2021

British Columbia Spartina Eradication Program Progress Report

Prepared By

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On Behalf of the BC Spartina Working Group

B.C. SPARTINA Working Group

protecting our shorelines

EXECUTIVE SUMMARY

In 2021, the British Columbia Spartina Working Group (BC SWG) continued to work towards the eradication of non-native, invasive *Spartina* spp. (*S. anglica*, *S. densiflora*, and *S. patens*) along the coastline of British Columbia (BC) through the BC Spartina Eradication Program. The BC SWG recognizes the potential impacts of *Spartina* spp. on local shorelines and wildlife habitat and strives to eradicate all non-native, invasive *Spartina* spp. along BC's coastline.

In 2021, approximately $460,000 CAD of in-kind and direct-value contributions were applied to complete program components focused on monitoring, removal, herbicide, coordination, and outreach within the Spartina eradication program. Approximately $38,000 of this funding was provided through the Federal Coastal Restoration Fund which went directly to staff time within the project. Approximately $50,000 in funding was provided by the Federal Canada Summer Jobs program to hire summer students for the program. 235 km of BC's coastline was surveyed for *Spartina* spp. in 2021 with 213 km of coastline being actively surveyed and the remaining 22 km were passively surveyed during other fieldwork. Surveying efforts continue to indicate that these invasive species are limited to the Fraser River Delta and Burrard Inlet in the Lower Mainland, and the Baynes Sound area of Vancouver Island.

We have seen an increase in plant numbers in 2021 which is most likely the result of missed treatments in the 2020 season caused by delays surrounding the Covid-19 pandemic. Although plant numbers have increased, we are seeing smaller plant sizes most likely from the seeding of plants which were not treated in the 2020 season. Full treatment of the *S. anglica* population was achieved in 2021 and we expect to see a large decline in plant numbers in 2022. Full coverage of the *S. anglica* and *S. patens* populations in the lower mainland were achieved and the most densly populated areas received a second pass of herbicide treatment. The *S. densiflora* population was removed using manual digging efforts which continue to be effective at treating the plant population. The entire *S. densiflora* population on the mainland of Vancouver Island was removed before the end of September meaning many plants did not have time to drop seeds. We achieved the best coverage to-date of the *S.patens* population in Baynes' Sound including treatments on Hornby Island and Jáji7em and Kw'ulh Marine Park (Sandy Island Marine Park). However, limited treatments were conducted within the Courtenay River Estuary where the densest population of *S. patens* is present. A greater focus on public outreach and the identification of treatment windows is needed to achieve adequate coverage in this region.

In 2021, the BC SWG continued to work with the City of Port Moody to monitor sites replanted with *Carex lyngbyei* planted as part of restoration efforts where *S. patens* had previously been present prior to treatment. The replanting sites showed little recurrence of patens, any plants found within the plantings were treated accordingly. Left untreated, *S. patens* grows into a dense monoculture meadow in the high salt marsh. Reestablishing native species within the now-bare patches can help prevent reinvasion by invasive species, including *S. patens.* The eradication of *S. patens* in this instance had been accomplished through shading them out with woven Nilex 2002 geotextile fabric as well as herbicide treatment efforts. Most other attempts to shade out *S. patens* with geotextile fabric have not been successful as wind and wave action as well as tampering by the public and wildlife had uncovered or damaged the mats. As such, the BC SWG plans to continue to use herbicide as the primary control method for *S. anglica* and *S. patens* as it has shown effective results. *S. densiflora* will continue to be treated with manual control methods and the effectiveness of these efforts will continue to be monitored to ensure progress towards eradication is being maintained.

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ACKNOWLEDGEMENTS

The work completed for the 2021 Spartina Eradication Program (SEP) could not have been undertaken without funding from:

Government of Canada | Gouvernement du Canada | British Columbia | Port of Vancouver

The British Columbia Spartina Working Group (BC SWG) is a Collaborative group that formed in 2004. It includes members from both government and non-government organizations. The SEP is primarily lead by the technical committee. However, the success of the programs early detection rapid response efforts is only possible from the entire Working Group (Figure 1).

Figure 1. Members of the BC SWG

In addition, special thanks are extended to the field coordinators and many other individuals and groups who contributed to finding and removing *Spartina* spp. in British Columbia (BC). Many landowners provided access through their properties to map and control Spartina, and we thank them for their support. Those contributions to the BC SWG program are acknowledged in Table 1.

Table 1. List of 2021 participants who helped in the mapping and control of Spartina spp. in BC

Organization	Participants
City of Surrey; SHaRP Program	The names were not recorded this year; however, the BC SWG is grateful for those that did participate in 2021 efforts. The BC SWG values to continued support and engagement by the City of Surrey and the SHaRP Program.
Corporation of Delta	Kevin Li
British Columbia Conservation Foundation	Katie Calon, Taylor Marriott, Nick Bartlett, Hannah Stoakes, Payton Bayly, Melissa Gee
Ducks Unlimited Canada	Matt Christensen, Richard Topp, Ben Kavanagh, Taylor Marriott, Jamie Gauk, Elliot Friesen, Tyffany Patrier, Madeleine Hayes
Environment Canada – Canadian Wildlife Service	Kathleen Moore
Ministry of Forests, Lands, Natural Resource Operations and Rural Development	Val Miller, Becky Brown, Derek Hogan
Port Metro Vancouver	Kim Keskinen, Spencer Chaisson
West Coast Conservation Lands Management Program	Tom Reid, Curtis Rispin, Shawn Lukas, Sammy Penner, Simon Ferguson
K'omoks First Nation	Cory Frank
Tsleil-Waututh First Nation	Lindsey Ogston, Graham Nicholas

BACKGROUND & ECOLOGY

In 2003, Gary Williams, a consultant for Port Metro Vancouver, discovered *S. anglica* growing in the Fraser River Delta while conducting habitat surveys of intertidal areas. This finding raised concerns about the spread of this invasive cordgrass as specimens of this species had not yet been discovered in BC.

Apart from *S. anglica*, two other species of invasive Spartina have been discovered in BC. *S. patens* was first identified in 1979 in both Burrard inlet as well as the Courtenay Estuary. *S. densiflora* was identified within the Baynes Sound area of Vancouver Island in 2005. Based on anecdotal evidence, however, this species has been present in the Baynes Sound area for some time.

Invasive *Spartina* spp. are detrimental to intertidal habitats. Throughout their establishment, *S. anglica* and *S. densiflora* convert important mudflat habitat into monoculture stands. These stands accrete sediments, modifying drainage patterns and reducing habitat for waterfowl and fish. *S. patens*, on the other hand, invades the higher salt marsh areas, outcompeting the diversity of salt marsh plants and replacing them with a dense, monoculture meadow that is very difficult to remove manually. Intertidal areas that became dominated by invasive Spartina in the state of Washington, USA, experienced large declines in their abundance of shorebirds and waterfowl. As a result, significant expenditures were required to control Spartina in the state, costing approximately $1,000,000 USD per year for more than two decades. The states of Oregon and Washington combined spent approximately $50,000,000 USD over a ten-year period in a concerted effort to eradicate *Spartina* spp. along their coastlines. It is only recently, with sustained funding and the use of herbicide, that these two states have significantly reduced their infestations of Spartina.

Controlling the spread of an invasive species early in its expansion is the most cost-effective approach to its eradication. The Fraser River Delta on its own contains approximately 25,000 ha of tidal mud flats that are internationally recognized as important habitat for fish and migratory birds. The Fraser Delta hosts the highest density of wintering waterfowl, shorebirds, and raptors in all of Canada. Failing to control invasive Spartina in BC would result in a massive loss of essential habitats beyond just the Fraser River Delta and would require considerably more resources to manage them in the future. It is crucial to control invasive *Spartina* spp. in BC as early as possible.

The BC SWG formed in 2004 with the intent of eradicating invasive *Spartina* spp. from BC's coastlines. The working group is comprised of members from both government and non-government organizations. The BC SWG liaisons with the San Francisco Estuary Spartina Project and the Washington State Department of Agriculture, two USA agencies involved in eradicating invasive *Spartina* spp. along the Pacific Coast. The BC SWG has built on the Pacific Coast Collaborative Agreement as well as the West Coast Governor's Agreement to eradicate *Spartina* spp. from BC's coastlines. The focus of the BC SWG is to employ early detection and rapid response methods to eradicate invasive *Spartina* spp. in BC. In 2021 these methods took the form of mapping and actively controlling for Spartina between BC's Lower Mainland and Vancouver Island. (Figure 2). Continued pressure is needed to further reduce the presence of *Spartina spp.* in BC. It is a goal of the BC SWG to expand control efforts on all *Spartina spp*. to eventually eradicate the species from BC shores.

DETECTION

The compilation and storage of data of *Spartina* spp. in BC has historically been a joint effort between Ducks Unlimited Canada (DUC) and the Community Mapping Network. In recent years, DUC has been responsible for the collection and storage of spatial data for all Spartina spp. in BC. The collected data is used for evaluating the progress of Spartina eradication between years, as well as for planning future monitoring and control activities. The spatial data of *Spartina* spp. in BC is uploaded to the provincial Invasive Alien Plant Program (IAPP) database. DUC also maintains a geodatabase of all the collected Spartina data since the beginning of the eradication program. The data is available for view through a digital web-atlas accessible through the BC SWG website. For more information on mapping methodology and spatial analyses, please visit www.spartina.ca. The location and approximate distribution of Spartina in BC in 2021 is shown in Figure 3.

METHODS

Since 2017, surveying for *Spartina* spp. has been completed using two ESRI[1] applications, *Collector* and *Survey123*. Both products are applications used on smart devices which take the place of Global Positioning System units. *Survey123* records the location and size of each individual plant or clone of *Spartina* spp. *Collector* provides real-time tracking of surveyors as well as preexisting Spartina mapping and tracking information. Data from multiple surveyors' *Collector* and *Survey123* applications are routinely uploaded to shared databases which the surveyors can then download onto their *Collector* apps. This process provides surveyors with accurate, updated visual representations as to what areas have already been surveyed as well as when these areas were surveyed. Such information is used to determine where subsequent surveying and control efforts are to be applied. These applications allow the BC SWG to accurately and consistently track populations of *Spartina* spp. over time across multiple regions. These sites are called IAPP sites within the ESRI database. These IAPP sites mirror sites in the provincial Invasive Alien Plant Program database hosted by the Government of BC. The collected plant data is summed for each IAPP site and uploaded to the Provincial database on an annual basis.

[1] ESRI (Environmental Systems Research Institute) is an international supplier of geographic information system software, web GIS and geodatabase management applications.

Figure 2. All areas searched for Spartina spp. in British Columbia in 2021

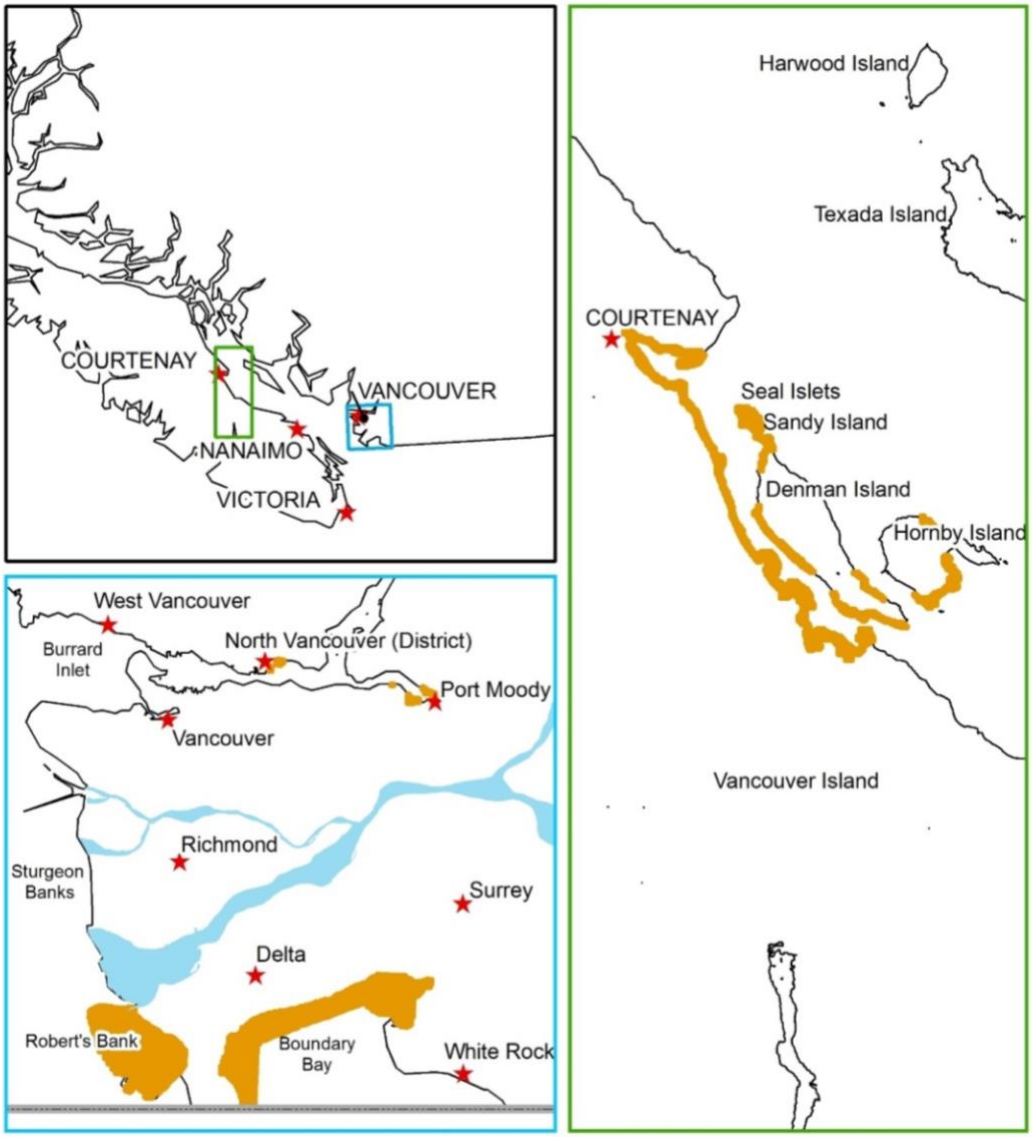


Figure 3. General locations where Spartina spp. are found in BC: Lower Mainland (Blue) and Baynes' Sound (Green). The approximate distribution of Spartina spp. is shown in Orange.

The BC SWG analyzes the surveyed IAPP sites by using several metrics:

1. The number of plants or plant clones detected
2. The size of each plant or plant clone
    I. Size S: single plant or seedling
    II. Size A: plant with diameter less than 30 cm
    III. Size B: plant with diameter of 30 cm to 1 m
    IV. Size C: plant with diameter of 1 m to 5 m
    V. Size D: plant with diameter of approximately 5 m
    VI. Size M: plant with diameter greater than 5 m
3. The estimated leaf area (number of plants or plant clones detected x size of each plant or plant clone = number of square meters a dispersed colony would occupy if all Spartina plants were grouped into a single cluster, see Appendix for full equation)

Each IAPP site is divided into a grid of 1 ha cells. The three metrics are then summarized at a single cell level within the grid as well as an accumulation of all the cells within a site. These summaries are titled Cell Summaries and Site Summaries, respectively (Figure 4). These summaries are generated on a per-species basis each year. With these summaries, the BC SWG determines how much shoreline has been impacted by *Spartina* spp. (how many 1 ha grid cells had one or more occurrences of Spartina). Together, the metrics used by the BC SWG depict spatial trends over time. By analyzing these trends, the BC SWG can effectively plan and develop monitoring and control activities for the future. For more information on how these metrics and summaries are calculated, see Appendix A.

Map of Comox Harbour with Spartina plants represented as points

Cell Summary showing the total number of plants in each cell representing total abundance

Site Summary (site boundary shown in red)

Figure 4. Cell Summaries and Site Summaries example in Comox Harbour, BC.

MAINLAND BC

In 2021, approximately 350 person days were spent surveying the Fraser River Delta, Boundary Bay, and Burrard Inlet areas for *Spartina* spp. (Figure 5). Surveying in the Fraser River Delta occurred from the tip of Robert's Bank, Delta, to the Canada-USA border south of the causeway that leads to the BC Ferries Terminal in Delta. Surveying along Boundary Bay occurred from the Canada-USA border south of Beach Grove Park, Delta, to where the Campbell River joins Boundary Bay in White Rock. The foreshore regions of Westham Island, Lulu Island, and Sea Island were surveyed and no *Spartina spp*. were found within these areas. Some of the surveying in Burrard Inlet occurred in The District of North Vancouver within the Maplewood Flats Conservation Area as well as in Deep Cove. The remainder

of the surveying in Burrard Inlet occurred in Port Moody, within the Pacific Coast Terminal property, in Old Mill Park, and in Old Orchard Park. Of all the surveys that took place in mainland BC in 2021, *S. anglica* was only found in the Fraser River Delta and Boundary Bay areas, and *S. patens* was only found in Burrard Inlet.

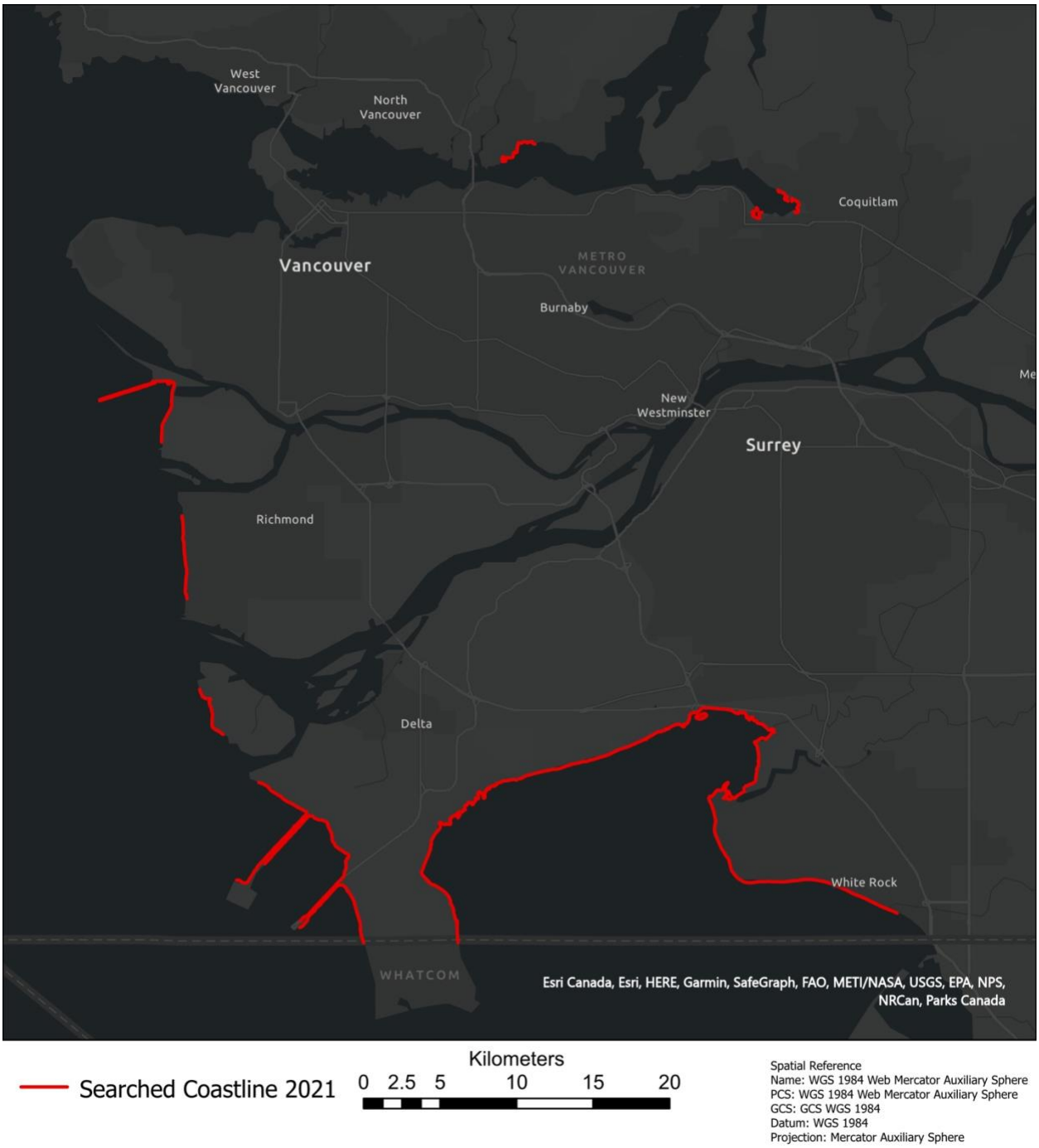


Figure 5. Fraser River Delta, Boundary Bay, and Burrard Inlet areas surveyed for Spartina spp. in 2021.

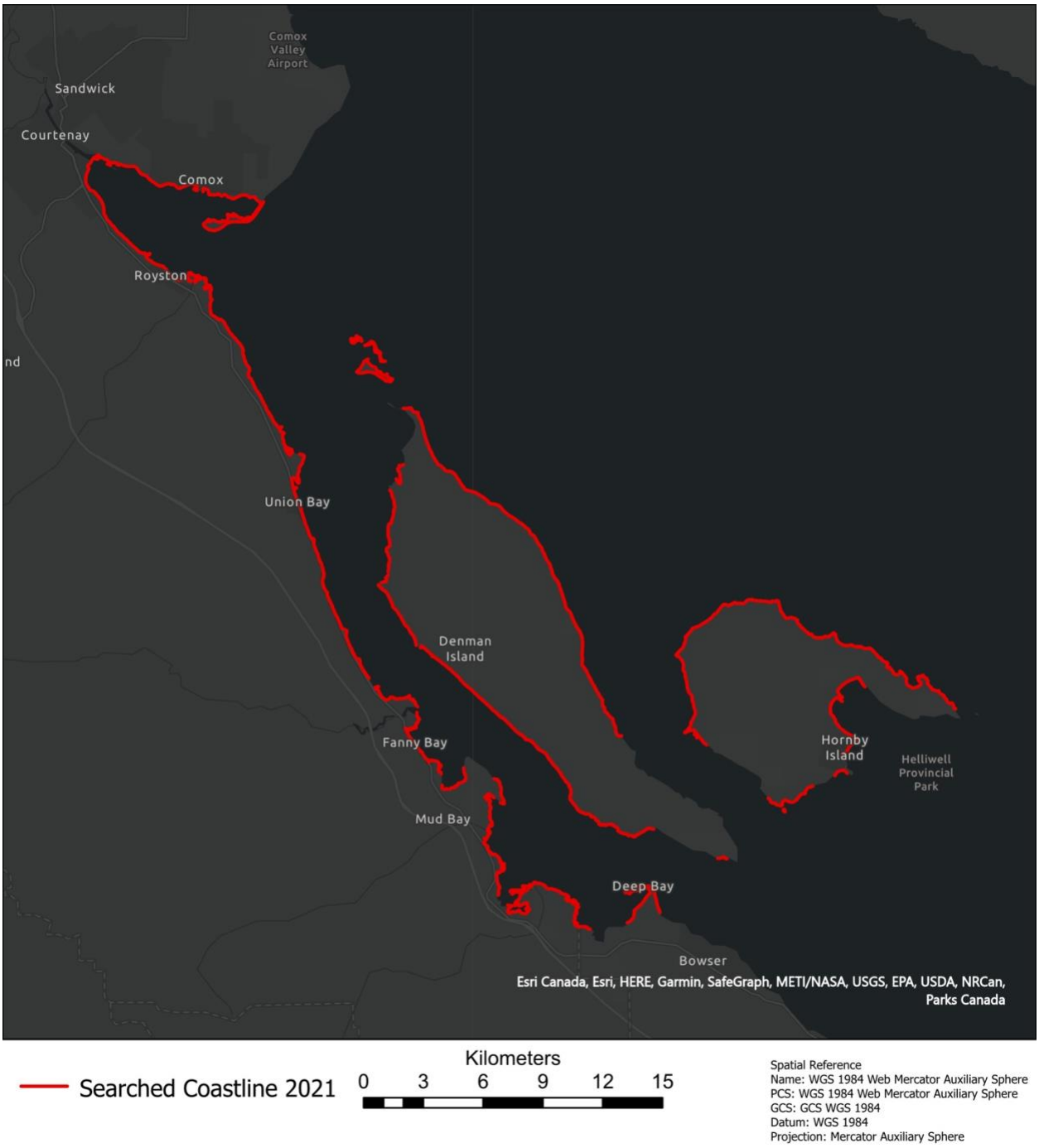


Figure 6. Baynes' Sound area surveyed for Spartina spp. in 2021.

A total of 76 person-days were spent mapping the Baynes Sound area for *S. patens* and *S. densiflora*. in 2021 (Figure 6). Surveying occurred from Goose Spit Park in Comox to Deep Bay in Bowser. Surveying also occurred around both Denman Island and Hornby Island. *S. densiflora* and *S. patens* were found within the Baynes Sound Area on Vancouver Island and some of the Gulf Islands (Figure 3). Passive surveys conducted during adjacent fieldwork were completed by members of Nature Trust BC in the Quatse Wildlife Management Area, the Englishman River, Little Qualicum River (Figure 8), Salmon River, Fullmore River, Nanaimo River, and Cowichan river estuaries (Figure 7).

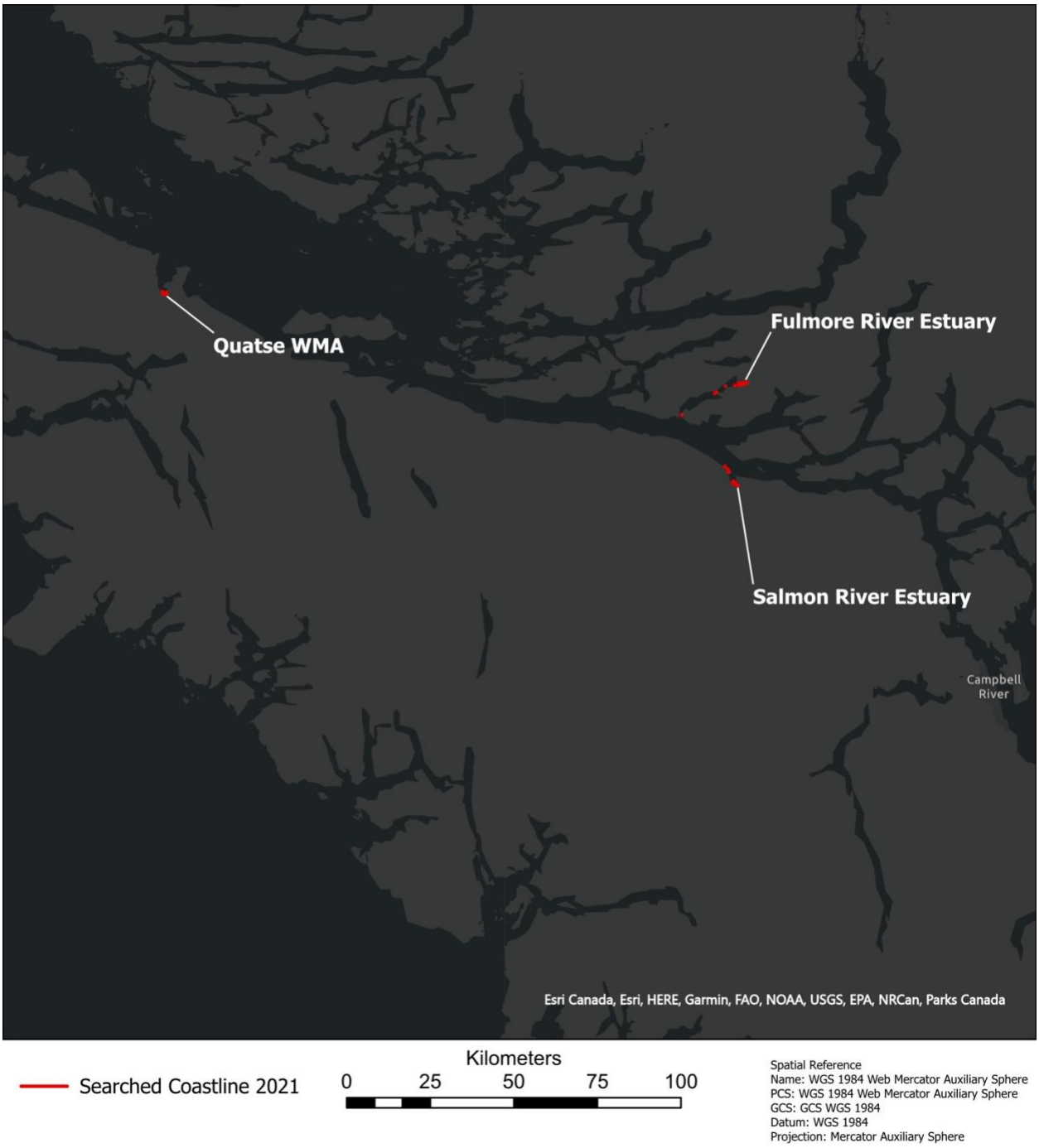


Figure 7. North Vancouver Island areas passively surveyed for Spartina spp. in 2021.

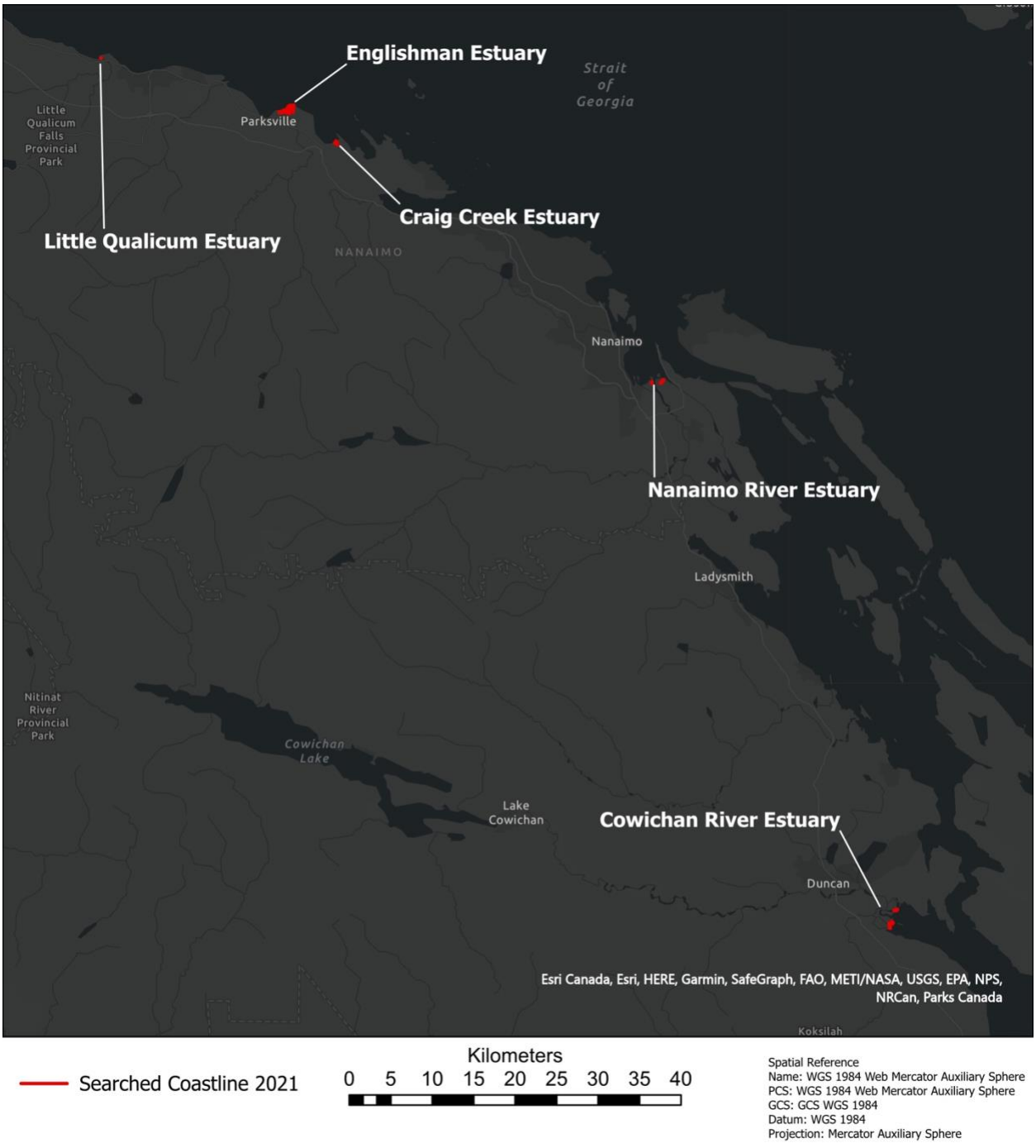


Figure 8. Additional Vancouver Island areas passively surveyed for Spartina spp. in 2021.

CONTROL & REMOVAL

MANUAL REMOVAL

S. ANGLICA

Unlike previous years, participants in 2021 did not manually remove size 'S' (single plants or seedlings) plants of *S. anglica* using hand shovels. Herbicide treatment has shown to be most effective at controlling the spread of S. anglica, even in the size S category. Removal of S. anglica plants by hand was done on a case by case basis where size 'S' plants could be removed easily and where their manual removal would significantly outweigh the effort needed to treat the plants with herbicide.

S. DENSIFLORA

Manual removal continues to be effective in controlling *S. densiflora*. No herbicide was used to control S. *densiflora*. In 2021, technicians on Vancouver Island and adjacent islands within Baynes Sound removed entire *S. densiflora* plants using pickaxes and transported them using barrel-packs (Figure 9). Plants bearing a mature seed head were bagged before being uprooted to reduce seed dispersal during removal. All clones were loaded into heavy plastic bags and dropped off at a local landfill for disposal. *S. densiflora* was controlled during the fall and winter as it is the only standing, green plant in the marshes during these months. The timing of control helped reduce search efforts. Approximately 905 kg of plant material was removed over the 2021 season. This value reflects the combination of plant matter as well as any mud and rocks entangled in the root system of the plants and is therefore an overestimate of the actual amount of plant matter removed over the season. DUC lead the operations on *densiflora* removals on the East Coast of Vancouver Island with the help of The Nature Trust of BC as part of the West Coast Conservation Land Management Program (WCCLMP). Taking the lead on *densiflora* removals saved money and resulted in *densiflora* removals being completed earlier than previous seasons.

Figure 9. Manual removal of S. Densiflora using Pickaxe and barrel-pack.

S. PATENS

Manual control for *S. patens* has historically involved covering mats of this species with a Nilex 2002 geotextile fabric. The intent behind this was to kill the mats by shading them out over a period of multiple years. Nilex 2002 geotextile fabric has been used to shade out *S. patens* in Burrard Inlet and Baynes' Sound as a means of control since 2012 with limited success. Numerous locations, methods and patch sizes have been trialed using the covering method. The fabric was installed over patches of *S. patens* for a minimum of 2 years and has only shown signs of reducing *S. patens* patch biomass before rapid re-establishment, typically within 1 growing season. Baynes' Sound has a more active shoreline, subject to wind and wave action that disturbs and removes the cover fabric, which requires maintenance and monitoring that is impractical. Due to the limited success with eradicating *S. patens* using covering and manual removal techniques and following a small herbicide pilot trial at PCT in 2015, operational scale herbicide treatment was employed on *S. patens* beginning in 2016. No manual removal was applied to *S. patens* in 2021. For a breakdown of the timeline of treatments for *S. patens* by the BC SWG, see Figure 10.

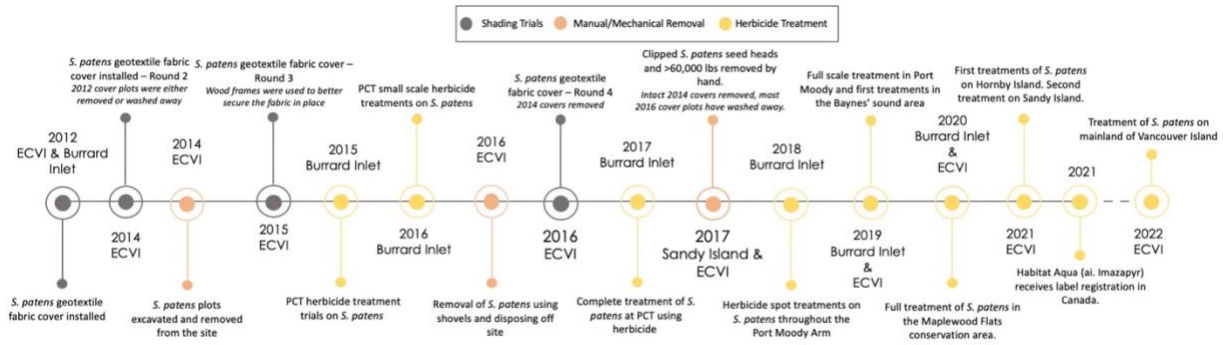


Figure 10. Timeline of S. Patens control methods.

HERBICIDE

For more than a decade, the treatment of *Spartina* spp. solely used non-herbicide control methods with limited success. Since 2010, a sub-group of the BC SWG has worked with federal and provincial Canadian agencies to determine the requirements and process of using herbicide to control *Spartina* spp. in BC. The sub-group evaluated the ecological impacts and best management practices of two herbicides used to control Spartina in the states of Washington, Oregon, and California, USA. From these evaluations, it was determined that herbicide was to be used but that the project first required the herbicides be registered with the federal Pest Management Regulatory Agency (PMRA) and that a Pesticide Use Permit (PUP) would be required from the BC provincial Ministry of Environment.

As members of the BC SWG, the BC Ministry of Environment and the BC Ministry of Forests, Lands, and Natural Resources Operations submitted an emergency use registration to the PMRA in February 2012 for the use of 2 herbicides with different active ingredients to control Spartina. These were Rodeo (glyphosate) and Habitat (imazapyr). The emergency response registration also included proposed methods on using the herbicides as well as proposed evaluation and monitoring processes. The PMRA granted the emergency registration of Habitat and Rodeo on February 13, 2013, allowing for their use until December 31, 2013. The PMRA requires a new application be submitted annually for the emergency use of herbicides. In 2013, it was decided that only Habitat, mixed with the surfactant Ag Surf II, was to be used to treat *Spartina* spp. in BC. This decision was made following consultation with agencies from Washington State, USA, with the purpose of minimizing the use and impact of herbicide to treat Spartina. By mixing Ag Surf II with Habitat, the herbicide would bind to targeted plants, reducing undesired spreading of herbicide to the adjacent environment. The decision to use Ag Surf II made by the PMRA following a review of multiple surfactants. The review identified Ag Surf II as having a lower toxicity among the other surfactants.

In 2021, Habitat Aqua (a.i. Imazapyr) was fully registered for use in Canada thanks to the efforts of the Spartina Eradication program. This formulation is specifically designed for use in and around aquatic environments and is the product of choice for the Spartina eradication program moving forward..

Annual reports are provided to the Section Head of the Integrated Pest Management Coastal Region by January 31 as a requirement of the PUP. Approval to use herbicides in Boundary Bay and Roberts Bank Wildlife Management Area for the 2019-2021 application seasons has been provided by the West Coast Operations Division of the BC Ministry of Forest, Lands, and Natural Resource Operations.

S. ANGLICA

In 2021, Approximately 80 person-days were spent applying herbicide to *S. anglica* in the Fraser River Delta and Boundary Bay areas. Just under 800 hectares of infested area were treated in 2021 with a total of 3844 plants receiving treatment. Second passes of herbicide treatment were conducted in Robert's Bank, Boundary Bay, Tsawwassen First Nation, and Mud Bay to treat any remaining plants that were missed during the first pass or any new plants that had appeared.

Figure 11. 2021 S. anglica treatment areas in Boundary Bay. Each pink square represents a 1 ha cell where one or more S. anglica plants were treated.

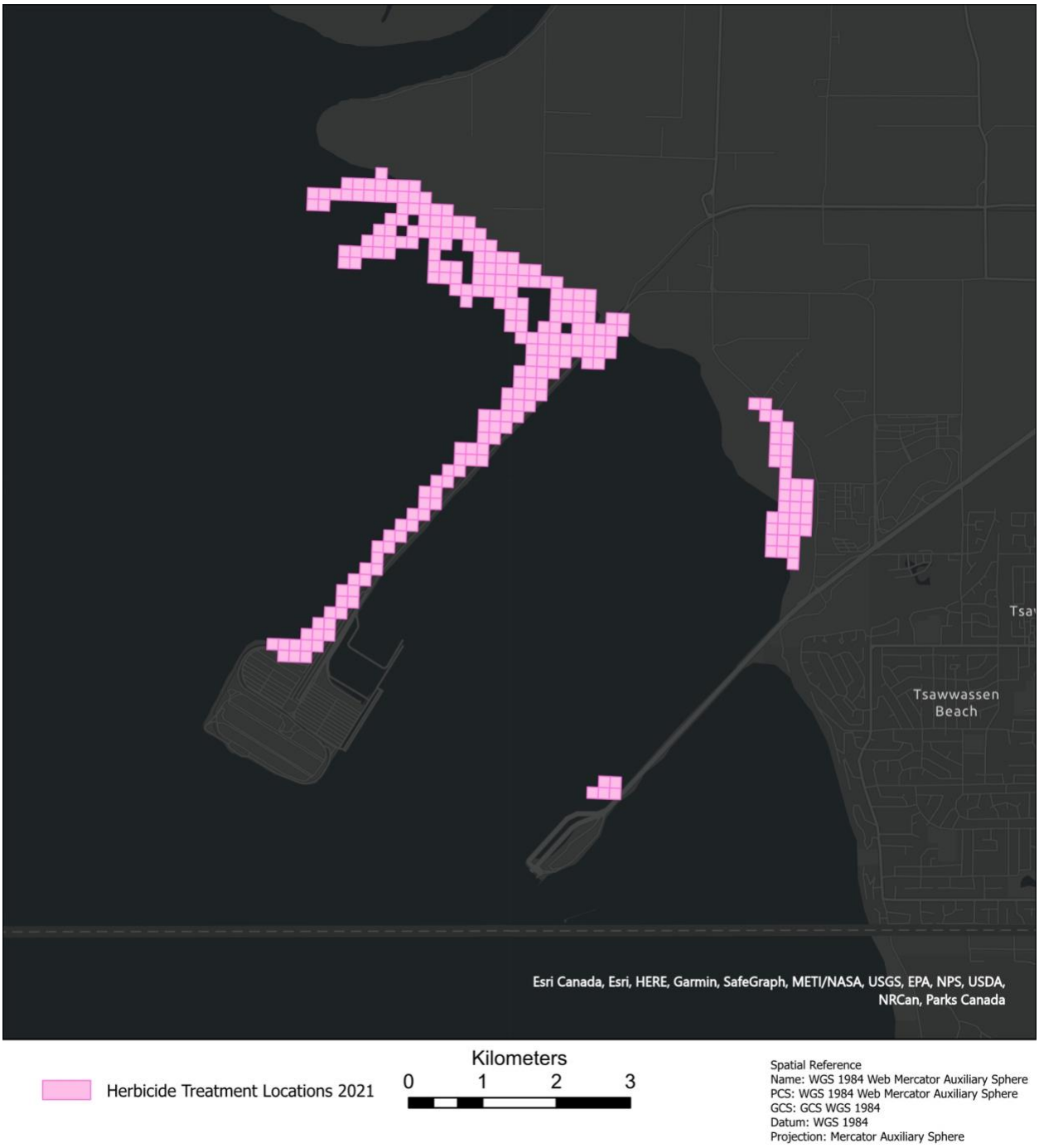


Figure 12. 2021 S. anglica treatment areas in the Roberts Bank Wildlife Management Area and Tsawwassen First Nation. Each pink square represents a 1 ha cell where one or more S. anglica plants were treated.

S. PATENS

Following several years of various manual and mechanical control efforts herbicide became the primary treatment method for *S. patens* in Burrard Inlet in 2016. No manual removal efforts were undertaken on *S. patens* in 2021; any *S. patens* receiving treatment in 2021 was treated with herbicide. 40 hectares of infested area containing 200 plant

individuals were treated in Burrard Inlet between The Maplewood Flats Conservation Area, Old Mill Park, and Pacific Coast Terminals.

S. patens is the only species treated with herbicide on the East Coast of Vancouver Island. In 2021 a total of 38 hectares of infested area were treated within Bayne's Sound including Jáji7em and Kw'ulh Marine Park (Sandy Island Marine Park) and Hornby Island. The densest population of S. patens exists within the Courtenay River Estuary which continues to be a logistical challenge for the program. The focus has been on limiting the extent of S. patens thus far and the treatment of S. patens populations on Hornby and Sandy Island are a major step forward in effectively treating the S. patens population on Vancouver Island.

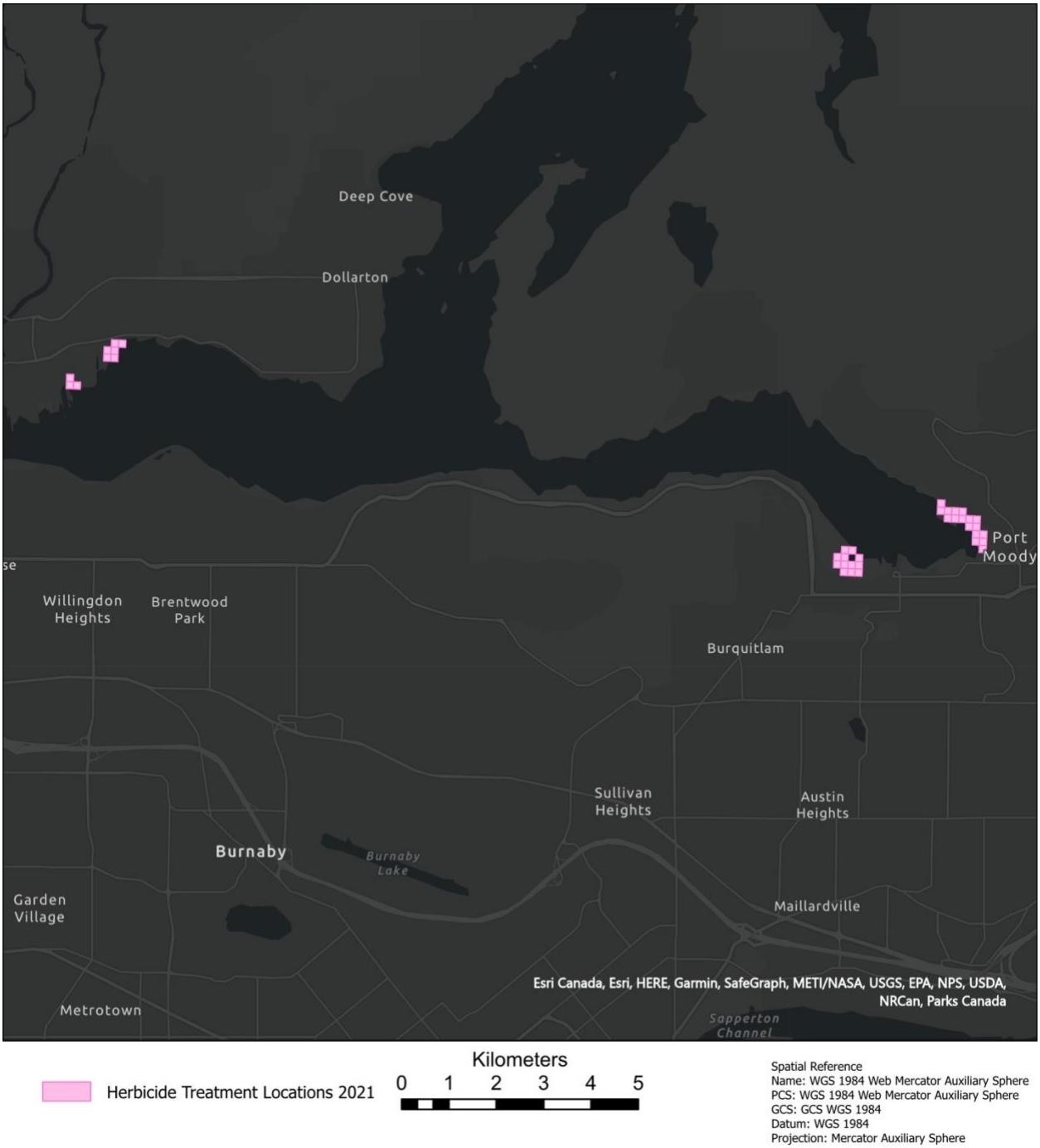


Figure 13. Herbicide treatment locations for S. patens in Burrard Inlet. Each pink square represents 1ha

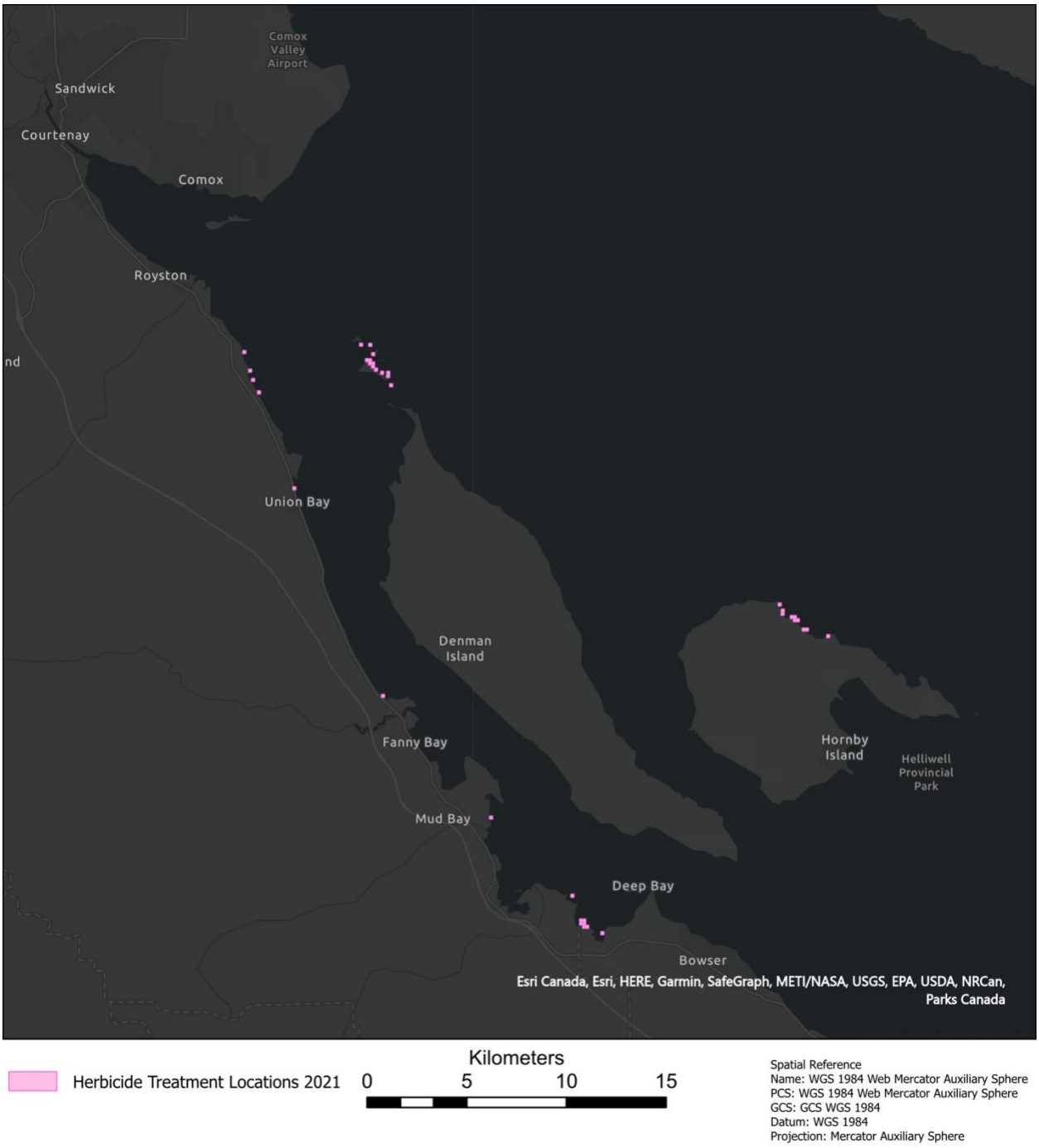


Figure 14. 2020 S. patens treatment areas in the Baynes' Sound area. Each pink square represents a 1 ha cell where one or more S. patens plants were treated.

Table 2. Amount of herbicide used to treat S. anglica since 2013.

	2013	2014	2015	2016	2017	2018	2019	2020	2021
Volume of herbicide mix used (L)	1089.5	2595	1949.5	3744	2412	1109	566	177.6	492
Volume of Habitat used (L)	8.17	19.46	14.62	28.08	18.09	8.32	4.25	1.33	3.690
Amount active ingredient (Imazapyr) used (kg)	1.96	4.671	3.51	6.74	4.34	2.00	1.02	0.32	0.886
Volume of surfactant Viterra Ag Surf II (alcohol ethoxylate) used (L)	5.44	12.97	9.75	18.72	12.06	5.55	2.83	0.89	2.46
Amount active ingredient (kg)	5.01	11.937	8.97	17.22	11.10	5.10	2.60	0.79	2.197
Estimated ha	1.75	4.17	3.90	6.01	3.87	1.78	0.909	0.285	0.790

Table 3. Amount of herbicide used to treat S. patens on the Lower Mainland since 2016.

	2016	2017	2018	2019	2020	2021
Volume of herbicide mix used (L)	216	583	17	25	782	48
Volume of Habitat used (L)	1.62	4.37	0.128	0.1875	5.865	0.36
Amount active Ingredient (Imazapyr) used (kg)	0.388	1.05	0.0306	0.0450	1.4076	0.0864
Volume of surfactant Viterra Ag Surf II (alcohol ethoxylate) used (L)	1.08	2.92	0.0850	0.125	3.91	0.24
Amount active ingredient used (kg)	1.17	3.17	0.0923	0.136	3.60	0.221
Estimated ha	0.347	0.94	0.0273	0.040	1.256	0.077

Table 4. Amount of herbicide used to treat S. patens in the Bayne's Sound area since 2019.

	2019	2020	2021
Volume of herbicide mix used (L)	567	345	298
Volume of Habitat used (L)	4.25	2.59	2.235
Amount active Ingredient (Imazapyr) used (kg)	1.02	0.62	0.5364
Volume of surfactant Viterra Ag Surf II (alcohol ethoxylate) used (L)	2.84	1.73	1.49
Amount active ingredient used (kg)	2.61	1.54	1.330
Estimated ha	0.912	0.554	0.479

RESULTS

When reporting on plant results from year-to-year we rely on the three metrics of plant abundance (Figure ##), impacted area (Figure ##), and leaf area (Figure ##). Plant abundance is defined by the sum-total of all identified plant individuals. Plant abundance can sometimes be over or underestimated, especially with regard to S. patens, as distinguishing where one plant ends and another begins can be tricky. Impacted area is based on a grid of cells, 1 hectare in area, where an occurrence of one or more Spartina plant within that cell counts as the entire cell being impacted. Impacted area helps give an understanding to the extent of the Spartina population. Lastly, leaf area is an estimation based on the size of a given Spartina plant and it's association to a leaf area coefficient (See Appendix A).

Anglica

We have seen an increase in S. anglica abundance with a total of 3844 plants found in 2021, an increase of almost 65% from the previous season. However, from Figure 17 we can see that smaller size classes of plants increased the most. Additionally we still see a decline in the leaf area (Figure 18) of S. anglica by around 12% since 2020 which indicates that due to missed treatments in 2020 the S. anglica population has rebounded slightly primarily because of plants in 2020 being allowed to go to seed. The impacted area (Figure 19) has remained generally unchanged from 2020, most likely another result of the missed treatments in 2020. The most noticeable increase in plant abundance, leaf area, and impacted area comes from the Mud Bay region which received no treatments in 2020 due to the Covid-19 pandemic and other scheduling issues.

Densiflora

The *S. densiflora* population has also rebounded from 2020 levels in all three metrics. Abundance increased from 1222 plants in 2020 to 1633 plants in 2021, impacted area increased from 127 ha to 153 ha, and leaf area increased from 0.008 ha to 0.01 ha. These increases are most likely the result of late removals in 2020 which were not completed until the end of November. Additionally, the lead contractor who handles Sandy Island Marine park and the Seal Islets was unable to remove the S. densiflora present in the region and these plants were left to grow for another year. *S. densiflora* removals were completed much sooner in 2021 having removed approximately 90% of the population before the end of September, hopefully reducing the ability for plants to go to seed. Even with the slight increase in plant population, manual removal continues to show effective results as overall abundance has decreased by 88% since peak levels and impacted area and leaf area have reduced by 47% and 97% respectively.

Patens

The S. patens population saw a decline in plant abundance dropping from 977 to 618 plants, however this change might be spurious, because of the plants mat-like growth, two plants identified one year may have combined into one larger plant the next year. Impacted area of S. patens has decreased from 196 ha to 162 ha. The decrease in impacted area is partially due to the results of successful treatments in the Burrard Inlet area as well as spot treatments on the East Coast of Vancouver Island near Bowser which occurred in 2020. However, leaf area of all S. patens in B.C. has increased by approximately 20% and now stands at just under 5 hectares. This season we achieved the greatest coverage of the Vancouver Island S. patens population treating 38 hectares of impacted area which includes the first treatments of the S. patens population on Hornby Island, and the second treatment on Sandy Island and the Seal Islets.

Table 5. Summary of Spartina spp. invasion since 2004.

	S. anglica			*S. patens*			*S. densiflora*		
Year	Estimated Leaf Area (ha)	Impacted Area (ha)	Number of Plants Detected	Estimated Leaf Area (ha)	Impacted Area (ha)	Number of Plants Detected	Estimated Leaf Area (ha)	Impacted Area (ha)	Number of Plants Detected
2004	0.0250	105	433	-	-	-	-	-	-
2005	0.0681	194	864	-	-	-	-	-	-
2006	0.2202	137	584	-	-	-	-	-	-
2007	0.1158	75	342	-	-	-	-	-	-
2008	0.1263	125	334	-	-	-	-	-	-
2009	0.1020	184	691	-	-	-	-	-	-
2010	0.2312	261	1217	-	-	-	-	-	-
2011	0.5525	242	2387	-	-	-	-	-	-
2012	0.5785	797	6846	-	-	-	-	-	-
2013	0.8209	940	8511	-	-	-	-	-	-
2014	0.5502	937	13921	-	-	-	-	-	-
2015	1.4353	898	18074	3.3502	107	320	0.2133	197	14090
2016	1.6373	973	23260	3.3892	127	354	0.3992	292	4181
2017	1.1676	900	12512	2.6770	156	823	0.0151	149	2872
2018	0.6362	709	8051	1.1295	165	617	0.4950	200	1836
2019	0.2578	496	4742	3.3382	167	963	0.0065	206	2557
2020	0.2352	338	2317	3.9784	196	977	0.0089	127	1222
2021	0.2073	348	3844	4.9115	162	618	0.0144	153	1633

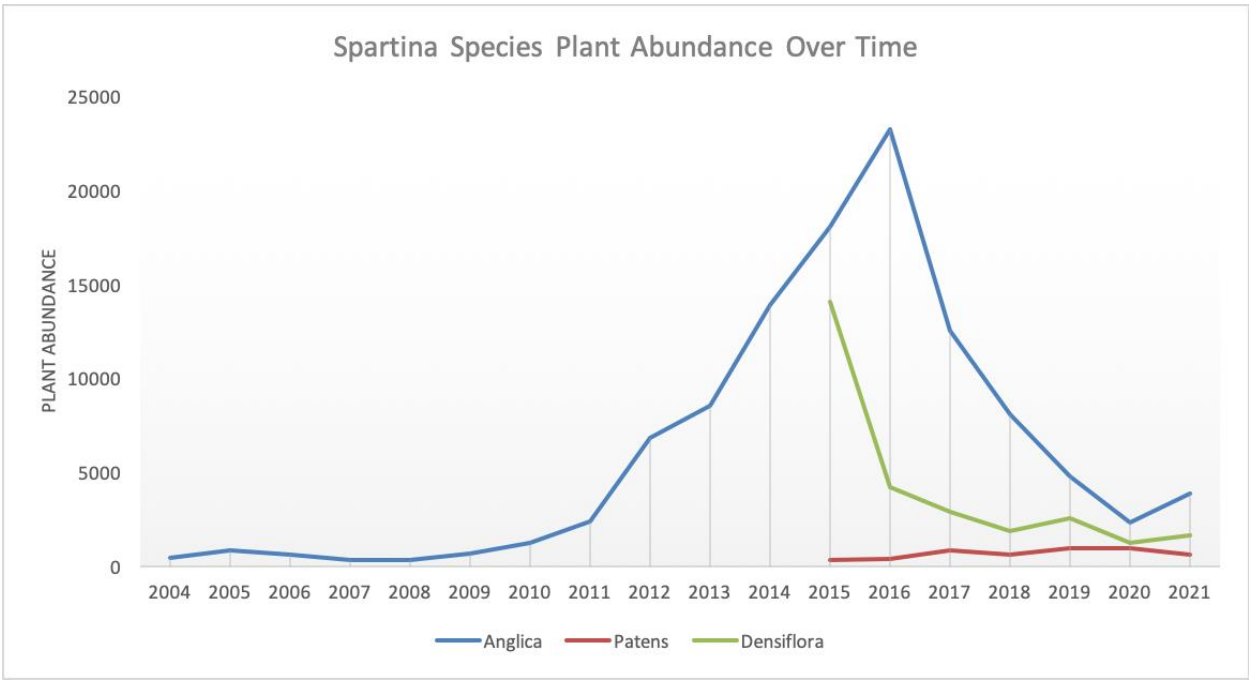
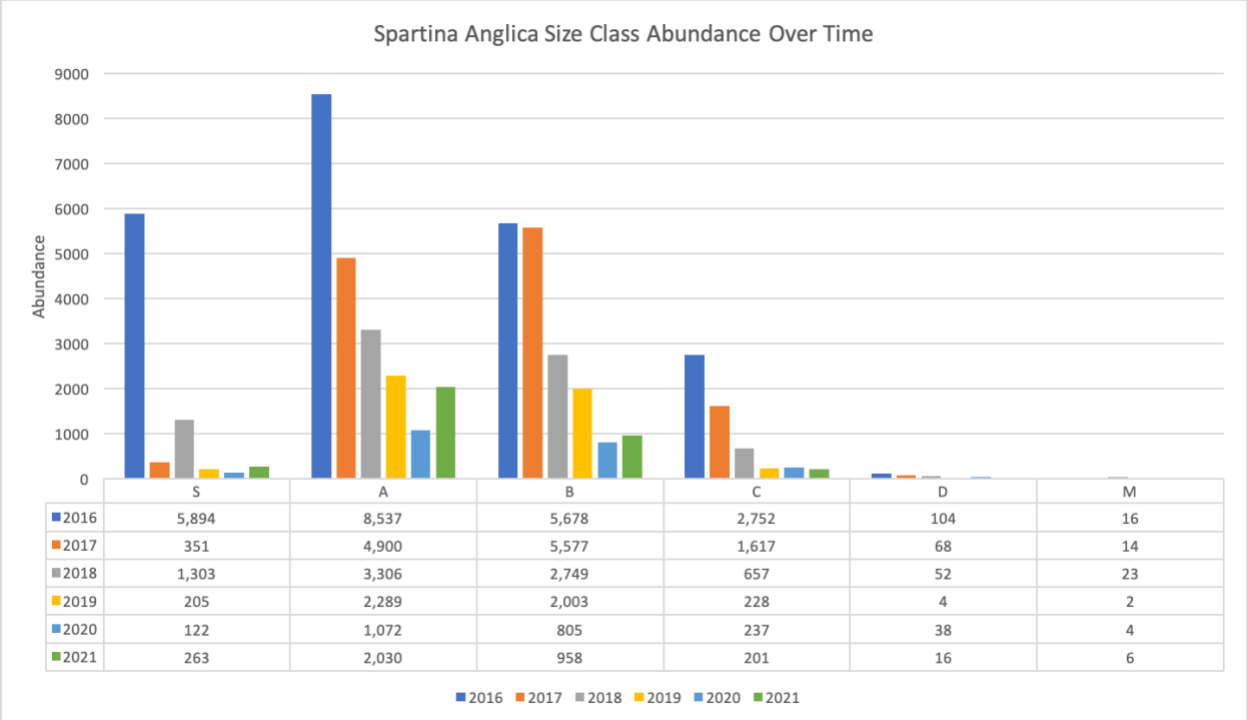


Figure 15. Plant abundance of Spartina spp. from 2004 - 2021.



	S	A	B	C	D	M
2016	5,894	8,537	5,678	2,752	104	16
2017	351	4,900	5,577	1,617	68	14
2018	1,303	3,306	2,749	657	52	23
2019	205	2,289	2,003	228	4	2
2020	122	1,072	805	237	38	4
2021	263	2,030	958	201	16	6

Figure 16. Abundance of S. anglica between 2016-2021 broken up by size class.

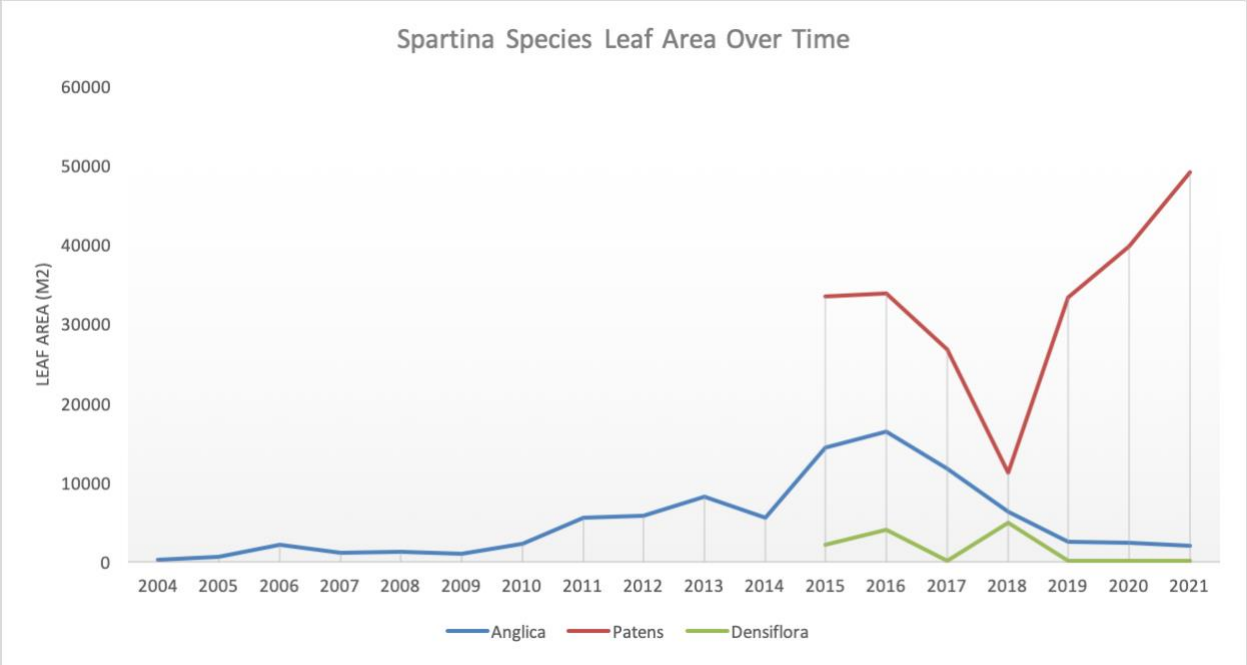


Figure 17. Estimated leaf area of Spartina spp. from 2004 - 2021.

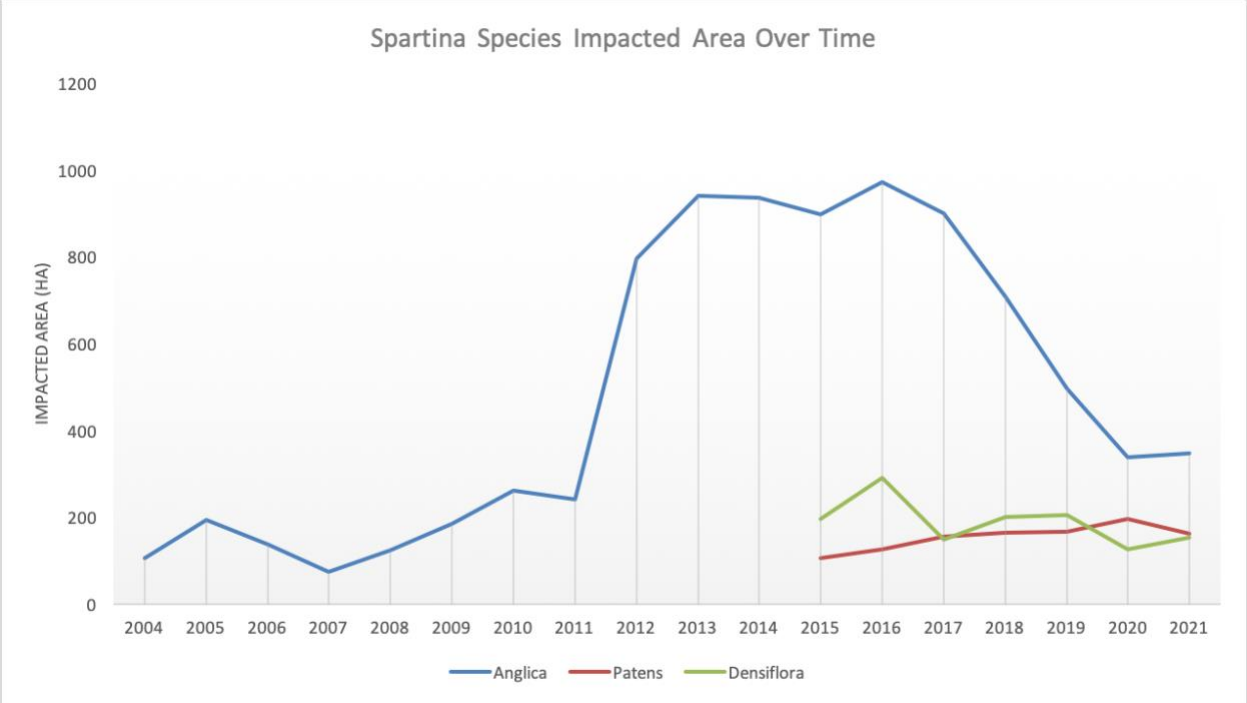


Figure 18. Amount of shoreline impacted by Spartina spp. from 2004 - 2021.

RESTORATION

Control and eradication efforts to date on *S. anglica* and *S. densiflora* have been successful without requiring additional restoration efforts. However, *S. patens* requires additional restoration beyond controlling for the invasive species. *S. anglica* and *S. densiflora* invade mudflats and areas of shoreline that typically has limited plant abundance

and diversity. Where *S. anglica* and *S. densiflora* occur within native vegetation, it is typically in clusters surrounded by native vegetation that rapidly re-establishes after Spartina treatments. *S. patens* tends to invade the high salt marsh where there is a much higher diversity and abundance of native plants. Planting of native species speeds up marsh restoration and prevents re-invasion. The large, barren areas that are left behind following the removal of these meadows are at risk of reinvasion by *S. patens* or another invasive plant species. By planting native species in these now-barren patches, the resilience of these habitats increases and the ability for invasive species to monopolize again is reduced. Considering this, the BC SWG is working with the City of Port Moody to test the planting of nursery *Carex lyngbyei* in areas where *S. patens* meadows have been removed. *Carex lyngbyei* is a dominant species that thrives at low- to middle-elevation tidal zones, which include high marsh elevations where *S. patens* grows. *Carex lyngbyei* was planted at the end of the 2018 program year. Goose grazing is a known pressure on marsh plants and particularly marsh restoration plantings, as such goose ex-closure fencing was installed to minimize these pressures. Regular monitoring and maintenance was conducted throughout 2018 to ensure the goose ex-closure fence remained intact and the plantings took root.

Discussions with the Wild Bird Trust, the Port of Vancouver and Tsleil-Waututh Nation continued in 2021 regarding the treatment of *S. patens* at Maplewood Flats and restoration of this salt marsh. As a part of these discussions some native plant seed from the marsh at Maplewood Flats was collected and propagated at the Wild Bird Trust nursery on site. Additionally, a short proposal has been drafted for a graduate student project; the proposal is targeted for the British Columbia Institute of Technology – Simon Fraser University Master of Science -Ecological Restoration Stream.

The Tsleil-Waututh Nation is reviewing the Burrard Inlet Spartina action plan which will include suggestions for replanting efforts incorporating Traditional Ecological knowledge.This updated action plan will serve to direct restoration efforts in areas where Spartina has significantly altered the ecology of the environment.

OUTREACH

INFORMATION AND INTERNET RESOURCES

- A new website which houses the Spartina Web Atlas has been published. The website provides information on the Spartina eradication program and houses the historical distribution of Spartina spp. in BC: www.spartina.ca This website will house all of the data collected throughout the lifetime of the project by the end of 2021.
- The Friends of Semiahmoo Bay Society uses their web site for volunteer call out, information, and partner links: http://www.birdsonthebay.ca/
- Corporation of Delta website: http://www.delta.ca/environment-sustainability/plants-wildlife/invasive-plants
- *City of Port Moody* website: http://www.portmoody.ca/index.aspx?page=1260#Saltmeadow Cordgrass (*S. patens*)
- Coastal Invasive Species Committee website: http://www.coastalisc.com/priority-invasive-plants

FINANCES

The Spartina Eradication Program has generated $3,460,000 of direct cash funding since it's creation in 2004 with an additional $1,400,000 of In-Kind contributions to the program. $1,800,000 of this funding has been provided by the province of BC through the Ministries of Environment, FLNRORD, and Agriculture over the life of the program.

The total program revenue in 2021 was approximately $460,000 through various donors (Table 6). In total $400,000 cash was raised for the Spartina Eradication Program directly through DUC, all of this was applied to eradicating *Spartina* spp. in BC.

For a breakdown of the revenue and expenditures for the SEP for 2020, see Table 6 and Table 7. The recent history of financial contributions (cash and in-kind) of the BC Spartina Working Group is found in Figure 18. The in-kind contributions were provided by the following agencies:

- BC Conservation Foundation
- BC Ministry of Environment
- BC Ministry of Forests, Lands and Natural Resource Operations
- City of Surrey – ShaRP & SNAP Programs
- Vancouver Island Conservation Land Management Program
- Corporation of Delta
- Environment Canada- Canadian Wildlife Service
- Friends of Semiahmoo Bay Society
- K'omoks First Nation
- Port of Vancouver
- City of Port Moody

Table 6. Total revenue from all funders towards the Spartina eradication program in 2021.

Revenue		
Source	**Through DUC**	**Through BC SWG Member**
Province of BC	$300,000	-
Port Metro Vancouver	$15,000	-
Government of Canada -Coastal Restoration Fund	$31,776	-
Habitat Conservation Trust Fund	$50,000	
Government of Canada – Canada Summer Jobs	-	$49,403
Subtotal	$396,776	$49,403

Grand Total	**$446,179**

*Money contributed by the Government of Canada through the Coastal Restoration Fund went towards staff time associated with managing field crews, reporting, and GIS analysis

Table 7. Expenditures related to the Spartina eradication program in 2021.

Expenditures		
Category	**Mainland BC**	**Vancouver Island & Gulf Islands**
Travel	$8,358	$4,642
Gas, Mileage, Truck Rental	$11,058	$786
Personnel - Contractors	$103,687	$33,965
Personnel - Staff	$109,524	$24,435
Small tools, Supplies etc.…	$6,200	$12,243
Administration/Overhead	$16,750	$16750
Subtotal	$239,827	$77,072
Total	**$348,398**	

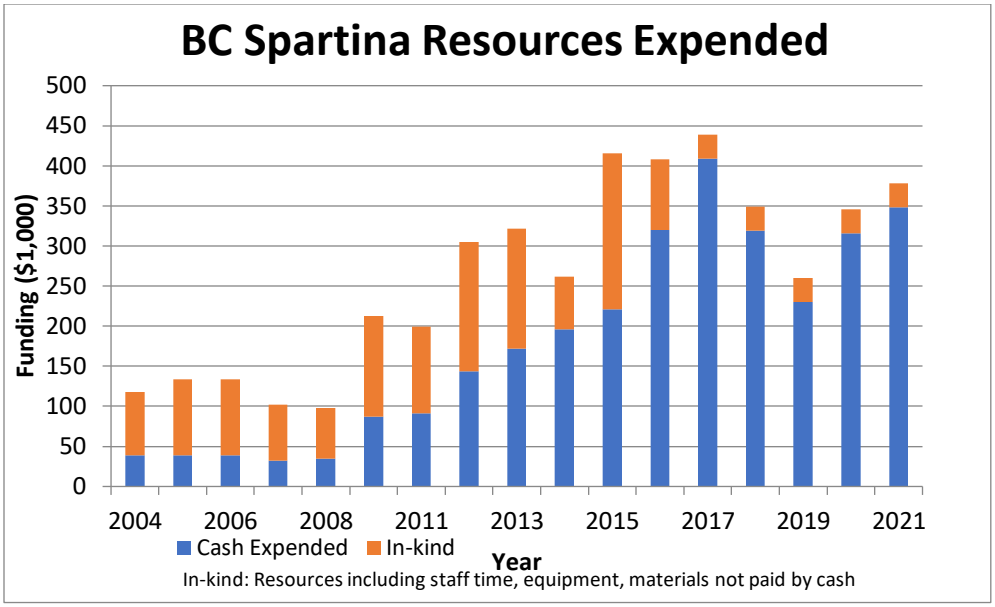


Figure 19. Funding history of the Spartina eradication program comparing In-kind donations to total cash expenditures each year since 2004.

RECOMMENDATIONS FOR 2022

COORDINATION

- Ensure reporting is up to date and on time. Set hard deadlines for reporting one month prior to report due date to ensure enough time to review.
- Resume annual planning meetings. Instead of one planning meeting, host two planning meetings-one for each region.

MONITORING

- Continue to inventory core areas for Spartina species to evaluate control effort success.
- Consider including some metric of distribution/density as an additional evaluation lens for the program to adhere to the IAPP database reporting template.
- Ensure summer crews reach the full extent of previous years efforts in surveying before moving to new areas
- Survey core areas twice before treatment and once before conducting a second pass.

TREATMENTS

- Apply herbicide twice over two passes to decrease chances of missing plants.
- Expand herbicide treatment on *S. patens* in Baynes' Sound to the extent feasible without compromising any progress made on *S. anglica* eradication made to date. Identify opportunities to improve herbicide treatment program delivery efficiency between regions given limited treatment season and treatment condition windows (tides and weather).
- Contract two herbicide applicator team, one for each region, to improve coverage of treatment throughout the season.

- Treat all documented *S. patens* at Maplewood Conservation Area and focus on restoration plans for the site. Treat all remaining *S. patens* in Burrard Inlet.
- Work with Tsawwassen, K'omoks, and Tsleil-Waututh First Nations to treat Spartina spp.

SCIENCE AND EVALUATION

- Complete an assessment on herbicide treatment efficacy. Include measures to detect any signs of resistance.
- Test aerial detection techniques with new techniques such as remote-controlled, electric, unmanned aerial vehicles (UAVs). These activities would be used to detect large clones and large meadows of *S. patens* in particular.

RESTORATION

- Continue to assess the establishment of *Carex lyngbyei* restoration plantings in Port Moody Arm and monitor for reinvasion of *S. patens*.
- Work with BCIT Ecological Restoration Program to develop marsh restoration plans for *S. patens* in the Mapplewood Flats conservation area.

CONCLUSION

The continued effort towards eradication of *S. anglica* in 2021 proved successful with the continued use of herbicide as well as the use of *Collector* and *Survey123* for inventory and data collection purposes. Plant numbers continue to decline and the area that they impacts is also in decline. The highest levels of infestation for Spartina anglica were observed in 2016. Since then, we have reduced the population of Spartina anglica in the lower mainland by 90%. While Spartina anglica remains the top priority for the eradication program, the decline in infestation will allow the working group to expand monitoring and control efforts to the two other Spartina spp. in BC that pose significant threats to the sensitive ecosystems of the areas they infest.

In 2021, increased mapping efforts in Baynes' Sound improved confidence in the BC SWG records of *Spartina* spp. locations and abundance. However, more years of complete surveys are required to more confidently detect trends. Baynes' Sound requires more resources for inventory and increasing control efforts; in particular herbicide treatment of *S. patens* will be the only effective means towards eradication, requiring adequate coverage of the infestation. Achieving full coverage of the S. patens population is necessary to restore these high marsh coastal ecosystems to their natural state. Achieving adequate coverage of the S. patens infestation within the Baynes sound area will be a primary goal for the Spartina eradication program in 2022.

The *S. densiflora* population in Baynes' Sound should continue to be inventoried and our progress towards eradication should be evaluated. If manual control efforts fail in continuing to suppress the population towards eradication, herbicide treatment may be required in the future. For the 2022 season, emphasis will be put on inventorying and removing all S. densiflora individuals before they can go to seed in the fall.

The Spartina eradication program has continually evolved its methods to match the changes in technology and best practices since the start of the program. The program has seen massive strides towards eradication of Spartina spp. in BC since 2016. With more years of intense pressure, we can continue to significantly reduce the presence of Spartina spp. in BC and eventually move into the monitoring stage until we can declare Spartina spp. as eradicated from our sites. The BC SWG will continue with its partnership approach in striving to protect BC's shores and eradicate invasive Spartina.

APPENDIX A – METRIC & SUMMARY CALCULATIONS

The point data for each species of Spartina is collated into a spatial database for subsequent analysis using three different metrics:

1. The number of plants or plant clones detected
2. The size of each plant or plant clone (single plant or seedling; patch with diameter less than 30 cm; patch with diameter of 30 cm to 1 m; patch with diameter of 1 m to 5 m; patch with diameter of approximately 5 m; patch with diameter greater than 5 m)
3. The estimated leaf area (number of plants or plant clones detected x size of each plant or plant clone = number of square meters a dispersed colony would occupy if all Spartina plants were grouped into a single cluster)

Each IAPP site is divided into a grid of 1 ha cells which is used to summarize the data that has been analyzed through the metrics above. These summaries occur at a single cell level as well as an accumulation of all the cells within the site. They are titled Cell Summaries and Site Summaries, respectively. Summaries occur on a per-species basis. Moreover, with these summaries, the BC SWG determines how much shoreline has been impacted by *Spartina* spp. (how many 1 ha grid cells had one or more occurrences of Spartina).

Cell Summaries: The total number of observations for each size class is calculated for each cell on a per species basis. The estimated leaf area of a species in a cell is calculated by multiplying the total number of observations for each size class by the size class's Areal Coefficient (Table 7) and summing the values for each size class.

Site Summaries: The summing of the metrics of all of the cells within an IAPP site.

Table 8. Size Classes and their Areal Coefficients

Size Class	Description	Areal Coefficient (m^2)
S	Single Plant or Seedling	0.002
A	Patch with diameter less than 30 cm	0.071
B	Patch with diameter of 30 cm to 1 m	0.785
C	Patch with diameter of 1 m to 5 m	3.14
D	Patch with diameter of approximately 5 m	19.625
M	Patch with diameter greater than 5 m	38.465

The resulting equation for the estimated leaf area of a Spartina species in a cell is:

Estimated Leaf Area =(**Σ**S*0.002)+(**Σ**A*0.071)+(**Σ**B* 0.785)+(**Σ**C*3.14)+(**Σ**D* 19.625)+(**Σ**M*38.465)

For example, a cell with multiple *S. anglica* observations of 10 seedlings (Size S), 3 patches of a diameter of 30 cm to 1 m (Size A), 5 patches with a diameter of 1 m to 5 m) Size C, and 1 patch greater than 5 m (Size M) would have an area of $54.398\ m^2$.

Area = (10*0.002 m^2)+(3*0.071 m^2)+(5*3.14 m^2)+(1*38.465 m^2)

$$\text{Area} = 0.020\ m^2 + 0.213\ m^2 + 15.7\ m^2 + 38.465\ m^2$$

$$\text{Area} = 54.398\ m^2$$

Appendix B – DATA INTEGRITY OVER TIME

The methods of collecting, analyzing, and reporting of Spartina data has changed significantly since the start of the program. The method of calculating leaf area, as described in Appendix A, was first introduced in the 2015 season and several IAPP sites were standardized between 2011-2013. We are now at a stage where our methods of collection, analysis, and reporting are consistent between years. As such, references made to previous years' data, regarding infested area, should be taken from the most recent Spartina report or from the online Spartina web-atlas.