Vegetation monitoring and mapping at tidal wetland restoration and reference sites:
Siletz Bay National Wildlife Refuge and Yaquina River Estuary

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Intertidal beaver dam, Millport South ("Jackson") restoration area, July 2006

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Table of contents

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Introduction

Scope of work and previous monitoring

This report documents vegetation monitoring and mapping conducted by Green Point Consulting during summer 2006 at six tidal wetland restoration and reference sites in the Siletz Bay National Wildlife Refuge of Oregon, and the upper Yaquina River estuary (near Toledo, Oregon). The reference sites were Millport North (in the Siletz Bay NWR) and Yaquina Site Y28; restoration sites included Millport South (Siletz Bay NWR), and Yaquina sites Y3, Y27 and Y30. Locations of study sites are shown in the vicinity maps (Figures 1 and 2); Table 1 provides a summary of monitoring at these sites.

Vegetation at all sites except Y30 had been monitored prior to restoration, providing baseline information for determination of restoration trajectory. The monitoring described in this report documents vegetation changes after restoration for those sites (Millport South, Y3, and Y27). No previous monitoring had been conducted at Site Y30; the land use history of this site is less well known than for the other sites. Y30 has not been actively restored, nor does it need active restoration work – see site history below. Site Y30 apparently had a natural dike breach many years ago.

We used a combination of spatial analysis of plant communities (vegetation mapping) and intensive sampling of plant community composition. This combination provides powerful data for analysis of change; the mapping provides the "big picture," while the intensive sampling provides a detailed picture of community composition, allowing increased map accuracy and statistical analysis of change over time. Combined spatial analysis and intensive sampling have been recommended for estuarine restoration monitoring by regional and national experts (Rice *et al*. 2005, Thayer *et al*. 2005, Erwin 1990).

Vegetation was mapped for all sites except Millport North in 2006. Millport South was the only site that had been mapped previously (in 2001) and was re-mapped to document changes prior to restoration. Vegetation was not re-mapped at Millport North due to funding limitations and the expectation that it would not have changed radically since the earlier work in 2001; this was confirmed through transect and quadrat sampling. Vegetation was mapped at the Yaquina sites for the first time, to provide input to analyses of juvenile salmonid use, and to provide a basis for comparing future vegetation and determining restoration trajectory. Uplands were generally not mapped, except for dikes (some of which may be transitioning to wetlands since restoration).

For all sites except Y30, we conducted intensive vegetation sampling in sample plots in quadrats along permanent transects and within permanent plots. (Vegetation was not sampled at Y30.) Intensive sampling included analysis of percent cover in all communities, and woody stem density and basal area in scrub-shrub and forested communities. The transect/quadrat monitoring was a repeat of work done in 2000-2001; therefore, we used the same methods, transect locations, and monitoring dates as in 2000-2001. The permanent plot in scrub-shrub tidal wetland (Yaquina Site Y28 Plot P5) was a new addition in 2006. This plot was established to document the upper portion of Site Y28, where vegetation transitions from tidal marsh to scrub-shrub tidal wetland. Methods are described in detail below.

Table 1 summarizes sites, transects and plots monitored under this contract with CTSI in 2006, and under previous Green Point Consulting contracts with other organizations in 2000-2001. We conducted the 2000-2001 monitoring in the Yaquina estuary under contract with the MidCoast Watersheds Council, Newport, OR (Brophy 2004) and the 2001 monitoring in the Siletz estuary under contract with Ducks Unlimited in collaboration with U.S. Fish and Wildlife Service, Oregon Coast National Wildlife Refuge Complex (Brophy 2002).

Table 1. Summary of vegetation monitoring at Siletz and Yaquina study sites. 2006 monitoring is described in this report.

Estuary	**Site**	**Site type and year restored**	**Year(s) of vegetation mapping (with citation)**	**Transects**	**Years of transect/quadrat monitoring; citation**
Siletz	Millport North	Reference	2001 (Brophy 2002)	MN-T1 through MN-T5	2001 (Brophy 2002)
Siletz	Millport South	Restoration; restored 2003	2001 (Brophy 2002); 2006	MS-T1 through MS-T8	2001 (Brophy 2002); 2006
Yaquina	Y3	Restoration; restored 2001	2006	T1 through T5	2000 and 2001 (Brophy 2004); 2006
Yaquina	Y27	Restoration; restored 2002	2006	T1 through T10	2000 and 2001 (Brophy 2004); 2006
Yaquina	Y28	Reference	2006	T3, T4, P5*	T3 and T4: 2001 (Brophy 2004); 2006. P5: monitored for the first time in 2006
Yaquina	Y30	Restoration; natural breach (year unknown)	2006	none	no transect/quadrat monitoring has been conducted at this site

*Two additional transects were monitored in 2000 at Site Y28 (Transects T1 and T2) (Brophy 2004). However, these could not be monitored again in either 2001 or 2006 due to private property access restrictions.

Figures 6, 9, 12 and 15 show transect and plot locations.

Site history

All of the restoration sites had been converted to agricultural use (pasture) in the first half of the 20th century. Alterations consisted of diking (at Y3 and Y27); possible diking or enhancement of the natural levee at Y30; installation of culverts and tidegates, and varying amounts of ditching for drainage. Millport South had the most intensive ditching; Sites Y3 and Y27 were less intensively ditched, and Site Y30 has relatively unaltered channels.

Historic vegetation

The typical vegetation of unaltered sites in the middle to upper Siletz and Yaquina estuaries includes high tidal marsh and tidal swamp. ("Tidal swamp" includes both scrub-shrub and forested tidal wetlands.) Few examples of scrub-shrub or forested tidal wetlands remain in Oregon outside the Columbia River estuary. Based on GPC investigations of the few remnants of tidal swamp in outer coast (non-Columbia) estuaries, forested tidal wetlands with summer surface water salinities in the oligohaline and low mesohaline range (0.5 to 10 ppt) are typically dominated by Sitka spruce. This is the approximate summer salinity range at Site Y28. Scrub-shrub tidal wetlands in this salinity zone are typically dominated by brackish-tolerant deciduous shrubs, especially black twinberry and Pacific crabapple, with a very diverse herbaceous layer (Brophy 2007, Christy and Brophy 2007). Freshwater forested and scrub-shrub tidal wetlands in outer coast estuaries were once common but are now very rare; the few remaining stands we have observed suggest that typical vegetation is similar to nontidal freshwater scrub-shrub and forested tidal wetlands of this area (Christy and Brophy 2007).

Historic vegetation mapping based on General Land Office Surveys (Hawes *et al.* 2002) was used to determine the historic vegetation at each site. The restoration sites that are located lower in the estuaries (Millport South and Y3) were originally tidal marsh, based on ONHP historic vegetation mapping (Hawes *et al*. 2002). The lower third of Site Y27 (opposite Mill Creek) is shown as crabapple swamp in the historic vegetation map. The upper 2/3 of Site Y27 is not mapped separately; it is included in a very large mapping unit of Douglas Fir forest. Historic vegetation of Site Y28 is shown as tidal marsh with the annotation that "Sitka spruce or crabapple may be included on elevations." Based on current vegetation at Site Y28, the upper 2/3 of Site Y27 was probably originally scrub-shrub tidal wetland with spruce present at least along channels. Site Y30 is not separately mapped in the ONHP layer, but based on its location above Sites Y27 and Y28 (which occupy the transition zone from marsh to swamp), it probably originally contained at least some tidal swamp.

Land use history, restoration actions, and beaver activity

Millport South was diked along Millport Slough prior to restoration. In 2003, the site was restored through dike removal and channel reconnection. The two halves of Millport South have distinctly different history, as described below.

The west half of Millport South (also referred to as "Gray") was affected by the construction of Highway 101 in the 1930s, which altered the configuration of the main tidal channel entering the site. After construction of Highway 101, the main tidal entry point for this area was a large channel just east of the highway; this channel was blocked with an earthen dam. Despite all of these hydrologic changes, Gray was never heavily ditched, and the main tidal channel retained its natural meandering form (except for the straight section next to Highway 101). The earthen dam that blocked the main tidal channel was breached by natural causes a number of years ago, restoring much of the site's tidal exchange. The dike along the site's north edge remained relatively intact until restoration in 2003. Restoration removed the east half of the north perimeter dike, and reconnected the smaller (but still substantial) tidal channels that enter the site from the north edge.

The east half of Millport South (referred to as "Jackson") was much more heavily ditched than Gray. Tidal exchange at the site's main channel was originally blocked by a tide gate, but the gate had deteriorated and fallen off, allowing muted tidal exchange within the main channel. This main channel retained its natural meandering form across the entire site to the forest edge, but its uppermost reaches were ditched. The rest of the site was also fairly heavily ditched, and parallel vegetation patterns suggest it was tilled or otherwise worked in parallel lines to improve drainage.

Interestingly, beaver have constructed and maintained several intertidal dams in the main tidal channel at Millport North (see cover photo of this report). The dams are inundated on higher high tides, but impound water at low tide. These dams were first observed in 2006, but may have been present prior to restoration. They are being actively maintained by the beaver despite their location in the strongly brackish zone of the estuary.

The three Yaquina restoration sites are described in detail in Brophy (2004) as well as a tidal wetland prioritization for the Yaquina and Alsea estuaries (Brophy 1999). All three sites were diked for use as pasture. Two of the three sites had natural dike breaches that had occurred many years prior to 1998 (Y3 and Y30); Site Y27 had two natural breaches that occurred in 1998 and 2001. Additional breaches were opened at Site Y3 in January 2001 and at Y27 in August 2002. Field work during summer 2006 showed that Site Y30 now has full tidal exchange and does not require additional restoration work. The third Yaquina restoration site, SiteY27, was restored through breaching the dike in 5 locations during summer 2002. The restoration work was described in detail by Brophy (2004).

This project documented vegetation during the third year after restoration for Millport South; the fifth year after restoration for Site Y27; and the sixth year after restoration for Site Y3.

List of products

The following products are provided along with this written report:

1. Excel spreadsheets of plot data and analyses (vegdata_CTSI-Siletz_2006.xls, vegdata_CTSI-Yaquina_2006.xls)
2. GIS shapefiles of 2006 plant communities, one for each site (MillptS_veg06.shp, Y3_veg06.shp, Y27_veg06.shp, Y28_veg06.shp, and Y30_veg06.shp). Vegetation at Millport N was not remapped (see **Scope of work** above). The GIS shapefile of 2001 plant communities at Millport South and Millport North is also included for comparison.
3. GIS shapefiles of vegetation transects (millpt_transects01.shp, Y3trnscts_GPS06.shp, Y28_trnscts06.shp, Y27_trscts_NAD83.shp). No transects were established at Site Y30; this site had not been monitored prior to 2006.
4. GIS shapefiles of vegetation transect endpoints (millpt_transpts01.shp, Y27_transpts_NAD83.shp, Y28_trsctpts06.shp, Y3tsctpts_GPS06.shp). The attribute tables for these shapefiles contain the GPS coordinates for each endpoint (UTM coordinates, NAD83 datum).

All GIS products are provided in the UTM Zone 10N coordinate system, NAD83 datum.

Methods

The study methods were designed to meet two criteria: First, they needed to match methods used in the earlier monitoring work, to allow valid comparisons. Second, in order to facilitate scientific data exchange, the methods needed to be widely accepted and standardized. References used in methods development included the National Vegetation Classification Standard (NVCS) (The Nature Conservancy and ESRI, 1994), NOAA guidance for coastal habitat restoration monitoring (Thayer *et al*. 2005), Rice *et al*. (2005), the Estuarine Habitat Assessment Protocol (Simenstad *et al.*, 1991), and Zedler (2001).

The information below describes the methods; detailed background information and rationale for these methods can be found in the earlier monitoring reports (Brophy 2002, Brophy 2004).

Sampling design – herbaceous vegetation

Herbaceous monitoring used the same transect and quadrat methods used in 2000-2001, as described below. Monitoring at each site was conducted as close as possible to the dates of 2001 monitoring (generally within 1 week).

Transect locations

Monitoring was repeated at the transects established during 2000-2001. These transect locations were selected in 2001 following standard methods for stratification of sampling. Each transect was placed within a homogeneous environmental stratum determined by visual observation of elevation, plant community distribution, and surface water flow patterns. The specific location of each transect was designed to sample a major plant community found on a substantial portion of the site at the time of transect establishment. Of course, vegetation has changed since restoration, so some transects now cross boundaries between plant communities, particularly in areas of rapid vegetation change. Given the stratified sample design used, it is likely that over time, plant communities will stabilize and transects will once more sample homogeneous communities.

Most of the transects are 91m (300 ft) in length; some are shorter in order to avoid crossing gradients. Endpoints of transects were marked in 2000-2001 with 5' long ¾" Schedule 40 PVC stakes driven at least a foot into the soil and labeled with the transect number. Almost all of these PVC stakes were still in place in 2006; the few that were missing were relocated using Global Positioning System (GPS) coordinates and re-staked. GPS coordinates for the endpoints of each transect are found in the transect shapefiles (see **List of Products** above).

Quadrat placement

Ten quadrats were placed at random locations along each transect. Randomization was conducted independently in 2006 so that the locations sampled did not duplicate those sampled in 2000-2001. We decided to re-randomize in order to reduce sampling bias, such as possible trampling at the sample location. Each quadrat was 1 sq m in size and was offset 1m from the central transect axis.

Sampling design – woody vegetation

Only very limited areas of woody vegetation are found on the restoration and reference sites, so woody vegetation was not sampled prior to 2006. However, we decided to establish one woody vegetation plot in 2006 at Site Y28 (Plot P5), in order to characterize the scrub-shrub tidal wetland community at the north end of the site. This community was probably present on Sites Y27 and/or Y30 prior to European settlement, since a portion of Site Y27 is mapped as crabapple swamp in the ORBIC historic vegetation mapping based on 1850's General Land Office surveys (Hawes *et al*. 2002). This community may also have occupied areas near the base of the hillslope at Millport South prior to diking.

Methods for Plot P5 at Site Y28 were based on Peet *et al*. (1998) and U.S. EPA (2006). The plot is 10m wide by 50m long, and is subdivided into 20 square "modules" each 5m by 5m. The central axis of the plot is marked with wooden survey stakes every 10m (including both ends), and tall PVC stakes were driven at least 2 feet into the ground at both ends. Metal re-bar stakes 2 ft in length were driven fully into the ground at each end of the transect.

Vegetation was sampled within 8 randomly selected modules out of the total of 20 modules. Percent cover was estimated visually for all species, both herbaceous and woody. Woody stems were counted by size class and the results summarized for the entire plot.

Data analysis

Results from the transect and plot sampling are presented as the average of all quadrats or modules within each transect or permanent plot, respectively. Vegetation percent cover is summarized in tables and charts below (**Results and discussion – Transects and plots**), and in the Excel workbooks (see Products above). Pie charts of vegetation composition (Figures 18 and 19) were also created to provide easier visualization of differences among transects.

Millport South was the only site where vegetation was mapped in 2001 and re-mapped in 2006. For this site, we analyzed change in area of alliances between 2001 and 2006. We conducted the analysis separately for the west portion of the site ("Gray") versus the east portion of the site ("Jackson"). This analysis is described in **Results and discussion – Plant community mapping** below.

Taxonomic references

Vegetation was identified to species in the field or laboratory using Hitchcock *et al*. (1969) and Kozloff (2005). Hitchcock *et al*. is the most detailed reference work for this area; however, species names in Hitchcock *et al*. are outdated. Therefore, Kozloff was used to update taxonomy to current regional standards. However, taxonomy is a rapidly changing field and plant names may have changed since the publication of Kozloff (2005). Six letter species codes, scientific names, and common names are cross-referenced in Table 2.

Plant community classification

Plant communities were classified in this study according to floristics. A two-level hierarchical classification was used, following the National Vegetation Classification Standard (NVCS). The higher level class is the **Alliance,** and the lowest-level classification is the finest level of the NVCS hierarchy, the **Association**. Alliances were taken from the NVCS classification as published by the Oregon Natural Heritage Program (Kagan *et al.*, 2004). Associations (also called communities) were defined specifically for this study, based on the dominant and associated species in the plant community. Dominance was defined by percent cover and frequency. In areas where quadrat analysis of plant community composition was conducted, percent cover was quantified by visual estimate, and frequency was determined by analysis of presence or absence for each species in each quadrat. In areas where quadrat analysis was not conducted, the plant community was classified using visual observation and professional knowledge of Oregon estuarine plant communities.

The goal of plant community mapping for this project was to provide high resolution definition of areas with differing environmental characteristics. This resulted in a finer classification with many more associations than are defined in the Oregon Natural Heritage Program's classification. Some of the communities we defined might be considered transitional between existing ONHP associations. We also defined mapping units that were mosaics of more than one plant community.

Although our associations were split much finer than the ONHP classification, we did cross-reference our classification to the ONHP system in order to improve interpretation and comparability of our data to other Oregon studies. Where our plant communities did not logically fit the ONHP classification system, we estimated the closest equivalent ONHP association (or alliance, in some cases), and we have listed that association or alliance in the field "ONHP_Apprx" in the plant community shapefile attribute tables. We also show the ONHP heritage list ranking for the closest equivalent ONHP classification unit; this information may facilitate future interpretation of restoration trajectories and management of rare plant communities.

In the plant community shapefiles, the alliance and association for each polygon are identified in the columns **Alliance** and **Associatio** in the attribute table. Each association was assigned a unique number within each site for map display purposes. Association numbers have no significance and are not cross-referenced between sites.

Species codes

Table 2 contains a list of the most common plant species at the study sites. (The table is not a complete species list for the sites.) Six-letter plant species codes are used in the quadrat data tables and in alliance and association descriptions. Table 2 also shows the native/non-native status and wetland indicator status for each species. Native/non-native status was taken from Hitchcock *et al*. (1969). USFWS Region 9 wetland indicator status categories (Reed, 1988) are also shown in Table 2; a key to those codes is found in Table 3.

Table 2. Plant species codes and characteristics for common dominants, Millport Slough and Yaquina tidal wetland reference and restoration sites 2006

Species code	Native/ Introduced	Common name(s)	Indicator status	Full name; [other names]*
AGRSTO	I	Creeping bentgrass	FAC	*Agrostis stolonifera*
ALNRUB	N	Red alder	FAC	*Alnus rubra*
ARGEGE	N	Pacific silverweed	OBL	*Argentina egedii* [also known as *Potentilla anserina*]
ATRPAT	N	Saltbush	FACW	*Atriplex patula*
CARLYN	N	Lyngbye's sedge	OBL	*Carex lyngbyei*
CAROBN	N	Slough sedge	OBL	*Carex obnupta*
CYTSCO	I	Scots broom	NOL	*Cytisus scoparius*
DESCES	N	Tufted hairgrass	FACW	*Deschampsia cespitosa*
DISSPI	N	Seashore saltgrass	FACW	*Distichlis spicata*
ELEPAL	N	Creeping spikerush	OBL	*Eleocharis palustris*
HOLLAN	I	Common velvetgrass	FAC	*Holcus lanatus*
JUNBAL	N	Baltic rush	FACW+	*Juncus balticus*
JUNEFF	N	Soft rush	FACW	*Juncus effusus*
LOLARU	I	Tall fescue	FAC-	*Lolium arundinaceum* [also known as *Schedonorus arundinacea* and *Festuca arundinacea*]
LONINV	N	Black twinberry	FAC+	*Lonicera involucrata*
LOTCOR	I	Birdsfoot trefoil	FAC	*Lotus corniculatus*
MALFUS	N	Pacific crabapple	FACW	*Malus fusca*
OENSAR	N	Water parsley	OBL	*Oenanthe sarmentosa*
PHAARU	I*	Reed canarygrass	FACW	*Phalaris arundinacea*
PICSIT	N	Sitka spruce	FAC	*Picea sitchensis*
RUBARM	I	Himalayan blackberry	FACU	*Rubus armeniacus* [formerly *Rubus discolor*]
RUBLAC	I	Evergreen blackberry	FACU+	*Rubus laciniatus*
RUBURS	N	Trailing blackberry	FACU	*Rubus ursinus*
SALHOO	N	Coast willow	FACW-	*Salix hookeriana*
SAMRAC	N	Red elderberry	FACU	*Sambucus racemosa*
SCHMAR	N	Seacoast bulrush	OBL	*Schoenoplectus maritimus* [also known as *Scirpus maritimus* and *Bolboschoenus maritimus*]
SCHTAB	N	Softstem bulrush	OBL	*Schoenoplectus tabernaemontanii* (also known as *Scirpus validus*)
SCIMIC	N	Small-fruited bulrush		*Scirpus microcarpus*
SYMSUB	N	Douglas' aster	FACW	*Symphyotrichum subspicatum* (also known as *Aster subspicatus*]
TYPLAT	N	Common cattail	OBL	*Typha latifolia*

* Reed canarygrass is listed as introduced, but its native/non-native status is uncertain (Antieau 1993).

Table 3. USFWS Indicator status categories (Region 9)

Status	Designation	Probability of occurring in wetlands
OBL	obligate wetland species	99%
FACW	facultative-wet wetland species	67 to 99%
FAC	facultative wetland species	33 to 67%
FACU	facultative-upland species	1 to 33%
UPL	upland species	1%
NI	no indicator	insufficient information to categorize
NOL	not on list	these are generally upland species
+/-	modifier	indicates higher likelihood of occurrence in wetter (+) or drier (-) habitats within category

GIS layer development

Projection and metadata

GIS products from this project use the following projected coordinate system: UTM Zone 10N (NAD83 datum). Metadata are included with all GIS products.

Plant communities shapefile

We used a combination of field reconnaissance, quantitative sampling, and airphoto interpretation to map wetland plant communities within the study area. Plant community maps are provided as shapefiles; digitization methods are described below. Table 4 contains a key to plant community shapefile attributes.

Table 4. GIS plant community shapefile attributes

Field	Description
Id	Unique ID code for polygon
Area	Area of polygon (sq m)
ALLIANCE	Vegetation alliance (community group)
ASSOCIATIO	Vegetation association (plant community)
ASSN_NO	Association number (numbered separately within each site)
COMMENTS	Notes about community and mapping
SITE_TYPE	Restoration vs. reference site
Base_photo	Photo used as base for in heads-up digitization
Perimeter	Perimeter of polygon (m)
ONHP_apprx	Closest equivalent ONHP association or alliance
ONHP_rank	Rank of closest equivalent ONHP association or alliance

Transect shapefiles

ArcView shapefiles of transects were created by importing GPS coordinates into ArcView and joining endpoints to create lines using EditTools. Transect shapefiles (see **Products**) contain attributes such as transect length, bearing and source of GPS data. Metadata are found in html format metadata files ([shapefile name]_metadata. htm).

GPS data used to create the transect shapefiles was collected in three ways: Most points were collected using submeter accuracy GPS equipment (Trimble GeoExplorer 3 with real-time differential correction using Beacon-on-a-belt). A few points were collected using consumer grade GPS (Garmin GPS12), and a very few points were hand-digitized using aerial photos as a base. GPS data were collected in the WGS84 datum and imported directly into ArcView maps as UTM Zone10 NAD83 coordinates (no data conversion was deemed necessary for WGS84 to NAD83).

Heads-up digitization of plant community boundaries

Plant community boundaries were determined using field investigation and stereoscopic interpretation of color infrared aerial photographs. The aerials were custom flown during June 2006 at a scale of 1:9000 (1” = 750’) on the contact prints, and orthorectified by CTSI for use in the GIS. For Millport South, the 2006 CIR imagery was supplemented by NAIP 2005 imagery (true color orthophotos, 1/2m resolution GEOTIFFs).

Plant communities were heads-up digitized as polygons in ArcView 8.3. Heads-up digitization was conducted at an on-screen scale of 1:1000 (consistent with 2001 mapping at Millport Slough).This translated to an on-screen scale of about 1” = 100’. Use of a consistent on-screen scale kept the level of detail consistent from polygon to polygon. Metadata for the vegetation shapefiles are provided in html-format documentation files ([shapefile name]_metadata.htm).

Plant community polygon size

Plant community mapping used a threshold (minimum) polygon size of 0.1 ha (about 0.25A), and a target average polygon size of 1 ha. Actual mapping was more finely detailed than this; mapping contained many polygons under 0.1 ha and average polygon sizes were about 0.5 ha for the Yaquina sites and about 1 ha for Millport South. A few polygons were fairly large; these were relatively homogeneous areas and division of these areas into smaller units was not considered necessary or desirable.

Results and discussion – Plant community mapping

In this section we discuss results of the GIS mapping of plant communities. This is a spatial analysis, revealing the total area of different types of vegetation. The next section, "**Results and discussion – Transects and plots**," provides more detailed analysis of plant community composition.

Total area mapped and number of plant associations

The number of plant communities ("associations") identified and mapped at each site, and the total area mapped, are shown in Table 5 below. Maps of these communities are found in Figures 4-17. Figures 4, 7, 10, 13 and 16 show communities color-coded by alliance, to provide the "big picture" of distribution of the communities. Figures 5, 8, 11, 14, and 17 show outlines of plant communities on the airphoto base, to help the user visualize plant community locations relative to site landmarks.

Table 5. Area and number of associations mapped at each site.

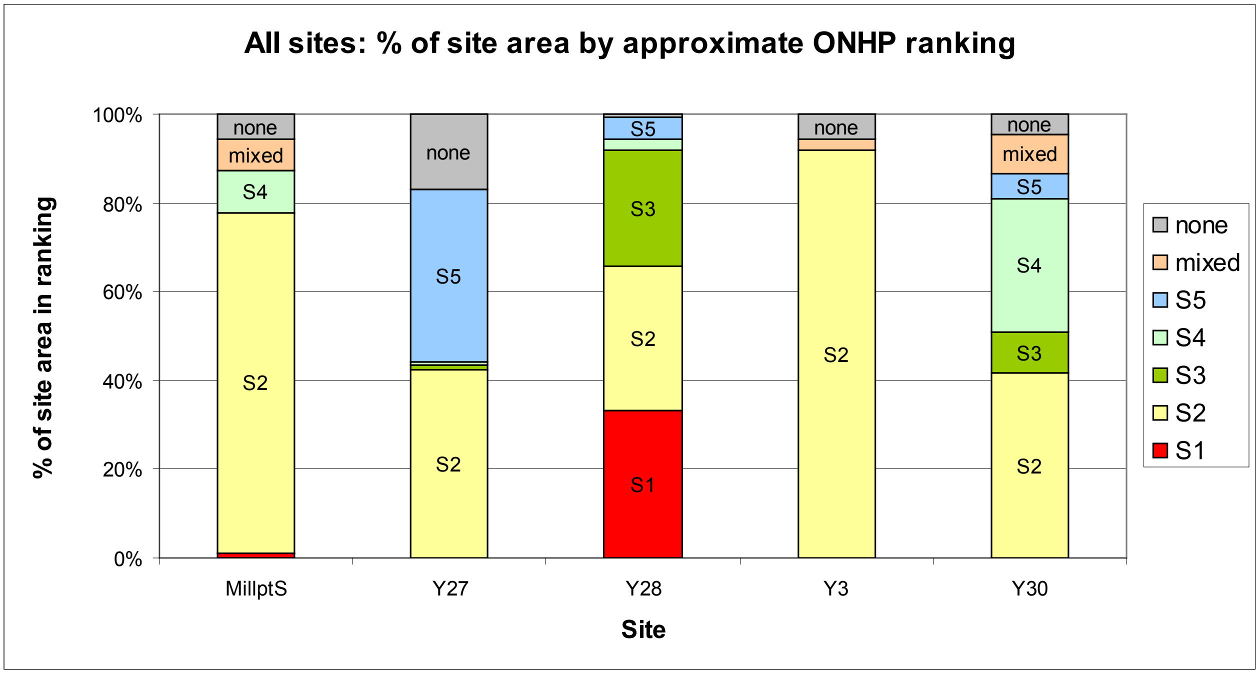
Site	**Total area mapped (ha)**	**Number of plant associations mapped**
Millport South	42.4	22
Y27	21.3	13
Y28	7.0	12
Y3	10.2	16
Y30	10.6	13
Total area mapped	**91.5**	

ONHP rankings

ONHP rankings (Kagan *et al*. 2004) provide information on rarity of plant communities (associations) in Oregon and globally. A lower number indicates a rarer community: a rank of 1 means the association is considered "critically imperiled"; 2 = imperiled; 3 = rare, threatened or uncommon; 4 = not rare, apparently secure; and 5 = abundant.

Chart 1 below shows the percentage of each site occupied by plant communities of different rarity levels (S1-S5). Chart 1 also shows areas of mixed rankings (mosaics of more than one association) and associations and areas that are not ranked (marked "none") – these are generally non-native communities or disturbed areas (ONHP does not rank non-native communities). This chart is based on the ranking of the ONHP classification that most closely resembles the mapped association. Therefore, these rankings are "approximate," because there was generally not a perfect match between the observed community and the ONHP classification. For example, some of the mapped communities are dominated by a mix of native and non-native species. Since the ONHP classification excludes non-native species, it can be challenging to assign the observed communities to the ONHP categories.

Chart 1. Percent of site by ONHP ranking



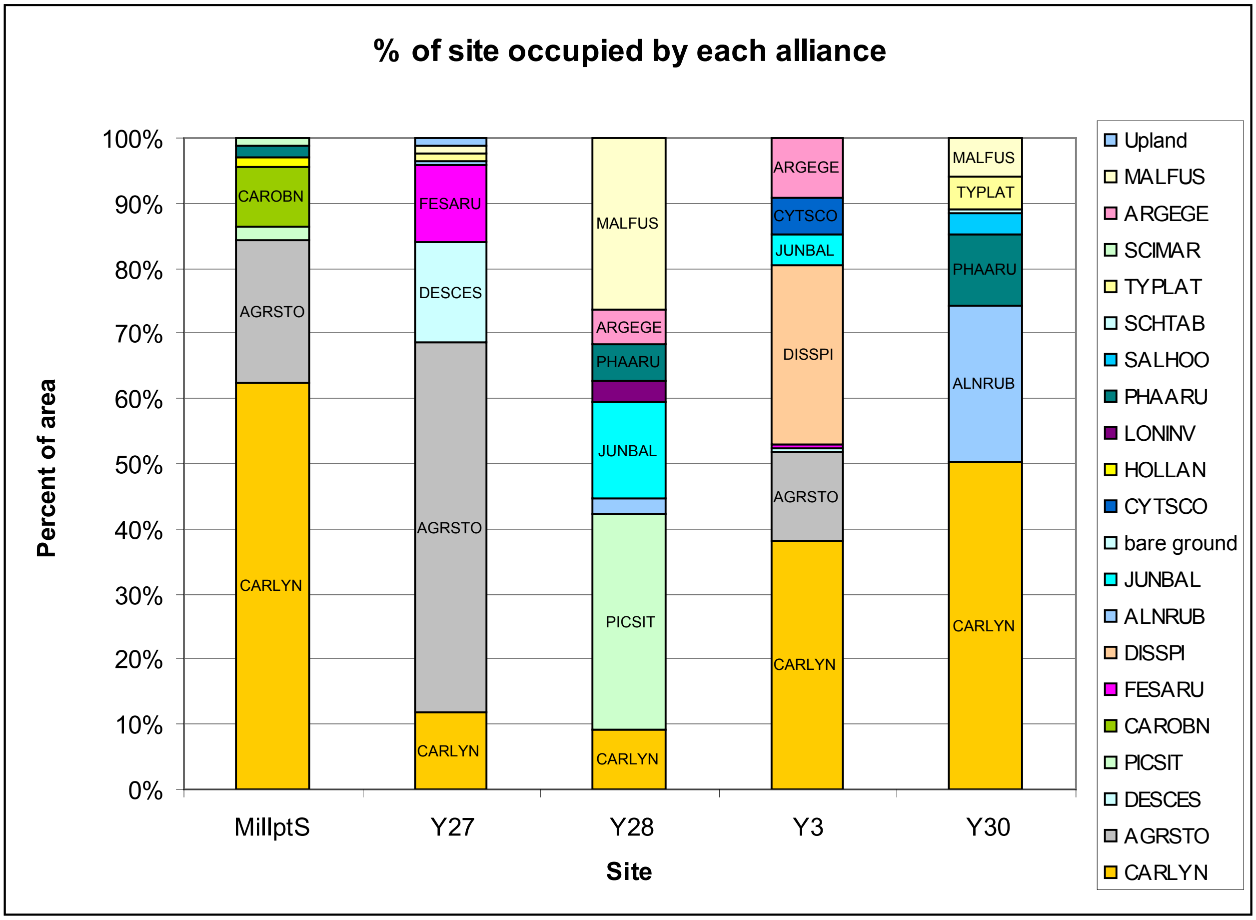
Diversity of alliances within sites

Chart 2 (below) shows the number of different vegetation alliances at each site, and the proportion of the site occupied by each alliance. (Alliances are groups of plant communities with a common characteristic or "diagnostic" dominant species.) The more alliances found on a site, and the more even the distribution of area among the different alliances, the wider the range of vegetation types on the site – a sort of "diversity" of vegetation types. (In this case, "diversity" means variety of different major vegetation types, not number of species.)

The four restoration sites (Millport South, Y3, Y27 and Y30) had over 50% of their area occupied by two alliances: Lyngbye's sedge and creeping bentgrass. Rapid colonization by Lyngbye's sedge and creeping bentgrass communities has been documented at other Oregon tidal wetland restoration sites, where they have been characterized as "competitively dominant permanent colonizers" (Cornu and Sadro 2002; Frenkel and Morlan 1991). Therefore, these restoration sites appear to be rapidly moving towards stable plant communities.

Reference Site Y28 has the most diverse mix of vegetation types, probably due to the site's internal gradients. These gradients include a range of tidal influence (the southern portion of the site is more strongly influenced by tidal flows) and an elevation gradient from riverbank to hillslope base (higher ground on the natural levee immediately adjacent to the river, and lower ground near the hillslope base).

Chart 2. Percent of site occupied by each vegetation alliance



Changes in spatial extent of vegetation alliances, Millport South, 2001-2006

The only site which had been mapped in 2001 and re-mapped in 2006 was Millport South. Therefore, this was the only site where we were able to determine changes in extent of plant communities from 2001 to 2006.

Chart 3 and Table 6 below show the change in area occupied by the three major alliances at Millport South between the first year of mapping (2001) and 2006. These three alliances occupied about 94% of the entire site in 2006. There were not any major changes in extent of these alliances between 2001 and 2006. The area of Lyngbye's sedge has increased about 16%, with most of this increase coming from the decreased area of creeping bentgrass and slough sedge.

Chart 3. Change in area of major alliances, Millport South, 2001 vs. 2006

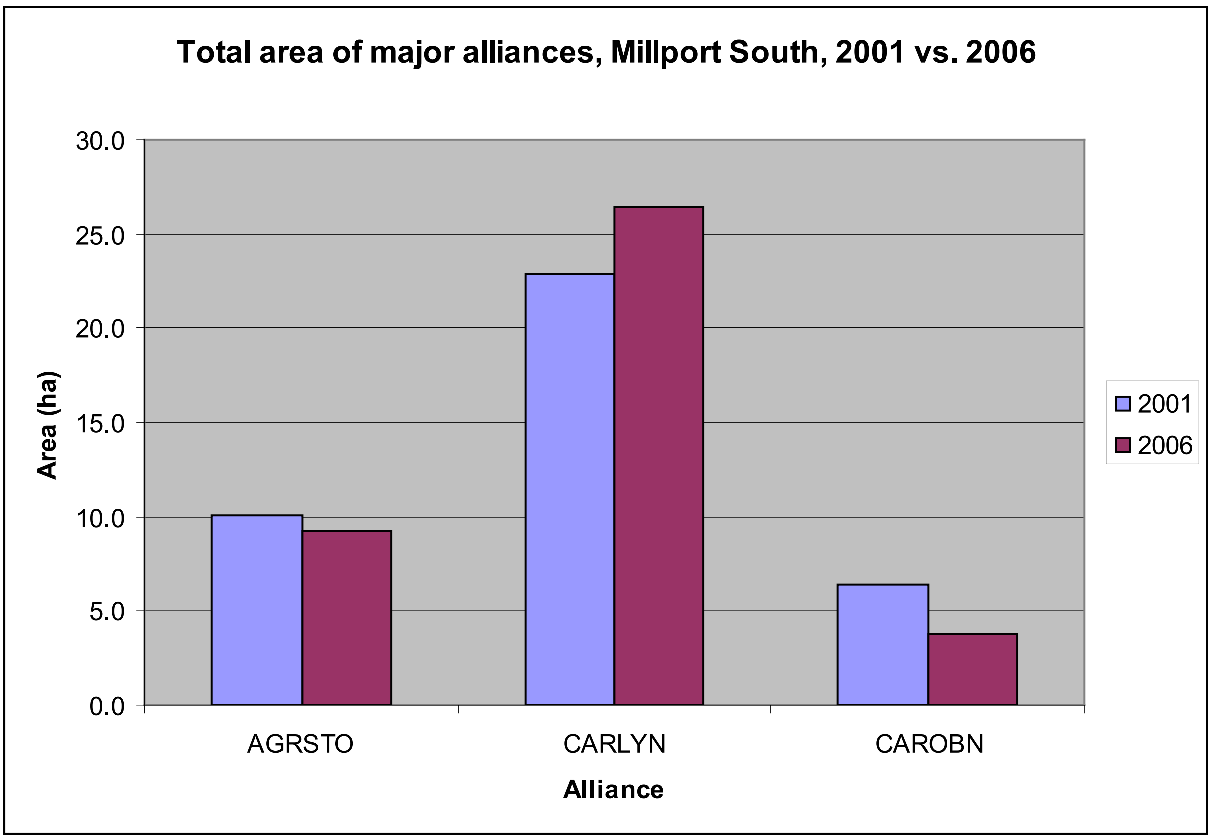


Table 6. Change in area of major alliances at Millport South, 2001-2006

Alliance	**2001 area (ha)**	**2006 area (ha)**	**Change in area (ha)**	**% change, 2001-2006**
AGRSTO	10.1	9.3	-0.8	-8.1
CARLYN	22.9	26.5	+3.6	+15.7
CAROBN	6.4	3.8	-2.6	-40.8

However, as described above ("Land use history and restoration actions"), the west and east halves of the Millport South restoration area have distinctly different history. When the analysis is broken down by subarea (west half or "Gray" vs. east half or "Jackson"), it is apparent that vegetation has changed considerably on Jackson but not on Gray (Charts 4 and 5). Jackson had a 37% increase in Lyngbye's sedge area in 2006 compared to 2001, with a 55% decrease in slough sedge area (Chart 6). This change is most likely due to increased salinity following restoration of this area. By contrast, Gray had little change in total area of these three alliances (Chart 5) – probably because vegetation had already stabilized at Gray due to the earlier natural breach of the earthen dam (see **Land use history and restoration actions** above).

Chart 4. Change in area of major alliances, Millport South east half ("Jackson"), 2001 vs. 2006

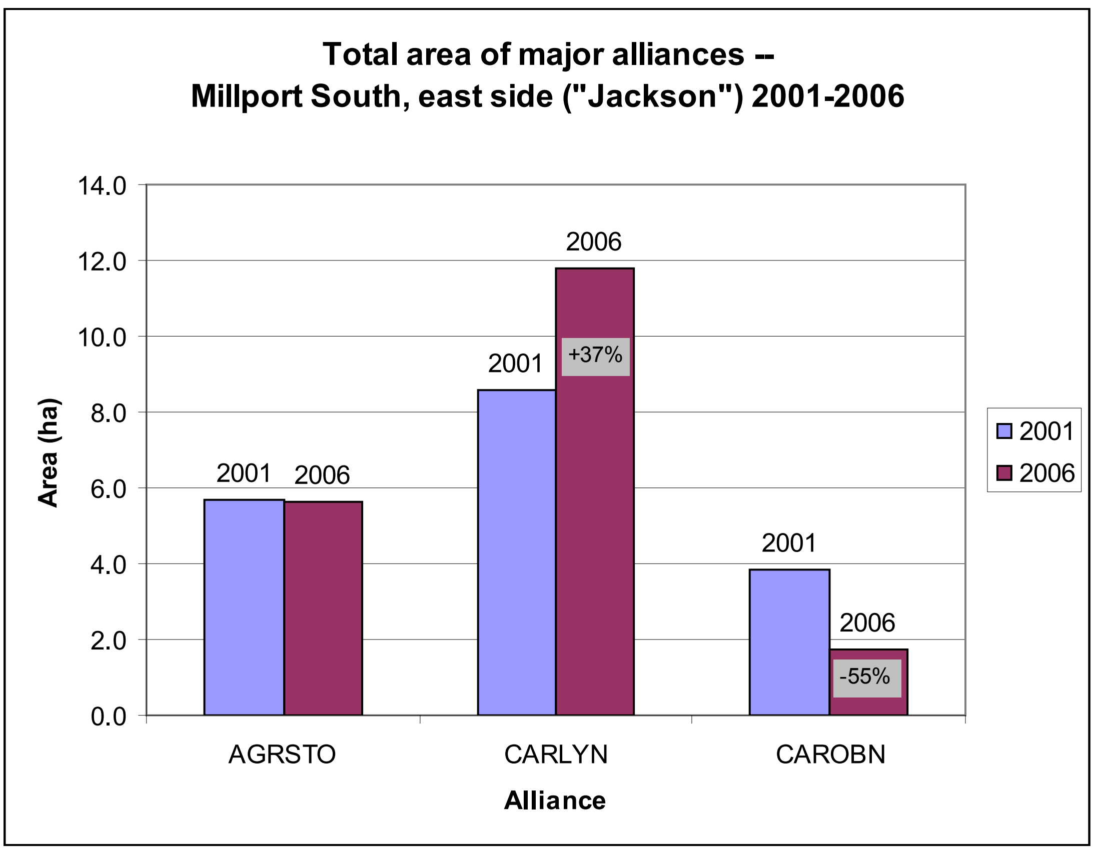
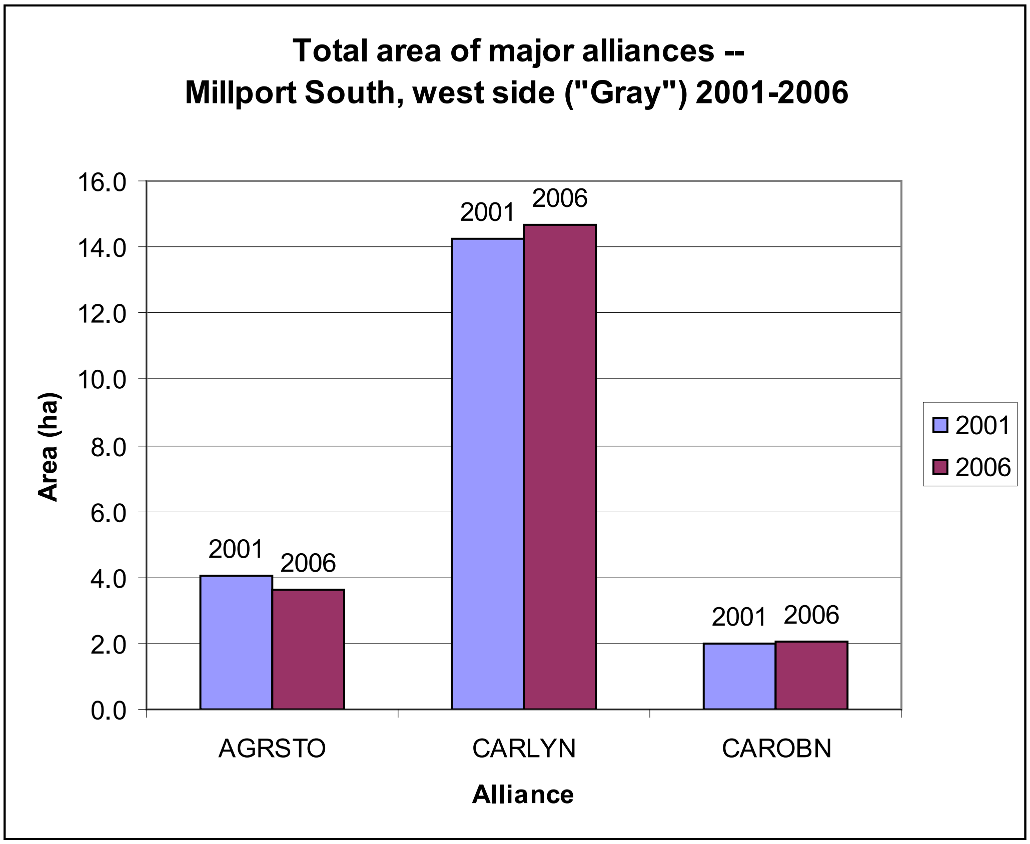


Chart 5. Change in area of major alliances, Millport South west half (“Gray”), 2001 vs. 2006



Results and discussion – Transects and plots

In this section we discuss results of the transect and quadrat analysis for herbaceous vegetation, and the permanent plot measurements of woody stem density and basal area at Site Y28 Plot P5.

Percent cover

Figures 18 and 19 show composition of plant communities at the transects and in plot P5 at Site Y28. These figures are based on visual estimates of percent cover. *For visual comparison to plant community composition in 2001, see the graphics in Appendix 2 of Brophy (2002), available online at https://files.secureserver.net/0s5YfqNWQaOIlA*.

Comparing the 2001 and 2006 cover data, 16 changes of at least 20% cover for a given species within a transect have occurred in the Yaquina sites, and 7 changes of this magnitude occurred at Millport South. Tables 7 and 8 compare average cover of major species across all transects at all sites. The most dramatic trends are described in the narrative following Tables 7 and 8.

Table 7. Changes in percent cover across all transects, Millport Slough (Siletz) sites.

Site	Year	AGRSTO	ARGEGE	CARLYN	DESCES	ELEPAL	JUNBAL	PHAARU	SCIMAR	Bare ground
Millport North	2001	35.7	28.6	5.6	11.7		17.0			
Millport North	2006	45.6	12.9	8.0	12.1		12.2			
Millport South	2001	19.1	6.1	56.2		8.4		7.6	1.2	0.0
Millport South	2006	17.9	2.7	63.4		5.3		2.1	3.5	8.1

Table 8. Changes in percent cover across all transects, Yaquina sites.

Site	Year	AGRSTO	ARGEGE	ATRPAT	CARLYN	CAROBN	DESCES	DISSPI	ELEPAL	JUNBAL	OENSAR	PHAARU	SYMSUB	TYPLAT	Bare ground	Vaucheria*
Y28	2001	9.6	27.8	7.3			7.5			41.0	10.3	1.3		3.5		
Y28	2006	11.3	14.6	0.6		5.2	9.1		0.1	25.7	9.9	3.7	1.4	2.9		
Y3	2001	35.6	9.0	1.4	9.7		2.4	17.5	0.4	28.6	0.5				0.5	1.9
Y3	2006	30.0	8.0	2.3	9.1	1.5	1.6	40.6	0.0	21.6	0.3		1.5			
Y27	2001	32.4		10.5			0.1		25.6			2.8			6.7	13.5
Y27	2006	64.1			11.7		0.7		16.5			1.8		2.0	3.5	

* The yellow-green alga Vaucheria was the only non-vascular plant that was monitored; it was the only non-vascular species with substantial cover at any site.

Millport North reference site

At Transect 1, average cover of Pacific silverweed was lower and cover of creeping bentgrass was higher in 2006 (Figure 18) than in 2001 (Brophy 2002). This was probably due to warm dry weather immediately preceding the monitoring work in 2006. Pacific silverweed can senescence suddenly in late July when weather is warm and dry, and since this plant tends to grow atop the mat of creeping bentgrass stems, bentgrass cover readings will be higher after the silverweed leaves wither. No other major changes were noted in cover data this reference site (Table 7). This relative stability is likely due to the site's least-disturbed status.

Millport South restoration site

As described in "Changes in spatial extent of vegetation alliances" above, cover of Lyngbye's sedge increased in 2006 compared to 2001, particularly on the east half of the site ("Jackson"). The changes were not dramatic, but field reconnaissance and plant community mapping confirmed that cover of this species is increasing in this area. Pacific silverweed cover was lower on Millport South in 2006 compared to 2001; as described above, this probably reflects weather conditions prior to monitoring.

Yaquina Site Y27

Creeping bentgrass (*Agrostis stolonifera*) generally increased in cover during the 4 year period at Site Y27 (T1-T6), with accompanying decreases in saltbush (*Atriplex patula*) and creeping spikerush (*Eleocharis palustris*). Saltbush is a "fugitive" species that tends to colonize in disturbed habitats or areas where salinity is changing rapidly, and creeping spikerush has been described as a "residual" species characteristic of freshwater wetlands (Frenkel and Morlan 1991; Cornu and Sadro 2005). Creeping bentgrass has been characterized as a competitively dominant permanent colonizer (Cornu and Sadro 2005, Frenkel and Morlan 1991), but as described in the next paragraph, Lyngbye's sedge is expanding rapidly on this site, and may replace much of the bentgrass, particularly on lower portions of the site.

Another striking vegetation change at Site Y27 over the 4 years since restoration is the increase in dominance and extent of Lyngbye's sedge. Lyngbye's sedge is a rapidly spreading and very competitive native marsh species that can spread rapidly within a few years after dike breaching on brackish high marsh restoration sites like Site Y27 (Cornu and Sadro 2005, Frenkel and Morlan 1991). The average cover of Lyngbye's sedge at Site Y27 increased from zero to 35-40% at two of the higher transects on Site Y27 (T8 and T9), and has already reached nearly 20% cover at T6 and T10 (Figure 19). New, growing clones of this species can be seen throughout the site, and it will probably increase considerably in cover over the next few years.

Other changes at Site Y27 included complete disappearance of the freshwater wetland species soft rush (*Juncus effusus*). This species had still persisted at Transects 5, 6 and 10 in 2001, but was completely absent from all transects in 2006 (Figure 18). Another freshwater wetland species, reed canarygrass (*Phalaris arundinacea*), was still present at T5 in 2006, but had decreased from 28% to 18% cover by 2006 (Figure 19) and was chlorotic and non-reproductive, indicating likely stress from the increasing salinities at the site.

Yaquina Site Y3

At Site Y3, vegetation changes also indicated increased salinity, but changes were less dramatic than at Site Y27. Average cover of seashore saltgrass (*Distichlis spicata*) increased from 17.5% to 40.6%, and many areas that had dense cover of creeping bentgrass in 2001 were being extensively colonized by seashore saltgrass in 2006. This was particularly true near the lower breaches on the site, in the area of Transects T4 and T5 (Figure 19).

Yaquina Site Y28

At Site Y28, as at the Millport sites, cover of Pacific silverweed was lower in 2006 (Figure 19) compared to 2001, probably due to warm weather prior to monitoring which caused early senescence of the foliage.

Woody stem densities and basal area

We counted woody stems of all shrub species in Plot 5 of Site Y28 in summer 2006. Plot 5 contained no trees, although the site as a whole has a number of Sitka spruce trees along channels. Methods followed Peet (1998). Stems were categorized as to diameter, with the lowest diameter class being 0-1cm and the maximum observed diameter class being 5-10cm. Data were analyzed to determine woody stem densities (stems/ha); results are shown in Table 9.

Table 9. Shrub stem densities (stems/hectare), Plot 5, Site Y28, in summer 2006.

	Stems/ha							
Site	**Black twinberry**	**Pacific crabapple**	**Hooker willow**	**Douglas' spiraea**	**Sitka spruce**	**Evergreen huckleberry**	**Salal**	**All trees and shrubs**
Y28 Plot 5	15,191	239	0	0	0	0	0	15,431

The very high density of black twinberry at Site Y28 Plot 5 is typical of oligohaline to low mesohaline forested and scrub-shrub tidal wetlands studied by GPC in other estuaries (Brophy 2007). As black twinberry grows, its stems tend to sprawl, so that the larger stems grow nearly horizontally and very low to the ground. Younger stems grow upwards, with the result that stem densities are very high when measured at knee to breast height (following typical shrub stem count protocols such as Peet [1998]).

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Figure list

Figure 1. Vicinity map, Yaquina sites

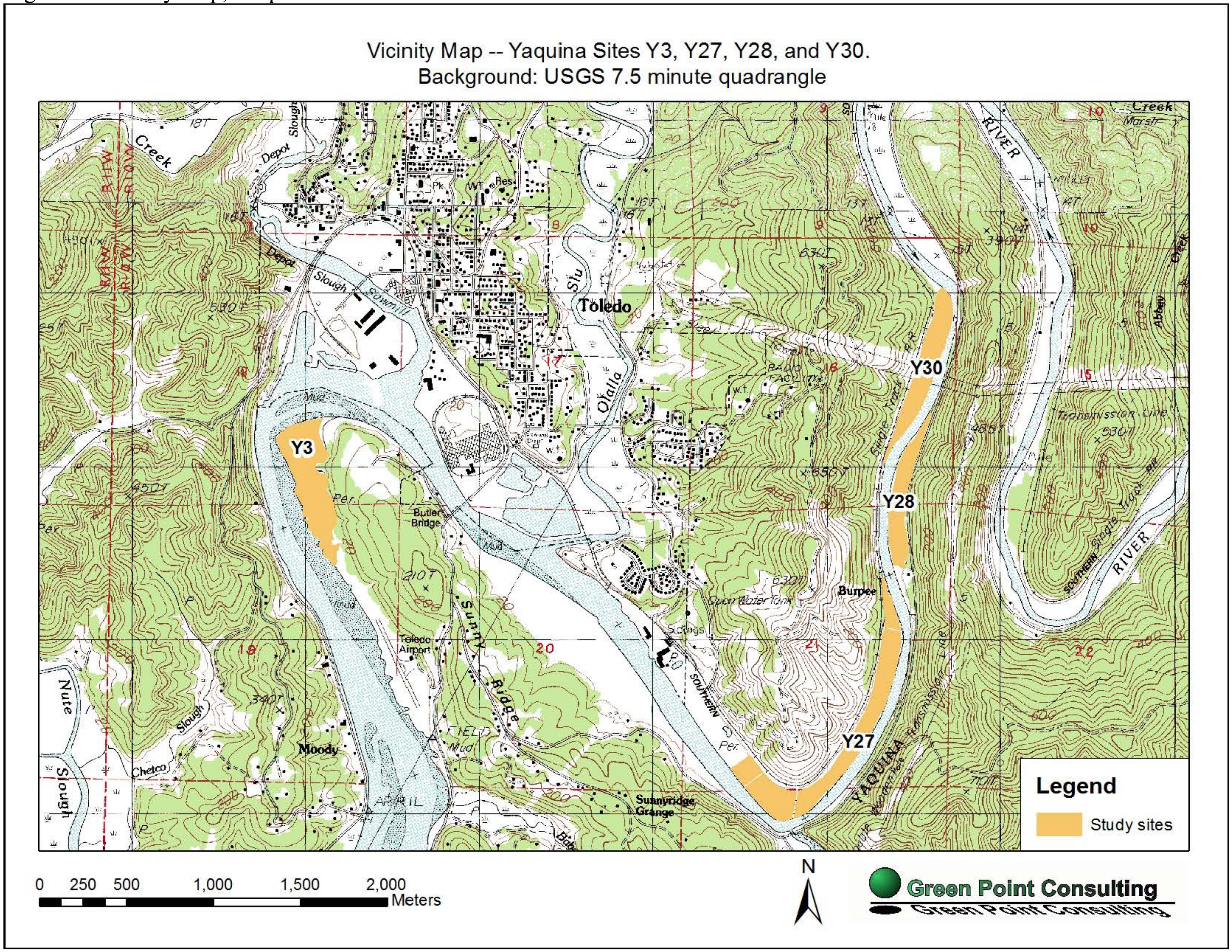


Figure 2. Vicinity map, Siletz sites

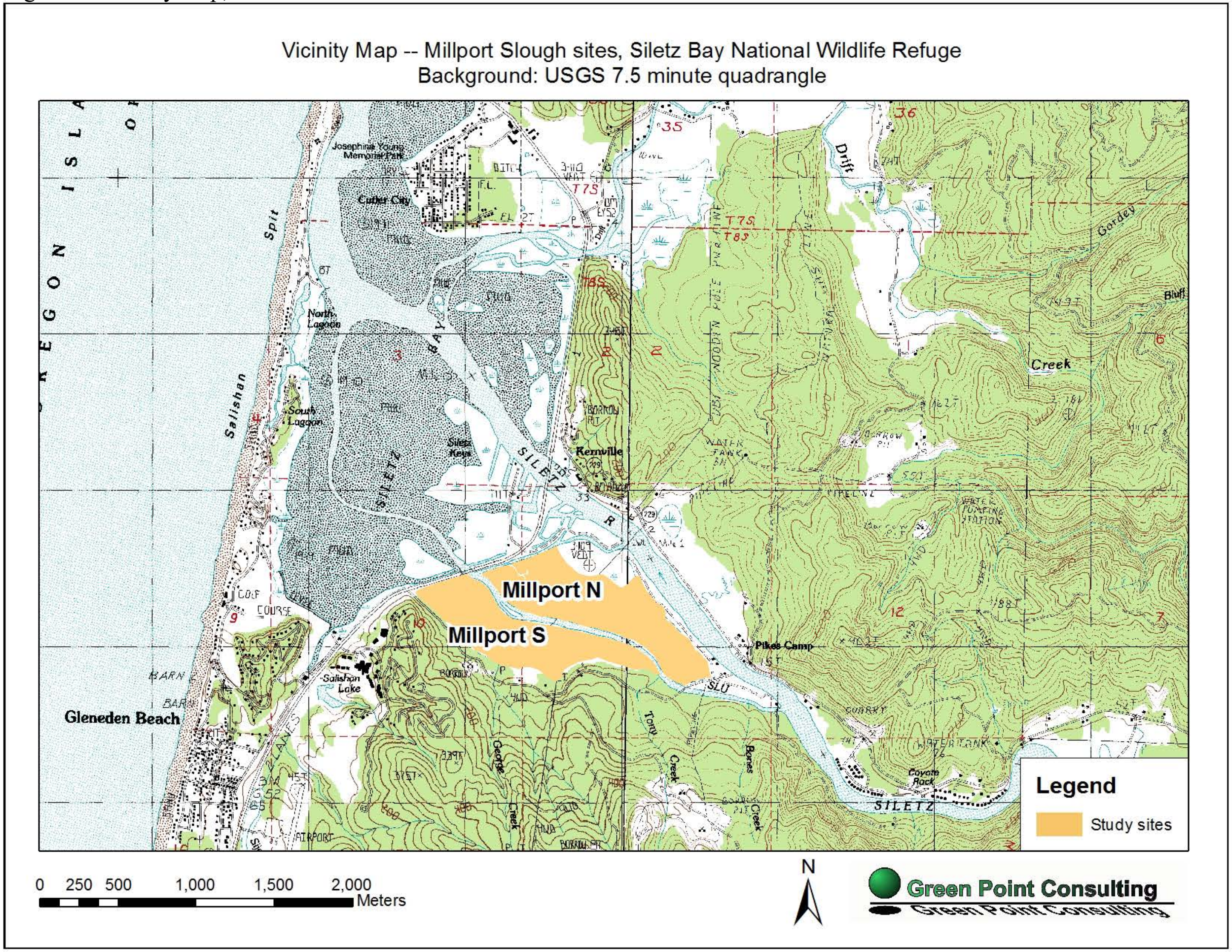


Figure 3. Transect locations, Millport North

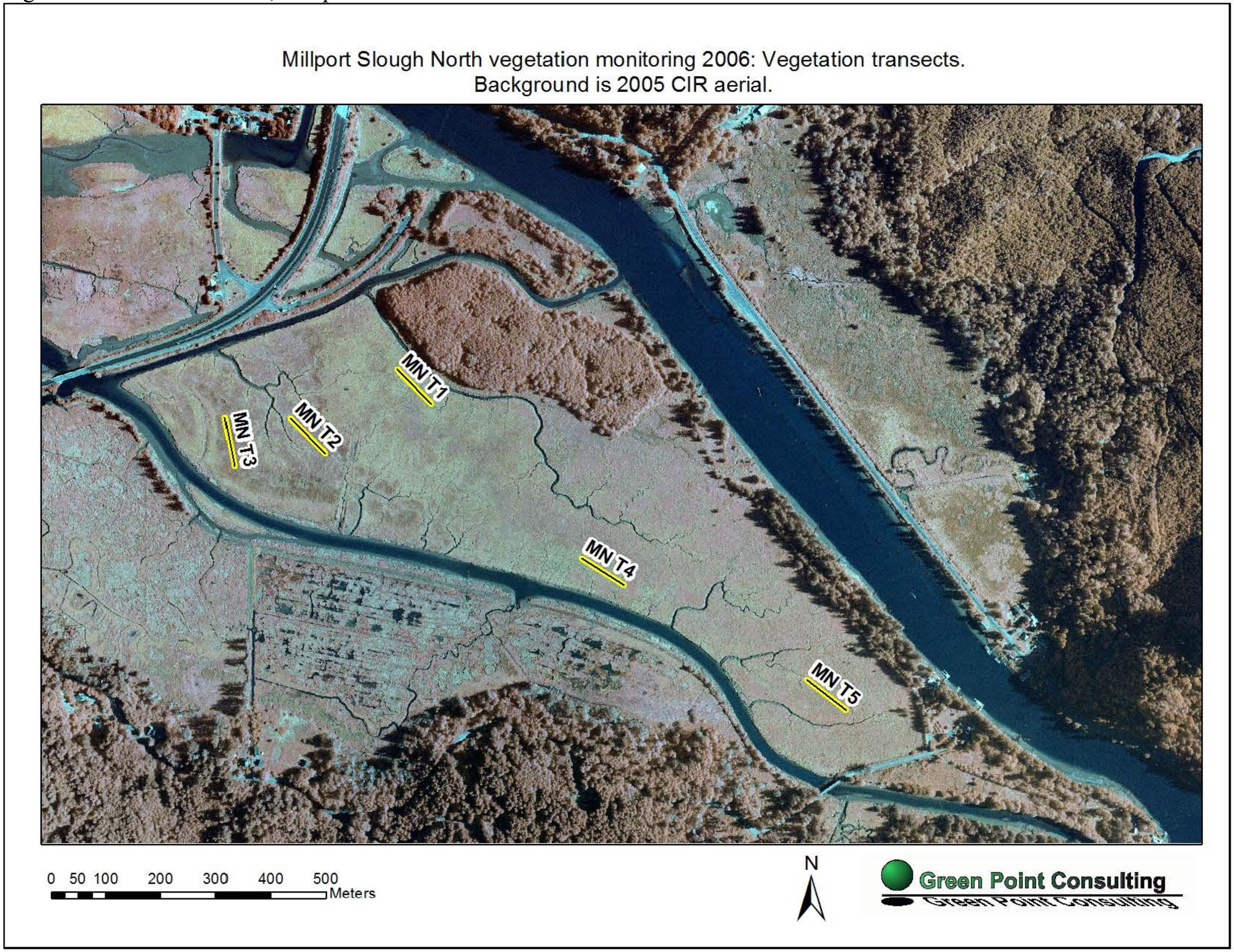


Figure 4. Plant communities (color-coded by alliances), Millport South

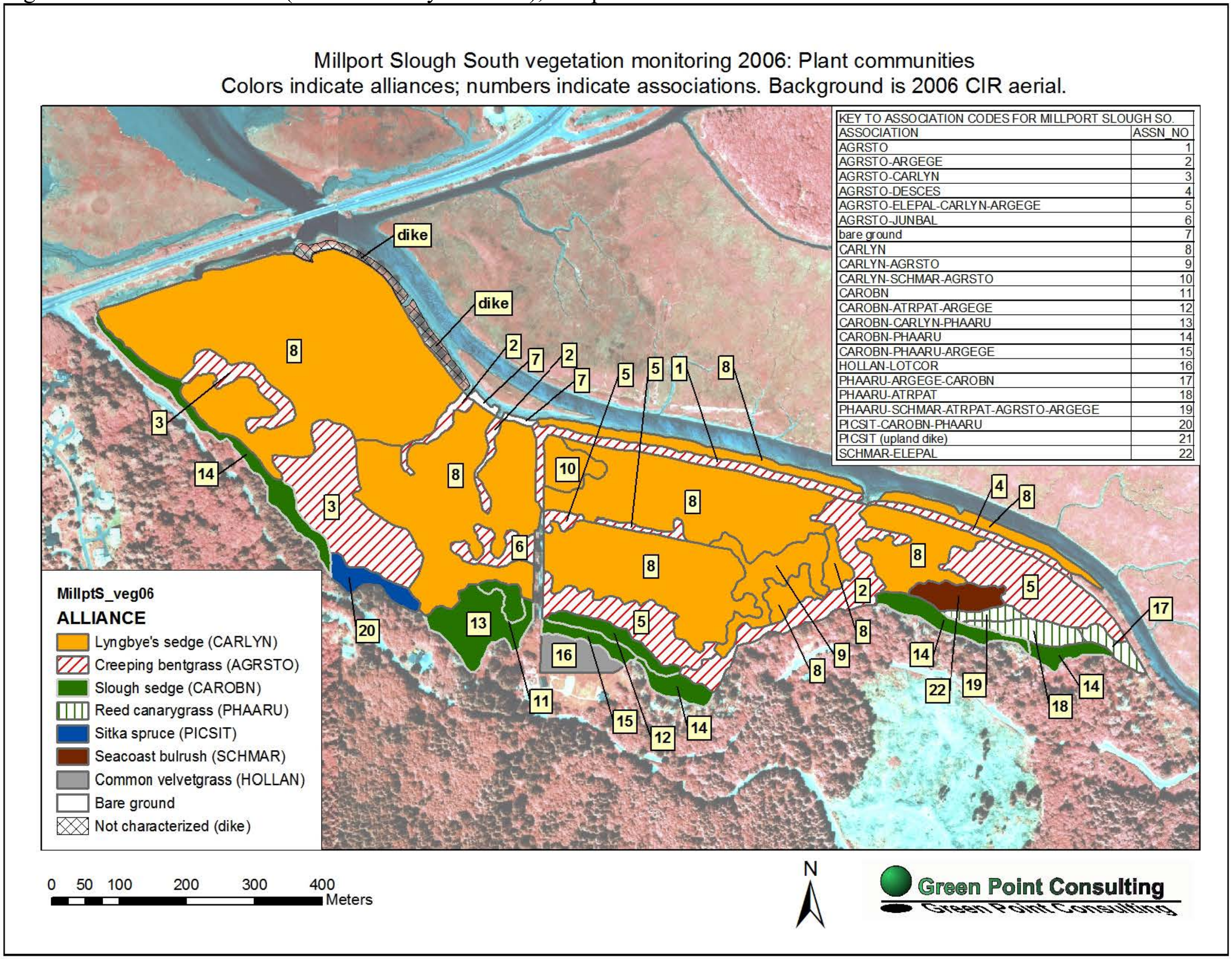


Figure 5. Plant community outlines, Millport South

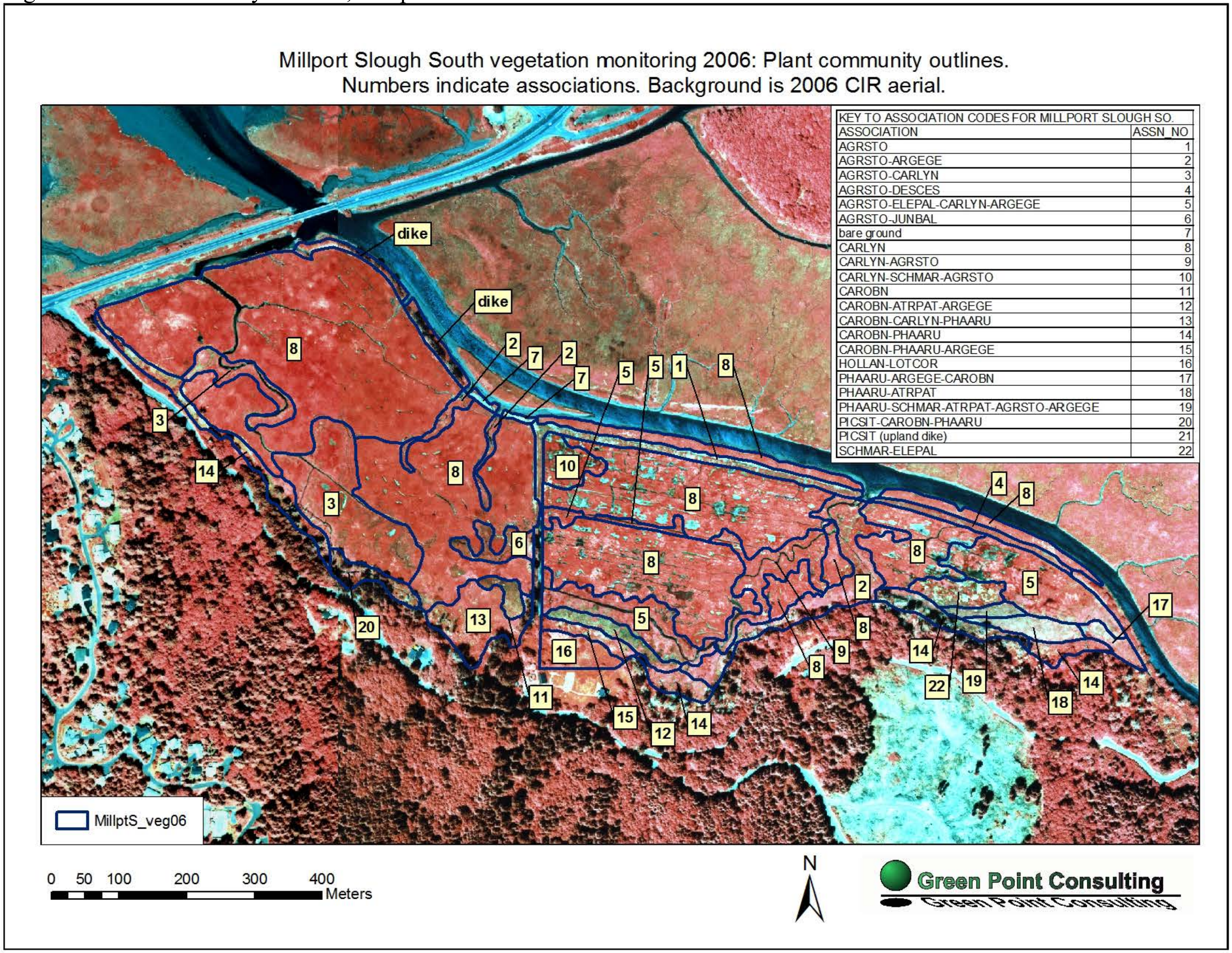


Figure 6. Transect locations, Millport South

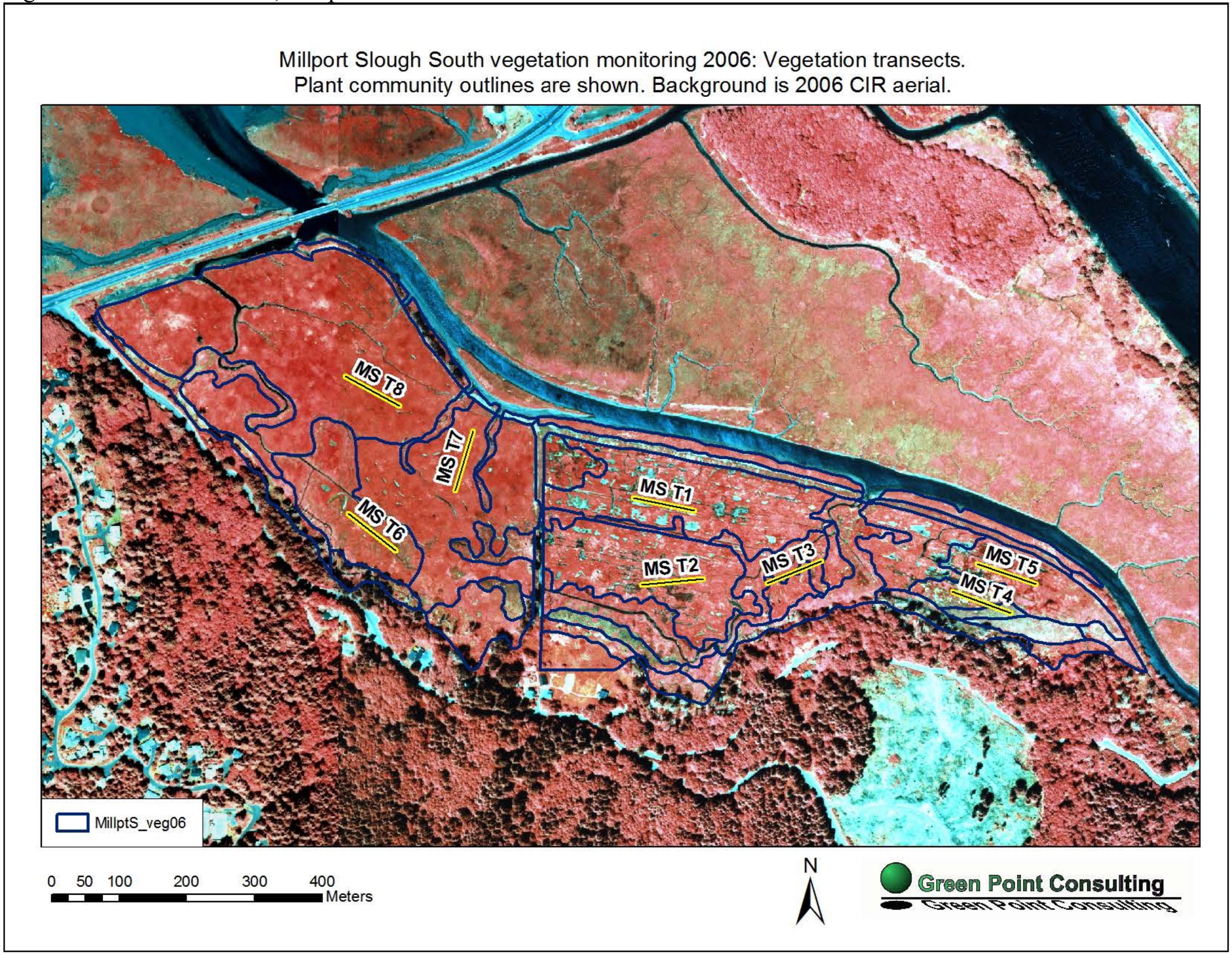


Figure 7. Plant communities (color-coded by alliances), Yaquina Site Y3

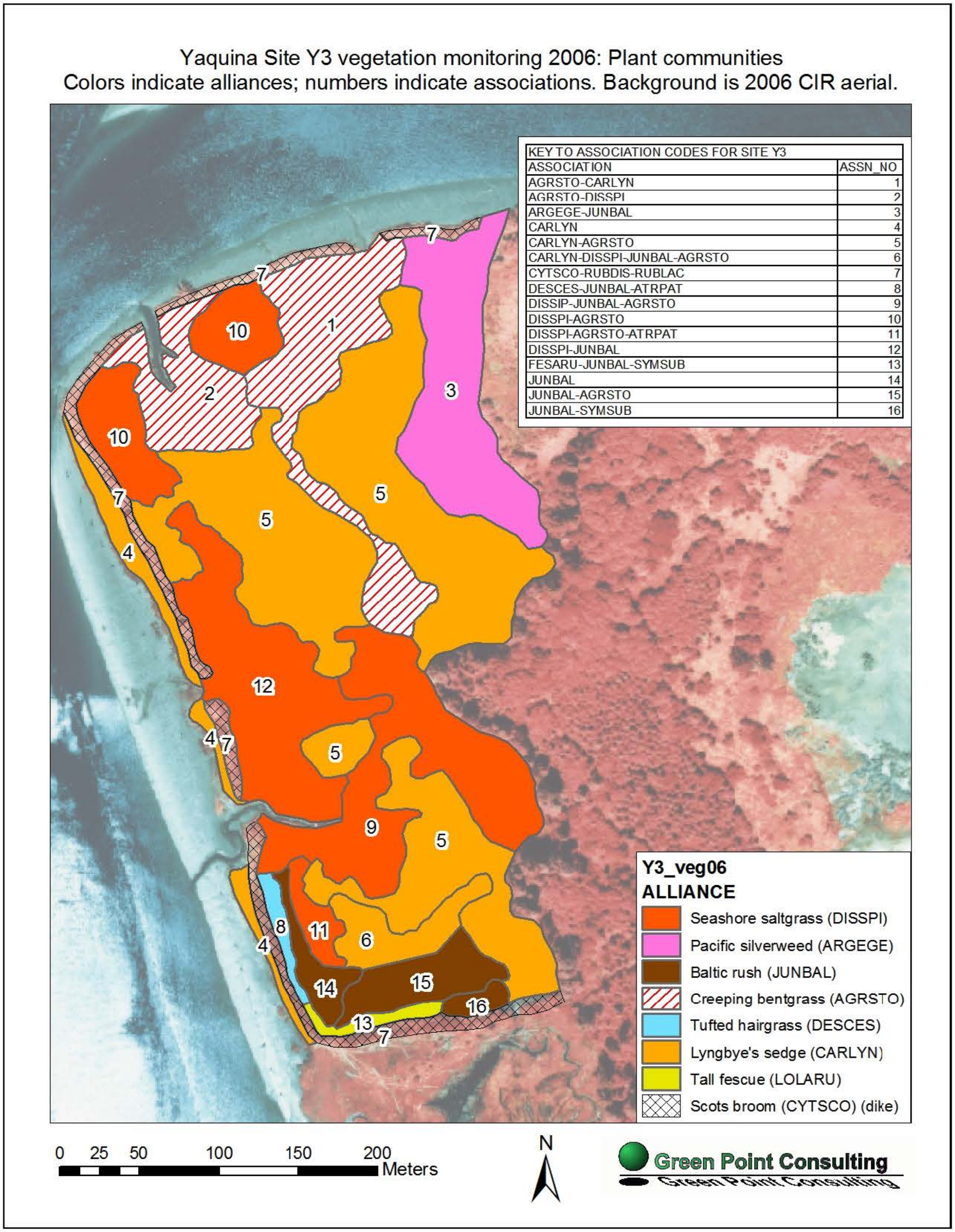


Figure 8. Plant community outlines, Yaquina Site Y3

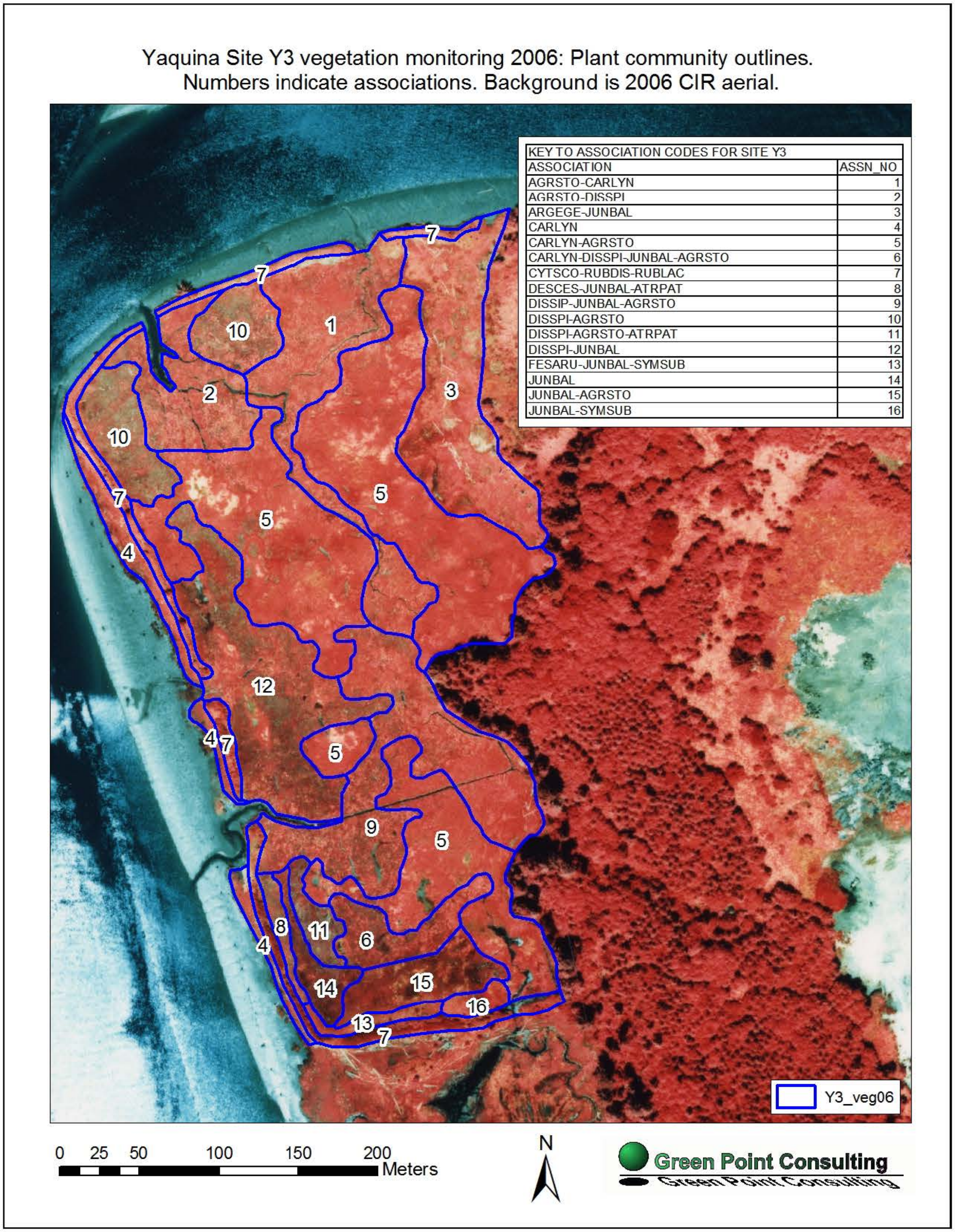


Figure 9. Transect locations, Yaquina Site Y3

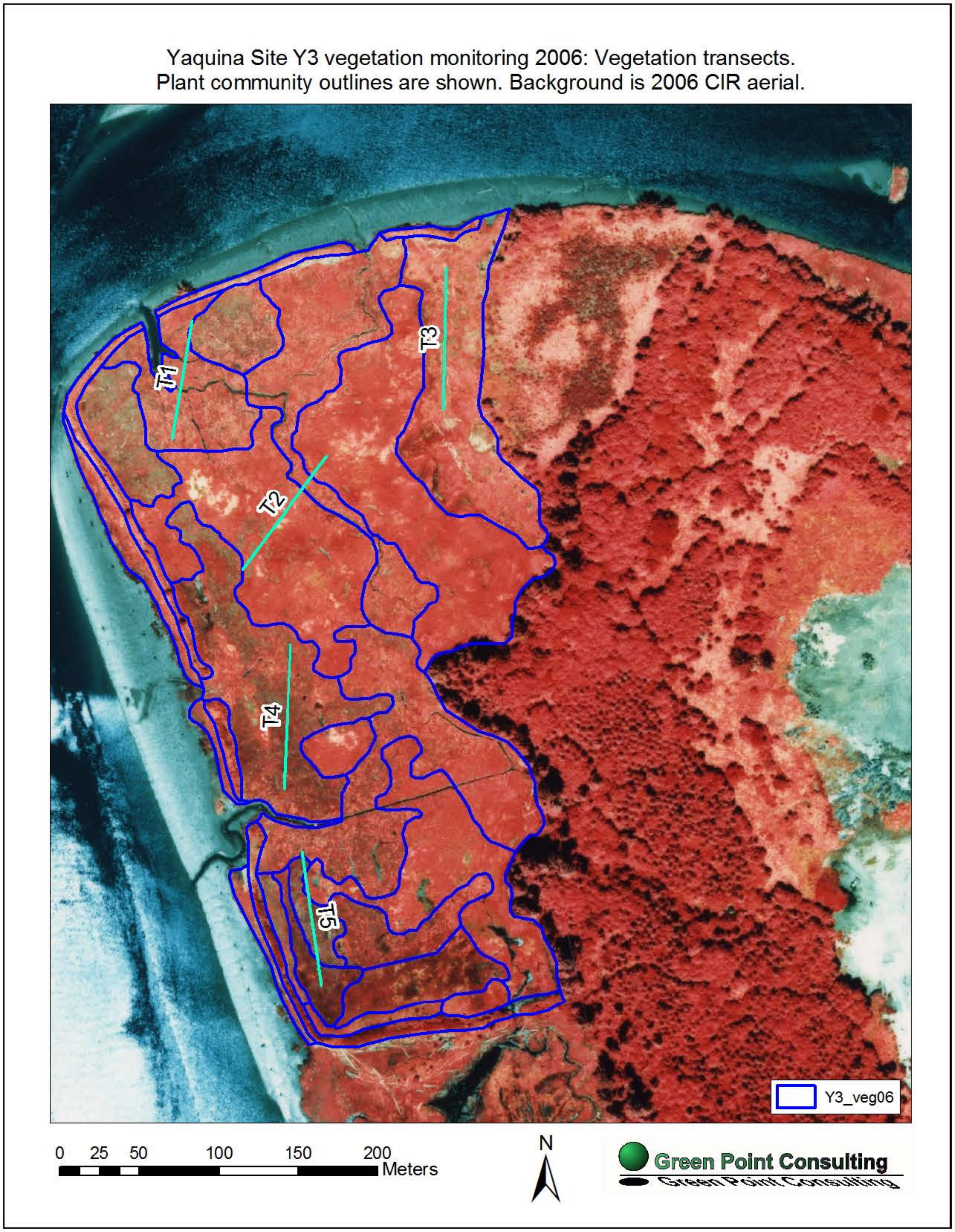


Figure 10. Plant communities (color-coded by alliances), Yaquina Site Y27

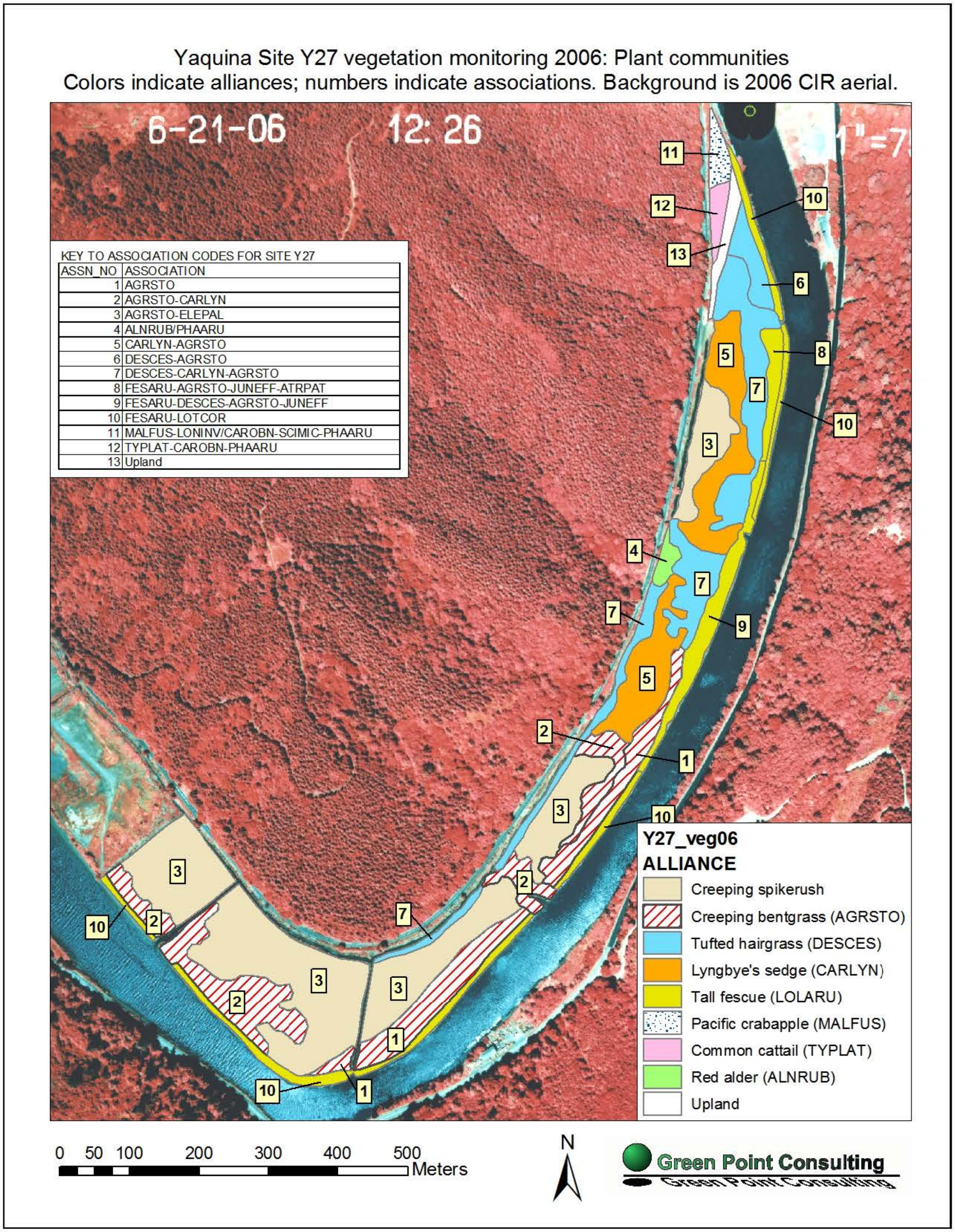
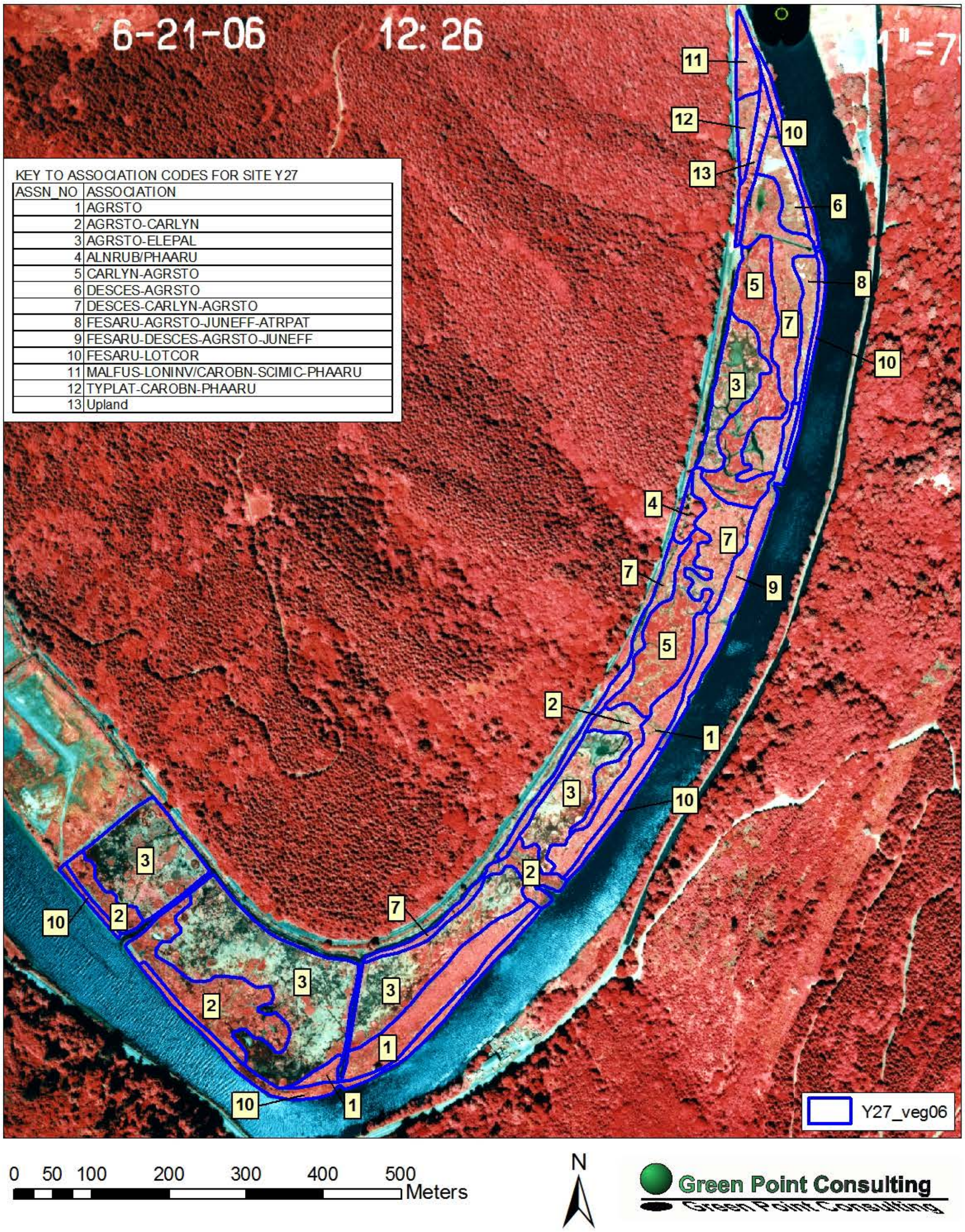


Figure 11. Plant community outlines, Yaquina Site Y27

Yaquina Site Y27 vegetation monitoring 2006: Plant community outlines.
Numbers indicate associations. Background is 2006 CIR aerial.



ASSN_NO	ASSOCIATION
1	AGRSTO
2	AGRSTO-CARLYN
3	AGRSTO-ELEPAL
4	ALNRUB/PHAARU
5	CARLYN-AGRSTO
6	DESCES-AGRSTO
7	DESCES-CARLYN-AGRSTO
8	FESARU-AGRSTO-JUNEFF-ATRPAT
9	FESARU-DESCES-AGRSTO-JUNEFF
10	FESARU-LOTCOR
11	MALFUS-LONINV/CAROBN-SCIMIC-PHAARU
12	TYPLAT-CAROBN-PHAARU
13	Upland

Figure 12. Transect locations, Yaquina Site Y27

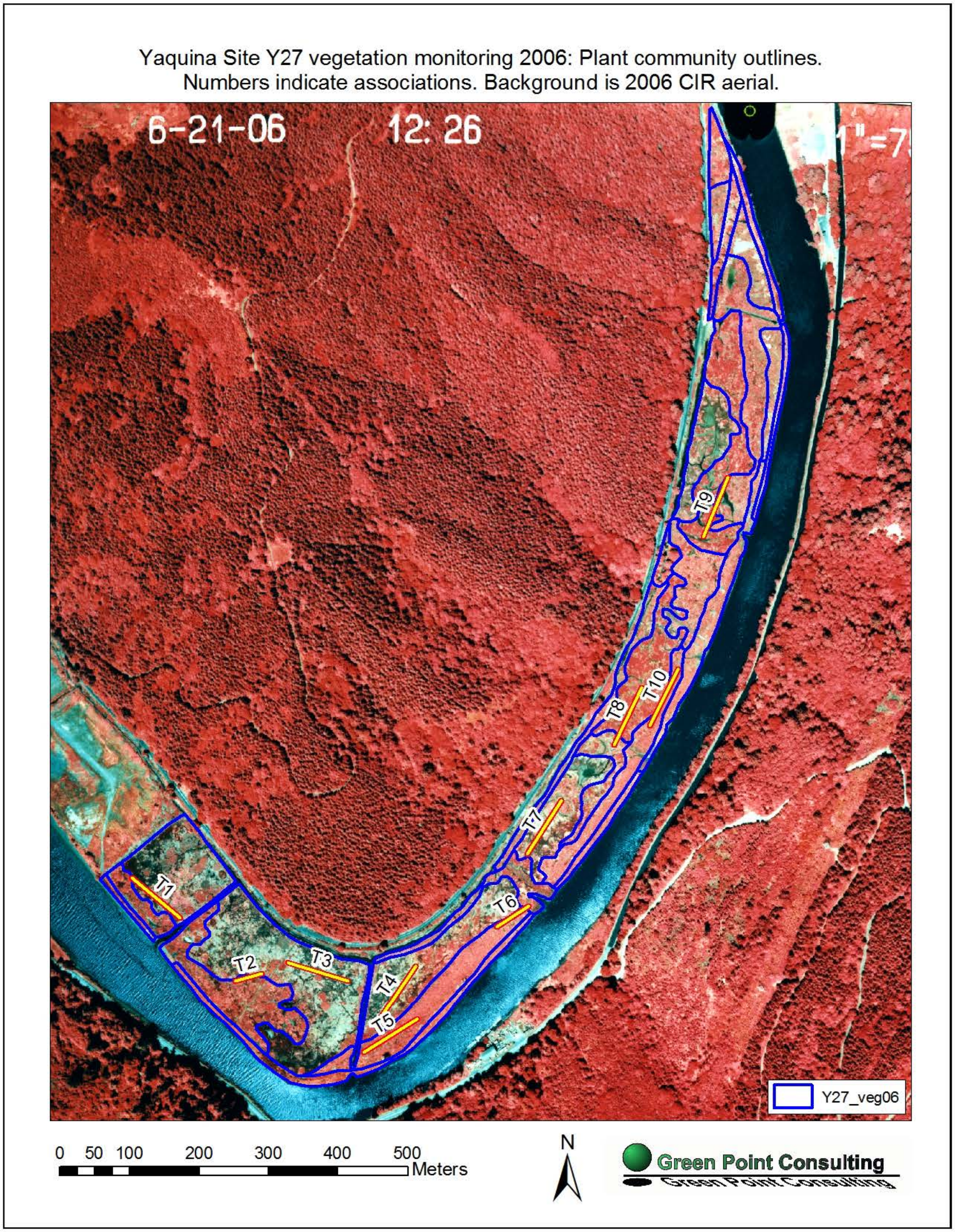


Figure 13. Plant communities (color-coded by alliances), Yaquina Site Y28

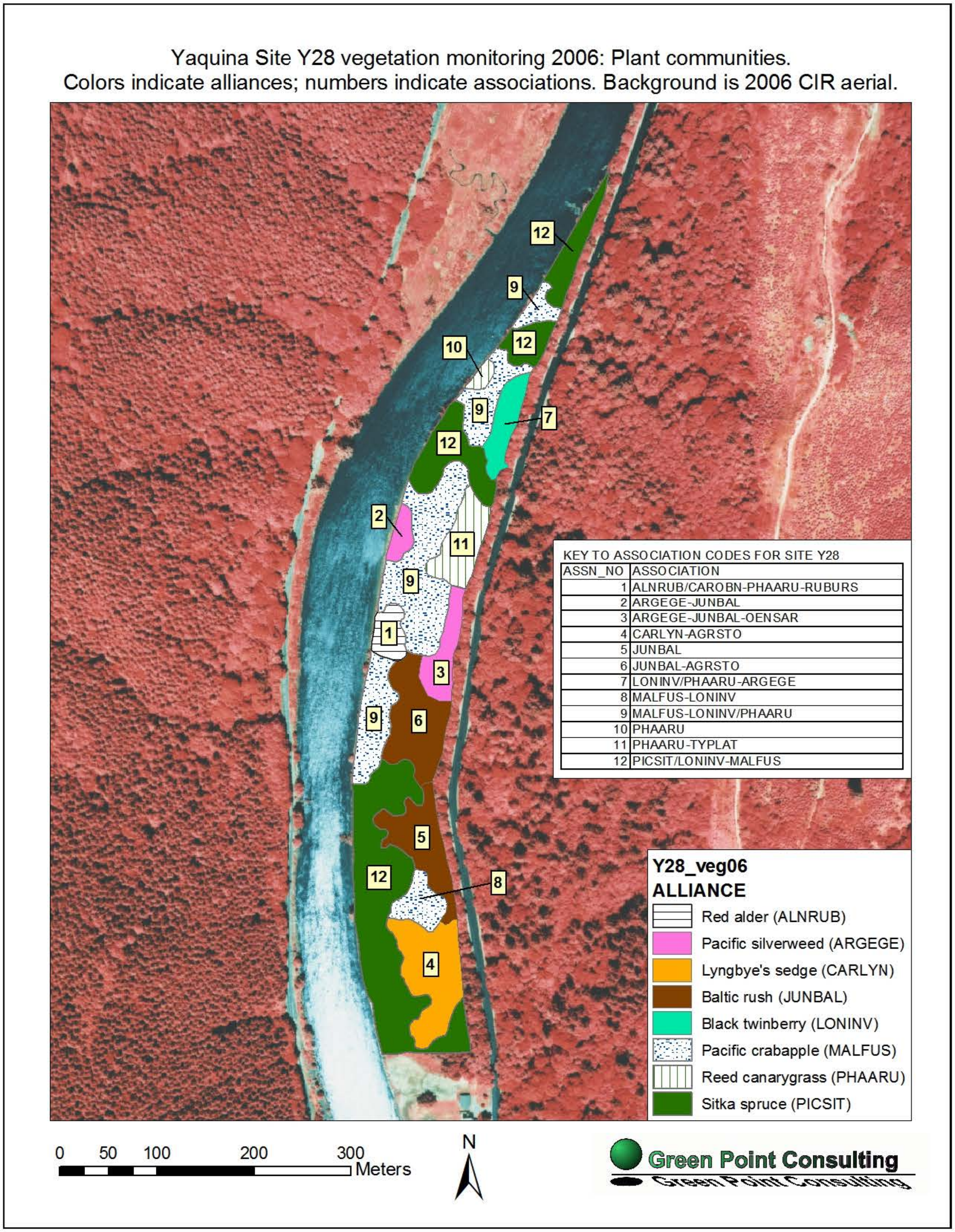


Figure 14. Plant community outlines, Yaquina Site Y28

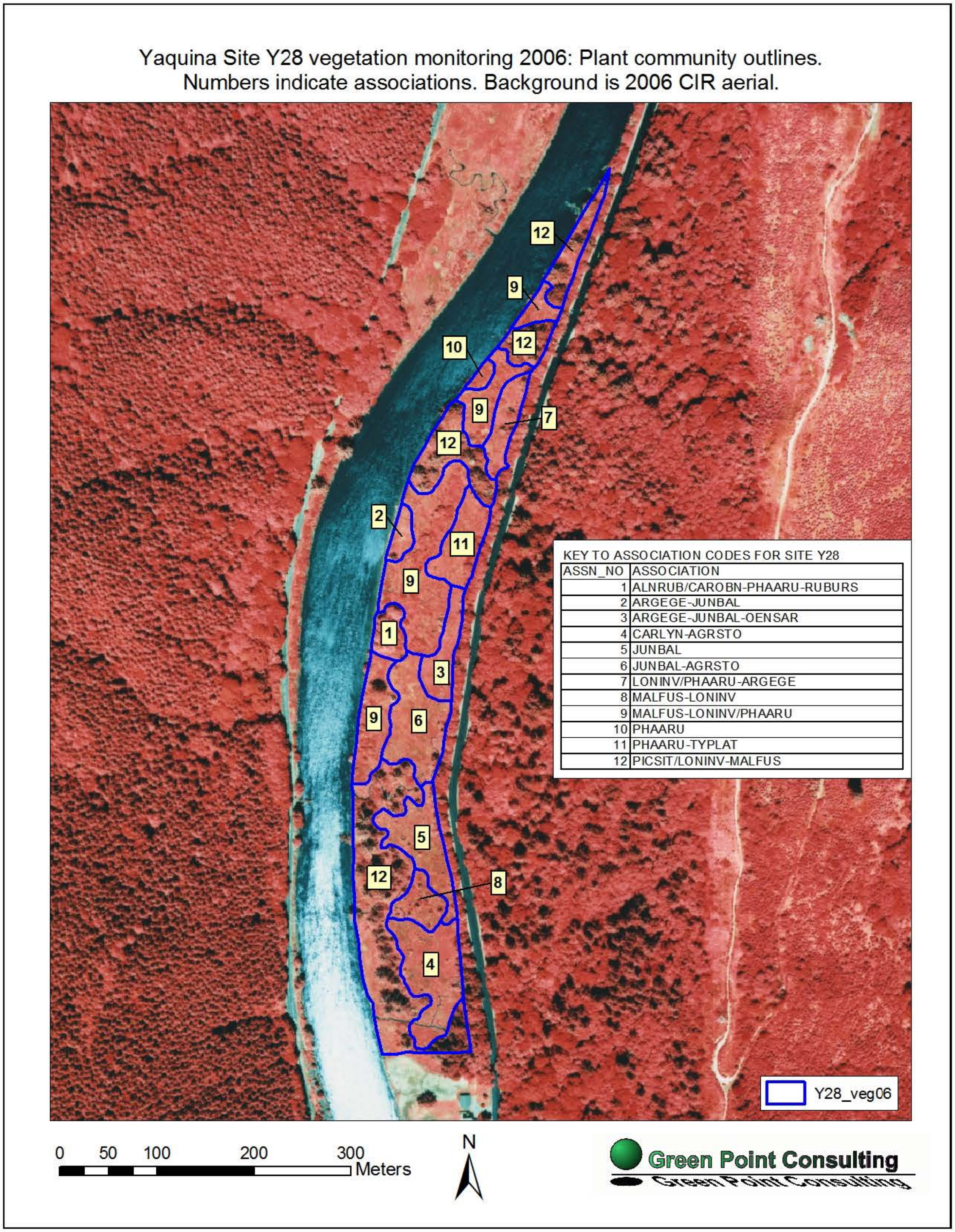


Figure 15. Transect locations, Yaquina Site Y28

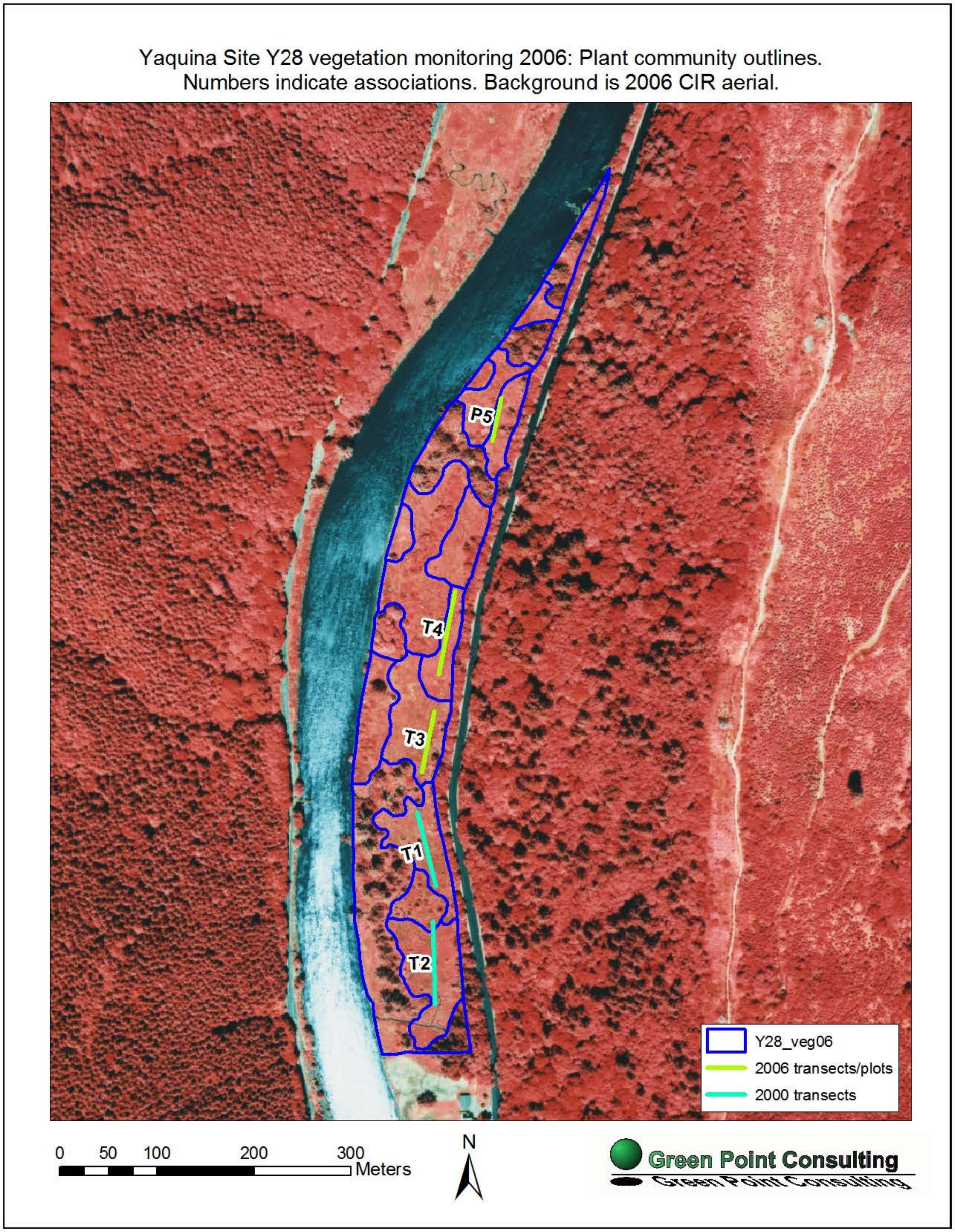


Figure 16. Plant communities (color-coded by alliances), Yaquina Site Y30

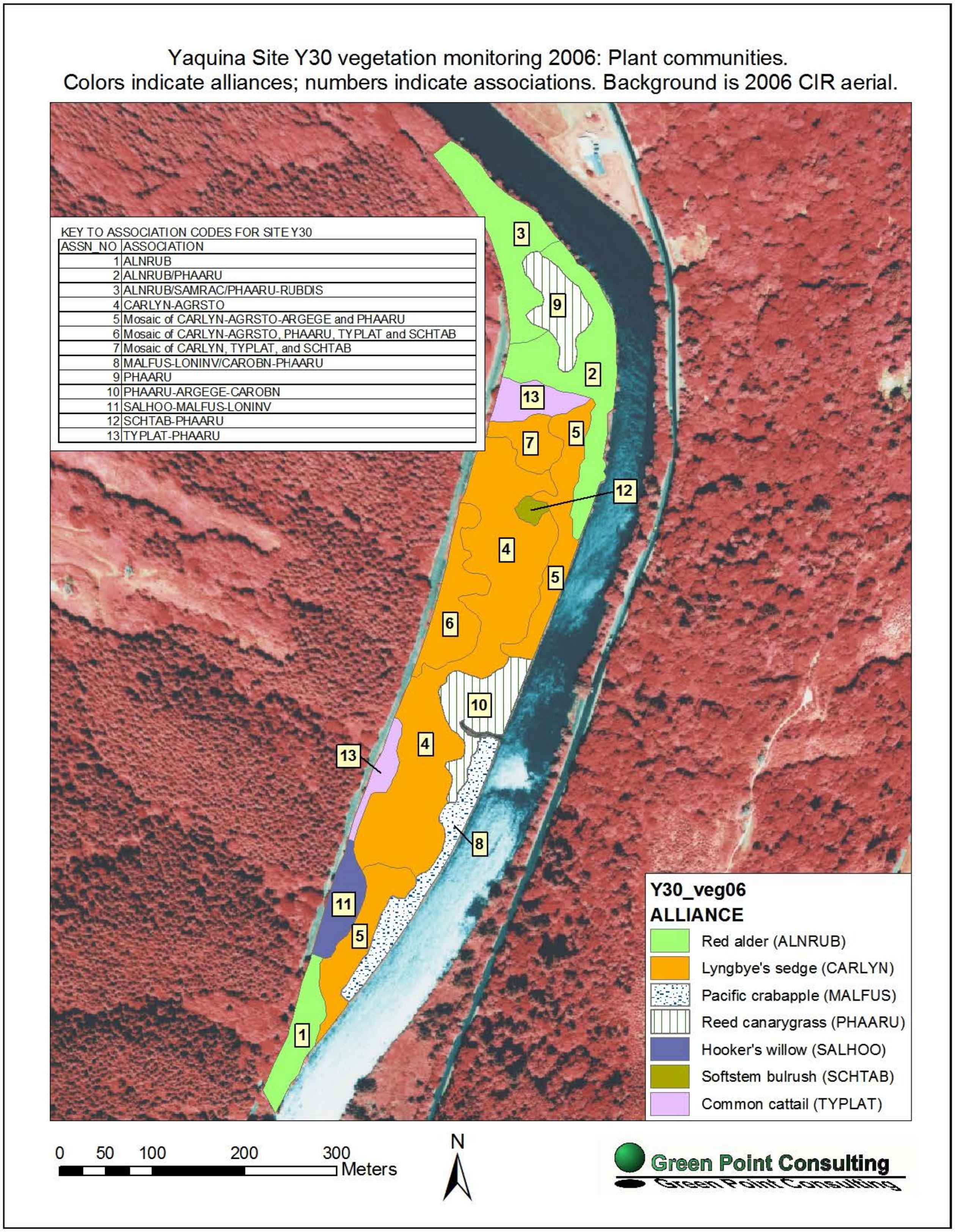
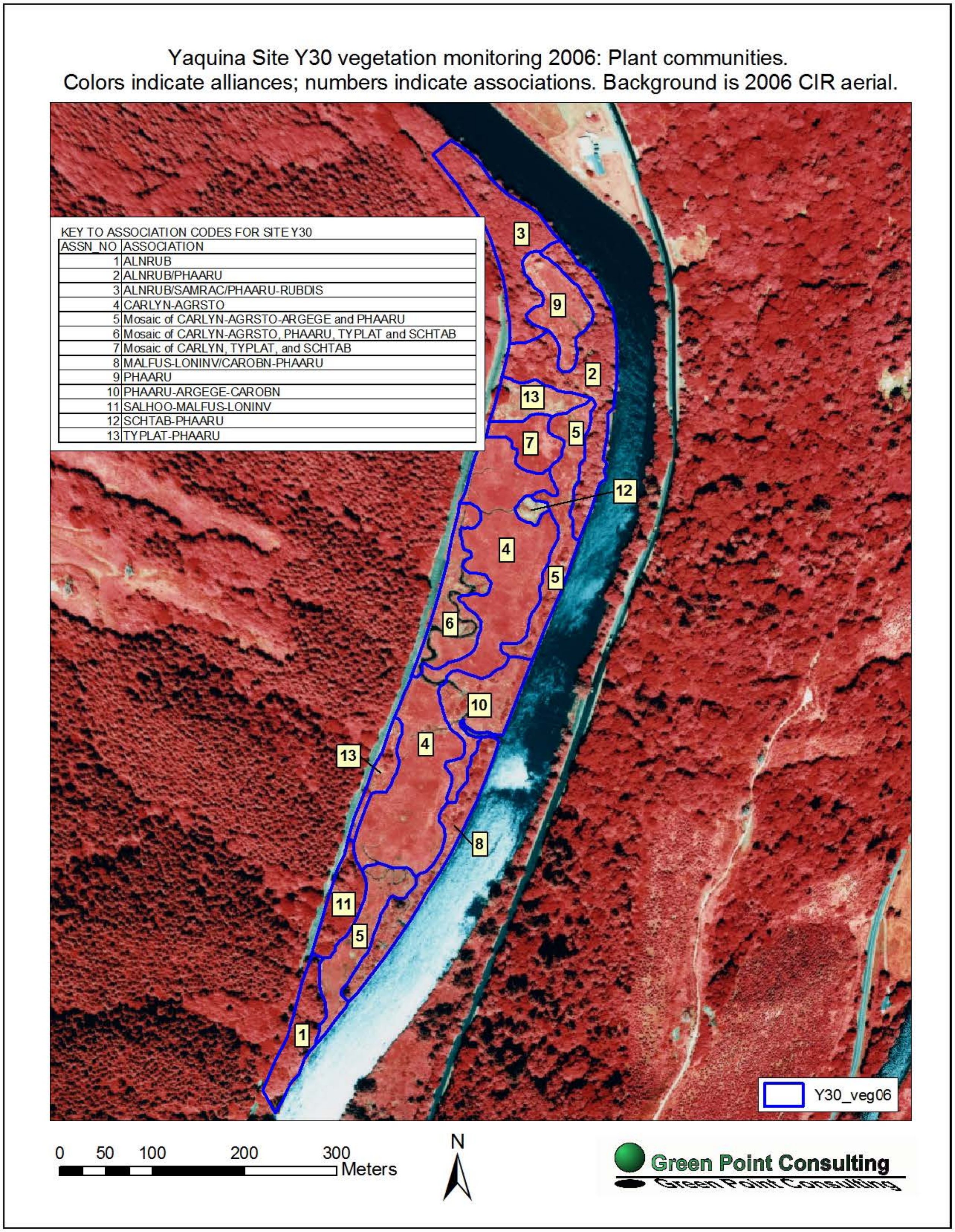


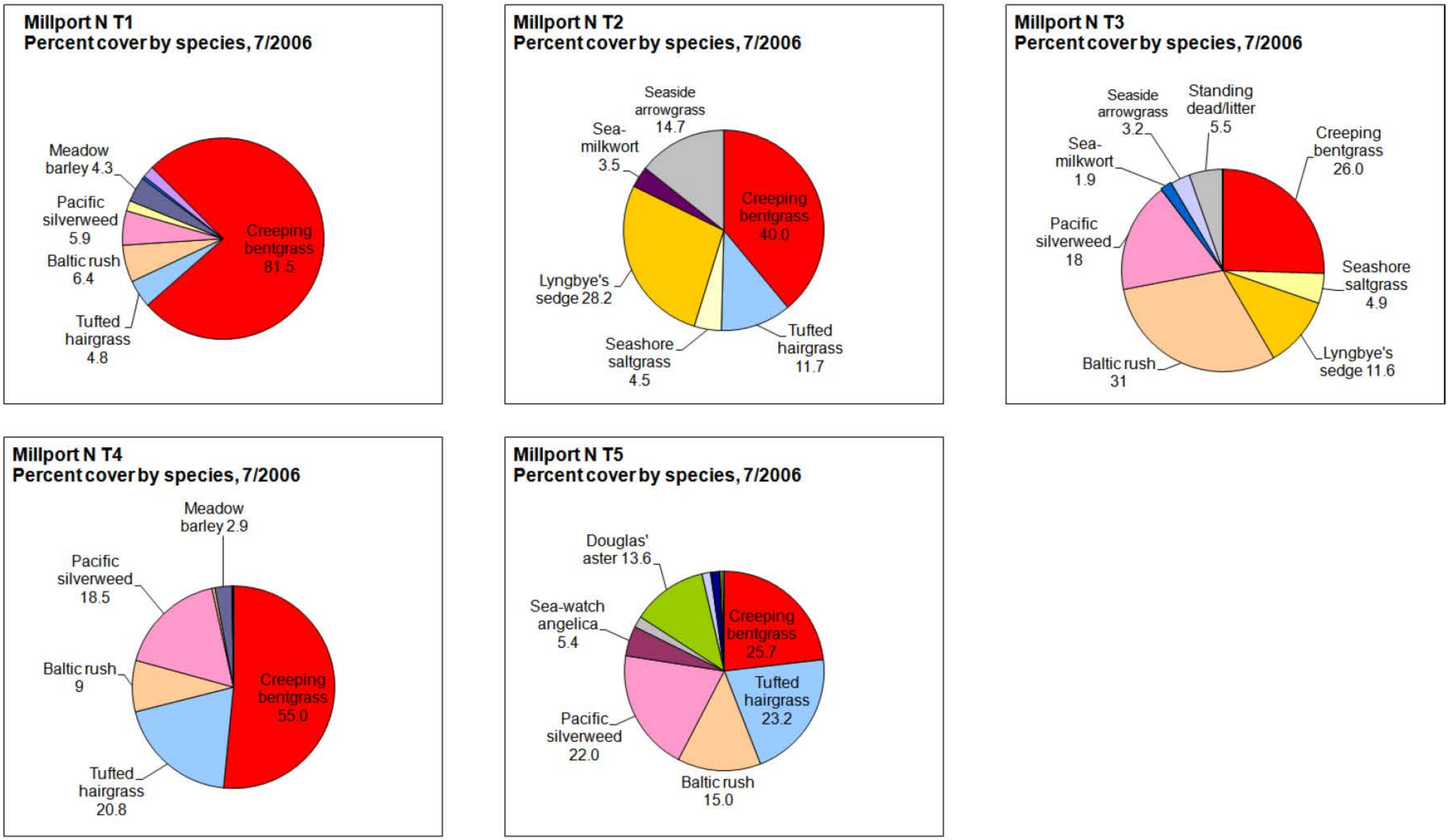
Figure 17. Plant community outlines, Yaquina Site Y30

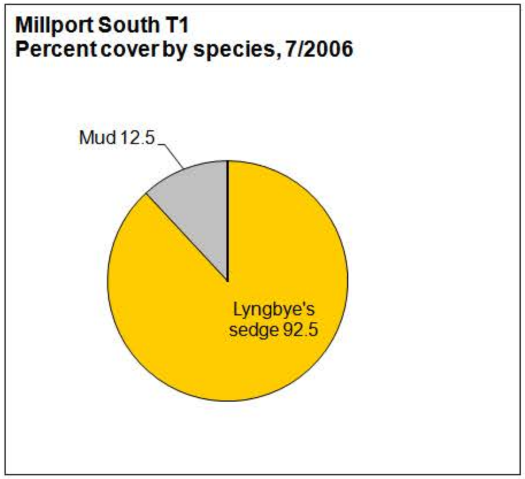


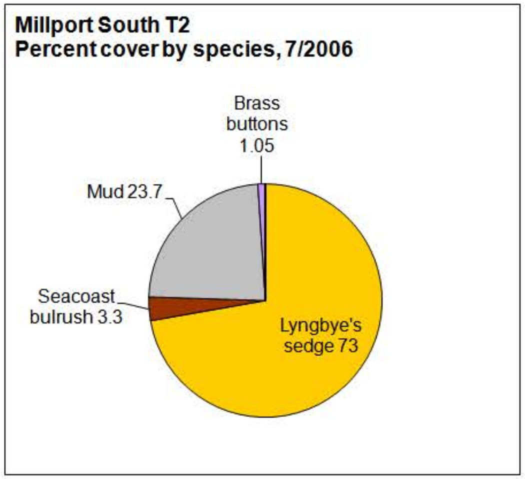
Excel charts of plant community composition

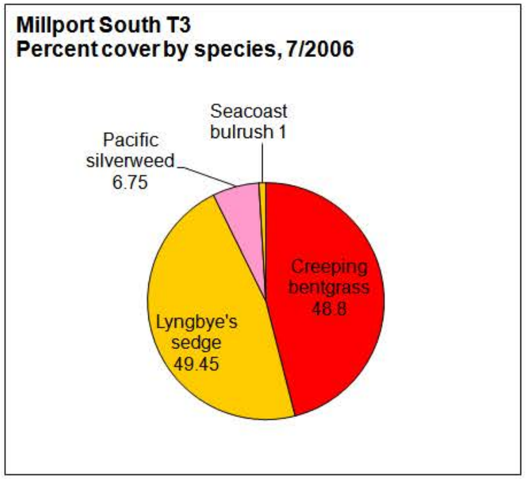
For visual comparison to plant community composition in 2001, see the graphics in Appendix 2 of Brophy (2002), available online at https://files.secureserver.net/0s5YfqNWQaOIlA or by contacting Green Point Consulting, (541) 752-7671.

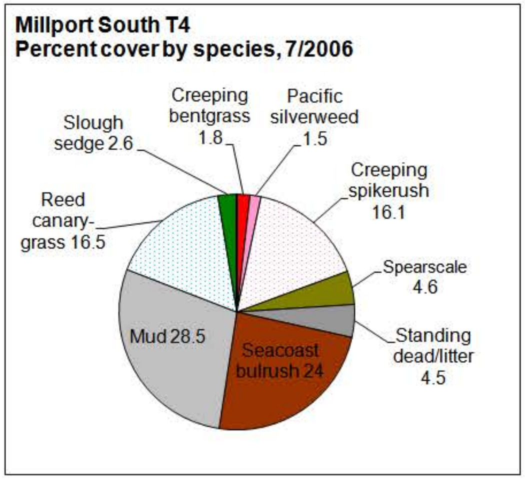
Figure18. Composition of plant communities at Siletz (Millport) tidal wetland restoration and reference site transects in 2006. Charts show average percent cover across all quadrats in transect. Total percent cover may add up to more than 100% due to layering. Species with less than 1% cover are not labeled but are included in pie charts.

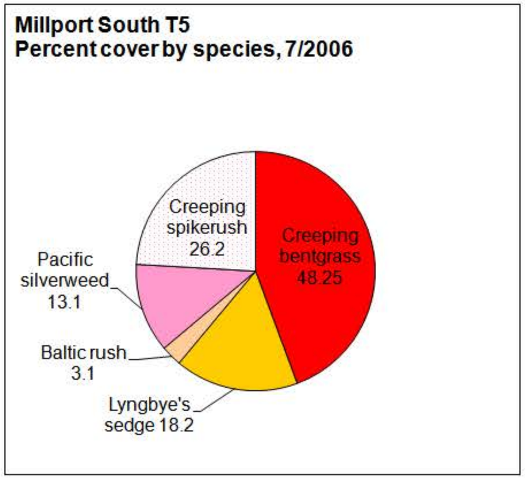


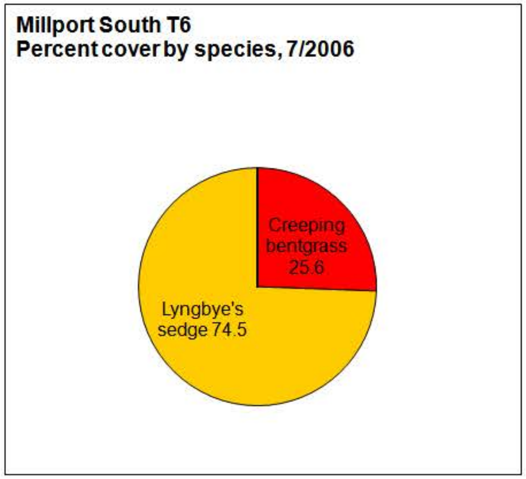

Millport South T1
Percent cover by species, 7/2006
Mud 12.5
Lyngbye's sedge 92.5

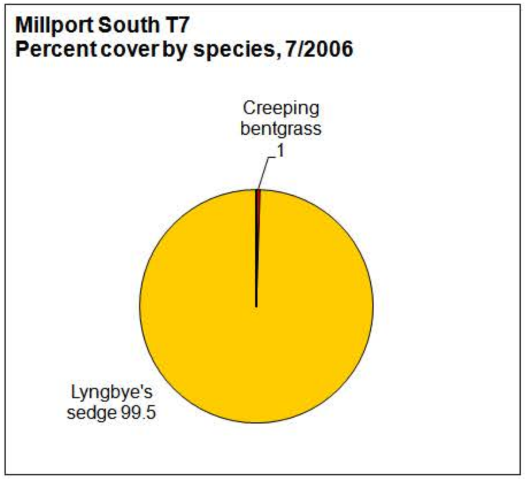

Millport South T2
Percent cover by species, 7/2006
Brass buttons 1.05
Mud 23.7
Seacoast bulrush 3.3
Lyngbye's sedge 73


Millport South T3
Percent cover by species, 7/2006
Seacoast bulrush 1
Pacific silverweed 6.75
Creeping bentgrass 48.8
Lyngbye's sedge 49.45


Millport South T4
Percent cover by species, 7/2006
Creeping bentgrass 1.8
Pacific silverweed 1.5
Slough sedge 2.6
Creeping spikerush 16.1
Reed canary-grass 16.5
Spearscale 4.6
Mud 28.5
Seacoast bulrush 24
Standing dead/litter 4.5


Millport South T5
Percent cover by species, 7/2006
Creeping spikerush 26.2
Creeping bentgrass 48.25
Pacific silverweed 13.1
Baltic rush 3.1
Lyngbye's sedge 18.2


Millport South T6
Percent cover by species, 7/2006
Creeping bentgrass 25.6
Lyngbye's sedge 74.5


Millport South T7
Percent cover by species, 7/2006
Creeping bentgrass 1
Lyngbye's sedge 99.5

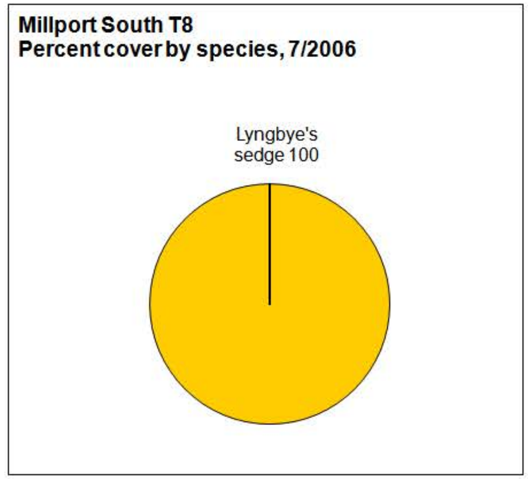
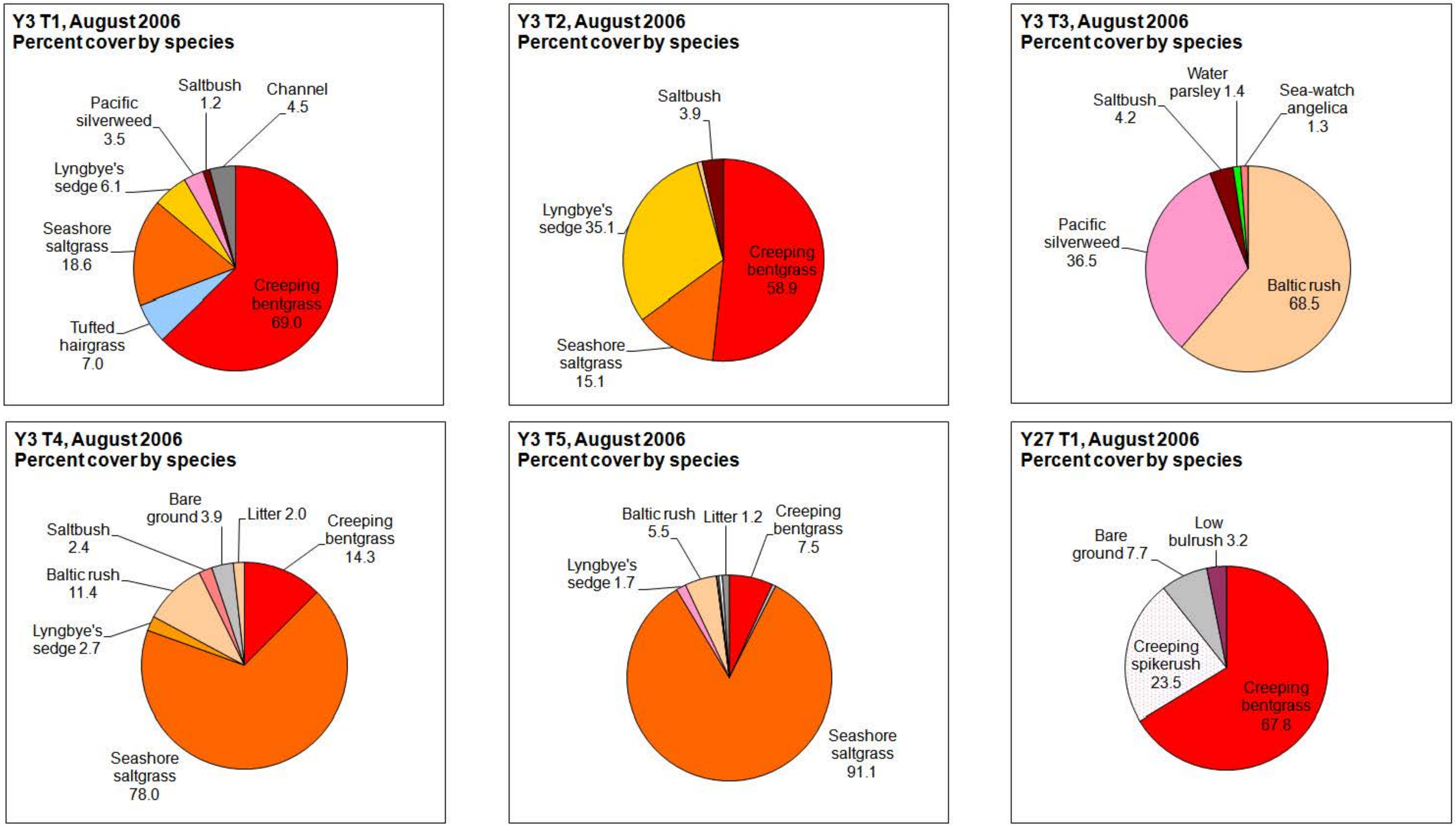
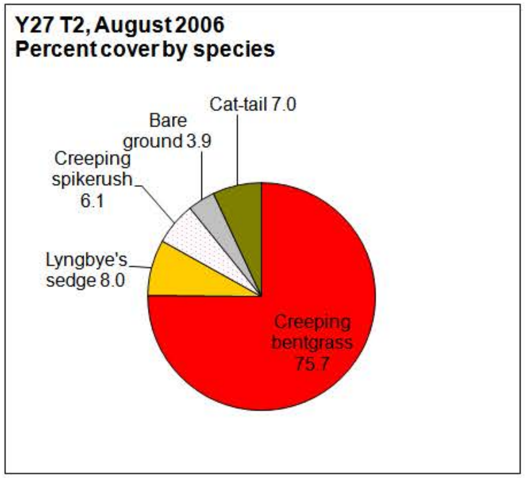
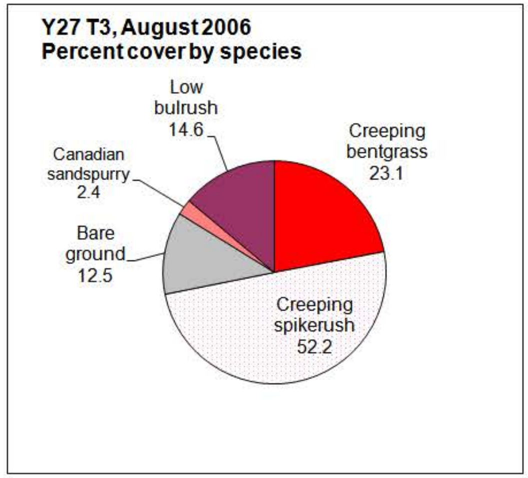
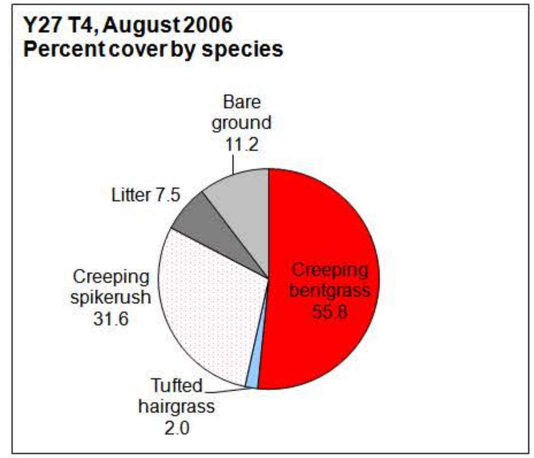

Millport South T8
Percent cover by species, 7/2006
Lyngbye's sedge 100

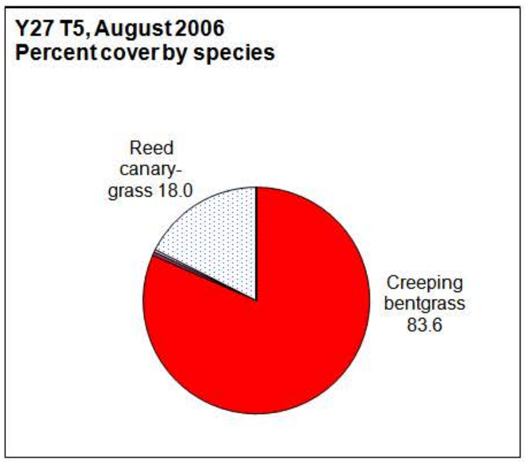
Figure 19. Composition of plant communities at Yaquina tidal wetland restoration and reference site transects and plots in 2006. Charts show average percent cover across all sample units for the transect/plot. Total percent cover may add up to more than 100% due to layering. Species with less than 1% cover are not labeled but are included in pie charts.

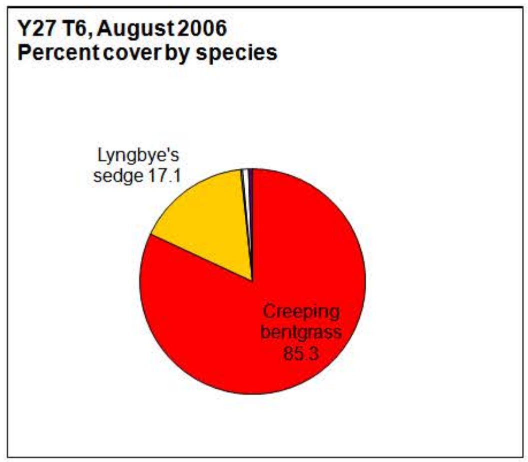


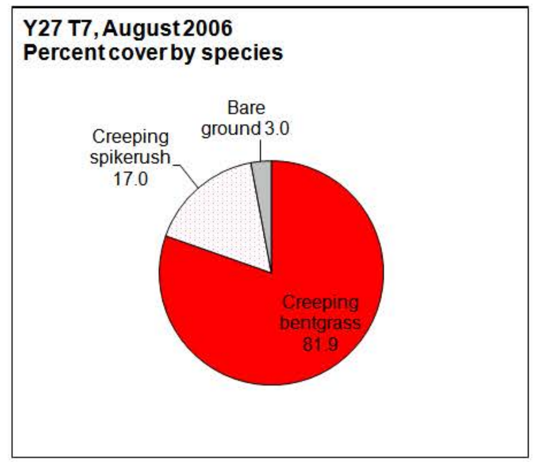

Y27 T2, August 2006
Percent cover by species
Cat-tail 7.0
Bare ground 3.9
Creeping spikerush 6.1
Lyngbye's sedge 8.0
Creeping bentgrass 75.7

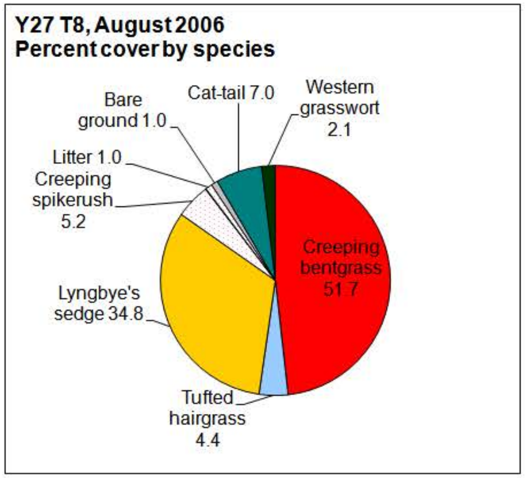

Y27 T3, August 2006
Percent cover by species
Low bulrush 14.6
Creeping bentgrass 23.1
Canadian sandspurry 2.4
Bare ground 12.5
Creeping spikerush 52.2

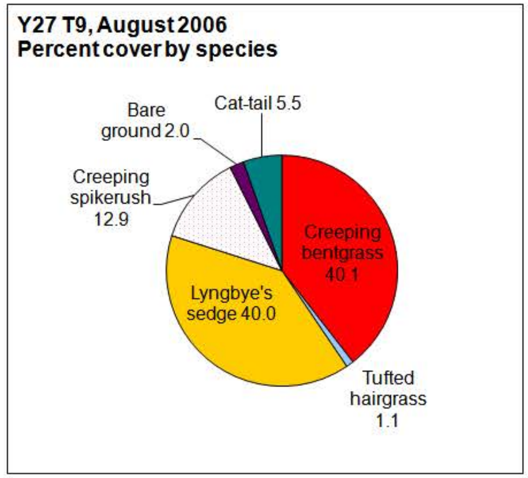

Y27 T4, August 2006
Percent cover by species
Bare ground 11.2
Litter 7.5
Creeping spikerush 31.6
Creeping bentgrass 55.8
Tufted hairgrass 2.0

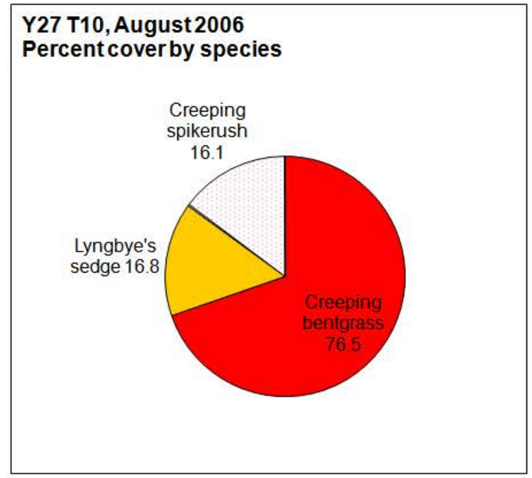

Y27 T5, August 2006
Percent cover by species
Reed canary-grass 18.0
Creeping bentgrass 83.6

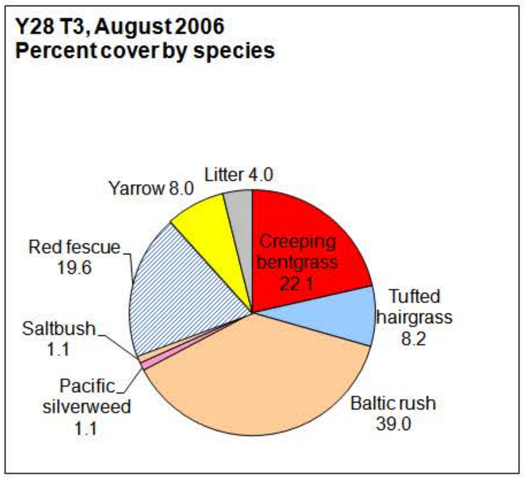

Y27 T6, August 2006
Percent cover by species
Lyngbye's sedge 17.1
Creeping bentgrass 85.3

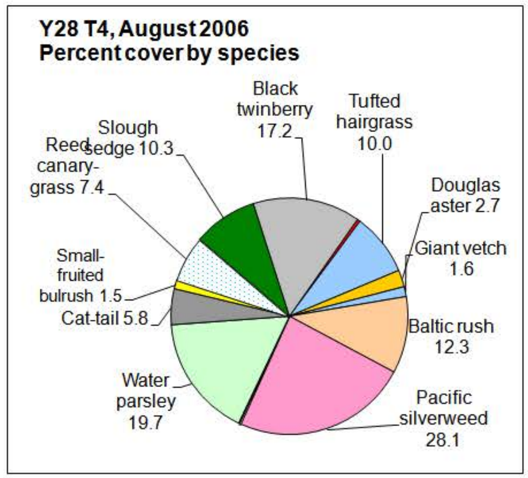

Y27 T7, August 2006
Percent cover by species
Bare ground 3.0
Creeping spikerush 17.0
Creeping bentgrass 81.9

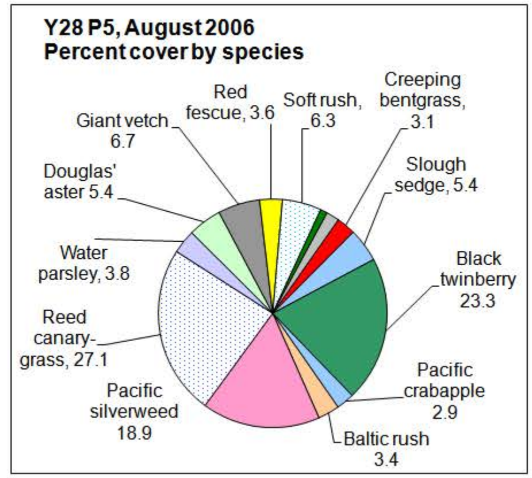

Y27 T8, August 2006
Percent cover by species
Bare ground 1.0
Cat-tail 7.0
Western grasswort 2.1
Litter 1.0
Creeping spikerush 5.2
Creeping bentgrass 51.7
Lyngbye's sedge 34.8
Tufted hairgrass 4.4


Y27 T9, August 2006
Percent cover by species
Bare ground 2.0
Cat-tail 5.5
Creeping spikerush 12.9
Creeping bentgrass 40.1
Lyngbye's sedge 40.0
Tufted hairgrass 1.1


Y27 T10, August 2006
Percent cover by species
Creeping spikerush 16.1
Lyngbye's sedge 16.8
Creeping bentgrass 76.5


Y28 T3, August 2006
Percent cover by species
Yarrow 8.0
Litter 4.0
Red fescue 19.6
Creeping bentgrass 22.1
Tufted hairgrass 8.2
Saltbush 1.1
Pacific silverweed 1.1
Baltic rush 39.0


Y28 T4, August 2006
Percent cover by species
Black twinberry 17.2
Tufted hairgrass 10.0
Slough sedge 10.3
Reed canary-grass 7.4
Douglas aster 2.7
Giant vetch 1.6
Small-fruited bulrush 1.5
Cat-tail 5.8
Baltic rush 12.3
Water parsley 19.7
Pacific silverweed 28.1


Y28 P5, August 2006
Percent cover by species
Red fescue, 3.6
Soft rush, 6.3
Creeping bentgrass, 3.1
Giant vetch 6.7
Douglas' aster 5.4
Slough sedge, 5.4
Water parsley, 3.8
Black twinberry 23.3
Reed canary-grass, 27.1
Pacific crabapple 2.9
Pacific silverweed 18.9
Baltic rush 3.4