RAP Progress in the Rochester Embayment of Lake Ontario: Population Monitoring, Trophic Relationships, and Levels of Bioaccumulative Chemicals of Concern in Mink, a Sentinel Species

Final Report

to

The New York Great Lakes Protection Fund
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EXECUTIVE SUMMARY

This project was designed to determine if two use impairments identified in the Remedial Action Plan (RAP) for the Rochester Embayment of Lake Ontario (RELO) can be delisted: 1) bird or animal deformities or reproductive problems, and 2) degradation of fish or wildlife populations. The eight research and one management questions addressed by this study, and the answers to those questions, follow.

1. *Are there differences in the relative abundance of lakeshore and inland mink populations in and out of the RELO AOC (Area of Concern)?* Video-trapping data tentatively suggested that there are no differences in the relative abundance of mink populations in and out of the AOC or between lakeshore and inland areas.
2. *Are mink reproducing in and out of the RELO AOC?* Video observations confirmed that mink are reproducing along the lakeshore in the AOC and at other locations studied. Mink less than one year old were physically trapped in all areas, implying reproduction in all areas.
3. *Can stable isotope analysis be used to evaluate mink diets, at lakeshore and inland areas in and out of the AOC, in terms of trophic levels and terrestrial and aquatic food sources?* Mink in the study areas fed on prey at an average trophic level of 2.5 (half way between first- and second-level predators). The percent aquatic diet could not be determined.
4. *Can stable isotopes be used to construct a food web/bioaccumulation model for mink in the RELO AOC to predict body burdens of BCCs (bioaccumulative chemicals of concern) in mink in relation to their diets?* Using trophic level determinations and estimated values from literature ranging from 50% to 90% aquatic diet, a food web bioaccumulation model, modified from Sample *et al*. (1996), was used to predict the exposure of mink in the AOC to BCCs based on a BCC's concentration in the water body supporting a mink's food web.
5. *What are the current levels of BCCs in lakeshore and inland populations of mink in and out of the RELO AOC?* Highly consistent patterns of BCC concentrations were observed across tissues and chemicals. The clear signal in the chemical data are that mink captured near Lake Ontario, and presumably eating organisms exposed to Lake Ontario water and its food web, have significantly higher BCC concentrations in their tissues than mink captured inland.
6. *Which BCCs, and at what levels, are known to cause adverse effects on populations or reproduction, or to cause deformities, in mink?* The answer to this question is chemical and

tissue specific. Jaw lesions associated with 40.2 ppb TEQ (toxic equivalents of 2,3,7,8-tetrachlorodibenzo-p-dioxin)/g liver appear to be the most sensitive bioindicator of the toxic effects of BCCs on mink.

7. *Are concentrations of BCCs in RELO AOC mink high enough to cause adverse effects?* The highest measured TEQ value for AOC lakeshore mink (and in the entire study) was 47.62 pg TEQ/g liver wet weight, which is slightly higher than the lowest LOAEL (40.2 pg TEQ/g liver) at which jaw lesions have been observed in 31-week mink kits.
8. *How do predicted levels of BCCs in mink tissues (based on concentrations in Lake Ontario water) compare with measured tissue residues in lakeshore mink specimens?* The bioaccumulation model (Sample *et al.* 1996) worked well for dioxin/furan TEQs and for total PCBs. In both cases, the predicted low and high values bounded measured values, except for the low estimate for PCBs which was very close to the lowest measured value in a lakeshore mink. The model did not predict tissue levels of mercury well.
9. *What is the most reliable and efficient way to monitor the health of RELO AOC mink populations in the future?* Mink jaw lesions have the lowest reported LOAEL in relation to mink reproduction and deformities, and these lesions are a simple, inexpensive bioindicator. Only the mink with the highest total PCB concentration and adipose TEQ and the third highest liver TEQ, vs. the mink with the next highest body burden of BCCs, had jaw lesions and it came from the lakeshore-AOC area.

Conclusion—. Mink are reasonably abundant in the RELO AOC, and they are reproducing. It is unlikely that BCC sources in the AOC are now contributing to “degradation of fish and wildlife populations” and “bird or animal deformities or reproductive problems.” Exposure to the Lake Ontario food web is associated with the highest levels of BCCs in mink. The bioaccumulation model used in this study should be used to predict concentrations of dioxins/furans and PCBs in mink as new data on the concentrations of these chemicals in Lake Ontario or Braddock Bay water become available. Once the model predicts concentrations below the LOAEL for jaw lesions, further mink monitoring should be done by sending teeth for aging and jaws for analysis of lesions. If age 1 mink, and older mink with no lesions, are found, confidence that mink exposed to the Lake Ontario food web are no longer at risk for population, reproductive or deformity problems will be high and delisting should proceed.

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INTRODUCTION

In the 1980s the binational (Canada, U.S.) International Joint Commission (IJC) began the process of creating and implementing remedial action plans (RAPs) in 43 contaminated areas of concern (AOCs) throughout the Great Lakes Basin. The IJC established 14 “use impairments” that could cause a local area to be “listed” as an AOC, including “degradation of fish and wildlife populations” and “bird or animal deformities or reproductive problems.” In 1988, Foley *et al.* reported that fish in Lake Ontario and the Genesee River had PCB concentrations within the range shown to cause reproductive failure in captive mink. This evidence, coupled with the perceived absence of mink within 2 miles of the lake, led to the inclusion of these two use impairments in the RAP (1993, 1997). This study (Haynes *et al.* 2002) was designed to determine if populations of mink on the shore of the Rochester Embayment of Lake Ontario (RELO) are negatively impacted by bioaccumulative chemicals of concern (BCCs) and, if so, whether the BCCs are originating in the Embayment watershed or elsewhere. The AOC includes the Embayment, a 35 square mile portion of Lake Ontario south of a line between Bogus Point in the town of Parma and Nine Mile Point in the town of Webster (both in Monroe County, New York); adjacent wetlands and bays; and the six mile reach of the Genesee River, from the Lower Falls to the mouth at Lake Ontario (Figure 1). The RAP also includes the sub-watersheds of Salmon Creek (western sub-basin), the Genesee River, and Irondequoit Creek (central sub-basin) (Figure 2).

The questions addressed by this study were:

1. Are there differences in the relative abundance of lakeshore and inland mink populations in and out of the RELO AOC?
2. Are mink reproducing in and out of the RELO AOC?
3. Can stable isotope analysis be used to evaluate mink diets, at lakeshore and inland areas in and out of the AOC, in terms of trophic levels and terrestrial and aquatic food sources?

4. Can stable isotopes be used to construct a food web/bioaccumulation model for mink in the RELO AOC to predict body burdens of BCCs in mink in relation to their diets?
5. What are the current levels of BCCs in lakeshore and inland populations of mink in and out of the RELO AOC?
6. Which BCCs, and at what levels, are known to cause adverse effects on populations or reproduction, or to cause deformities, in mink?
7. Are concentrations of BCCs in RELO AOC mink high enough to cause adverse effects?
8. How do predicted levels of BCCs in mink tissues (based on concentrations in Lake Ontario water) compare with measured tissue residues in lakeshore mink specimens?
9. What is the most reliable and efficient way to monitor the health of RELO AOC mink populations in the future?

The purpose of this final report is to summarize the key findings related to questions 1-8 above (Appendices 1-4), and to propose a plan for monitoring RAP progress by monitoring the health of RELO AOC mink populations in the future.

The mink as a sentinel species

The mink is commonly found along water edges and in wetlands wherever there is cover such as emergent vegetation, brush or forest. It is a predator and eats anything it can catch, including aquatic invertebrates, fish, frogs, birds, and small mammals (Illinois Natural History Survey 2001). Its position atop the aquatic food chain makes it highly susceptible to toxic pollutants in its environment due to the processes of bioaccumulation and biomagnification.

The sensitivity of mink to BCCs became evident in the 1960s when farmed mink exhibited reproductive problems and mortality after feeding on fish taken from the Great Lakes. In 1968, mink fed Lake Michigan coho salmon as 15% of their diet suffered 80% kit mortality (Aulerich and Ringer 1977). Feeding mink coho salmon from Lake Michigan had adverse effects almost identical to those of giving the mink 30 ppm PCBs (Aroclor mixture) in their feed (Aulerich et al. 1971). Both the PCBs and the Lake Michigan salmon caused reproductive problems such as reduced whelping and kit survival and decreased kit weight. Other adverse effects were increased adult mortality and digestive and excretory system problems such as anorexia, bloody stools, gastric ulcers, and degeneration of liver and kidney.

Since mink are an economic resource, there was great interest in research into pollutants' effects on them, and by 1991 many lab studies had shown mink "particularly sensitive to toxic chemicals" (Wren 1991). These studies were done on laboratory animals that were otherwise healthy, well nourished, and living in a climate-controlled environment; wild populations likely are more sensitive due to stresses of hunger, weather, disease, or injury. By 1991 the accumulated evidence prompted this pronouncement from the editors of the Proceedings of the Expert Consultation Meeting on Mink and Otter: "The mink is the free-living mammal most sensitive to toxic substances such as PCBs and TCDD, and its diet provides an integrated exposure to contaminants in shoreline wetlands" (Addison *et al.* 1991). BCCs of concern in Rochester AOC (defined by G. N. Neuderfer, aquatic toxicologist, NYSDEC, Avon, NY) are PCBs, dioxins/furans, aldrin/dieldrin, chlordane, mirex/photomirex, DDT/metabolites, and methyl-mercury. Thus, the mink is an appropriate sentinel species for the RELO RAP.

METHODS

The methods for each phase of this study are described in Appendices 1 (*Are There Differences in the Relative Abundance of Lakeshore and Inland Mink In and Out of the Rochester Embayment of Lake Ontario Area of Concern*; Wellman and Haynes 2006a), 2 (*Age, Size, and Stable Isotope Data of Mink Populations, and a Predictive Model of Biaccumulation of Chemicals of Concern in the Rochester Embayment of Lake Ontario*; Wellman and Haynes 2006b), 3 (*Levels of Bioaccumulative Chemicals of Concern in Mink In and Out of the Rochester Embayment Area of Concern and On and Off the Shoreline of Lake Ontario*; Pagano and Haynes 2007), and 4 (*Bioaccumulative Chemicals of Concern in Mink: Adverse Effects Levels and Results of a Predictive Model for the Rochester Embayment of Lake Ontario*; Wellman and Haynes 2007).

It is important to clear up one matter arising from PI Haynes' confusion and subsequent miscommunication with NYS GLPF Administrator. The original proposal

(Haynes et al. 2002) stated that "Polychlorinated Biphenyls (99 zones, 132 congeners), Mirex/Photomirex, HCB, and DDE" would be analyzed by PI Pagano and that "Columbia Analytical Services, Inc. will conduct dioxin/furan (Houston, TX) and Methyl-mercury (Kelso, WA) analyses for this project." Because there are 209 PCB congeners, many of which do not elute in the standard total PCB analysis (including the dioxin-like, co-planar PCB congeners), and because co-planar PCB analysis is also a separate, expensive activity from dioxin-furan analysis, it was never proposed to do analyses for co-planar PCBs for this project. Using well-established values from the literature (Appendix 4), TEQs from the dioxin-furan analyses were recalculated to include estimated contributions from co-planar PCBs. Thus, the predicted toxicity of BCCs in mink was fully accounted for in the study. Finally, polybrominated diethyl ethers (PDBEs) not proposed for analysis in the original proposal also were quantified in mink tissues.

RESULTS AND DISCUSSION

Are there differences in the relative abundance of lakeshore and inland mink populations in and out of the RELO AOC? (Appendix 1)

Video-trapping data tentatively suggest that there are no differences in the relative abundance of mink populations in and out of the AOC or between lakeshore and inland areas. However, the statistical power (probability of avoiding a Type II error) of the analyses was low due to high variability within and between sampling sites and small sample sizes. A Type II error is the conclusion that there is no significant difference between treatments (e.g., lakeshore vs. inland relative population size) when, in fact, a difference exists. To be confident about delisting a use impairment requires high confidence that the probability of a Type II error is low (e.g., lakeshore vs. inland and AOC: in vs. out comparisons). Video-trapping data alone do not provide a high level of confidence for delisting the "degradation of fish and wildlife populations" use impairment for mink.

Are mink reproducing in and out of the RELO AOC? (Appendix 1)

Video observations confirmed that mink are reproducing along the lakeshore in the AOC and at other locations studied. Mink less than one year old (based on counting annual age rings in teeth) were physically trapped in all areas, implying reproduction in all areas. Although our observations cannot indicate whether reproduction is taking place at levels that would be considered "normal," these data suggest that the "reproductive problems" part of the "bird or animal deformities or reproductive problems" use impairment can be delisted in the AOC.

Can stable isotope analysis be used to evaluate mink diets, at lakeshore and inland areas in and out of the AOC, in terms of trophic levels ($\delta^{15}N$ ratio) and terrestrial and aquatic food sources ($\delta^{13}C$ ratio)? (Appendix 2)

Analysis of $\delta^{15}N$ showed that mink in the study area feed on prey at an average trophic level of 2.5 (slightly higher along the lakeshore and in the AOC than elsewhere, with the highest level (2.8) along the lakeshore in the AOC), where trophic level 1 is plants, trophic level 2 is herbivores, and trophic level 3 is primary carnivores. The percent aquatic diet could not be determined for lack of $\delta^{13}C$ values for carbon sources (i.e., phytoplankton, submergent and emergent macrophytes) in the AOC wetlands.

Can stable isotopes be used to construct a food web/bioaccumulation model for mink in the RELO AOC to predict body burdens of BCCs in mink in relation to their diets? (Appendix 2)

Using trophic level determinations ($\delta^{15}N$) and estimated values from literature ranging from 50% to 90% aquatic diet, a food web bioaccumulation model, modified from Sample et al. (1996), was used to predict the exposure of mink in the AOC to BCCs based on a BCC's concentration in the water body (e.g., Lake Ontario) supporting the minks' food web.

What are the current levels of BCCs in lakeshore and inland populations of mink in and out of the RELO AOC? (Appendix 3)

Highly consistent patterns of BCC concentrations were observed across tissues and chemicals. Correlations among concentrations of the seven most notable chemicals analyzed were mostly high and significant in adipose and liver tissue. There were no significant differences in BCC concentrations in and out of the RELO AOC but BCC concentrations in mink captured near the Lake Ontario shore were significantly ($P < 0.05$) or suggestively ($0.05 < P < 0.1$) greater than concentrations in mink captured inland. The clear signal in the chemical data are that mink captured near Lake Ontario, and presumably eating organisms exposed to Lake Ontario water and its food web, have significantly higher BCC concentrations in their tissues than mink captured inland.

Which BCCs, and at what levels, are known to cause adverse effects on populations or reproduction, or to cause deformities, in mink? (Appendix 4)

During the literature search for this project, the lowest observed adverse effect level (LOAEL) was for dioxin (CDD); 0.053 ppb in the diet of mink was associated with reduced kit survival at three weeks (Appendix 4—Appendix A-1). For PCB TEQ (toxic equivalents in relation to TCDD), the lowest LOAEL found was 26.9 ppb in liver associated with changes in retinol and retinyl ester concentrations in 27-week juvenile mink (Appendix 4—Appendix A-2). For mercury, the lowest LOAEL found was 1.06 ppm in liver associated with smaller litter sizes (Table 1). Because the relationship between retinol and retinyl esters and problems with mink populations in terms of reproduction and deformities is unknown, more-easily-detected jaw lesions associated with 40.2 ppb TEQ/g liver appear to be the most sensitive bioindicator of the toxic effects of BCCs on mink (Table 1).

Table 1. Selected endpoints and effects levels reported for mercury, PCBs, and TEQs in mink diets and tissues. (Values in italics were estimated using the average brain:liver ratios from Evans *et al.* 2000, Wobeser *et al.* 1976, and Wren *et al.* 1987a, b.) CDD = chlorinated dibenzo dioxins, CDF = chlorinated dibenzo furans, HCB = hexachlorobenzene.

Impairment	Endpoint	Toxin	Effect Level	Conc. (ppm or ug/g) Diet	Conc. (ppm or ug/g) Tissue	Reference
					Brain	
Population	Adult mortality	Hg	LC100	5 ppm	19.9 ppm	Aulerich et al. 1974
Reproduction	Whelping reduced	Hg in fish	LOAEL	0.5 ppm	*23.2 ug/g*	Dansereau et al. 1999
Reproduction	Litter size reduced	Hg in fish	LOAEL	0.22 ppm	*1.06 ppm*	Halbrook et al. 1997
Population	Hg intoxication	MeHg	LOAEL	1.1 ppm	8.2 ppm	Wobeser et al. 1976
Reproduction	Litter size reduced	MeHg	LOAEL	1.0 ug/g	2.0 ug/g	Wren et al. 1987a,b
					Liver	
Reproduction	Kit survival 3 & 6 wks	PCBs	LOAEL	720 pg/g	2190 pg/g	Heaton et al. 1995, Tillit et al. 1996
		CDDs	LOAEL	60 pg/g	2626 pg/g	
		CDFs	LOAEL	13 pg/g	335 pg/g	
		TEQs	LOAEL	22.4 pg/g	208.3 pg/g	
Deformities	Jaw lesion in 31-wk kits	PCBs	LOAEL	0.96 ug/g	1.698 ug/g	Bursian et al. 2006a, b
		TEQs	LOAEL	9.2 pg/g	40.2 pg/g	
Deformities	Jaw lesion in 27-wk kits	PCBs	LOAEL	1.1 ug/g	16 ug/g	Bursian et al. 2006c
		TEQs	LOAEL	47 pg/g	75 pg/g	

Reproduction	Litter size	PCBs	LOAEL	1360 ppb	7250 ppb	Halbrook et al. 1999
Reproduction	P-1 Whelping reduced	PCBs	LOAEL	0.25 ppm	860 ng/g	Restum et al. 1998
	F-2 Kit mortality	PCBs	LOAEL	0.5 ppm	464 ng/g	
					Adipose	
Reproduction	Kit mortality	HCB	LOAEL	1 ppm	95 ppb	Rush et al. 1983

LOAELs have been determined for many organochlorine (OC) pesticides (Appendix 4—Appendix A-4) but according to Giesy *et al.* (1994) studies in the 1970s and 1980s determined that OC pesticides did not cause the effects seen in mink that ate Great Lakes fish. Because OC pesticide levels have decreased in the environment since then, they would be even less significant today, which probably accounts for the lack of recent studies regarding them.

Are concentrations of BCCs in RELO AOC mink high enough to cause adverse effects? (Appendix 4)

An estimate of the total environmental TEQ exposure, based on analysis of only dioxins and furans, would range from two to ten times the dioxin/furan TEQ measured in mink tissues (Appendix 4). The highest measured TEQ value for AOC lakeshore mink in our study was 47.62 pg TEQ/g liver wet weight (Appendix 3), which is slightly higher than the lowest LOAEL (40.2 pg TEQ/g liver) at which jaw lesions were seen in 31-week kits (Table 1). The lowest measured TEQ value in lakeshore mink (0.22 pg TEQ/g), even when multiplied by ten, is still an order of magnitude smaller than the LOAEL, indicating no risk (Table 2). However, the average (excluding high and low TEQ values for the analyzed mink) of 7.8 pg TEQ/g for lakeshore mink (Table 2), if multiplied by five, approaches the LOAEL for jaw lesions. This indicates that some lakeshore mink are at risk of developing jaw lesions known to lead to jaw deformities, osteolysis, and tooth loss (Render *et al.* 2001).

The highest measured TEQ for inland mink was 4.16 pg TEQ/g (Appendix 3). When multiplied by ten, the result is approximately equal to the 40.2 pg TEQ/g LOAEL for jaw lesions, indicating that the most exposed of the inland mink may be at low risk for developing jaw lesions. However, the lowest (0.00 pg TEQ/g) and average (0.25 pg TEQ/g) TEQ values for inland mink (excluding high and low TEQ values for the analyzed mink), even when multiplied by ten, indicate that the majority of inland mink are not at risk (Table 2).

Table 2. TEQ values (pg/g) for dioxins and furans from Lakeshore and Inland mink livers, showing high, low and average (excluding high and low) values for each category.

Location	Value	TEQ	TEQ*2	TEQ*10
Lakeshore	Low	0.22	0.44	2.2
	Average (8)	7.75	15.50	77.5
	High	47.62	95.24	476.2
Inland	Low	0.00	0.00	0.00
	Average (8)	0.25	0.50	2.50
	High	4.16	8.32	41.6

Total mercury concentrations in the brains of AOC mink averaged 0.281 ppm along the lakeshore and 0.158 ppm inland (Appendix 3—Table 7), levels 3-6 times lower than lowest LOAEL of 1.06 ppm reported to cause a reduction in litter size of mink. Therefore, it is unlikely that mercury is having an adverse effect on mink in the AOC.

How do predicted levels of BCCs in mink tissues (based on concentrations in Lake Ontario water) compare with measured tissue residues in lakeshore mink specimens? (Appendix 4)

The bioaccumulation model (Sample *et al.* 1996) worked well for dioxin/furan TEQs and for PCBs. In both cases, the predicted low and high values bounded measured values, except for the low estimate for PCBs which was very close to the lowest measured value in a lakeshore mink (Table 3). This was expected, as the AOC is neither the most polluted nor the cleanest portion of Lake Ontario (Luckey and Litton 2005; J. Vincent, pers. comm.).

The model did not predict tissue levels of mercury well; the measured values were up to three orders of magnitude higher than predicted values. The reason for this discrepancy is not known. One possibility is the fact that the model is based on the octanol-water partition coefficient, a concept which applies only to lipophilic compounds, which mercury is not. However, Sample *et al.* (1996) apparently intended the model to be used with mercury, as they provided BAF factors for it (as well as several other heavy metals). Another possibility is that the model predicts mercury concentrations in tissue based only on aquatic exposures; mink in our study might have had exposure to mercury through terrestrial sources unaccounted for by the model.

Further investigation and development of the model will be required if it is deemed necessary to predict mercury levels in mink of the Rochester Embayment.

Table 3. Predicted versus measured values for tissue residues of dioxin/furans (TEQs), methylmercury, and PCBs, based on water concentrations in Lake Ontario as reported by J. Vincent (2006, Environment Canada, pers. comm..) and Luckey and Litton (2005).

			Tissue Level	
	Water Conc.		Predicted	Measured
Value	pg/kg	BCC	ng/g	ng/g
Low	0.00006	TEQs (liver)	0.0000552	0.00022
High	0.0024		0.0621	0.0213
Low	0.0	MeHg (brain)	0.0	90
High	18.0		4.70	1,550
Low	26.0	PCBs (liver)	19.2	13.6
High	915.0		160,000	5,870

What is the most reliable and efficient way to monitor the health of RELO AOC mink populations in the future?

Mink jaw lesions have the lowest reported LOAEL in relation to mink reproduction and deformities (Appendix 4), and these lesions are a simple, inexpensive (~$40/sample) bioindicator of exposure to BCCs, particularly dioxins and furans. Jaws from 12 specimens collected in this study were sent for histological preparation (Kerrie Beckett, Woodlot Alternatives, Topsham, ME) and analysis (Steven Bursian, Dept. of Animal Science, Michigan State University) including the animals with the highest, typical and lowest BCC levels at the inland and lakeshore study areas in and out of the AOC. The only mink with jaw lesions (multiple squamous epithelial cysts or cell proliferations at multiple zones along the entire dental arcade, including bone lysis and cell atypia consistent with malignancy; Beckett et al. 2005, Bursian et al. 2006) was captured along the lakeshore in the AOC. It also had the highest total PCB concentration (by a factor of 2.46) and adipose TEQ (by a factor of 8.85) and the third highest liver TEQ (by a factor of 0.45) of the animals analyzed (Appendix 5). Therefore, it is still possible for a mink in the AOC to accumulate body burdens of BCCs that produce jaw lesions, the most sensitive indicator of exposure currently known. However, there is no evidence in the literature or from our observations of juvenile mink that current levels of exposure along the lakeshore or inland, in or out of the AOC, are adversely affecting mink populations.

CONCLUSION

This study documented the presence of mink populations, and mink reproduction, in the RELO AOC. Except for a single lakeshore mink with the highest BCC concentrations in its tissues, analytical, modeling and literature review results all suggest that mink reproduction is unlikely to be impaired in the AOC. Therefore, it is unlikely that BCC sources in the AOC are now contributing to the "degradation of fish and wildlife populations" and "bird or animal deformities or reproductive problems" use impairments identified in the RAP (1993, 1997). The results make clear that exposure to the Lake Ontario food web is associated with the highest levels of BCCs in mink in the AOC and elsewhere along the lakeshore.

The bioaccumulation model used in this study should be used to predict concentrations of dioxins/furans and PCBs in mink as new data on the concentrations of these chemicals in Lake Ontario or Braddock Bay water become available. We recommend that the USEPA or NYDEC sample the waters of Braddock Bay and lower Salmon Creek, the capture location of mink #17 with the highest concentrations of BCCs, during their future monitoring of Lake Ontario. Once the model predicts concentrations below the LOAEL for jaw lesions, further biological monitoring should be done by contracting with trappers to capture mink and sending their teeth for aging and their jaws for analysis of lesions. If age 1 mink, and older mink with no lesions, are found, confidence that mink exposed to the Lake Ontario food web are no longer at risk for population, reproductive or deformity problems will be high and delisting should proceed.

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FIGURES

Figure 1. Rochester Embayment of Lake Ontario Area of Concern (RELO AOC).

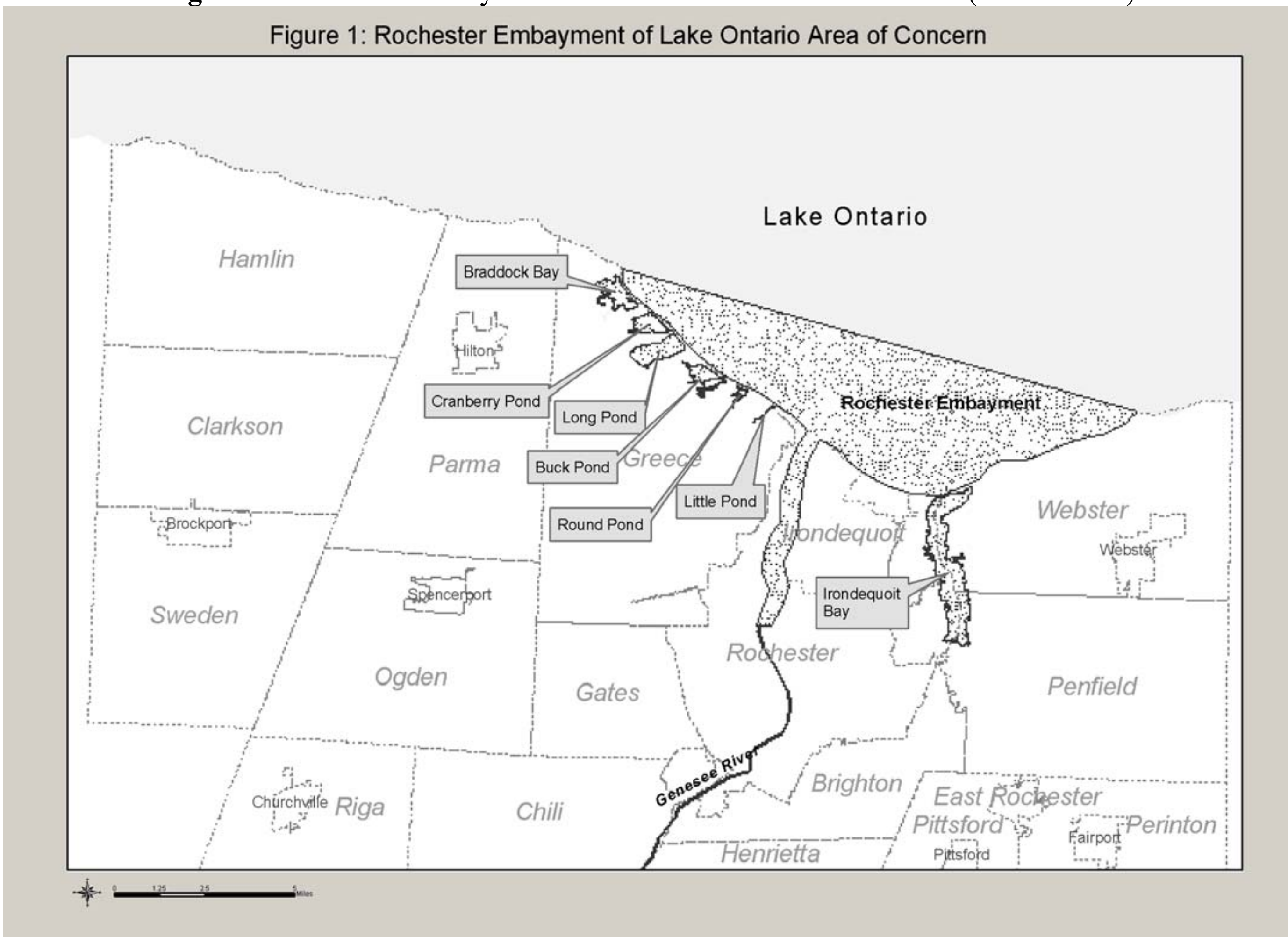
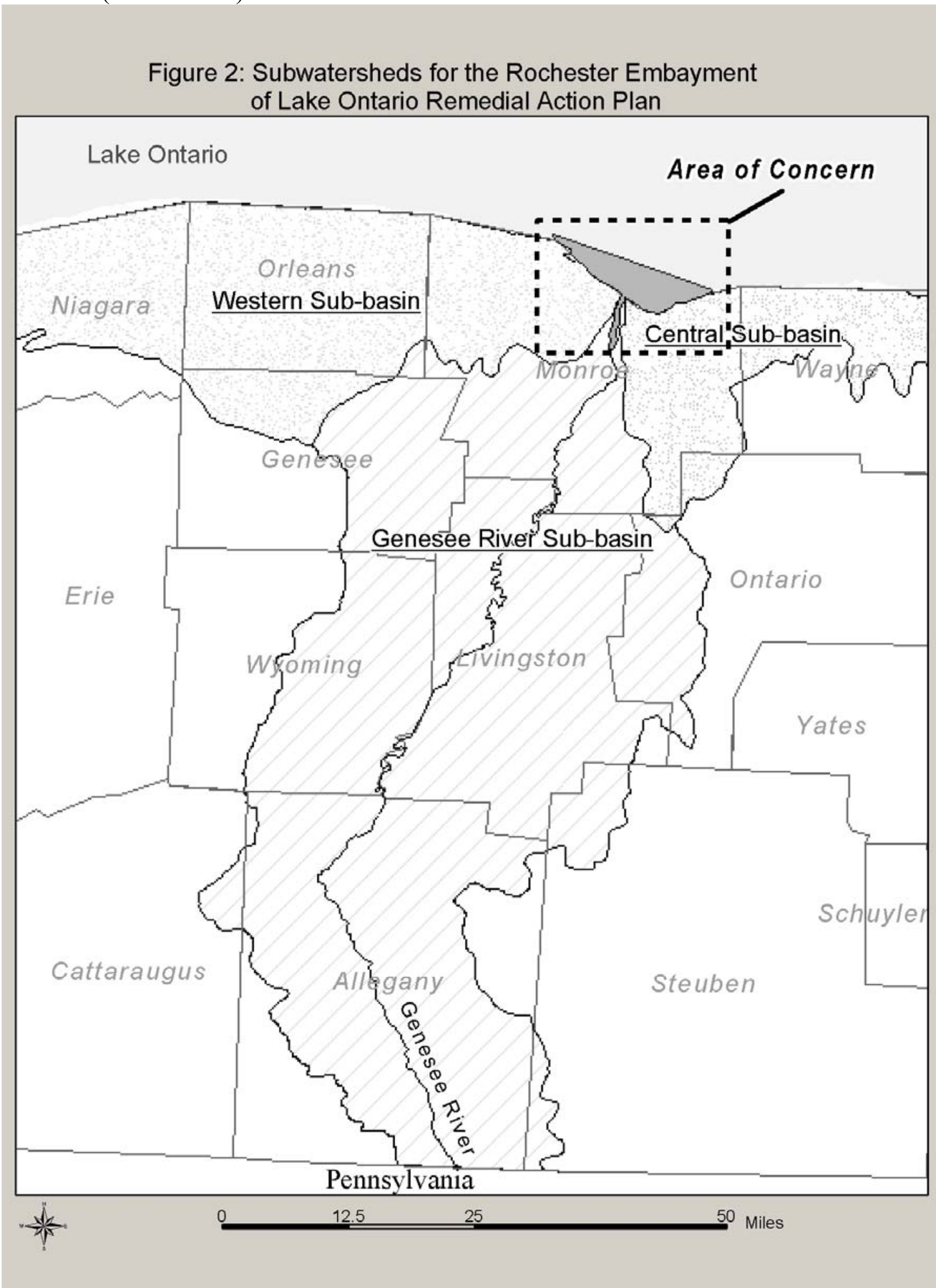


Figure 1: Rochester Embayment of Lake Ontario Area of Concern

Figure 2. Sub-basins considered in the Rochester Embayment of Lake Ontario Remedial Action Plan (RELO RAP).



APPENDICES

Appendix 1

Are there Differences in the Relative Abundance of Lakeshore and Inland Mink Populations In and Out of the Rochester Embayment of Lake Ontario Area of Concern?: Monitoring Mink Populations Using Video Traps

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OVERVIEW

This report is the first of four from project C302399, "*RAP Progress in the Rochester Embayment of Lake Ontario: Population Monitoring, Trophic Relationships, and Levels of Bioaccumulative Chemicals of Concern in Mink, a Sentinel Species*," funded by the New York Great Lakes Protection Fund in 2004. The project addresses use impairments related to water quality identified in the Remedial Action Plan for the Rochester Embayment of Lake Ontario (RELO RAP). This report deals with the development and use of video trapping systems that established the presence and reproduction of mink (*Mustela vison*) in and out of the RELO RAP Area of Concern (AOC). Three more reports will be written in 2006: (1) trophic positions (stable isotope analysis) and ages of mink (Wellman and Haynes, in preparation), (2) levels of bioaccumulative chemicals of concern (BCCs) in mink tissues (Pagano and Haynes, in preparation), and (3) a literature review of the effects BCCs on mink (Wellman, in preparation). Because the mink is the most sensitive species to BCCs known, the results of this study will determine if the fish and wildlife reproduction impairment for the RELO AOC can be recommended for delisting.

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INTRODUCTION

In the 1980s the binational (Canada, U.S.) International Joint Commission (IJC) began the process of creating and implementing remedial action plans (RAPs) in 43 contaminated areas of concern (AOCs) throughout the Great Lakes Basin. The IJC established 14 "use impairments" that could cause a local area to be "listed" as an AOC, including "degradation of fish and wildlife populations" and "bird or animal deformities or reproductive problems." In the Rochester AOC, both uses were defined as impaired because "very few" mink were then being trapped or observed within 2 miles of the lake (RAP 1993, 1997). This study was part of a project (Haynes *et al.* 2002) to determine whether lakeshore populations of mink along the Rochester Embayment of Lake Ontario (RELO) are negatively impacted by bioaccumulative chemicals of concern (BCCs) and, if so, whether the BCCs are originating in the embayment watershed or elsewhere.

The RELO AOC includes the Embayment, a 35 square mile portion of Lake Ontario south of a line between Bogus Point in the town of Parma and Nine Mile Point in the town of Webster (both in Monroe County, New York); adjacent wetlands and bays; and the six mile reach of the Genesee River from the Lower Falls to the mouth at Lake Ontario. The RAP also includes the subwatersheds of Salmon Creek, the Genesee River and Irondequoit Creek (RAP 1993, 1997; Figure 1).

The question addressed by this portion of the study was: Are there differences in the relative abundance of lakeshore and inland mink populations in and out of the RELO AOC? Our approach was to record the passage of mink using four "MustelaVision" videotrap systems in each of four regions designated as Lakeshore/AOC, Inland/AOC, Lakeshore/Out of AOC, and Inland/Out of AOC (Figure 1). Previous studies (cf. Gerrell 1970, Birks and Linn 1982, Eagle and Whitman 1987, Yamaguchi and MacDonald 2003) support our assumption that the number of mink passages recorded is related to relative population abundance (see Discussion). We tested the null hypothesis that there were no differences in passage rates among regions. We also went beyond the scope of our contract to look at the effect of several physical environmental variables on mink passage rates, and report on some observed mink behaviors.

METHODS AND MATERIALS

Locations of Study Sites

To maximize the chances of recording mink passages, we placed the Mustela-Vision systems in locations where mink were most likely to be found. Mink are semi-aquatic animals, found in wetlands and along water edges, especially with cover such as emergent vegetation, brush or forest (Linscombe *et al.* 1982, Allen 1986, Eagle and Whitman 1987, Dunstone 1993, Yamaguchi *et al.* 2003, Illinois Natural History Survey 2005, USDA Forest Service 2005).

Based on this information, the region chosen as Lakeshore/AOC was the Braddock Bay State Wildlife Management Area (BBWMA), a wetlands complex broadly connected to the RELO, separated only by narrow barrier beaches. The Inland/AOC region was around the Bergen Swamp, a smaller wetlands complex on Black Creek

(BLKCK), within the RELO watershed. The Inland/Out of AOC region was the Iroquois National Wildlife Refuge (INWR) and two connected state WMAs, a huge managed wetlands complex known to harbor abundant mink. Finally, the Lakeshore/Out of AOC region was along the Lake Ontario State Parkway (LOSPW) west of the RELO watershed, where creeks and small wetlands drain directly into Lake Ontario (Figure 1).

With the help of experienced trappers, we chose sites in each region most likely to be frequented by mink; in many cases we were guided by mink tracks or previous trappers' success. Each camera was placed near a water edge, either in a wetland or along a stream. Mink run along the edge of the water whenever possible (Burgess 1978, cited by Allen 1986; Eagle and Whitman 1987; Dunstone 1993; Yamaguchi *et al.* 2003; Yamaguchi and Macdonald 2003). Therefore, trappers usually set their traps at the corners of culverts and bridges where the minks' paths are funneled into these openings (Jamison 1983, Krause 1984, Geary 1985, National Trappers' Association 2005), and we looked for such tunnels when placing MustelaVision systems. Mink often use paths or "runways" through tall grass, cattails, and brush (Schladweiler and Storm 1969, Dunstone 1993, Racey and Euler 2003), and, according to trappers, ledges just under the water's surface along the bank, which also informed our choices of sites.

Because we were still searching for a suitable Lakeshore/Out of AOC region, no MustelaVision systems were placed in the LOSPW region in 2003. Systems were placed at 14 sites in the other three regions from June through October 2003. We considered the 2003 season our "exploratory season" during which we tried to find the best sites (i.e., most likely to observe mink passages) in each region, so either during 2003 or before the 2004 season, two systems in each of the original three regions were moved to potentially better locations. Thus, eight sites found in 2003, along with two new sites each in BBWMA and BLKCK and four new sites in the LOSP West region, were monitored from May to October 2004 (Table 1).

MustelaVision System

System Requirements

The MustelaVision system (Appendix A) was designed and built for this project by Jeffrey Wellman, an electrical engineer. We required a system usable in remote locations, powered by DC batteries, weatherproof, portable, lockable and affordable. To save battery power, videotape, and time for tabulating data, the system had to be triggered by the animal, rather than recording continuously. It also had to work day and night, because mink are considered predominantly nocturnal (cf. Birks and Linn 1982, Allen 1986, Eagle and Whitman 1987), and to operate quietly and invisibly to avoid disturbing the wary animals (Jamison 1983, Krause 1984, Barker 1991, Dunstone 1993).

System Components

The MustelaVision system (Appendix A-1a, b) consisted of an electronic camera head (Appendix A-1a, c) designed for security applications (Model PIC-I, SpyCameras ForLess.com), a 12-volt, 2-head videocassette recorder (Jensen KVC1500), a 12-volt DC deep-discharge battery, and a custom-built circuit board (Appendix A-1d) to protect the batteries from over-discharge which would shorten their useful lives. The camera head was attached to the VCR by a 50-foot cable, and it communicated with the VCR with an IR LED (infrared light emitting diode) that emulated the VCR's remote control unit.

The black and white Sony CCD (charge-coupled device) camera had a 464 X 625 pixel array, with 8-bit resolution, and a 92-degree field of view. The camera monitored an area 3 m wide by at least 12 m deep (depending on the camera angle relative to the ground). For image capture in the dark the camera head had six IR LEDs, providing a pool of illumination on the ground about 1 m wide by 2 m deep (again depending on camera angle. However, animals could be detected up to at least 10 m from the camera at night due to eye shine and their body heat against a cooler background.

The camera head had an IR motion detector that monitored a 104-degree by 15 m field. (Motion detection outside the viewing area meant fewer missed targets but more false triggers.) When the sensor detected motion it issued a “start recording” command to the VCR and started a 30-sec timer. If further motion was detected during the 30-sec period, the timer reset and recording time was extended. If no more motion was detected, after 30 seconds the camera head issued a “stop recording” command to the VCR.

System Placement

With one exception (a potential den site about 2 m from the water on Bald Eagle Creek’s west bank, LOSPW), each camera was placed on a stake within a meter of the water’s edge; often the stake was placed in the water. Each camera was aimed at the water’s edge to include in its field of view the pathway along which a mink would travel and the edge of the water in and along which it would forage. If the site included a tunnel, we aimed the camera at the opening through which mink would be forced to travel.

Along with mink habitat preferences, certain characteristics of the MustelaVision system dictated site choice and camera placement for optimal performance. Sites had to be near a road because of heavy batteries. To minimize tampering, the system had to be hidden in brush near a tree or other structure to which we could lock it. Also, we looked for high ground to avoid flooding and for shade to avoid overheating the electronics.

Camera angle was also important to avoid spurious triggers. We had to avoid sunbeams directed into the camera or reflected off water, vegetation near the camera that would trigger it during a breeze, and road and pedestrian traffic.

Field Service

Each MustelaVision system was serviced once per week. The batteries and videotapes were replaced, the camera lens was cleaned, the system was checked for functionality, and the field of view was checked for mink tracks and scats.

Data Recording

Data Sheets

System Log: Each MustelaVision system was assigned a letter to identify it, and had a separate log sheet (Appendix A-2a). During each field service session, we recorded on each System Log sheet the date of service, the ID numbers of the videotape cassette and battery, and comments such as mink tracks observed or operational problems.

Tape Log: Before viewing each videocassette, we recorded on its Tape Log (Appendix A-2b) which system the tape had been in, system location, dates during which the tape was in the system, and the total length of videotape recorded during that time. As we viewed the tape, we recorded periods of daylight and darkness, and all animals coming into the field of view of the camera.

Definitions and Formulas

Session: A Video Session was defined as the video recorded at one site on one cassette between service dates noted in System Log.

Mink Passage: A Mink Passage was defined as any time a mink came into the field of view of the camera and the camera was triggered and then turned off 30 sec after the mink left. Thus, if the mink passed out of the field of view and then back in before the camera stopped recording (no matter how many times), that was recorded as only one passage. In the rare cases in which multiple mink were recorded, their number was noted for that passage.

Trap Nights: Trap Nights were the number of 24-h periods observed on a video tape. In the video data log, a Trap Night was recorded for each period of contiguous dark shots, separated by daylight shots. If the camera was not triggered during a day, two consecutive nights could have been counted as one Trap Night. Thus, estimates were bounded by using Minimum and Maximum Trap Night calculations, in which the Min Trap Nights was the number of Trap Nights seen on the video during that session, and the Max Trap Nights was the number of nights between service dates in the System Log. If no nights were seen, but there were day shots, the Min Trap Nights was recorded as one. If the system triggered properly when started (recording our initial test hand wave, indicating that it was functioning properly), but otherwise did not trigger during the week (Session), the Trap Nights and Passages were recorded as zeros. If the system was non-functional throughout the Session (i.e. nothing on videotape at all, not even our hand wave), the Trap Nights and Passages were left blank and excluded from calculations.

Day vs. Night: A mink Passage was recorded as occurring during "Day" at any time that the natural illumination was sufficient to see outside the field of illumination of the camera head's IR LEDs. When only objects illuminated by the camera's LEDs could be seen, Passages were defined as "Night". Light levels could not be used to define twilight because the camera had automatic brightness compensation, so that apparent light levels did not correspond to true ambient light levels.

Regional Descriptors: For the sake of easy reference during the following analyses, we define "Regional Descriptors" as those describing the four separate regions in which we worked, based on their characteristics on a landscape scale of many square kilometers. These Regional Descriptors were Inside vs. Outside the AOC (AOC In vs. Out); Inland vs. Lakeshore; and Landscape: Wetlands (large wetlands complex) vs. Mixed (habitat including uplands, streams, and small wetlands) (Table).

Site Descriptors: In order to evaluate the influence of ecological factors at each site on mink Passage Indices, we classified each camera site according to four factors. Habitat was classified as wetland, upland, or mixed, based on the types of vegetation visible around each camera site (many square meters). Cover was classified as cattail, brush, or forest, based on the vegetation at the camera's specific location and in its field of view (a few square meters). We also recorded whether the water ran through a Tunnel (i.e., culvert or bridge) and whether each site had an underwater Ledge (Table).

Data Analysis

System Log sheets, Tape Log sheets, data keeping, and non-statistical calculations were done using Microsoft ® Excel 2000 by Microsoft Corporation.

Statistical analysis was done using Minitab™ Statistical Software Release 14.13 (Minitab Inc. 2005).

Data from each year at each site were originally kept separately because the habitat quality of each site could have varied from year to year due to weather or wetland management practices. We also kept the yearly data separate because we wanted to determine the potential impact on MustelaVision results of trapping we had contracted for in the AOC to collect tissue samples for other parts of the project.

Passage Rates (PRs) were calculated by dividing the number of mink Passages by the number of Trap Nights at a site. Since the Trap Nights had minimum and maximum values, corresponding maximum (Max) and minimum (Min) PRs were calculated for each site in each year. To determine whether the PRs changed from 2003 to 2004, we calculated "Delta PRs" at each site for which we had data from both years. To estimate the maximum possible change in passage rate (Max Delta PR) for each site, we subtracted that site's 2003 Min PR from its 2004 Max PR; to estimate the minimum possible change in passage rate (Min Delta PR) we subtracted the 2003 Max PR from the 2004 Min PR. Thus, a positive Delta PR would indicate an increase in PR from 2003 to 2004. Using the Max Delta PRs from all sites as one data set, and the Min Delta PRs as a separate data set, we used one-sample T-tests to see if the mean difference (e.g., for either Max Delta PR or Min Delta PR) between years was different from zero. Means other than zero would have indicated a change in PRs from year to year. Since no differences were found, for subsequent analyses we combined the Passage Rate data from both years into two data sets (Max and Min PR) in which values for each year at each site were used as separate observations.

The INWR (Out of AOC study area) has a long history of targeted mink trapping, whereas the AOC does not. Therefore, we were concerned that when we contracted for mink trapping in the AOC (BBWMA and BLKCK regions) we would deplete a population already thought to be small. To assess the impact of our trapping in the AOC, we used two-sample T-tests to compare Min and Max PRs between the AOC and the INWR (we had no Delta PR data for LOSP West since no work was done there in 2003).

To evaluate the effects of the Regional Descriptors (AOC: In vs. Out, and Inland vs. Lakeshore) on the PRs, we used Minitab's General Linear Model (GLM, a 2-way ANOVA with unbalanced cells, Tukey pairwise comparisons). We did an analysis for Max and Min PR. In a preliminary analysis, the site at Route 77 in the INWR in 2004 (Inland/Out of AOC) was an outlier with a standard residual greater than 4.7 (Figure 2). Therefore, we eliminated Min and Max PRs for that site in 2004. Also, because in the preliminary analysis the interaction between the Regional Descriptors AOC: In vs. Out, and Inland vs. Lakeshore was stronger than the effect of the descriptors themselves, we included a third Regional Descriptor, Landscape: Wetlands vs. Mixed Habitat, which exactly accounted for (i.e., the P-values were identical) the interactions in the earlier test. We estimated the power of the GLM using Minitab's 2-Level Factorial power calculator (Factors = 3, Corners = 4, Replicates = 4, Effects = the differences between the means for each Regional Descriptor). Although this calculator was not designed for use with unbalanced cells, using the minimum number of replicates present in any of our regions yielded a conservatively low estimate of the actual power (Minitab support staff 2006, personal communication).

To evaluate the influences of the Site Descriptors on the variability of the PRs within each study Region, we did a one-way ANOVA for each Site Descriptor (Habitat: wetland, upland, mixed; Cover: cattail, brush, forest; Ledge: present, absent; Tunnel: present, absent). We also compared mink Passages during Day and Night, summed over all sites and both years, using a Chi-square test to determine whether there was any significant difference between the numbers of Passages during day and night.

RESULTS AND DISCUSSION

Relative Abundances

Relationship of Mink Passage Rates to Mink Abundances

Mink population density varies with habitat type; prey density, distribution and reliability; den availability; intraspecific aggression; and predation (Birks and Linn 1982, Linscombe *et al.* 1982, Allen 1986, Eagle and Whitman 1987, Dunstone 1993, Halliwell and MacDonald 1996, Sidorovich and Macdonald 2001,Yamaguchi *et al.* 2003). The sizes of minks' home ranges likewise vary with habitat quality, especially food supply, population structure and social stability of a population (Mitchell 1961, Allen 1986, Eagle and Whitman 1987). Thus, with reliably abundant food, mink populations are more dense and home ranges smaller, although in heavily trapped areas, the remaining males may have larger home ranges (Birks and Linn 1982, Eagle and Whitman 1987).

A number of studies show that mink are not strictly territorial and that their home ranges often overlap. Eagle and Whitman (1987) reported intrasexual territoriality in which home ranges of individuals of the same sex did not overlap, but females had home ranges inside males' territories. In contrast, Mitchell (1961) observed that adult male home ranges overlapped with juvenile males (even during the breeding season) but not with adult males. Gerrell (1970) reported that the home ranges of two of the four adult males he radio-tracked were visited by other adult males and females. The other two adult males visited other minks' home ranges, with one of them using the same den and core area used by an adult female two months earlier. He found that adult male home ranges often included home ranges of females with zones of overlap and zones monopolized by each mink. Occasionally both mink were present simultaneously in the zone of overlap, but usually intrusions occurred without direct confrontations when the owner was not present at that end of the home range. Linscombe *et al.* (1982) observed no active defense of any part of minks' home ranges from other mink of the same sex. Yamaguchi and MacDonald's (2003) radio-tracking study showed home range overlap ranging from 33% for female overlapping male to 88% for male overlapping male.

Mink use multiple dens within their home ranges, and move frequently between them as they cover their home range. Birks and Linn (1982) reported that the number of dens correlated with linear distance of home range, and that most den stays lasted less than one day. Allen (1986) reported stays ranging from a single night to a maximum of 40 days, with average distance between dens ranging from less than 90 m to 234 m in the U.S. In Sweden, Gerrell (1970) observed that mink usually used the nearest available den, with an average distance between dens used on consecutive days of 544 m. A juvenile female radio-tagged in east-central Minnesota by Schladweiler and Storm (1969) used 20 different dens prior to and during a 29-day study; only once was a den used for two consecutive days. The straight-line distance between her daily dens varied from 99 to 849 m, averaging 353 m. Stevens *et al.* (1997) radio-tracked three males on large streams in eastern Tennessee, and found that the number of dens within home ranges varied from 8 to 24, and overnight movements of up to 4300 m were recorded.

Gerell (1970) reported that mink movements showed oscillations on two scales; small-scale movements, usually within <300m, were repeated in different parts of the home range until the entire home range was covered. All mink radio-tracked by Birks and Linn (1982) twice a day revealed more than 80% of their total home range within 5 days, and their entire home range within 10 days. Furthermore, Halliwell and MacDonald's (1996) statement that "most" territories were established by November implies that territories and home ranges may have been relatively fluid during the months of our study (May through October) when transients and dispersing juveniles would have been moving about.

Given the above, if mink are abundant enough, their home ranges or territories should abut one another, if not overlap. As population densities increase, home ranges become smaller, overlaps become greater, or both. Thus, because of the peripatetic nature of mink, higher population densities should result in higher rates of passage, whether from more mink passing through the same site, the same mink passing more often, or both. Thus, we are confident that our Passage Rate indices reflect relative mink numbers.

Mink Passage Rates

Mink Passages per Trap Night (Figure 2) varied from zero to 2.21 (INWR Route 77, 2004; Inland/Out of AOC) among sites and years, with a grand mean between 0.116 (Min PRs) and 0.216 (Max PRs). PRs were zero at nine of the 30 sampling sites; a Chi-square test showed no significant difference in the proportions of zero PRs between regions (Chi-Sq = 0.883, DF = 3, P = 0.830). The Passage Rates appeared to be higher and more variable in the AOC/Lakeshore (BBWMA) and the Out of AOC/Inland (INWR) regions, both of which are large wetlands complexes managed for the benefit of wildlife.

We suspect that mink had denned very close to the MustelaVision camera located on Route 77 in the INWR in 2004 (the statistical outlier), resulting in the unusually high PRs at this site (Figure 2). Several times in mid-August we recorded multiple mink traveling together there. This led us to suspect the presence of a den, since mink are normally solitary except during mating season (January through March, when we were not recording) and when mothers are raising their young from May through late summer (Mitchell 1961, Gerell 1970, Linscombe *et al.* 1982, Dunstone 1993, Illinois Natural History Survey 2005).

We tried to establish AOC Inland sites in the large Bergen Swamp complex, but there are no roads through it, so we had to choose sites on private lands outside the swamp. The Lakeshore Marshes Wildlife Management Area east of Sodus Bay would have been a close match in many ways to the BBWMA, but again there were no roads through the wetlands, so we had to resort to the LOSP West sites. (Roads were important primarily because they provide bridges or culverts at which to place cameras, and secondarily for convenience of servicing MustelaVision systems.) Thus, the AOC: In/Inland and the AOC: Out/Lakeshore regions consisted of more upland or mixed habitat than the large wetlands complexes of the AOC: In/Lakeshore and the AOC: Out/Inland regions, a circumstance that complicated our analyses (see below).

Changes in Passage Rates from 2003 to 2004

Changes in Passage Rates (Delta PRs) at sites for which we had two years' of data are shown in Figure 3. In 2003 and 2004, Delta PRs in the AOC (Lakeshore and Inland combined) were close to zero but they varied somewhat from zero in the Inland-Out of AOC area. However, the means of the Min and Max Delta PRs did not differ from zero (Min Delta PR: P = 0.428, Max Delta PR: P = 0.511; Appendix B: Table B-1), indicating that overall Passage Rates did not change between 2003 and 2004. This lack of change in PRs from year to year allowed us to combine both years' data for subsequent analyses.

There was no difference between the AOC and the Out of AOC regions in either Min Delta PR (P = 0.554) or Max Delta PR (P = 0.938) (Appendix B: Table B-2). The lack of differences among the Delta PRs for the BBWMA and the INWR between 2003 and 2004 was reassuring because we had contracted for mink trapping in the AOC (where mink had not been targeted previously) to get tissue samples required for other portions of the project. We were apprehensive about trapping the populations of concern, but the results showed no negative effect on the AOC populations, either Inland or Lakeshore.

The larger variation in Delta PRs in the INWR (Inland-Out of AOC) as compared to the BBWMA (Lakeshore-In AOC) may have been due to the fact that the INWR is a managed wetlands complex in which different areas were flooded in 2004 than in 2003. This could have changed the habitat quality in the areas around the MustelaVision sites, resulting in larger or smaller numbers of mink near each site. In contrast, the water levels in the BBWMA wetlands are naturally controlled by their connections to Lake Ontario, the level of which is tightly regulated; thus, habitat quality at MustelaVision sites there should have been more consistent from 2003 to 2004.

Influence of Regional Descriptors: Inland vs. Lakeshore, AOC: In vs. Out, and Landscape: Wetlands vs. Mixed

In the General Linear Model crossing the three Regional Descriptors, AOC: In vs. Out; Inland vs. Lakeshore; and Landscape: Wetlands vs. Mixed (Table 2), the descriptive statistics (Appendix C-1: Tables C-1a-c) and the main effects plots of the GLM (Appendix C-2: Figures C-1a-b) suggest that Passage Rates were lower inside the AOC than out of it, lower along the lakeshore than inland, and higher in the wetlands complexes than in mixed landscapes. However, the GLM itself (Appendix C-3: Table C-3) showed that AOC: In vs. Out had no significant effect (Max PR: P = 0.404; Min PR: P = 0.446), nor did Inland vs. Lakeshore (Max PR: P = 0.251; Min PR: P = 0.342). In contrast, the P-values for Landscape: Wetlands vs. Mixed were significant, at 0.026 and 0.042 for the Max and Min PRs, respectively.

The strong effect of Landscape (Table 2) was no surprise, as wetlands are known to be preferred habitat for mink (Allen 1986, Eagle and Whitman 1987, Dunstone 1993, Sidorovich and Macdonald 2001). The significance of the results for Landscape also make power calculations irrelevant (Chittenden 2002). The ability of the GLM to factor out this effect was important in evaluating our ability to answer the questions posed by this study.

The P-values (Table 2) for the Regional Descriptors AOC: In vs. Out (0.404-0.446) and Inland vs. Lakeshore (0.251-0.342) supported the null hypotheses of no difference between mink PRs for either descriptor. However, due to the small sample sizes the power of the GLM was low (≥ 0.254 for AOC: In vs. Out and ≥ 0.094 for

Lakeshore vs. Inland, although the actual power was somewhat higher because these numbers were calculated assuming only four sites in each region). In order to achieve a power of 0.8 for each test, given the differences between the means the number of replications (MustelaVision sites) in each region would have to have been 17 for AOC: In vs. Out, and 71 for Lakeshore vs. Inland. Although these results suggest that it may be possible to delist the "Degradation of Fish and Wildlife Populations" use impairment for mink in the Rochester Embayment, the low power of the tests (i.e., probability of finding no significant differences among treatments when differences exist) suggests that further evidence is needed before delisting can occur, such as results from the portion of this study on the levels of bioaccumulative chemicals of concern (BCCs) in mink tissues (Pagano and Haynes, in preparation).

Influence of Site Descriptors

None of Cover (brush, cattails, forest; Appendix D-1: Table D-1a), Habitat type (wetland, upland, mixed; Appendix D-1: Table D-1b), or underwater Ledge (presence or absence; Appendix D-1: Table D-1c) significantly affected PRs, but again, because of low sample sizes, statistical power to distinguish these effects was low (Table 3). While Habitat (wetland, upland, mixed) and Cover (cattail, brush, forest) had similar definitions, they applied to larger and smaller areas, respectively, around the MustelaVision sites. That the P-values for Cover were lower than those for Habitat implies that the likelihood of observing mink passage is more heavily influenced by site choice at a small scale, particularly the type of cover present at the camera site. This is similar to Bonesi and Macdonald's (2004) finding that the habitat characteristics closest to the water had the strongest effect upon the duration of coexistence of otter and mink in England.

The Site Descriptor Tunnel had a highly significant effect on Passage Rates (Table 3; Appendix D-1: Table D-1d). This result was not unexpected. We were repeatedly told by trappers to place the cameras at culverts and bridges where mink following the water's edge would enter the tunnel rather than leave the water to cross a road. Examination of the sites' characteristics showed that the lack of a tunnel was the one thing that all sites with PRs of zero had in common (although not all sites without tunnels had PRs of zero). Unfortunately, the sites with tunnels were not evenly distributed between the Wetlands and the Mixed Landscapes. In the Wetlands regions, nine of 17 sites were tunnels, but in the Mixed regions only one of 12 sites was a tunnel (Chi-square = 6.196, DF = 1, P = 0.013). Thus, the effect of Tunnels on the PRs likely confounded the Wetlands effect in the Regional Descriptors GLM, indicating that careful camera site choice is an important factor in a study of this type, especially for animals with microhabitat preferences as specific as mink. Future studies should be certain that tunnels are fully represented in all experimental treatments or blocks.

Ecological Observations

Mink Groups in the AOC

The most exciting results were a hoped-for bonus of the study. We recorded four instances of mink families in the AOC: two in the BBWMA (Lakeshore-In AOC) and two in the BLKCK (Inland-In AOC) region. (We also recorded family groups at Route 77 in the INWR Inland-Out of AOC, but none in the LOSPW Lakeshore-AOC region.) At the Sackett Road site in the BLKCK region (AOC-Inland) on 23 June 2003, we recorded one adult and two young mink traveling together. At the same site on 30 June 2004, we recorded two mink together. At Round Pond Creek in the BBWMA (AOC-Lakeshore) on 19 July 2004, we recorded one adult and four young. About two weeks later, on 5 August 2004, we recorded two animals traveling together at that site.

As mentioned above, mink are normally solitary except for mating pairs and mothers with kits. In two of the recordings of multiple mink in the AOC, it was obvious that there was one adult and several young. Since fathers take no part in raising the young (USDA Forest Service 2005), the adults observed with young were assumed to be their mothers. In the two cases in which we recorded two mink traveling together in the AOC, and their relationship was not obvious, we assumed that they were family members because these recordings were made during summer, before the young would have dispersed, rather than during mating season. This assumption is supported by Mitchell (1961) who reported that mink often travel in pairs, either two kits or a mother and daughter, until late fall.

This proof of reproduction of mink in the AOC, especially along the lakeshore, may justify delisting the current "Bird or Animal Deformities or Reproductive Problems" use impairment for the Rochester Embayment of Lake Ontario.

Observed Behaviors of Mink

Nocturnality of Mink

Many sources indicate that mink are primarily nocturnal (Birks and Linn 1982, Linscombe *et al.* 1982, Jamison 1983, Krause 1984, Geary 1985, Allen 1986, Eagle and Whitman 1987, Illinois Natural History Survey 2001, USDA Forest Service 2005). Our observations refuted this widely held belief. In 2003 and 2004, respectively, 65 of 109 mink passages (59.6%) and 71 of 116 (61.2%) were recorded as "Day," i.e., the majority of mink passages were observed by natural light rather than the camera's IR illumination. There was a statistical trend ($0.05 < P < 0.1$) toward a greater number of day than night Passages (Chi-square = 0.058, DF = 1, P = 0.809), which would not be the case if mink were mostly nocturnal. Given the observed ratio of Day to Night passages of 3:2, even if we had missed one-third of the night passages the conclusion of non-nocturnality would not be affected. This scenario is extremely unlikely, as the infrared VCR trigger is more sensitive at night because of the surroundings being cooler and the lack of IR from the sun. Also, since most animals' eyes are highly reflective in the IR, and warm-blooded animals emit IR, we often saw them long before they entered the pool of IR that illuminated the entire animal on camera. Finally, the frequency at which we observed mice outside the IR pool of illumination at night causes us to believe that we would not often have missed a mink.

Although our definition of "Day" could apply during the twilight hours of dawn and dusk, it was obvious when watching the videos, judging by sun and shadow angles and knowing the orientation of the camera, that most of the "Day" passages took place in broad daylight, many at midday. Linscombe *et al.* (1982) cited reports by Gerell (1969) that females with kits were primarily diurnal and by Marshall (1936) that both sexes were most active between dawn and dusk in winter. However, neither of these reports would explain our findings, as less than 4% of our observations were of family units, and we were not recording during winter. Birks and Linn (1982) reported that 75% of inter-den or long distance movements were made at night, speculating that that may be why most are trapped at night and thus thought to be nocturnal.

Repeated Passages

On a number of occasions, mink were seen passing through the camera's field of view several times during the same day or night. They might then not be seen again for days or weeks, having apparently moved out of the area. At Cayuga Pool in the INWR (Inland-Out of AOC) on 27 June 2003, a mink crossed the field of view eight times while exhibiting searching behavior and covering the area thoroughly before disappearing. As it occurred in broad daylight, we were able to judge by shadow angles that this happened within a fairly short period of time (minutes rather than hours). This corresponds with Gerrell's (1970) reports of small-scale oscillatory movements superimposed upon larger-scale movements covering the home range.

Flight from a Predator

At the same location on the same day, a very different behavior was seen—a mink ran fast and straight through the entire field of view, disappearing in seconds. The probable explanation for this unusual behavior was following several feet behind the fleeing mink—the shadow of a large bird such, probably a hawk, was easily visible. Eagle and Whitman (1987) and Dunstone (1993) reported that mink are preyed upon by hawks, owls and eagles.

This potential for predation from overhead may explain why Cover was such an important factor in determining Passage Rates at a camera site. Mason and Macdonald (1983), Allen (1987), Eagle and Whitman (1987) and Yamaguchi *et al.* (2003) agree that mink prefer to stay under cover and avoid open areas. In retrospect, we realized that most of the sites with zero PRs had no cover immediately adjacent to the water's edge, though it may have been less than a meter away. At one of these sites, Cole Road in the BLKCK region in 2004, we recorded a hawk taking a duck from alongside the bank.

Predation on a Fish

At a stream site in the BLKCK region (Inland-In AOC) on 23 June 2004, we recorded a mink catching a fish. Although this was a night shot, and the event occurred at the edge of the IR field of illumination, recognition of the event was aided by the fact that this particular camera had a microphone. We heard a splash, and then saw the mink on the bank holding a fish; the mink had apparently dived into the water after sighting the fish, exactly as Dunstone (1993) and Eagle and Whitman (1987) reported.

Ice-breaking

At Bill's Point, a site in the BBWMA (Lakeshore-In AOC) on 25 November 2002, we recorded a mink breaking up a thin film of ice which was forming over an area where mink had frequently been seen swimming before. The mink swam under the ice and butted its head up against it until it broke; it repeated this behavior many times until most of the ice film was broken up, before swimming out of view.

CONCLUSION

The central question addressed by this study was: Are there differences in the relative abundance of lakeshore and inland mink populations in and out of the AOC? Our MustelaVision data tentatively suggest that there are no differences in mink populations inside and outside the AOC or between the lakeshore and inland areas, but the statistical power of our tests was low due to small sample sizes. We also showed that (1) landscape-scale features (wetland complexes) and microhabitat factors (tunnels) are key predictors of mink presence or absence at a sampling site, (2) mink are successfully reproducing in the AOC, and (3) mink are not chiefly nocturnal. While the data in this report alone do not support delisting the RELO AOC use impairments for wildlife population degradation and reproductive problems, in combination with the chemical data also collected in this study (Pagano and Haynes, in preparation), we believe the time for delisting is approaching in the near future.

Many researchers have tried to estimate mink abundances. Some rely upon harvest records (cf. Linscombe 1982, Eagle and Whitman 1987), but this method can be confounded by trapping conditions, weather, number of trappers working the area, and other factors. Other studies rely on live-trapping (cf. Mitchell 1961, Halliwell and Macdonald 1996), but this can be fatal to mink. Mitchell reported that over 5% of trapped mink died upon capture, and Barker (1991) reported that, although released alive and apparently unharmed, mink may die of stress-related gastric hemorrhaging within a few days. Finally, some studies (cf. Mason and Macdonald 1983, Sidorovich and Macdonald 2001, Racey and Euler 2003) rely on the abundance of mink signs such as tracks, scats and scent posts, all of which can be easy to overlook and hard to relate to numbers of individuals if their home ranges overlap.

Our literature review found only two other studies that referred to the use of video cameras in population monitoring, neither of which was comparable to this study. Rutberg *et al.* (2004) used hand-held video cameras to record deer while driving around the perimeter of their study area, but this was only part of their effort, most of which focused on counting deer while “beating” or “driving” them with large numbers of people on foot. Westera *et al.* (2003) used video cameras to count fish attracted to bait stations in an effort to estimate abundances, but unlike our study they were not recording natural rates of passage. Hence we believe that we have developed a novel method that shows potential for monitoring relative population size, with appropriate care in camera placement, and has the added benefit of revealing the natural behaviors of the animals under study.

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Tables

Table 1. MustelaVision camera sites characterized by regional and site descriptors.

MustelaVision Camera Site	Region	Regional Descriptors			Site Descriptors			
		AOC: In vs. Out	Lakeshore vs. Inland	Landscape	Cover	Habitat	Ledge	Tunnel
Bogus Creek 2003	BBWMA	In	Lakeshore	Wetlands	Forest	Upland	No	No
Bogus Creek 2004	BBWMA	In	Lakeshore	Wetlands	Forest	Upland	No	No
Larkin Creek A 2003	BBWMA	In	Lakeshore	Wetlands	Forest	Mix	Yes	No
Larkin Creek B 2004	BBWMA	In	Lakeshore	Wetlands	Forest	Mix	Yes	No
Round Pond Creek 2003	BBWMA	In	Lakeshore	Wetlands	Brush	Mix	Yes	Yes
Round Pond Creek 2004	BBWMA	In	Lakeshore	Wetlands	Brush	Mix	Yes	Yes
Bill's Point 2003	BBWMA	In	Lakeshore	Wetlands	Cattails	Wetland	No	Yes
Cranberry Pond Trib 2004	BBWMA	In	Lakeshore	Wetlands	Forest	Mix	No	Yes
Black Creek/ Rte 19 2003	BLKCK	In	Inland	Mix	Forest	Upland	Yes	No
Black Creek/ Rte 19 2004	BLKCK	In	Inland	Mix	Forest	Upland	Yes	No
Black Creek/ W Sweden Rd 2003	BLKCK	In	Inland	Mix	Forest	Upland	Yes	No
Black Creek Trib/ W Sweden Rd 2004	BLKCK	In	Inland	Mix	Brush	Upland	No	No
Black Creek/ Mud City Rd 2003	BLKCK	In	Inland	Mix	Cattails	Wetland	Yes	No
Black Creek/ Cole Rd 2004	BLKCK	In	Inland	Mix	Brush	Upland	Yes	No
Black Creek Trib Sackett Rd 2003	BLKCK	In	Inland	Mix	Brush	Mix	No	No
Black Creek Trib Sackett Rd 2004	BLKCK	In	Inland	Mix	Brush	Mix	No	No
Rte 63 2003	INWR	Out	Inland	Wetlands	Cattails	Mix	No	No
Rt 77 2003	INWR	Out	Inland	Wetlands	Cattails	Wetland	No	Yes
Rt 77 2004	INWR	Out	Inland	Wetlands	Cattails	Wetland	No	Yes
Cayuga Pool 2003	INWR	Out	Inland	Wetlands	Cattails	Wetland	No	No
Cayuga Pool 2004	INWR	Out	Inland	Wetlands	Cattails	Wetland	No	No
Sour Springs Road 2003	INWR	Out	Inland	Wetlands	Cattails	Wetland	Yes	Yes
Sour Springs Road 2004	INWR	Out	Inland	Wetlands	Cattails	Wetland	Yes	Yes
Feeder Road 2003	INWR	Out	Inland	Wetlands	Cattails	Mix	No	No
Albion Rd 2003	INWR	Out	Inland	Wetlands	Cattails	Mix	No	Yes
Albion Rd 2004	INWR	Out	Inland	Wetlands	Cattails	Mix	No	Yes
Bald Eagle beaver den 2004	LOSPW	Out	Lakeshore	Mix	Brush	Mix	No	No
Yanty Creek 2004	LOSPW	Out	Lakeshore	Mix	Brush	Mix	No	No
Bald Eagle west bank 2004	LOSPW	Out	Lakeshore	Mix	Forest	Upland	No	No
Yanty Culvert #2 2004	LOSPW	Out	Lakeshore	Mix	Cattails	Wetland	No	Yes

Table 2. Results of analysis of variance (GLM) of mink Passage Rates by Regional Descriptors: AOC: In vs. Out; Inland vs. Lakeshore; and Landscape: Wetlands Complex vs. Mixed Habitat (Full MiniTab output in Appendix C). Bold indicates a significant difference. *The significance of the results for Landscape make those power calculations irrelevant.

Regional Descriptor	**PR Used**	**N**	**Mean (SE)**	**P-value**	**Power**
AOC: In vs. Out					
	Max			0.404	0.254
AOC: In		16	0.0768 (0.0238)		
AOC: Out		13	0.1675 (0.0611)		
	Min			0.446	0.248
AOC: In		16	0.0399 (0.0130)		
AOC: Out		13	0.0859 (0.0339)		
Lakeshore vs. Inland					
	Max			0.251	0.096
Inland		17	0.1424 (0.0479)		
Lakeshore		12	0.0821 (0.0309)		
	Min			0.342	0.094
Inland		17	0.0720 (0.0266)		
Lakeshore		12	0.0443 (0.0168)		
Landscape: Wetlands vs. Mixed					
	Max			**0.026**	0.112*
Mixed Habitat		12	0.0352 (0.0106)		
Wetlands Complex		17	0.1755 (0.0479)		
	Min			**0.042**	0.112*
Mixed Habitat		12	0.0180 (0.0056)		
Wetlands Complex		17	0.0905 (0.0267		

Table 3. Results of ANOVAs of mink Passage Rates by Site Descriptors: Cover, Habitat, Ledge, and Tunnel (Full MiniTab output in Appendix D). Bold indicates a significant difference.

Site Descriptor	PR Used	N	Mean (SE)	P-value	Power
Cover	Max			0.166	0.268
Brush		8	0.0942 (0.0387)		
Cattails		12	0.1843 (0.0643)		
Forest		9	0.0490 (0.0255)		
	Min			0.193	0.259
Brush		8	0.0566 (0.0227)		
Cattails		12	0.0935 (0.0360)		
Forest		9	0.0200 (0.0100)		
Habitat	Max			0.245	0.279
Mix		13	0.1125 (0.0459)		
Upland		8	0.0512 (0.0289)		
Wetland		8	0.1918 (0.0757)		
	Min			0.341	0.197
Mix		13	0.0706 (0.0305)		
Upland		8	0.0204 (0.0115)		
Wetland		8	0.0842 (0.0337)		
Ledge	Max			0.872	0.052
Absent		18	0.1214 (0.0421)		
Present		11	0.1109 (0.0459)		
	Min			0.970	0.050
Absent		18	0.0610 (0.0235)		
Present		11	0.0597 (0.0244)		
Tunnel	Max			**0.004**	0.743
Absent		19	0.0557 (0.0227)		
Present		10	0.2348 (0.0658)		
	Min			**0.001**	0.874
Absent		19	0.0222 (0.0075)		
Present		10	0.1333 (0.0387)		

Figures

Figure 1. Map showing placement of MustelaVision systems in four regions during 2003 and 2004. Each red triangle is the site of one MV system. In LOSP West, there were actually four sites, but the triangle symbols are almost superimposed in pairs due to their proximity. RELO is the Rochester Embayment of Lake Ontario. (Map courtesy of Albert Fulton 2005.)

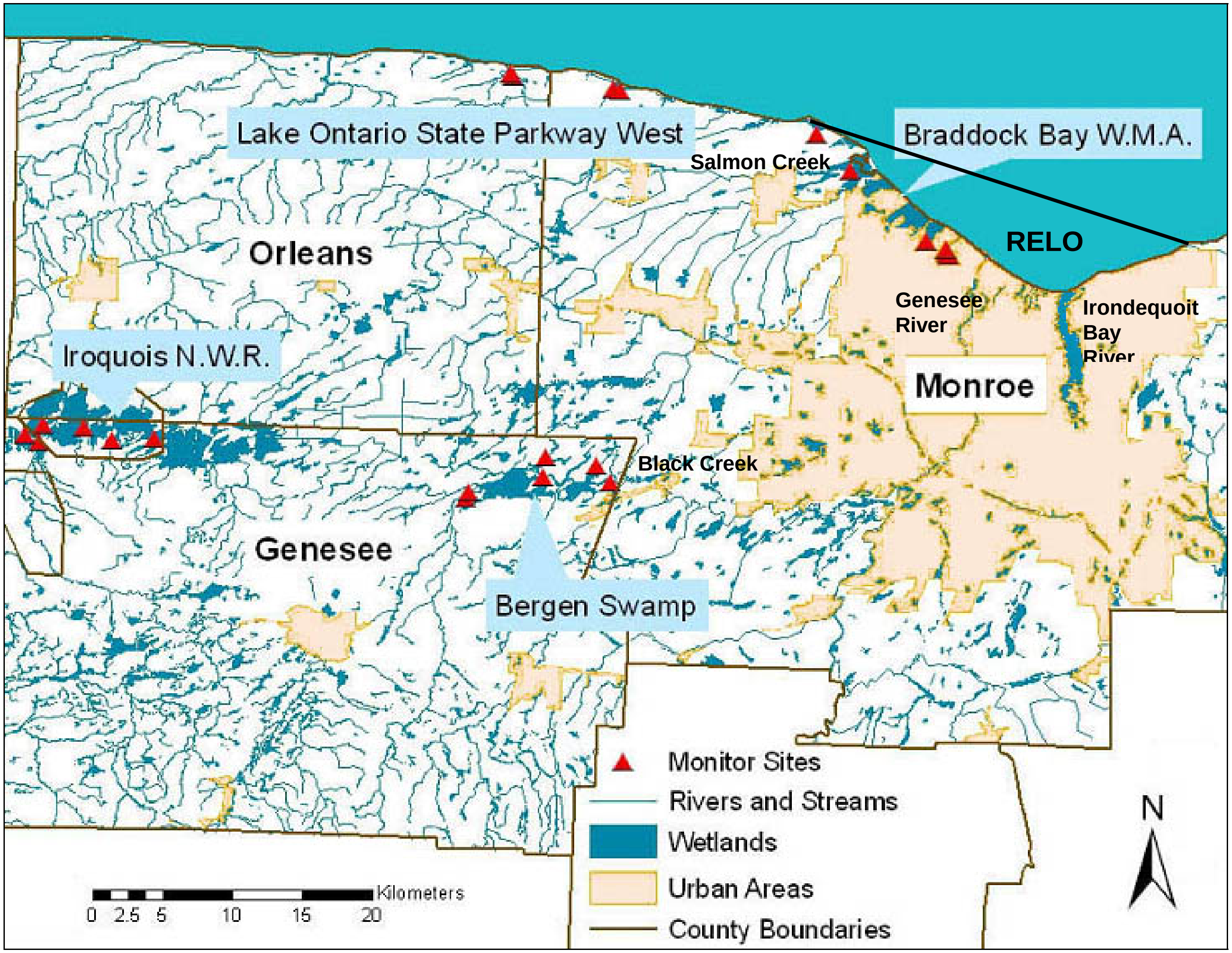


Figure 2. Mink Passage Rates calculated for each camera site during 2003 and 2004. The bars show the range between the Min and Max Passage Rates, based on the Max and Min number of Trap Nights, respectively, at each site. The sites are grouped by Region (In AOC vs. Out of AOC, and Inland vs. Lakeshore) labeled at the bottom. Data from both years at one site are shown side by side.

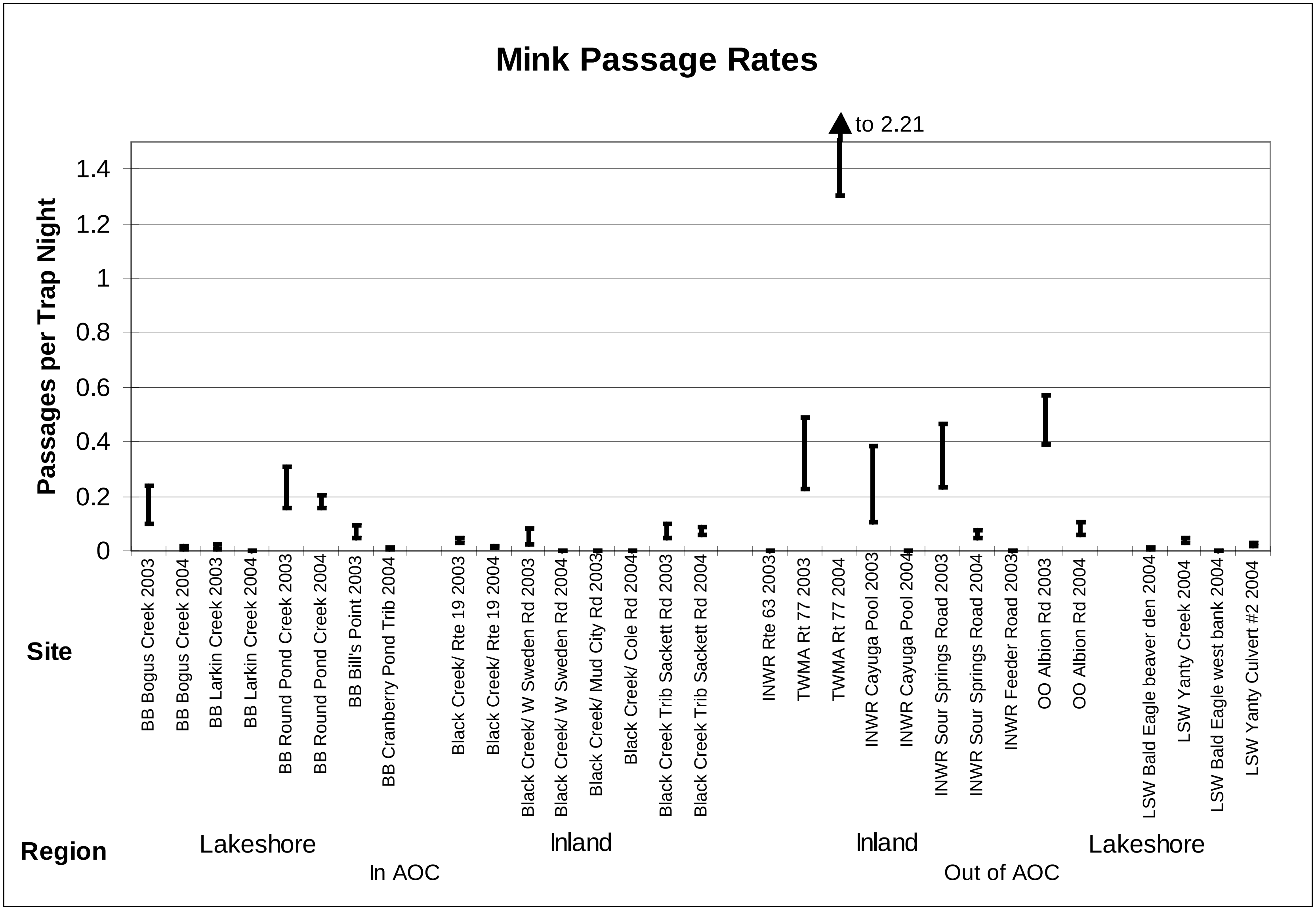
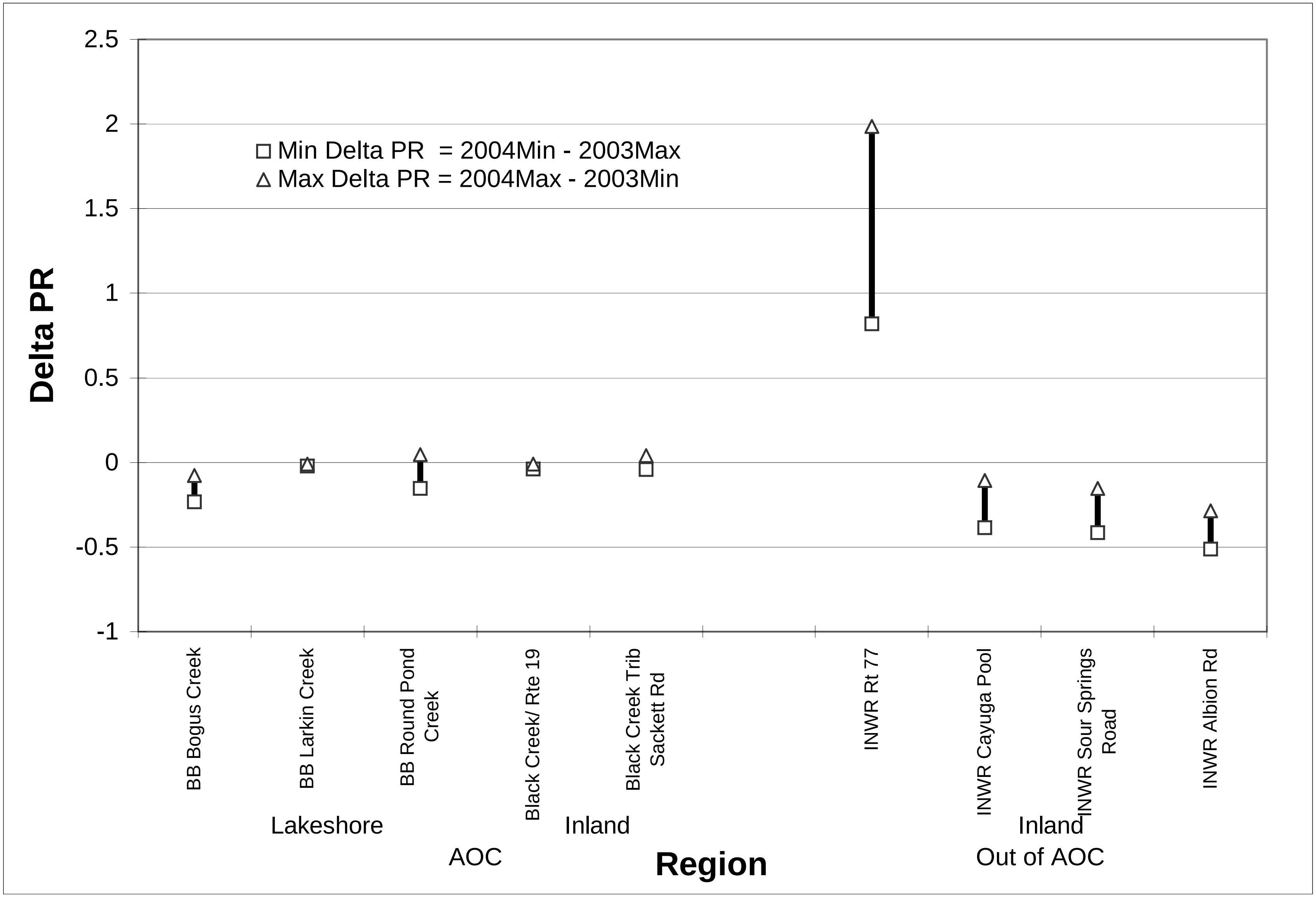


Figure 3. Yearly changes (Delta Passage Rates) in mink passages for sites at which data were taken both years. BB = Braddock Bay Wildlife Management Area, INWR = Iroquois National Wildlife Refuge.



Appendices

Appendix A: MustelaVision Operations

<u>Appendix A-1: MustelaVision System</u>

Figure A-1a. MustelaVision system: camera head on stake at right, VCR on platform in front of battery, protective circuit board mounted underneath VCR platform.

Figure A-1b. Schematic of a MustelaVision system. The remote monitor is used only during field testing and camera alignment.

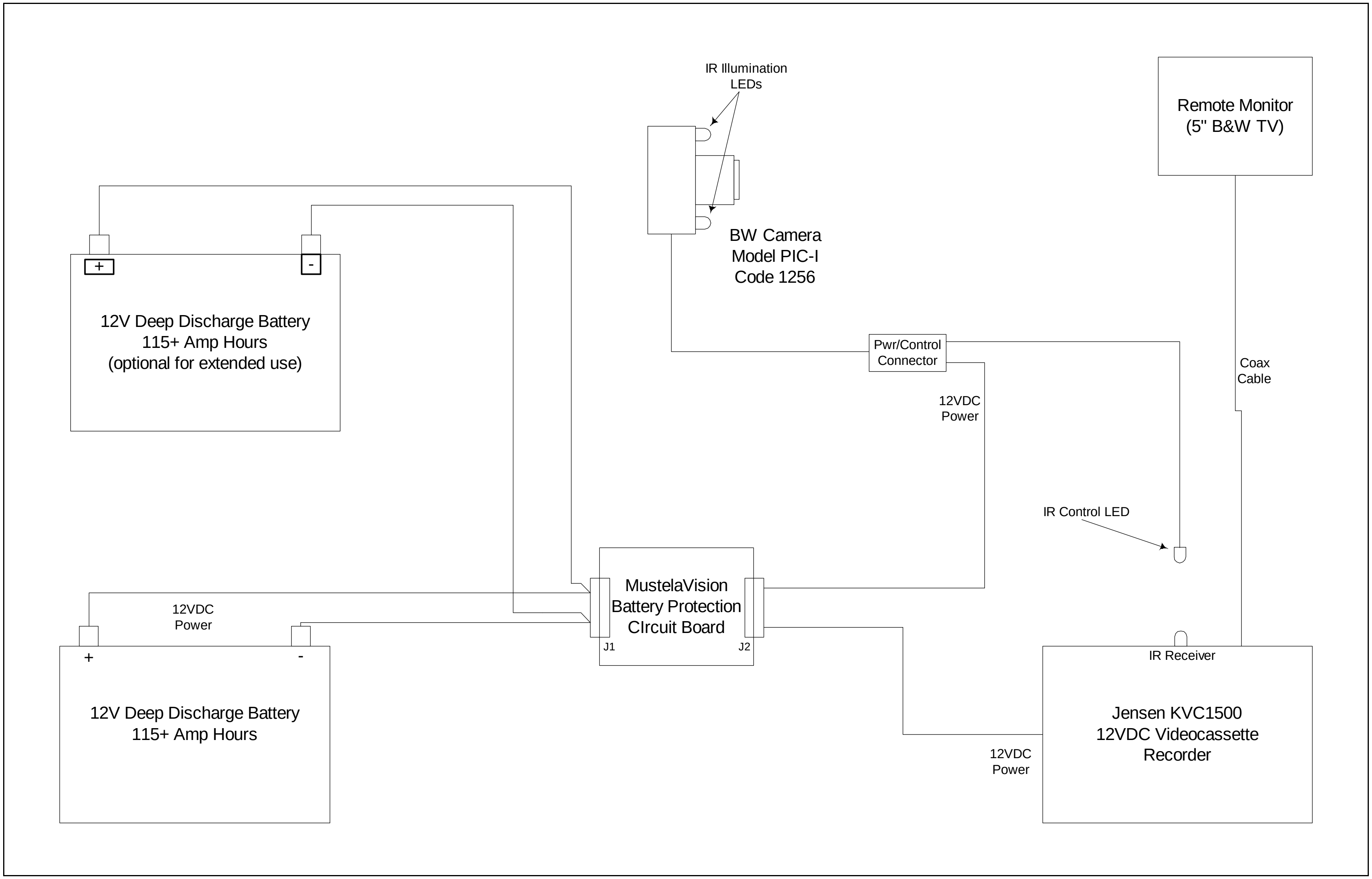

IR Illumination LEDs
BW Camera
Model PIC-I
Code 1256
Remote Monitor
(5" B&W TV)
+
-
12V Deep Discharge Battery
115+ Amp Hours
(optional for extended use)
Pwr/Control
Connector
12VDC
Power
Coax
Cable
IR Control LED
12VDC
Power
MustelaVision
Battery Protection
CIrcuit Board
J1
J2
IR Receiver
+
-
12V Deep Discharge Battery
115+ Amp Hours
Jensen KVC1500
12VDC Videocassette
Recorder
12VDC
Power

Figure A-1c. Back view of a MustelaVision camera head mounted on stake at the Round Pond Creek site in the BBWMA.

Figure A-1d. Battery protection circuit board, which protected against over discharge of battery, reversal of battery hook-up, and component fusing.