PI Name / Short Description: Muskrat (*Ondatra zibethicus*) – house density in drowned river mouth wetlands (Upper St. Lawrence River – Thousand Islands area) **[E19]**

Credit: Jason A. Toner

Technical Workgroup: Environmental TWG

Researched By: John M. Farrell, Jason A. Toner, and Jerry V. Mead
Modeled By: Jason A. Toner, Jerry V. Mead, John M. Farrell and LTI (DePinto, Redder)

Performance Indicator Metric: The presence/absence (probability of occupancy) for a wetland coupled with prediction of the annual density of active muskrat houses (number of active houses per hectare) was used to represent the performance of muskrat (*Ondatra zibethicus*) in the Upper St. Lawrence River.

Ecological Importance/Niche: Muskrats are often the primary herbivore within wetland vegetation communities and have strong influences on both wetland structure and function. Foraging and lodge construction by muskrats influences many wetland species by creation and maintenance of habitat complexity. In the Upper St. Lawrence River the low density of muskrats is likely a contributing factor to the dominance of cattail in coastal wetlands. Muskrat consumption of cattail can exceed 27% of its annual production (Farrell et al. 2003). Vegetation species richness in wetlands is positively associated with muskrat herbivory where their preferred food item is the dominant vegetation type (Nyman at al. 1993). Abandoned lodges offer suitable substrate for seed germination, support high densities of important microbes that facilitate decomposition processes (Wainscott et al. 1990), provide nesting sites for birds and turtles, and create microtopography in wetlands. The black tern (*Chlidonias niger*), a species at risk (SA), directly benefits from muskrat activity through its use of abandoned lodges for nesting (Weller and Spatcher 1965; Bailey 1977) and open water areas for feeding. Many bird, mammal, plant, and likely fish species such as northern pike, respond favorably to the increases in open water and edge and channel effects created from muskrat disturbance.

Temporal Validity: Fall and winter wetland water depth and winter air temperature are used to compute the muskrat performance indicator for each simulation year. The fall and winter represent the seasonal conditions most limiting for muskrat populations. Data on existing populations for muskrats was collected in recent years (2001-2004) and represents population conditions within cattail dominated wetlands during the post-water level regulation era. Simulations performed for the 101-year period of record represent the muskrat response to the historical conditions of water level and temperature with habitat conditions developed for the recent period.

Spatial Validity: The muskrat performance indicator was developed for the Thousand Islands region of the upper St. Lawrence River drowned river geomorphic type based on field derived relationships at six sampling locations. The muskrat model predicts house density for the portion of wetland between 74.30 and 75.15 m (243.77 and 246.56 ft) (IGLD85).

Hydrology Link: Muskrat house abundance and distribution is largely dependent on the water depth and dewatering history at a particular wetland elevation. Air temperature interacts with water depth in wetlands and is important to muskrats that over-winter in shallow water depths. Muskrats typically build houses during the fall in areas where water depths are suitable for over-wintering.

Algorithm: The muskrat performance indicator model uses water level (mean quarter monthly periods m (IGLD85) for December, January, and February) and wetland specific digital elevation models to compute the mean water depth (m) for wetland elevations between 74.30 and 75.15 m (243.77 and 246.56 ft) (IGLD85). The probability that a wetland contains active muskrat houses (occupancy) is estimated from a logistic regression using winter water depths (Figure 1). The logistic muskrat probability model was developed from house counts in six upper St. Lawrence River drowned river mouth wetlands (n=29 surveys; 2001-2004) including two wetlands that were water levels are managed independent of St. Lawrence River levels to determine muskrat responses to flooding as:

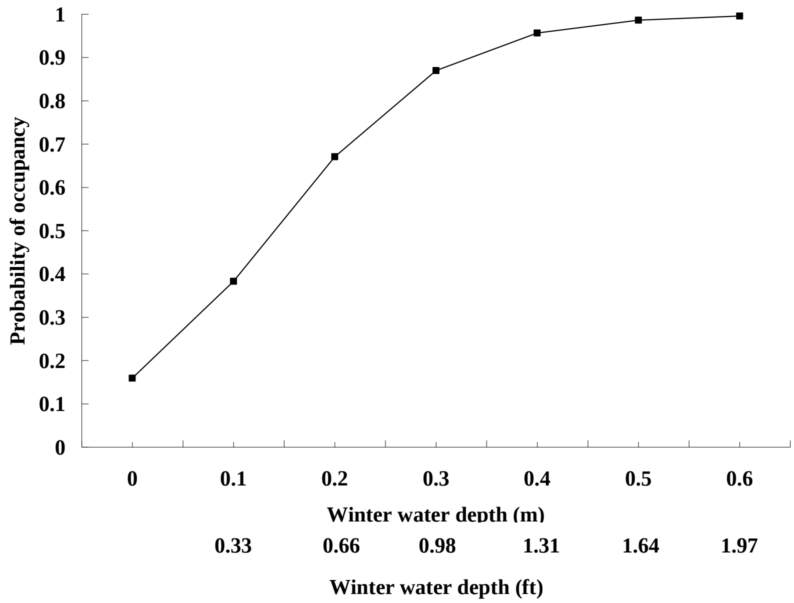
$$PROB_i = 1 \div [1 + e^{(1.6692 - (11.9129 \times WINTERWD_i))}]$$

where,

$WINTERWD_i$ = was the mean water depth during winter months (December, January, and February) for a geomorphic type (i) and,

$PROB_i$ = was the probability that geomorphic type (i) contains active muskrat houses (occupancy).

Figure 1. Logistic probability of muskrat occupancy in a wetland derived from field surveys in the Upper St. Lawrence River given mean water depth (January thru February). For probability greater than 0.35 the house density was calculated using a stepwise multiple regression relationship.



If the occupancy probability ($PROB_i$) was equal to, or greater than, a threshold value of 0.35, active muskrat house density (number/hectare/geomorphic type) is then estimated using a stepwise multiple regression model. Probability thresholds were statistically determined through an error minimization process using Solver™. At occupancy probability <0.35, muskrat house density per hectare was assigned to zero. The stepwise multiple regression model used to estimate active house density was developed from upper St. Lawrence River drowned river mouth sites (n=12 surveys; 2001-2004) where muskrats were present as:

$$HD_i = 2.05276 + (2.7395 \times FALLWD_i) + (0.00910 \times WINTERTEMP_i)$$

where,

HD_i = was the number of active muskrat houses per hectare of geomorphic type (i);

$FALLWD_i$ = was the mean water depth (m), within the specified elevation range, for fall months (September, October, and November) for geomorphic type (i),

$WINTERTEMP_i$ = was the cumulative air temperature difference from freezing (32˚F or 0ºC) for quarter monthly average temperatures during the winter period (December, January, and February).

Calibration Data: Winter muskrat house censuses conducted from 2001 to 2004 and digital elevation maps created for six upper St. Lawrence River study sites: French Creek, Carpenters Branch, Cranberry Creek, Chippewa Tributary, Little Cranberry Creek upstream and downstream of NYS Rte. 12, and Cranberry Extension upstream and downstream of NYS Rte. 12 were used for model development. Air temperature data was obtained from the Watertown International Airport and used for all calibration sites.

Validation Data: Validation was performed within the six calibration sites for surveys conducted in 2005 that were not used in model development. An additional site at Cobb Shoal Marsh at Collins Landing, New York (located at the Thousand Islands Bridge) was surveyed in 2005 for validation purposes.

Documentation & References: Muskrat house counts offer a reliable, efficient technique that allows both spatial and temporal comparisons of muskrat populations where bank dens are not predominant (Bellrose 1950; Dozier et al. 1948; Errington 1961). Water depth was used as a primary variable for analyses because of its strong effect on muskrat populations (Errington 1961). Winter air temperature interacts with water depth in north temperate climates as a factor that limits annual muskrat densities. Muskrat populations often crash during "freeze outs" common in marshes with low water depths and severe winters.

Logistic regression has been successfully used to determine important wetland variables that help predict presence or absence of muskrat burrows along river shorelines (Nadeau et al. 1995). A similar approach was applied to our study sites to determine the probability that a site contained muskrat houses based on seasonal water levels.

Risk and Uncertainty Assessment: Muskrat populations have been observed to fluctuate regularly from high to low abundance over 8 to 9 years (Erb et al. 2000) in regions near to the Thousand Islands of the upper St. Lawrence River. For the development of the performance indicator, sites were sampled four consecutive years with little change in population estimates. It is likely that the natural population trend has been interrupted within wetlands perturbed by water level regulation. Density dependent factors such as disease, food limitation, or intra-specific strife may also become important if environmental conditions (water level and air temperature) allow muskrats to over-populate areas. We are uncertain about how populations will fluctuate, over longer time periods (decadal), due to these factors. It is possible that higher muskrat populations, resulting from improved water level conditions, will fluctuate according to natural density-dependent factors. Current population levels are extremely low, making changes in density due to changes in predation or climate difficult to assess.

The potential for muskrat food limitation associated with long-term habitat change and herbivory effects is not used in the model predictions. It is possible that water level changes alone may not reduce dense cattail stands given their tolerance to wide range of water depths and a shift to dominance of the more resilient hybrid *Typha* x glauca (Farrell et al. 2003). However, water level changes resulting in favorable muskrat habitat are likely to influence these stands. The 101-year temporal prediction to determine the muskrat performance ratio between regulation plans goes beyond temporal coverage for which the model was built because of the uncertainty of the habitat structure during this historical period. Therefore, predictions over this time represent how muskrats would respond given current wetland habitat conditions.

We are also uncertain if the muskrat model can accurately predict occupancy and densities for the remaining three geomorphic types (barrier beach, open and protected embayment). Therefore, the model should only be applied to drowned river mouth wetlands.

Based on the relationship between active house density and the % of cattail production consumed by muskrats, an increase in average house density to 1.5 per hectare would be important to wetland structure and ecology. Many of the sites sampled did not contain active muskrat houses, suggesting that any potential increase in density would be significant.

Bailey, P. F. 1977. The breeding ecology of the black tern. Masters Thesis, University of Wisconsin, Oshkosh, WI.

Bellrose, F. C. 1950. The relationship of muskrat populations to various marsh and aquatic plants. Journal of Wildlife Management 14:299-315.

Dozier, H. L., M. H. Markley, and L. M. Llewellyn. 1948. Muskrat investigations on the Blackwater National Wildlife Refuge, Maryland, 1941-1945. Journal of Wildlife Management 12:177-190.

Erb, J., N. C. Stenseth, and M. S. Boyce. 2000. Geographic variation in population cycles of Canadian muskrats (*Ondatra zibethicus*). Canadian Journal of Zoology 78:1009-1016.

Errington, P. 1961. Muskrats and marsh management. University of Nebraska Press. 183 pages.

Farrell, J. M., J. A. Toner, A. D. Halpern, M. Beland, B. Murry, A. Cushing, K. Hawley, and D. J. Leopold. 2003. Restoration of coastal wetlands in the St. Lawrence River through re-establishment of natural hydrologic regimes. SUNY College of Environmental Science and Forestry, Syracuse, NY. Final Report submitted to the Great Lakes Protection Fund. 79 pages.

Nadeau, S., R. Decarie, D. Lambert, and M. St-Georges. 1995. Nonlinear modeling of muskrat use of habitat. Journal of Wildlife Management 59:110-117.

Nyman, J. A., R. H. Chabreck, and N. W. Kinler. 1993. Some effects of herbivory and 30 years of weir management on emergent vegetation in a brackish marsh. Wetlands 13:165-175.

Wainscott, V. J., C. Bartley, and P. Kangas. 1990. Effect of muskrat mounds on microbial density on plant litter. American Midland Naturalist 123:399-401.

Weller, M. W. and C. S. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Iowa State University Agriculture and Home Economics Experiment Station Special Report No. 43, Ames, IA.