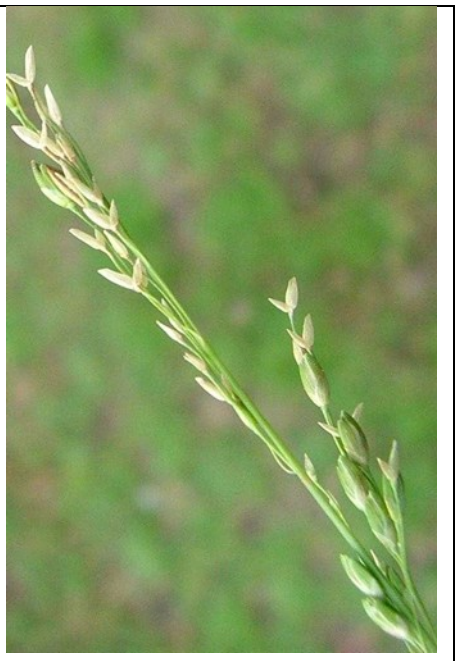
Description:
A tall, branched weed with long (up to 12 cm) narrow pods. The lower rosette leaves are deeply lobed, but the degree to which the leaf is lobed decreases up the stem. The upper leaves are unlobed. All leaves have a distinct petiole (leave stalk). The stems, leaves and pods are slightly hairy with unbranched hairs. The flowers are yellow, with petals about twice the length of the sepals. Flowers typically April-August.

Last seen: North of trail to east landing and behind Carpenter shop between water catchments.

If you see this species please remove it and please report it to Refuge Manager.

BE ON THE LOOKOUT FOR THIS PLANT

Ehrharta grass or Veldt Grass (*Ehrharta erecta*)



Description: Stems: culms erect or ascending from a base along the ground, branching, 12-24 in (30-60 cm) tall. Leaves are flat blades 2-5 in (5-12 cm) long, 0.2-0.4 in (4-9 mm) wide. Inflorescence (grass flower): 2-6 in (6-15 cm) long, contracted to open panicle. Laterally compressed attached directed to flower stem or with small stalk, 0.1 in (3-3.5 mm), falling as one unit. Glumes 0.06-0.1 in (1.5-3 mm), about equal, longer than sterile florets. Three florets per spikelet, lower two sterile and without palea; upper floret fertile with palea. Sterile lemmas awnless, glabrous (Hickman 1993).

Ehrharta (Ehrharta erecta) is a perennial grass, with a crabgrass-like habit with decumbent as well as ascending jointed stems. The sterile lemmas of E. erecta are without awns. Ehrharta grass is a **very invasive** plant on SEFI. If you see it take care to remove it along with its roots.

Last seen: on South slope on trail to lighthouse. If you see this species please remove it and please report it to Refuge Manager.

END