Report on 2022 Crescent Lake Aquatic Invasive Species Management Monitoring

(Oneida County, Wisconsin)

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Submitted to

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And

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Contacts: Scott Van Egeren

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Introduction

We begin with the premise that aquatic plants are crucial to the health of inland lakes, they form the basis of habitat and food for many aquatic organisms including fish. Occasionally, the balance of a native plant community is disturbed by a non-native invader. This often causes alarm, but in our earnest desire to control the invasive species, we have to be mindful of the health of the entire native plant community.

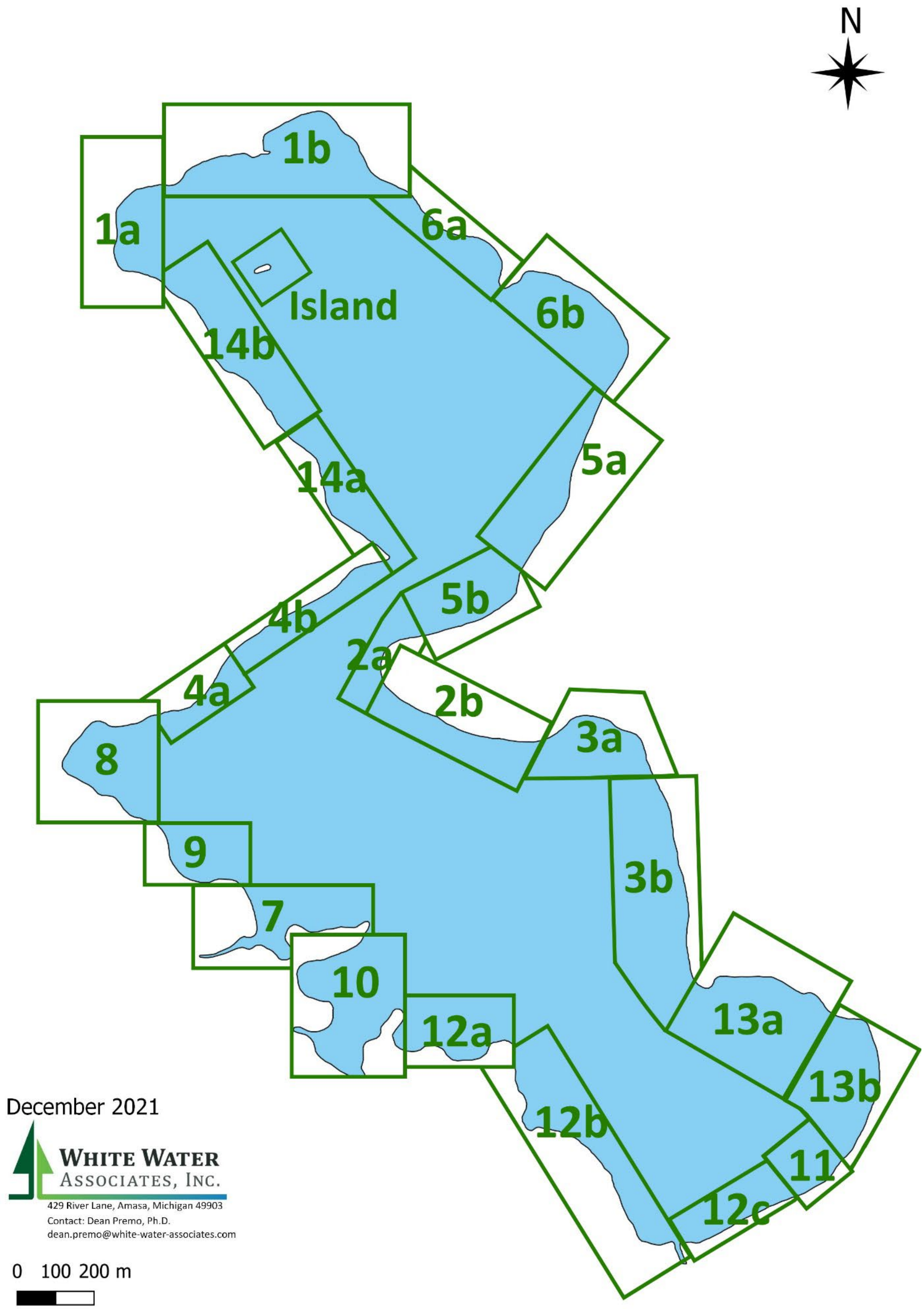
The ultimate goal of our work in 2022 was to monitor the outcomes of chemical treatment and manual treatment on the target species (*Myriophyllum spicatum*, Eurasian watermilfoil, EWM) and the entire aquatic plant community of Crescent Lake. In this report, we will present (1) the aquatic plant monitoring history and geography of the treatments, (2) the distribution of the EWM and the native aquatic plant species monitored in 2022 and then (3) compare the data. The only tool used in 2022 for monitoring EWM treatments is the point-intercept aquatic plant survey protocol developed by the Wisconsin DNR. In order to convey the findings to the plant managers and decision-makers we have produced the maps, histograms and tables contained in this report. We have organized all of the exhibits from the fine scale (looking at EWM) to the coarse scale (considering the entire aquatic plant community). We end the report with a few concluding statements and recommendations.

Lake presentation: history of treatments and polygon naming system

Since 2019, the Eurasian watermilfoil (EWM) in Crescent Lake has been the subject of chemical and manual treatment in specific areas. In addition, aquatic plant monitoring has tracked the outcomes of the treatments. Specific areas (polygons) that have received management have been given names over the years, however, nomenclature has not always been consistent from one year to the next (see Table in Appendix). In 2021, the names of the polygons were standardized for the entire shore line of the lake combining the historic names with newly named areas.

EWM treatment history

	Point-Intercept grid Yes/No	2019	2020	2021	2022
Polygon 1a	Yes	Chemical treatment	No treatment	No treatment	Manual treatment
Polygon 1b	Yes	Chemical treatment	No treatment	No treatment	Manual treatment
Polygon 2	No	No treatment	No treatment	Manual treatment	No treatment
Polygon 3a	Yes	Manual treatment	Chemical treatment	No treatment	No treatment
Polygon 3b	Yes	No treatment	No treatment	No treatment	No treatment
Polygon 4	No	No treatment	No treatment	No treatment	No treatment
Polygon 5a	Yes	Manual treatment	No treatment	Chemical treatment	No treatment
Polygon 5b	Yes	Manual treatment	No treatment	Chemical treatment	No treatment
Polygon 6a	No	No treatment	No treatment	Manual treatment	No treatment
Polygon 6b	Yes	Manual treatment	No treatment	No treatment	No treatment
Polygon 7	Yes	No treatment	No treatment	No treatment	No treatment
Polygon 8	Yes	Manual treatment	No treatment	No treatment	Chemical treatment
Polygon 9	Yes	Manual treatment	Chemical treatment	No treatment	Manual treatment
Polygon 10	Yes	Manual treatment	Manual treatment	Manual treatment	Chemical treatment
Polygon 11	Yes	Manual treatment	Manual treatment	Manual treatment	Chemical treatment
Polygon 12a	Yes	No treatment	Manual treatment	Manual treatment	Chemical treatment
Polygon 12b	No	Manual treatment	Manual treatment	Manual treatment	No treatment
Polygon 12c	Yes	No treatment	Manual treatment	No treatment	Chemical treatment
Polygon 13a	Yes	Manual treatment	Manual treatment	Manual treatment	Chemical treatment
Polygon 13b	Yes	Manual treatment	Manual treatment	Manual treatment	Chemical treatment
Polygon 14a	Yes	No treatment	No treatment	No treatment	No treatment
Polygon 14b	No	No treatment	No treatment	No treatment	No treatment
Island	Yes	Manual treatment	No treatment	Manual treatment	Manual treatment



Polygon names and distribution

History of EWM distribution and rake fullness by polygons

Point-Intercept (PI) monitoring allows us to create maps that show the spatial distribution of EWM over time for each of the surveyed polygons. The maps also show the amount of EWM at individual points by using a rake fulness rating. Rake fullness is a rating given to each rake pull on a PI survey that indicates the amount of EWM plant material. There are four ranks: 0 (not present), 1, 2, and 3 (a 3 represents the highest value of plant material on the rake). The maps also show the distribution of points samples for each of the sub-PI areas and “visual” (EWM observed but not actually collected with the rake within 6 feet of the sampling points).

In 2022 PI monitoring survey, EWM was sampled and observed only in Polygon 1 (1a+1b).

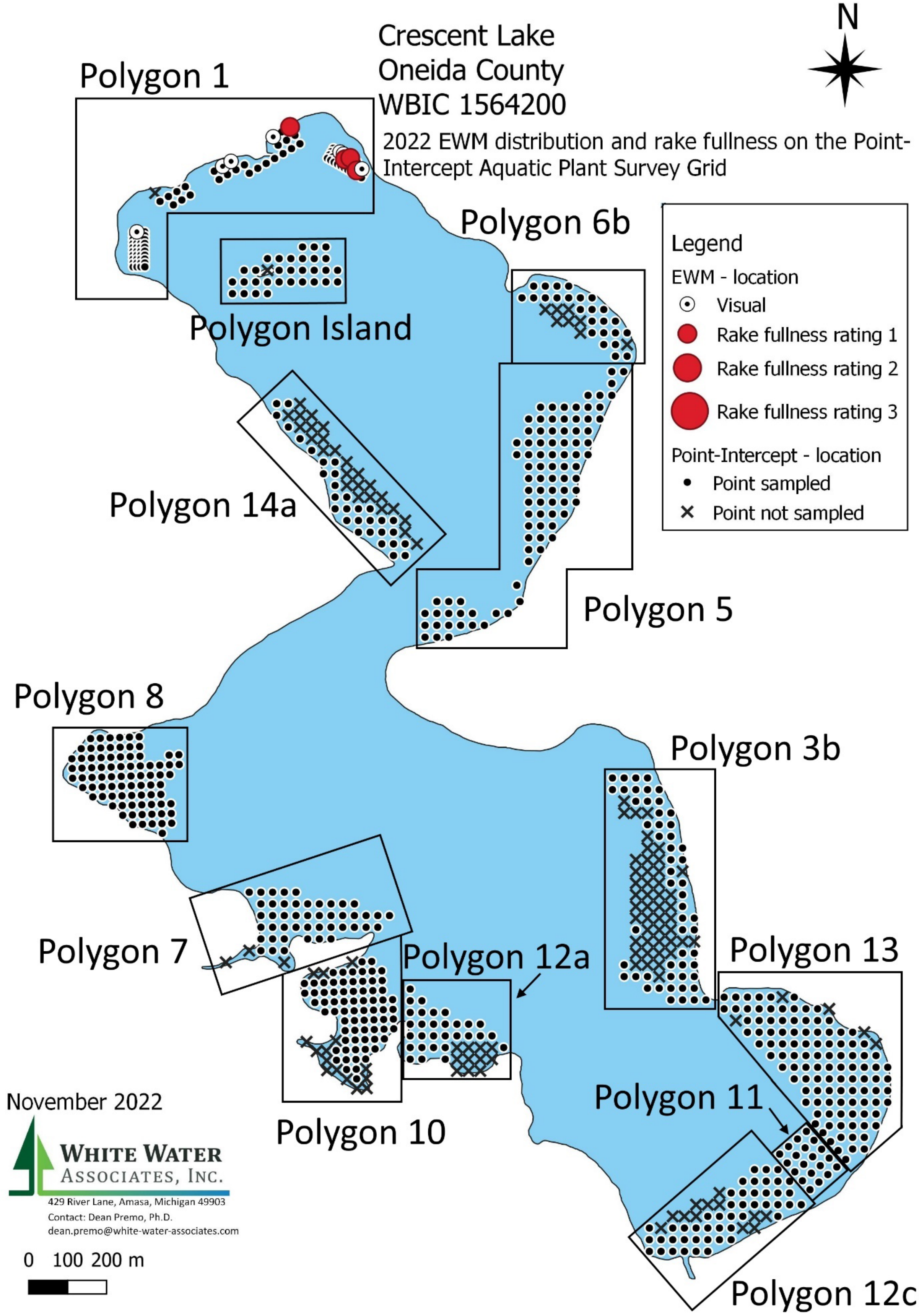
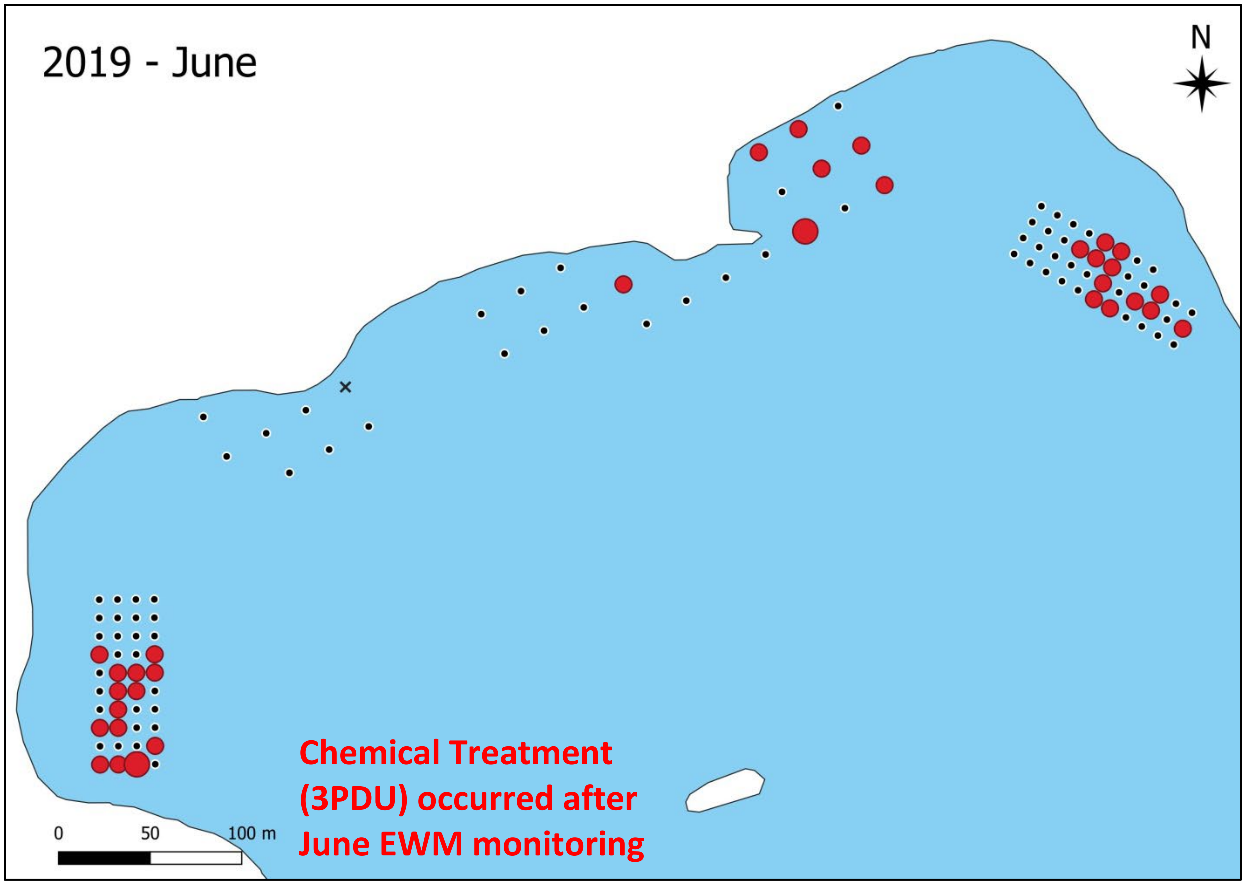
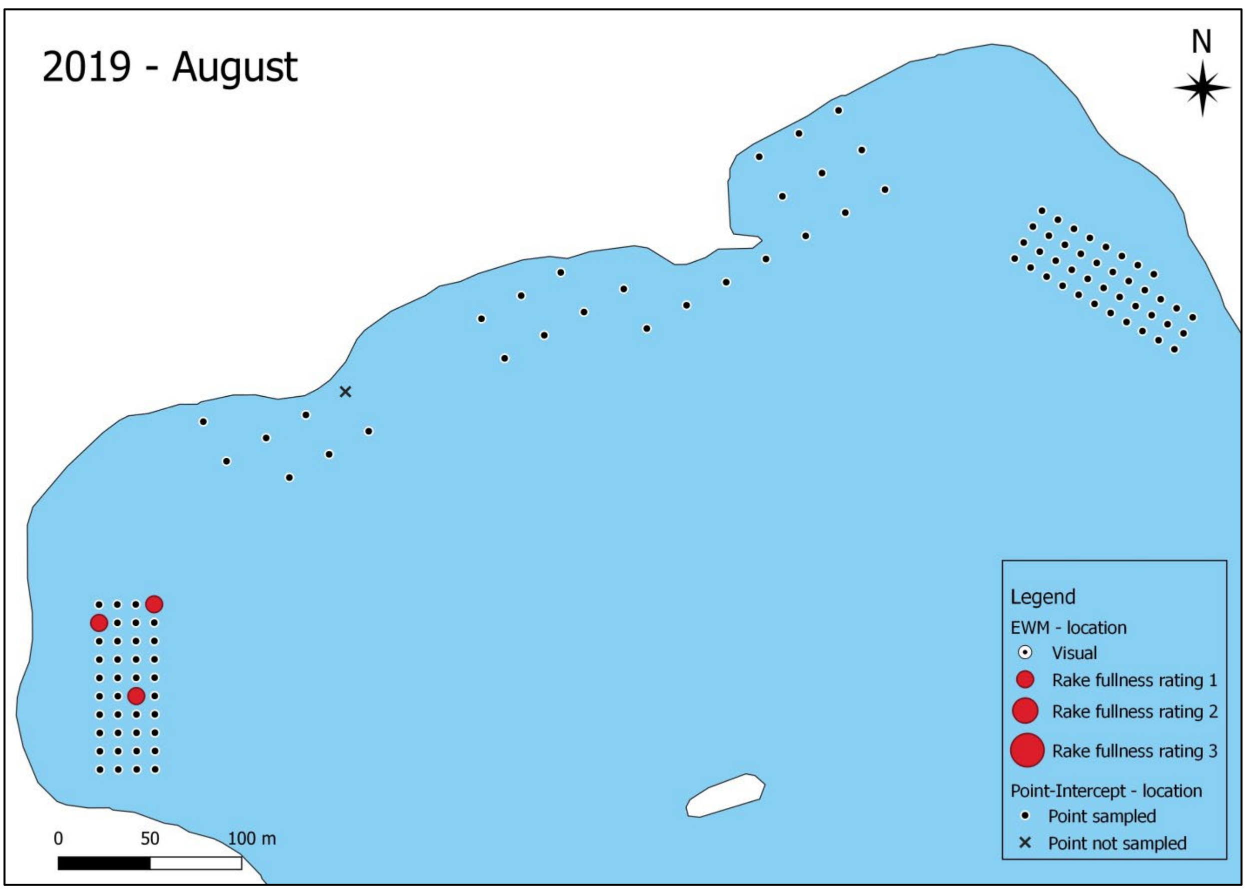


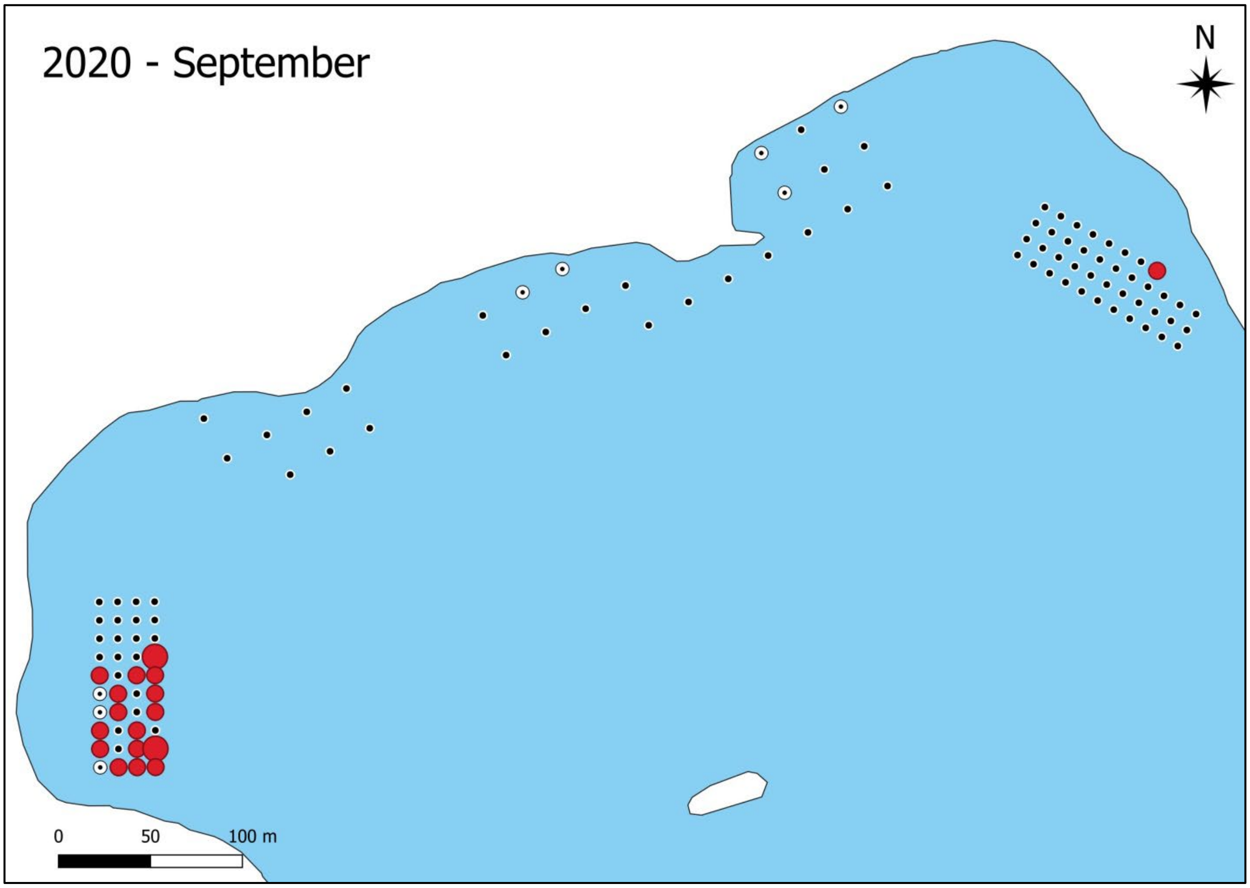
Figure 1. 2022 EWM distribution and rake fullness on the PI monitoring survey

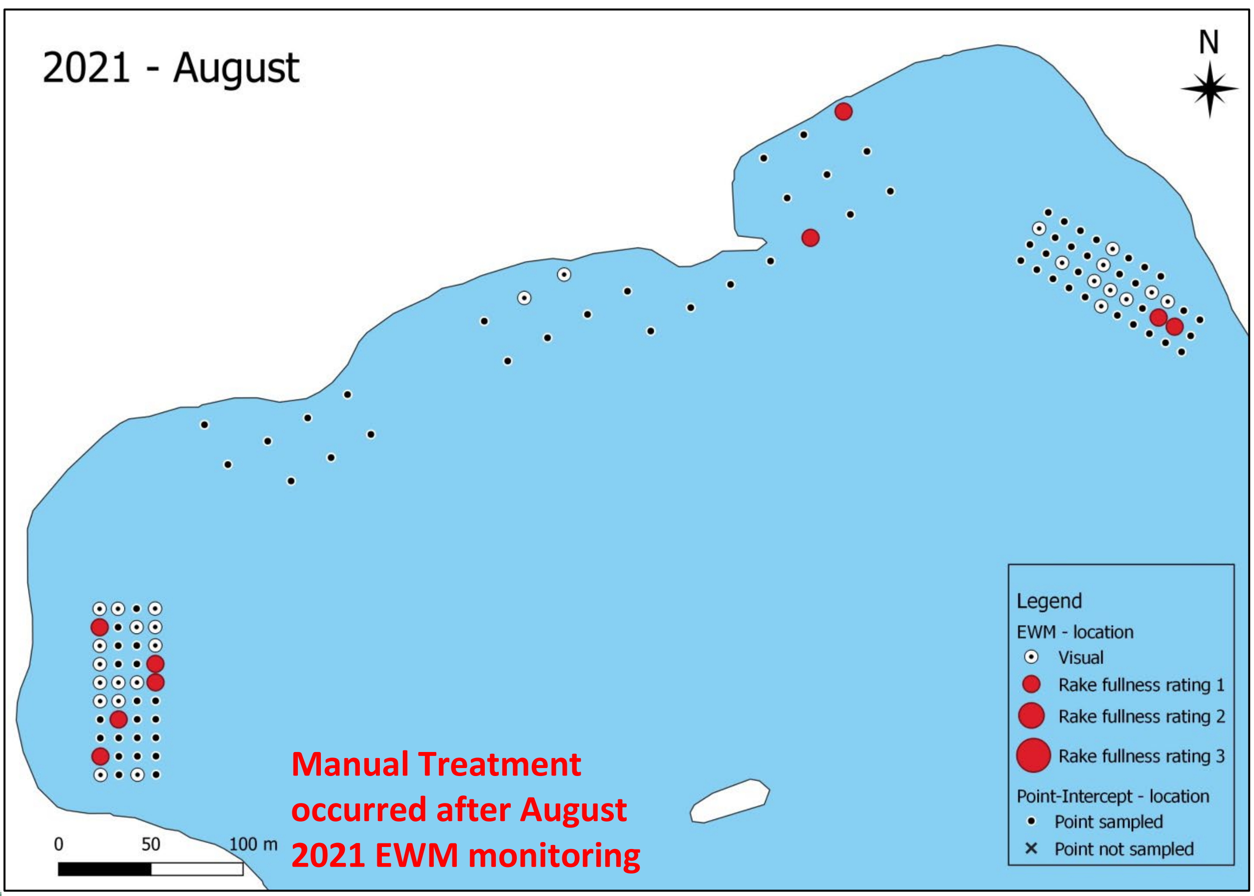
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 1



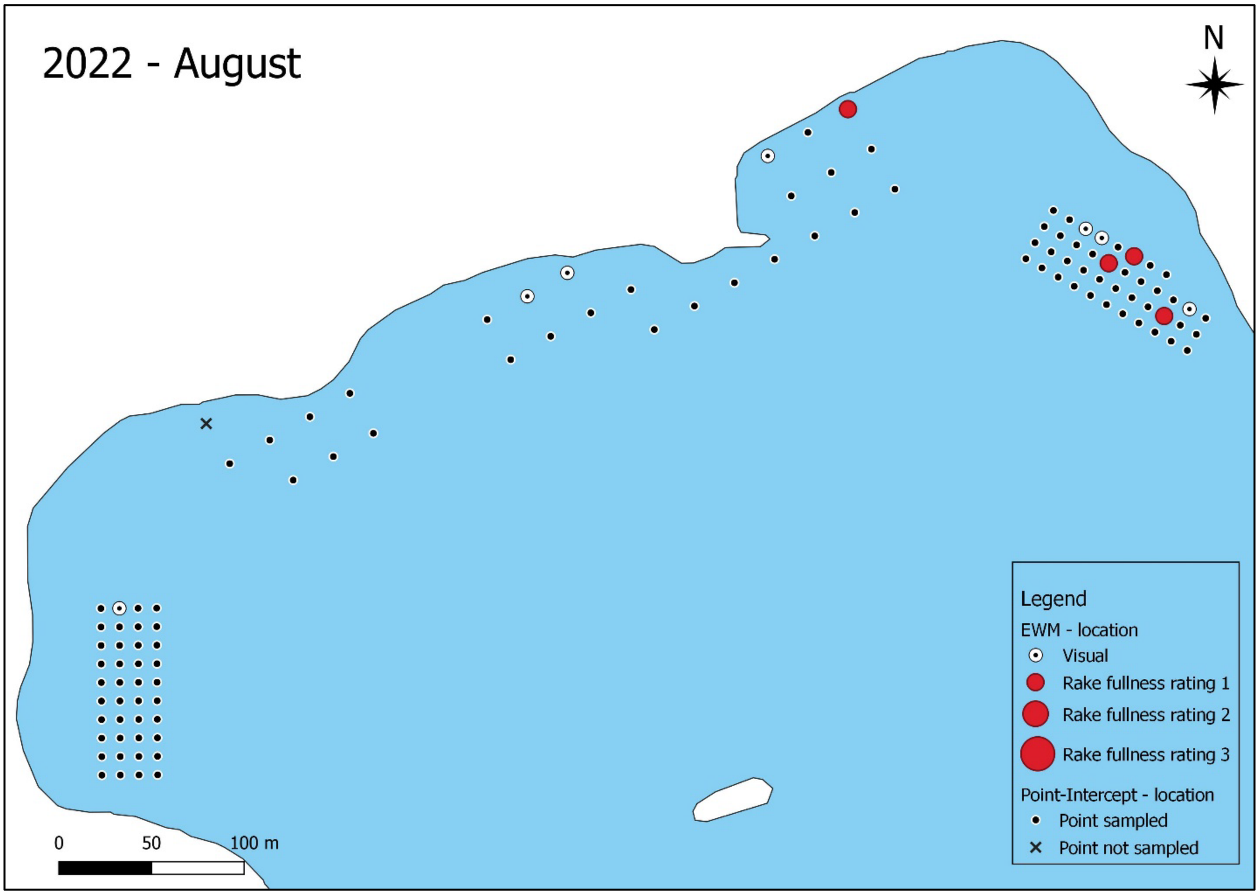


History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 1

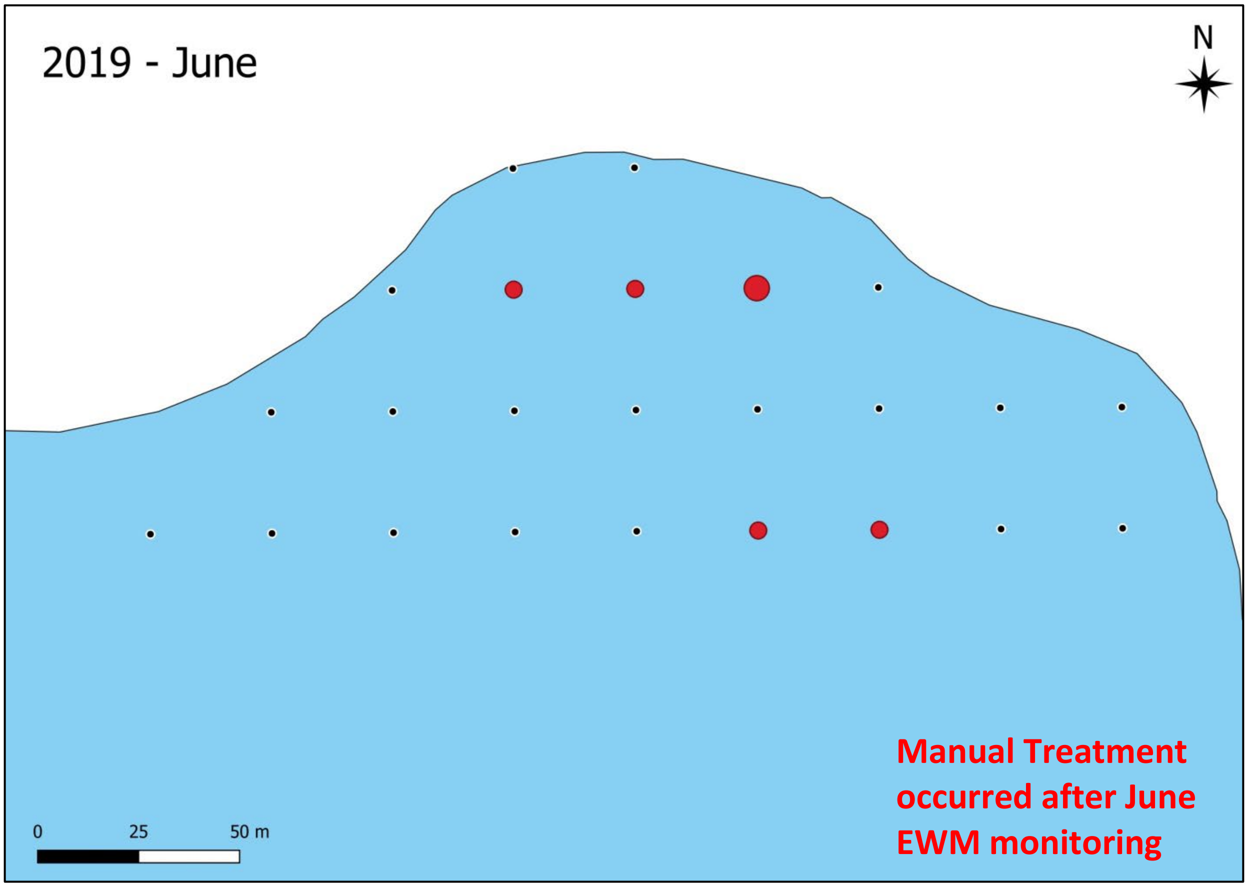


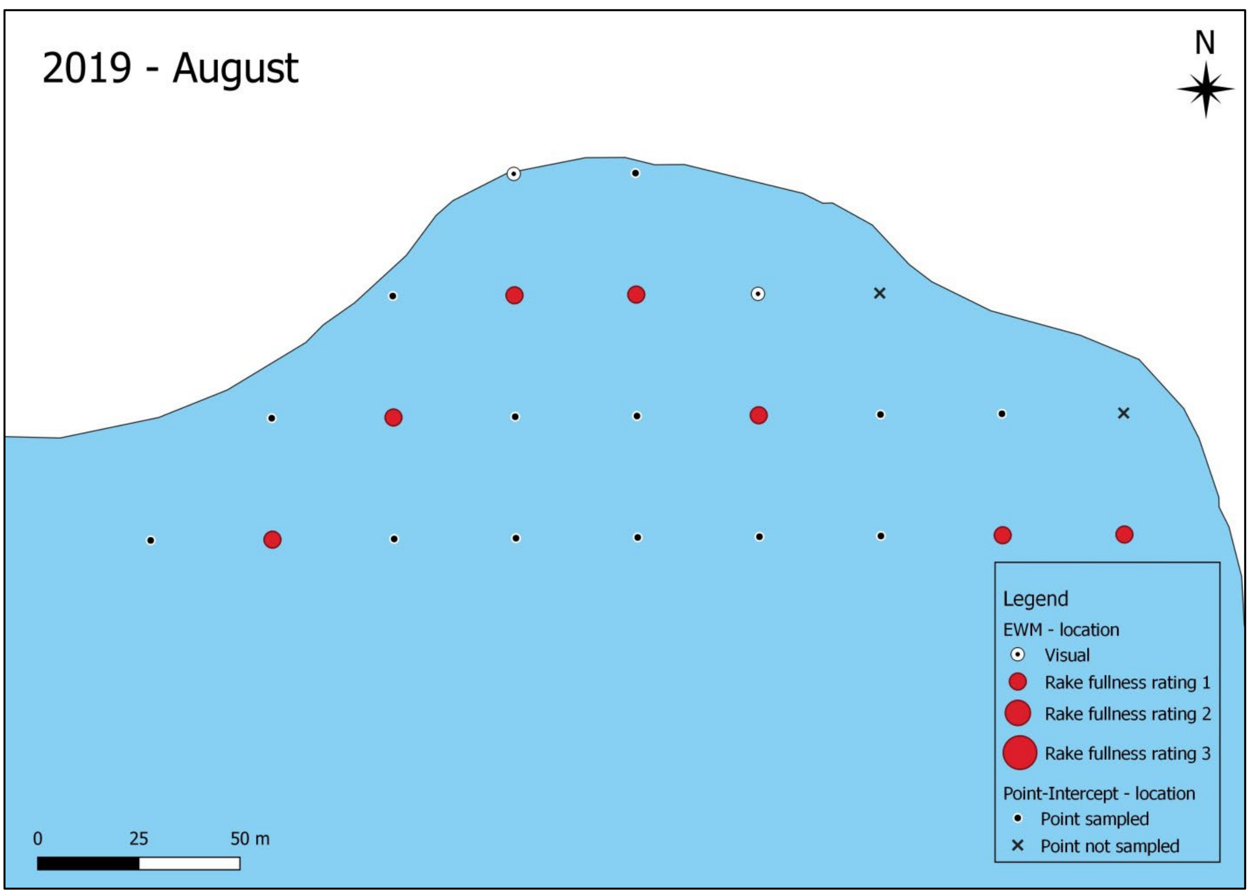


History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 1

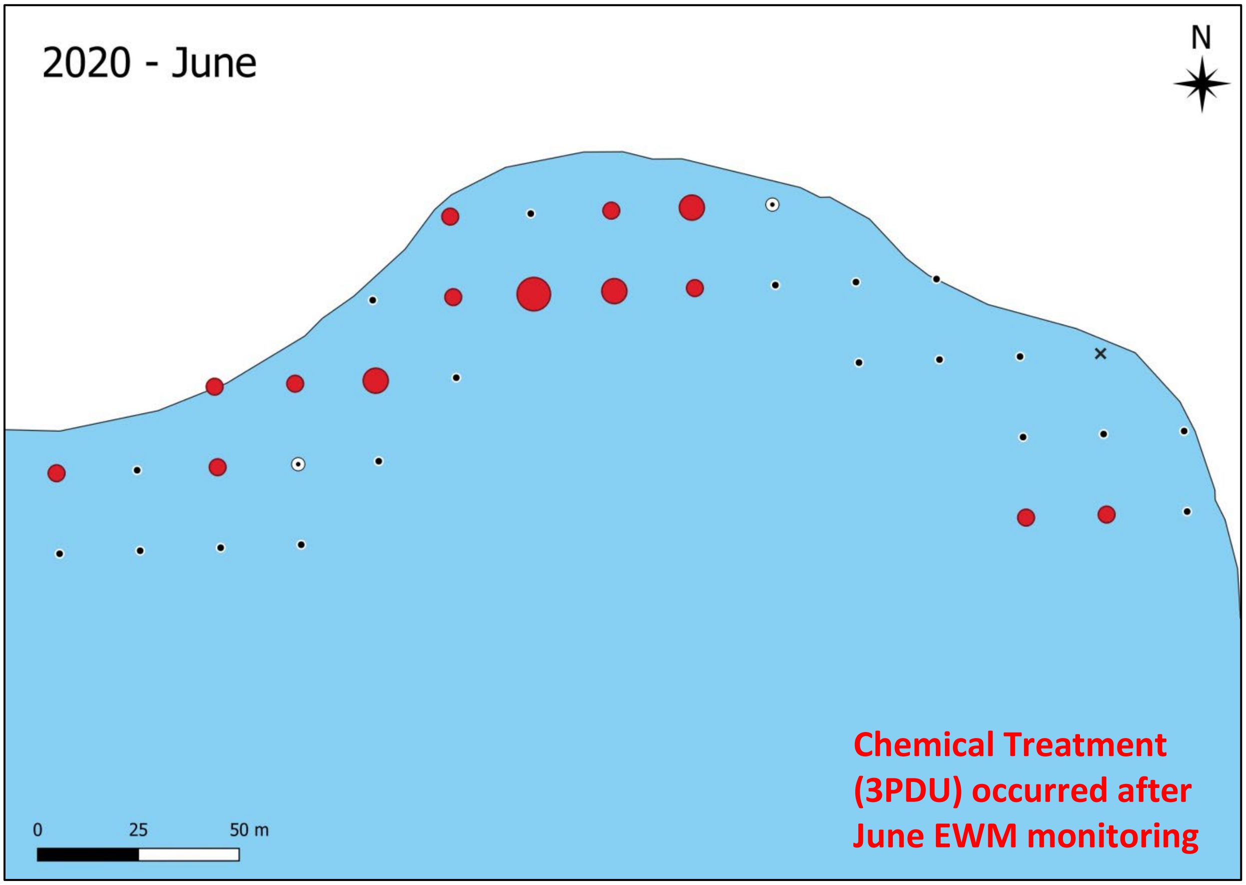


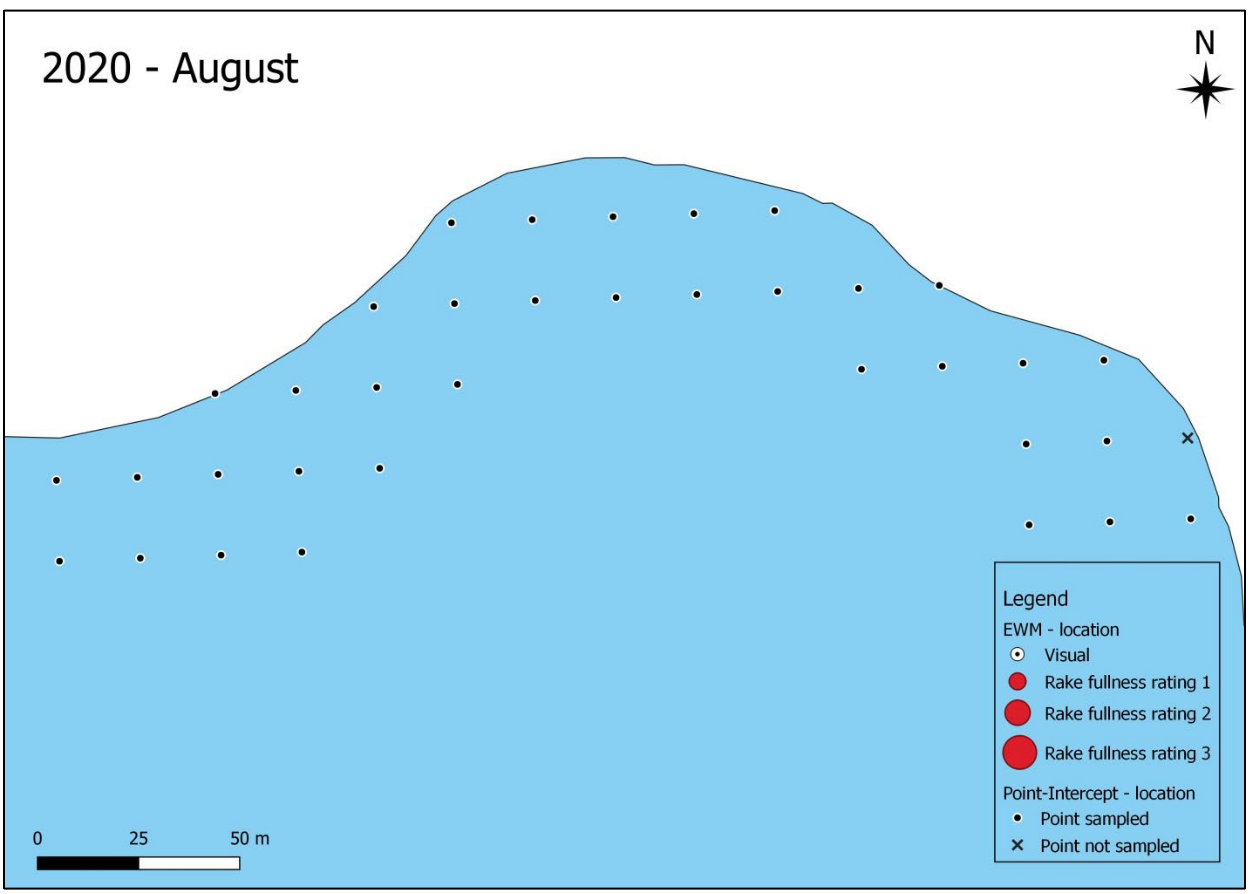
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 3a



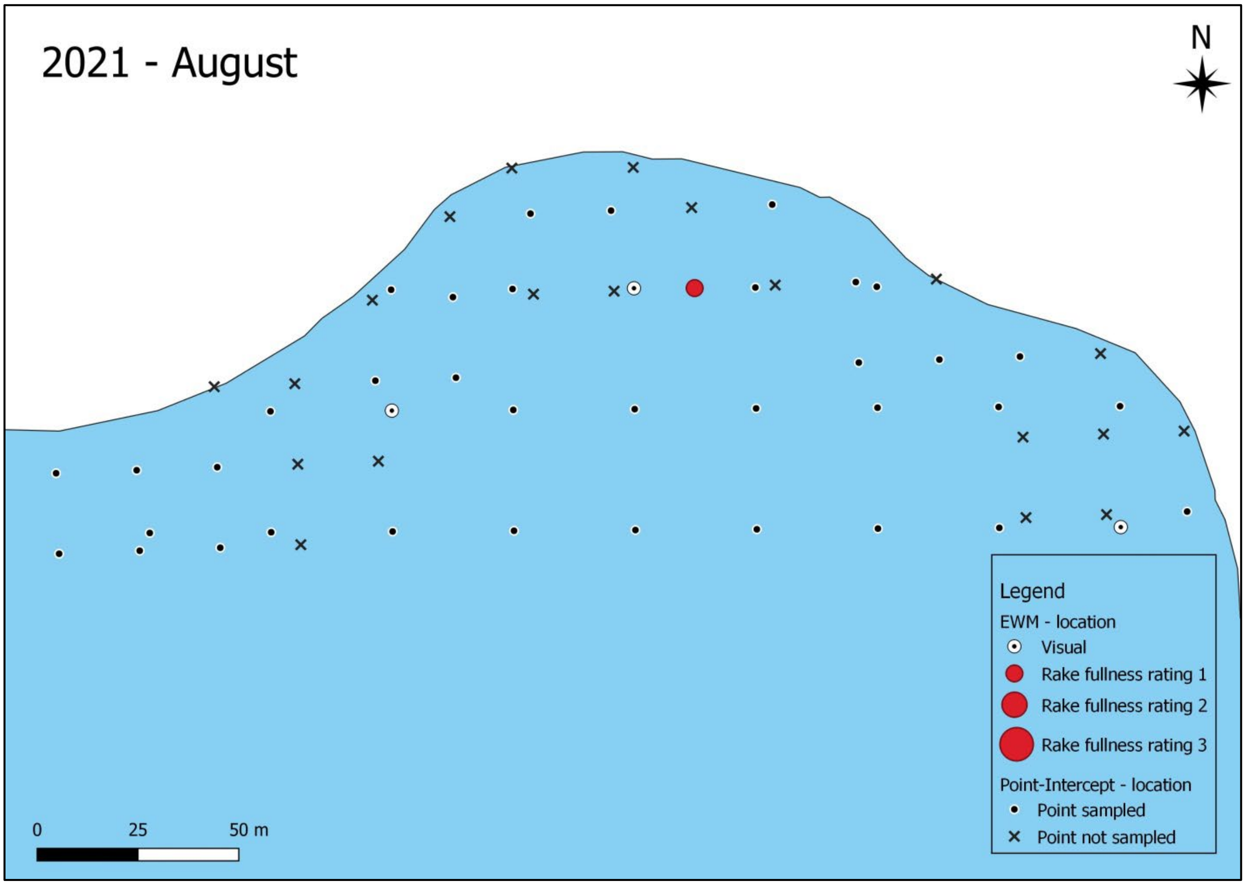


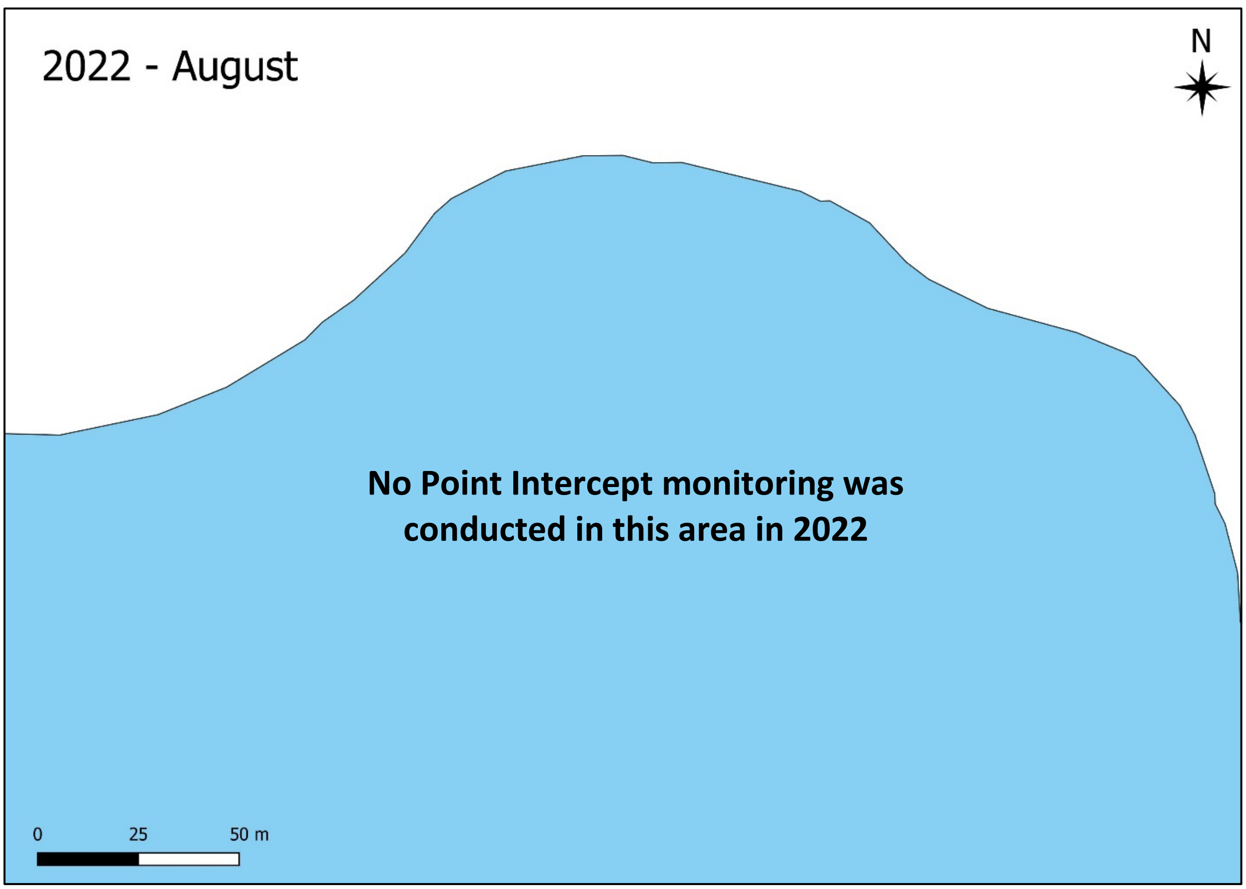
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 3a



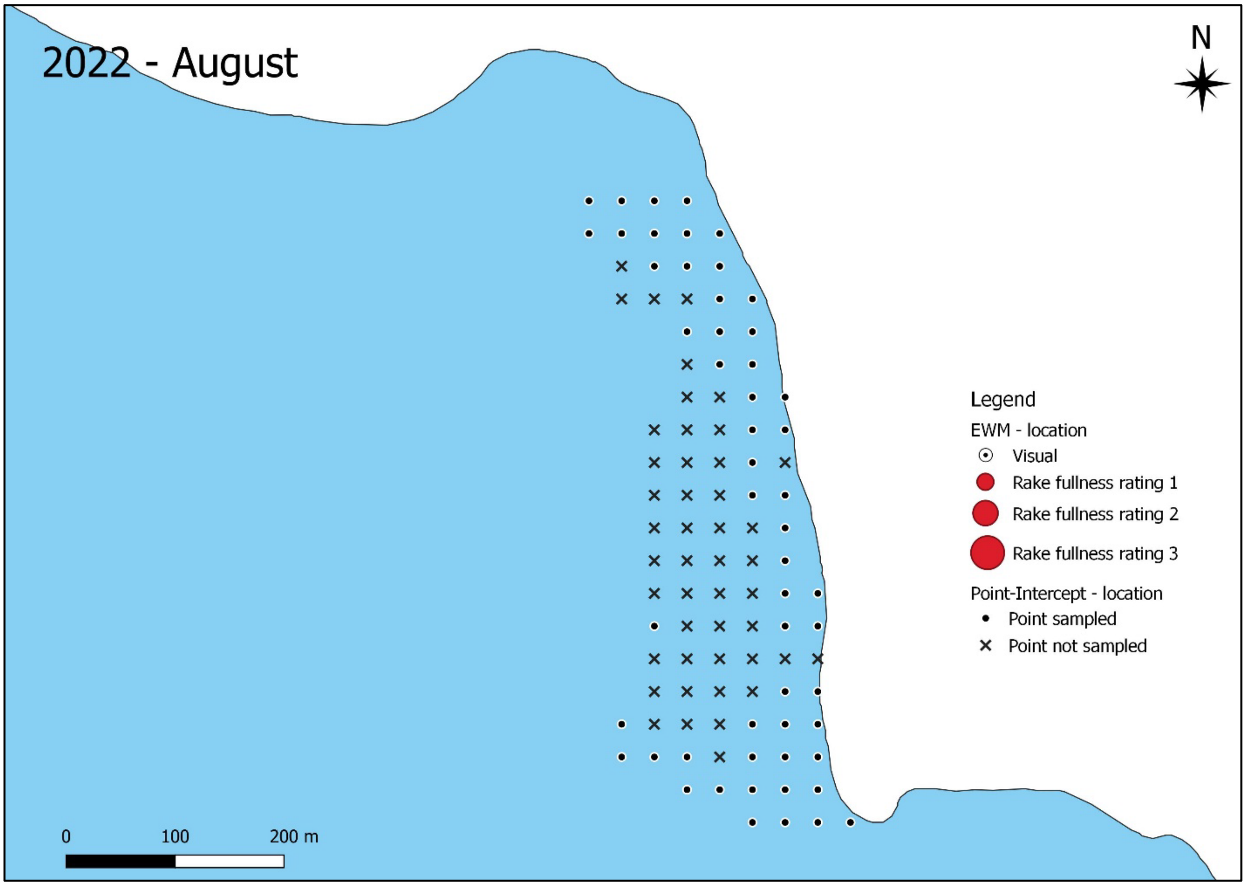


History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 3a

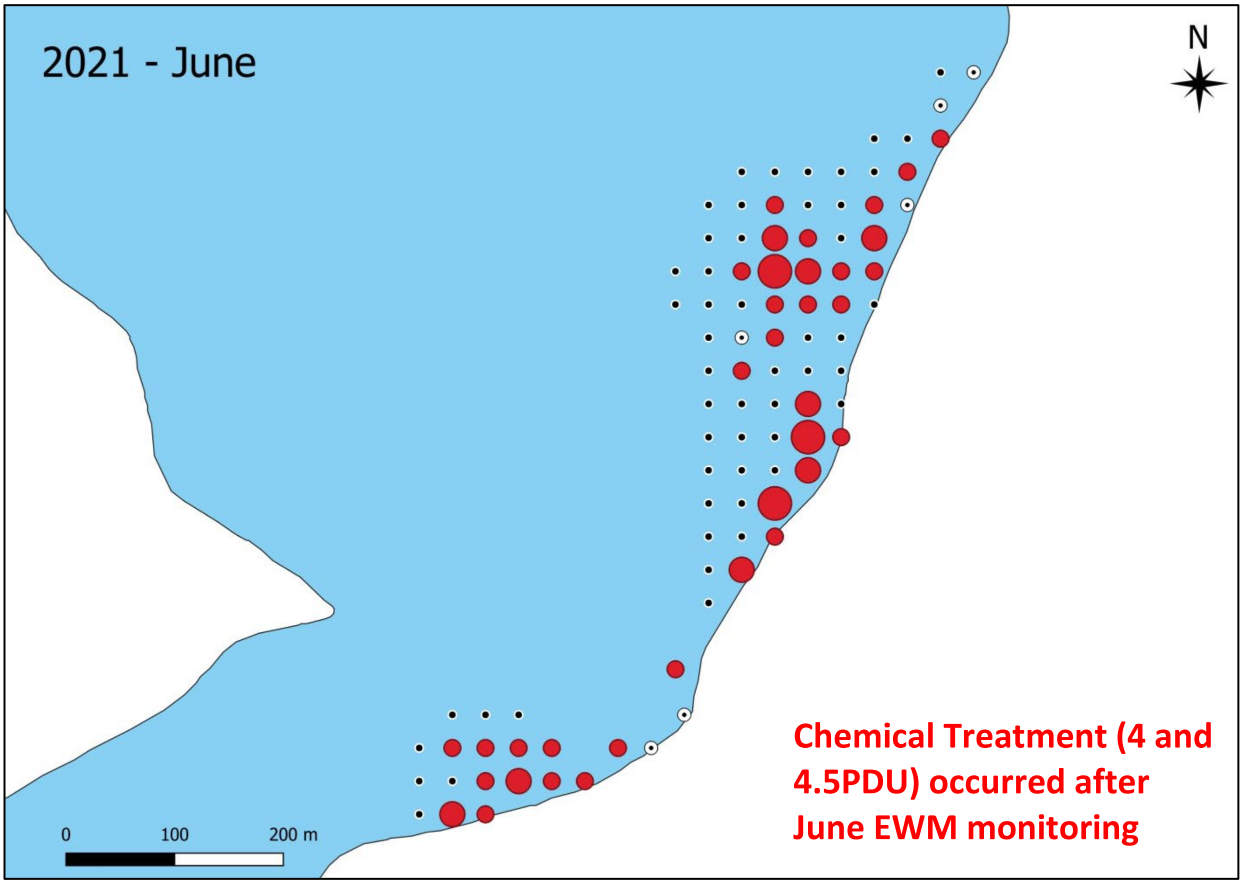


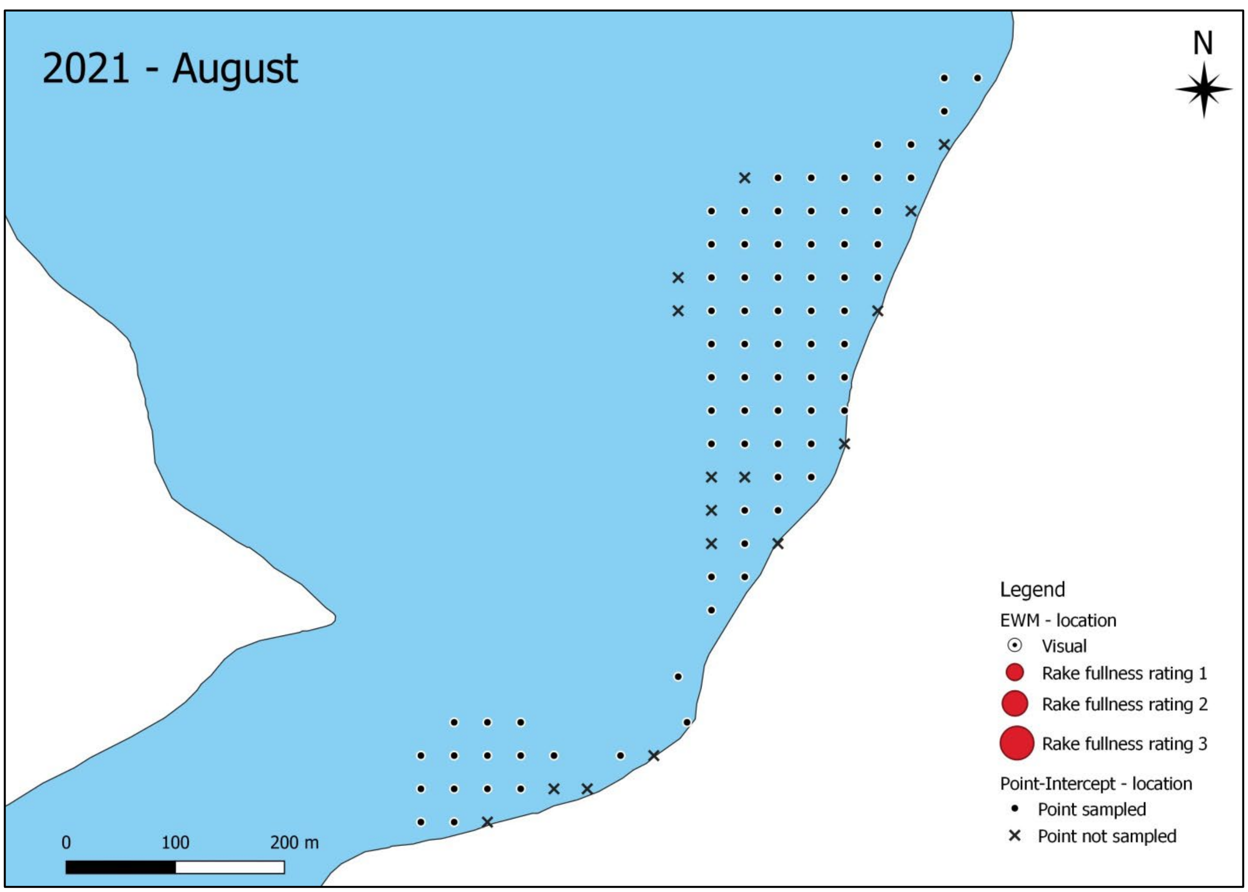


History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 3b

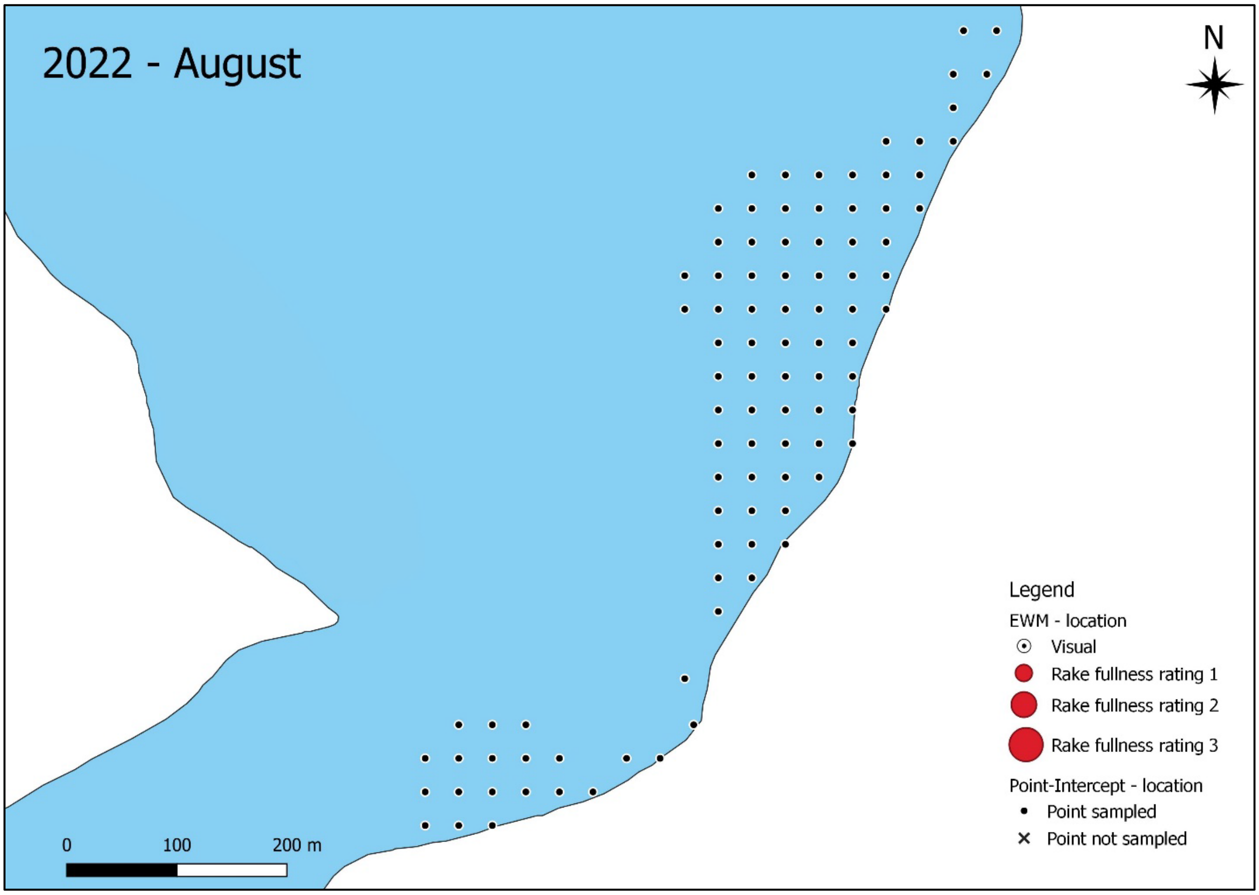


History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 5

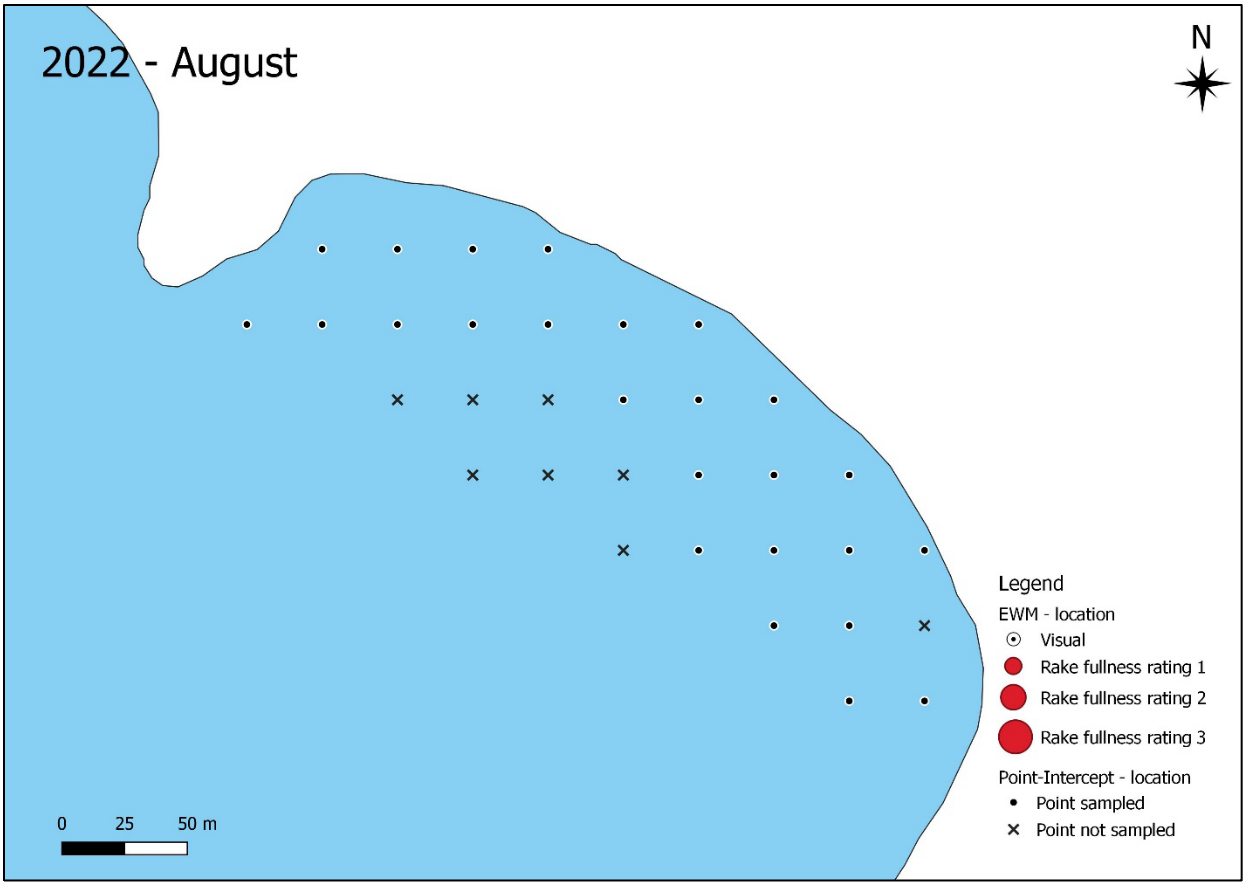




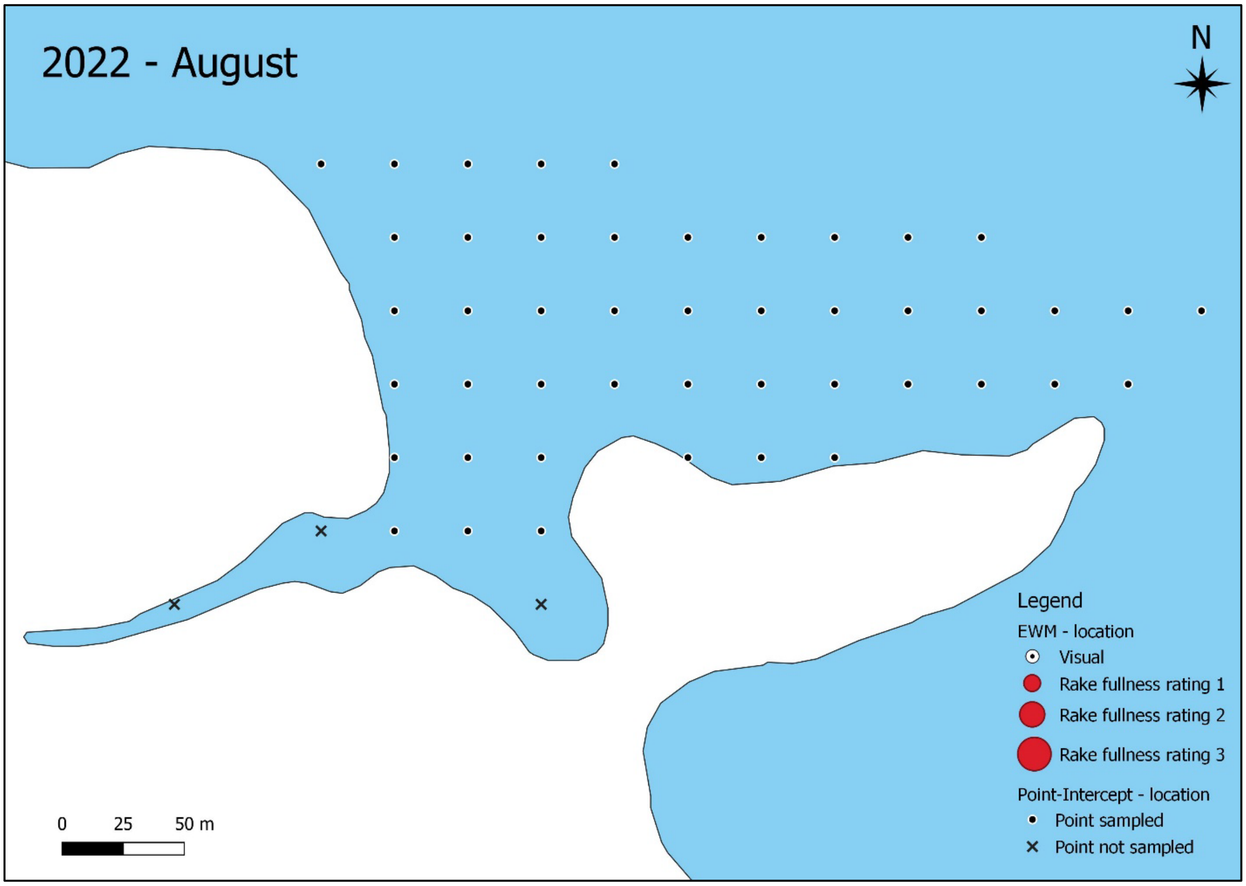
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 5



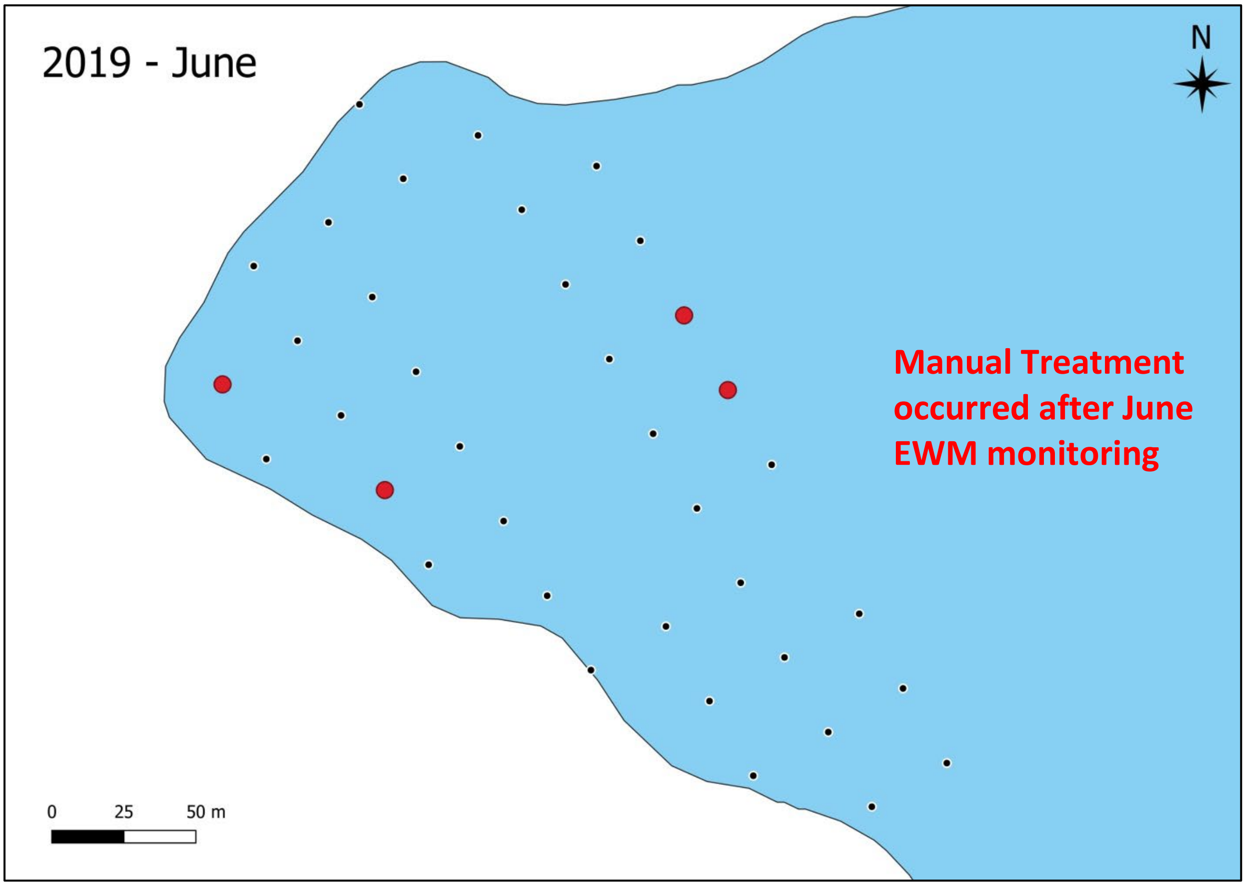
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 6b

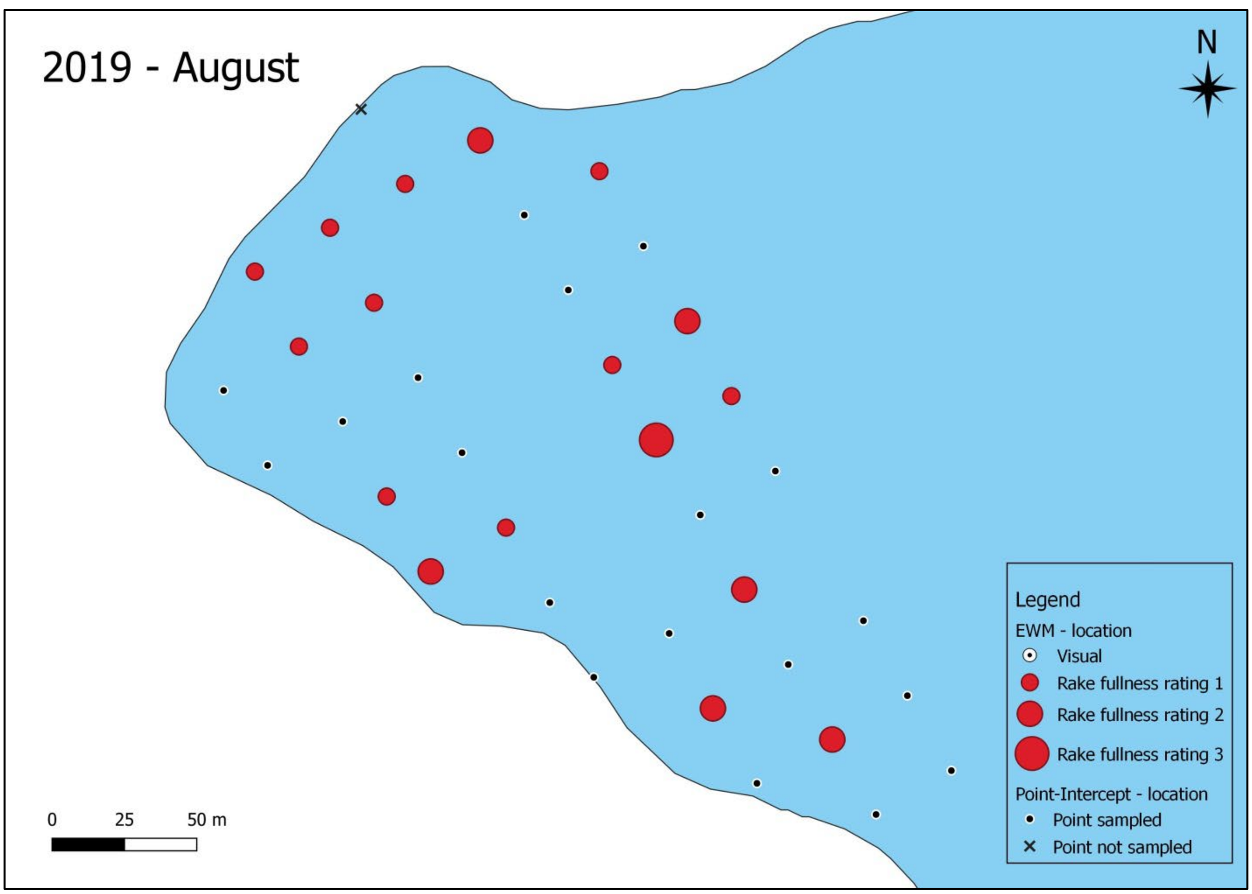


History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 7

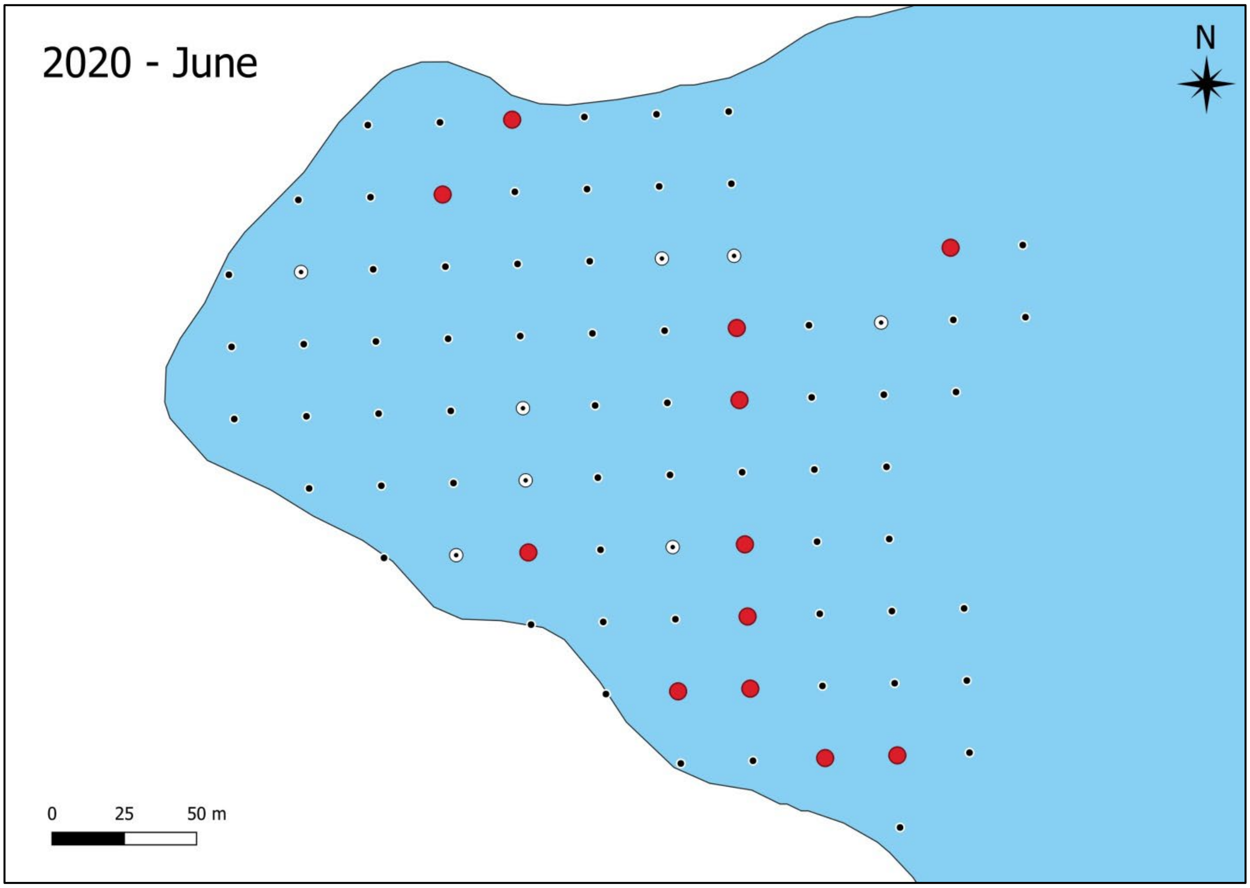


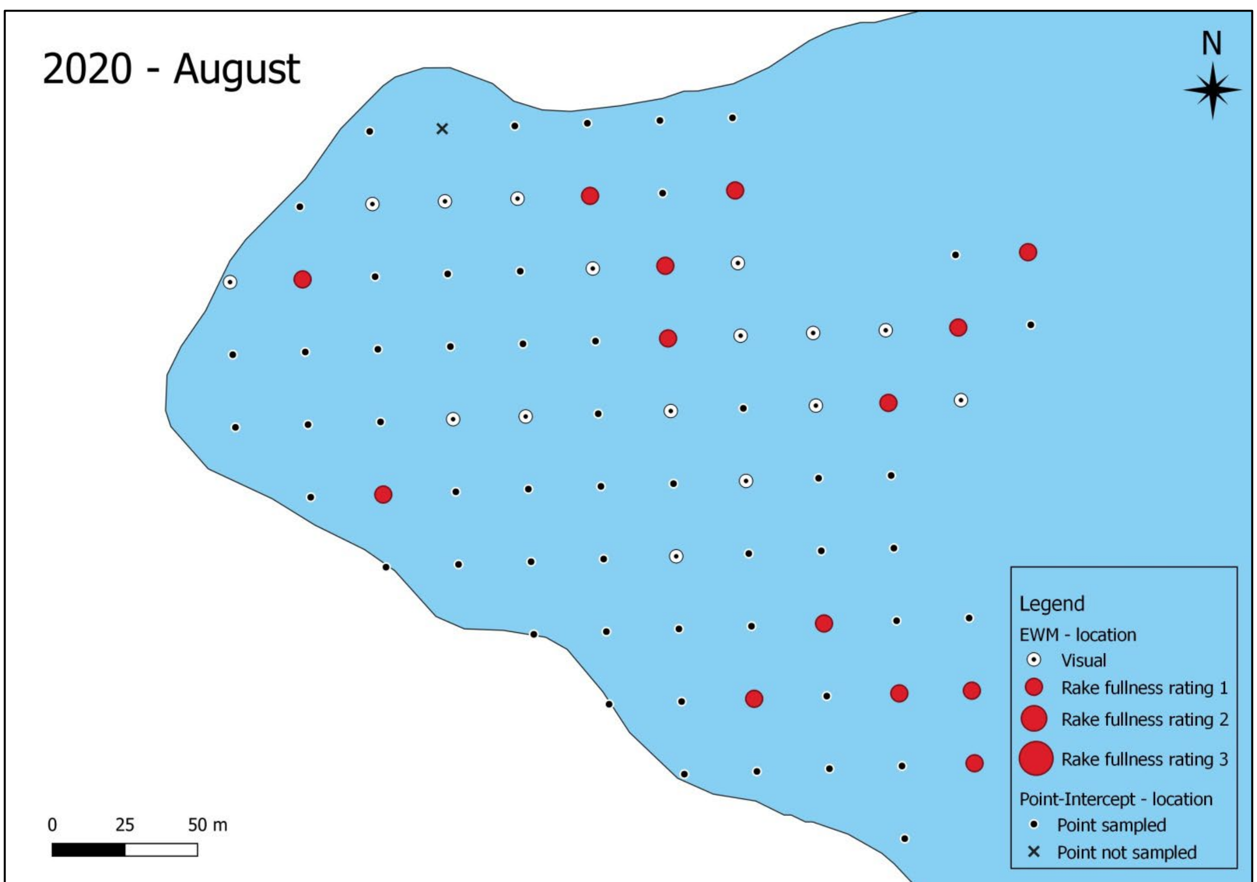
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 8



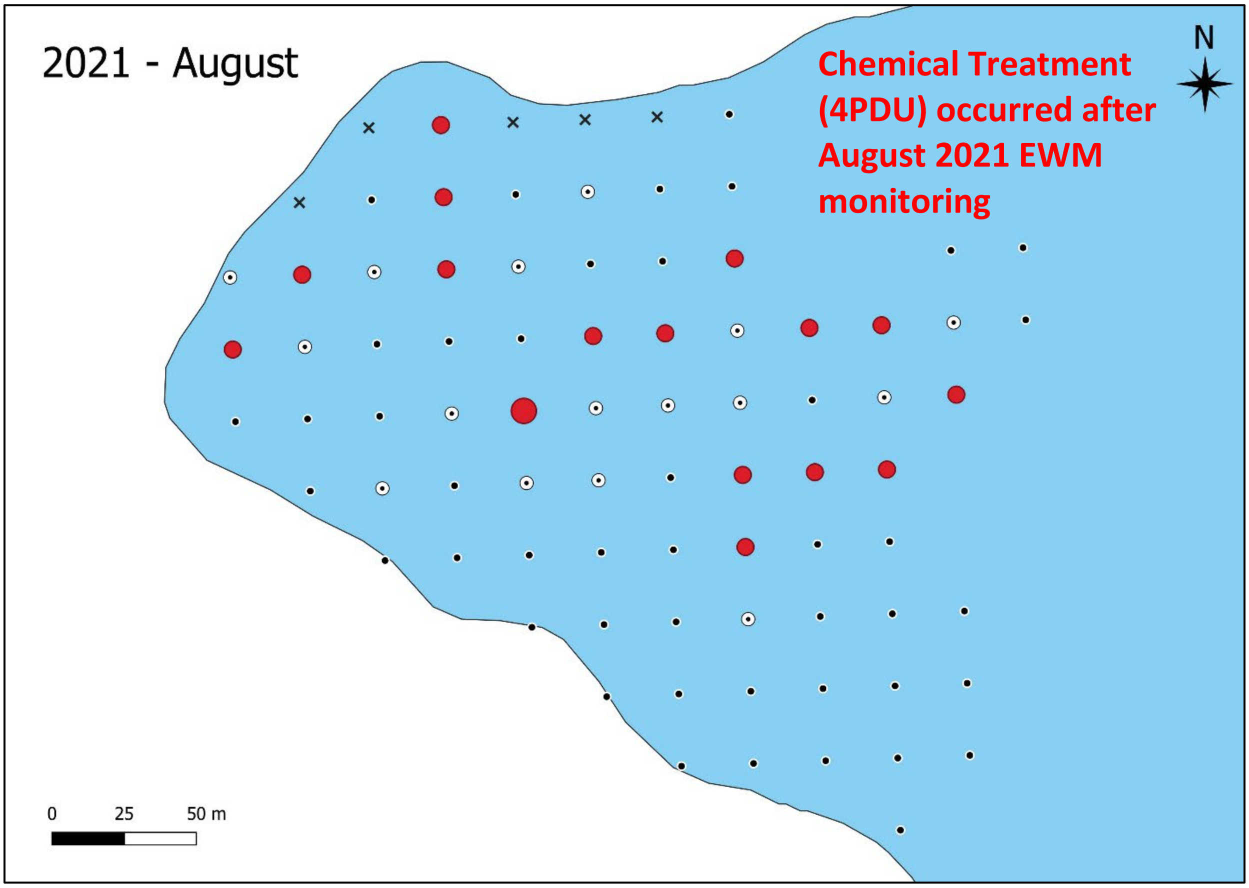


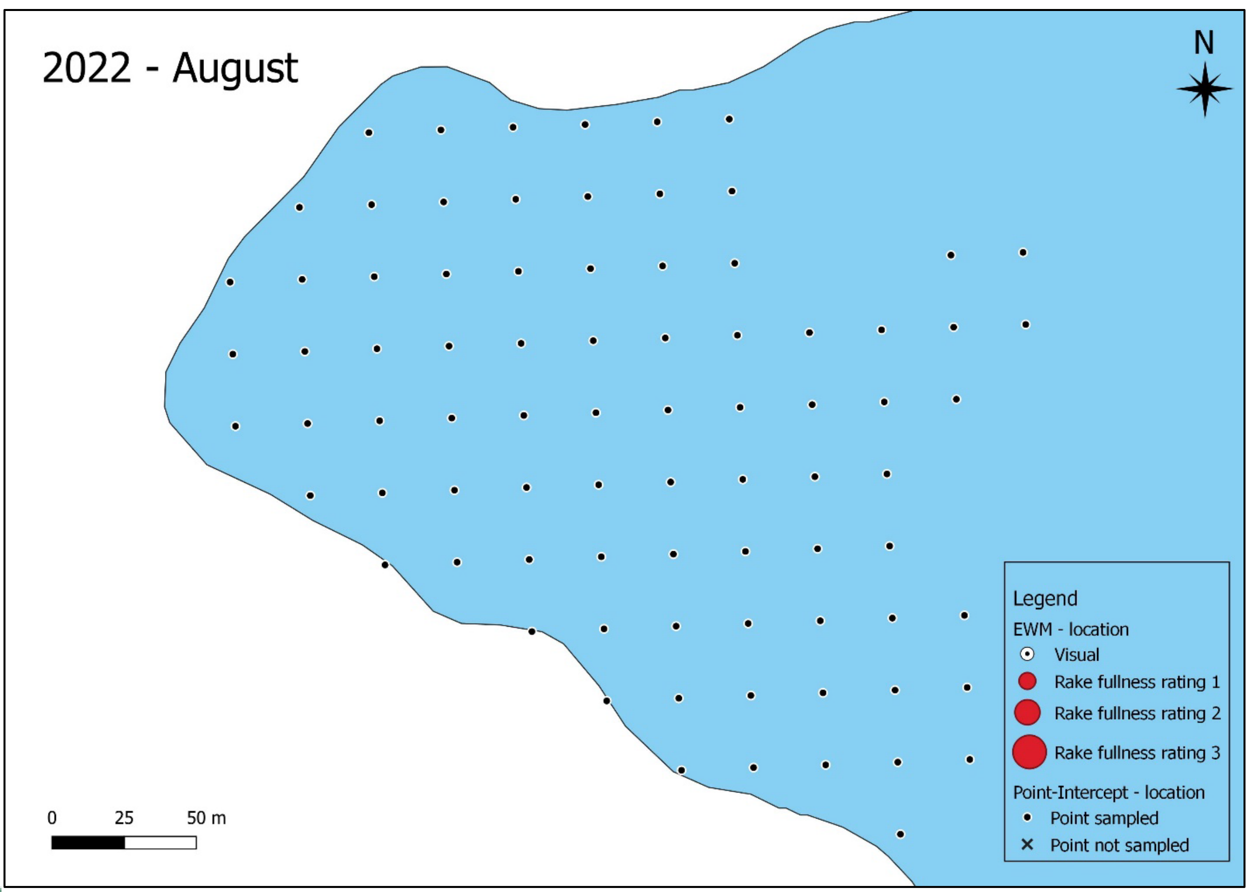
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 8



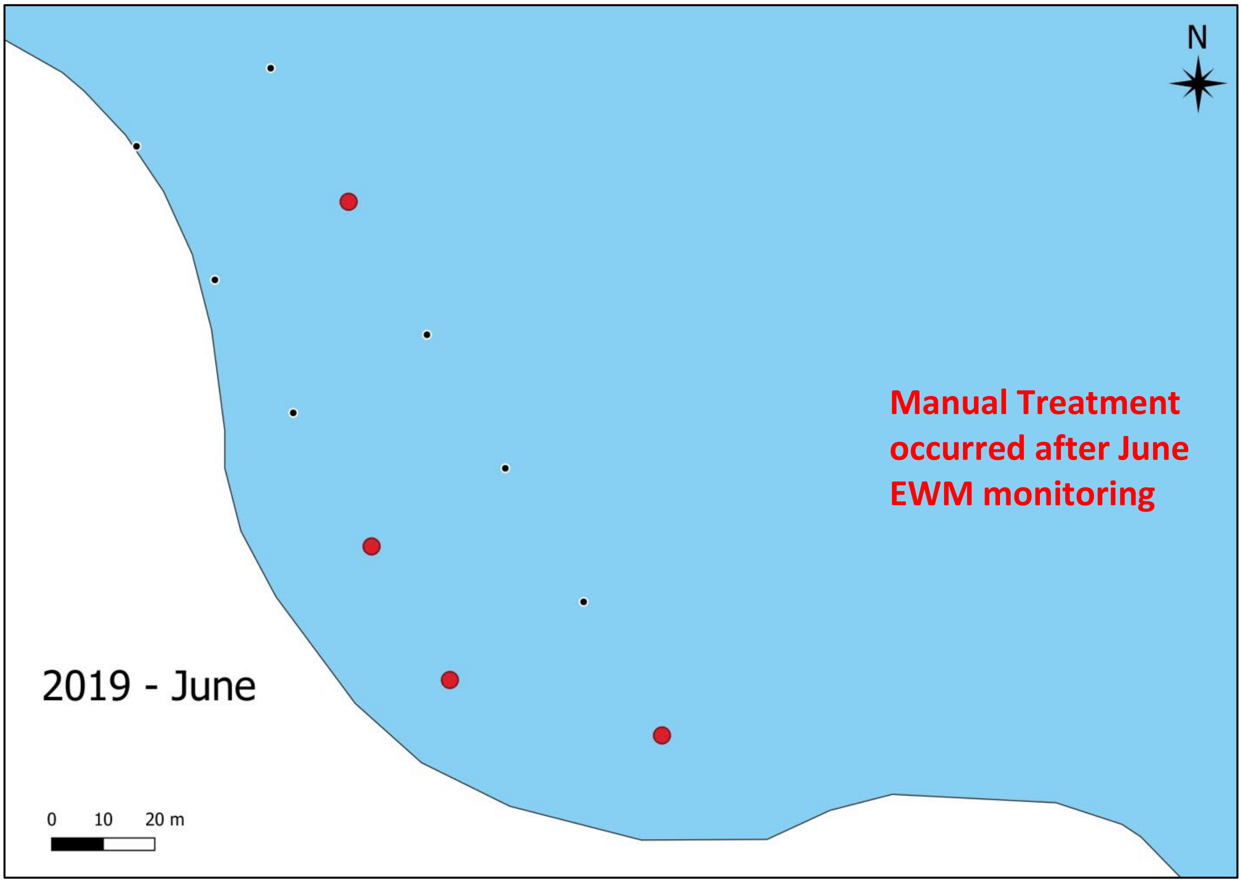


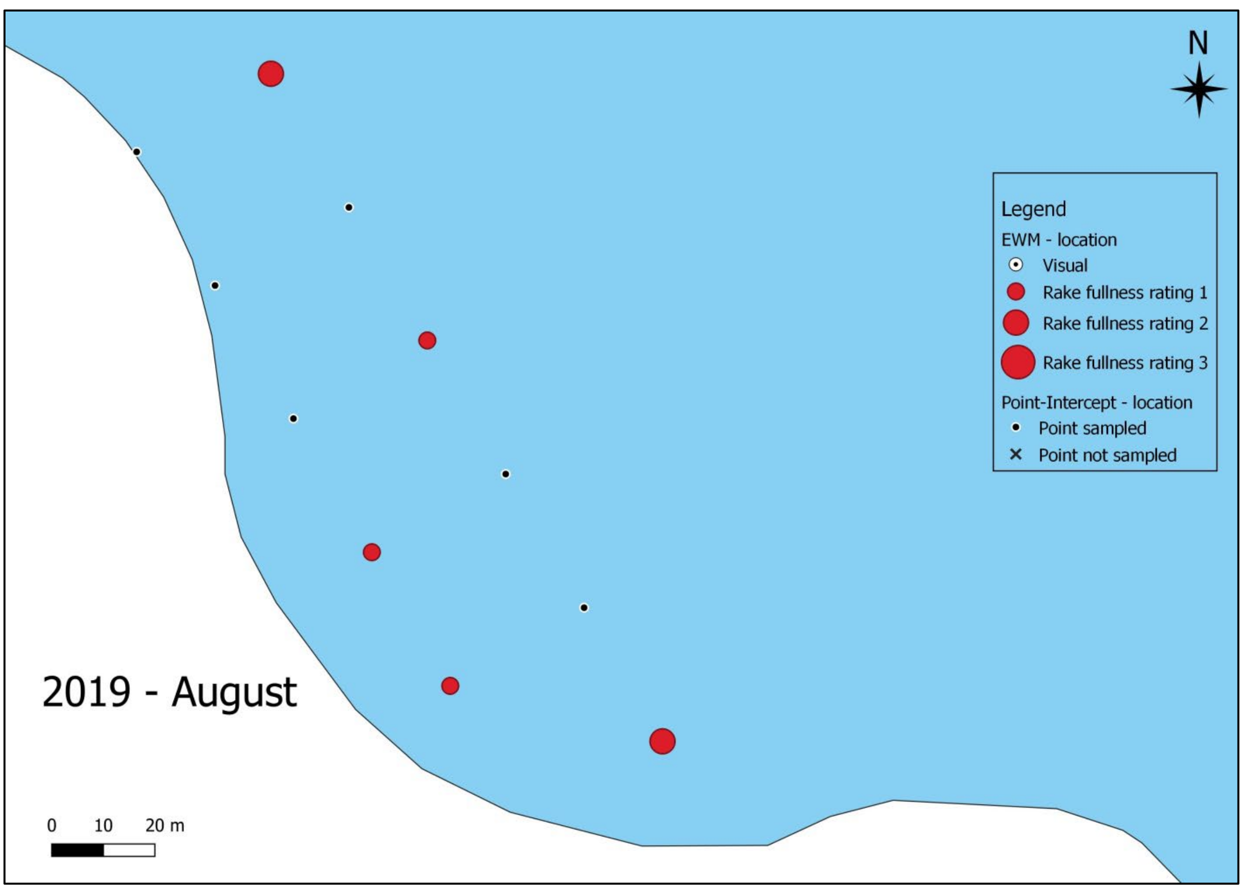
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 8



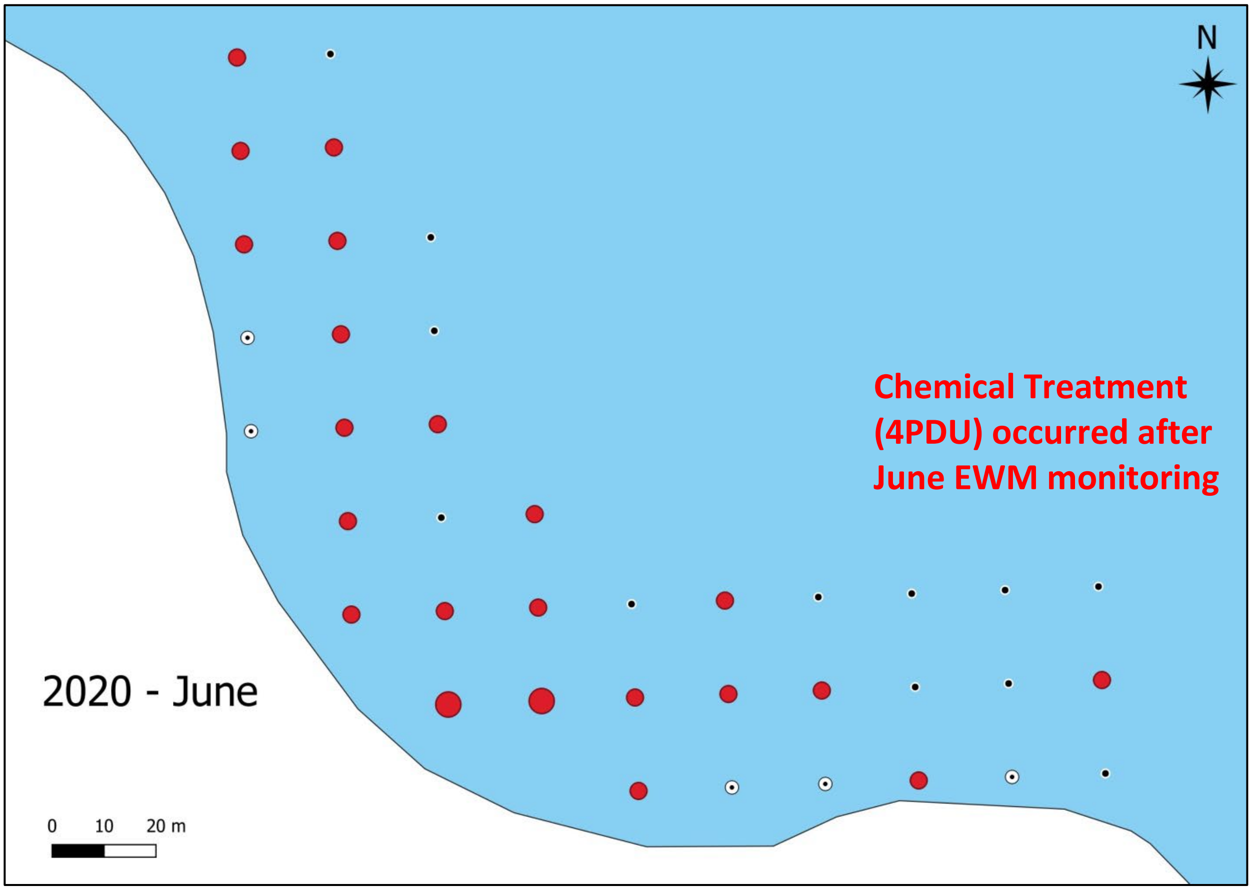


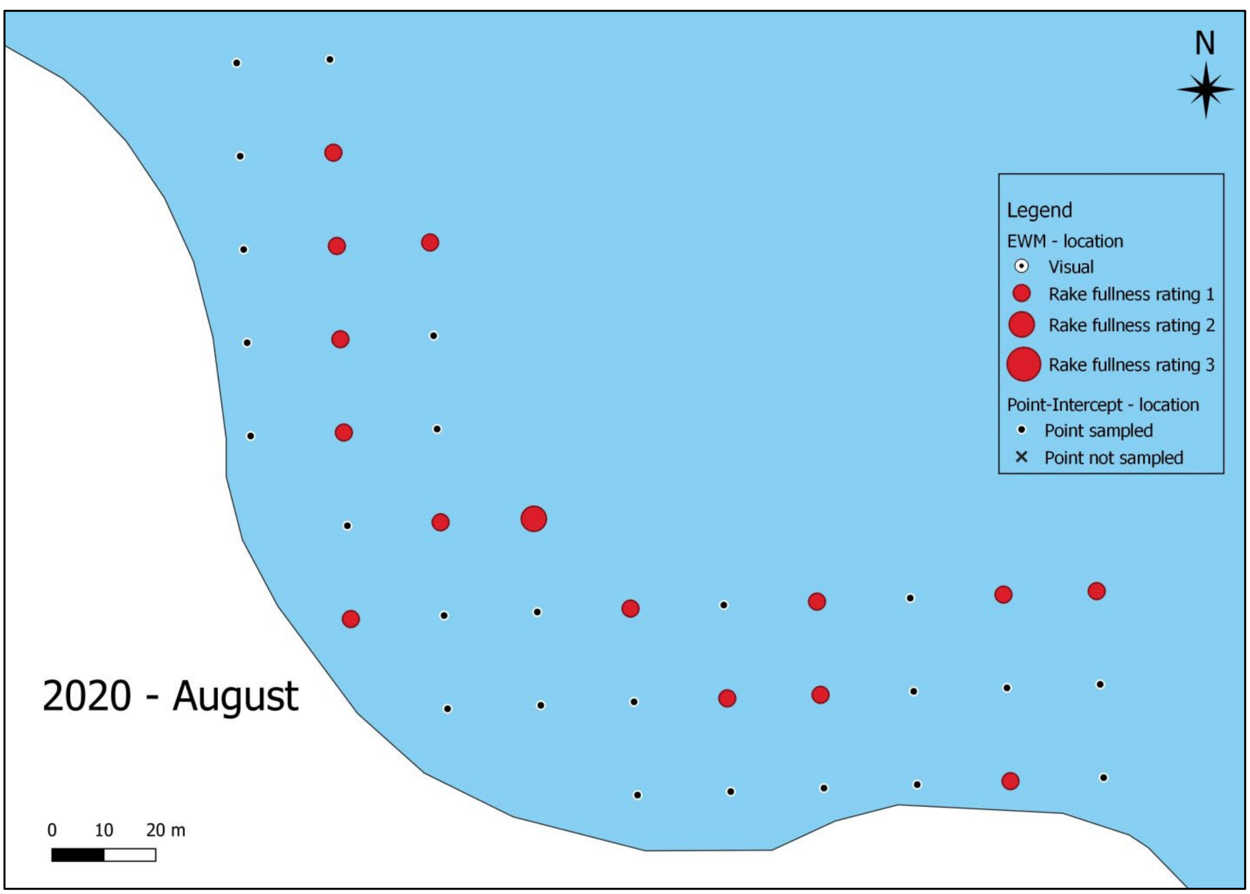
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 9



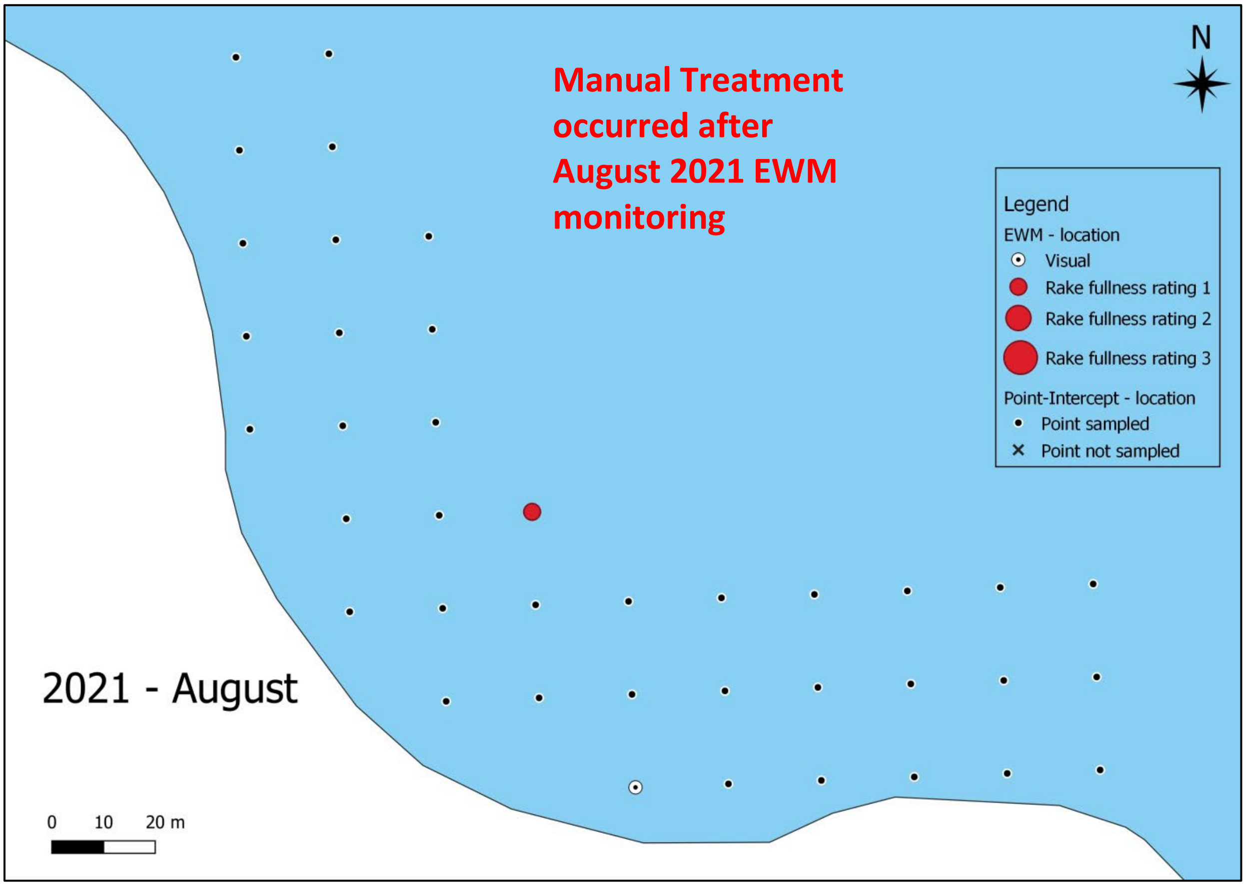


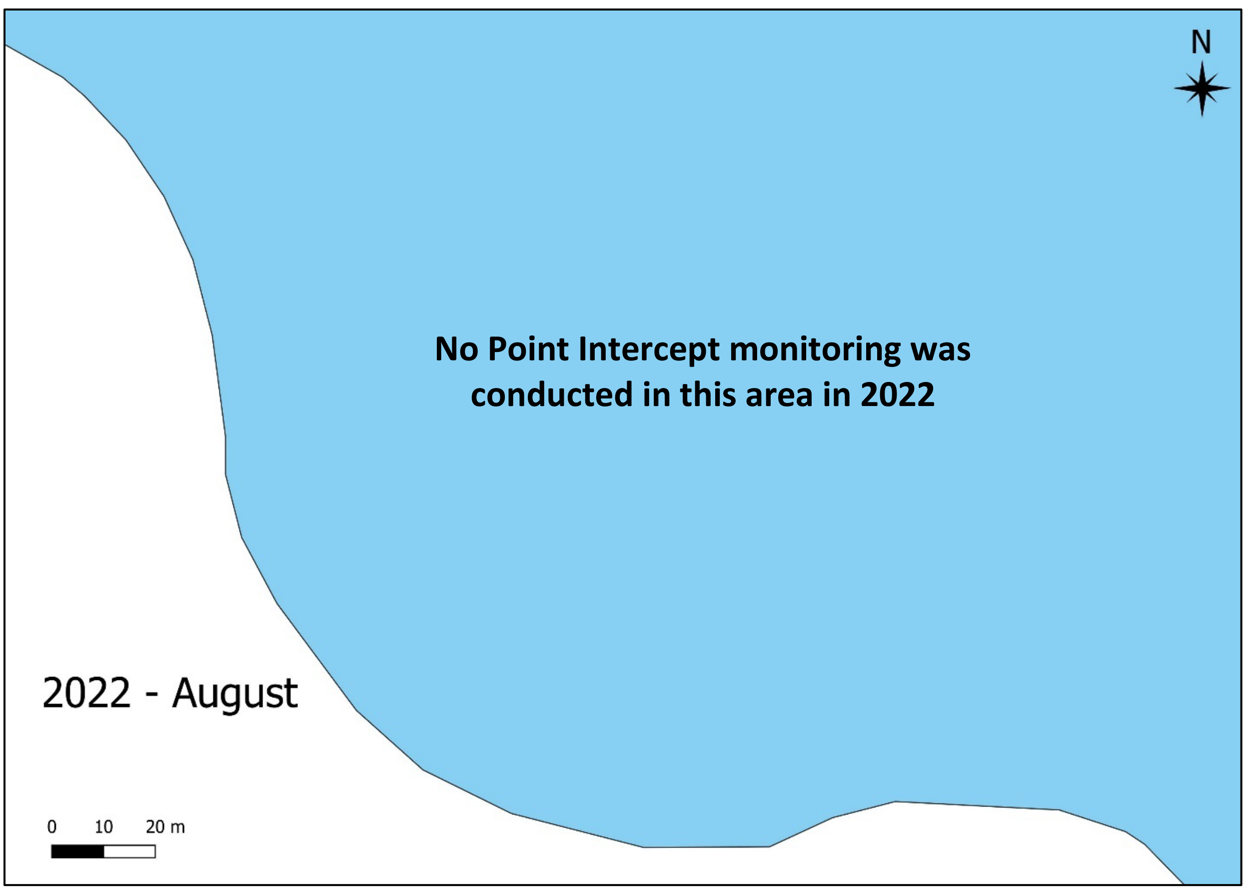
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 9



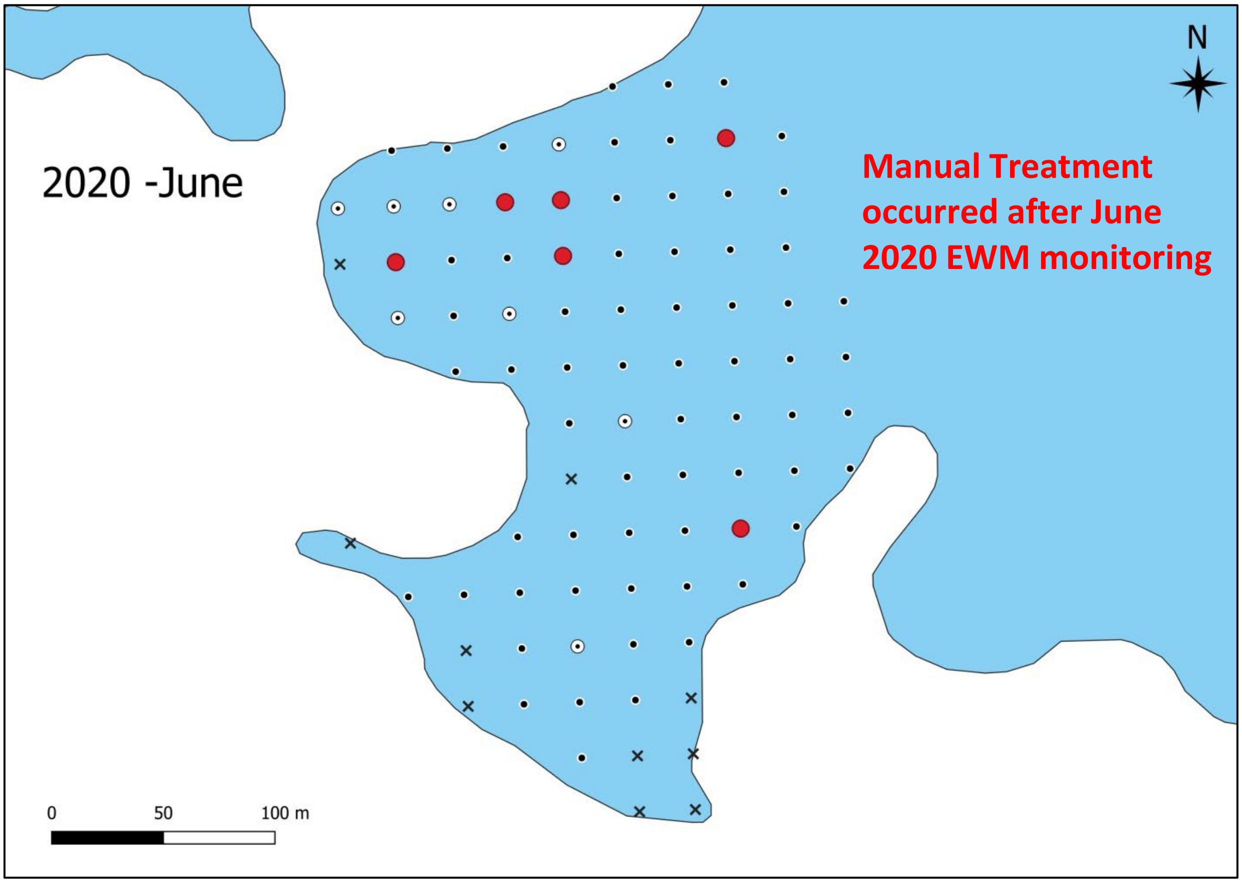


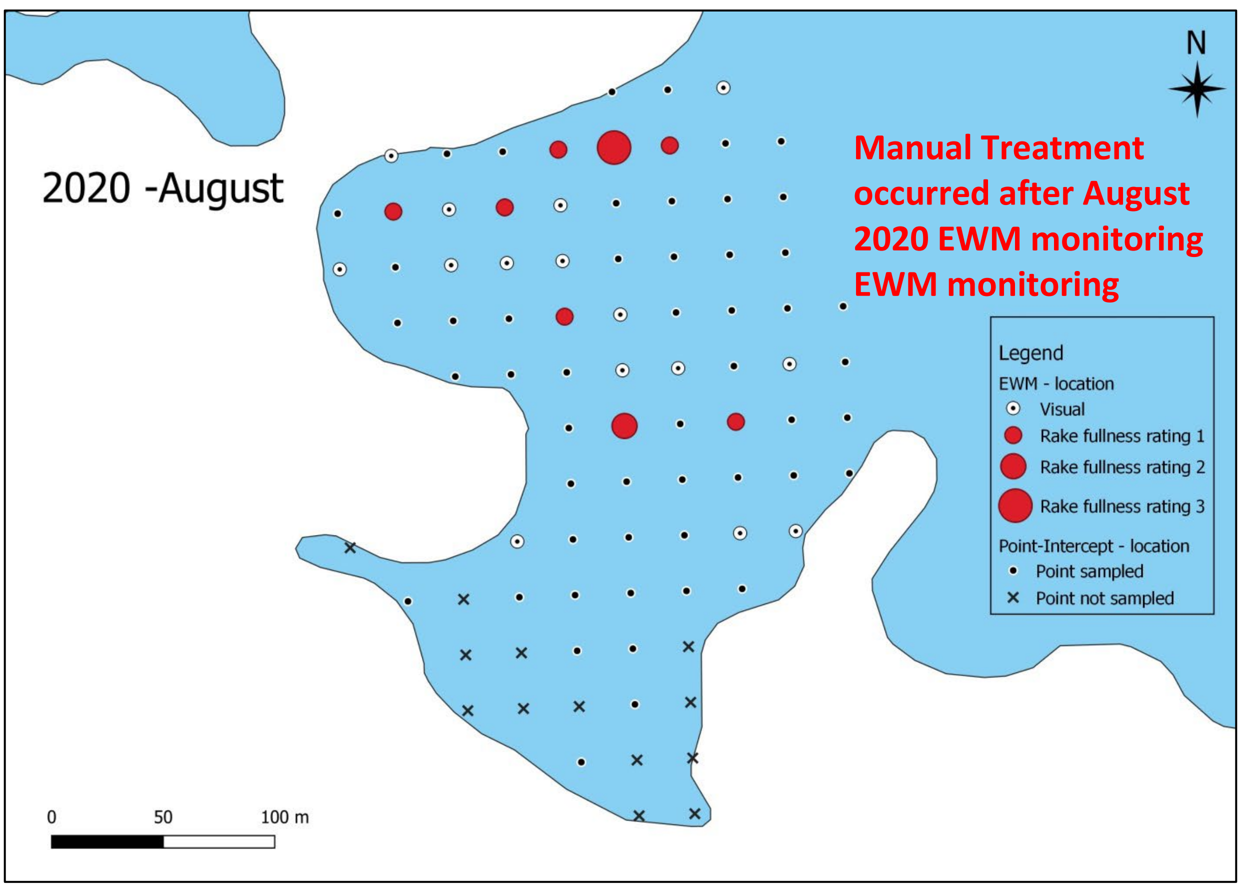
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 9



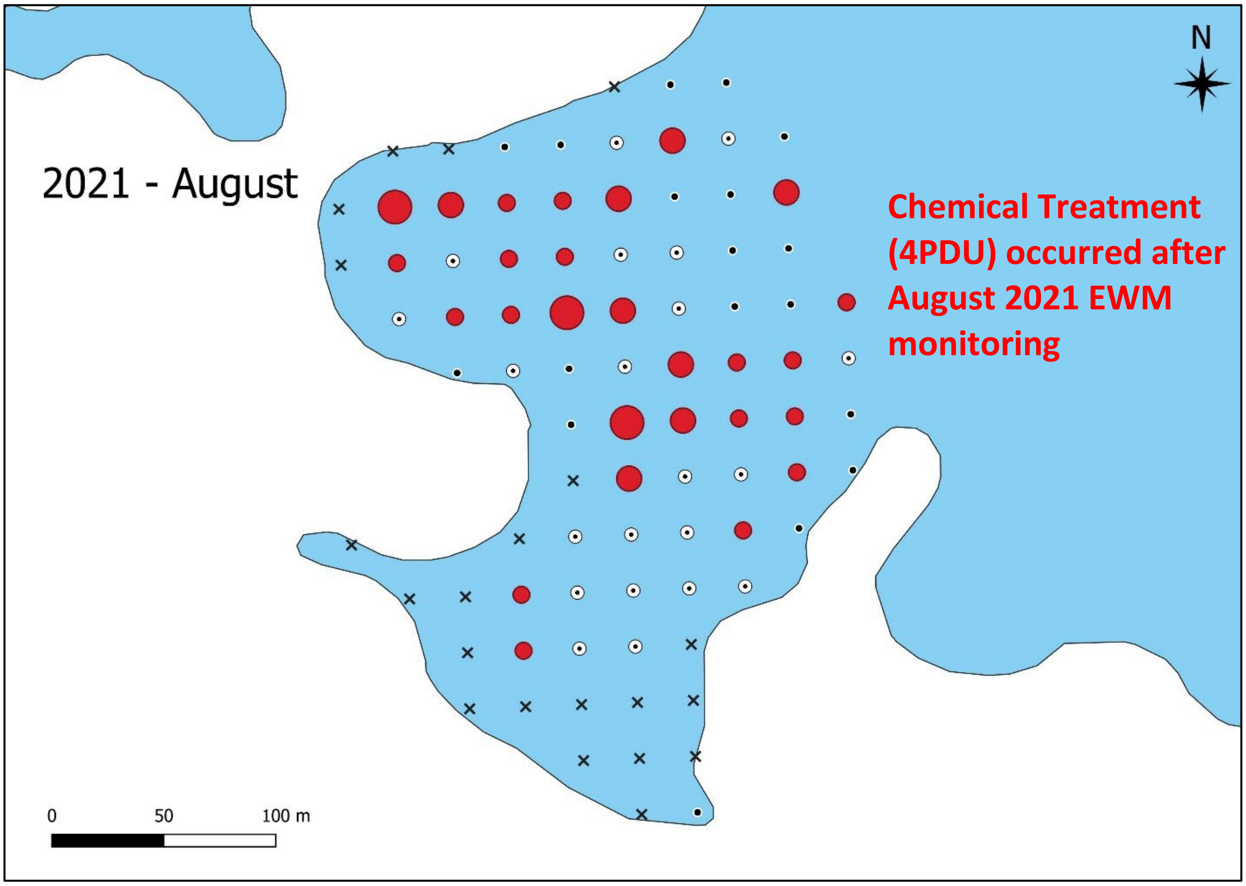


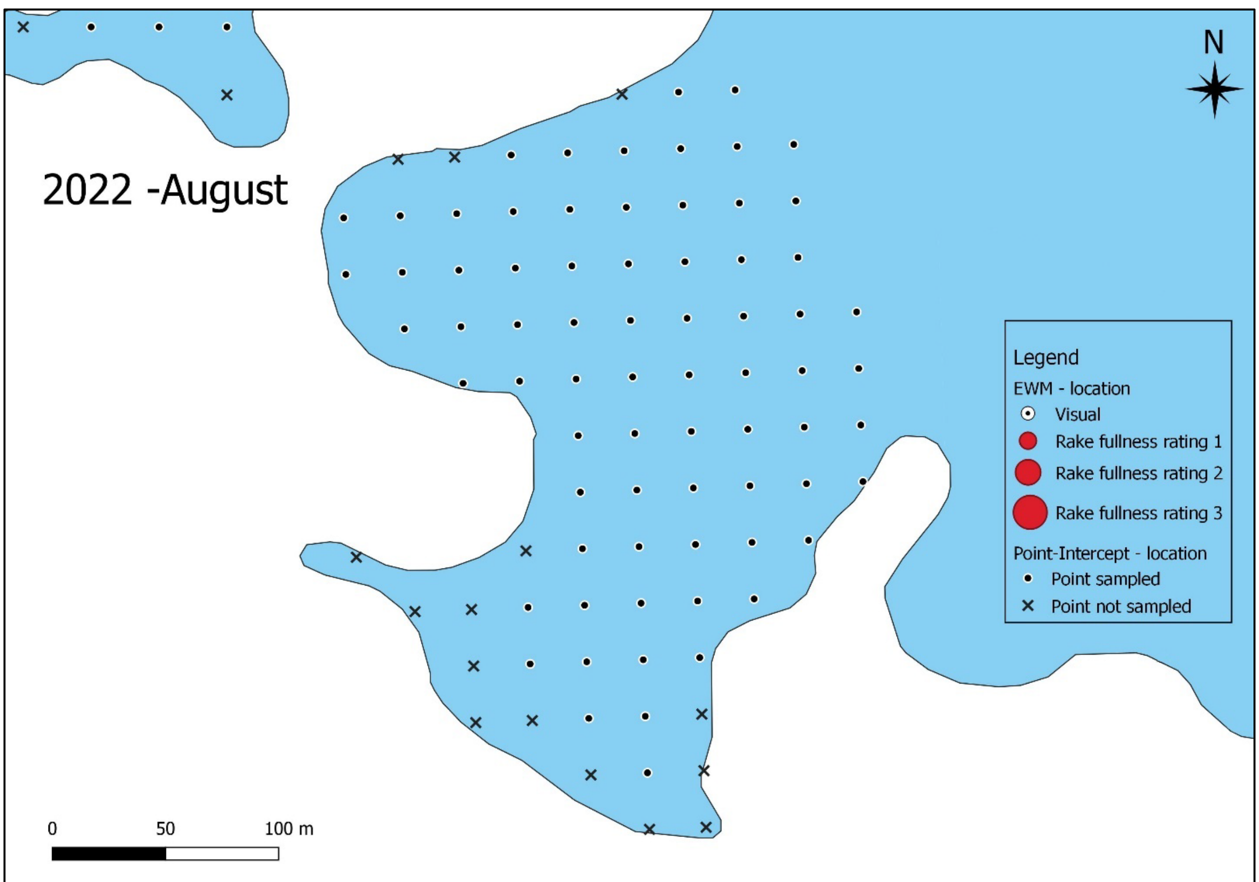
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 10



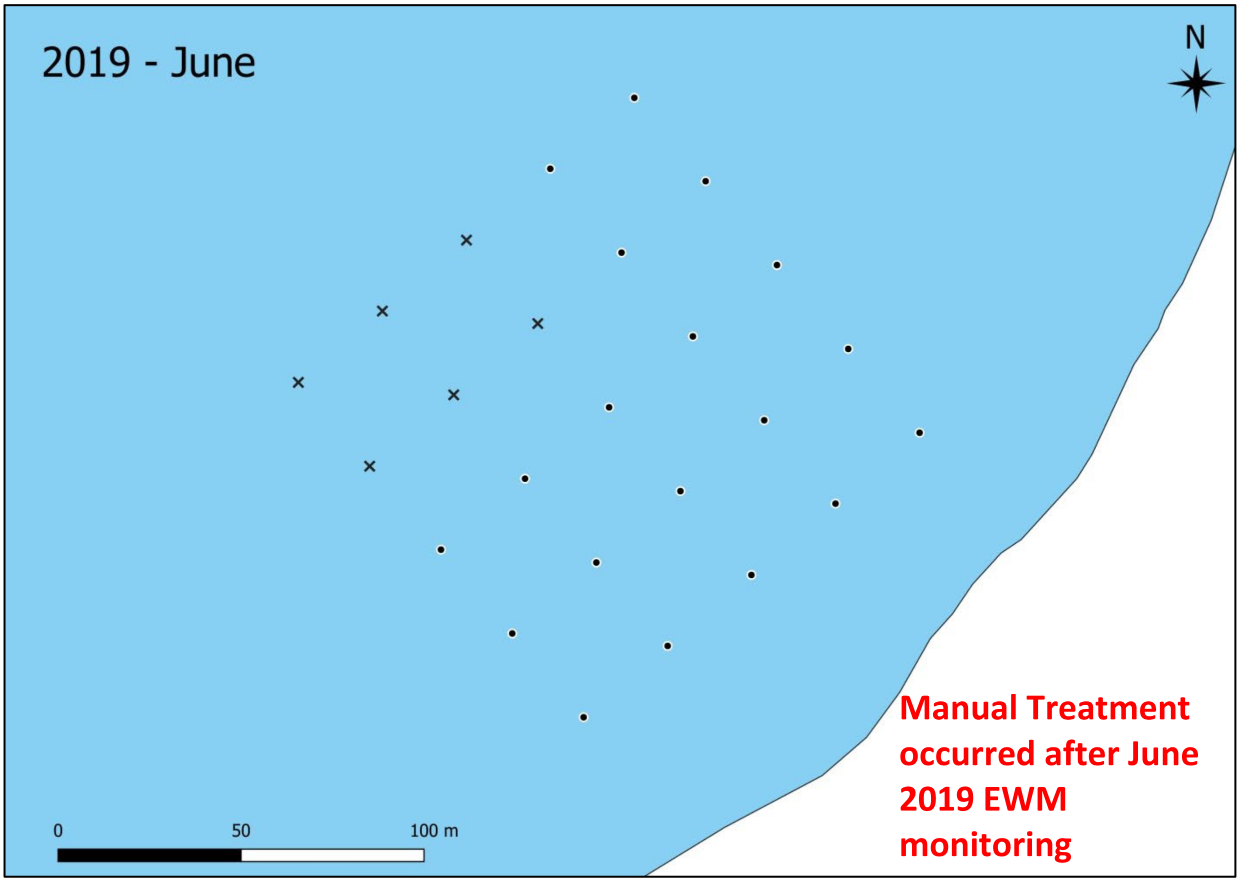


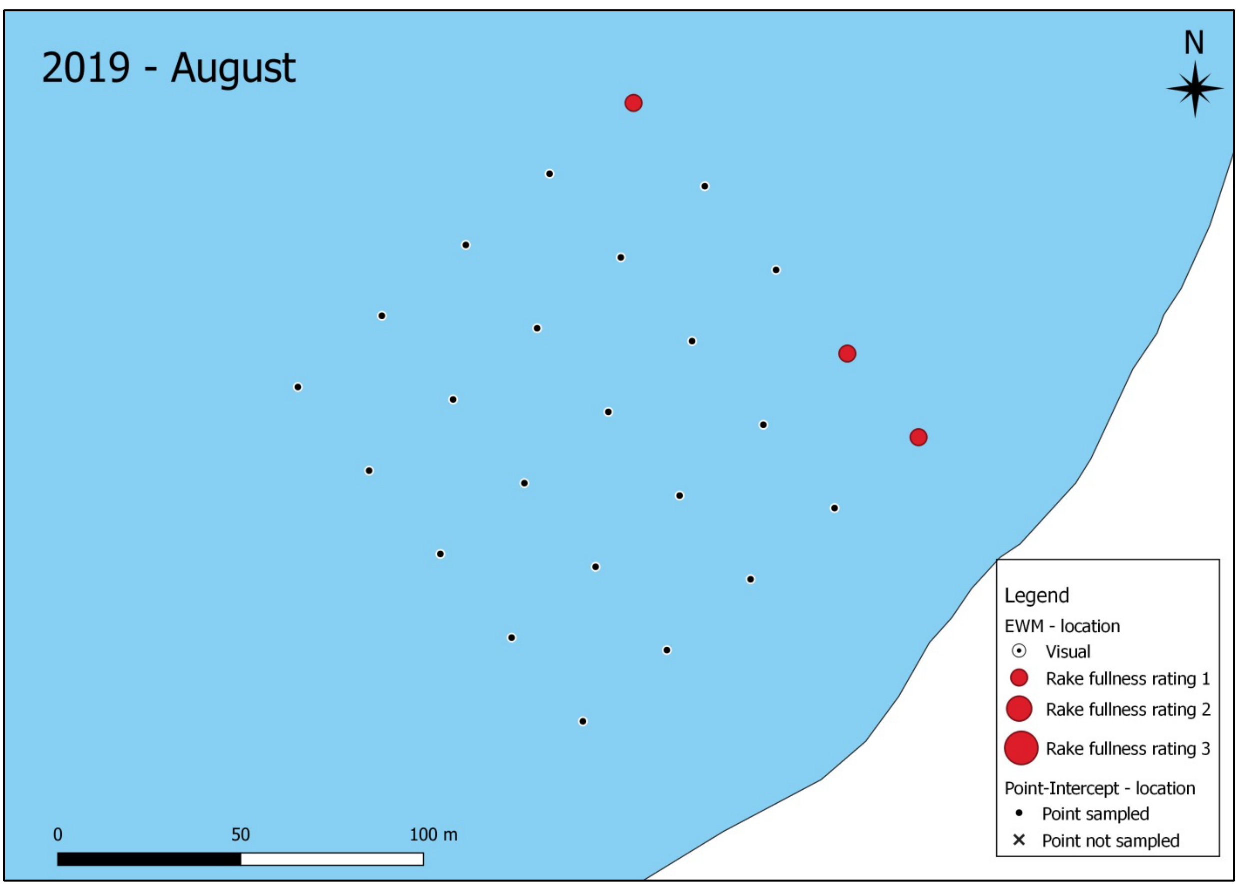
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 10



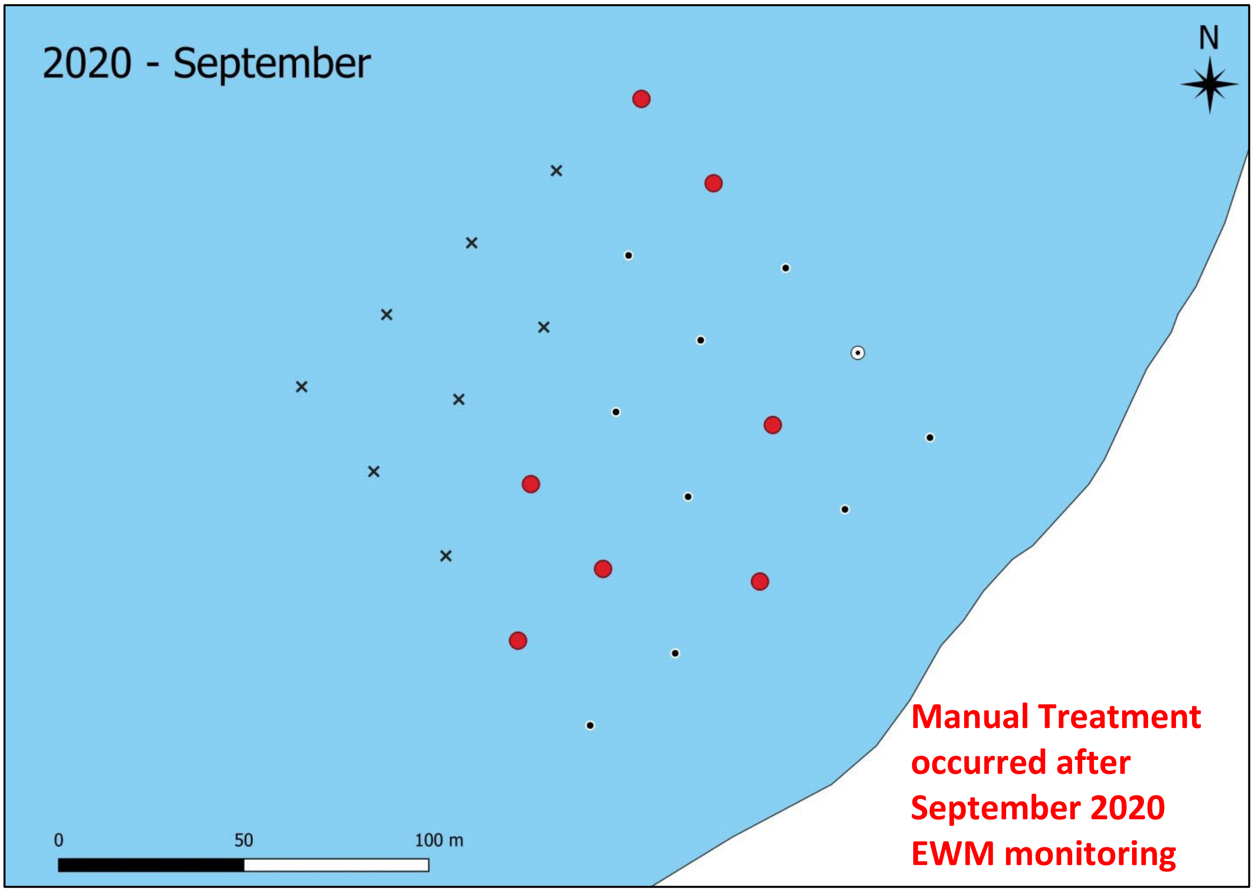


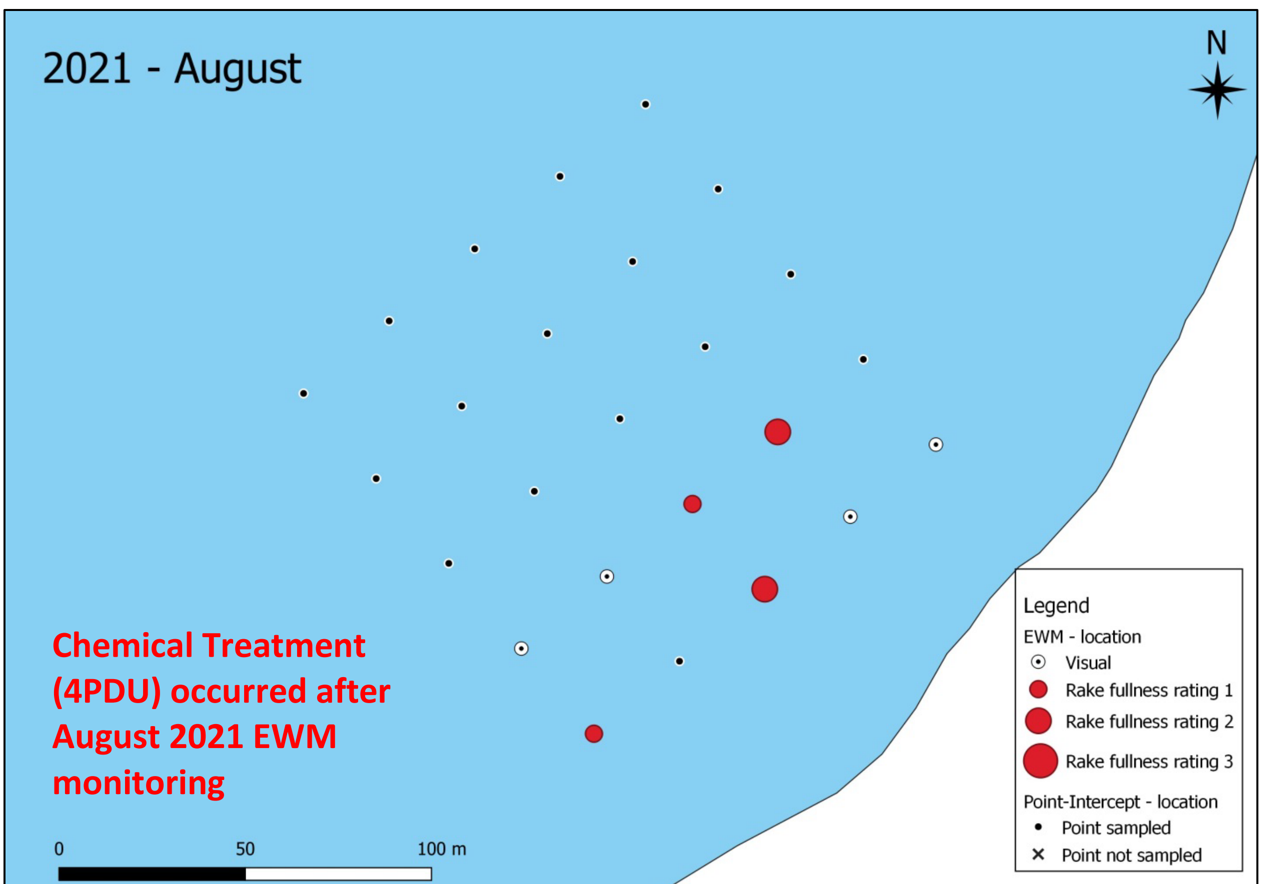
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 11



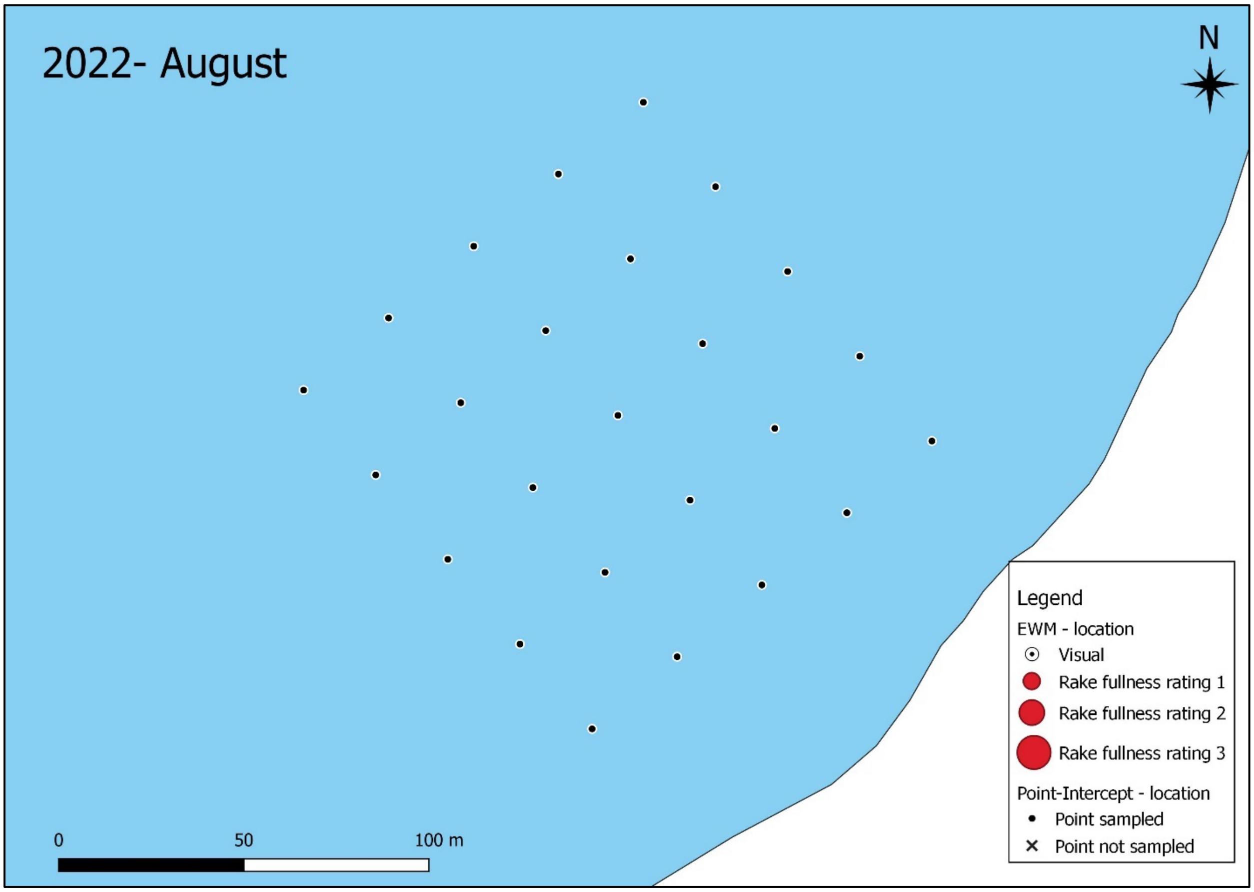


History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 11

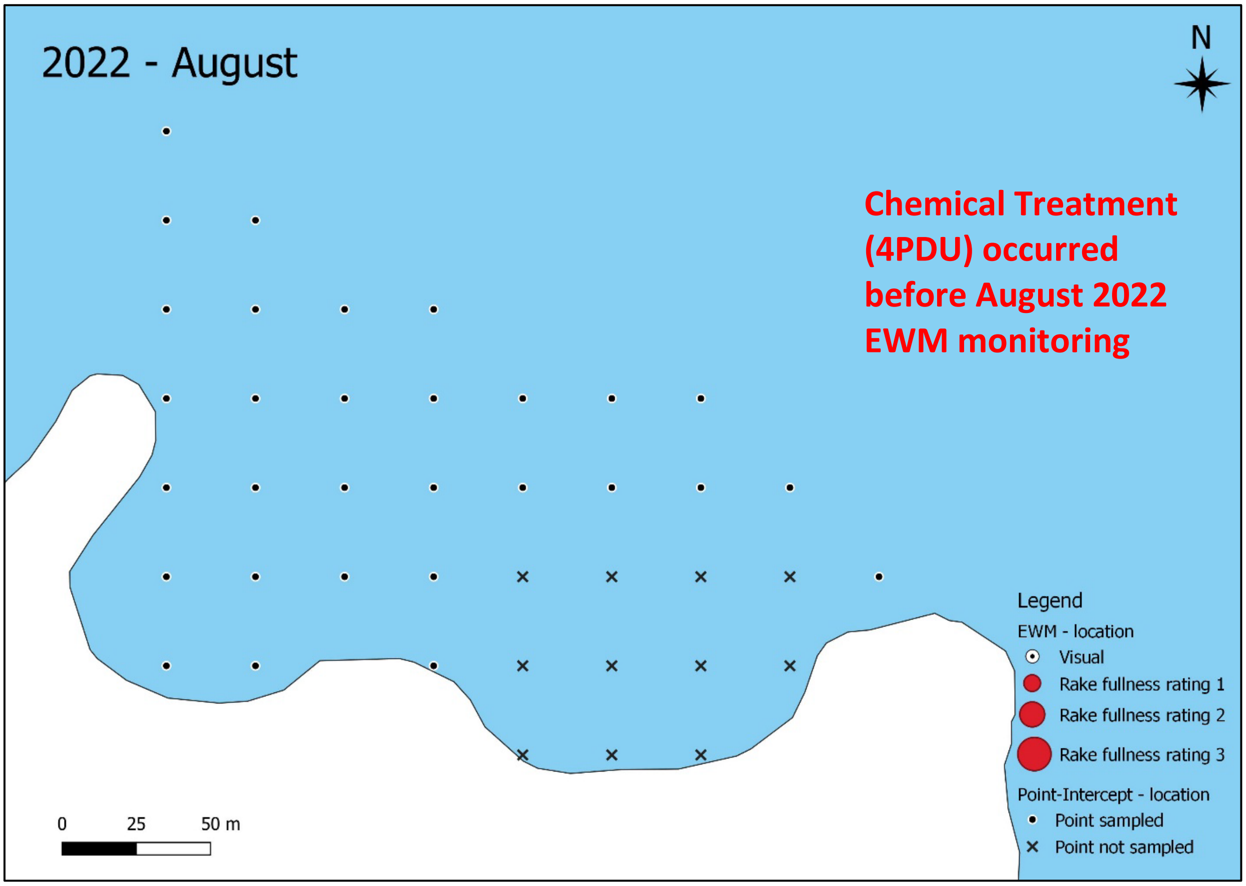




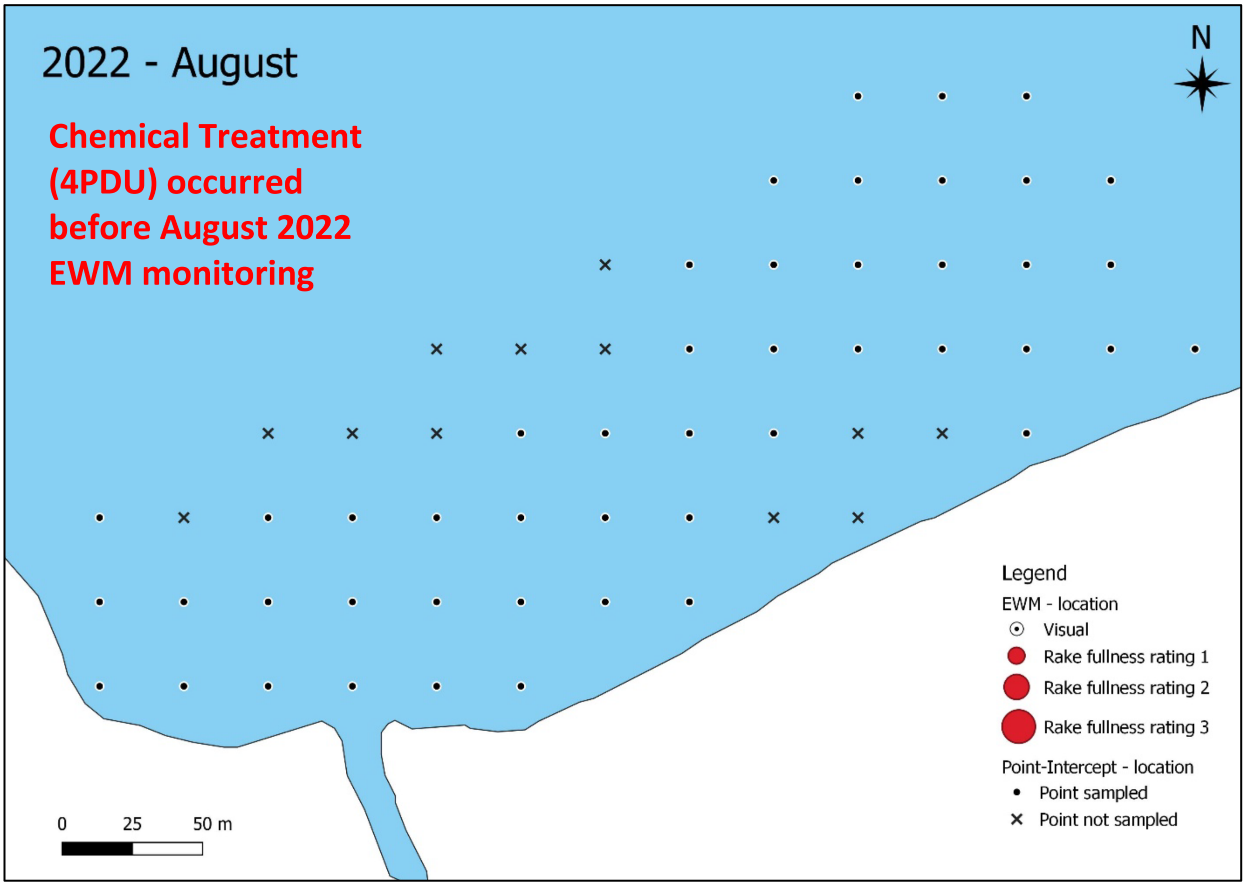
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 11



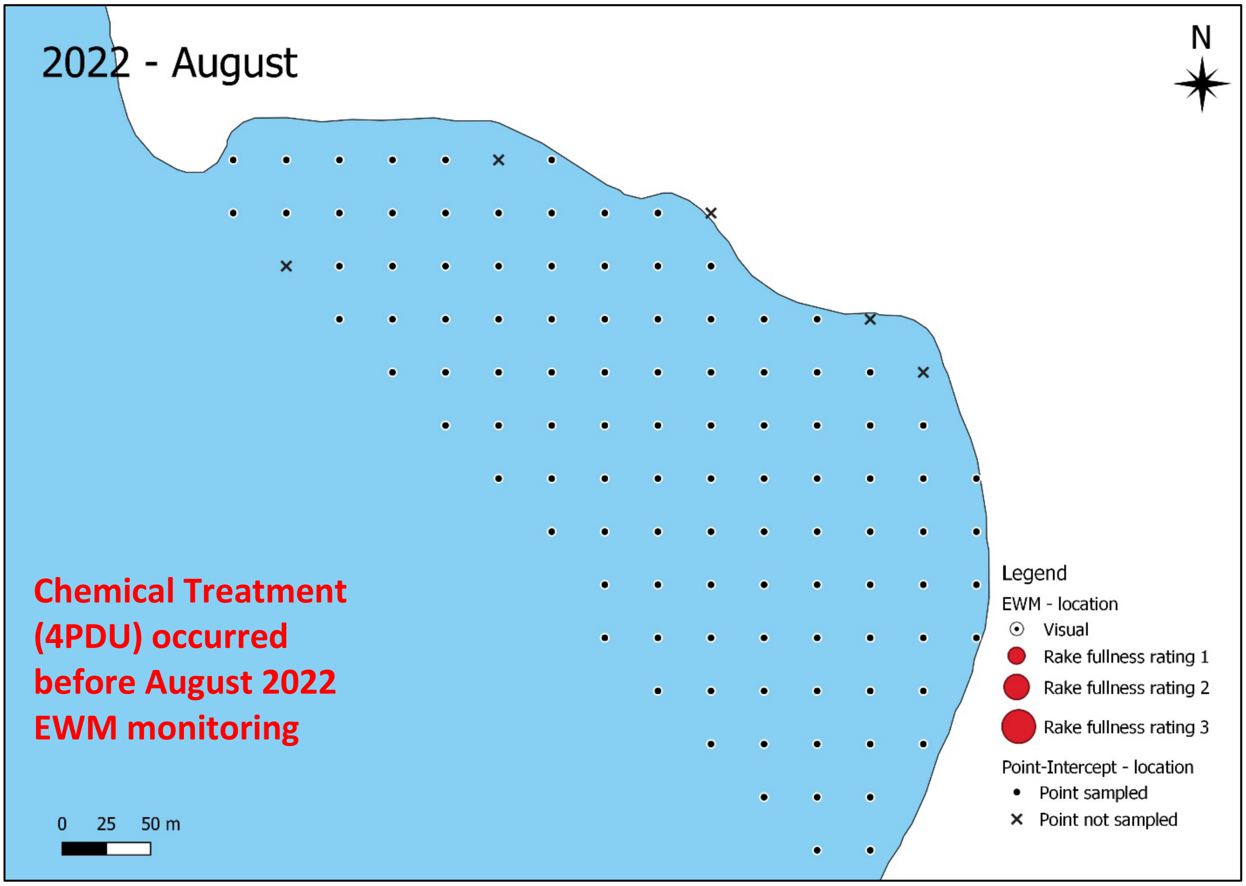
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 12a



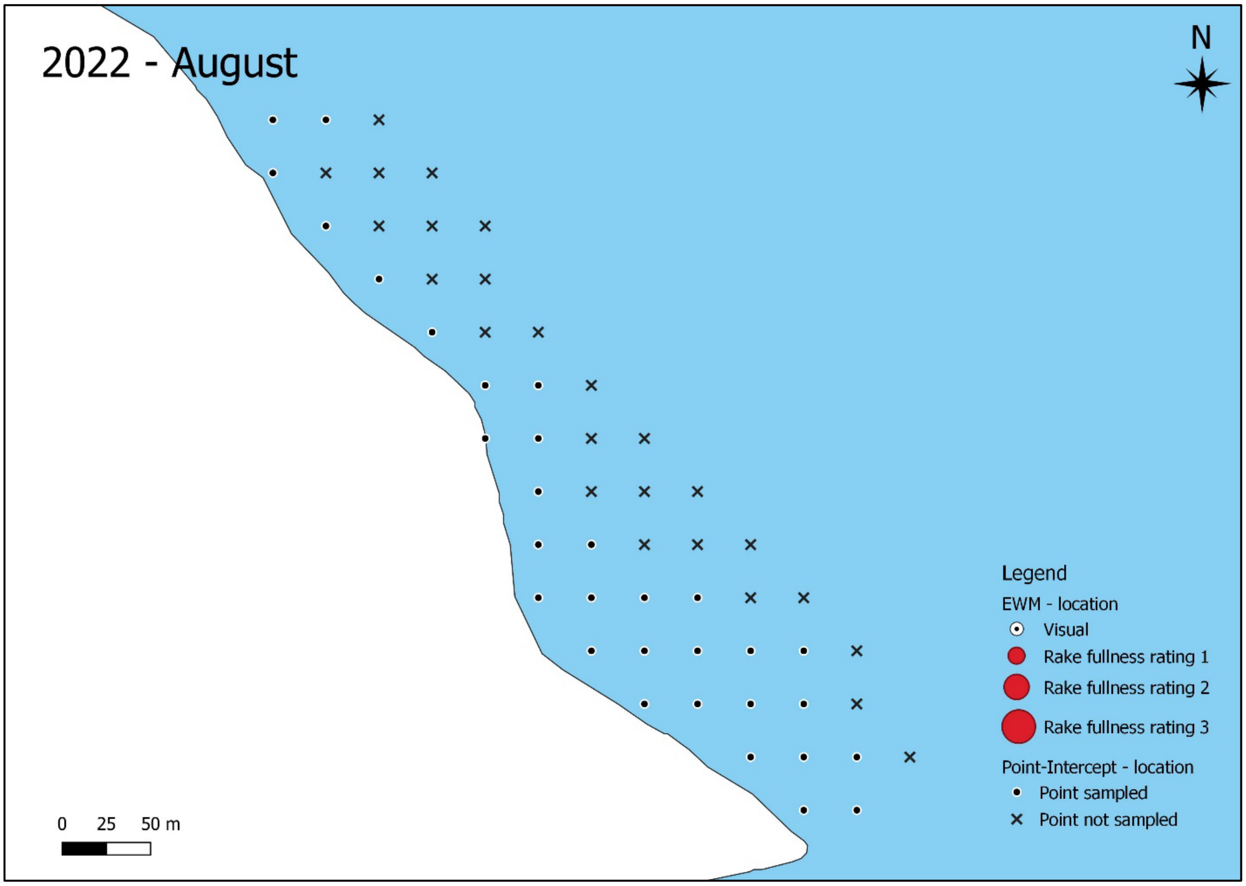
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 12c



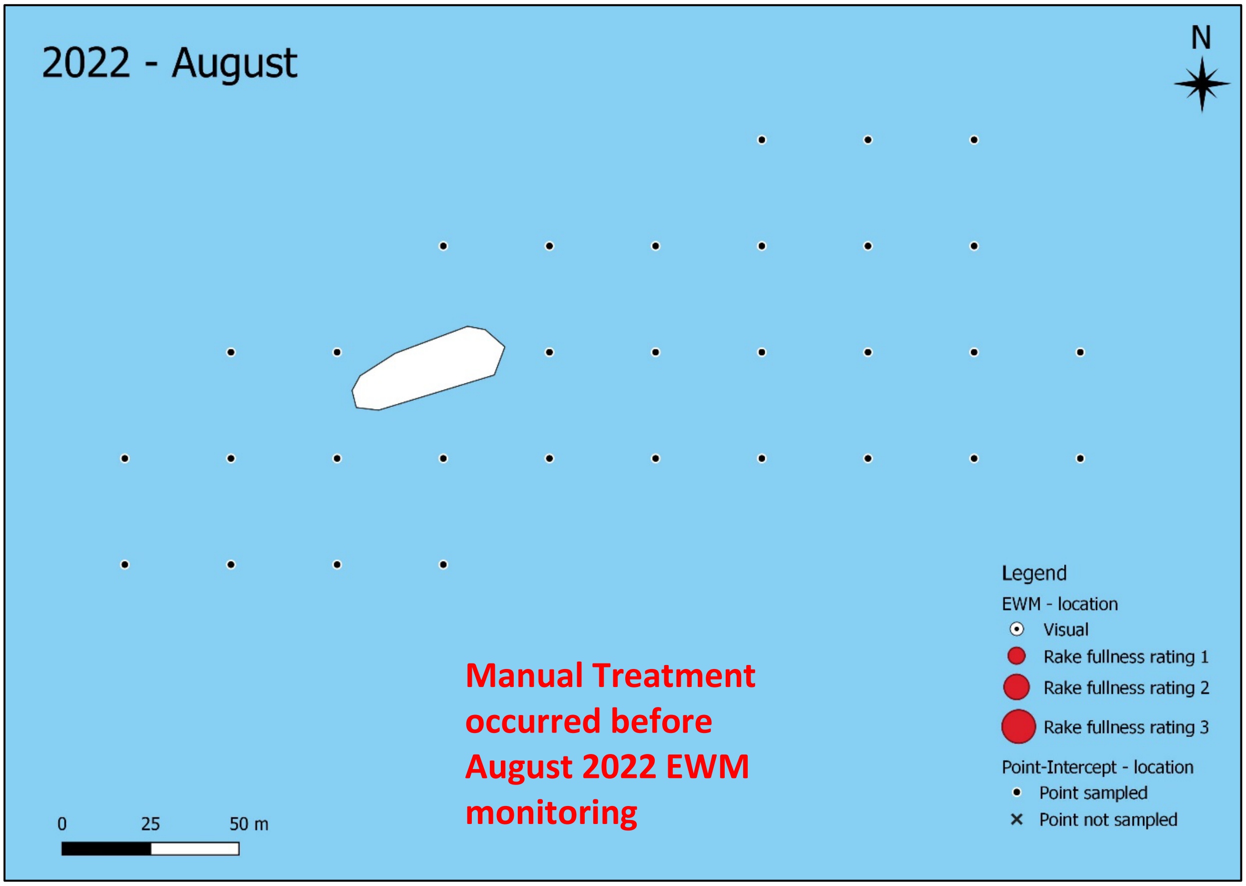
History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 13 (a & b)



History of EWM distribution and rake fullness on the Point-Intercept grid of Polygon 14a

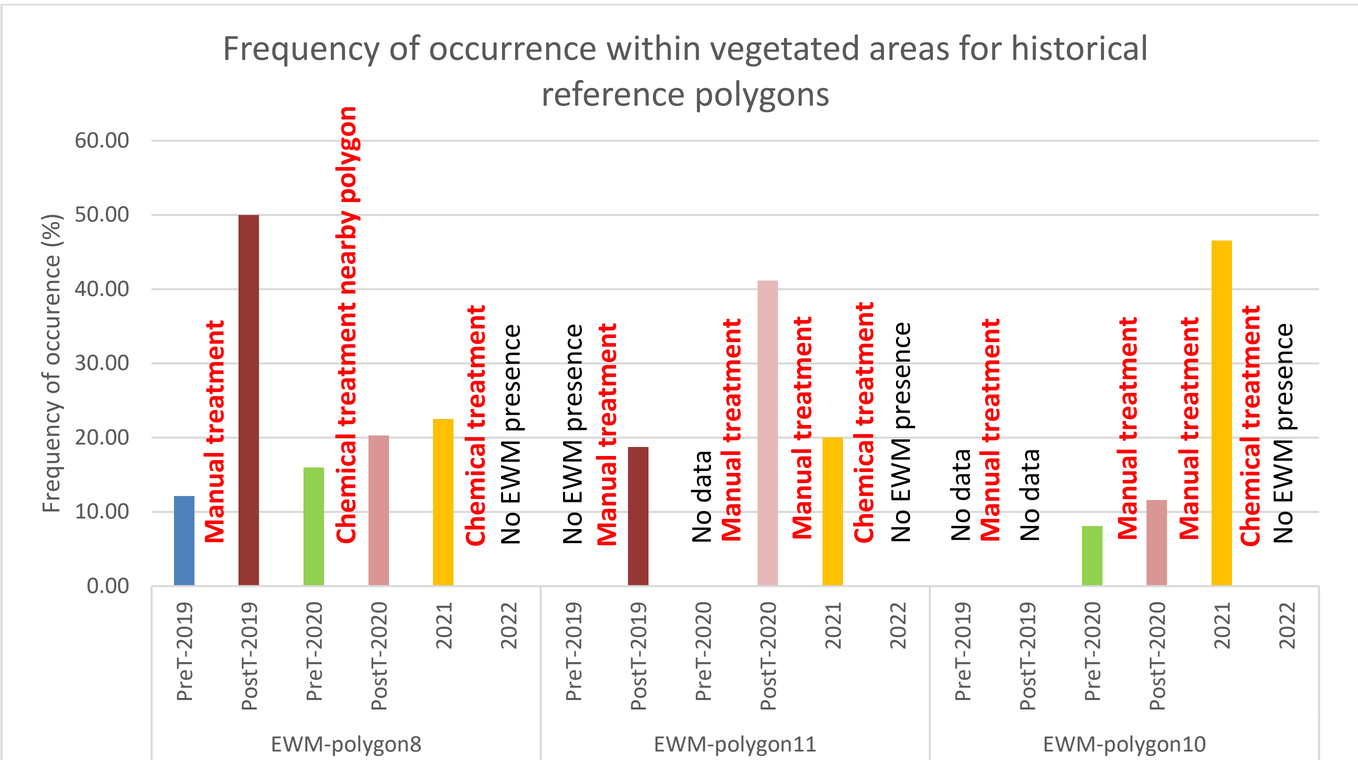


History of EWM distribution and rake fullness on the Point-Intercept grid of the Island Polygon



The practical value of reference polygons

The concept and need for a reference polygon (also called control polygons) is an important topic to consider in management of aquatic invasive species. Ideally, reference polygons are areas consistently left un-managed so that the effectiveness of the management can be clearly assessed. It is crucial to compare a treated area to an untreated area to feel confident that you are actually evaluating the plants' response to the treatment. Established reference polygons are important for the duration of the management process.

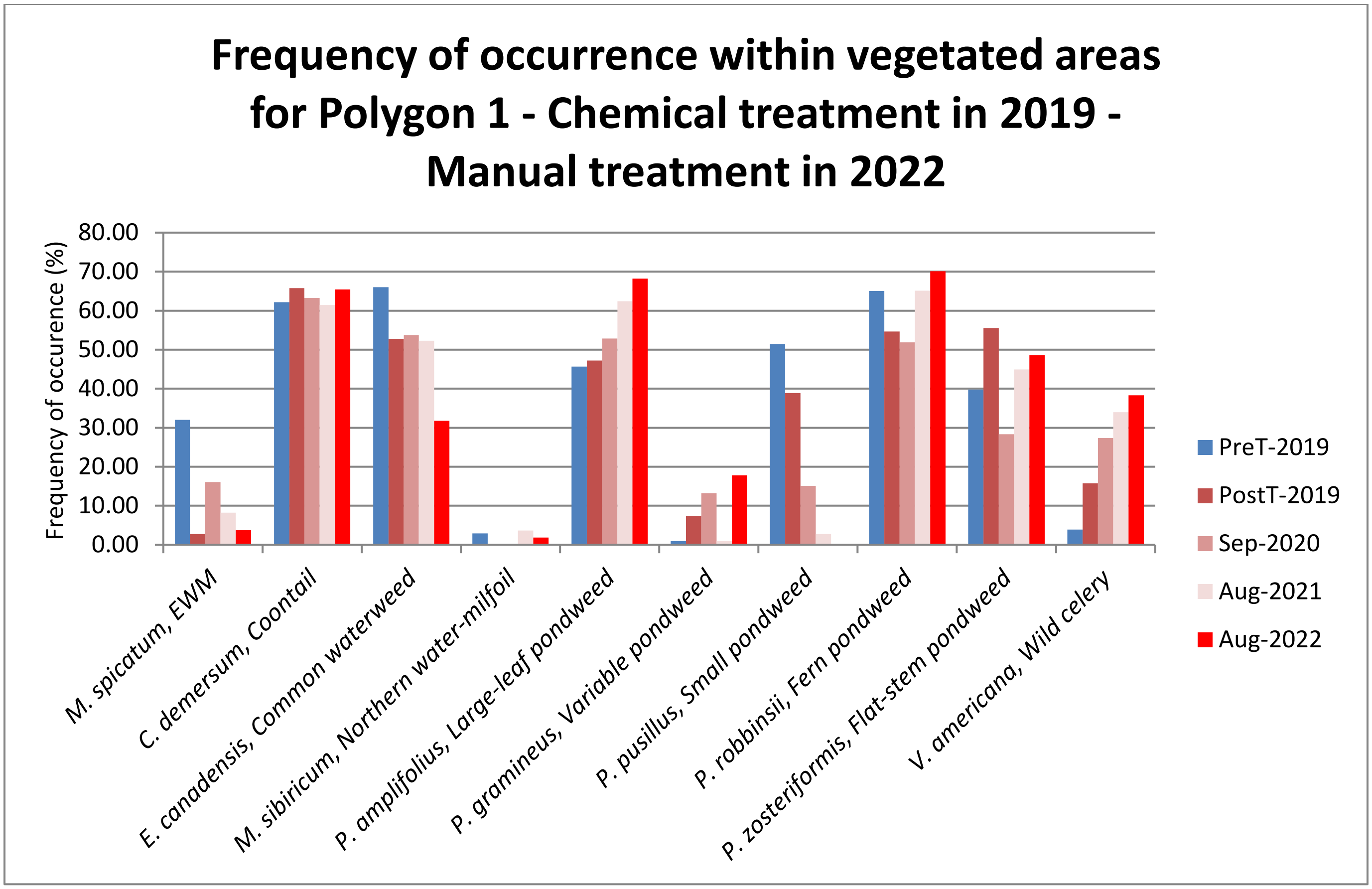


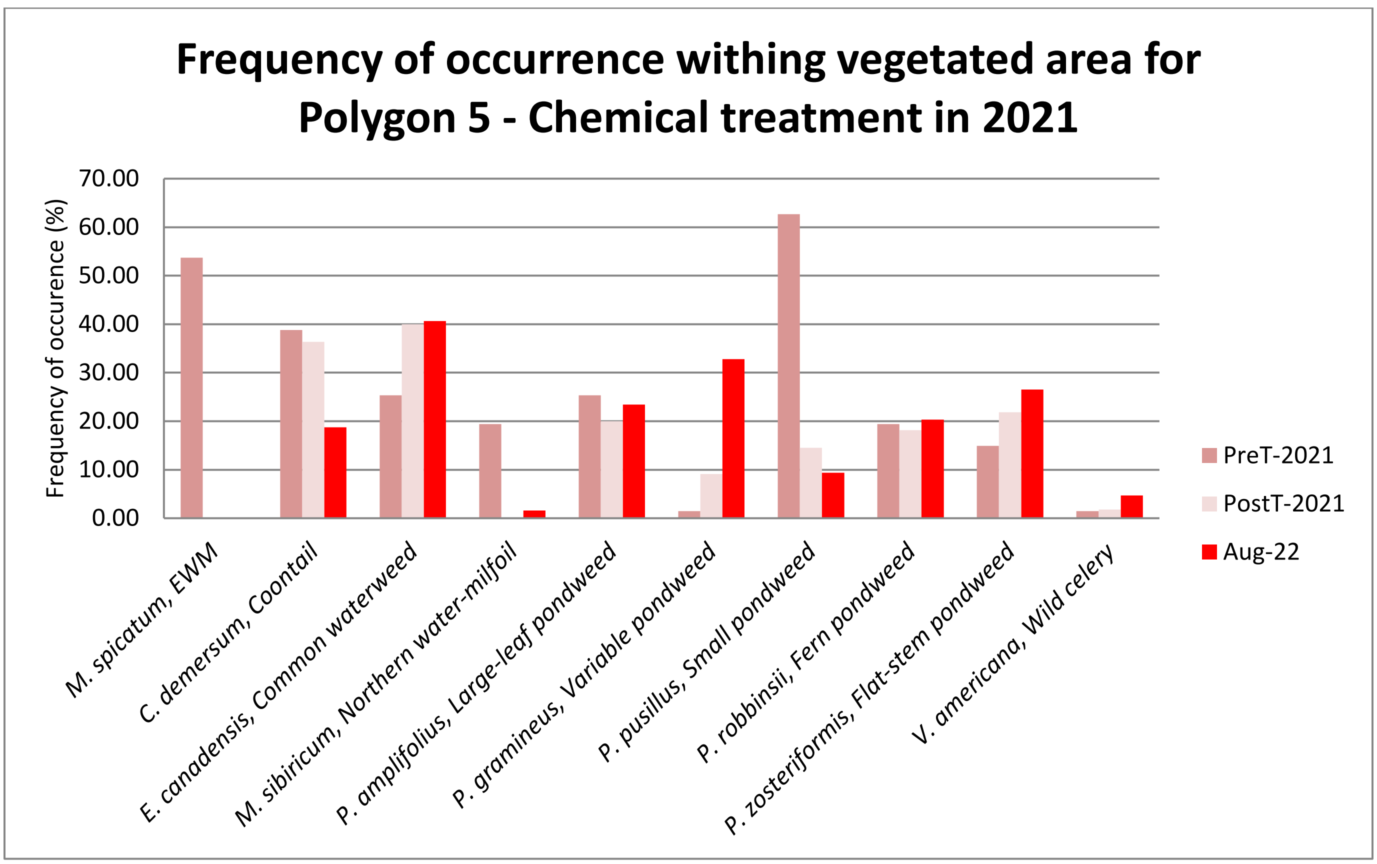
Three reference polygons have been used over the years to compare the outcomes of the chemical treatment. Within the three polygons, the frequency of occurrence for EWM has not been consistent from one reference polygon to another for a variety of reasons including management treatments that in retrospect should not have been conducted at these locations.

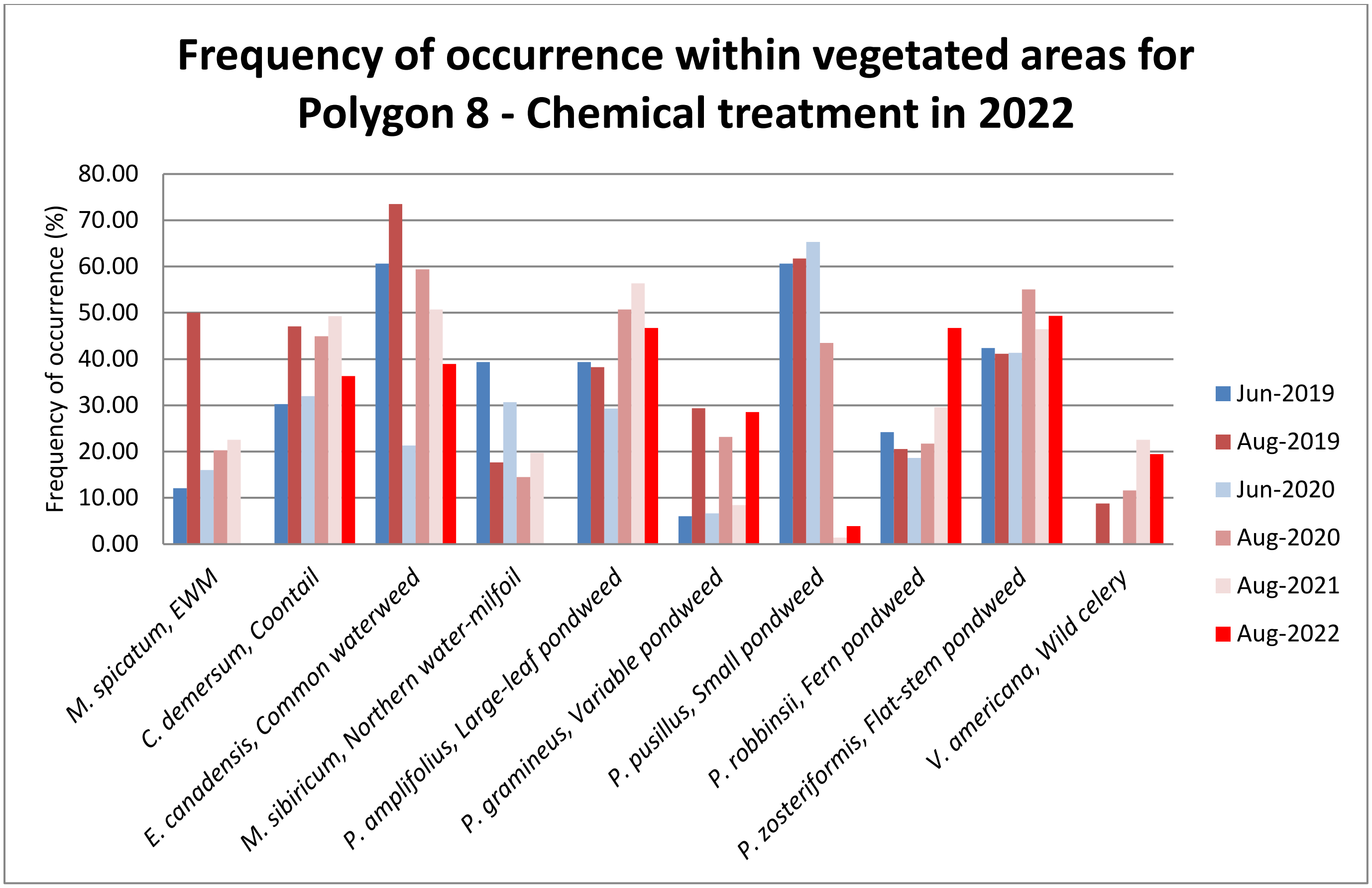
In 2022, all three reference polygons received a chemical treatment and therefore can no longer be considered as true reference sites. In fact, no other polygon was suitable to be considered reference site in 2022. Because of this, a comparison of before and after treatment conditions does not evaluate the effect of the treatment alone but is possibly confounded by other environmental variability (for example, turbidity, water temperature, nutrients, and weather).

Histograms of the frequency of occurrence for the ten most common Crescent Lake aquatic plant species over time

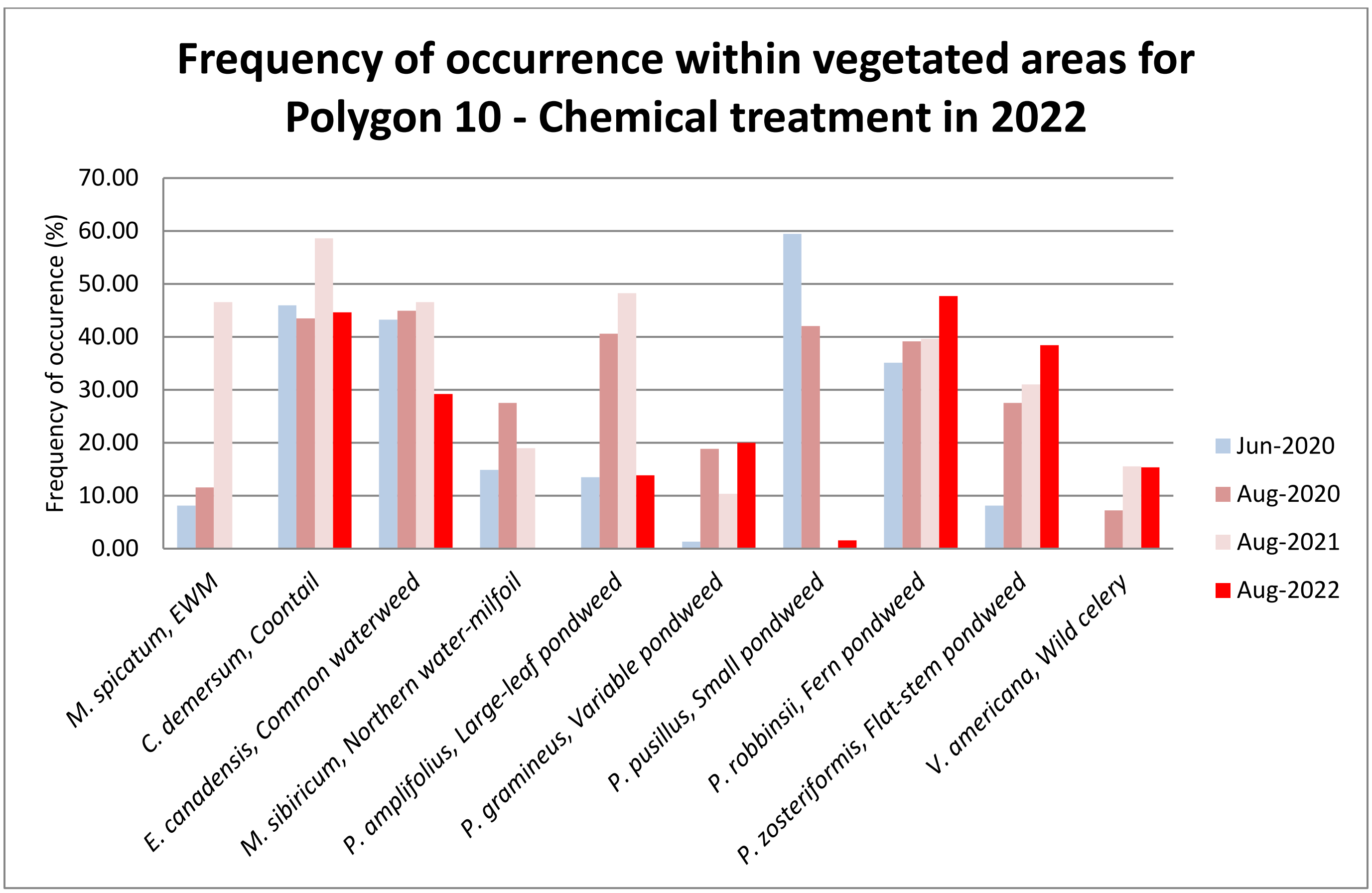
The following histograms present the change overtime of the frequency of occurrence within vegetated areas for the ten most common aquatic plant species in Crescent Lake. This frequency of occurrence represented in percentage (%) is the number of sites at which a species was observed divided by the total number of vegetated sites. These histograms permit us to assess if any common species has been affected by the chemical treatments and how the affected species frequency of occurrence has changed over the period of study.


Frequency of occurrence within vegetated areas for Polygon 1 - Chemical treatment in 2019 - Manual treatment in 2022
Frequency of occurence (%)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
PreT-2019
PostT-2019
Sep-2020
Aug-2021
Aug-2022

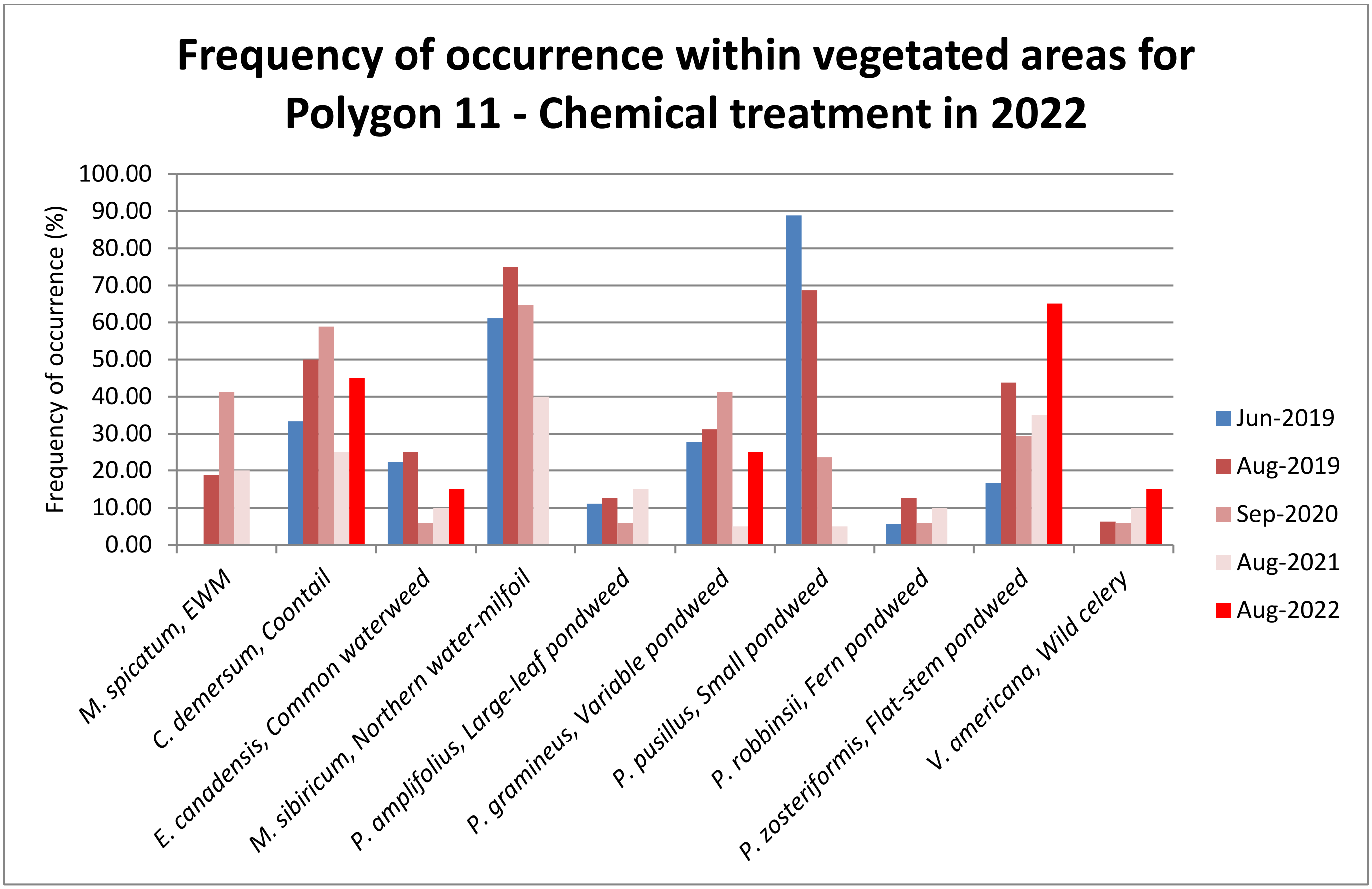

Frequency of occurrence withing vegetated area for Polygon 5 - Chemical treatment in 2021
Frequency of occurence (%)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
PreT-2021
PostT-2021
Aug-22



Frequency of occurrence within vegetated areas for Polygon 8 - Chemical treatment in 2022
Frequency of occurrence (%)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Jun-2019
Aug-2019
Jun-2020
Aug-2020
Aug-2021
Aug-2022



Frequency of occurrence within vegetated areas for Polygon 10 - Chemical treatment in 2022
Frequency of occurence (%)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Jun-2020
Aug-2020
Aug-2021
Aug-2022



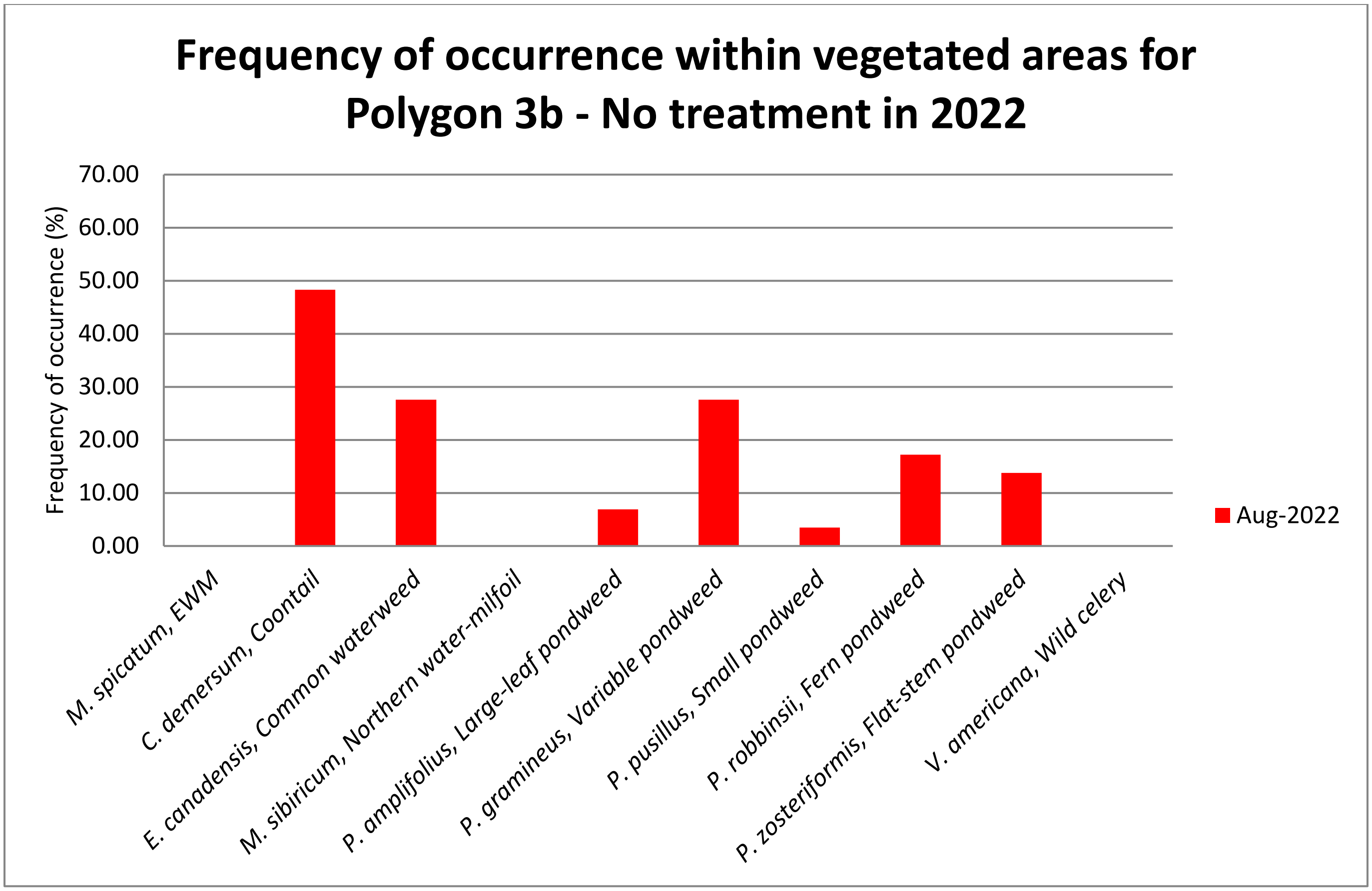
The features of the histograms on the preceding pages are integrated in the following table that states the observed outcomes of chemical treatment for the ten most common Crescent Lake aquatic plant species.

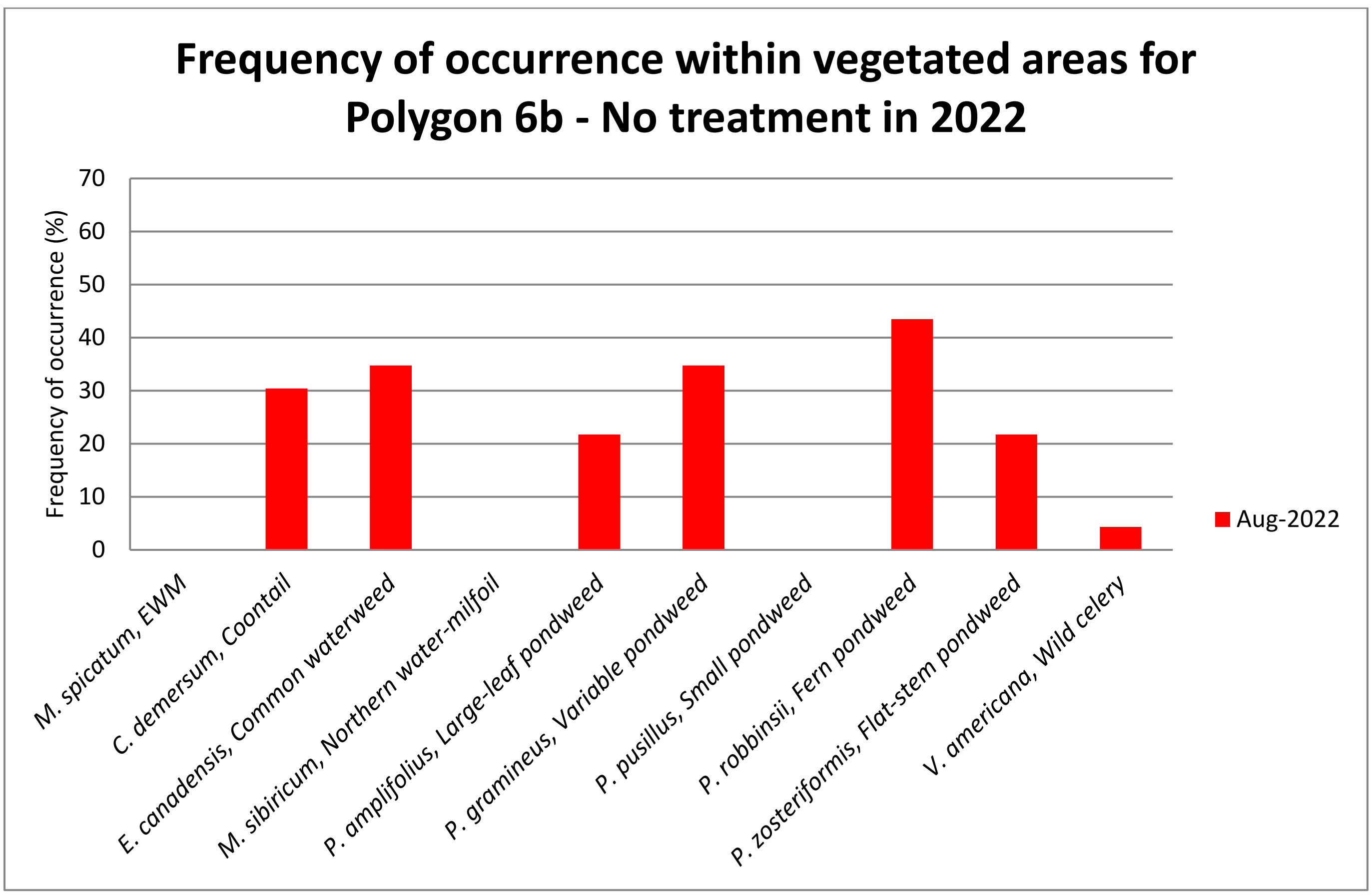
Table 1. Observed outcomes of chemical treatment for the ten most common Crescent Lake aquatic plant species

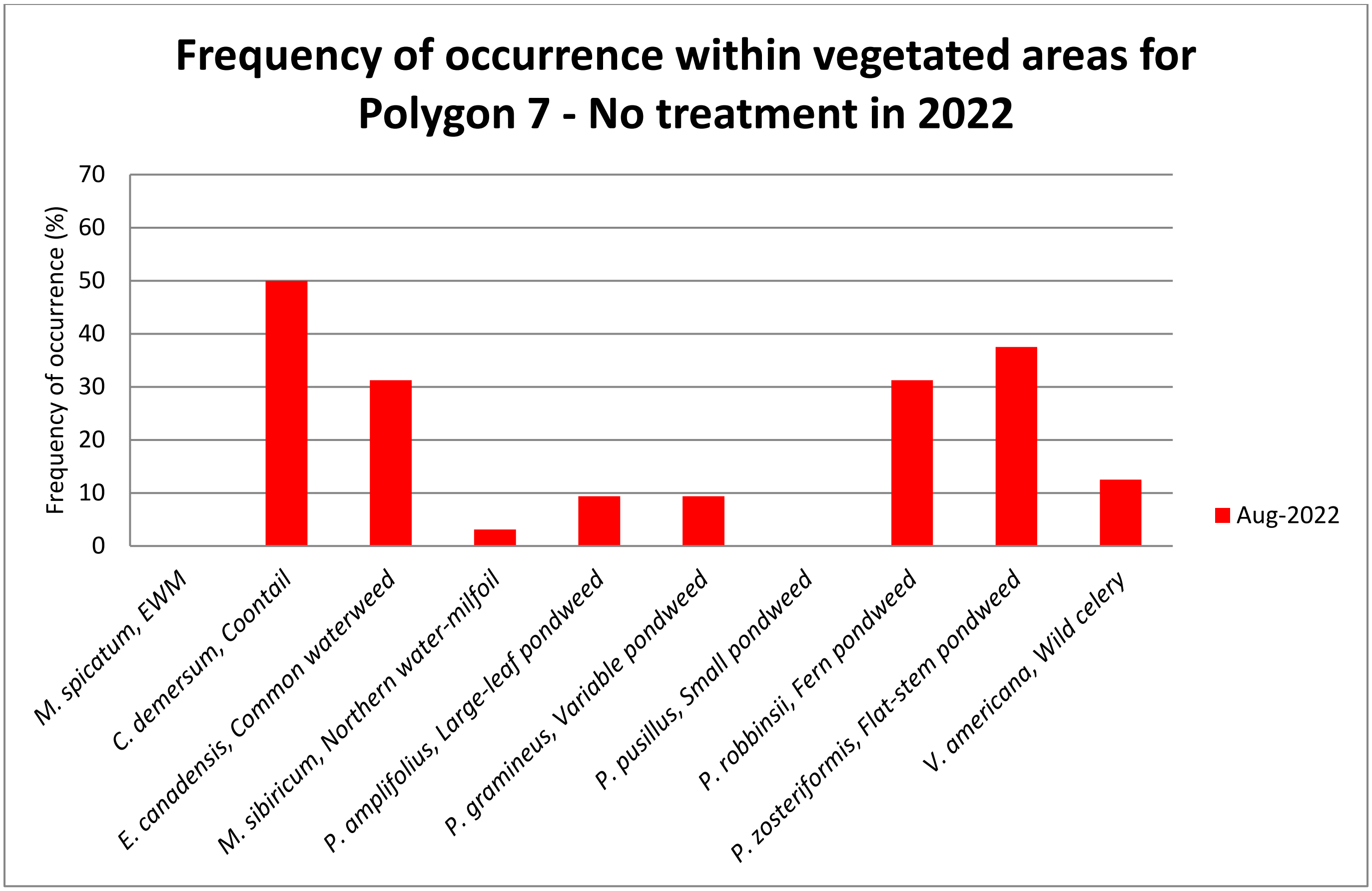
Species	Treatment observation	Chemical treatment effect
M. spicatum, Eurasian watermilfoil (EWM)	EWM was absent after the treatment for all the 2022 chemically treated Polygons and still absent in Polygon 5. The frequency of occurrence in Polygon 1 is very low.	Direct chemical effect is likely
C. demersum, Coontail	No consistent change in frequency of occurrence	No apparent direct chemical effect
E. canadensis, Common waterweed	No consistent change in frequency of occurrence	No apparent direct chemical effect
M. sibiricum, Northern watermilfoil	The three 2022 chemically treated polygons had a disappearance of this species. The two historically treated polygons have a low frequency of occurrence.	Direct chemical effect is likely
P. amplifolius, Large-leaf pondweed	Decrease of frequency after treatment. The two historically treated polygons have an increase of frequency of occurrence.	Direct chemical effect is likely
P. gramineus, Variable pondweed	No real consistent pattern	No apparent direct chemical effect
P. pusillus, Small pondweed	Decrease of frequency over the years	No apparent direct chemical effect
P. robbinsii, Fern pondweed	No real consistent pattern	No apparent direct chemical effect
P. zosteriformis, Flat-stem pondweed	No real consistent pattern	No apparent direct chemical effect
V. americana, Wild celery	Light increase of the frequency of occurrence for all the polygons over the years	No apparent direct chemical effect

Histograms of the frequency of occurrence for the ten most common Crescent Lake aquatic plant species of the new polygons monitored in 2022

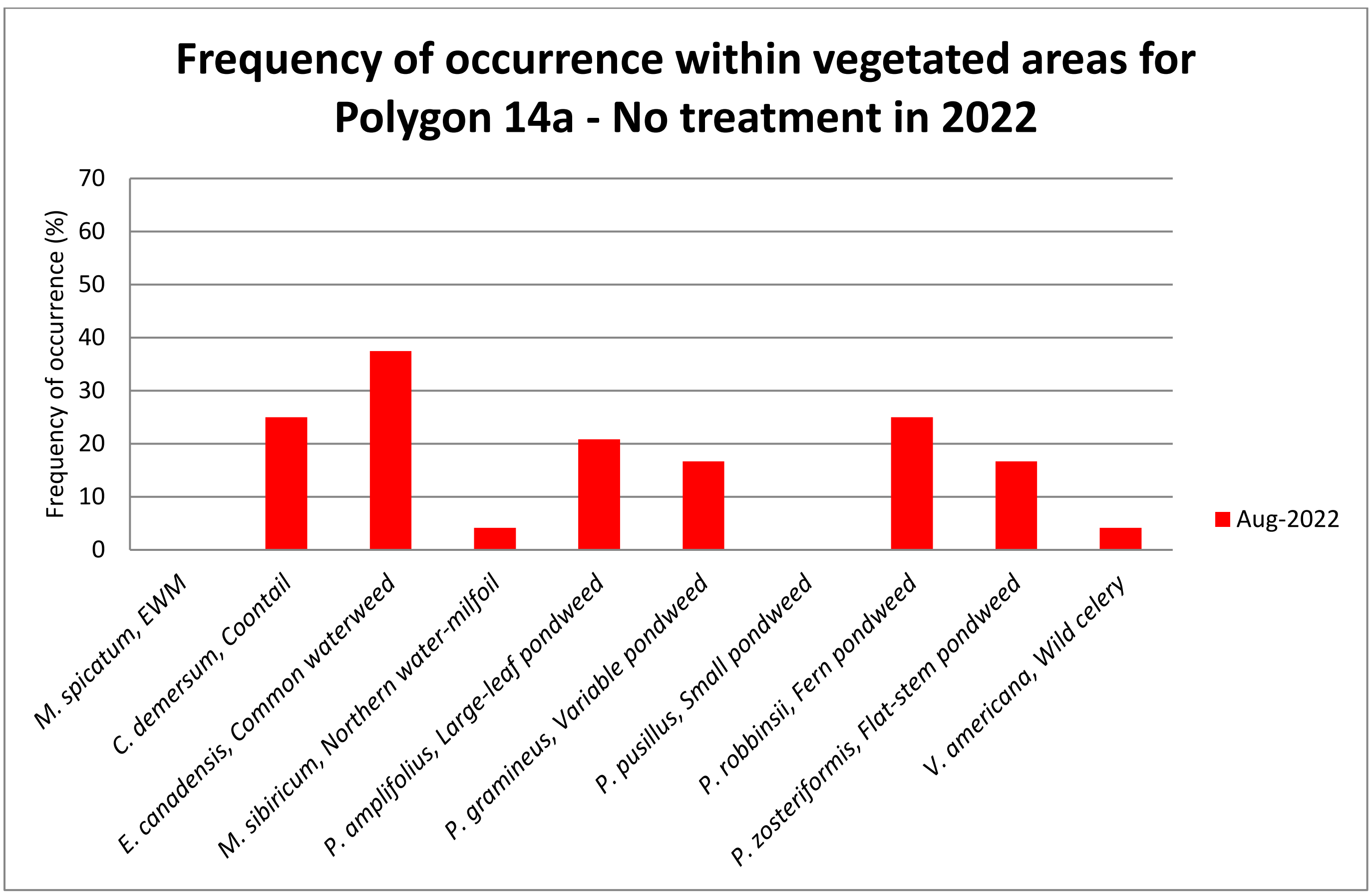
The following histograms present the frequency of occurrence for the ten most common aquatic plant species in Crescent Lake in the eight new polygons monitored in 2022 using the point-intercept method. Some polygons were chemically treated prior to the point-intercept aquatic plant survey (Polygon 12a, 12c and 13). The Island polygon was manually treated by a Diver Assisted Suction Harvesting (DASH) team. Polygons 3b, 6b, 7 and 14a were not treated in 2022. These histograms illustrate the 2022 frequencies of occurrence for the ten most common aquatic plant species and could be used in the future to analyze changes over time.


Frequency of occurrence within vegetated areas for Polygon 3b - No treatment in 2022
Frequency of occurrence (%)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Aug-2022

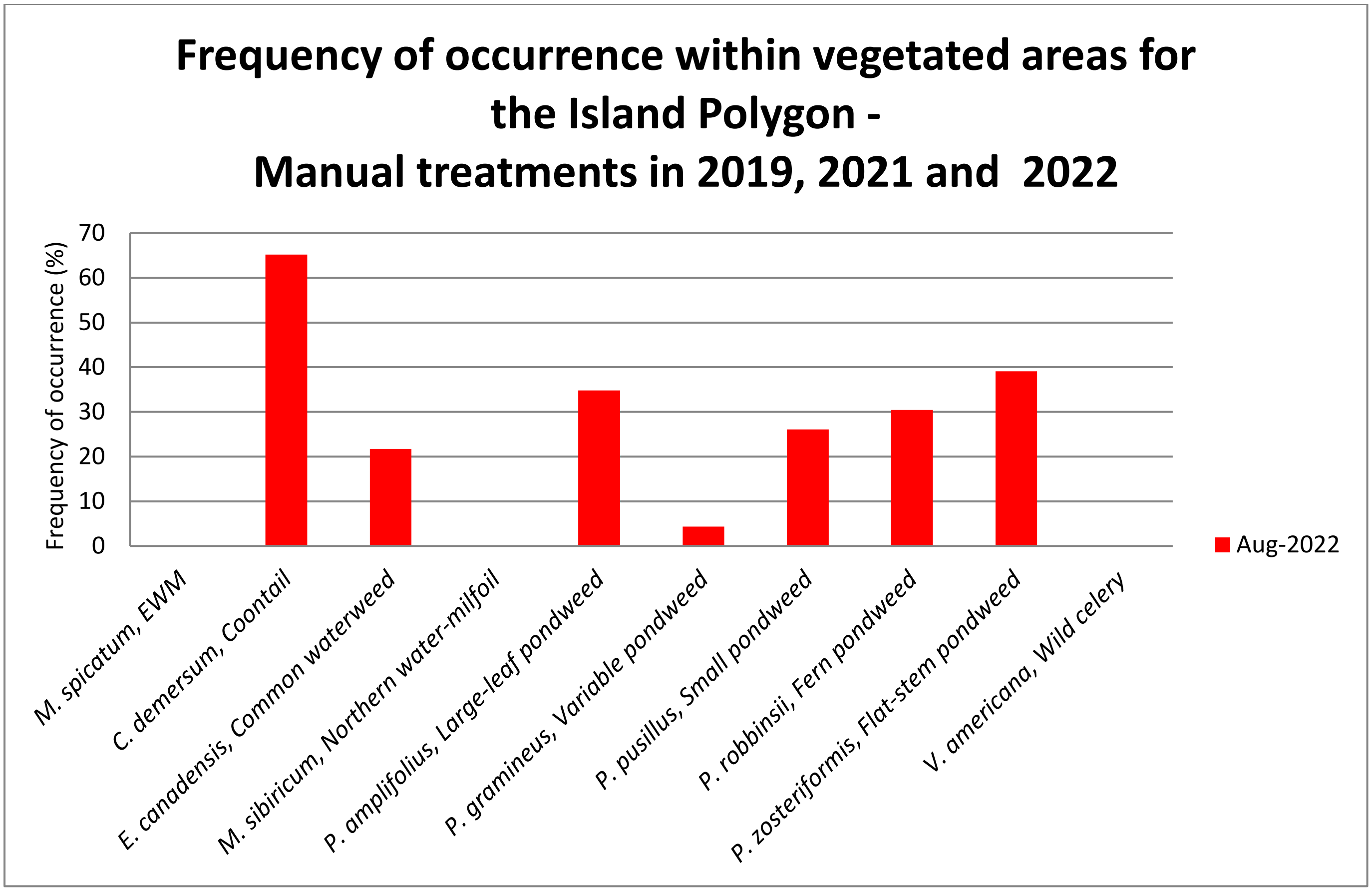

Frequency of occurrence within vegetated areas for Polygon 6b - No treatment in 2022
Frequency of occurrence (%)
70
60
50
40
30
20
10
0
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Aug-2022

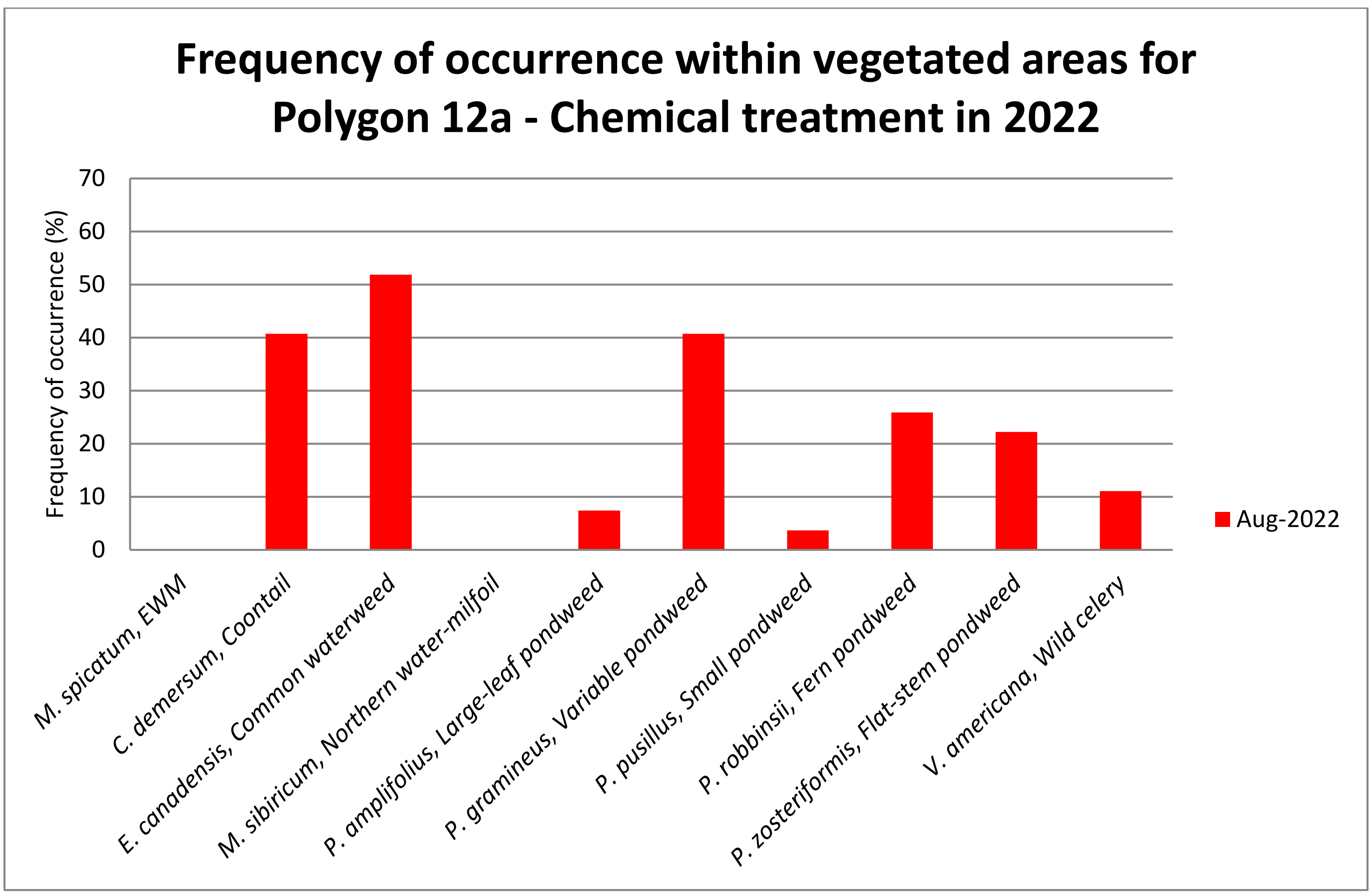


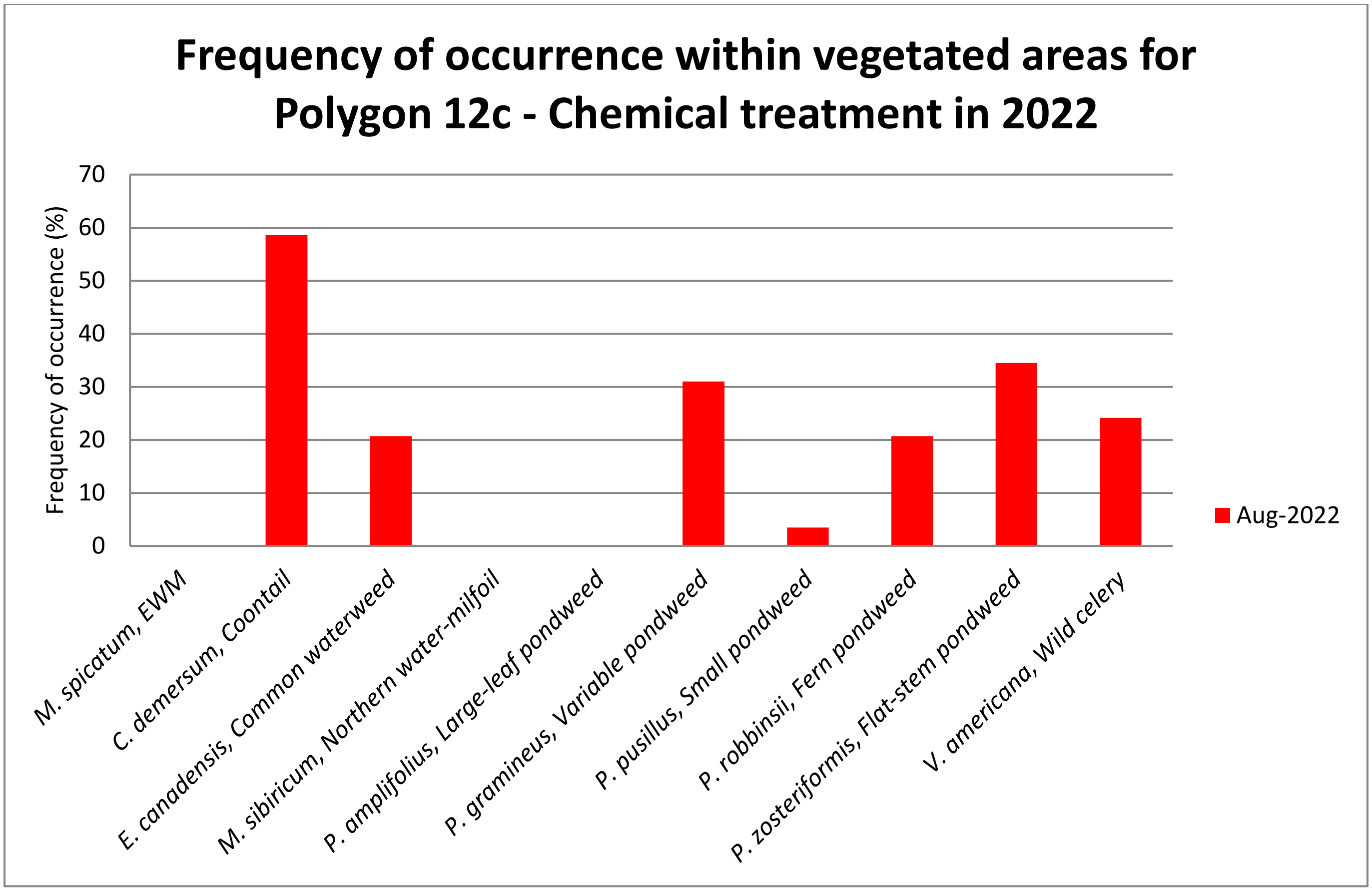
Frequency of occurrence within vegetated areas for Polygon 7 - No treatment in 2022
Frequency of occurrence (%)
0
10
20
30
40
50
60
70
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Aug-2022



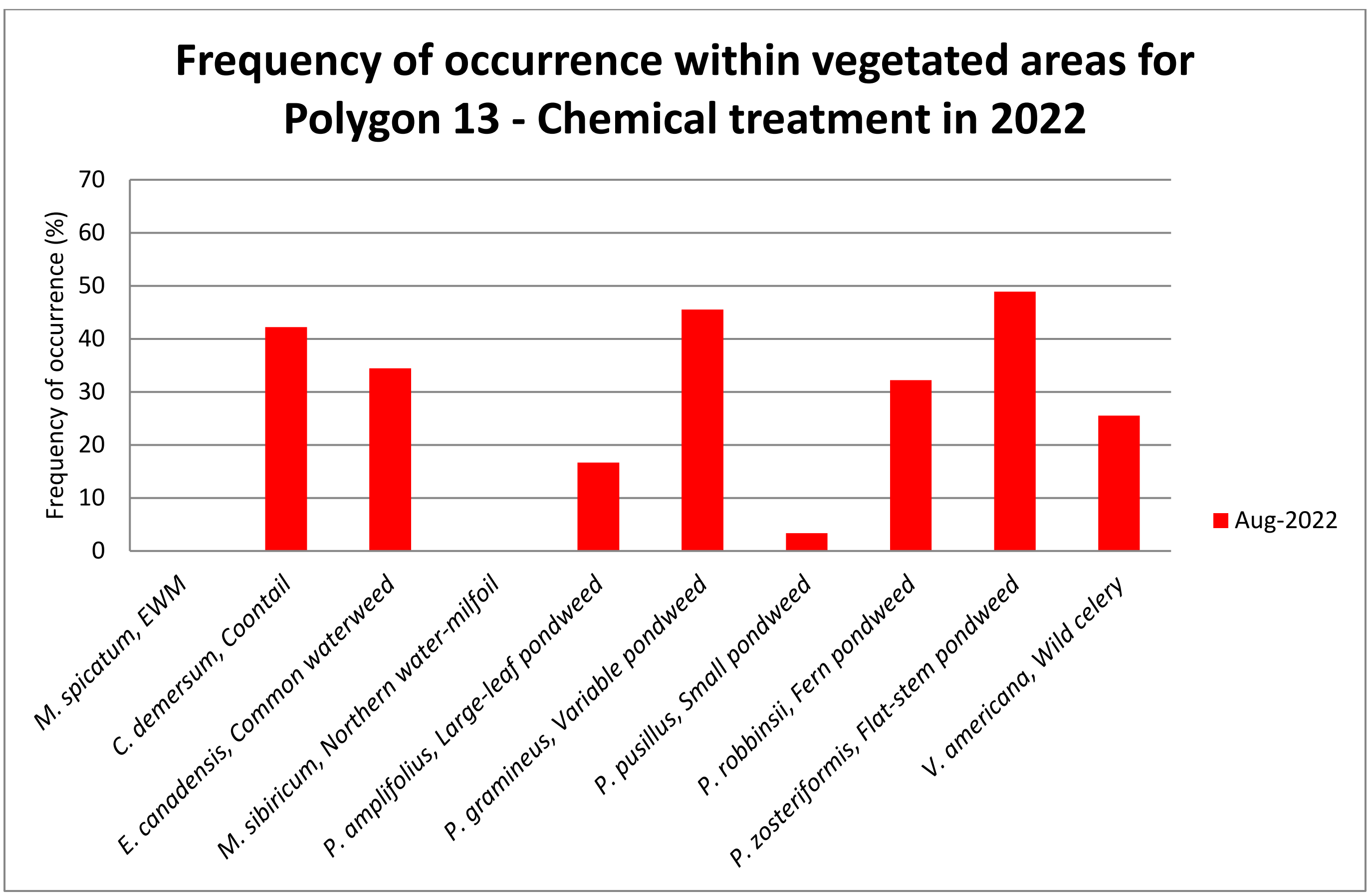
Frequency of occurrence within vegetated areas for Polygon 14a - No treatment in 2022
Frequency of occurrence (%)
0
10
20
30
40
50
60
70
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Aug-2022


Frequency of occurrence within vegetated areas for the Island Polygon - Manual treatments in 2019, 2021 and 2022
Frequency of occurrence (%)
70
60
50
40
30
20
10
0
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Aug-2022


Frequency of occurrence within vegetated areas for Polygon 12a - Chemical treatment in 2022
Frequency of occurrence (%)
70
60
50
40
30
20
10
0
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Aug-2022



Frequency of occurrence within vegetated areas for Polygon 12c - Chemical treatment in 2022
Frequency of occurrence (%)
70
60
50
40
30
20
10
0
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Aug-2022



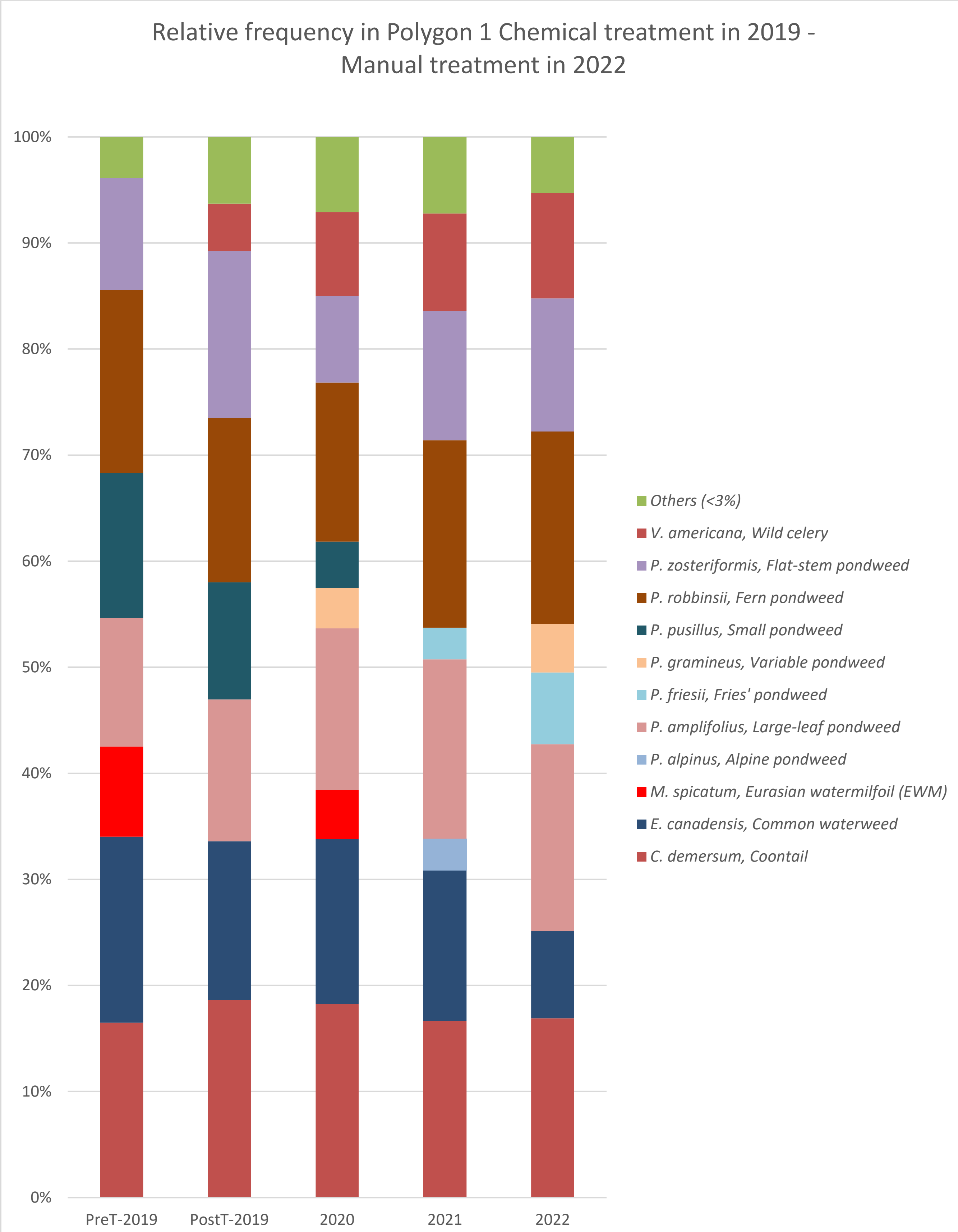
Frequency of occurrence within vegetated areas for Polygon 13 - Chemical treatment in 2022
Frequency of occurrence (%)
70
60
50
40
30
20
10
0
M. spicatum, EWM
C. demersum, Coontail
E. canadensis, Common waterweed
M. sibiricum, Northern water-milfoil
P. amplifolius, Large-leaf pondweed
P. gramineus, Variable pondweed
P. pusillus, Small pondweed
P. robbinsii, Fern pondweed
P. zosteriformis, Flat-stem pondweed
V. americana, Wild celery
Aug-2022

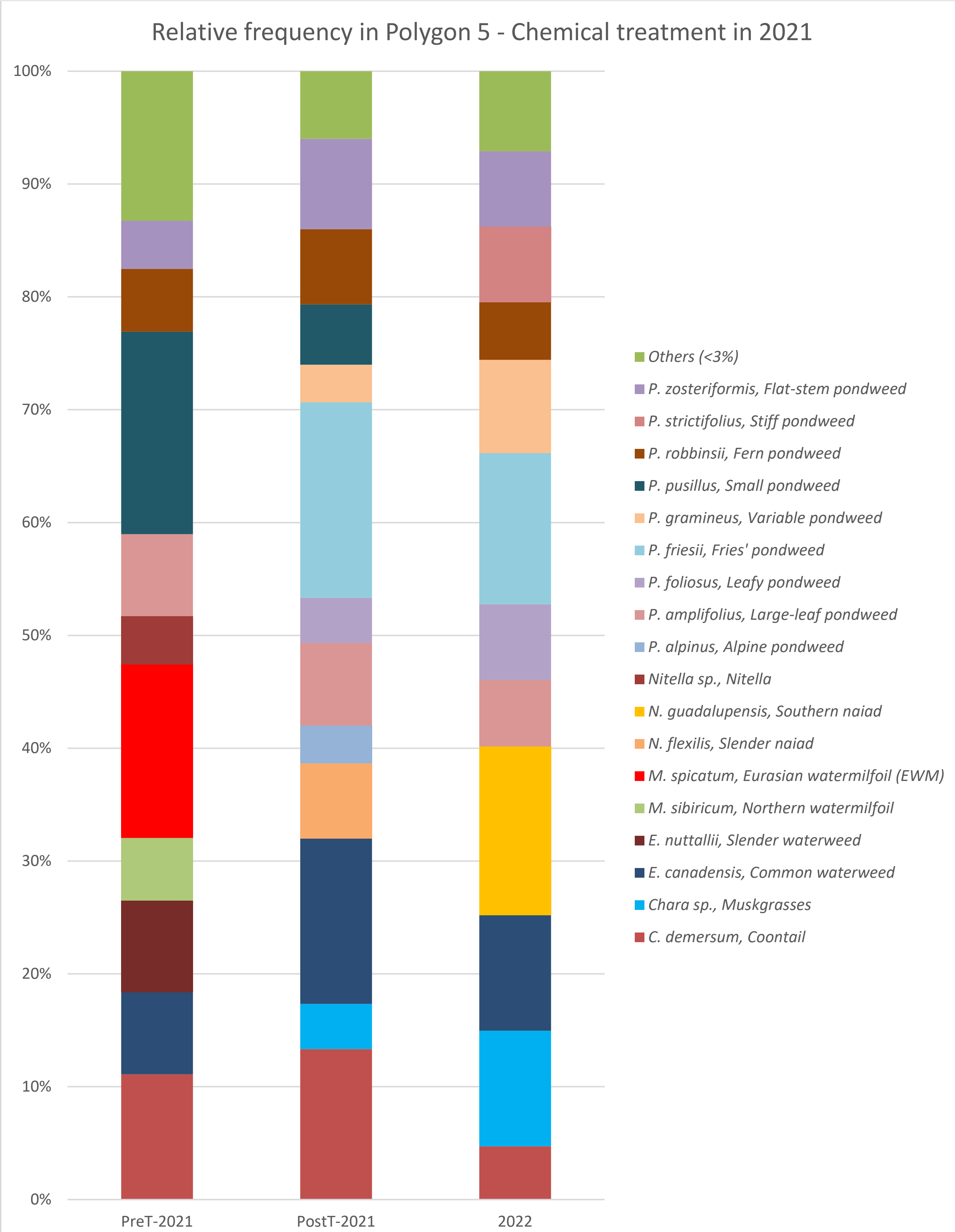
Histograms of the relative frequencies of occurrence for the plant community of Crescent Lake in the studied polygons

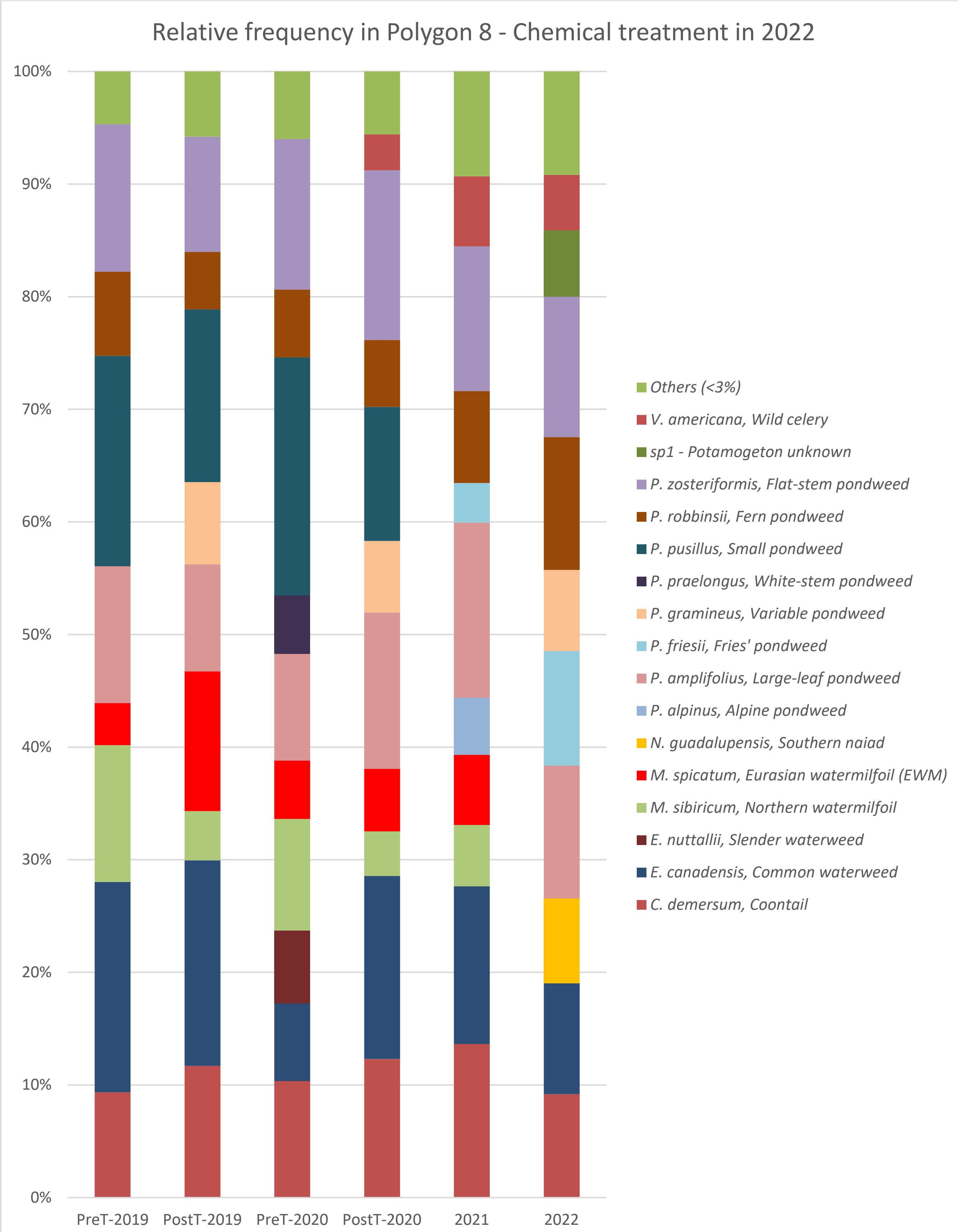
The following histograms present the relative frequencies of occurrence for the aquatic plant species in Crescent Lake in the studied polygons. This is a proportional value that reflects the degree to which an individual species contributes to the sum total of all species observations. The sum of the relative frequencies of all species is 100%. Relative frequency is not sensitive to whether all sampled sites, including non-vegetated sites, are included. It gives a good representation of the aquatic plant species composition in each polygon. Each polygon has its own suite of habitat characteristics including depth, substrate, sun exposure, current, boat activity and EWM management. This leads to each polygon having unique species composition.

If you are interested in learning about the identification of aquatic plants, we recommend two excellent references:

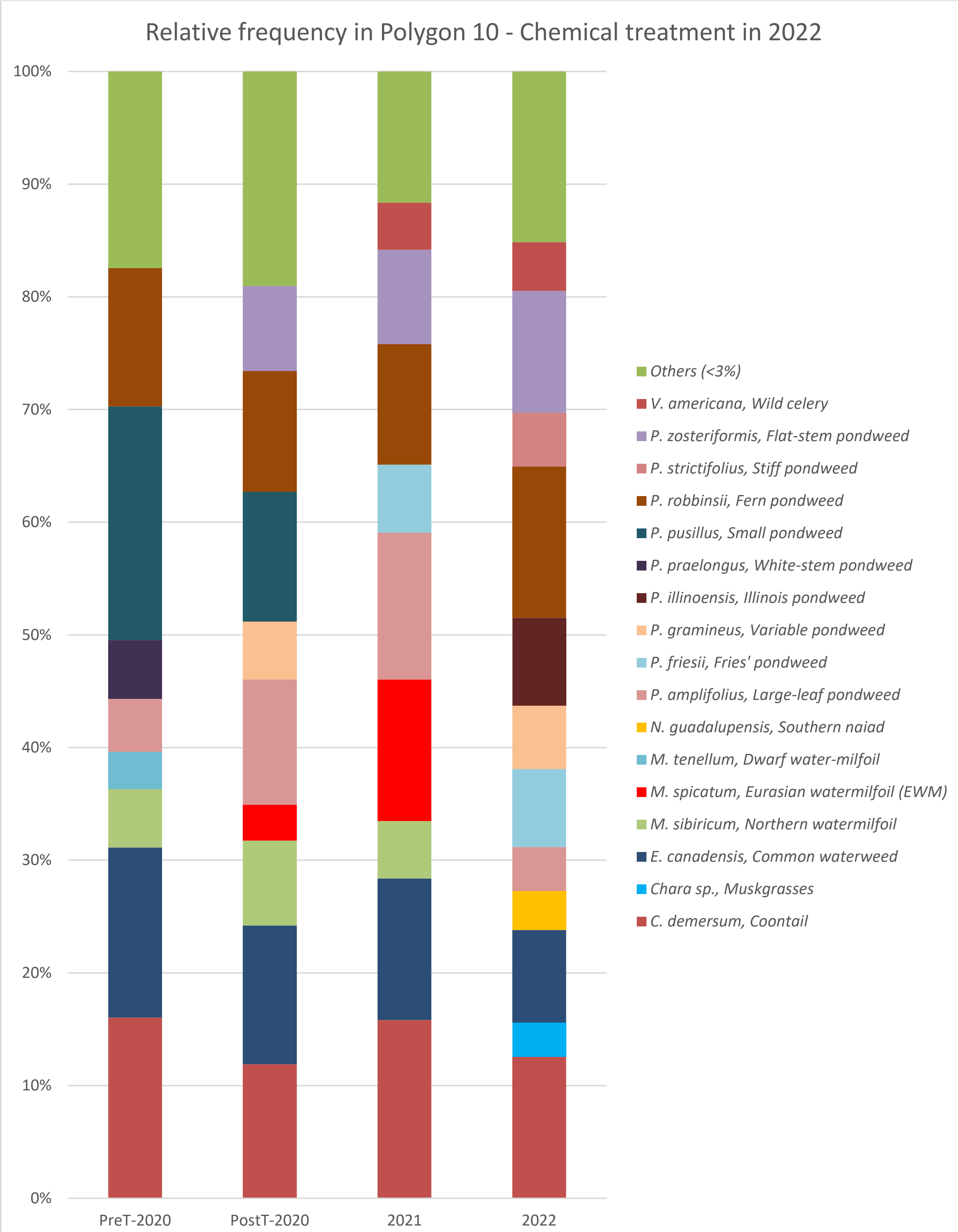
- Aquatic Plants of the Upper Midwest: A Photographic Field Guide to Our Underwater Forests. 4^{th} Edition (2019). Paul M. Skawinski.
- Through the Looking Glass: A Field Guide to Aquatic Plants. 1997. Susan Borman, Robert Korth, Jo Temte. Wisconsin Lakes Partnership.

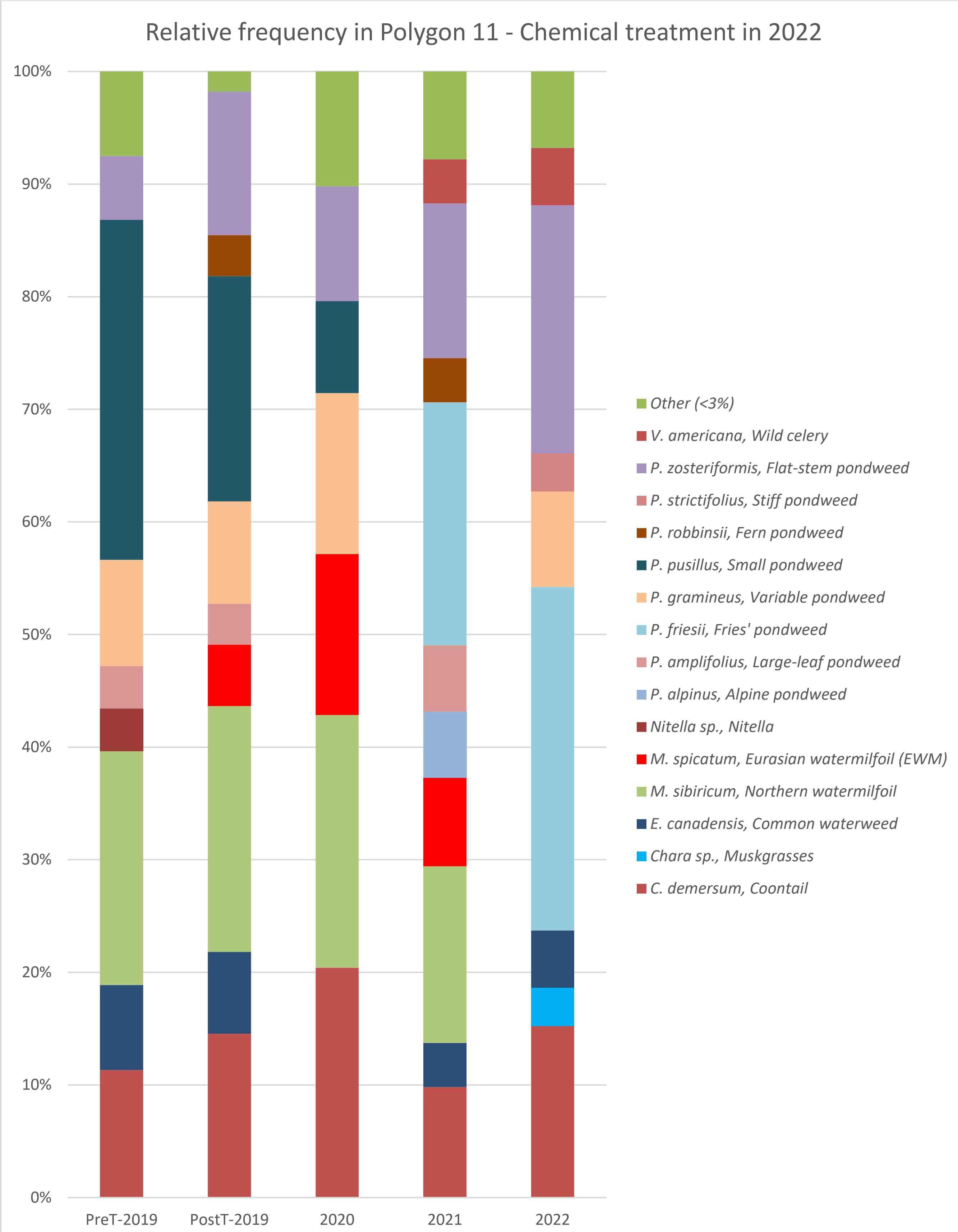

Relative frequency in Polygon 1 Chemical treatment in 2019 - Manual treatment in 2022
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
PreT-2019
PostT-2019
2020
2021
2022
Others (<3%)
V. americana, Wild celery
P. zosteriformis, Flat-stem pondweed
P. robbinsii, Fern pondweed
P. pusillus, Small pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. amplifolius, Large-leaf pondweed
P. alpinus, Alpine pondweed
M. spicatum, Eurasian watermilfoil (EWM)
E. canadensis, Common waterweed
C. demersum, Coontail

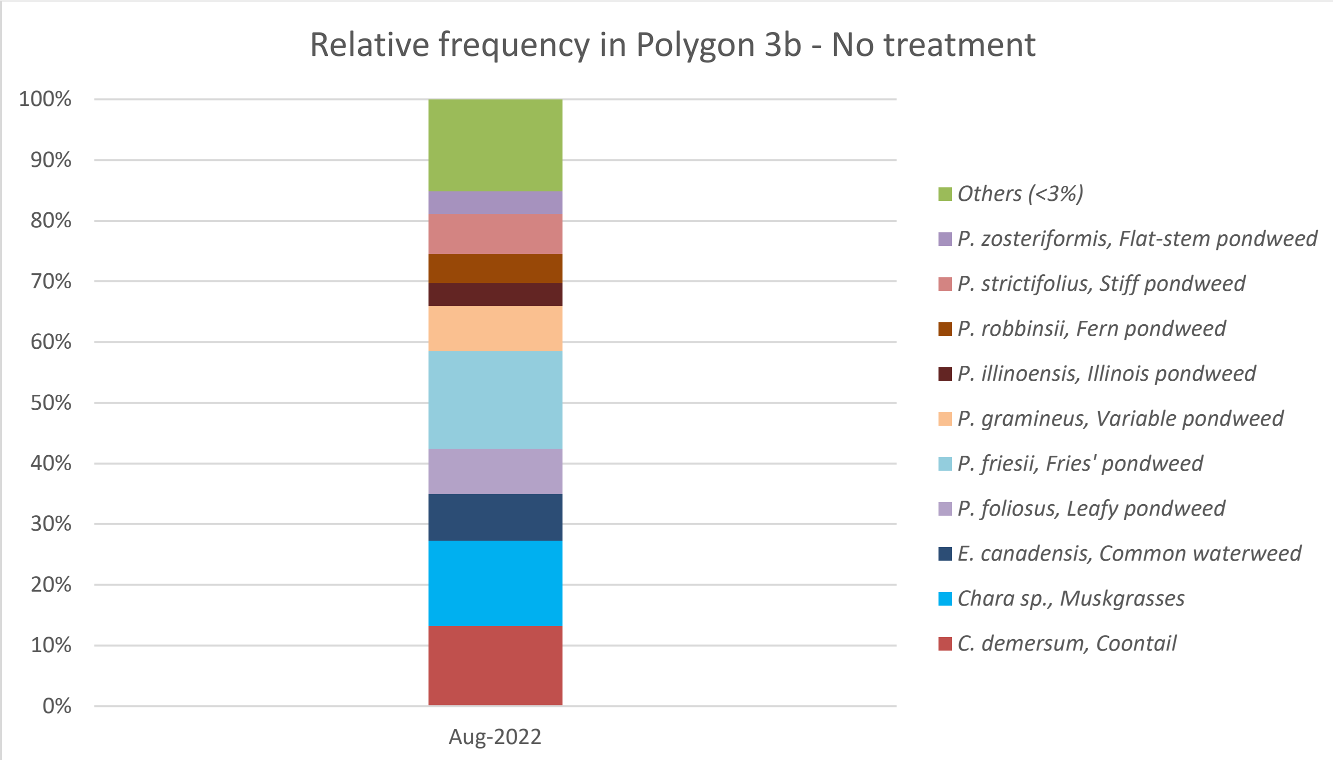

Relative frequency in Polygon 5 - Chemical treatment in 2021
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
PreT-2021
PostT-2021
2022
Others (<3%)
P. zosteriformis, Flat-stem pondweed
P. strictifolius, Stiff pondweed
P. robbinsii, Fern pondweed
P. pusillus, Small pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. foliosus, Leafy pondweed
P. amplifolius, Large-leaf pondweed
P. alpinus, Alpine pondweed
Nitella sp., Nitella
N. guadalupensis, Southern naiad
N. flexilis, Slender naiad
M. spicatum, Eurasian watermilfoil (EWM)
M. sibiricum, Northern watermilfoil
E. nuttallii, Slender waterweed
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail

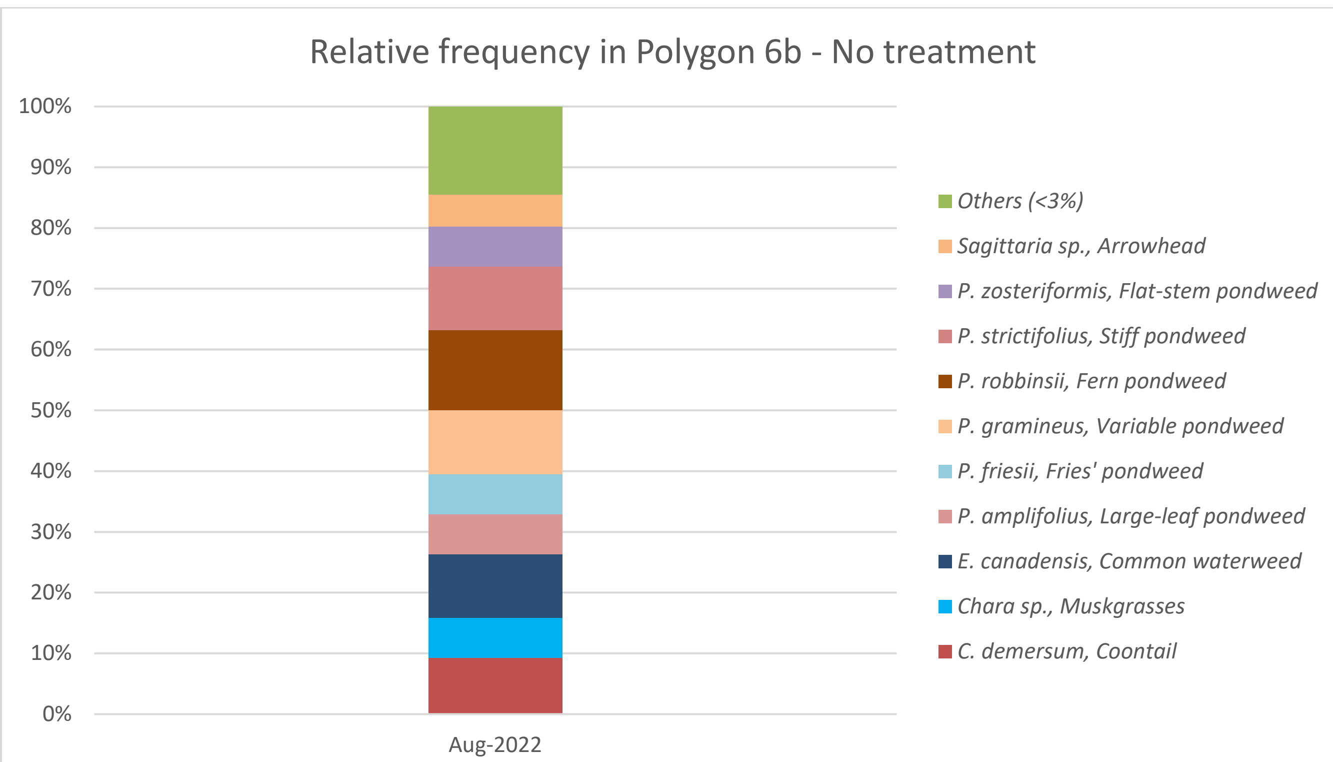


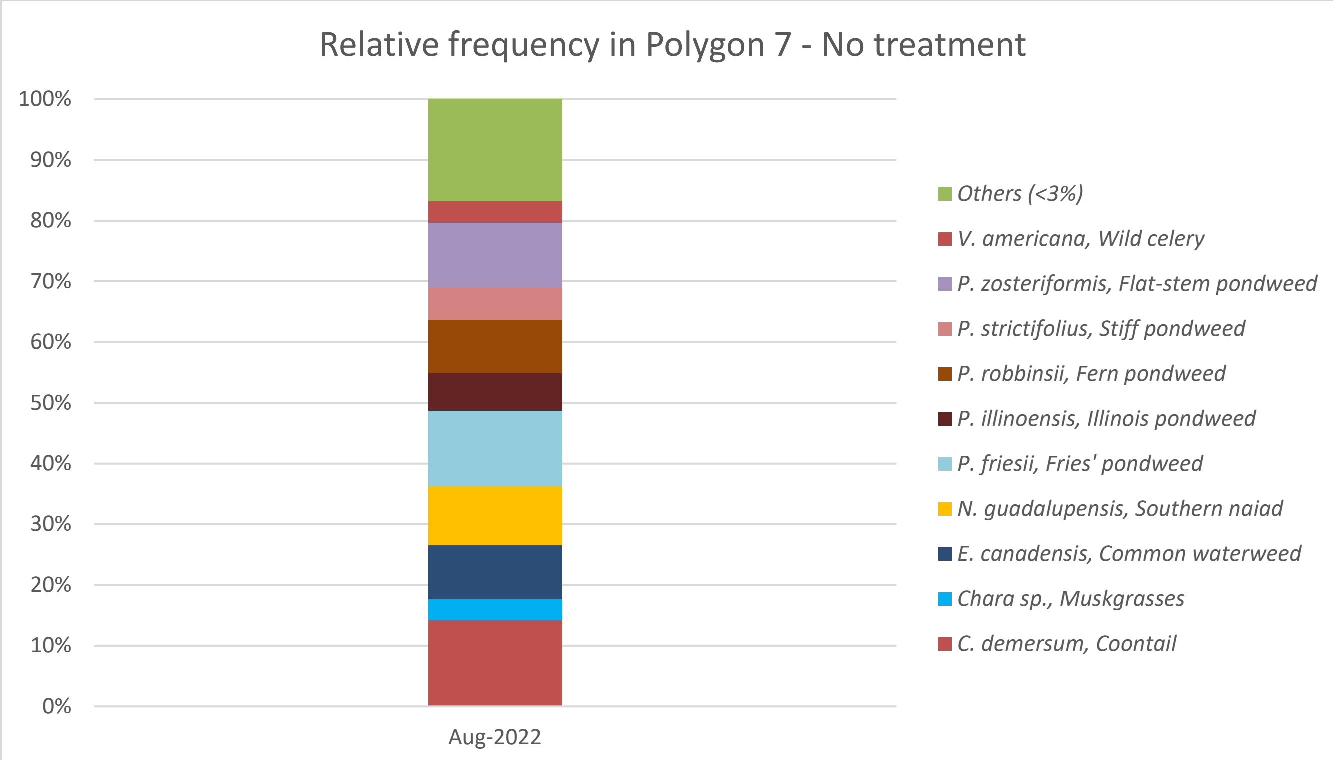
Relative frequency in Polygon 8 - Chemical treatment in 2022
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
PreT-2019
PostT-2019
PreT-2020
PostT-2020
2021
2022
Others (<3%)
V. americana, Wild celery
sp1 - Potamogeton unknown
P. zosteriformis, Flat-stem pondweed
P. robbinsii, Fern pondweed
P. pusillus, Small pondweed
P. praelongus, White-stem pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. amplifolius, Large-leaf pondweed
P. alpinus, Alpine pondweed
N. guadalupensis, Southern naiad
M. spicatum, Eurasian watermilfoil (EWM)
M. sibiricum, Northern watermilfoil
E. nuttallii, Slender waterweed
E. canadensis, Common waterweed
C. demersum, Coontail


Relative frequency in Polygon 10 - Chemical treatment in 2022
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
PreT-2020
PostT-2020
2021
2022
Others (<3%)
V. americana, Wild celery
P. zosteriformis, Flat-stem pondweed
P. strictifolius, Stiff pondweed
P. robbinsii, Fern pondweed
P. pusillus, Small pondweed
P. praelongus, White-stem pondweed
P. illinoensis, Illinois pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. amplifolius, Large-leaf pondweed
N. guadalupensis, Southern naiad
M. tenellum, Dwarf water-milfoil
M. spicatum, Eurasian watermilfoil (EWM)
M. sibiricum, Northern watermilfoil
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail

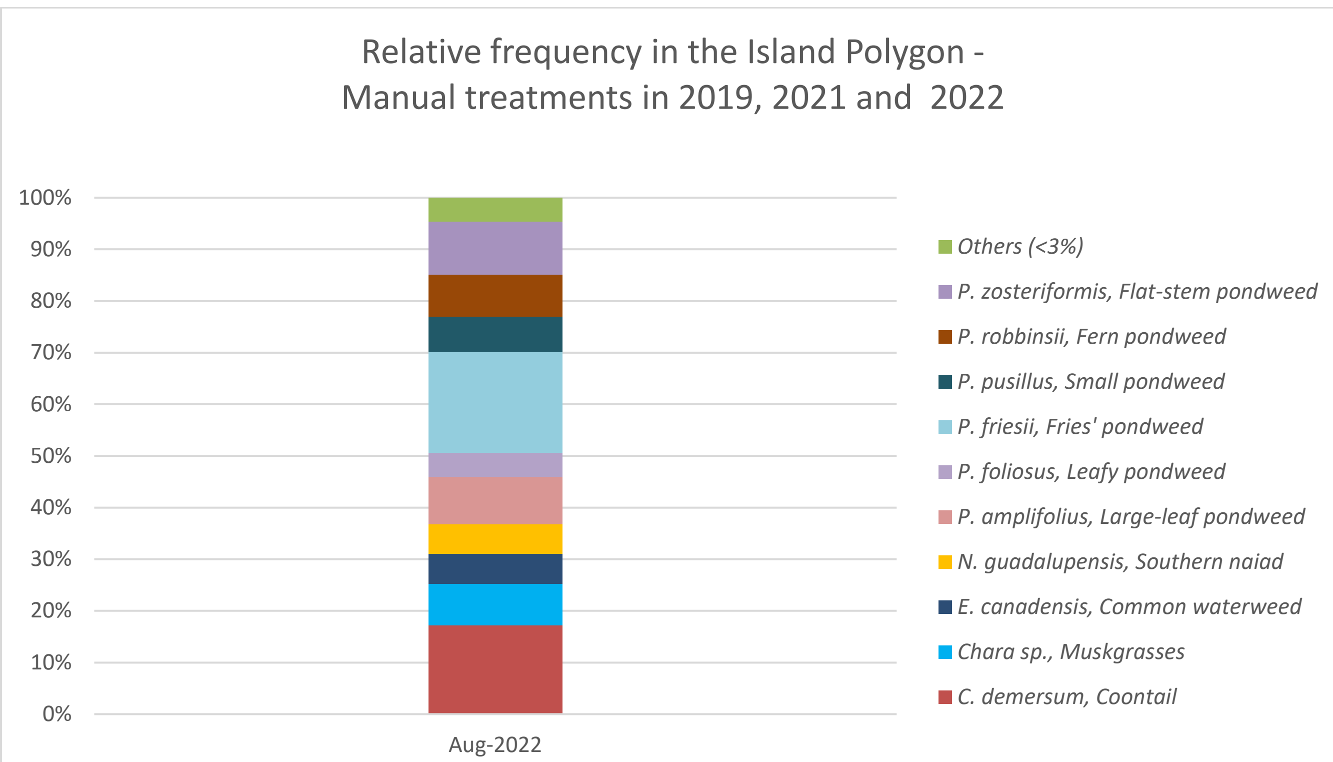

Relative frequency in Polygon 11 - Chemical treatment in 2022
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
PreT-2019
PostT-2019
2020
2021
2022
Other (<3%)
V. americana, Wild celery
P. zosteriformis, Flat-stem pondweed
P. strictifolius, Stiff pondweed
P. robbinsii, Fern pondweed
P. pusillus, Small pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. amplifolius, Large-leaf pondweed
P. alpinus, Alpine pondweed
Nitella sp., Nitella
M. spicatum, Eurasian watermilfoil (EWM)
M. sibiricum, Northern watermilfoil
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail


Relative frequency in Polygon 3b - No treatment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aug-2022
Others (<3%)
P. zosteriformis, Flat-stem pondweed
P. strictifolius, Stiff pondweed
P. robbinsii, Fern pondweed
P. illinoensis, Illinois pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. foliosus, Leafy pondweed
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail

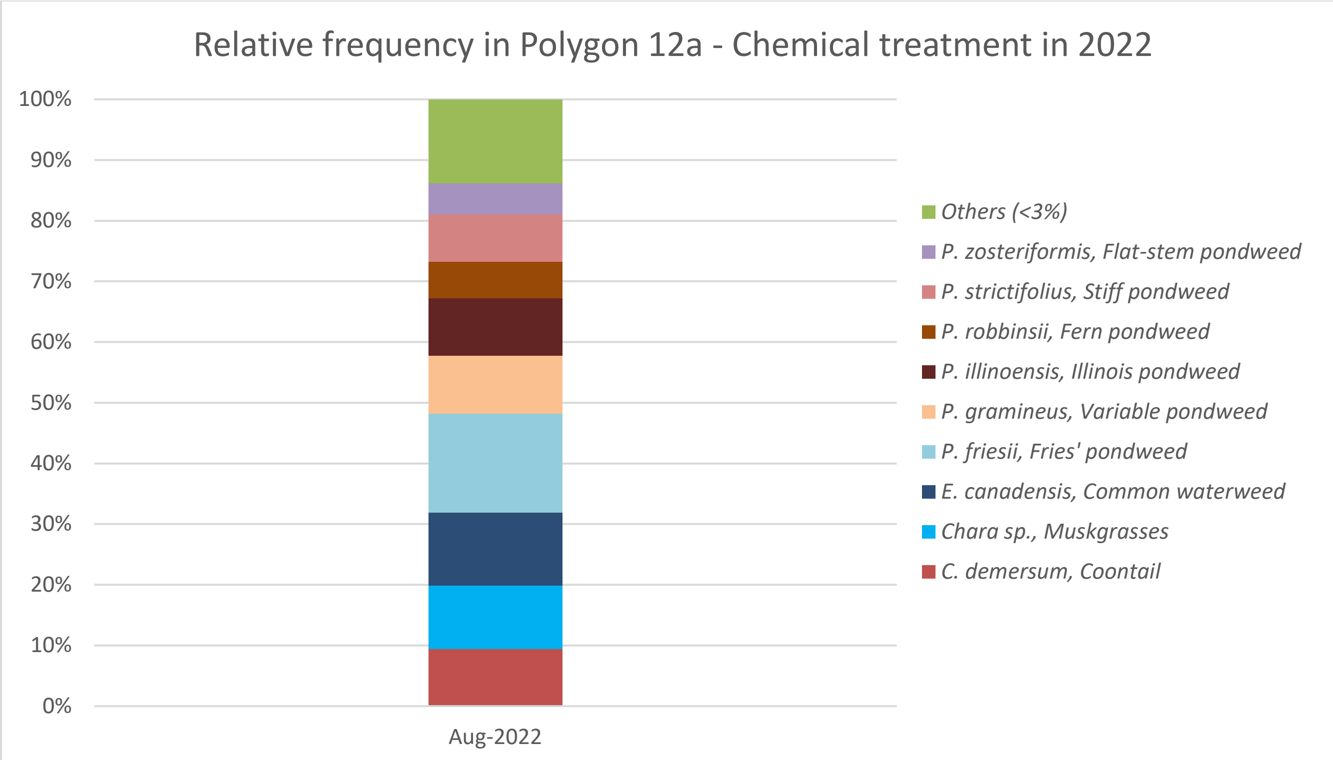

Relative frequency in Polygon 6b - No treatment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aug-2022
Others (<3%)
Sagittaria sp., Arrowhead
P. zosteriformis, Flat-stem pondweed
P. strictifolius, Stiff pondweed
P. robbinsii, Fern pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. amplifolius, Large-leaf pondweed
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail

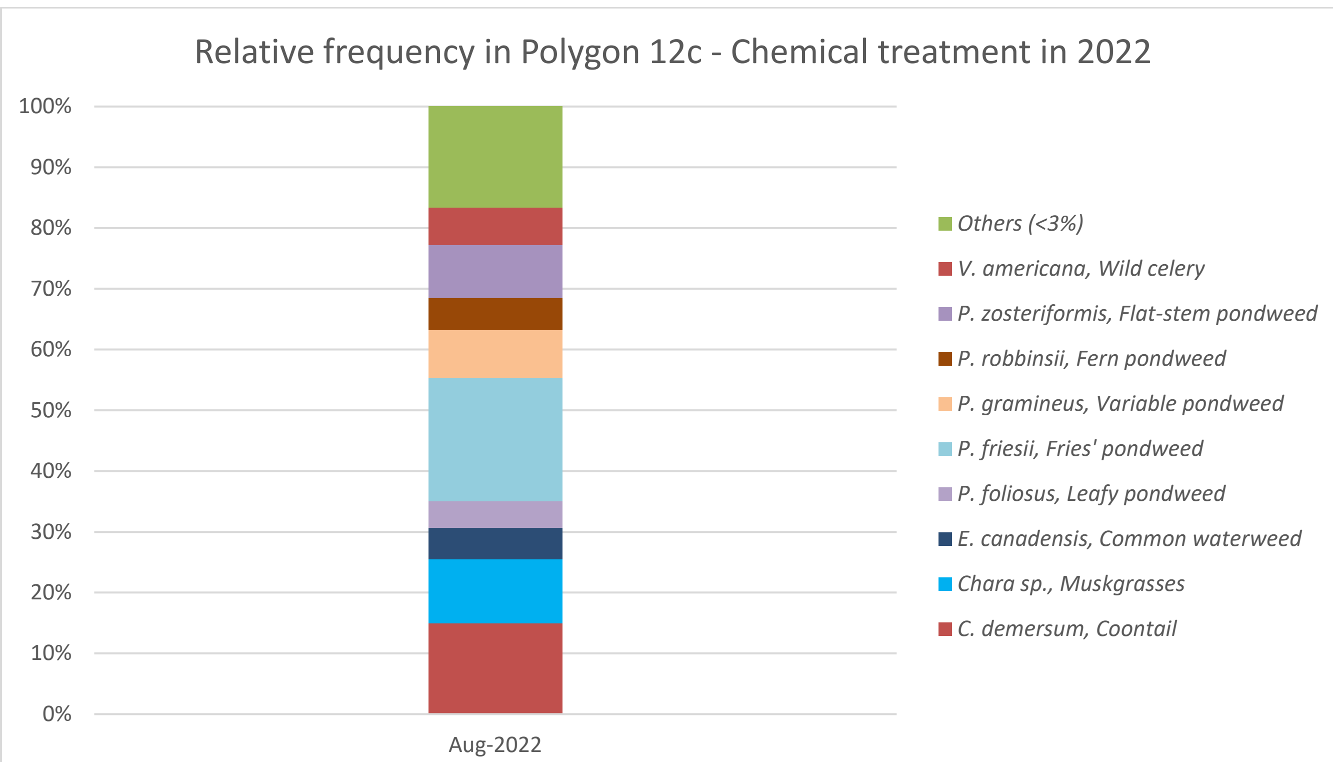


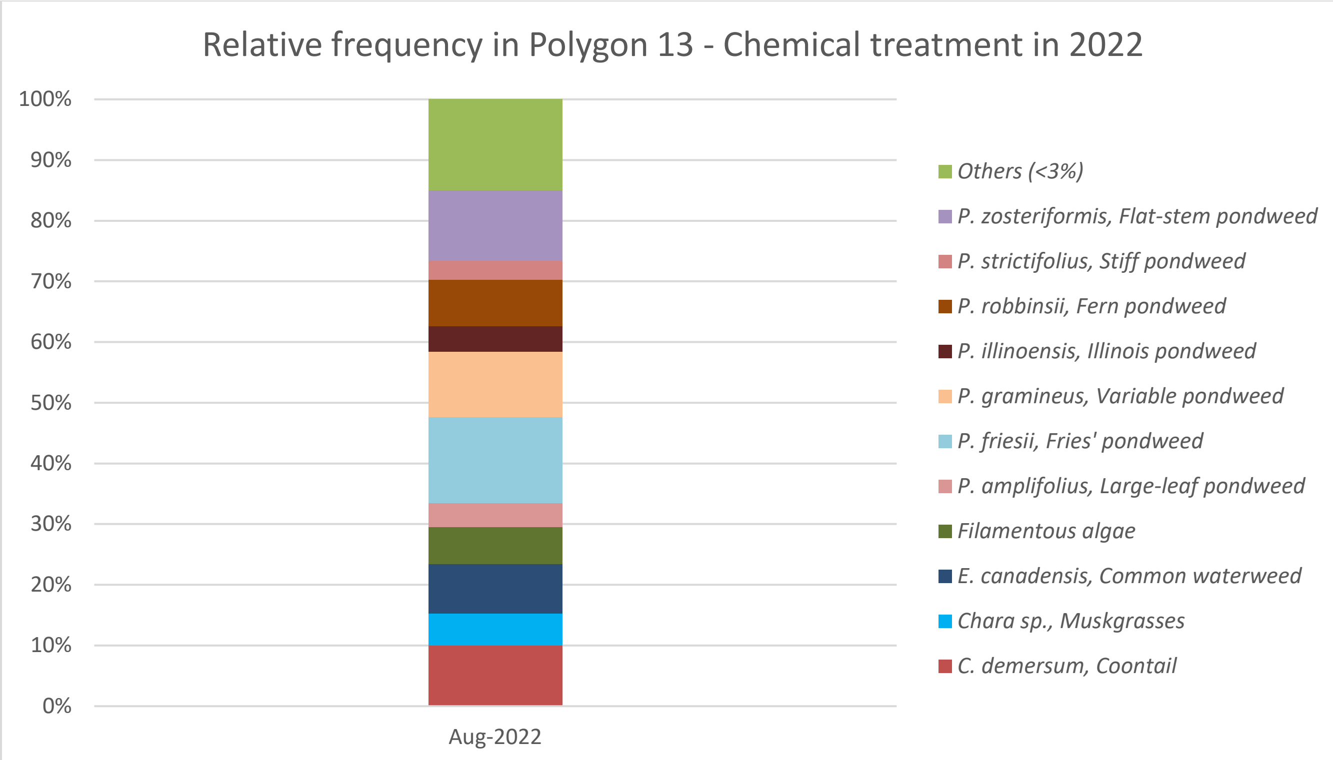
Relative frequency in Polygon 7 - No treatment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aug-2022
Others (<3%)
V. americana, Wild celery
P. zosteriformis, Flat-stem pondweed
P. strictifolius, Stiff pondweed
P. robbinsii, Fern pondweed
P. illinoensis, Illinois pondweed
P. friesii, Fries' pondweed
N. guadalupensis, Southern naiad
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail



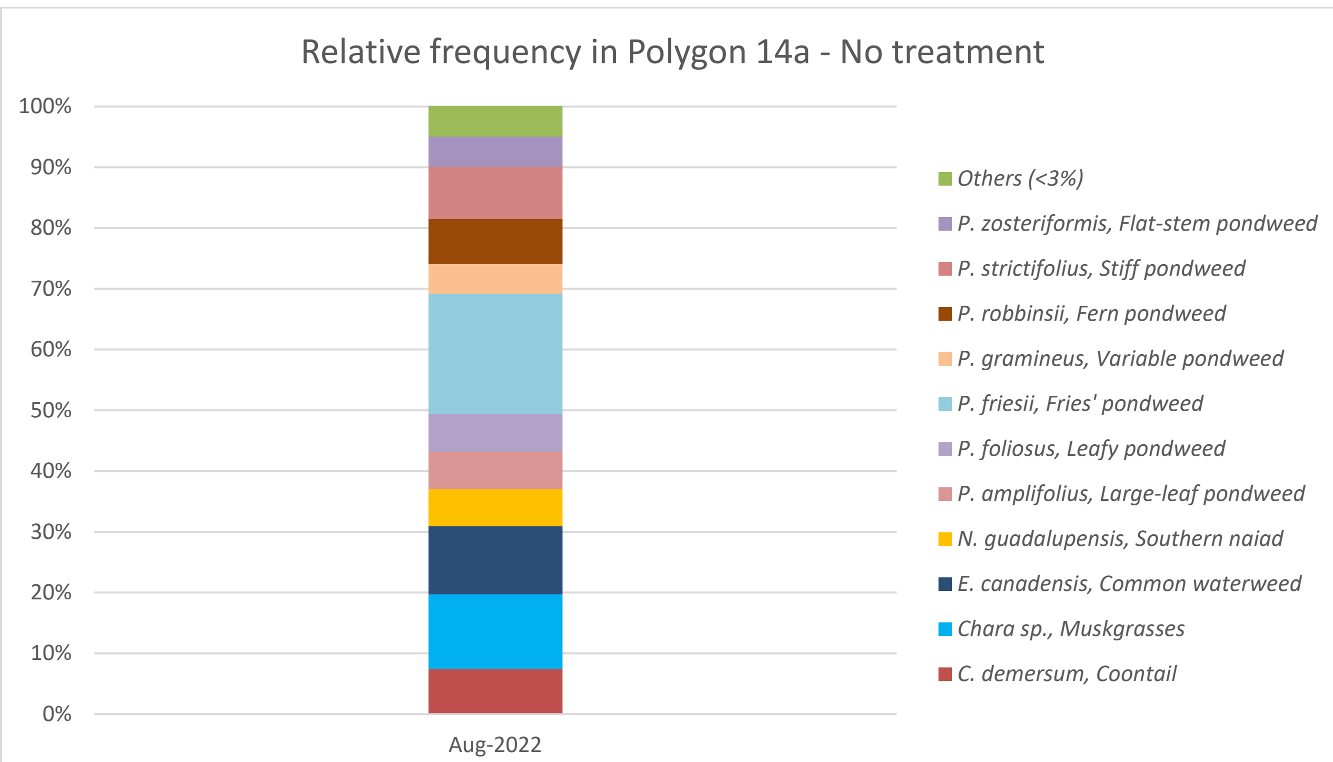
Relative frequency in the Island Polygon -
Manual treatments in 2019, 2021 and 2022
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aug-2022
Others (<3%)
P. zosteriformis, Flat-stem pondweed
P. robbinsii, Fern pondweed
P. pusillus, Small pondweed
P. friesii, Fries' pondweed
P. foliosus, Leafy pondweed
P. amplifolius, Large-leaf pondweed
N. guadalupensis, Southern naiad
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail


Relative frequency in Polygon 12a - Chemical treatment in 2022
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aug-2022
Others (<3%)
P. zosteriformis, Flat-stem pondweed
P. strictifolius, Stiff pondweed
P. robbinsii, Fern pondweed
P. illinoensis, Illinois pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail


Relative frequency in Polygon 12c - Chemical treatment in 2022
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aug-2022
Others (<3%)
V. americana, Wild celery
P. zosteriformis, Flat-stem pondweed
P. robbinsii, Fern pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. foliosus, Leafy pondweed
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail



Relative frequency in Polygon 13 - Chemical treatment in 2022
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aug-2022
Others (<3%)
P. zosteriformis, Flat-stem pondweed
P. strictifolius, Stiff pondweed
P. robbinsii, Fern pondweed
P. illinoensis, Illinois pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. amplifolius, Large-leaf pondweed
Filamentous algae
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail



Relative frequency in Polygon 14a - No treatment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Aug-2022
Others (<3%)
P. zosteriformis, Flat-stem pondweed
P. strictifolius, Stiff pondweed
P. robbinsii, Fern pondweed
P. gramineus, Variable pondweed
P. friesii, Fries' pondweed
P. foliosus, Leafy pondweed
P. amplifolius, Large-leaf pondweed
N. guadalupensis, Southern naiad
E. canadensis, Common waterweed
Chara sp., Muskgrasses
C. demersum, Coontail

How did the overall plant community react to chemical treatments?

Since chemical treatments are administered into the water, they potentially affect the entire plant community of Crescent Lake. The Point-Intercept data allows us to generate statistics that reflect the health of the entire aquatic plant community. The following tables provide comparative statistics for polygons over the years, starting with a table that defines the statistical terms.

Table 2. Description of the aquatic plant community statistical terms

Statistical term	Description
Maximum depth of plants (ft)	Since aquatic rooted aquatic plants require sunlight at the lake bottom in order to root and grow, water depth and transparency ultimately limit where plants can grow. By repeated sampling in a lake, we can determine the maximum depth at which plants grow. By definition this area where plants can grow is called the littoral zone. Beyond that depth plants are absent.
Frequency of occurrence at sites shallower than maximum depth of plants	Not every area of the lake bottom that is shallower than the maximum depth of plants actually has plants living there. Other things like the kind of substrate can influence whether a plant can take root. Frequency of occurrence at sites shallower than maximum depth of plants documents the proportion of sites where rooted plants actually occur within the littoral zone.
Average number of all species per site (veg. sites only)	This metric is the average of the number of plant species documented at each of the point-intercept sampling points. Lakes with diverse plant communities tend to have higher average number of plant species at each site.
Species Richness	This metric is a simple count of the number of species in an area. In the case of the point-intercept survey, this refers to the number of plant species actually collected on the rake for the point-intercept sampling points in a given area (e.g., an entire lake or a sub-PI plot). The species richness of a lake would mean the total number of plant species in the entire lake. Species richness is a simple measure of diversity. More species equals higher diversity.
Species Richness (including visuals)	This metric includes the simple count of the number of plant species collected on the rake for the point-intercept sampling points in a given area and those observed (but not actually collected with the rake) within 6 feet of the sampling points.
Simpson Diversity Index	This is a more sophisticated measure of biological diversity than species richness. It is an index that takes into account species richness (number of species) as well as evenness. Species evenness is a description of the distribution of abundance across the species in a community. Species evenness is highest when all species in a sample have the same abundance. The most diverse systems have both high number of species and high evenness.
Floristic Quality Index	This is an index that tries to capture how "pristine" a plant community is in terms of its species composition. Some plant species are very sensitive to human presence and are less likely to occur in lakes where human influences are strong. At the other end of the spectrum are plants that do very well in the presence of human influence. The FQI attempts to evaluate the mix of sensitive and non-sensitive plants in a lake.
Average Rake Fullness	Rake fullness is a rating given to each rake pull on a PI survey that indicates the amount of plant material for each species as well as combined species. There are four ranks: 0 (not present), 1, 2, & 3 (3 represents the highest value of plant material on a rake). Average rake fullness is the mean value for all the point-intercept points.

Aquatic plant community statistics for the historically chemically treated polygons

For the following tables, red highlighted cells indicate highest values in the row

	Polygon 1 - Chemical treatment in 2019				
	PreT-2019	PostT-2019	Sep-2020	Aug-2021	Aug-2022
Maximum depth of plants (ft)	13.50	13.00	13.00	13.00	13.00
Frequency of occurrence at sites shallower than maximum depth of plants	95.37	100.00	97.25	100.00	99.07
Average number of all species per site (veg. sites only)	3.77	3.53	3.46	3.69	3.87
Species Richness	14	14	16	18	19
Species Richness (including visuals)	14	15	19	19	20
Simpson Diversity Index	0.86	0.86	0.88	0.87	0.87
Floristic Quality Index	23.02	24.96	-	27.16	25.95
Average Rake Fullness	1.63	2.06	1.74	1.55	1.32

	Polygon 5 - Chemical treatment in 2021		
	PreT-2021	PostT-2021	Aug-2022
Maximum depth of plants (ft)	23.00	20.00	16.50
Frequency of occurrence at sites shallower than maximum depth of plants	76.14	78.57	85.33
Average number of all species per site (veg. sites only)	3.49	2.73	3.97
Species Richness	19.00	16.00	18
Species Richness (including visuals)	20.00	16.00	20
Simpson Diversity Index	0.90	0.90	0.91
Floristic Quality Index	28.05	25.75	26.87
Average Rake Fullness	1.35	1.11	1.22

Aquatic plant community statistics for the chemically treated polygons

	Polygon 8 - Chemical treatment in 2022					
	Jun-2019	Aug-2019	Jun-2020	Aug-2020	Aug-2021	Aug-2022
Maximum depth of plants (ft)	13.50	13.00	14.00	14.00	15.00	14.00
Frequency of occurrence at sites shallower than maximum depth of plants	89.19	94.44	91.46	85.19	93.42	95.06
Average number of all species per site (veg. sites only)	3.24	4.03	3.09	3.65	3.62	3.96
Species Richness	11	14	15	18	17	19
Species Richness (including visuals)	11	15	18	20	20	24
Simpson Diversity Index	0.87	0.88	0.89	0.89	0.90	0.91
Floristic Quality Index	18.00	23.57	22.19	28.13	24.25	28.28
Average Rake Fullness	1.27	2.12	1.47	1.93	1.55	1.34

	Polygon 10 - Chemical treatment in 2022			
	Jun-2020	Aug-2020	Aug-2021	Aug-2022
Maximum depth of plants (ft)	13.00	13.00	13.00	13.00
Frequency of occurrence at sites shallower than maximum depth of plants	96.10	94.52	89.23	90.28
Average number of all species per site (veg. sites only)	2.86	3.65	3.71	3.55
Species Richness	20	27	22	26
Species Richness (including visuals)	23	30	24	28
Simpson Diversity Index	0.88	0.92	0.90	0.92
Floristic Quality Index	28.05	33.88	30.99	34.29
Average Rake Fullness	1.37	1.70	1.78	1.30

Aquatic plant community statistics for the chemically treated polygons

	Polygon 11 - Chemical treatment in 2022				
	Jun-2019	Aug-2019	Sep-2020	Aug-2021	Aug-2022
Maximum depth of plants (ft)	15.00	16.00	15.00	17.00	17.00
Frequency of occurrence at sites shallower than maximum depth of plants	100.00	64.00	94.44	83.33	90.91
Average number of all species per site (veg. sites only)	2.94	3.44	2.88	2.55	2.95
Species Richness	12	10	11	14	12
Species Richness (including visuals)	12	10	11	14	12
Simpson Diversity Index	0.83	0.86	0.85	0.88	0.82
Floristic Quality Index	21.65	17.67	-	22.19	22.01
Average Rake Fullness	1.33	1.94	1.65	1.48	1.20

Polygon 12a – Chemical treatment in 2022

	Aug-2022
Maximum depth of plants (ft)	14.00
Frequency of occurrence at sites shallower than maximum depth of plants	90.00
Average number of all species per site (veg. sites only)	4.30
Species Richness	20
Species Richness (including visuals)	20
Simpson Diversity Index	0.91
Floristic Quality Index	29.96
Average Rake Fullness	1.19

Aquatic plant community statistics for the chemically treated polygons

Polygon 12c – Chemical treatment in 2022

	Aug-2022
Maximum depth of plants (ft)	16.00
Frequency of occurrence at sites shallower than maximum depth of plants	76.32
Average number of all species per site (veg. sites only)	3.93
Species Richness	19
Species Richness (including visuals)	19
Simpson Diversity Index	0.90
Floristic Quality Index	28.76
Average Rake Fullness	1.10

Polygon 13 – Chemical treatment in 2022

	Aug-2022
Maximum depth of plants (ft)	16.00
Frequency of occurrence at sites shallower than maximum depth of plants	90.00
Average number of all species per site (veg. sites only)	4.22
Species Richness	27
Species Richness (including visuals)	28
Simpson Diversity Index	0.92
Floristic Quality Index	34.80
Average Rake Fullness	1.47

Aquatic plant community statistics for the studied polygons

Polygon 3b – no treatment

	Aug-2022
Maximum depth of plants (ft)	18.00
Frequency of occurrence at sites shallower than maximum depth of plants	53.70
Average number of all species per site (veg. sites only)	3.66
Species Richness	20
Species Richness (including visuals)	24
Simpson Diversity Index	0.91
Floristic Quality Index	30.28
Average Rake Fullness	1.25

Polygon 6b – no treatment

	Aug-2022
Maximum depth of plants (ft)	14.50
Frequency of occurrence at sites shallower than maximum depth of plants	100.00
Average number of all species per site (veg. sites only)	3.30
Species Richness	17
Species Richness (including visuals)	20
Simpson Diversity Index	0.92
Floristic Quality Index	25.75
Average Rake Fullness	1.26

Polygon 7 – no treatment

	Aug-2022
Maximum depth of plants (ft)	17.00
Frequency of occurrence at sites shallower than maximum depth of plants	82.05
Average number of all species per site (veg. sites only)	3.53
Species Richness	20
Species Richness (including visuals)	22
Simpson Diversity Index	0.92
Floristic Quality Index	30.19
Average Rake Fullness	1.31

Aquatic plant community statistics for the studied polygons

Polygon 14a – no treatment

	Aug-2022
Maximum depth of plants (ft)	17.00
Frequency of occurrence at sites shallower than maximum depth of plants	85.71
Average number of all species per site (veg. sites only)	3.38
Species Richness	15
Species Richness (including visuals)	15
Simpson Diversity Index	0.90
Floristic Quality Index	25.30
Average Rake Fullness	1.21

Island Polygon– manual treatment in 2019, 2021 and 2022

	Aug-2022
Maximum depth of plants (ft)	15.00
Frequency of occurrence at sites shallower than maximum depth of plants	82.14
Average number of all species per site (veg. sites only)	3.78
Species Richness	14
Species Richness (including visuals)	15
Simpson Diversity Index	0.89
Floristic Quality Index	24.32
Average Rake Fullness	1.26

Conclusions and future management

Other reviewers may discover novel interpretations of the preceding maps, histograms and tables. In our review, we recognize the following conclusions:

- The chemical treatment seems to have eliminated *Myriophyllum spicatum* (Eurasian watermilfoil) from the chemically treated polygons.
- The native *Myriophyllum sibiricum* (Northern watermilfoil) has been greatly reduced or eliminated from all monitored polygons. This also seems to be related to chemical treatment.
- The Crescent Lake plant community like all plant communities is dynamic. From year to year, some species increase, other decline. A variety of factors influence these changes. From our data, we note that some plants like *Potamogeton pusillus* (Small pondweed) are decreasing in frequency of occurrence in all the monitored polygons. In contrast, in 2022 *Potamogeton friesii* (Fries' pondweed), *Chara* species (Muskgrass) and *Najas guadalupensis* (Southern naiad) have increased in frequency of occurrence in the point-intercept aquatic plant survey results. Also, a native plant, *Najas guadalupensis* population has grown to nuisance level population in other northern Wisconsin lakes.
- Polygon 1 monitoring results (as seen on maps and histograms) demonstrate a reduction of EWM likely resulting from the manual treatments.
- The plant community statistics (for example species richness, Floristic Quality Index and Simpson Index) do not reveal any short-term effects of chemical treatment on the plant community of Crescent Lake.

Other than Polygon 1, no EWM was found during the 2022 point-intercept aquatic plant surveys at Crescent Lake. Because there was no meander survey conducted in Crescent Lake in 2022, we cannot be confident of the presence or absence of EWM in the 2022 non-monitored polygons. We strongly recommend that a thorough meander survey be conducted in early spring 2023 to evaluate and map the EWM population. This meander search will be important for planning future EWM management. We also recommend that point-intercept surveys be conducted on selected polygons so that both EWM and native plants are monitored.

Appendix

Nomenclature for management and monitoring polygons

2019 name	2020 name	standardized name
N - treatment area		Polygon 1a
N - treatment area		Polygon 1b
		Polygon 2
G - Sample, ID 158-181	Area 3	Polygon 3a
H+I		Polygon 3b
C		Polygon 4
F		Polygon 5a
part of M		Polygon 5b
Part of M		Polygon 6a
E		Polygon 6b
		Polygon 7
A1+A2 - Sample, ID 110-157	Area 1	Polygon 8
B - Sample, ID 110-157	Area 2	Polygon 9
L	L - Reference site	Polygon 10
Part of J - Sample, ID 182-206	Part of I	Polygon 11
	K	Polygon 12a
K	J	Polygon 12b
	H	Polygon 13a
Part of J	Part of I	Polygon 13b
D		Island