

Developing an Observational Database for Golden
paintbrush (*Castilleja levisecta*)

Prepared for
US Fish and Wildlife Service

Prepared by
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ON THE COVER: Golden paintbrush (*Castilleja levisecta*), observed at Ebey's Landing, Washington.

Photograph from WNHP files.

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Introduction

Castilleja levisecta (Golden paintbrush) is a perennial herb with 3-5 lobed, bright yellow floral bracts and soft, slightly sticky-hairy stems. This member of the broomrape family (Orobanchaceae) is restricted to remnant prairie grasslands from southern Vancouver Island, British Columbia through the San Juan Islands and Puget Trough of western Washington to the northern Willamette Valley of northwestern Oregon (Camp and Gamon 2011). It is listed as Threatened under the US Endangered Species Act due to extensive conversion of prairie habitat to agriculture and human residential development, competition with invasive plant species, succession to wooded vegetation in the absence of disturbance, and hybridization with the related species, *Castilleja hispida* (Fertig 2019).

Rangewide, *Castilleja levisecta* is currently known from 12 extant and 26 historical or presumed extirpated occurrences. As part of the ongoing effort to recover (and ultimately de-list) this species, 59 new locations have been planted with plugs or seeds since 2007 to establish new populations within the species' historic range in Oregon, Washington, and British Columbia. At least 42 of these "outplantings" have been successfully established (based on the long-term persistence and reproduction of *C. levisecta* plants), including 10 in Washington (Dunwiddie and Pelant 2019), one in British Columbia, and 31 in Oregon (Kaye 2019). As of 2019, outplanted populations contained over 333,000 individuals, compared to just 2800 plants estimated from surviving, naturally occurring populations in Washington and British Columbia (Fertig 2019, Fertig 2020, in press).

Keeping track of annual monitoring data of naturally occurring and outplanted populations of *Castilleja levisecta* is critically important for tracking progress towards recovery of the species. It has also been a data management challenge due to the large number of records found across multiple states and jurisdictions. For more than a decade, the Washington Natural Heritage Program (WNHP) has been a repository for statewide data on natural occurrences of *C. levisecta* in the state and for outplantings in Oregon, Washington, and British Columbia (Fertig 2019). Location and annual monitoring data for extant and historical occurrences from Washington is maintained in WNHP's Biotics database. Comparable information from outplantings has not been stored in Biotics, which is intended for natural occurrences, but has been maintained in an Excel spreadsheet of ever-increasing complexity and in paper files in the WNHP office.

In 2019, WNHP received Section 6 funding from the US Fish and Wildlife Service to develop an ArcGIS-based observation database to better capture spatial and monitoring data for natural and outplanted occurrences of *Castilleja levisecta* in Washington. This database is modeled after a similar database developed for another federally listed plant species from the state, *Silene spaldingii* (Niggemann and Fertig 2018) and builds on similar efforts to standardize and record outplanted population data for the species in Oregon (Kaye 2019). The following report summarizes the development and application of such an observation-based system for *C. levisecta* occurrences in Washington.

Methods

We developed an ESRI geodatabase, version 10.6.1, based on the schema for the *Silene spaldingii* database (Niggemann and Fertig 2018) and created additional fields for various

population, habitat, location, and management attributes relevant to *Castilleja levisecta* conservation. The database was then populated with *C. levisecta* records from Biotics (WNHP 2020), outplanting data from Washington Natural Heritage Program files, and information from Dunwiddie and Pelant (2019). When available, we transferred population-specific data from comments fields in the original data via field mapping and by entering data by hand. Descriptions of each data element in the database, their dependencies, related IDs, and examples can be found in Table 3.

A new table was added to the database that was not in the *S. spaldingii* database: the “IOID_TO_EOID” table. This table connects Introduced Occurrences (IOs) that relate to Element Occurrences (EOs) from Biotics. At augmented populations, where outplantings of *C. levisecta* occur alongside natural populations, one IO will match to one or more EOs. This table relates the IDs across both datasets to connect introduced population data to the natural population surrounding it. This relationship is demonstrated in Figure 2, where there are three EOs within a <1km area of each other but only one IO. These EOs have previously been separated in Biotics for simplicity of tracking in Biotics, but the IO is consolidating these populations based on the actual EO separation guidelines (NatureServe 2004).

Observation data includes both observations of naturally occurring populations and observations of introduced populations. For this reason, the geometry of introduced source features are also found within the observation data (Figure 3). This duplication exists because the shapes are stored in the introduced_source_features table along with information specific to outplantings, such as the provenance of the plantings, whether seeds or plugs were planted, and how many plants were planted. The same geometries of those plantings are duplicated in the observations table as observations of the planting, with fields more specific to observational data like plant count method and who completed the survey.

Observations frequently overlap with other observations. On the right-side of Figure 3, for example, two polygons are displayed. But upon closer inspection, one will notice that selecting the blue polygon yields 17 records, indicating there have been 17 plantings in that area. Similarly, selecting the pink polygon would yield 28 records, for each time that the natural population has been visited and counted.

Appendix A includes metadata that explains the structure of the database and the various data entry fields in greater detail.

Results and Discussion

Along with this report, the *Castilleja levisecta* observation database was submitted to USFWS in file geodatabase format.

There are 511 separate observation records of *Castilleja levisecta* in Washington (Figure 1). These observations are distributed amongst 23 natural element occurrences and 31 introduced element occurrences. Occurrences are based on standardized rules developed by NatureServe (i.e., observations within 1 km are considered part of the same element occurrence, unless separated by a barrier that would restrict gene flow).

Over 43% of the observations of *C. levisecta* are from Island County, Washington. Combining Island County, Thurston County, and San Juan County observations accounts for over 95% of all observations (Table 1). About 50% of the observations come from private lands. Observations on county, state, and federal lands combine for the other 50% of *C. levisecta* observations (Table 2).

This database was designed to meet multiple information needs of the project's stakeholders, and will be useful for relocating known locations of *C. levisecta* for future monitoring. The basic data fields are easy to incorporate into existing monitoring protocols and data recording systems to facilitate data sharing. Figure 5 illustrates what information one might find when they "identify" an observation within the geodatabase in ArcGIS. This basic system can be readily adapted to accommodate data from other states with *C. levisecta* occurrences as well as other elements of biological diversity (plant and animal species or plant communities). It could also be used to help record absence data, which currently is rarely collected or archived. Absence data already exist in the database, and can be found when an observation listed for a date and the number of plants found is equal to zero. Fine-grained presence and absence data would greatly improve the ability of researchers to model the potential distribution of *C. levisecta* across its range.

The WNHP intends to continue to maintain and enhance this database as funding is available. Future enhancements include adding domain tables, constraints, and triggers to better control data integrity; moving the database to a cloud format, enabling approved entities outside of WNHP to enter and retrieve data; and creating a mobile device entry form that could then be used to populate the database. However, as built, the database will improve the ability to meet the recovery objectives for *C. levisecta* in Washington State.

Acknowledgements

This project was funded through a US Fish and Wildlife Service Traditional Section 6 grant (F18AF01214) to the Washington Natural Heritage Program. WNHP would like to thank staff with the USFWS and the Institute for Applied Ecology for their initial thoughts about observation databases. Additional appreciation goes out to thank Peter Dunwiddie and Adam Martin for providing information towards this effort. Lastly, WNHP wished to extend an extra large "thank you" to their former data manager, Rebecca Niggemann, who designed and built the *Silene* database, which provided the initial framework for this effort.

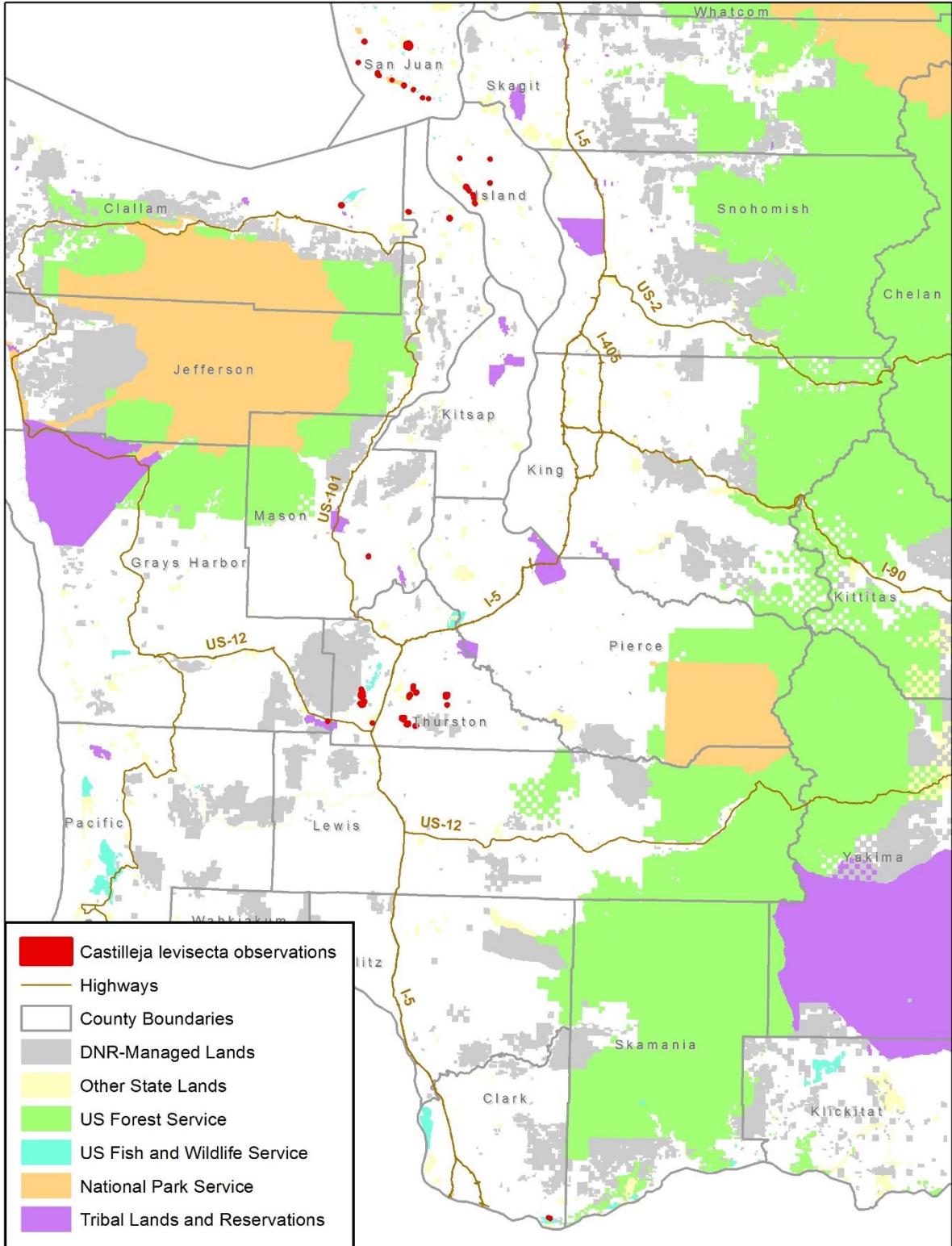


Figure 1. *Castilleja levisecta* observations in Washington; data are current as of March 6, 2020.

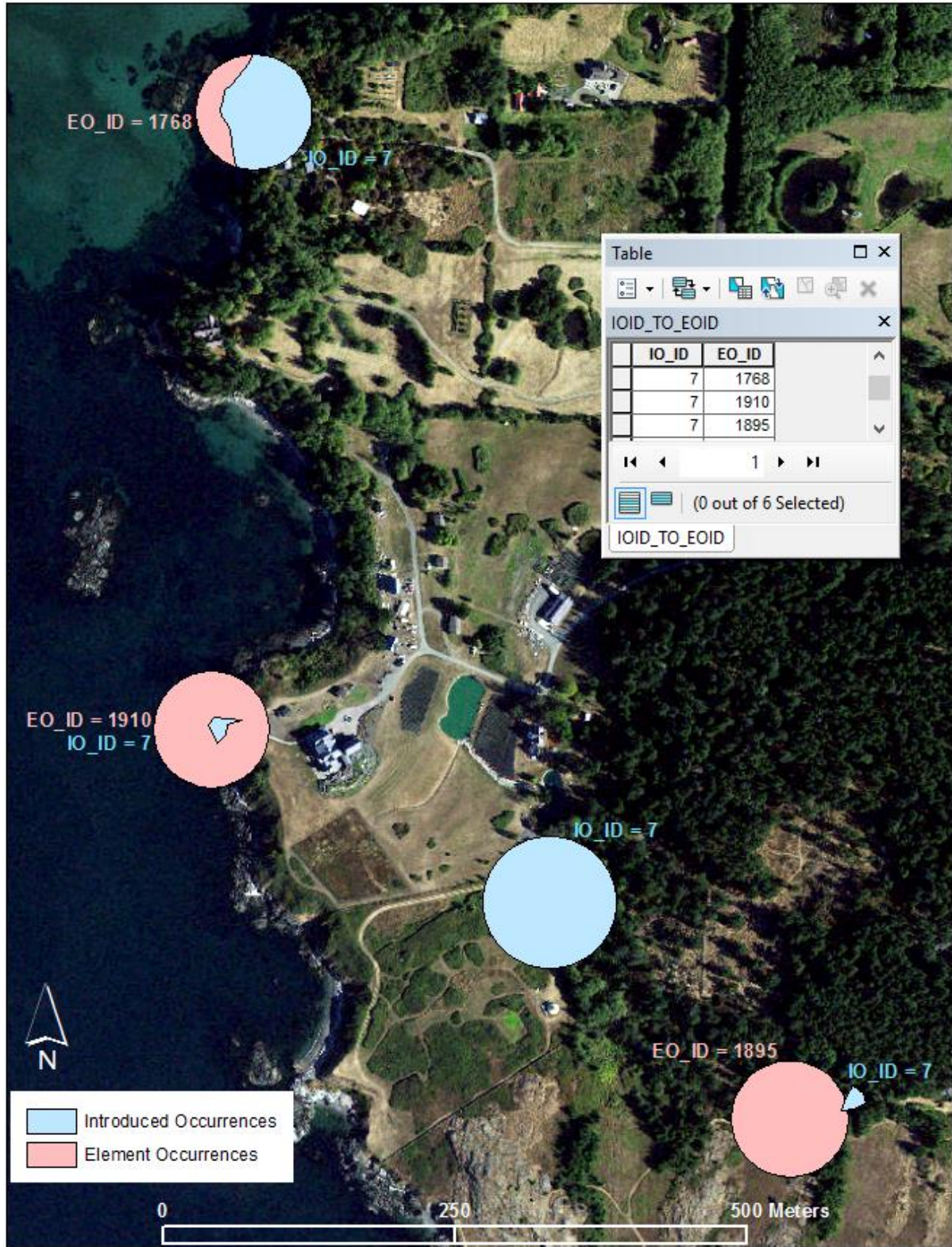


Figure 2: Connecting Introduced Occurrences (IOs) to their Element Occurrences (EOs). The reddish polygons are three EOs from Biotics that have been separated to help manage their information. The blue polygons represent one multi-part IO for the various outplantings in the area. The relationship between the EOs and IO in this map are highlighted in the IOID_TO_EOID table.

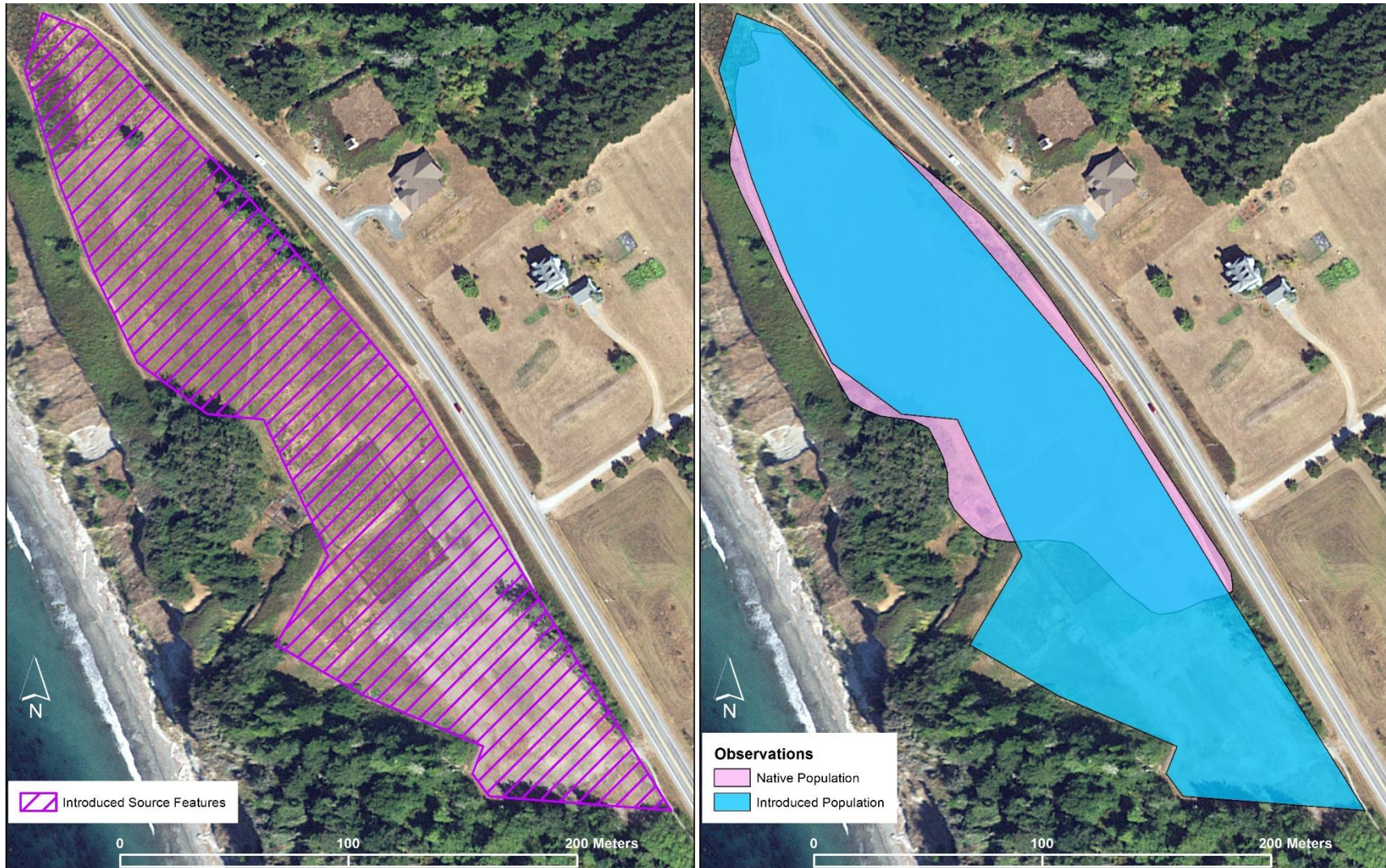
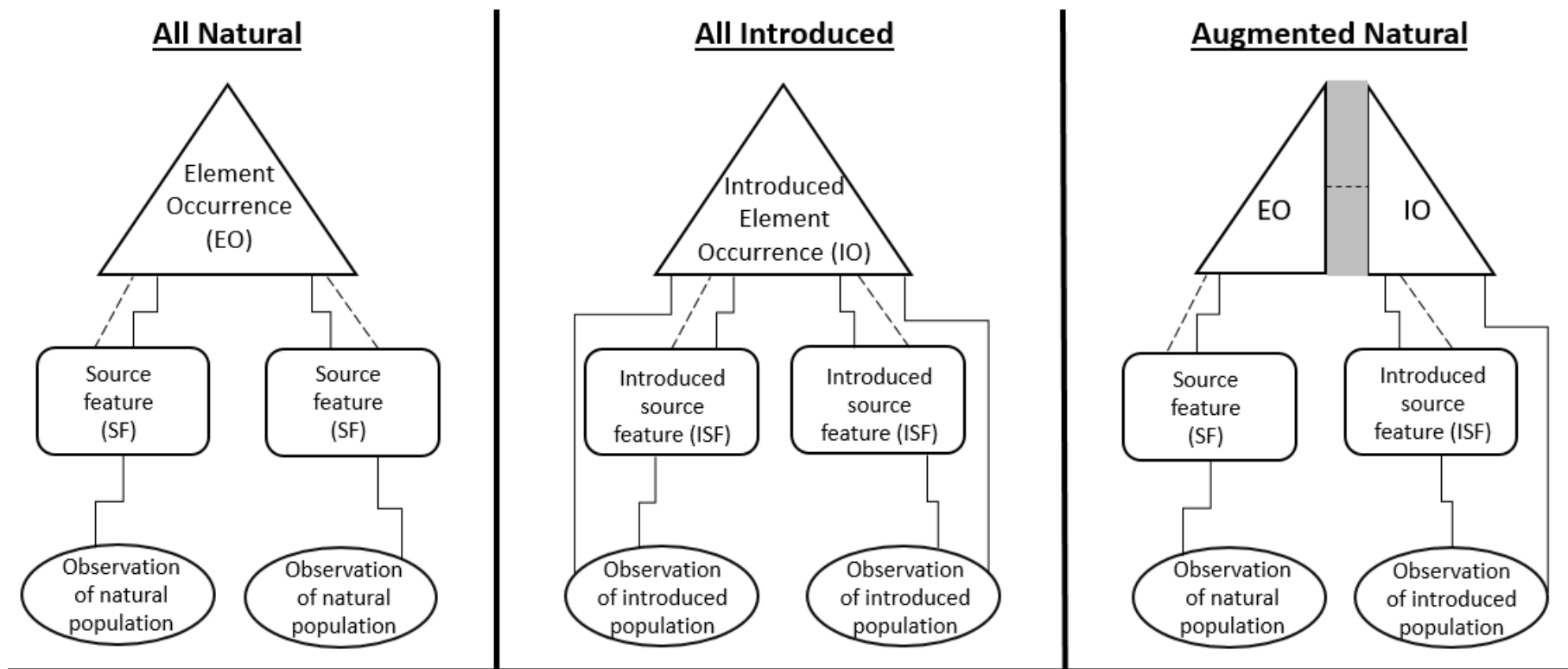


Figure 3: Overlapping introduced source features and observations. The polygon on the left represents several introduced source features with identical geometries, representing multiple *Castilleja levisecta* planting events. On the right are more overlapping polygons: the blue polygon has identical geometry to the introduced source features at left, and represents observations of planting events. The pink polygon represents observations of the *Castilleja levisecta* natural population.



--- Dashed straight line means the two features are connected through their data (e.g. IO_ID is one field within an introduced source feature record, and connects an Introduced Occurrence to the introduced source feature).

┌ Kinked solid line means the two features are connected spatially (e.g. an observation of a planting would share geometry with an introduced source feature; both observations and introduced source features fall within an EO and/or IO).

At an augmented population, there is some “grey area”. The EO and IO are connected via the IO_ID_TO_EO_ID lookup table, however the EO and IO shapes may, or may not, overlap. At an introduced population, only an IO is needed. At a natural population, only an EO is needed.

Figure 4: Schematic of the spatial and data relationships between observations, introduced source features, and occurrences.

Identify from: <Top-most layer>

- ... Castilleja levisecta
- ... Castilleja levisecta
- ... Castilleja levisecta
- ... Castilleja levisecta
- ... Castilleja levisecta
- ... Castilleja levisecta
- ... Castilleja levisecta
- ... Castilleja levisecta

Location: 123°3'36.622°W 48°28'25.793°N

Field	Value
OBJECTID	235
Shape	Polygon
OBSERVATION_ID	4958
SITE_ID	510
SCI_NAME	Castilleja levisecta
MONITOR_DATE	5/18/2006
MONITOR_YEAR	2006
NUMBER_PLANTS	352
PLANT_COUNT_UNITS	PLANTS
PLANT_EST_MAX	<null>
PLANT_EST_MIN	<null>
PLANT_COUNT_METHOD	CENSUS
SEEDLING_COUNT	<null>
VEGETATIVE_MATURE_COUNT	40
REPRO_COUNT	312
DEAD_COUNT	<null>
SURVEYOR	Arnett, J., & K. Birkhauser
OBSERVATION_COMMENTS	2006: 312 flowering and 40 v...
OBSERVATION_PHOTO_PATH	<null>
ID_DOCUMENTATION	<null>
SPP_CODE	CALE27
MAPPED_BY	Jake Kleinknecht
MAPPED_DATE	2/10/2020
DATA_SOURCE	Biotics5
FEDERAL_ID	<null>
IS_POP_INTRODUCED	FALSE
INTRO_SOURCE_FEATURE_ID	<null>
Shape_Length	412.281676
Shape_Area	13526.274649

Identified 16 features

Figure 5: Example of information contained within an observation record. You can see here that we know there was an observation from 2006 where 352 plants were counted, of which 312 were flowering plants and 40 were mature non-flowering plants. This population is naturally occurring (IS_POP_INTRODUCED = FALSE), and there are 15 other observations that have occurred in this same place (“Identified 16 features”).

Table 1. Number of *C. levisecta* observations by Washington county.

Number of Observations	County
3	Clallam
5	Clark
1	Grays Harbor
217	Island
7	Jefferson
1	King
1	Mason
1	Pierce
4	Skagit
176	Thurston
95	San Juan

Table 2. Number of *C. levisecta* observations in Washington state by land owner.

Number of Observations*	Owner
256	Private
5	US Bureau of Land Management
48	US Dept of Defense
10	US Fish and Wildlife Service
3	US National Park Service
66	Thurston County
2	University of Washington
32	WA Dept of Fish and Wildlife
40	WA Dept of Natural Resources
52	WA State Parks and Recreation Commission

* A small number of observations are double-counted since they cross multiple ownerships.

Table 3. Data definitions and relationships in the *Castilleja levisecta* observation database

Data concept	Spatial scale	Temporal scale	Dependencies	Related IDs	Example
Observations	One survey of plants	Hours to a few days, depending on how long the plant survey / outplanting takes to complete	N/A	N/A	John Smith counted 200 flowering plants in this location on this date
Managed Area	Larger area of land that is managed by a public entity or nonprofit to manage the rare plant	N/A	N/A		This area, managed by the National Park Service, has had various places where plants have been surveyed over time.
Introduced Source Feature (ISF)	One outplanting	Hours to a few days, depending on how long the outplanting takes to complete	All introduced source features are part of an introduced occurrence (Many:1 relationship ISFs:IOs) Note: all introduced source features have a corresponding observation with identical geometry and IS_POP INTRODUCED = True	Introduced Occurrence ID	This is an outplanting that occurred in this area on this date.
Introduced Occurrence (IO)	One area where outplantings occur, in which none of the source features are >1km apart, and there is no area of persistently unsuitable habitat to separate them	N/A	N/A Note: Some outplantings occur where natural populations already exist. For these augmented populations, there is a record connect the IO ID to the EO ID in the IOID_TO_EOID table. (Many:1 relationship EO:IO)		This is an area that encompasses one or more introduced source features and matches NatureServe's EO Separation Guidelines (NatureServe 2004).
IOID_TO_EOID	N/A	N/A	Augmented populations (where outplantings occur alongside natural populations) have an entry in the IOID_TO_EOID table connecting the IO to the EO.	IO ID EO ID	At Rocky Prairie, there is an entry in the IOID_TO_EOID table connecting the outplanted <i>C. levisecta</i> IO to the natural population's EO.

Table 4: Related concepts in the Biotics database and the *Castilleja levisecta* observation database

Biotics data concept	Related concept in <i>C. levisecta</i> observation database	Data connection	Key differences
Source Feature (SF)	Introduced Source Feature (ISF)	<p>SFs are connected to EOs spatially and by ID, and ISFs are connected to IOs spatially and by ID.</p> <p>At augmented populations, SFs and ISFs are connected spatially and by IDs through their respective occurrences.</p>	<p>1) Source features are for natural populations while Introduced source features are for introduced populations</p> <p>2) Introduced source features are more “event based” – they capture information about the planting (where did the seed come from, what day did the planting occur, how many plants were planted, etc.). For this reason there can be overlapping ISFs for multiple plantings where there would only be one SF for a natural population</p>
Element Occurrence (EO)	Introduced Occurrence (IO)	<p>At augmented populations, the IO is connected to the EO spatially, and via the IOID_TO_EOID table at augmented populations.</p>	<p>Element occurrences are for natural populations while Introduced occurrences are for introduced populations</p>

Literature Cited

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http://help.natureserve.org/biotics/Content/Methodology/PlantEOSpecs_DecisionTree.htm
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Appendix A. Metadata for WNHP *Castilleja levisecta* Observation Database

This ESRI file geodatabase contains observation-level information about rare plants in Washington.

The file geodatabase is native to ArcGIS 10.6.1.

The Observation feature class has overlapping polygons, one for each observation event. The Managed Area feature class represents administrative units that contain observations.

The Introduced Source Features feature class are primarily single part polygons, with some multipart polygons. The Introduced Occurrences may be multipart polygons containing/overlapping the Introduced Source Features. The Introduced Occurrences and Introduced Source Features are meant to be used in conjunction with the Element Occurrences from WNHP, which can be found here: https://data-wadnr.opendata.arcgis.com/datasets?group_ids=266f0b3bdc014f5ab2a96ad4ea358a28 . The WNHP Source Features are available upon request. The Introduced Occurrences are new occurrences established by humans through the outplanting of seeds or plugs and designed to expand the number of populations of a species to improve its conservation status. Introduced occurrences are not currently included in the WNHP Biotics database.

Null values in tables denote unknown/no information available.

Contacts

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Feature Class Field Descriptions

OBSERVATIONS FEATURE CLASS:

OBSERVATION_ID: Unique identifier for each observation event. Required.

SITE_ID: Identifier for each site. M:1 relationship with SITE_ID from the Site feature class.

**The “sites” feature class is not used in the *Castilleja levisecta* database but the schema remains for extensibility with former and future observation databases where these data are pertinent.

SCI_NAME: Scientific name of the element being observed. Required.

MONITOR_DATE: Date of the observation

MONITOR_YEAR: Year the element was observed

NUMBER_PLANTS: Number of plants observed or estimated at the time of the observation event. The number zero indicates no plants were found whereas null values indicate no information was available.

PLANT_COUNT_UNITS: Units of the plant count. Not constrained to the values listed below.

PLANTS

STEMS

GENETS

RAMETS

FLOWERS

FRUITS

PLANT_EST_MAX: The estimated maximum number of plants in the observation at the time of observation.

PLANT_EST_MIN: The estimated minimum number of plants in the observation at the time of observation.

PLANT_COUNT_METHOD: Method of the plant count. Not constrained to the values listed below.

CENSUS

ESTIMATE

MONITOR PLOT

DATA_SOURCE: Data source of the original observation. Include dataset name and date in a YYYYMMDD format.

OBSERVATION_COMMENT: Comments relevant to that observation

SURVEYOR: People conducting the observation

REPRO_COUNT: Count of reproductive plants

VEGETATIVE_MATURE_COUNT: Count of mature but not reproducing plants

SEEDLING_COUNT: Count of non-mature plants

DEAD_COUNT: Count of dead plants

OBSERVATION_PHOTO_PATH: Path to the folder of photos that were taken during the time of observation. Use UNC paths.

ID_DOCUMENTATION: Any documentation used to ID the plant

MAPPED_BY: Name of the person that added the observation to table. Required.

MAPPED_DATE: Date the observation was added to table. Required.

FEDERAL_ID: Unique ID in original data source for the observation. BLM's GeoBOB:

FLSITE_CN; USFS's NRIS: SPATIAL_ID.

IS_POP_INTRODUCED: A True/False field that indicates whether the observed population is an introduced population (True) or a wild population (False)

INTRO_SOURCE_FEATURE_ID: This field links observations of an outplanting effort to a source feature in the introduced_source_features feature class via its INTRO_SOURCE_FEATURE_ID.

If the value in this field is -1, and IS_POP_INTRODUCED is False, then this is not an introduced population. If the value in this field is -1 and IS_POP_INTRODUCED is True, then this is a survey of an introduced population, not an observation of the outplanting effort. If this field has a value, then the record represents an observation of the planting effort.

SITES FEATURE CLASS:

***Note, not populated for the *C. levisecta* observation database because it is not as biologically relevant as it is for other species. The skeleton of this feature class remains in place for extensibility with former and future observational databases.**

SITE_ID: Unique identifier for each area containing at least one observation. Required.

SITE_NM: Name of a site. Not necessarily unique.

SITE_MANAGER_CONTACT: Contact person for the site

SITE_MANAGER_PHONE: Contact person's phone number. Format: 1234567890

SITE_MANAGER_ADDRESS: Contact person's mailing or physical address.

SITE_PROTECTION_LEVEL: Description of the site's level of protection.

PLANT_RECOVERY_ZN: Any recovery units associated with that population of the species.

SITE_COMMENTS: Comments about the site.

SITE_ACRES: GIS acres of the site polygon.

SITE_CONTACT_INFO_UPDATED: Date of the last time the contact information was updated.

MAPPED_BY: Name of the person that added the site to table. Required.

MAPPED_DATE: Date the site was added to table. Required.

SITE_PHOTO_PATH: Path to the folder of photos that were taken during the time of observation. Use UNC paths.

SITE_NAME_SYNONYM: Site names can change over time and old names can be stored here. If a site has more than one name, others can be stored here.

MANAGED_AREA_ID: Unique identifier for a managed area, defined by the site polygon's centroid since a site can cross managed areas. M:1 relationship with the managed areas feature class. Whitman County records without managed areas have a MANAGED_AREA_ID = -1.

SITE HABITAT TABLE:

M:1 relationship with the site feature class.

SITE_ID: Unique identifier for each area containing at least one observation. Required.

HABITAT_DATE: Date the habitat was observed

HABITAT_YEAR: Year the habitat was observed

WOODY_COVER_PCT: Woody cover percent

NATIVE_COVER_PCT: Native cover percent

EXOTIC_COVER_PCT: Exotic cover percent

EXOTIC_SPP_CONCERN: Exotic species of concern

NATIVE_FORB_PCT: Native forbs percent

NATIVE_GRASS_PCT: Native grass percent

OTHER_TESP_PRESENCE: Other TESP species present

SURVEYOR: Surveyor name

SURVEY_TYPE: Habitat survey type

HABITAT_COMMENTS: Habitat comments

HABITAT_PHOTO_PATH : Path to the folder of photos that were taken at the time of observation. Use UNC paths.

SOILS: Soil types

GEOLOGY: Geology of the area

TOPOGRAPHIC_POSITION_DESC: Topographic position description

MANAGED AREA FEATURE CLASS:

MANAGED_AREA_ID: Unique identifier for a managed area

MANAGED_AREA_NM: Managed area name. Not necessarily unique.

MANAGED_AREA_OWNER: Land owner of the managed area

MANAGED_AREA_OWNER_CONTACT: Contact person for the managed area

MANAGED_AREA_OWNER_PHONE: Contact person's phone number. Format:
1234567890

MANAGED_AREA_OWNER_ADDRESS: Contact person's mailing or physical address.

MANAGED_AREA_PROTECTION_LEVEL: Description of the managed area's level of protection.

MANAGED_AREA_COMMENTS: Comments about the managed area

MANAGED_AREA_ACRES: GIS acres of the managed area polygon.

MANAGED_AREA_CONTACT_INFO_UPDATED: Date of the last time the contact information was updated.

MANAGED_AREA_NAME_SYNONYM: Managed area names can change over time and old names can be stored here. If a managed area has more than one name, others can be stored here.

MAPPED_BY: Name of the person that added the site to table. Required.

MAPPED_DATE: Date the site was added to table. Required.

INTRODUCED OCCURRENCES FEATURE CLASS:

IO_ID: Unique identifier for each introduction occurrence

IO_NUM: Number that identifies this particular occurrence of the introduced element. Not unique within the table, unique only within a single species.

SCI_NAME: Scientific name of the introduced element.

COM_NAME: Common name of the introduced element as defined by the Washington Natural Heritage Program.

IO_COMMENTS: Comments about the introduced occurrence.

INTRODUCTION_TYPE: Records if this is an augmentation of a naturally-established population or a brand new introduction. If an IO has an introduction_type of "AUGMENTATION", then its IO_ID will correspond to the natural population's EO_ID in the IOID_TO_EOID table

AUGMENTATION: augmentation of a naturally-established population.

OUTPLANTING: introduction where there were no recorded occurrences or the occurrence was

INTRODUCED SOURCE FEATURES FEATURE CLASS:

INTRO_SOURCE_FEATURE_ID: A unique identifier for each introduced source feature

IO_ID: Unique identifier for each introduction occurrence. This is not unique in this table as there can be multiple introduced source features within one introduced occurrence.

SCI_NAME: Scientific name of the introduced element.

COM_NAME: Common name of the introduced element as defined by the Washington Natural Heritage Program.

PROVENANCE: Where the seed or plugs of the introduced occurrence originated.

INTRODUCED_DATE: Date on which the introduction occurred

INTRODUCED_YEAR: Year in which the introduction occurred

INTRODUCTION_LAYOUT: Describe how the introduction was laid out. (i.e. were seeds dispersed in a grid or along a transect, were plugs planted according to a grid scheme or randomly, etc.)

INTRODUCED_QUANTITY: How many plugs or seeds were introduced

INTRODUCED_QUANTITY_UNIT: Units of how many seeds or what size plugs were introduced. Not constrained to the values listed below.

POUNDS

OUNCES

GRAMS

SEEDS

4 INCH

INTRODUCED_QUANTITY_TYPE: Type of introduction:

SEED

PLUG

INTRODUCTION_COMMENTS: Comments about the introduction

INTRODUCTION_TYPE: Records if this is an augmentation of a naturally-established population or a brand new introduction

AUGMENTATION: augmentation of a naturally-established population

OUTPLANTING: introduction where there were no recorded occurrences or the occurrence was extirpated

INTRO_SOURCE_PHOTO_PATH: Path to the folder of photos of the introduction area. Use UNC paths.

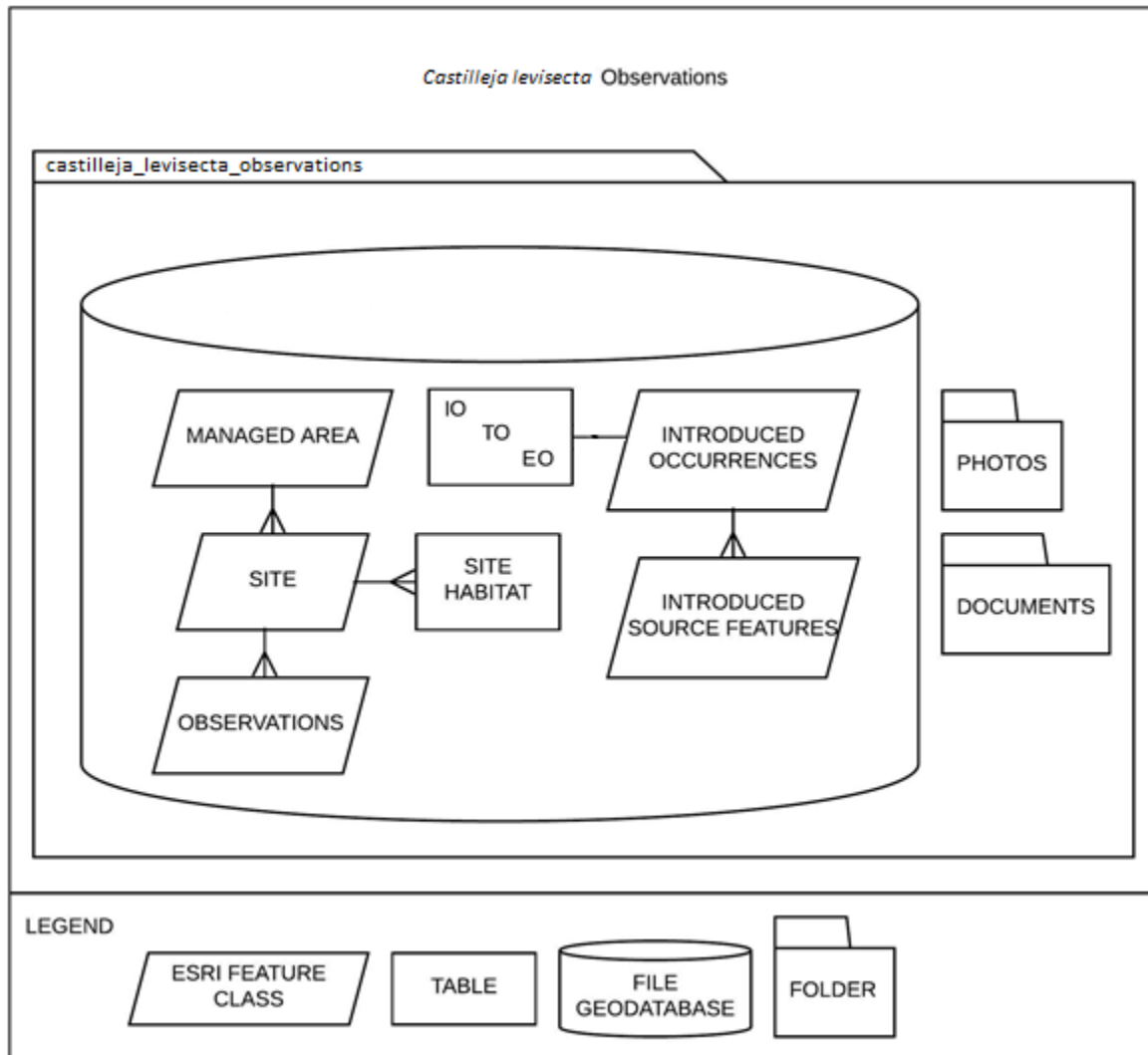
IOID_TO_EOID Table:

This table related Introduced Occurrences (IOs) that represented augmentations of natural populations with the Element Occurrences (EOs) being augmented. This relationship is being represented as a table because, for record-management reasons, some of the EOs are split up further than the “Habitat-based Element Occurrences Delimitation Guidance” would suggest. Since the IOs are less finely-delineated, this creates a One:Many relationship between IOs and EOs. However, since Biotics cannot be altered to include IO_IDs in the EO, this relationship must be delineated via this linking table.

IO_ID: The Introduced Occurrence ID that represents an introduction augmenting a natural population

EO_ID: The Element Occurrence ID of the natural population being augmented

Data Diagram



Note: For biological reasons, the “Site” feature class will remain unimplemented in the *Castilleja levisecta* observation database, although the empty table still remains in this file geodatabase to allow for extensibility with the existing *Silene spaldingii* observations database and future observation databases.