Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Science Group

Monitoring Te Waihora shoreline wetland vegetation, 2007-2017

Report No. R19/134
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978-1-98-859386-9 (web)

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December 2019

Environment Canterbury
Regional Council
Kaunihera Taiao ki Waitaha

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Executive summary

Background:

Te Waihora/Lake Ellesmere is a large, shallow brackish coastal lake (Taylor, 1996), in geomorphic terms the lake is described as a Waituna-type lagoon (Hume *et al.,* 2016). Lakeshore wetlands around the margin of Te Waihora are of national and international importance, they constitute the largest contiguous remaining area of wetland habitat in lowland Canterbury, at around 4500 ha. These wetlands support some of the largest remaining areas of native vegetation on the lowland-coastal Canterbury Plains, there is a high diversity of wetland habitats, vegetation types and plant species.

What we did:

We undertook a field survey of Te Waihora shoreline vegetation from January to April 2017. We mapped and described the lakeshore vegetation and habitats following the system for wetlands developed by Johnson and Gerbeaux (2004), and the vegetation mapping and description system of Atkinson (1985). During field survey, mapping units were delineated on recent large-scale aerial photographs and their vegetation / habitat was described.

We entered the field survey information into a Geographical Information System (GIS), we captured each vegetation/habitat mapping unit with a polygon and entered the survey information associated with the polygon into a GIS attribute table. We divided the attribute data into subjective hierarchical levels of vegetation types, for each mapping unit. We generated statistics from the 2017, 2007 and 1983 surveys, GIS database attributes tables, using the Arc tool box summary statistics tool. We also generated statistics from the attribute's tables using the 'field tap tool summarise' function.

What we found:

Te Waihora margins continue to support, at *c.* 4,500 ha, the largest contiguous wetland habitat and expanse of native vegetation in lowland Canterbury. The state of lakeshore wetland vegetation has generally improved over the last ten years. However, exotic willows and other weeds continue to pose a threat to indigenous vegetation, particularly in freshwater wetland habitats. Some localised clearance of indigenous lakeshore wetland vegetation for farming purposes has also taken place in the last ten years. Grazing of lake edge wetlands by sheep and/or cattle was occurring along about half the lakeshore at time of the 2017 survey. There has since been further substantial retirement of lake margins, and new plan rules are being implemented to control stock access to the lakeshore wetlands and lake bed. Conversely though, vehicle damage to nationally significant native saltmarsh vegetation on public conservation land at Greenpark Sands has worsened since the 2007 survey.

What does it mean?:

To describe trends in shoreline wetland vegetation over more than three decades, it is important to distinguish between the vegetation of saltmarsh and freshwater wetland habitats. The relative extent of saltmarsh and freshwater wetland habitats, on the lakeshore, have remained at about 90% and 10% respectively, with some minor fluctuations, over the monitoring period.

For saltmarsh and freshwater wetlands, a main driver of vegetation change has been the progressive reduction, over the last 30+ years, of stock grazing pressure on both public and private land around the lakeshore. For saltmarsh habitats, the general vegetation response has been an increase in extent and cover of native saltmarsh vegetation. In contrast, freshwater wetland habitats main response has been a spread of exotic weed species, especially willows, with associated loss of ecologically significant native freshwater wetland vegetation such as harakeke flaxland, rushland and raupō reedland. This issue is now well-recognised. While the reduction or removal of grazing benefits native vegetation of shoreline freshwater wetland habitat, it needs to be accompanied by weed management. Where this has been done, native freshwater wetland vegetation has recovered well.

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1 Introduction

Te Waihora/Lake Ellesmere is a large, shallow brackish coastal lake (Taylor, 1996). Geomorphically, Te Waihora is described as a Waituna-type lagoon, within the classification system developed for New Zealand's coastal hydrosystems by Hume *et al.* (2016). This report describes the state of Te Waihora shoreline vegetation following a field survey in January-April 2017. It also discusses trends in lakeshore vegetation and wetland habitats since previous surveys in 1983 (Clark and Partridge, 1984) and 2007 (Hughey and Taylor, 2009; Pompei and Grove, 2009). We defined 'shoreline' as the area directly surrounding a water body; it encompasses the shallow area near shore as well as the area on land adjoining the water.

Lakeshore wetlands around the margin of Te Waihora are of national and international importance. Their ecological values have been well described (e.g. Taylor, 1996) and are recognised in the revised 2011 National Water Conservation Order. The margins of Te Waihora constitute what is now, by an order of magnitude, the largest contiguous remaining area of wetland habitat in lowland Canterbury, at around 4500 ha. These wetlands in turn support some of the largest remaining areas of native vegetation on the lowland-coastal Canterbury Plains. There is a high diversity of wetland habitats, vegetation types and plant species. Te Waihora shoreline wetlands are linked to other areas of high ecological and biodiversity value: the lake itself; Banks Peninsula hill-fed and plains spring-fed tributary streams; native dryland and coastal dune vegetation on Kaitorete Spit.

The planning and regulatory environment in relation to Te Waihora has changed considerably since the first lakeshore wetland vegetation survey in 1982. The Resource Management Act (1991) provided the statutory framework for the preparation of regional plans to address issues relating to sustainable management of natural and physical resources. The Act also required management agencies to provide for the protection of significant indigenous vegetation and habitats of indigenous fauna. Taylor (1996), provided information to help guide development of objectives, polices and methods within the Canterbury Natural Resources Regional Plan (NRRP), operative in 1998. The next regional plan iteration, the Canterbury Land and Water Regional Plan (2013) has further special provisions contained within Section 11 relating to protection of Te Waihora's outstanding ecological and cultural values.

Lakeshore wetland vegetation (as surveyed in 1982) was described by Trevor Partridge in Chapter 6 of Taylor (1996). The author attributed patterns and variation in lakeshore vegetation to three main factors: elevation in relation to lakes water level; degrees of salinity; and the effects of human disturbance. Present lakeshore vegetation has developed under the artificial lake opening regime of the last 150 or so years, with vegetation patterns along the lakeshore reflecting the varying tolerances to inundation and exposure of different plant species. There are also gradients from freshwater to brackish to saline conditions occurring at different times and places around the lakeshore. Brackish wetlands, supporting species tolerant of fluctuating salinity, occupy most of the lakeshore while freshwater wetlands occur in the vicinity of surface and groundwater inflows. The most highly-saline habitats around the lakeshore are on mid-elevation sand flats, where brackish lake water forms shallow ponds during high lake levels, and salts are concentrated by subsequent evaporation. Human disturbance in this context includes direct clearance of vegetation; hydrological modifications such as construction of drains and stopbanks; and the impacts of introduced plants and animals (including livestock). Other factors influencing vegetation patterns identified were substrate physical composition (i.e. sand, silt or gravel) and nutrient concentrations. All these factors continue to drive lakeshore vegetation patterns.

Results from lakeshore wetland vegetation surveys in 1982 and 2007 were analysed and trends described in Chapter 4 of Hughey and Taylor (2009). Within the 4,400 ha surveyed in both 1983 and 2007, there was a *c.* 100 ha decrease in extent of brackish wetland or saltmarsh vegetation. Although the total area of saltmarsh habitat had declined by about 100 ha, there had been an increase in extent of native saltmarsh vegetation. And while there had been a corresponding increase in freshwater wetland habitat, there was a marked decline in extent of native freshwater wetland vegetation over the monitoring interval. Change in relative extent of saltmarsh and freshwater wetland habitats were attributed to the lower average lake levels and reduced lake salinity; while changes in vegetation cover reflected reduced stock grazing pressure along parts of the shoreline, the spread of exotic willows in freshwater wetlands and human disturbance. A notable change was that area of crack willow (*Salix* *fragilis*) and grey willow (*Salix cinerea*) dominant forest and scrub vegetation doubled from 67 ha of the lakeshore survey area in 1982 to 140 ha in 2007 (Hughey and Taylor, 2009).

Distribution and infestation density of invasive willows in Te Waihora shoreline wetlands as recorded in 2007 was described in more detail in a report by Pompei and Grove (2009). The occurrence of several other environmental weeds of concern in lakeshore wetlands and lake tributaries has been discussed in subsequent 'State of the Lake' reports. For example, reed canary grass (*Phalaris arundinacea*) is abundant along the margins of the lower Selwyn River/Waikirikiri from where it appears water-borne seeds and vegetative material have been carried to other freshwater wetlands on the lake edge (von Tippelskirck, 2014). An update on willow and other weed infestations around the lake shore is included in this report.

2 Methods

Monitoring of Te Waihora shoreline vegetation has been carried out through repeated survey, mapping and description of lakeshore habitats.

For the 2017 survey, lakeshore vegetation and habitats were mapped and described following the hierarchical classification system for wetlands developed by Johnson and Gerbeaux (2004), and the vegetation mapping and description system of Atkinson (1985). While lakeshore wetland vegetation was the focus of the survey effort, unvegetated wetland habitats, such as shallow water ponds, and some areas of adjoining terrestrial vegetation were also mapped.

2.1 Field survey and data capture

During field survey, mapping units were delimited on recent large-scale aerial photographs and their vegetation / habitat described. Definitions of vegetation structural classes (forest, treeland, scrub, shrubland etc.) and relationships (emergent, canopy, understorey etc.) follow those developed by Atkinson (1985). Where possible, field descriptions followed the Atkinson system of notation for mapping vegetation. Prominent plant species were listed and identified by six letter codes derived from their botanical name, vegetation tiers were separated by a '/' and estimated abundance of listed species indicated. Notes were made on wetland type and other plant species of interest (e.g. rare native species, weeds) not otherwise covered by the vegetation description.

Changes from previous survey methodology included the use of higher resolution aerial photographs. These permitted mapping to a finer level of detail than previous surveys and reduced the need for 'mosaic' mapping units. Vegetation descriptions of mapping units delineated in the 2017 survey followed the Atkinson (1985) notation, rather than the classification system of Clark and Partridge (1984), to be consistent with the method used for describing vegetation in other wetland surveys around the region.

Field survey information was entered into a geodatabase, with each vegetation/habitat mapping unit delineated by a polygon, and survey information entered into the associated attribute table. Where the Atkinson vegetation mapping notation was used, abundance of listed species was indicated by a system of letter cases and brackets as shown in the example below:

PLA DIV	>76% canopy cover of marsh ribbonwood (*Plagianthus divaricatus*)
PLA div	51-75% cover of marsh ribbonwood
Pla div	26-50% cover of marsh ribbonwood
(Pla div)	6-25% cover
[Pla div]	1-5% cover

2.2 Habitat and wetland type classification

Vegetation mapping units were classified by habitat. The wetland vegetation tool (Clarkson, 2013) rapid assessment methodology, used to classify mapping units as 'wetland' or 'terrestrial' habitats based on their plant species composition, was followed. For wetland habitats, further classification of wetland types followed Johnson and Gerbeaux (2004), with reference to habitat preferences of wetland plant species as described in Johnson and Brook (1998).

2.3 Vegetation classification

A subjective hierarchical classification of vegetation types developed during surveys of other Canterbury coastal wetlands (Grove *et al.,* 2012) was also used to describe vegetation mapping units for the 2017 Te Waihora survey. Primary classification was based on vegetation structure (e.g. shrubland, reedland, grassland), with composition data (i.e. dominant species plus associates) informing the vegetation types described for each structural class.

In addition to field survey records, the geodatabase includes three nested hierarchical levels of vegetation classification for each mapping unit. The most detailed classification, the 'vegetation composition' grouping was developed first. A higher level or more generalised 'vegetation type' classification was then developed to help with production of clear maps and generation of summary statistics for trend analysis and regional reporting. The highest level of vegetation classification is structure alone, without any composition information. Finally, but sitting outside the hierarchical classification, each mapping unit was assigned into a 'nativeness category' of 'indigenous, exotic or mixed indigenous-exotic on the basis of canopy composition, as noted in the field survey records.

2.4 Calculations

Statistics were generated from the 2017 and 2007 survey GIS database attributes tables by utilising the Arc tool box summary statistics tool. Statistics were also generated from the attributes tables by utilising the 'field tap tool summarise' function.

2.5 Willows

Database descriptions and recent aerial photos of mapping units containing willows were re-examined and classified according to their density of willow infestation. Willow infestations were categorised as a percentage of canopy cover, using a modified Braun-Blanquet cover scale adapted from Hill *et al.* (2005).

Location of individual outlying willow trees and shrubs were also recorded.

3 Results

Results from the 2017 lake shore survey are presented first, followed by trend analysis for a smaller *c.* 4,400 ha area that has been repeat-surveyed in 1983, 2007 and 2017.

3.1 Results 1 – 2017 survey

The 2017 survey geodatabase contains 3,161 individual mapping units covering a total area of 5,655 ha – an expansion on the area covered by previous surveys. Of this, 4,538 ha were wetland habitats. The 1,116 ha of terrestrial habitat surveyed largely comprised adjoining Environment Canterbury reserve lands on Kaitorete Spit (Figure 3-1).

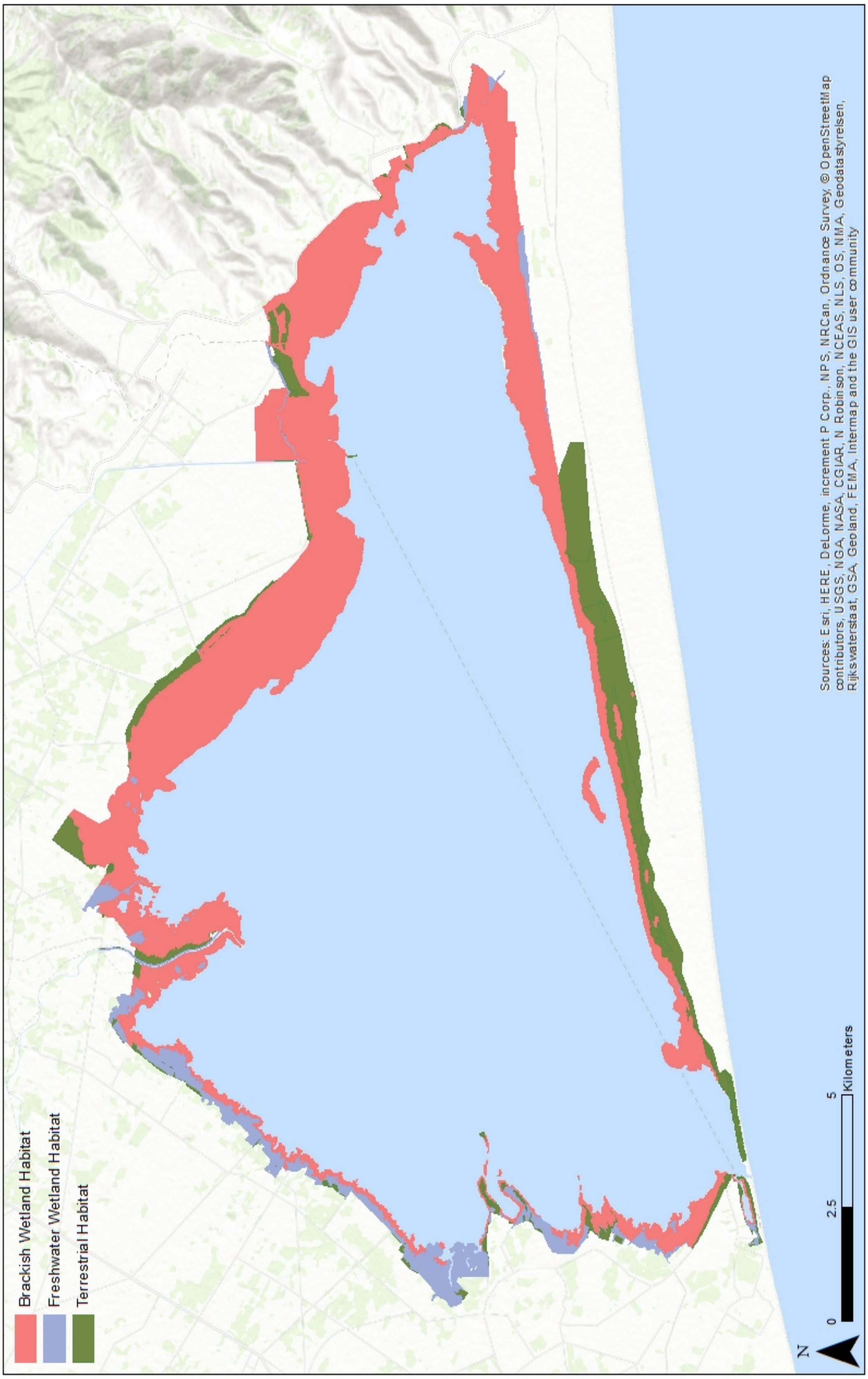

Figure 3-1: Overview of Te Waihora 2017 lakeshore survey area showing estuarine wetland, freshwater wetland and terrestrial habitats

3.1.1 Lakeshore habitats

Of the total 4,538 ha mapped lakeshore wetland area, 3,970 ha (87%) was brackish wetland habitats with saltmarsh vegetation. These are most extensive along the southern and eastern sides of the lake but are also present on the western shoreline. As in previous surveys, freshwater wetland habitats were most extensive along the western side of the lake, generally in the vicinity of freshwater inflows, both surface and groundwater. A total of 568 ha freshwater wetlands were mapped in the 2017 lake shore survey. These were mostly palustrine marsh and swamp habitats, but with smaller areas of palustrine fen, riverine swamp and marsh, and lacustrine marsh and shallow water also present (Table 3-1).

Table 3-1: Wetland hydrosystems and classes within 2017 Te Waihora lake shore survey area

Habitat	Hydrosystem and class	Area (ha) and % of total
Brackish wetland	Lacustrine / estuarine (when lake open to the sea) saltmarsh	3,970 (87%)
Freshwater wetland	Palustrine marsh	330
	Palustrine swamp	171
	Palustrine fen	17
	Riverine marsh	21
	Riverine swamp	6
	Lacustrine marsh	<1
	Lacustrine shallow water	3
Total freshwater wetland		568 (13%)
Total wetland survey area		4,538

3.1.2 Lake shore vegetation

34 lakeshore wetland vegetation types were recognised from the mapping unit vegetation composition descriptions delineated during survey. Vegetation types with area totalling ten or more ha are listed in Table 3-2. The most extensive vegetation types, visible at whole-of-lake scale map, are shown in Figure 3-2.

The most extensive lakeshore saltmarsh / brackish wetland vegetation types were saltmarsh herbfield, saltmarsh grassland, marsh ribbonwood shrubland, three square reedland and sea rush rushland. The most extensive freshwater wetland vegetation types were grassland, willow forest and treeland, and raupō reedland

Terrestrial vegetation/habitats were mapped where they occurred as 'islands' surrounded by wetland or aquatic habitats. Terrestrial vegetation adjoining or landward of the lake shore wetlands was generally not mapped as these habitats were not the focus of the survey. The main exceptions were the terrestrial vegetation of Environment Canterbury reserve land at Kaitorete Spit, and several native restoration planting sites around the lake shore. The most extensive terrestrial vegetation types were exotic grassland (672 ha) and mixed native-exotic grassland (350 ha) where a range of native plants species (shrubs, rushes, tussocks, sedges, grasses, herbs) were also common. Some exotic shrubland (12 ha - mostly gorse, broom, lupin) and 11 ha of native restoration plantings were also mapped within the lakeshore survey area.

Native plant species were generally the predominant cover in saltmarsh habitats, while introduced plants tended to dominate in freshwater wetlands. However, most vegetation mapping units contained a mix of native and introduced plant species. Exceptions were areas of low-elevation saltmarsh communities which were entirely composed of native plant species and some 'wet pasture' seasonal freshwater wetlands that were entirely introduced.

Individual vegetation mapping units were classified as 'mostly' native, 'mostly' exotic, or mixed native-exotic based on canopy composition. So, for example, shrubland vegetation where native marsh ribbonwood shrubs formed the main canopy cover was classed as 'native', although exotic grass species could dominate in the groundcover. And similarly, willow forest was classified as an 'exotic' vegetation type, although native plants may be present or even common in the forest understorey. Vegetation types classified as 'mixed' had both native and exotic plant species common in their canopy cover. A typical example of 'mixed' vegetation was grassland of exotic tall fescue and/or creeping bent in which native species (e.g. shrubs, tussocks, rush, sedge and herbs) were also prominent. Other common examples of 'mixed' vegetation were saltmarsh herbfield communities that had both native and introduced species co-dominant in their cover.

For the total 5,655 ha survey area (estuarine wetland, freshwater wetland and terrestrial habitats), 2,370 ha were classified as native cover, 2,468 ha as mixed native-exotic vegetation, and 794 ha as exotic vegetation. Estuarine wetland habitats supported 2,273 ha (40%) of native, 1,478 ha (26%) of mixed and 205 ha (4%) of exotic vegetation cover. For freshwater wetlands there were 81 ha (1%), 230 ha (4%), 249 ha (4%) of native mixed and exotic respectively.

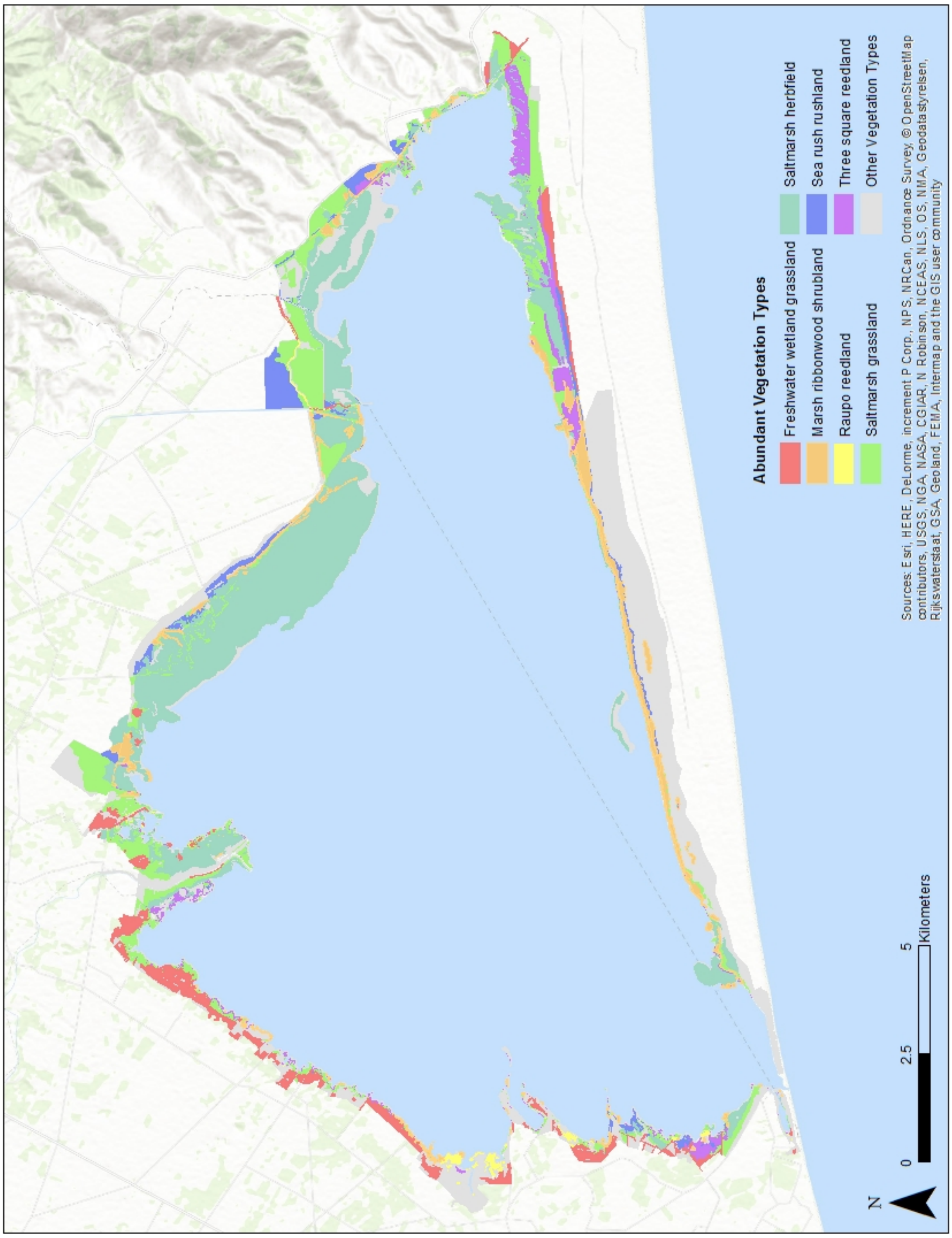

Figure 3-2: Location of the seven most extensive lakeshore vegetation types described in the 2017 survey

Table 3-2: Total extent of the fourteen most extensive wetland vegetation types around Te Waihora surveyed in 2017. Wetland habitat and 'nativeness' of the vegetation are noted

Vegetation	Total Area ha	Exotic Area ha	Native Area ha	Mixed Area ha
Saltmarsh herbfield (brackish wetland; native and mixed native-exotic)	1,946	0	1,518	428
Saltmarsh grassland (brackish wetland; exotic and mixed native-exotic)	925	185	0	740
Marsh ribbonwood shrubland (brackish wetland; native and mixed native-exotic)	333	0	264	69
Freshwater wetland grassland (freshwater wetlands; exotic and mixed native-exotic)	284	139	0	145
Three square reedland (brackish wetland; native and mixed native-exotic)	283	0	116	167
Sea rush rushland (brackish wetland; native and mixed native-exotic)	250	0	176	74
Sparsely vegetated (brackish wetland; native and mixed native-exotic)	199	6	184	9
Willow forest and treeland (freshwater wetland; exotic and mixed native-exotic)	130	109	0	21
Raupo reedland (freshwater wetland; native)	49	0	38	11
Native freshwater wetland rushland (freshwater wetland; native and mixed native-exotic)	26	0	4	22
Bog rush tussockland (freshwater wetland; native and mixed native-exotic)	19	0	4	14
Harakeke flaxland (freshwater wetland; native)	17	0	12	4
Freshwater sedgeland (freshwater wetland; mixed native-exotic)	15	0	11	4
Carex secta tussockland (freshwater wetland; native and mixed native-exotic)	10	0	8	2

3.2 Results 2 – trends in lakeshore habitats and vegetation

3.2.1 Change in habitat type and extent

The total 2017 lake shore survey area was 5,655 ha. A smaller *c.*4,400 ha area repeat-surveyed in 1983, 2007 and 2017 was available for analysis of trends in lake shore habitats and vegetation over this time.

There was a net reduction of about 500 ha of lake shore vegetation from within the repeat-surveyed area over the period 2007-17. This was evident in reduced total extent of all three main lakeshore habitats - brackish wetland, freshwater wetland and terrestrial – over the last 10 years and a corresponding increase in extent of open water and/or unvegetated lake bed (Table 3-3).

Table 3-3: Change in extent and type of habitats

Habitat	Proportion of lake shore survey area		
	1983	**2007**	**2017**
Brackish wetland	82% (3,603 ha)	80% (3,532 ha)	83% (3,317 ha)
Freshwater wetland	10% (452 ha)	12% (554 ha)	10% (410 ha)
Terrestrial	8% (330 ha)	8% (337 ha)	7% (282 ha)
Miscellaneous	< 1% (11 ha)	< 1% (13 ha)	0% (0 ha)
Total	4401 ha	4436 ha	4008 ha

3.2.2 Vegetation change

The shift to Atkinson notation to describe and classify Te Waihora wetland vegetation, while consistent with the method used in other parts of the region, made quantitative comparison with results of earlier Te Waihora surveys problematic. The finer scale mapping possible with recent aerial imagery was also an issue, for example a single large unit previously mapped as ‘shrubland’ can now be subdivided into smaller units identified as ‘shrubland’, ‘grassland’ and ‘herbfield’. These methodological changes meant it was not possible to directly compare 2017 vegetation type results summed for the lake shore survey area with those of previous 1983 and 2007 surveys.

We provide instead a descriptive and qualitative assessment of changes in vegetation over the 2007-2017 period from field survey observations. Lake levels were very low during the summer-autumn 2017 survey period, following lake opening in September 2016. At this time the lake remained open to the sea and functioned as a tidal estuary for 34 days. The previous summer 2015-16 also saw prolonged low lake levels. At time of survey, lake freshwater inflows (surface and groundwater) were also greatly reduced from normal levels, following two dry winters in succession (2015 and 2016). During field survey we observed moisture stress and localised dieback of some saltmarsh plants such as marsh ribbonwood, sea rush and glasswort. Freshwater wetlands were drier than in 2007 and supported more exotic grass cover than previously.

Overall however, native lake edge vegetation appeared taller and denser than in 2007. In saltmarsh habitats we noted further increase in cover of native marsh ribbonwood, sea rush, oioi, Caldwell’s sedge and three-square associated with reduced grazing pressure along parts of the lake shore. In freshwater wetlands, along with increased exotic grass height and cover at many sites, we noted more raupō, toetoe, bog rush, pukio – a response to reduction/removal of stock grazing around the lake shore and, locally, willow control operations.

Amongst the rare or locally uncommon native flora of freshwater wetland habitats, there was a substantial increase in location records and abundance of At Risk-Declining swamp nettle (*Urtica perconfusa*), while locally uncommon baumea (*Machaerina rubiginosa*) and four-square (*Lepidosperma australe*) also expanded their range. New records were made for Threatened-Nationally Critical dwarf musk (*Mazus novaezeelandiae* ssp. *impolitus*) and At Risk-Declining pygmy clubrush (*Isolepis basilaris*) in the 2017 survey. However, some 2007 rare plant records – lady’s tress orchid (*Spiranthes novae-zelandiae*), bladderwort (*Utricularia dichotoma*) and sundew (*Drosera binata*) - were not seen in 2017 due to change in their habitats, which were drier and grassier than previously.

In the lake shore saltmarsh wetlands, the 2017 survey produced a new record for At Risk – Naturally Uncommon sneezewort (*Centipeda aotearoana*). Native musk (*Thyridia repens*), another At Risk-Naturally Uncommon species, covered many hundreds of hectares of low-elevation mudflats around the lake shore at the time of the 2017 survey. Te Waihora is the regional and possibly national stronghold for this species.

3.3 Results 3 – willows and other weeds

3.3.1 Willows

Information on willow distribution and abundance from the 2017 Te Waihora lake shore survey area is shown in maps appended to this report. Willows, at densities ranging from sparsely scattered tree/shrubs through to close-canopy forest, were present in 405 ha of the total 5,655 ha lake shore survey area (Table 3-4).

Most of the lake shore survey area is saltmarsh or brackish wetland habitat and largely resistant to willow spread. Small areas of willow, 26 ha in total, were recorded on the margin of or within these habitats where microsite conditions permitted willow establishment. Another 73 ha of willows were mapped as a component of terrestrial, generally riparian, habitats within the survey area. As in previous surveys, willows were a prominent feature of lake shore freshwater wetland habitats. Some level of willow infestation, from sparsely scattered trees or shrubs to close-canopy forest, was recorded for 306 ha of the total 568 ha freshwater wetland habitats present (Table 3-4). In addition, another 49 individual outlier willows – 40 grey/pussy willow, 6 crack willow, 3 uncertain (observed from a distance) – were recorded.

Targeted willow control operations began around the lake shore in 2010. In the 2017 survey we also, as a separate category, recorded a number of willow control sites where a low level (< 1% cover) of willow survival or willow regeneration was evident (Table 3-4, 3-5, 3-6).

Table 3-4: Total extent for each of five willow infestation categories, expressed as percentage willow canopy cover, within the 2017 lake shore survey area

Category of infestation	% cover	Extent
Sparse willows	1-5% cover	155 ha
Scattered willows	6-25% cover	87 ha
Moderate infestation	26-50% cover	47 ha
Dense infestation	51-80% cover	12 ha
Close-canopy willow forest	81-100% cover	91 ha
Control area with surviving or regenerating willows	<1%	13 ha
Total willow infested area		405 ha

Infestation area breakdown by willow species: crack willow (*Salix fragilis*); and grey (*S. cinerea*) and/or pussy willow (*S.* x *reichardtii*) is shown in Table 3-5.

Table 3-5: Infestation area breakdown by willow species

	Grey or pussy willow	Crack willow	Mixed crack and grey / pussy willow
Sparse willows	57 ha	46 ha	52 ha
Scattered willows	31 ha	2 ha	53 ha
Moderate infestation	12 ha	10 ha	25 ha
Dense infestation	1 ha	1 ha	11 ha
Close-canopy willow forest	24 ha	29 ha	37 ha
Control area with surviving or regenerating willows	3 ha	2 ha	8 ha
Total	128 ha	90 ha	186 ha

Comparison was also made of the extent and density of willow infestations within the lake shore survey area mapped in both 2007 and 2017. Within the repeat-surveyed area, extent of close-canopy willow forest and dense willow infestations reduced over the 10-year monitoring interval, following targeted control operations. However, overall willow infestation area nearly doubled over the monitoring period, with substantial increases in areal extent of sparse-to-moderate infestation categories (Table 3-6).

Table 3-6: Extent of each of five willow infestation categories within the lake shore area repeat-surveyed in 2007 and 2017

Infestation category	% cover	2007 survey	2017 survey
Sparse willows	1-5% cover	15 ha	129 ha
Scattered willows	6-25% cover	15 ha	35 ha
Moderate infestation	26-50% cover	3 ha	39 ha
Dense infestation	51-80% cover	27 ha	9 ha
Close-canopy willow forest	81-100% cover	104 ha	79 ha
Control area with surviving or regenerating willows	<1%	0 ha	12 ha
Total willow infested area		164 ha	303 ha

3.3.2 Other weeds

Location records from 2017 survey for the following environmental weeds are shown on Figures 3-3 – 3-5: reed canary grass (*Phalaris arundinacea*), yellow flag (*Iris pseudacorus*), beggars tick (*Bidens frondosa*), alder (*Alnus glutinosa*), old man's beard (*Clematis vitalba*), arum lily/green goddess (*Zantedeschia aethiopica*) and tutsan (*Hypericum adrosaemum*).

Margins of the lower Selwyn River are densely infested with reed canary grass. From there, seeds and plant fragments are carried out to the lake and re-deposited along the shoreline. If deposited in a freshwater wetland, a new infestation can result. Freshwater wetlands along the western shoreline, between Rennies Bay and Harts Creek, are the main infestation sites for the other environmental weeds of concern.

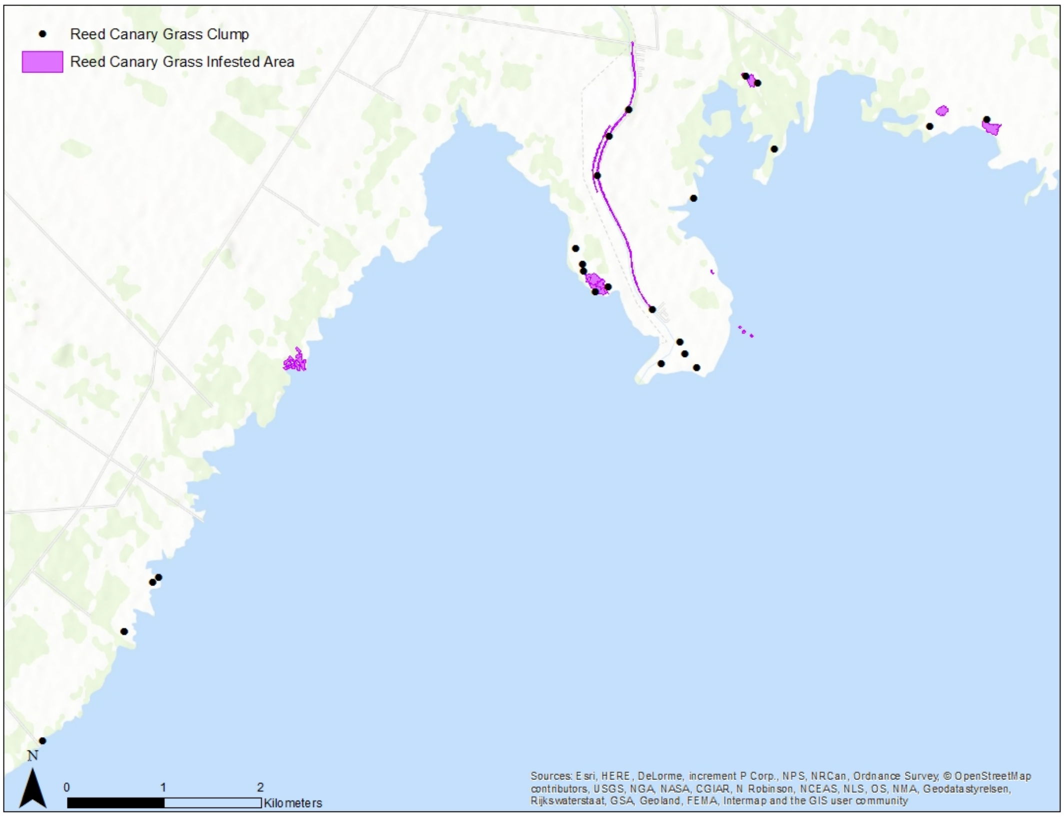

Figure 3-3: Reed canary grass distribution in 2017 lake shore survey area

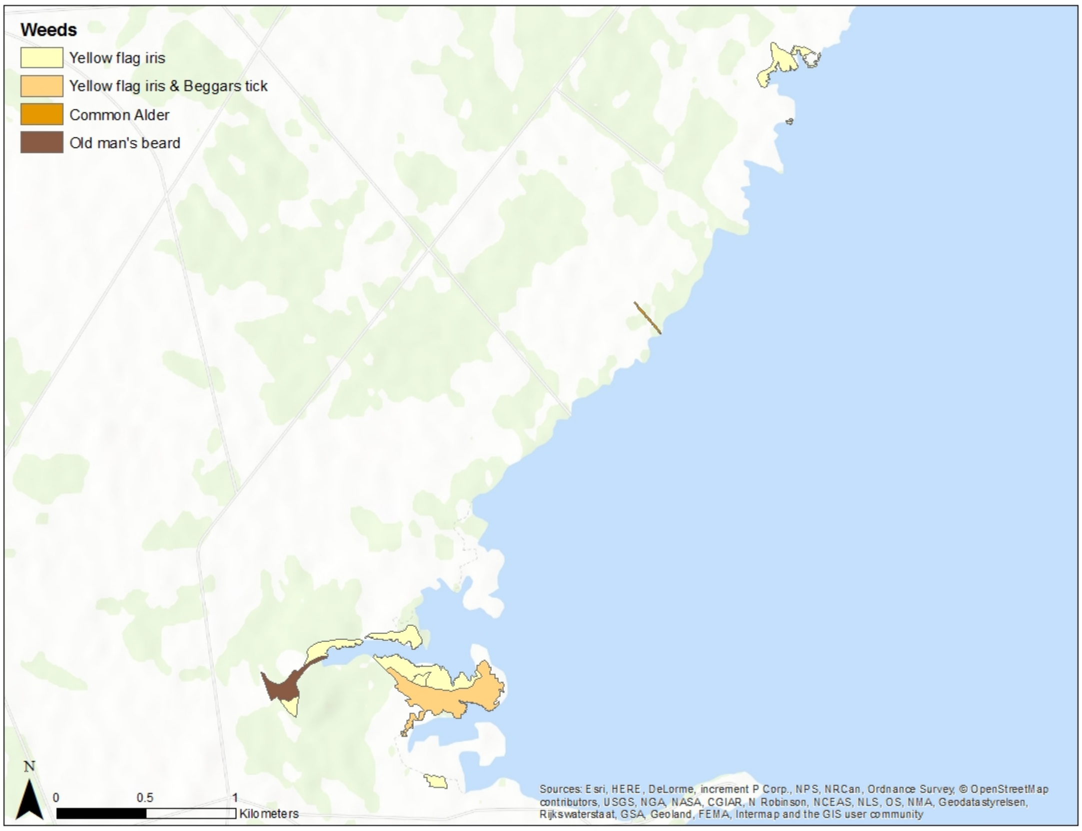

Figure 3-4: Yellow flag, beggars tick, alder and old man's beard weed distribution in part of 2017 lake shore survey area

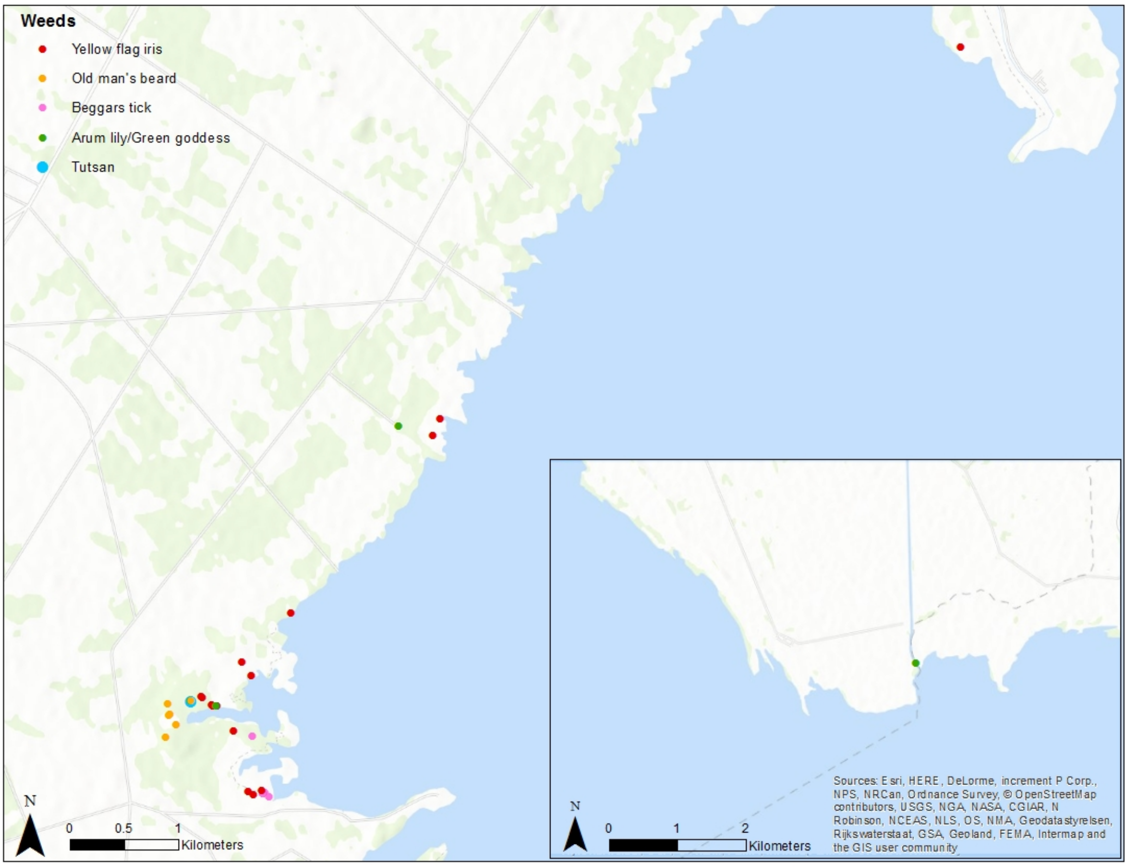

Figure 3-5: Yellow flag, old man's beard, beggars tick, arum lily and tutsan weed distribution in 2017 lake shore survey area

4 Discussion

4.1 Lake shore habitats

Results of the 2017 lake shore vegetation survey show that Te Waihora margins continue to support, at *c.* 4,500 ha, the largest contiguous wetland habitat and expanse of native vegetation in lowland Canterbury.

We suggest that the approximate 500 ha net reduction in extent of all three main lakeshore habitats - brackish wetland, freshwater wetland and terrestrial – within the re-surveyed area over the last 10 years, results from a combination of factors: post-earthquake changes to bed levels; wave-lap erosion; and a succession of very dry years and low freshwater inflows in the years prior to 2017 survey.

When comparing aerial photographs used at the time of the 2007 survey to those of the 2017 survey, we noticed that extent of low-elevation mudflats and sandflats supporting saltmarsh herbfield vegetation was reduced, particularly along the eastern lakeshore (Figure 4-1). Areas that had been regularly exposed at times of low lake water level and mapped as saltmarsh herbfield in earlier 1983 and 2007 surveys remained underwater when surveyed in summer 2017. This was despite lake water levels being very low (*c.* 0.6 m asl) at that time. There were also a number of mapping units along this part of the lake shore described as terrestrial in 2007 that were brackish wetland in 2017. This may be a result of change in lake bed levels following the 2010-11 Canterbury earthquakes, although we are not aware that this has been documented for Waihora. Marked changes to bed levels of Ihutai/Avon-Heathcote Estuary (Measures *et al.,* 2011) and the lower Waimakariri-Brooklands Lagoon estuaries occurred following the earthquakes, with resulting hydrological alterations and associated changes in extent and type of wetland habitats and plant communities (Cochrane *et al.,* 2014).

Figure 4-1: 2015 aerial photo of eastern Waihora shoreline showing retreat of the vegetated area of low-elevation mudflats and saltmarsh herbfield, surveyed and mapped in summer 2007 and summer 2017

Wavelap erosion of Te Waihora shoreline has been recorded for many years along around the entire lake shoreline at various times (Taylor, 1996). Over the last 10 years, wavelap erosion has been most noticeable along parts of the south-west shoreline where mid-to-high elevation lake margin wetland vegetation, such as three square reedland, has retreated in places (Figure 4-2). However, other parts of the vegetated shoreline have been stable or even advanced over the same period.

Figure 4-2: 2015 aerial photo showing advance of open water and retreat of lake margin wetland vegetation on the western shoreline, surveyed and mapped in summer 2007 and summer 2017

4.2 Lake shore vegetation

We consider that, overall, the state of lakeshore wetland vegetation has improved over the last ten years. A general trend of progressive reduction in grazing pressure (both in terms of area grazed and stock type/numbers) described in earlier survey reports had continued over the 2007-17 period. At the time of the 2017 survey, about half of lakeshore wetlands were still being grazed. However, since completion of the 2017 field survey, further substantial areas of lakeshore wetland have been retired from grazing.

Reduced grazing pressure in saltmarsh habitats has resulted in increased height and cover density of three square and other native saltmarsh species such as sea rush and marsh ribbonwood along parts of the lakeshore where these species were already established. Where exotic saltmarsh grassland was the main cover, grazing reduction/removal has quickly resulted in increased height and cover of tall fescue. Tall fescue is persistent, but over time sea rush, marsh ribbonwood and other native species can establish and spread though these grasslands, especially at sites that experience regular inundation of brackish lake water.

Grazing reduction or removal does not tend to alter the composition of saltmarsh herbfield communities, as environmental conditions (inundation, salinity) remain the key drivers. However, it is clearly beneficial in preventing or reducing physical damage from stock to these habitats and plant communities.

For freshwater wetland habitats, reduction/removal of grazing promotes recovery of both native species (sedges, rushes, raupō, harakeke) and exotic grass. Environmental conditions are also a factor: native species recovery is generally greater in 'wetter' wetlands, with exotic grasses more persistent and competitive on drier sites. As noted in the results section, low groundwater and freshwater inflow levels in the two years prior to the 2017 survey appear to have reduced not only the extent, but also the 'wetness' of lake shore freshwater wetlands. This provided more favourable conditions for exotic grass growth at the expense of natives at some sites.

4.3 Weeds and other threats to lake shore wetland vegetation

Another recognised effect of grazing removal from Te Waihora freshwater wetlands has been the spread of introduced willows. The surrounding area provides a large and ongoing supply of willow propagules – vegetative water-borne fragments in the case of crack willow, and wind-dispersed seed in the case of grey and pussy willow. Our observations (from Yarr's Flat Wildlife Management Reserve) are that 'wet pasture' provides a particularly suitable habitat for willow establishment in the first few years following grazing removal. If this 'first flush' of willow growth is effectively controlled, re-growth of native vegetation can restrict, if not entirely prevent, subsequent willow re-invasion. However, ability to resist willow spread varies depending on site conditions, and some native freshwater wetland vegetation types, such as raupō reedland, remain highly susceptible to willow invasion.

Control operations carried out in Te Waihora shoreline wetlands over the last eight or so years have reduced willow extent within targeted areas (mostly DoC reserves). There are now some spectacular examples of freshwater wetland vegetation recovery following willow control (Figure 4-3). Spread of willows into freshwater wetlands on the lake shore east of the Selwyn River/Waikirikiri mouth have been effectively contained.

Figure 4-3: Recovery of native wetland vegetation at a Selwyn delta willow control site

However, outside of these control sites willows, especially grey willow, have continued to spread through freshwater wetland habitats west of the Selwyn River/Waikirikiri mouth. At present, most of the affected area is sparse-scattered willows. These need to be a priority for control, especially where invading native freshwater wetland vegetation.

We observed that some stands of mature crack willow swamp and riparian forest provide valuable habitat for native fish and wildlife, while also supporting naturally regenerating native plant species. The 2017 survey noted areas of tall willow forest that had shown an increase in self-sown native ferns, shrubs and small trees in the understorey – including kiokio, ti kouka, pate, kohuhu, tarata, mikimiki (*Coprosma propinqua*). It is recommended that experts clearly identify where ecologically important areas of swamp and riparian willow forest be retained as part of an overall willow management strategy for the lakeshore wetlands, and where opportunities to facilitate or enhance regeneration of native forest plants within these habitats exist.

Further spread and/or new infestations of previously noted weed species of concern were recorded from the 2017 survey: yellow flag, reed canary grass, grey willow, purple loosestrife, gorse. There were also some new weed species records for the lake shore survey area: beggars tick, old man's beard, arum lily, alder, lady fern, montbretia, tutsan, ivy. We recommend these (geo-referenced) records are used to help in the development or review of environmental weed control strategies for Te Waihora shoreline vegetation. Other recent surveys have identified infestations of *Carex pendula* in Boggy Creek catchment and described the threat to freshwater wetlands from invasive *Epilopbium hirsutum*, now established in Travis Swamp, Christchurch, and wetlands at Pegasus Town north of Christchurch. Surveillance monitoring for these species should also be part of Te Waihora weed control strategies and work plans.

Although overall condition of shoreline vegetation has improved over the last 10 years, we still noted localised adverse impacts from farming activities during survey. These included recent examples of vegetation clearance and pasture development, and stock access resulting in de-vegetation and pugging of wetland habitats. New plan rules are currently being implemented to better control stock access to lake shore wetlands.

The other significant adverse impact on lakeshore wetland vegetation is from vehicle use. This is a problem on public conservation land, particularly the large and nationally important Greenpark Sands Conservation Area. Damage to native saltmarsh vegetation from vehicles here has worsened over the last ten years.

Figure 4-4: Vehicle damage at Greenpark Sands Conservation Area

4.4 Conclusion – an overview of trends in lake shore wetland vegetation in the last 3 decades

The 1983 lake shore vegetation survey area totalled approximately 4,400 ha. Subsequent surveys covered a wider extent, but for comparative purposes this discussion is restricted to the repeat-surveyed area. Within the repeat-surveyed area, there have been some changes in relative extent of lakeshore habitats – saltmarsh wetland, freshwater wetland and terrestrial – over the last 34 years. A decline in proportion of saltmarsh and corresponding increase in freshwater wetland habitats over the 1983-2007 period was largely reversed over the succeeding 2007-2017 monitoring interval. However, while total extent of vegetated lake shore habitats stayed more-or-less constant over the earlier 1983-2007 interval, there was a net loss of about 400 ha of vegetated lakeshore wetland and terrestrial habitats from 2007-2017, replaced by an expanded area of unvegetated lake bed/shallow water. Environmental drivers such as changes to freshwater inflows, lake levels, storm events and, we suggest, the 2010-11 Canterbury earthquakes were the cause of these more recent alterations to lake shore habitat area and relative extent.

In providing an overview of trends in lake shore wetland vegetation over the 34-year interval between survey in 1983 and the most recent survey in 2017, it is necessary to distinguish between the vegetation of saltmarsh and freshwater wetland habitats. For both habitat types, a main driver of vegetation change has been the progressive reduction or removal of stock grazing pressure on both public and private land around the lakeshore. In saltmarsh habitats, the general vegetation response has been an increase in extent and cover of native saltmarsh vegetation types such as marsh ribbonwood shrubland, sea rush rushland and three-square reedland from what was formerly exotic (tall fescue and creeping bent) grassland. Extent and type of saltmarsh herbfield vegetation has generally not changed in response to grazing removal, as environmental factors of elevation (in relation to lake levels) and salinity are the main influence. However, grazing removal has reduced physical damage to saltmarsh herbfield vegetation – a benefit that continues to be undermined on parts of the lakeshore with public vehicle access.

For freshwater wetland habitats by contrast, the main response to grazing reduction or removal over recent decades has been a spread in exotic weed species, especially willows, with associated loss of native freshwater wetland vegetation types such as harakeke flaxland, raupō reedland and baumea rushland. Native freshwater wetland vegetation also benefits from reduction or removal of grazing, but as these habitats are considerably more susceptible to weed invasion than saltmarsh, changes to grazing regime need to be accompanied by weed management in order to ensure recovery and persistence of native vegetation. This problem is now well-recognised; willows and other freshwater wetland weeds around the lakeshore are currently the focus of a dedicated control programme led by the Department of Conservation. Where effective willow control has been carried out in ungrazed freshwater wetlands, for example at the Selwyn delta and Yarr's Flat Wildlife Management Reserve, native freshwater wetland vegetation has regenerated well. The challenge now will be to extend willow and other weed control areas along the more heavily-infested western lakeshore, as well as resource ongoing weed surveillance and control programme to deal with any re-infestations and new incursions into lakeshore freshwater wetland habitats.

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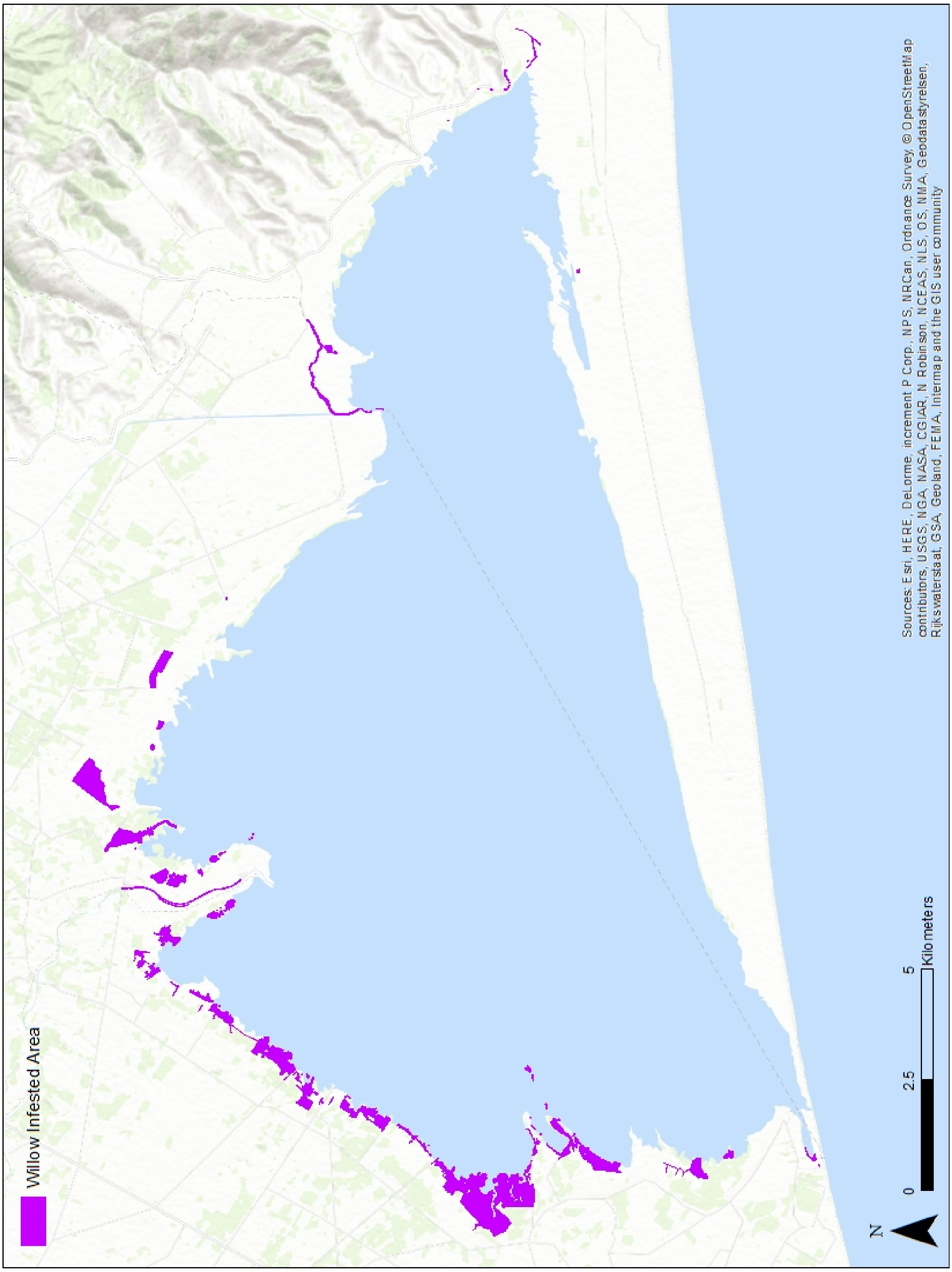
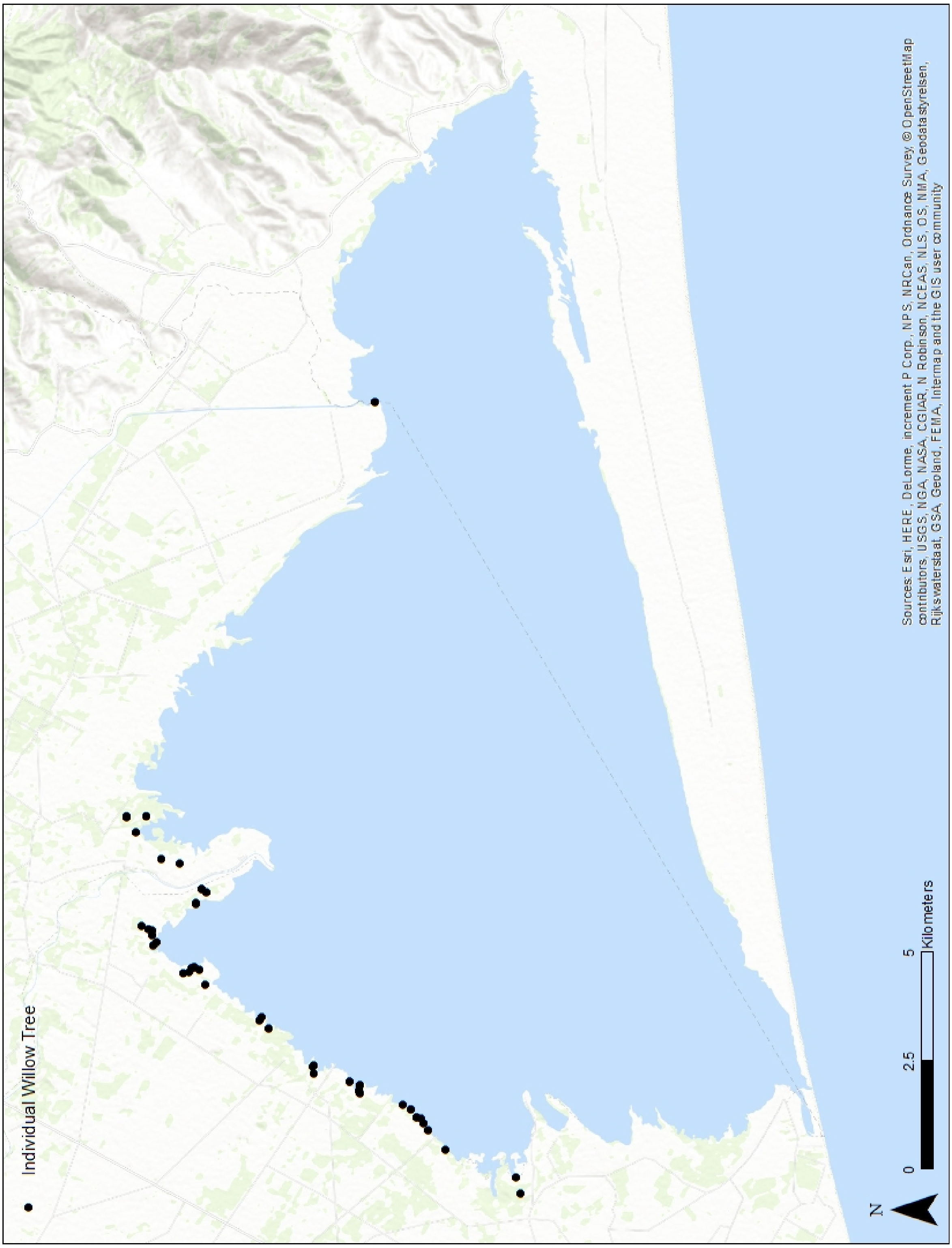
Appendix 1: Maps

Maps showing location of willow infestations and infestation densities in 2017 Te Waihora lakeshore survey area.


Willow Infested Area
N
0
2.5
5
Kilometers
Sources: Esri, HERE, DeLorme, increment P Corp., NPS, NRCan, Ordnance Survey, © OpenStreetMap contributors, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community


Individual Willow Tree
0
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Kilometers
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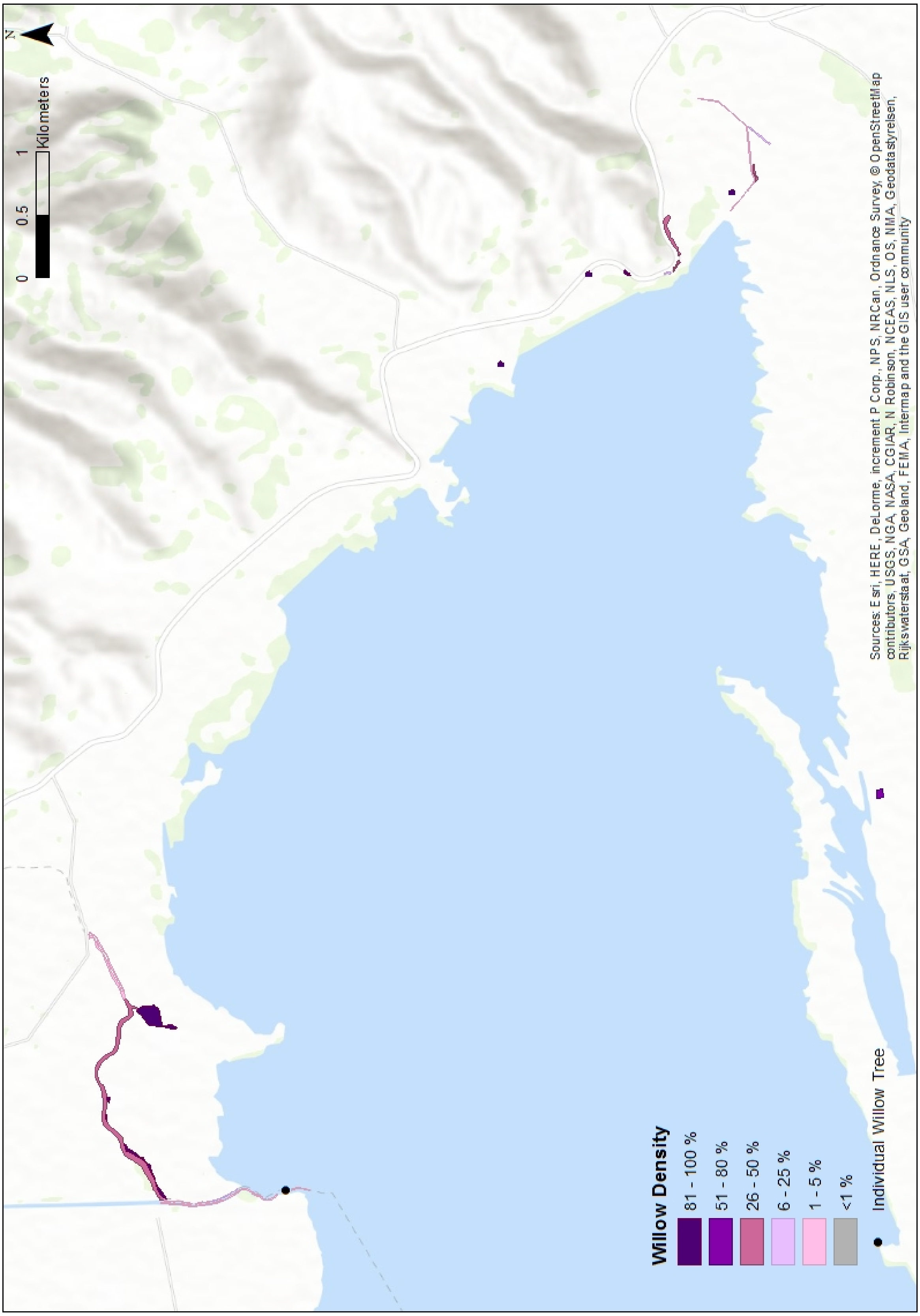
Sources: Esri, HERE, DeLorme, increment P Corp., NPS, NRCan, Ordnance Survey, © OpenStreetMap contributors, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community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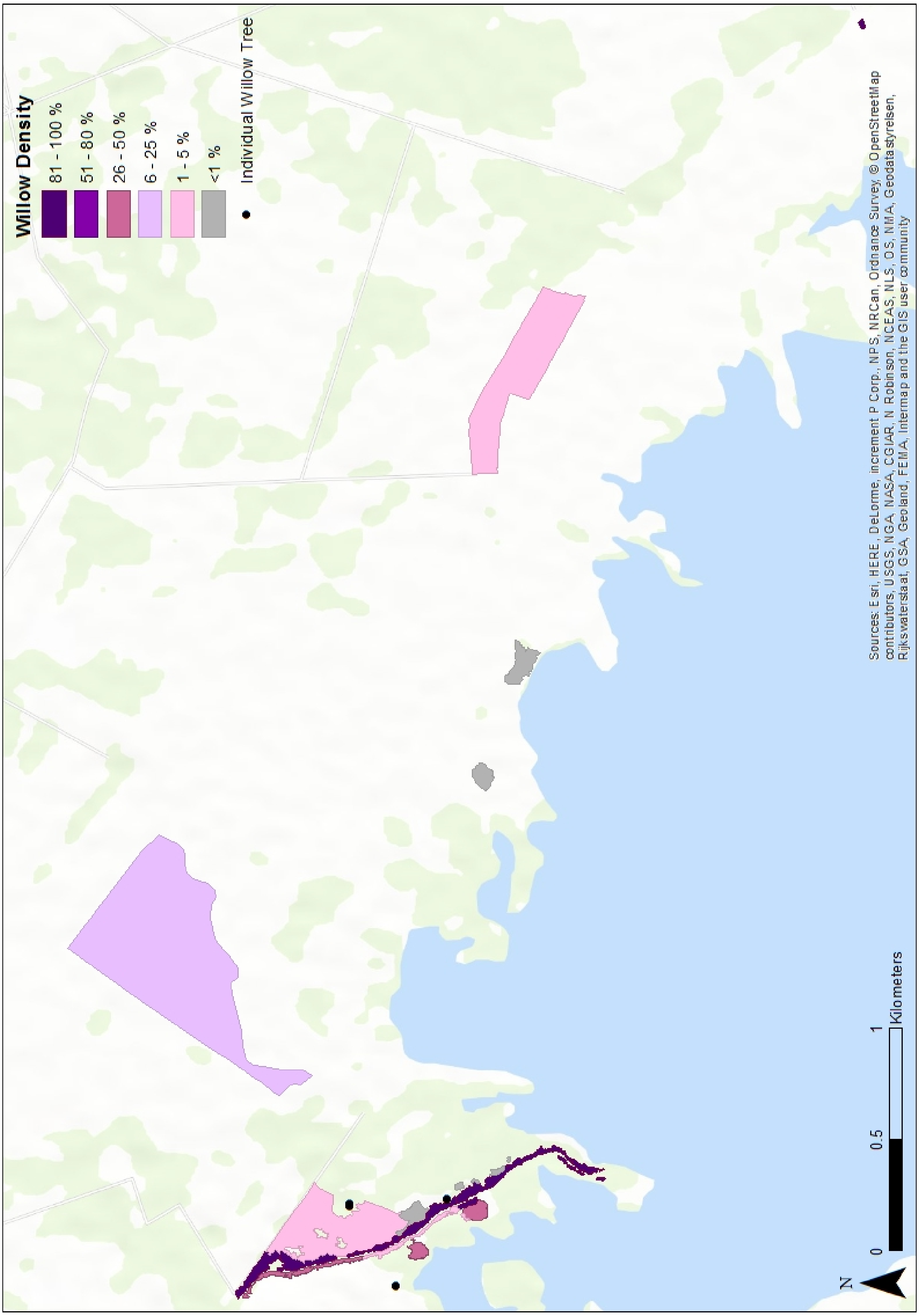
Sources: Esri, HERE, DeLorme, increment P Corp., NPS, NRCan, Ordnance Survey, © OpenStreetMap contributors, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community
Willow Density
81 - 100 %
51 - 80 %
26 - 50 %
6 - 25 %
1 - 5 %
<1 %
Individual Willow Tree


Willow Density
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51 - 80 %
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Individual Willow Tree
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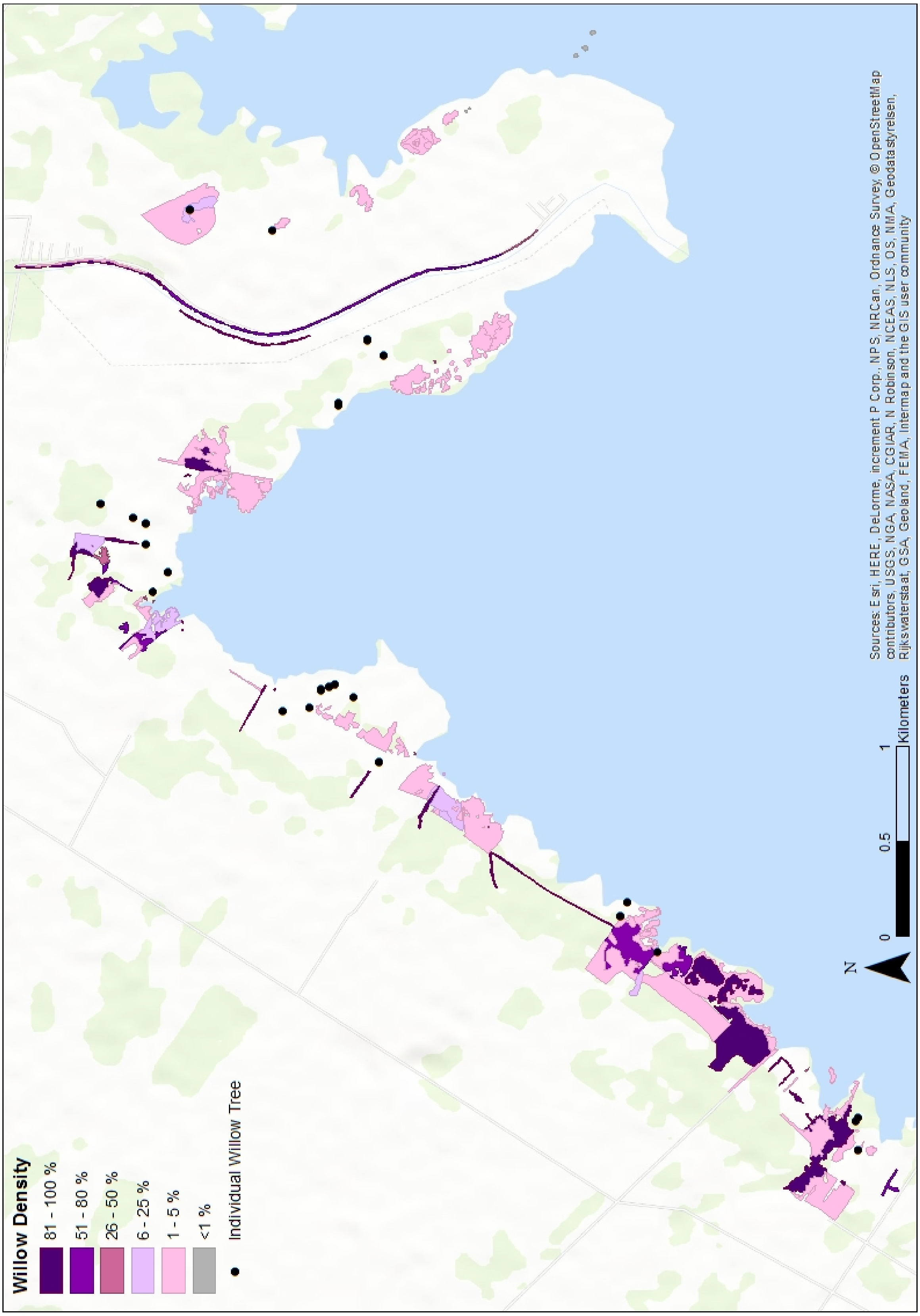
Sources: Esri, HERE, DeLorme, increment P Corp., NPS, NRCan, Ordnance Survey, © OpenStreetMap contributors, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community


Willow Density
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51 - 80 %
26 - 50 %
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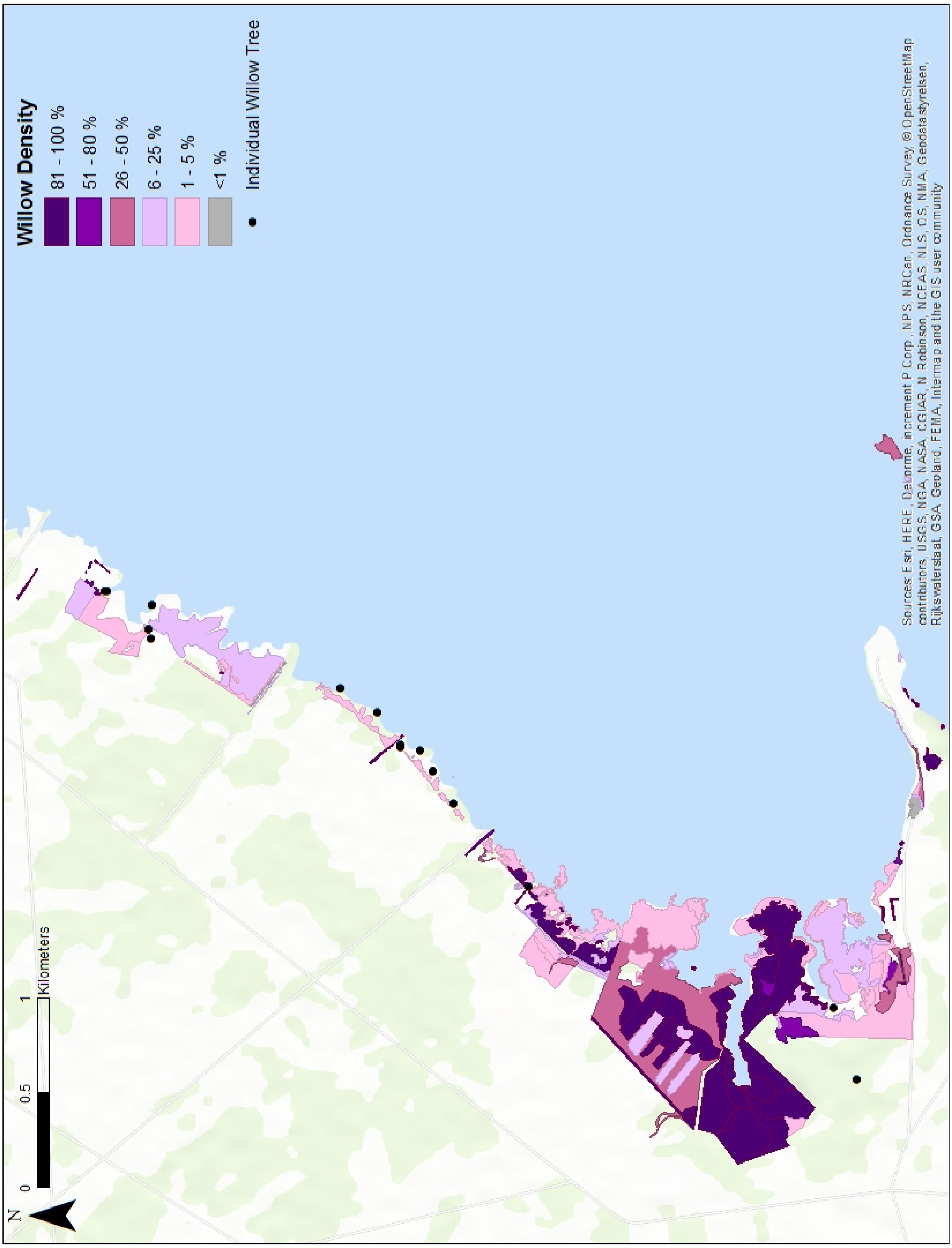
Sources: Esri, HERE, DeLorme, increment P Corp., NPS, NRCan, Ordnance Survey, © OpenStreetMap contributors, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community


Willow Density
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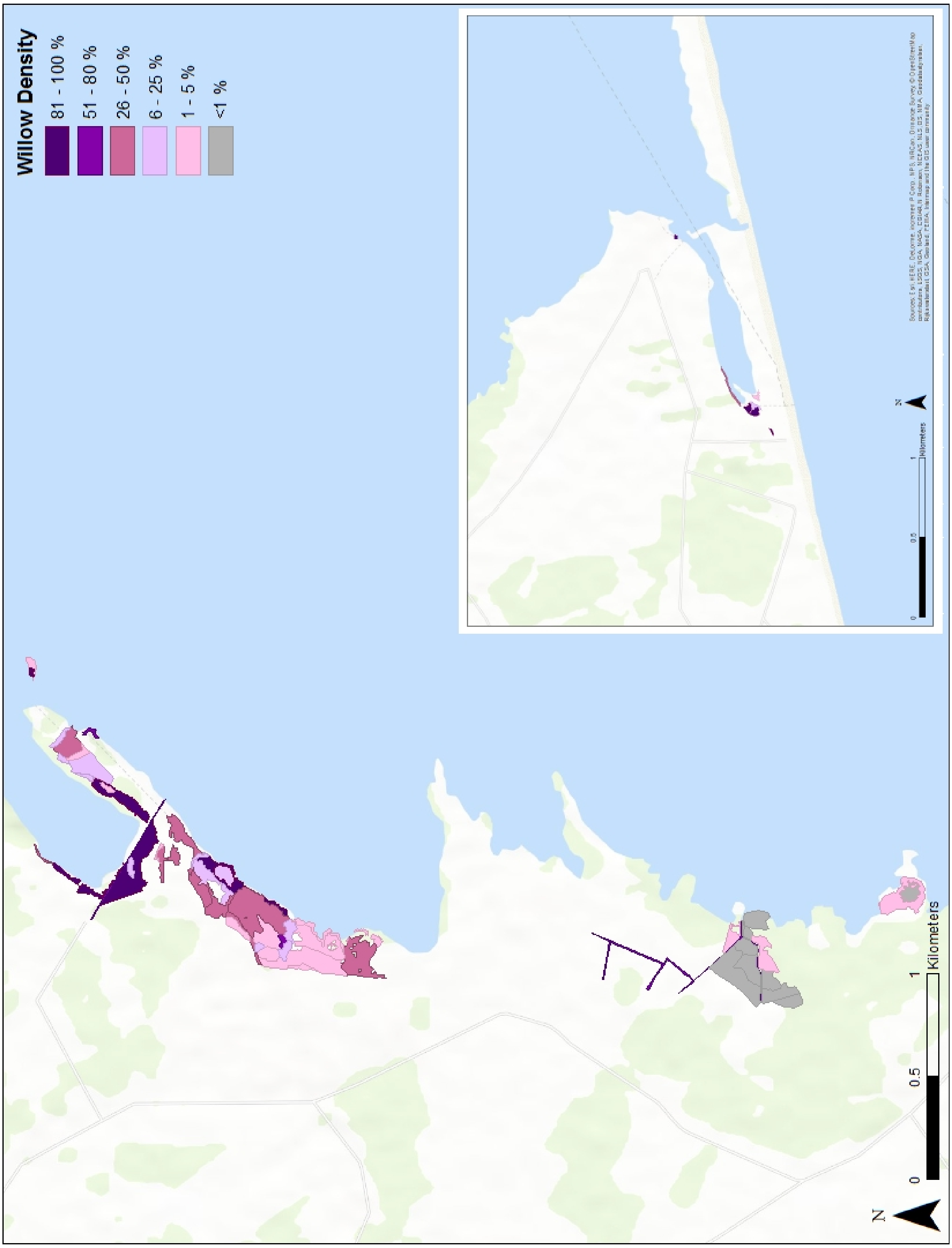
Sources: Esri, HERE, DeLorme, increment P Corp., NPS, NRCan, Ordnance Survey, © OpenStreetMap contributors, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community


Willow Density
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