Special Note

The partners of the SLELO PRISM have identified 24 Priority Conservation Areas on which we conduct early detection surveillance on a two year rotation. This report is considered as an addendum to the original field report.

St. Lawrence Eastern Lake Ontario Partnership for Regional Invasive Species Management

Eastern Lake Ontario Dunes D-3 Assessment

SLELO-PRISM Dune Willow Monitoring and Early Detection Surveillance

July 18th, 21st, 22nd, 24th, 25th, 30th

Report prepared by Elizabeth MacEwen and Sabrina Dreythaler on 8/22/14

Figure 1. Backdunes of Lakeview Wildlife Management Area, facing west, between Goose Pond and Floodwood Pond. Photo by Sabrina Dreythaler

Background

In 2012, SLELO field-crew members Mike McHale and Greg Chapman conducted early detection surveillance on the Eastern Lake Ontario Barrier Beach and Wetland Complex, between Eldorado Nature Preserve/Black Pond Wildlife Management Area (WMA) and Deer Creek WMA (**Figure 1**). The survey focused on detection of swallow-wort species (*Cynanchum* spp.) and buckthorn species (*Rhamnus* spp.). After the survey was completed, the SLELO-PRISM partnership determined it was unnecessary to manage the buckthorn populations. For this reason, the buckthorn survey was not continued in 2014. However, swallow-wort species' occurrences were still noted.

Figure 2. *Disonycha alternata* adult feeding on the sand dune willows at Black Pond WMA, taken by Sabrina Dreythaler

In 2012 the early detection crew also surveyed two dune willow (*Salix cordata)* populations, one in Eldorado Nature Preserve/ Black Pond WMA and one in Sandy Pond Beach Natural Area. This survey was to investigate the presence of two black metallic beetle species (*Altica subplicata* and *Plagiodera versicolora*) that were reported to be feeding on the dune willows. Although these beetles were not seen, there were multiple occurrences of another beetle, *Disonycha alternata* (**Figure 2**), which was also noted to be feeding on the dune willow. Due to the high frequency of occurrences of *D. alternata*, this survey focused solely on it rather than the black metallic beetles.

Introduction

Dune willows are important to the fragile dune ecosystem because their rhizomes help to stabilize the sand. These plants are listed as threatened in New York, with only 7 populations in the state, but are considered globally stable ("Sand dune", 2013). The impact of herbivory by *A. subplicata* on *S. cordata* and sand dune succession was studied by Bach in 1994. It was determined that beetle herbivory decreased the growth and increased the mortality of *S. cordata*, which indirectly impacted patterns of plant succession on the dunes. According to the study by DeSwarte and Balsbaugh (1973) *A. subplicata* and *D. alternata* have biological similarities. They are known to both be host-specific to the sandbar willow (*Salix interior)* and can cause erosion control problems. Due to the ecological importance of the sand dunes and the rarity of the dune willows, it's important to keep track of insect herbivory which could lead to a decline in the dune willow populations.

Methods

Aquatic Survey

El Dorado Nature Preserve[1]/Black Pond WMA[2], Lakeview WMA, Deer Creek WMA, and Sandy Pond Beach Natural Area were resurveyed for invasive species. The perimeter of each body of water was canoed (**Appendices A, B, C and D**). All invasive species' occurrences were noted.

Dune Willow Monitoring

In 2012, field crew members surveyed two patches of dune willows, one in Black Pond WMA/Eldorado Nature Preserve and one in the Sandy Pond Beach Natural Area. During the summer of 2014 field crew members surveyed the Deer Creek WMA and Lakeview WMA, in addition to the two areas previously studied. When a patch of dune willows was sighted, a GPS point was made and every dune willow in the patch was

Figure 3. *D. alternata* larvae feeding on the sand dune willows at Black Pond WMA, taken by Sabrina Dreythaler

[1] El Dorado Nature Preserve/Black Pond treated as a single site, will be referenced as Black Pond WMA.
[2] Wildlife Management Area

counted. The amount of dead dune willows, the amount of dune willows with *D. alternata* adults and the amount of dune willows with *D. alternata* larvae (**Figure 3)** were also counted along with damage estimates (**Figure 4**).

Results

Aquatic Survey

There were **no occurrences** of prevention/watch-list species (Williams, 2012). The target management species seen during the visual aquatic survey included purple loosestrife *(Lythrum salicaria*), Eurasian water-milfoil (*Myriophyllum spicatum*), Japanese knotweed (*Fallopia japonica*), water chestnut (*Trapa natans*), and swallow-wort (Cynanchum spp.). Other invasive species seen included brittle naiad (*Najas minor),* European frog-bit (*Hydrocharis morsus-ranae*) and curly leaf pondweed (*Potamogeton crispus).*

Statistical Analysis

After collecting the data, it was decided that statistical analysis should be conducted on the dataset. Performing statistical tests on the data was determined to be the best way to conclude if any differences existed between the sites observed or if there were any correlations. Rather than making any conclusions using only observational data, such as in past surveys, statistics allow for additional confidence. Having confident determinations in this particularly important monitoring project is crucial so the appropriate management decisions of *D. alternata* can be made, if needed. These tests included comparing the average damage to the patches between sites, and comparing the amount of larvae and adults between sites.

Statistical analysis were done to compare the average damage to the patches between sites and to compare the amount of larvae and adults between sites. Two-sided t-tests assuming unequal variance were performed. All t-tests were conducted with a 99% confidence interval ($\alpha = .01$). Pearson's correlation coefficients were also found to determine any correlation between the amount of larvae/adults and the damage done to the plants at each site.

A linear regression model was created to show the relationship between the average damage per patch and the percentage of plants per patch with *D. alternata* adults. A second linear regression model was created to show the relationship between the average damage per patch and the percentage of plants per patch with *D. alternata* larvae. Both linear regression models were based on the entire set of data collected, not individual sites. Pearson's correlation coefficients were found to show the strength of these relationships.

Deer Creek WMA was not included in the t-test analysis because there was only one patch found at that area. The patch was included in the dataset for the linear regression models.

Dune Willow Monitoring

A total of 729 dune willows were counted at Black Pond WMA, with a total of 52 plants with *D. alternata* adults and 149 plants with *D. alternata* larvae. The average damage to the dune willows per patch at Black Pond WMA was 12.625% ± 10.677% (**Appendix A**). Pearson's correlation coefficient of r = 0.45 indicates there was a moderately weak positive relationship between the percentage of plants with *D. alternata* **adults** and the amount of damage to the patches at Black Pond WMA. There was also a very weak positive relationship (**r = 0.06**) between the percentage of plants with *D. alternata* **larvae** and the amount of damage to the patches at Black Pond WMA.

At Sandy Pond Beach Natural Area there were a total of 412 dune willows, with zero plants having *D. alternata* adults and four plants having *D. alternata* larvae. The average damage to the dune willows per patch at Sandy Pond Beach Natural Area was 0.847% ± 0.877% (Appendix B). There was a moderately weak positive relationship (**r = .42**) between the percentage of plants with *D. alternata* **larvae** and the amount of damage to the patches. There were **no** *D. alternata* **adults** seen at this location, therefore there was no relationship.

There were a total of 269 dune willows found at Lakeview WMA, with a total of two plants with *D. alternata* **adults** and 23 plants with *D. alternata* **larvae**. The average damage to the dune willows per patch at Lakeview WMA was 0.75% ± 0.791% (**Appendix C**). There was a very strong positive relationship **(r = 1.00)** between the percentage of plants with *D. alternata* **adults** and the amount of damage to the patches at Lakeview WMA. **Figures 6 and 7** depict healthy verses damaged Dune Willows. There was also a very strong positive relationship (**r = .96**) between the percentage of plants with *D. alternata* **larvae** and the amount of damage to the patches.

A percent cover reference guide from the Center for Natural Resource Information Technology (**Figure 4**) was modified to be used as a percent damage reference guide. Each patch was given a damage estimate based on this guide. This estimate was of the patch as a whole, not of the individual plants.

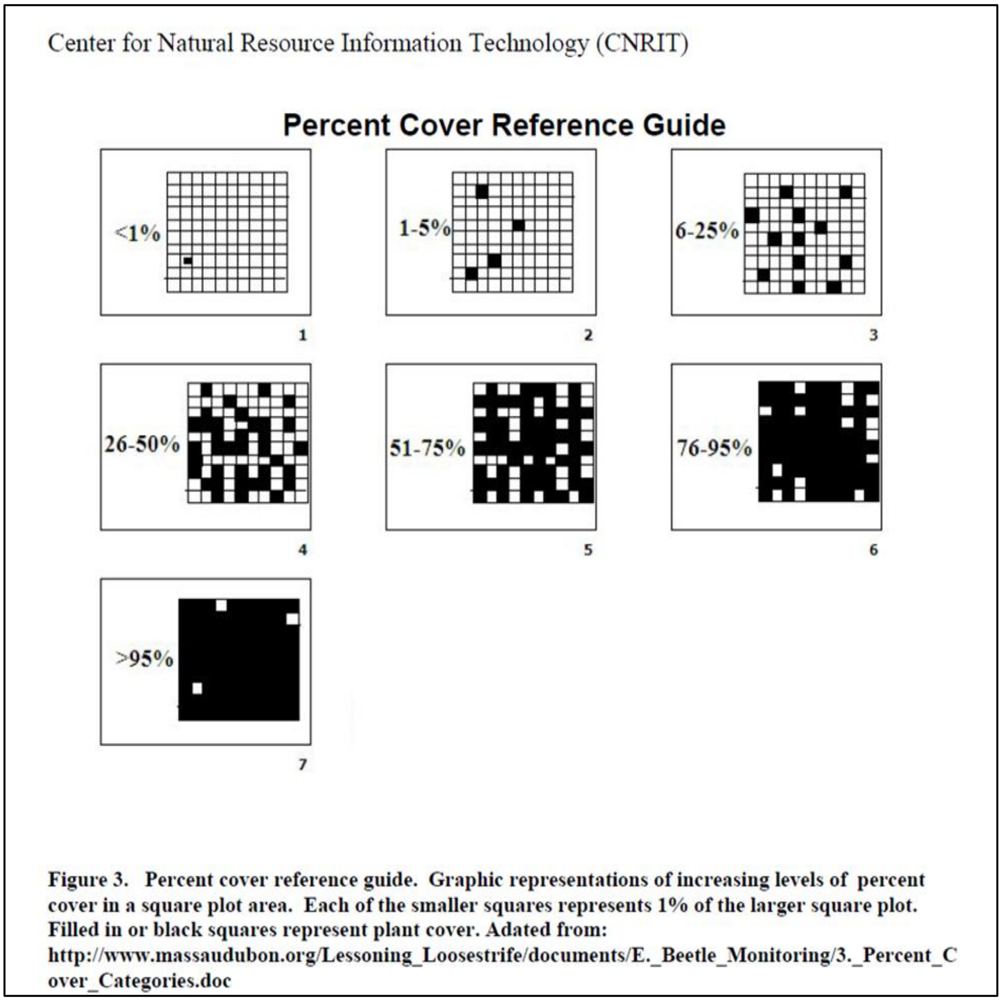

Figure 4. Chart modified to use for damage estimate.

In total, 1440 dune willows were counted during the surveillance, with 54 of the plants having *D. alternata* adults on them. The linear regression model (**Figure 5)** shows that there was a moderately strong positive relationship (r = .63) between the percentage of plants with *D. alternata* adults and the amount of damage to the patches.

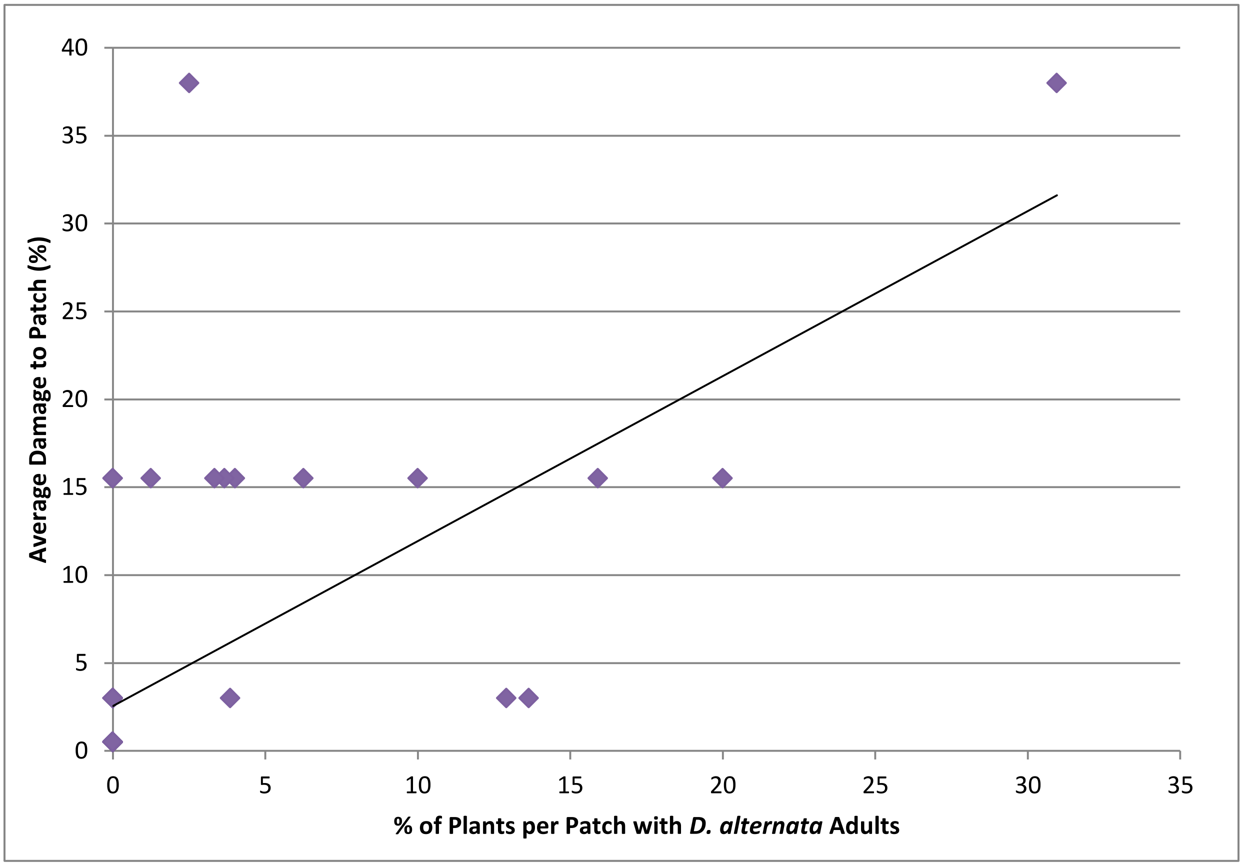

Figure 5. Relationship between the % of plants per patch with *D .alternata* **adults** and the amount of damage done to the patches

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At Deer Creek WMA there was only one dune willow patch, with a total of 30 dune willows. There weren't any plants with *D. alternata* adults or larvae and the average damage was 0.5%.

Figure 6. Particularly healthy dune willow, with < 1 % damage, taken by Sabrina Dreythaler

There was a significant difference between the amount of damage, t(19) = 4.92, p < .001, to the dune willow patches in Black Pond (**Appendix A)** and the amount of damage to the patches in Sandy Pond Beach Natural Area (**Appendix B**). There was also a significant difference between the percentage of plants with *D. alternata* adults, t(20) = 3.23, p = .004, at Black Pond WMA and the percentage of plants with *D. alternata* adults at Sandy Pond Beach Natural Area. There was also a significant difference between the percentage of plants with *D. alternata* larvae, t(22) = 5.32, p < .001, at Black Pond WMA and the percentage of plants with *D. alternata* larvae at Sandy Pond Beach Natural Area.

Figure 7. Heavily damaged dune willow, with 51 – 75% damage, taken by Sabrina Dreythaler

There was a significant difference between the amount of damage, t(19) = 4.95, p < .001, to the dune willow patches in Black Pond WMA and the amount of damage to the patches in Lakeview WMA. There was a significant difference between the percentage of plants with *D. alternata* adults, t(21) = 3.00, p = .007, at Black Pond WMA and the percentage of plants with *D. alternata* adults at Lakeview WMA. There was also a significant difference between the percentage of plants with *D. alternata* larvae, t(26) = 3.30, p = .003, at Black Pond WMA and the percentage of plants with *D. alternata* larvae at Lakeview WMA.

There wasn't a significant difference between the amount of damage, t(10) = 1.30, p = .22, to the dune willow patches in Sandy Pond Beach Natural Area and the amount of damage to the patches in Lakeview WMA. There wasn't a significant difference between the percentage of plants with *D. alternata* adults, t(9) = 1.00, p = .34, at Lakeview WMA and the percentage of plants with *D. alternata* adults at Sandy Pond Beach Natural Area.

There also wasn't a significant difference between the percentage of plants with *D. alternata* larvae, $t(10) = 1.30$, $p = 0.22$, at Lakeview WMA and the percentage of plants with *D. alternata* larvae at Sandy Pond Beach Natural Area.

Of the 1440 dune willow plants observed, 176 of the plants had *D. alternata* larvae on them. The linear regression model (**Figure 8**) showed that there was a moderately positive relationship ($r = .50$) between the percentage of plants with *D. alternata* larvae and the amount of damage to the patches.

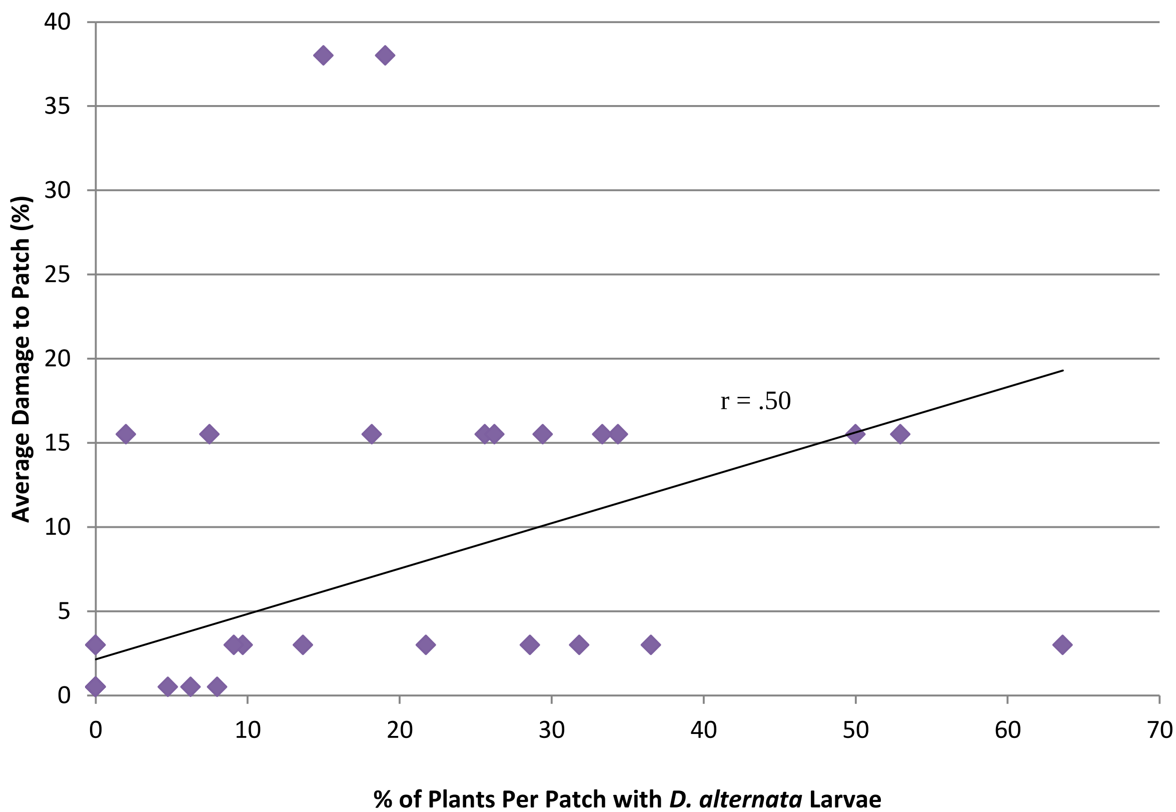

Figure 8. Relationship between the % of plants with *D. alternata* **larvae** and the damage done to the patches

Discussion

Aquatic Survey

Brittle naiad was seen previously in the 2012 survey in the Floodwood Pond area of Lakeview WMA. Water chestnut was not seen in Black Pond WMA in 2012, but one plant was seen and pulled during the 2014 survey. Further monitoring for water chestnut is required for this area. In 2012 water chestnut was seen at Lakeview WMA, and since then, yearly pulls have been undertaken. On July 29th and August 6th 2014 organized chestnut pulls were conducted by the DEC, the Great Lakes Restoration Initiative (GLRI) crew, the SLELO early detection field crew and Leaders in Environmental Action for the Future (LEAF) interns from the Nature Conservancy. A total of 87 bags of water chestnut were pulled from the Floodwood Pond area of Lakeview WMA. Future monitoring is required for this area.

Dune Willow Monitoring

The observational data accompanied by statistical analysis suggest that the presence of *D. alternata* has a positive correlation with the damage to the dune willow patches (Figure 9). Lakeview WMA had the strongest correlation between percentage of plants with adults/larvae and the damage done to the patches. This is because the only patch (WP 65, Appendix C) at Lakeview WMA with damage also had plants with *D. alternata* adults and larvae on them. The patches at Lakeview WMA without *D. alternata* adults or larvae did not have any damage. This was not the case with Black Pond WMA. Although Black Pond WMA had the most damage to the willow patches, the correlation between damage and *D. alternata* adults/larvae being present was not as strong. This could be due to a high amount of damaged dune willows not having *D. alternata* adults or larvae on them at the time of the survey. Because of the strong correlation found at Lakeview WMA, it is safe to say that *D. alternata* are causing the damage to the dune willows throughout the Eastern Lake Ontario Barrier Beach and Wetland Complex.

Sites with Dune Willow	Herbivory Correlation
Lakeview WMA	Very Strong
Sandy Pond	Moderately Weak
Black Pond	Moderately Weak
Deer Creek	n/a

Figure 9: Summary of the *D. alternata* herbivory correlation between dune sites.

The past study by Catherine Bach shows the negative effects that herbivory of *A. subplicata* has on the dune willows, which in return can negatively affect the fragile dune ecosystem (Bach 1994). In comparison, the herbivory of *D. alternata* on the dune willows could also negatively affect the fragile dune ecosystem of Eastern Lake Ontario. Therefore, management of *D.*

alternata is suggested, particularly in Black Pond WMA where the presence of beetles and damage to the dune willow patches are the highest.

Management Options

There have been no previously documented management strategies to control *D. alternata*. Information on management of dune willows is also lacking. The following are management options that seem to be the most suitable for controlling the *D. alternata* population on the dune willows.

Hand Harvesting of Larvae via Citizen Science

A study in 1973 determined that *D. alternata* lay their eggs in the sand from late May until early July under their host species. After larvae emerge they climb to the top of their host plant to eat the leaves. *D. alternata* has 3 larval instars, a prepupal and a pupal stage. When they are ready to pupate, the prepupae burrow into the sand which triggers the pupation into adults. In the laboratory experiments the average time from egg to adult was 43 – 53 days, with an average of 46 days (DeSwarte & Balsbaugh).

Because of the biology of this species, it would be possible to monitor for the emergence of larvae and hand harvest the larvae off of the dune willows once they have emerged. A group of volunteers, stewards or citizen scientists could go out at periodic intervals and hand harvest the larvae. This should be done throughout the summer, starting after the first emergence of larvae and ending when the remaining larvae have pupated into adults. This would be approximately 8-10 weeks. Monitoring of larval emergence and hand harvesting of the larvae should continue the following years until the population has been suppressed and the damage to the dune willows has been reduced.

Natural Control

As an effort to identify any natural means of controlling *D. alternata*, it was found that Black Terns (*Chlidonias niger)* may help to control the population of *D. alternata* on the dune willows. Black terns are NYS listed endangered birds that migrate from Canada to South America and nest in some of the wetlands in NYS ("Black Tern", 2014). Throughout this dune willow study, black terns were seen nesting in the Lakeview WMA (**Figure 10)**; however they were not as far north as Black Pond WMA. Studies show that this species has a varied diet, which could possibly

Figure 10. Juvenile black terns in Lakeview WMA

include beetles. If the black terns could be attracted to nest or feed in Black Pond WMA, this may help control the *D. alternata* population. Appropriate measures would also have to be taken to be sure that Black Pond has suitable sites for nesting based on the needs of the black terns and particular methods would have to be used to attract the birds to nest.

The diets of Black terns consist primarily of insects and small fish. The percentages of fish and insects in their diets depend on the availability of these species. A study by Cuthbert (1954) showed that black tern parents bring back insects for their chicks, between zero and eight days of age, 93.6% of the time. A thesis by Firstencel (1987) showed that black terns in Northern New York ate damselflies (22% of diet), dragonflies (16%), other insects (45%), small fish (14%) and caterpillars or unidentified items (3%). Although there haven't been studies specifically about the amount of beetles in black terns' diets, they are known to pick insects off leaves of plants in areas where *D. alternata* are located.

Black terns would benefit from being introduced to Black Pond WMA because of the increased number of ideal nesting sites. Black terns have very specific needs when looking for nesting sites. They are area dependent species; in order to nest they need over 20 hectares of isolated wetlands, or more than 11 hectares of a wetland complex (Brown & Dinsmore, 1986). Black Pond WMA is approximately 213 hectares, with an estimated 1/3 of the area being wetlands (**Figure 11**). Black Pond WMA is also part of the 17 mile long Eastern Lake Ontario Barrier Beach and Wetland Complex. This suggests that Black Pond WMA has enough wetlands for the black terns to nest. A study by J.M. Hickey and T.A. Malecki (1997) showed that black tern nesting sites need to have 21-50% cover, less than two meters of water and the vegetation must be dominated by cattails (Typha spp.), bur-reeds (Sparaganium spp.) or other emergent vegetation. If these qualities exist within Black Pond WMA, the black terns may be able to nest successfully here.

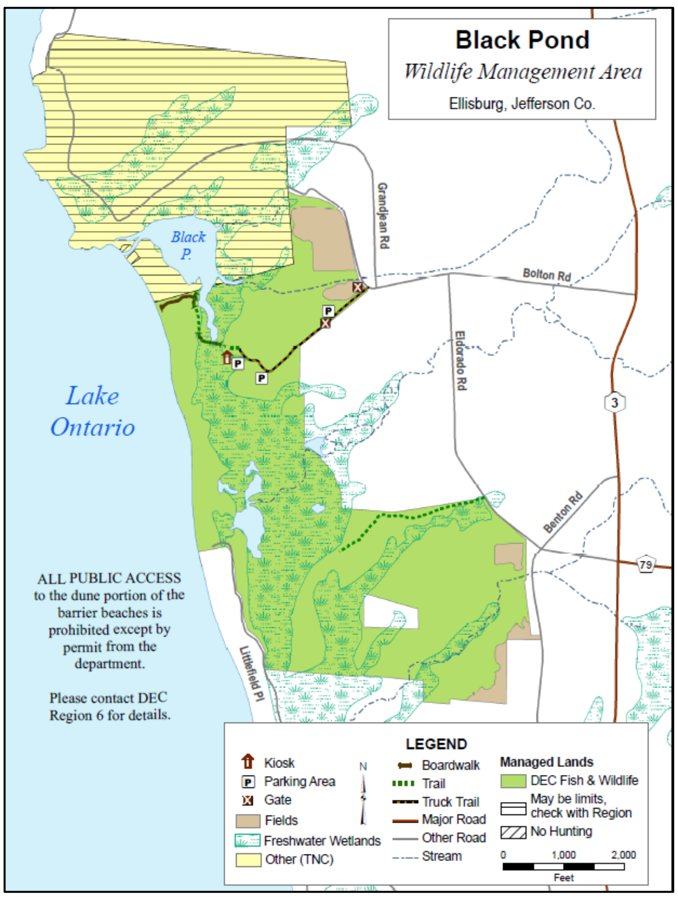

Figure 11. NYS DEC map of Black Pond WMA ("Black Pond", 2014)

A logistic model was created in this study that correctly classified 77.2% of all plots sampled as either nesting sites or non-nesting sites. This model could be used to determine if Black Pond WMA would be a suitable habitat for black terns' nesting sites, and which spots within Black Pond WMA would be the most suitable. Black terns could be attracted to the area using decoys, sound recordings and artificial nesting platforms. In a study by L.J. Bernard (1999), two different types of black tern decoys were used: wood carvings of black terns with their wings raised and clay mouldings of black terns in a sitting position. Tape players wired to 12 volt batteries playing black tern calls were placed next to the decoys and had a light sensitive switch which turned them off at night. Floating nest platforms were made with a wooden frame, hardware cloth, and Styrofoam. These two feet by two feet platforms were placed near the decoys and covered in dead plant material, which is typical nesting material for black terns. The platforms were anchored using rope with a brick on the end and placed 20 meters apart. This attempt at attracting black terns was unsuccessful, only attracting two black terns to nest near the decoys; however this was only undergone for one breeding season. In a study by Kress (1983) wooden arctic tern (*Sterna paradisaea)* decoys were used to attract arctic terns and common terns (*Sterna hirundo)*. These decoys were carved from sugar pine trees, sanded and hand painted. The decoys were made in alert and incubating postures and non-threatening arctic tern calls were played from tape players placed near the decoys. These decoys were placed for four consecutive years. This significantly increased the populations of common terns and arctic terns, bringing their nesting pairs up from almost non-existent to over 400 pairs within 5 years.

In Black Pond, a combination of these methods could be used. After using the logistic model to determine whether Black Pond WMA is a suitable habitat, appropriate sites within the WMA could be found. Decoys could be made using similar materials, such as clay and wood, and then painted. Floating nest platforms could be made with appropriate materials, such as the ones used in the study by L.J. Bernard. Equipment could be used to play black tern calls. If these methods are used for several consecutive years, black terns could be attracted to Black Pond WMA.

<u>Neem Oil</u>

Neem oil is a naturally occurring pesticide found in the seeds and leaves of the neem tree, *Azadirachta indica*, which has been proven to be effective as a control for multiple types of leaf beetles, although it has not used specifically for *Disonycha* species thus far. The active ingredients in neem oil are azadirachtin and salannin, which act as a repellant towards insects, including beetles in the family *Chrysomelidae.* It interferes with the insects' hormone systems which stops them from growing to maturity and hinders their ability to lay eggs. Neem oil can be irritating to the eyes and skin, but if ingested by humans, it is broken down by the body and studies show that it does not cause problems normally. It is sometimes found in many household products, such as toothpaste, soap, and some medicines. However, it is slightly toxic to fish.

However, typically the insects don't die from eating the plant; they die from starvation because they are repelled from the plant. This means that if fish do eat the beetles they wouldn't be affected by the neem oil unless the beetle had eaten the infected plant ("Neem oil", 2012).

In 1989, Karel studied the effects neem oil had on the abundance of *Oootheca bennigseni* (Coleoptera: Chrysomelidae) and the damage done to the bean plants that *O. bennigseni* were inhabiting. This study showed that neem oil, in the form of an extract from the leaves (4%) and an extract from the seed kernels (2-4%), reduced the amount of beetles infesting the bean plants and reduced the amount of damage done to the bean plants. In 2013, Aza-Direct spray, 1.2% azadirachtin, was used (compared to other biopesticides) to control two crucifer flea beetles, *Phyllotreta crucifera* and *Phyllotreta striolata (*Coleoptera: Chrysomelidae), that are pests of canola, *Brassica napus* and *Brassica rapa,* in Montana (Reddy, Tangtrakulwanich, Wu, Miller & Prewett). Neem spray reduced the leaf damage by nearly 50%. Neem oil has also proven effective against the Colorado potato beetle (Trisyono & Whalon, 1999) and cucumber beetles (Reed, Warthen, Uebel & Reed, 1982) which are both in the family Chrysomelidae. Although there hasn't been research about the effects of neem oil on *Disonycha* species, evidence shows that neem oil is effective on most chrysomelid beetles which suggests it will most likely affect *Disonycha alternata* as well.

There are multiple types of insecticides with the active ingredients of azadirachtin or salannin. All of these are proven to work about the same except for one: AzaSol. AzaSol is a water soluble powder with a higher amount of azadirachtin present. Typically in an insecticide (such as Azatrol, Nemzal, Margosan, or Neemix) there is 300 parts per million (ppm) – 12,000 ppm of azadirachtin and there is the presence of sugars and lipids that aren't used and could lead to unexpected ecological and biological effects. In AzaSol, there are 60,000 ppm of azadirachtin and the unwanted sugars and lipids are completely removed. Because of the strength of AzaSol, it is more toxic to fish and aquatic invertebrates. Another difference is that typical neem insecticides are not water soluble, which means they just layer the plant, and are only active for a couple days while it stays on the plant. AzaSol is water soluble which means the plants can absorb the azadirachtin which will then stay in their system for 2-4 weeks. This allows for the azadirachtin to work much longer. Unlike other neem insecticides that can only be sprayed, AzaSol can be sprayed, injected into the stems, applied to the soil and fed to the roots This will allow for non-targeted plants to not get sprayed if that seems to be an issue ("The AzaSol", n.d.). The affects of Neem oil have been proven to be reduced by increasing amount of ultra violet rays" (Mohapatra, Sawarkar, Patnaik & Senapati, 1956). The soluble properties of AzaSol could combat this dilemma because once the azadirachtin is absorbed by the plant, the sunlight shouldn't affect it.

It is recommended that AzaSol be tested on a small portion of a dune willow before applying it to a large area, in case it causes the plants to wilt or die. AzaSol can be harmful if it gets in your eyes or if it is absorbed through the skin. For beetles it is recommended to use 6 oz of AzaSol per 50 gallons of water for one acre of land. It’s recommended to be used every 7-10 days with a total of 2-3 treatments. AzaSol is most effective against larval, pupal and nymphal stages, so this would be most effective if sprayed early in the season, from late May to June. AzaSol should not be sprayed when rain is in the immediate forecast, to prevent runoff and contamination of the nearby waters (Complete label, n.d.).

Other Insecticides

Other insect control products include Entrust®, an insecticide containing spinosad (a mixture of spinosyn A and spinosyn D). It can be used to control various types of insects on crops and gardens, including chrysomelid leaf-feeding beetles to protect herbaceous and woody shrubs. It has not been tested on *D. alternata* specifically, or the effect it may have on dune willows. For target organisms, like beetles, it is most effective when ingested and causes active feeding to cease. It can also kill on contact. It is toxic to aquatic invertebrates and should not be sprayed below the high water line or next to surface water. It can cause eye irritation for humans and can be harmful if the product makes contact with skin. It is also toxic to honey bees for three hours after application. Directions state that for willow leaf beetles, application would be best in the spring and early summer when feeding is observed. For this purpose, it is recommended for these types of insects that Entrust® be applied at 2 ounces per acre, while diluting it in water at 1 ounce per 100 gallons. A small patch should be tested by applying the product and observing it for five to seven days (“Entrust specimen”, 2011).

Another product that could potentially be used is Novodor®, a product that has been used to control the Colorado potato beetle. The active ingredient is *Bacillus thurigiensis* subspecies *tenebrionis* fermentation solids and solubles. It is a protein crystal produced by the microorganism and can cause general gut paralysis within the target species and mortality within two to five days. The product requires the specific gut conditions of the target pest to cause general gut paralysis and cessation of feeding. It is most effective against first and second instar larvae in the target species. The product can cause moderate eye injury in humans and can be harmful if absorbed through the skin. The application rate depends on the stage of larval development and the density of infestation. For light to moderate populations of young larvae, it is recommended that one to three quarts of Novodor® be applied per acre. For heavy infestations, two to three quarts should be applied per acre. When there are mixed populations of younger and older larvae, three to four quarts should be applied per acre. It is also recommended that the product be diluted in a minimum of three gallons of water per acre (“Novodor flowable”, 2000).

Conclusion

The implementation of one or more of these management options could control the herbivory of *D. alternata* on the dune willows, which may serve to increase the stability of the sand dunes. Continuous protection of this barrier beach will be crucial to protection of the fragile wetland habitat in this area.

Acknowledgments

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Peer review provided by; Rob Williams, Cody Mendoza and Brian Roet.

Appendices

Charts and Maps

KEY TO ALL CHARTS

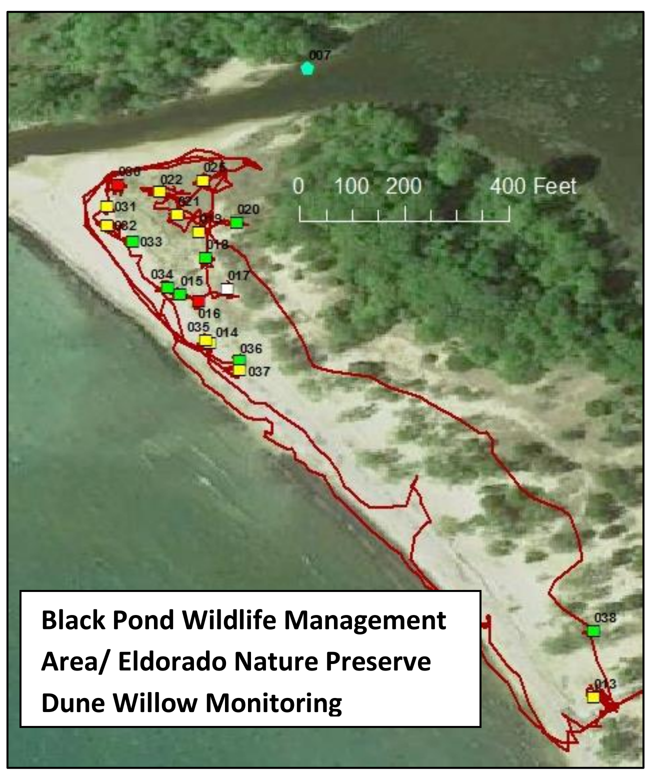
EFB- European frog-bit	CLPW- Curly leaf pondweed
PL- Purple loosestrife	EWM- Eurasian water milfoil
JK- Japanese knotweed	WC- Water chestnut
PH- Phragmites	BN- Brittle naiad
SW- Swallow-wort spp.	

KEY TO ALL MAPS

White Square: < 1 % Damage
Green Square: 1-5 % Damage
Yellow Square: 6-25 % Damage
Red Square: 26-50 % Damage
Blue Pentagon: Damage unknown
Red Circle: Aquatic invasive Species
Green Circle: Terrestrial Invasive Species
Green Track: Aquatic Survey
Red Track: Terrestrial Survey

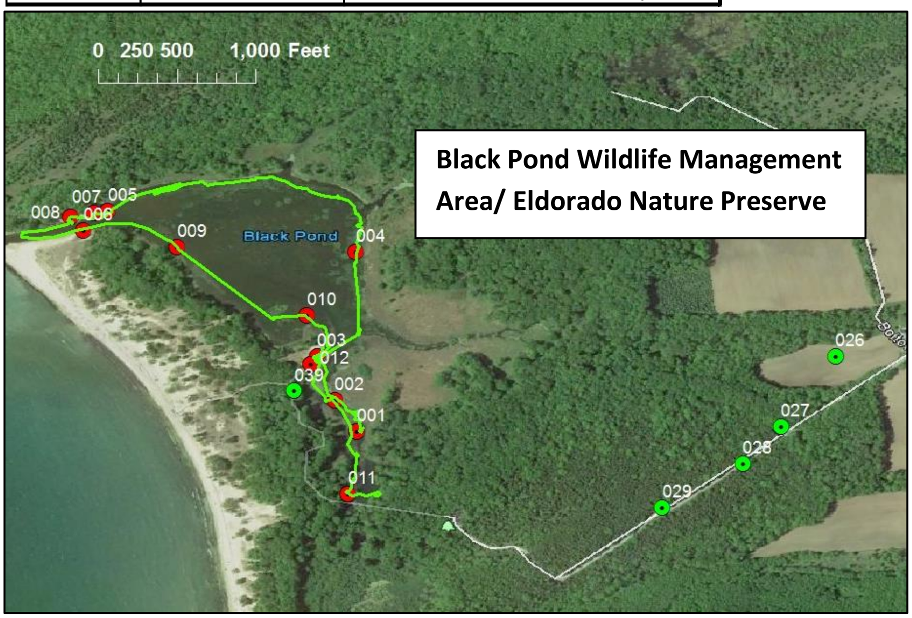
Appendix A. Dune willow monitoring results at Black Pond WMA

Location: Black Pond			Dates: 7/18/14 & 7/21/14			
Waypoint	# Dune Willows Alive	# Dune Willows Dead	# Plants with Adults	# Plants with Larvae	% Damage to Plants	Average Damage to Plants
007	15	0	0	0		
013	44	4	7	8	6-25 %	15.5
014	17	2	0	9	6-25 %	15.5
015	23	0	0	5	1-5 %	3
016	40	5	1	6	26-50 %	38
017	33	3	0	0	< 1 %	0.5
018	11	3	0	7	1-5 %	3
019	32	6	2	11	6-25 %	15.5
020	4	0	0	0	1-5 %	3
021	50	7	2	1	6-25 %	15.5
022	82	7	3	21	6-25 %	15.5
025	30	5	1	15	6-25 %	15.5
030	42	0	13	8	26-50 %	38
031	40	1	8	3	6-25 %	15.5
032	30	2	3	10	6-25 %	15.5
033	22	1	3	3	1-5 %	3
034	62	2	8	6	1-5 %	3
035	17	0	0	5	6-25 %	15.5
036	33	0	0	3	1-5 %	3
037	80	1	1	21	6-25 %	15.5
038	22	0	0	7	1-5 %	3
TOTAL:	729	49	52	149		252.5
Mean	34.71429	2.333333	2.4761905	7.0952381		12.625
Variance	425.0143	5.933333	12.761905	36.390476		113.9967
S.D.	20.61587	2.435843	3.5723808	6.0324519		10.67692



Appendix A. Aquatic surveillance results at Black Pond WMA

Location: Black Pond		Dates: 7/18/14 & 7/21/14
Waypoint	**Species Observed**	**Notes**
001	EFB, CLPW	EFB dominating
002	EFB	dominating
003	PL	Small patches, dying
004	EFB, CLPW	EFB small patches
005	EWM	large patches
006	WC	1 plant, pulled
026	SW	Both sides of road
027	SW	Both sides of road
028	SW	Both sides of road, had pods
029	SW	Both sides of road, had pods



Appendix B. Dune willow monitoring and aquatic surveillance results at Sandy Pond Beach Natural Area

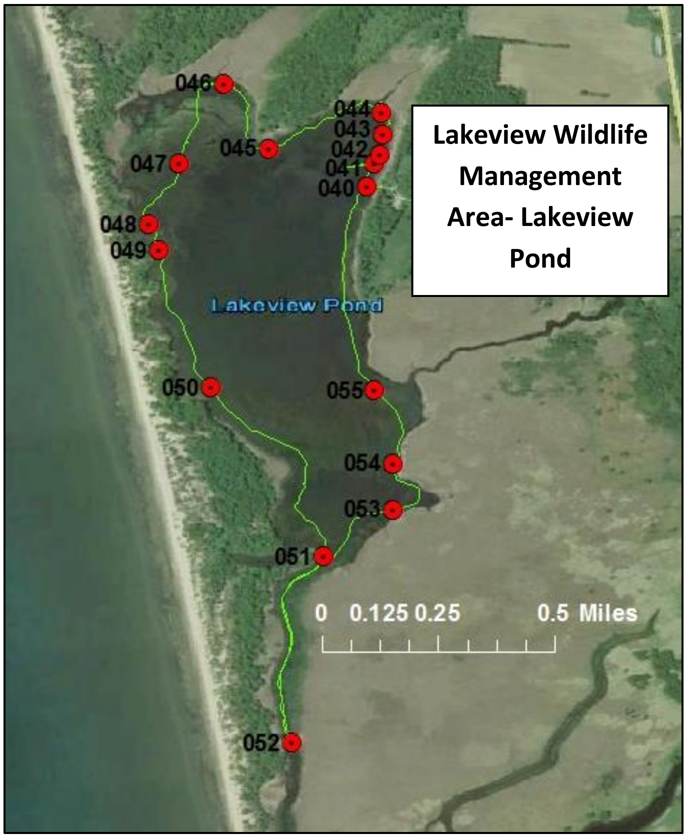
Location: Sandy Pond				Dates: 7/22/14 & 7/30/14		
Waypoint	# Dune Willows Alive	# Dune Willows Dead	# Plants with Adults	# Plants with Larvae	% Damage to Plants	Average Damage to Plants
056	14	2	0	4	1-5 %	3
100	10					
102	3	0	0	0	<1 %	0.5
103	4	0	0	0	<1 %	0.5
104	7	0	0	0	<1 %	0.5
105	15	0	0	0	<1 %	0.5
106	3	0	0	0	<1 %	0.5
107	10	0	0	0	<1 %	0.5
108	10	0	0	0	<1 %	0.5
109	25	0	0	0	<1 %	0.5
110	12	0	0	0	<1 %	0.5
112	25	0	0	0	<1 %	0.5
113	3	0	0	0	<1 %	0.5
114	4	1	0	0	<1 %	0.5
115	3	1	0	0	<1 %	0.5
116	3	0	0	0	<1 %	0.5
117	12	1	0	0	<1 %	0.5
118	10	0	0	0	<1 %	0.5
119	12	0	0	0	<1 %	0.5
120	2	0	0	0	<1 %	0.5
121	12	2	0	0	1-5 %	3
122	6	0	0	0	1-5 %	3
123	10	0	0	0	<1 %	0.5
124	17	0	0	0	1-5 %	3
125	5	0	0	0	<1 %	0.5
126	3	1	0	0	1-5 %	3
127	7	1	0	0	<1 %	0.5
128	20	0	0	0	<1 %	0.5
129	3	1	0	0	<1 %	0.5
130	15	0	0	0	<1 %	0.5
131	50	1	0	0	<1 %	0.5
132	60	0	0	0	<1 %	0.5
133	4	0	0	0	<1 %	0.5
134	3	1	0	0	<1 %	0.5
135	7	1	0	0	<1 %	0.5
136	2	0	0	0	<1 %	0.5
137	1	0	0	0	<1 %	0.5
Total:	412	13	0	4		30.5
Mean	11.13514	0.361111	0	0.1111111		0.847222
Variance	153.0646	0.351587	0	0.4444444		0.768849
S.D.	12.37193	0.592948	0	0.6666667		0.87684

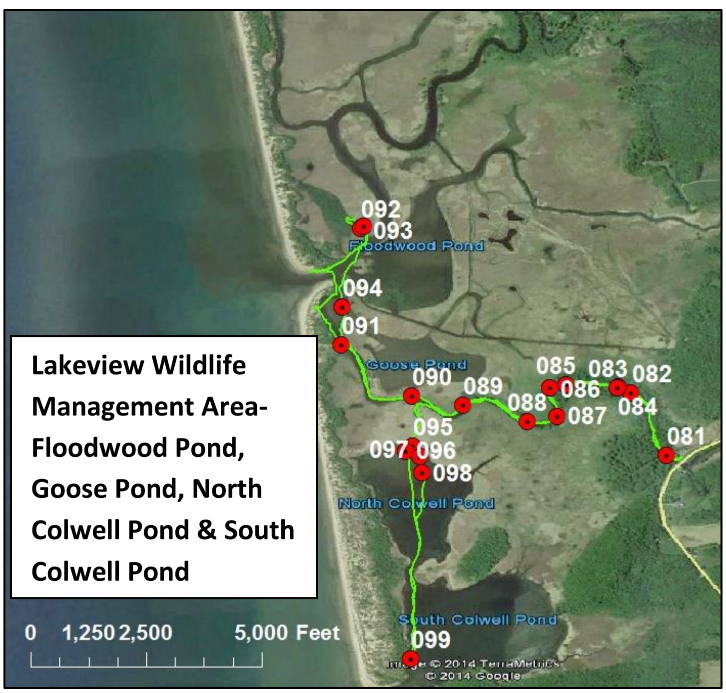
Location: Sandy Pond Beach Natural Area		Dates: 7/30/14
Waypoint	Species Observed	Notes
101	PL	Large Patch
111	PH	Large Patch

Appendix C. Dune willow monitoring results at Lakeview WMA

Location: Lakeview WMA				Dates: 7/22/14 & 7/24/14		
Waypoint	# Dune Willows Alive	# Dune Willows Dead	# Plants with Adults	# Plants with Larvae	% Damage to Plants	Average Damage to Plants
057	19	1	0	0	< 1 %	0.5
058	16	0	0	1	< 1 %	0.5
059	21	1	0	1	< 1 %	0.5
060	3	0	0	0	< 1 %	0.5
061	2	0	0	0	< 1 %	0.5
062	17	0	0	0	< 1 %	0.5
063	20	0	0	0	< 1 %	0.5
064	94	3	0	0	< 1 %	0.5
065	52	13	2	19	1-5 %	3
066	25	8	0	2	< 1 %	0.5
TOTAL:	269	26	2	23		7.5
Mean	26.9	2.6	0.2	2.3		0.75
Variance	743.211111	19.6	0.4	34.9		0.625
S.D.	27.2618985	4.427189	0.632456	5.907622		0.790569

Appendix E. Aquatic surveillance results at Lakeview



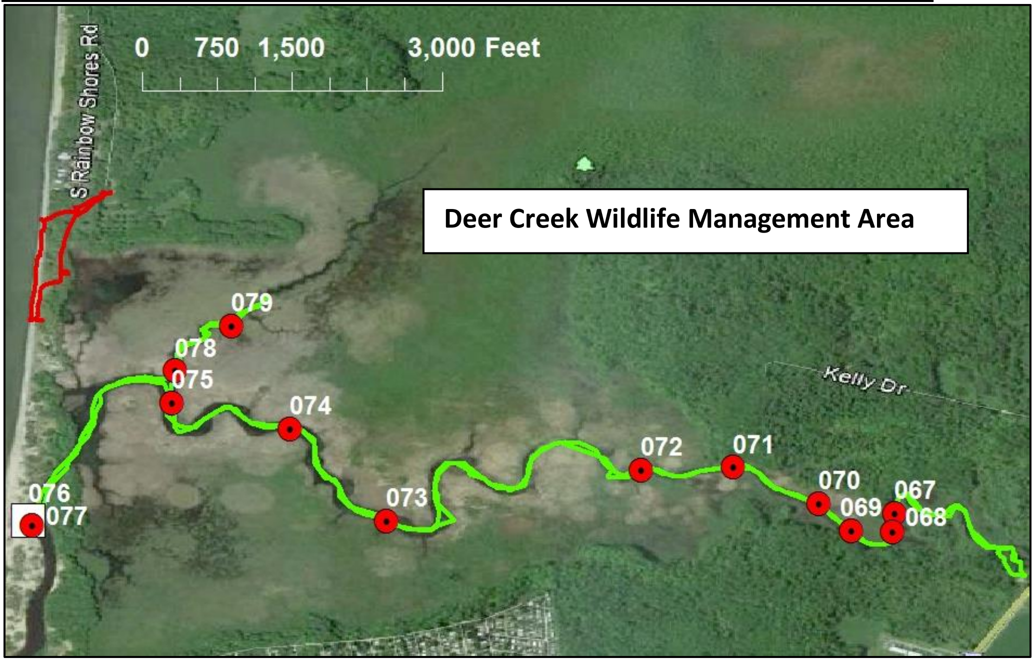


Location: Lakeview WMA		Dates: 7/21/14 & 7/25/14
Waypoint	**Species Observed**	**Notes**
040	EWM	Small patches
043	EWM, CLPW	
044	EWM, CLPW, EFB	EFB only 1 plant
045	EWM	
046	EFB	
047	EWM, CLPW	
048	EWM	Large patches
050	EWM	
051	PL	Patches along shore
052	CLPW, EWM	
053	EWM	
054	PL	Patches along shore
081	JK	Large patch along shore
082	JK, PL	Large patches of both
083	JK	Large patch
084	JK	Large patch
085	CLPW	Small patches
086	JK	Large patches
087	PH	Tall, large patch
088	CLPW	Small patch
089	PH	Small patch
090	CLPW, EFB	Small patches of both
091	EWM	Large patch
092	EFB, WC	Large patch EFB, 1 WC pulled
093	WC	Large patch, not pulled
094	BN, EWM	Large patch, small patch
095	WC	1 plant pulled
096	WC	Small patch, pulled
097	WC	Small patch, pulled
098	BN	Large patch
099	EWM	Large patch

Appendix F. Dune willow monitoring and aquatic surveillance results at Deer Creek WMA

Location: Deer Creek WMA		Dates: 7/24/14
Waypoint	**Species Observed**	**Notes**
067	CLPW	Small patch
068	PL	Small patches along shore
069	EFB	Small patch
070	EWM	Large patches
071	PL	Large patch on shore
072	CLPW	Small patch
073	CLPW	Small patch
074	PL	Small patches on shore
075	EWM, CLPW	Large patch, small patch
077	PL	Along shore
078	CLPW, PL	Large patches of both
079	EFB	Large patch

Location: Deer Creek WMA					Dates: 7/24/14	
Waypoint	**# Dune Willows Alive**	**# Dune Willows Dead**	**# Plants with Adults**	**# Plants with Larvae**	**% Damage to Plants**	**Average Damage to Plants**
076	30	2	0	0	< 1 %	0.5



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