MEMO

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Subject: Eighteenmile Creek Area of Concern: Final Conceptual Site Model (CSM) Memo

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BACKGROUND

Eighteenmile Creek is one of forty-three areas of concern (AOCs) established within the Great Lakes due to loss of "beneficial uses" from degraded water quality. The AOC encompasses Eighteenmile Creek from its entry into Lake Ontario, upstream to the Burt Dam (approximately 2 miles). The AOC has three identified use impairments linked to sediment contamination: (1) restrictions on fish and wildlife consumption; (2) degradation of benthos; and (3) restrictions on dredging activities.

Previous studies indicate elevated levels of polychlorinated biphenyls (PCBs), chlorinated pesticides, and metals in surficial sediments throughout most of the AOC. Invertebrate bioaccumulation testing also suggests that organic contaminants moving through the food chain are creating environmental risks (Karn et al. 2004). Contamination sources to the river have not been fully delineated. However, recent investigations by New York State Department of Environmental Conservation (NYSDEC) have focused on a contamination source in Lockport, NY, near the upper reach at the Erie Canal (approximately 12 miles upstream of Burt Dam). High levels of PCBs have been detected in sediments near this facility and fish tissue contaminant levels are also elevated (samples above 2 mg/kg total PCBs wet weight) in the river reach above the Burt Dam.

To date, there have been several data collection efforts in and upstream of the AOC to define contaminant levels in sediments, surface water, and biota. However, they have been limited in scope and have not focused on understanding contaminant bioaccumulation, movement in the food chain, and consequent environmental risks. Developing such an understanding will assist site managers as they move toward greater resolution on the nature of impairments at the site, develop remedial actions, and ultimately delist the area.

The US Army Engineer Research and Development Center is conducting a bioaccumulation modeling effort at the AOC in response to a request from the US Army Corps of Engineers (USACE) Buffalo District. This memorandum provides the proposed conceptual site model that will guide the bioaccumulation modeling effort. Additional data have been collected following the development of the final data gaps memorandum in August, 2010. These data will soon be available.

This memorandum describes the conceptual site model, providing an overview of the physical, chemical, and biological aspects of the system that will be modeled, including site-specific assumptions used to establish modeling conditions.

CONCEPTUAL SITE MODEL (CSM) FOR *TROPHICTRACE* MODELING

Modeling Area

The modeling approach focuses on two areas: the lower reach of Eighteenmile Creek from Lake Ontario to Burt Dam and an upper reach from Burt Dam to the Newfane Dam (Figure 1). The definition of the two areas assumes that the dams act as physical barriers and that fish populations will not interact and only be exposed to conditions in those areas.

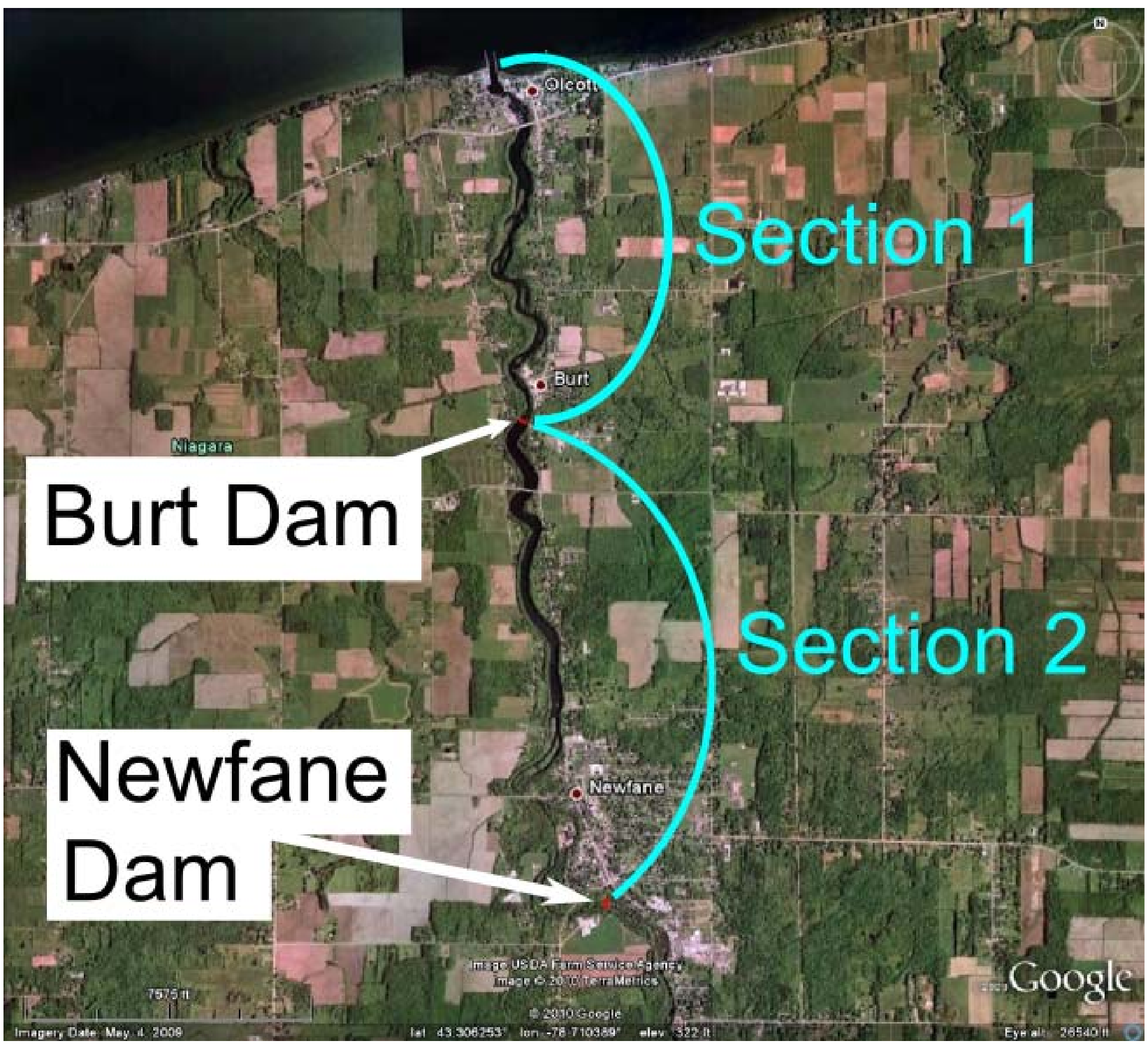

Figure 1. Map of the sections of Eighteenmile creek to be modeled in this study. Section 1 is defined as downstream of Burt Dam to Olcott Harbor at Lake Ontario, and Section 2 is defined as downstream of Newfane Dam and upstream of Burt Dam.

Above Burt Dam, a substantial reservoir extends approximately 2 miles before more typical stream morphology continues for another mile to the Newfane Dam. The Newfane Dam along with the relatively swift shallower bedrock and gravel channel below the Newfane dam are hydraulically significant features and serve as impediments to fish movement, so Newfane Dam will represent the upstream extent of the project boundary.

Since the AOC and the Burt Dam backwater area are the closest in environmental conditions, habitat, and fishery, they are appropriate conditions to fulfill the SOW objective "to evaluate organic contaminant bioaccumulation, trophic transfer and consequent risks in river sections above and below Burt Dam of the Eighteenmile Creek." Upstream from Newfane Dam, the conditions are more complex with more typical stream reach/run morphology; these areas will support a different fishery and exhibit a different dynamic of contaminant exposure between modeled organisms, sediments, dietary constituents, and water.

Food Web Composition and Exposures

The *TrophicTrace* food web bioaccumulation model will be applied at the site to evaluate contaminant bioaccumulation across trophic levels. *TrophicTrace* and its underlying mathematical structure (Gobas 1993) are well-accepted and have been used in a number of regulatory applications. Appendix B of the Data Gaps Memorandum provides more detailed information on the *TrophicTrace* Bioaccumulation Model. Two critical aspects of the model are described below 1) food web composition and 2) contaminant concentrations in media used to depict exposure concentrations to the food web.

Aquatic Food Web

Figure 2 presents a simplified conceptual model for the aquatic food web. As the concern is primarily sediment-associated contaminants (e.g. PCBs), the goal is to develop a modeling framework that captures these exposures. Because PCBs are known to bioaccumulate, it is also important to include fish species that consume other fish, and to focus on fish that are resident in Eighteeenmile Creek rather than transient species such as salmonids. Therefore, the proposed food web starts with invertebrates that serve as a prey base for fish. Contaminant concentrations in benthic invertebrates are assumed to be in equilibrium with those in local sediments, and pelagic invertebrates are assumed to be in equilibrium with dissolved-phase water concentrations. These organisms are then consumed in different proportions by forage fish, including young-of-year bluegill, pumpkinseed, and shiner (*Lepomis* spp., *Notemigonus* spp.). Sampling for the forage fish has focused on fish less than 4 inches in size. In this size range, primary consumption forage fish consumption is on zookplankton with some epibenthic invertebrates, depending on the species (Mittelbach 1984).

The next feeding guild that is important to capture is the demersal fish species, such as brown bullhead (*Ictalurus nebulosus*). The fish sampling effort has focused on collecting individual fish ranging from 6 to 10 inches. In this size range, bullhead consume primarily benthic invertebrates but also some small fish and a small percentage of pelagic invertebrates.

The piscivorous feeding guild is represented by largemouth bass (*Micropterus salmoides*). The size range targeted for sample collection ranges from 11 to 14 inches. This is the size range that would be most attractive to anglers and larger ecological receptors such as otter. In this size range, bass consumes primarily smaller forage fish, including young-of-year of their own species, but is also known to consume benthic invertebrates, including crayfish. The exact parameterization of the model with respect to feeding preferences will be established from a literature review of feeding preferences and stomach contents analyses of sampled fish that is ongoing for largemouth bass and brown bullhead.

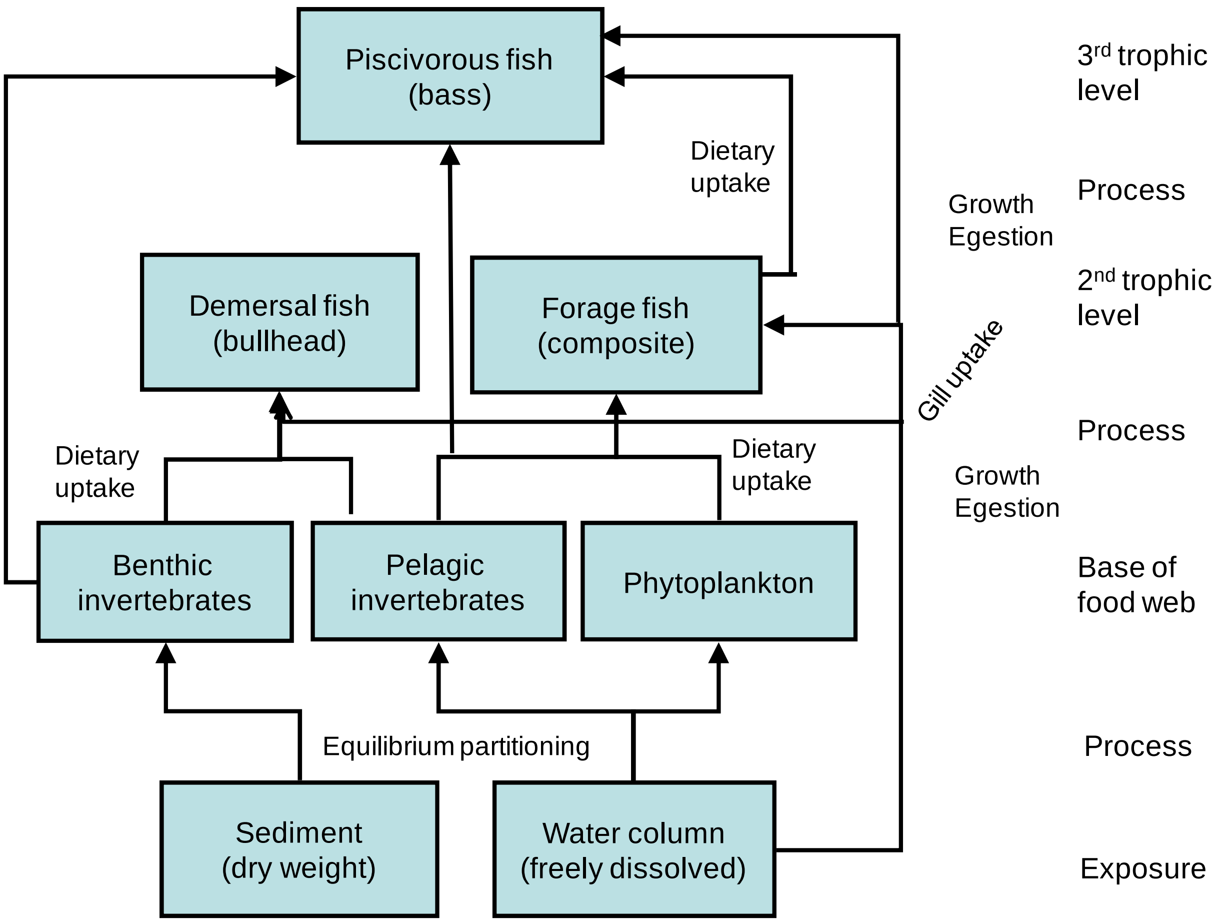

Figure 2. Schematic of the Conceptual Site Model of the Aquatic Food Web for Eighteenmile Creek

Terrestrial Food Web

Fish and invertebrates potentially impacted by contaminated sediments in Eighteeenmile Creek also serve as a prey base for ecological receptors, including fish eating birds and mammals. Figure 3 presents a simplified conceptual model for terrestrial receptors that consume fish. The selected species are chosen based on the following criteria:

- Observed in the study area or could occur in the study area
- Fish consumers (typically select a smaller sized species that consumes a smaller fish and

a larger species that consumes a larger fish)

- Life histories and foraging strategies that lead to potential exposures from Eighteenmile Creek
- Modeling parameters are readily available (e.g., knowledge of quantitative foraging preferences, etc.)

We propose two avian receptors known to inhabit Eighteenmile Creek: the belted kingfisher (*Ceryle alcyon*) and the great blue heron (*Ardea herodias*). The belted kingfisher is a medium-sized bird, measuring about 13 in (33 cm) (Peterson 1980). It is blue-gray with a ragged bushy crest and broad gray breastband. It generally feeds on fish that swim near the surface or in shallow water (USEPA 1993). The kingfisher may also feed on crayfish, and in times of food shortages it can feed on a variety of invertebrates and vertebrates. Kingfishers nest in burrows that they excavate in embankments. Kingfisher are found throughout the study area (Ecology and Environment 2007, p 7-33,7-47; also as documented on the Atlas 2000 website for block 1980C; http://www.dec.ny.gov/cfmx/extapps/bba/).

The great blue heron is one of the largest wading birds found in upper New York State. It can stand over 4 ft high (ave. 42 to 52 in) with a wing span of 6 to 7 ft. It has a blue-gray color and adults are white about the head. Their long legs, necks, and bills are adapted for wading in the shallow water and stabbing prey. Fish are the preferred prey of great blue herons, but they also eat amphibians, reptiles, crustaceans, insects, birds, and mammals (USEPA 1993b). Great blue heron have been observed throughout New York State, and have been observed in the study area (http://www.guides.nynhp.org/guide.php?id=6752&part=3; Ecology and Environment 2007, p 7-47) and as documented on the Atlas 2000 website (http://www.dec.ny.gov/cfmx/extapps/bba/).

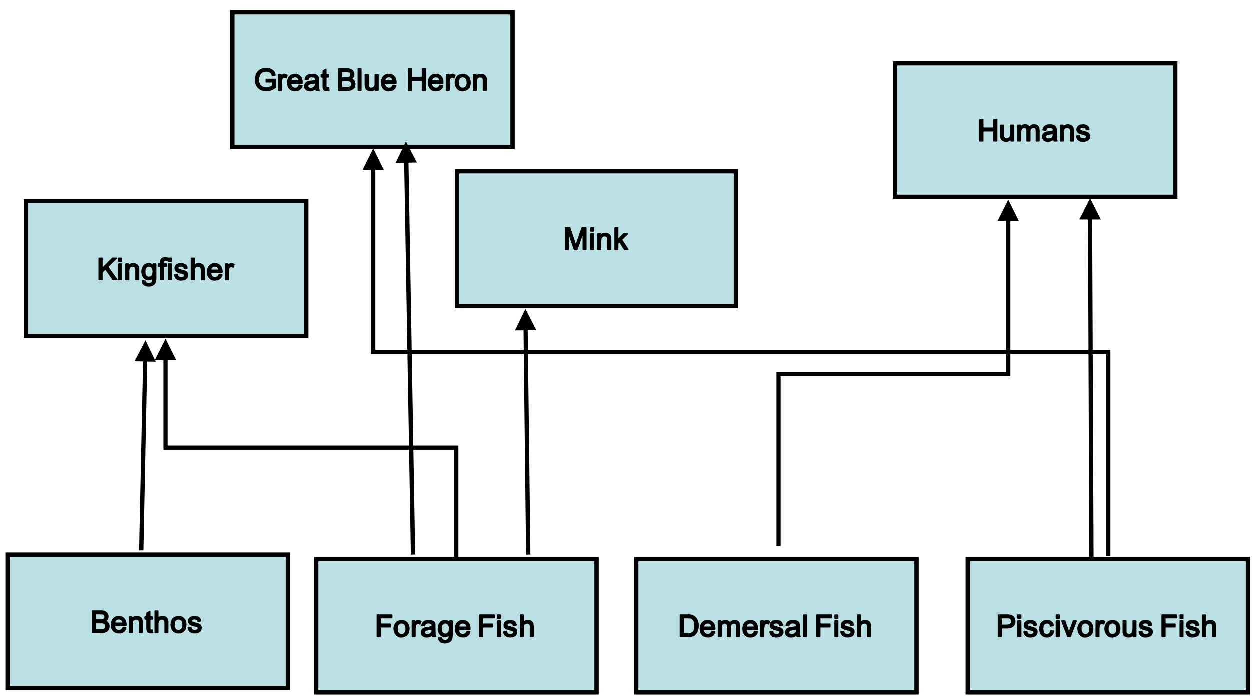

Figure 3. Schematic of the Proposed Terrestrial Conceptual Site Model for Eighteenmile Creek

The proposed mammalian receptor is the mink (*Mustela vison*). The mink is a small carnivore that is widely distributed throughout New York State (http://nyfalls.com/wildlife/Wildlife-mammals-weasel-like.html) and is found throughout the study area as well (Ecology and Environment 2007, p 7-47. Generally, mink are opportunistic in their feeding habits and prey varies according to seasonal abundance of prey and habitat. They feed on a variety of prey including fish, aquatic invertebrates, and small mammals. Their sensitivity to PCBs is well understood.

Further information on the feeding strategies and life histories of the selected species is provided in Appendix A of this document.

Exposure Concentrations

As described in the previous memorandum (Final data gaps memorandum, 8/3/2010) and summarized above in Modeling Area, the *TrophicTrace* model will be parameterized and run for two distinct sections downstream and above Burt Dam (sections 1 and 2, respectively). Sediment and water exposure concentrations from these distinct areas will be used as inputs to the *TrophicTrace* model.

As described in the 8/3/2010 memorandum, during the 2000s, there were 21 sediment samples collected from below Burt Dam (18 samples in 2003; three in 2008) and 13 water samples collected annually from 2002 – 2008. In 2010; USACE-Buffalo District conducted surface sediment sampling to update exposure conditions since the 2003 effort (both events sampled surface sediments from the same location and analyzed for PCB congeners). Results from that sampling are being generated. Following comparison to the earlier dataset, we will determine whether averaging over both datasets is appropriate to represent long term surface sediment exposures in this area. In Section 2, upstream of the dam, 16 additional sediment samples were collected during EPA's 2010 sampling program. These data will be used to depict surface sediment exposures for Section 2.

For both sections, we will evaluate the most appropriate averaging technique, taking into account available information on preferential foraging and habitat of the fish species (e.g., nearshore, vegetated areas). The way in which the sediment samples are averaged assumes a particular exposure, for example, an arithmetic average (equal weight across all samples) assumes that fish are equally likely to forage from any location within the particular Section.

There are less data available for water concentrations (the model requires a truly dissolved water concentration). In general, unless there is evidence for strong disequilibrium conditions, estimating a freely dissolved water concentration using equilibrium partitioning with sediments will result in an upper-bound estimate of potential water exposures. We will use the sediment data to estimate water concentrations in this way. In addition, we will also compare the relationship between synoptic sediment and water samples (insofar as these are available for Section 1) and compare those to the equilibrium partitioning estimates. Because the *TrophicTrace* model allows a range of likeliest values as model inputs (to capture uncertainty), we will use both estimates. For Section 2, we will use equilibrium partitioning and apply the observed relationship between sediment and water for Section 1 to obtain bounded estimates of water exposure concentrations.

Table 1: Environmental data used to estimate sediment and water exposure concentrations

	Data Source	**Anticipated Processing**
Section 1 Water	EPA	Evaluate relationship between synoptic (in time and space, as much as possible) sediment and water samples; compare to predicted water concentrations based on equilibrium partitioning with 2009 sediment samples
Section 1 Sediment	USACE-Buffalo District 2010 PCB congener analysis of surface sediments; USACE-Buffalo District 2003	Spatially-weighted average concentration
Section 2 Water	None available	Use relationship between sediment and water from Section 1
Section 2 Sediment	GLNPO 2009 PCB congener analysis of surface sediments; EPA 2008	Spatially-weighted average concentration

Next Steps

Using the conceptual model presented here, our next steps involve parameterizing the *TrophicTrace* model using a combination of site-specific and literature-derived data. For example, for fish lipid, we will use the measured lipid contents from the fish sampling program supplemented with values from the literature. Feeding preferences for fish will largely be based on the results of a site-specific stomach contents analysis conducted for bass and bullhead, again supplemented with information from the literature. Feeding preferences for the ecological receptors will be obtained from the literature. Table 2 provides an overview of the specific data required to run the *TrophicTrace* model. The model itself has been described in Appendix B of the 8/3/2010 data gaps memorandum.

Table 2: Model inputs for *TrophicTrace*

Data	**Units**	**Source**
Environmental / Chemical		
PCBs in sediment	ng/g	Sampling program
PCBs in water	ng/L	Sampling program; equilibrium partitioning
Total organic carbon	Fraction	Sampling program
Log K_{ow}	Unitless	Literature
K_{oc} (for equilibrium partitioning)	Unitless	Literature
Water temperature	Deg C	Site specific; related waterbodies
Benthic Invertebrates		
Percent lipid	%	Literature

Fish		
Percent lipid	%	Sampling program; literature
Feeding preferences	Fraction	Site-specific stomach contents; literature
Toxicity reference values for PCBs	mg/kg-day	Literature
Ecological Receptors		
Feeding rate	mg/day	Literature
Feeding preferences	Fraction	Literature
Toxicity reference values for PCBs	mg/kg-day	Literature

In general, a site specific application of any model requires calibration and validation. Calibration is the process of optimizing model inputs to achieve the least difference between model predictions and observed data. Validation is the process of using a calibrated model to predict an independent data set. Often, there isn't enough data for both calibration and validation. In this case, we propose to calibrate the model for Section 1 and validate it by applying the calibrated model to Section 2. Note, however, there may be legitimate reasons as to why a bioaccumulation model calibrated for one Section would not necessarily apply to the other. As a result, it is important to evaluate the factors that might contribute to such a situation, as well as to design a number of model diagnostics to provide greater confidence in model performance.

Once the model has been parameterized, we will run it for total PCBs and selected congeners and compare the results to the observed fish tissue data for Section 1. If the comparison is favorable, (e.g,. within a factor of 3), we will consider the parameterization successful and use the model as is for all subsequent analyses. If the comparison is not favorable, we will calibrate the model for total PCBs by slightly adjusting the Log K_{ow} to optimize the fit between predicted and observed. Because total PCBs represents a mixture (strictly speaking, up to 209 individual congeners contribute to that mixture), the actual Log K_{ow} in the field may differ from what has been measured in the laboratory for any given total PCB mixture, and this parameter is highly sensitive in the model (e.g., small changes in Log K_{ow} lead to between a factor of 5 and 10 difference in predicted fish tissue concentrations). This is not the case for individual congeners, for which there is far less uncertainty around the true Log K_{ow}; therefore, modeling individual congeners will provide an important model diagnostic.

One very important reason why a single calibrated model might not apply across all Sections of Eighteenmile Creek is if the relationship between sediment and water differs across the modeling Sections. This will not be captured by the model (e.g., we are assuming the same relationship as was observed in Section 1, and we are also applying equilibrium partitioning across both sections), and it will not be possible, given the available data, to evaluate and determine whether that might be the case. However, given the ability of the *TrophicTrace* model to incorporate "fuzzy" inputs (e.g., a range of values rather than deterministic estimates), we anticipate it will be possible to capture the likeliest range of conditions at the site.

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Appendix A: Species Life History Information

LARGEMOUTH BASS

The largemouth bass, *Micropterus salmoides*, is a relatively large, robust fish that has a tolerance for high temperatures and slight turbidity (Scott and Crossman 1973). It occupies waters with abundant aquatic vegetation. Largemouth bass show a low tolerance for low oxygen conditions. The largemouth bass represents a top predator in the aquatic food web, consuming primarily fish but also benthic invertebrates.

Foraging

Young largemouth bass feed on algae, zooplankton, insect larvae, and microcrustaceans (Boreman 1981). Largemouth bass can grow to 136 grams on a diet consisting of insects and plankton. Larger prey is needed to continue growth after reaching a total length of 20 mm. Young largemouth bass compete for food with a variety of other warmwater and bottom-feeding fishes.

Johnson (1983) found that the diets of juvenile fish foraging in the St. Lawrence River varied somewhat by location and length of the fish. Fish, insects including corixids, and other invertebrates made up the diets in varying proportions.

Largemouth bass longer that 50 mm total length usually forage exclusively on fish. Observed prey species include gizzard shad, carp, bluntnose minnow, silvery minnow, golden shiner, yellow perch, pumpkinseed, bluegill, largemouth bass, and silversides. (Scott and Crossman 1973). Cannibalism is more prevalent among largemouth bass than among many species. Ten percent of the food of largemouth bass 203 mm and longer is made up of their own fry (Scott and Crossman 1973).

Largemouth bass take their food at the surface during morning and evening, in the water column during the day, and from the bottom at night. They feed by sight, often in schools, near shore, and almost always close to vegetation. Feeding is restricted at water temperatures below 10°C and decreases in winter and during spawning. Largemouth bass do not feed during spawning.

Information on feeding habits of largemouth bass in the upper Hudson River was obtained for 73 juvenile and adult fish collected in Spring 1997 by the New York Department of Environmental Conservation and analyzed by Menzie-Cura & Associates. Thirty-one of the bass (42%) had fish remains in their digestive system and represented the most common food item for adult bass. Crayfish were eaten occasionally at most river locations. However, six of twenty bass collected at Catskill Creek had eaten crayfish. Primarily benthic invertebrates were observed in the diet of juvenile bass. On the basis of the available data it is estimated that fish comprise between 75 and 90% of the diet. The spring 1997 data indicate that the balance of the diet is made up of benthic invertebrates.

Further gut content analyses of 32 adult largemouth bass from the Hudson River in Fall 1997 and 21 bass collected from in Spring 1998 show similar results. Thirty-one of the bass (58%) had fish in their digestive systems and crayfish were occasionally eaten. Smaller invertebrates (insects and crustaceans) were commonly present. Frogs were also occasionally eaten.

Largemouth bass feed on a variety of invertebrates that inhabit sediments, live on plants, or are part of the zooplankton. Predominant invertebrate species observed in the gut contents of bass include amphipods (both *Hyallella* and *Gammarus*), isopods (*Caecidotea*), cladocerans (*Bosmina*, *Chydorus*, *Eurycercus*, and *Simocephalus*), cyclopoid copepods, ostracods (e.g., *Podocopa*), and some chironomid larvae. The crustacea observed include a number of species that inhabit the water column (e.g., *Bosmina*), occupy the littoral area and also open water (e.g., *Chydorus sphaericus*) , and live in close association with surface sediments (e.g., *Gammarus* and *Caecidotea*). The amphipod *Gammarus* spp. also occur in the plankton of the river and are likely influence by both water and surficial sediment exposures. The isopod is probably a surface deposit feeder and is also likely influenced by surface water as well as surficial sediment exposure.

On the basis of the available data, we estimate that fish comprise between 75 and 90% of the average adult largemouth bass diet. The balance of the diet is made up primarily of invertebrates including crayfish. Our estimates consider the relative size of the prey organisms as well as the frequency of prey animals in the diet. Terrestrial animals are also occasionally eaten. A qualitative assessment of data from the Hudson River suggests that 54% and 68% of the invertebrates are associated with sediments and 34 to 46% are associated with water. Invertebrates associated with sediments such as amphipods and isopods are also likely influenced by water exposures. The extent to which water or sediment affect the body burdens of surface deposit feeders and meroplanktonic animals such as *Gammarus* is not known.

Range, Movement and Habitat

Largemouth bass have distinct home ranges and are generally found between 8 and 9 kilometers of their preferred range (Kramer and Smith 1960). Kramer and Smith found that 96 percent of the fish remained within 91 meters of their nesting range. Fish and Savitz (1983) found that bass in Cedar Lake, Illinois, have home ranges from 1,800 to 20,700 square meters. The average home range was 9,245 square meters and the average primary occupation area, defined as that area within the home range in which the fish spends the majority of its time, including foraging, was 6,800 square meters.

Largemouth bass are almost universally associated with soft bottoms, stumps, and extensive growths of a variety of emergent and submerged vegetation, particularly water lilies, cattails, and various species of pond weed. It is unusual to find largemouth bass in rocky areas. Largemouth bass are rarely caught at depths over 20 feet, although they often move closer to the bottom of the river during the winter.

Mobility of largemouth bass also varies seasonally. Daily movements increase with temperature from March through June, but decrease sharply during the hottest months (Mesing and Wicker 1986). Activity during warmer seasons occurs primarily near dawn and dusk, while cool-water activity is most extensive in the afternoon.

Largemouth bass prefer to establish habitats near dense vegetation not just during winter, primarily near milfoil (*Myriophyllum verticillatum*) (Carlson 1992). A study of largemouth bass in two freshwater lakes in central Florida found a positive correlation between the use of specific habitats in proportion to the availability of those habitats to the fish (Mesing and Wicker 1986). Vegetative habitat covers included *Panicum* spp., cattails (*Typha* spp.), and water lilies (*Nuphar* spp.).

Reproduction

Largemouth bass mature at age five and spawn from late spring to mid-summer, in some cases as late as August. Male largemouth bass construct nests in sand and/or gravel substrates in areas of nonflowing clear water containing aquatic vegetation (Nack and Cook 1986). This aquatic vegetation generally consists of water chestnut (*Trapa natans*), milfoil (*Myriophyllum verticillatum*), and water celery (*Valisneria americana*).

Females produce 2,000 to 7,000 eggs per pound of body weight (Smith 1985) and leave the nest after spawning.

BROWN BULLHEAD

The brown bullhead, *Ictalurus nebulosus*, is a demersal omnivorous species occurring near or on the bottom in shallow, warmwater situations with abundant aquatic vegetation and sand to mud bottoms. Brown bullhead are sometimes found as deep as 40 feet, and are very tolerant of conditions of temperature, oxygen, and pollution (Scott and Crossman 1973).

Foraging

The brown bullhead feeds on or near the bottom, mainly at night. Adult brown bullhead are truly omnivorous, consuming offal, waste, molluscs, immature insects, terrestrial insects, leeches, crustaceans including crayfish and plankton, worms, algae, plant material, fishes, and fish eggs. Raney and Webster (1940) found that young bullheads in Cayuga Lake near Ithaca, New York fed upon crustaceans, primarily ostracods and cladocerans, and dipterans, mostly chironomids. For brown bullhead in the Ottawa River, algae have also been noted as a significant food source (Gunn et al. 1977).

Another study conducted in the Hudson River near Newburgh (LMS 1975) showed that brown bullhead displayed a varied and seemingly opportunistic feeding behavior. Smaller bullheads (size interval I) ate primarily chironomid insect larvae, amphipods., odonata, and oligochaete worms. Larger bullheads displayed a similar feeding behavior but also ate young-of-the-year fish. Observations made on gut contents of brown bullheads collected in the Kingston area indicated that oligochaete worms were a major part of the diet.

Further Hudson River brown bullhead stomach contents analyses indicate that the diet reflects a large benthic invertebrate component. Only one fish was observed in a gut of one bullhead. The data indicate that predominant prey items for bullheads included small clams, amphipods (*Gammarus*), isopods (*Caecidotea*), a few of the cladoceran species, and chironomid insect larvae that are typically considered to burrow into sediments (e.g., *Procladius*). It was also observed that the diet of brown bullhead frequently contain oligochaete setae (worms are usually quickly digested or unidentifiable).

Data for the Hudson River show that 71 to 83% of the invertebrates found in brown bullhead stomachs were associated with sediments and 17 to 29% were associated with water. Because oligochaete worms may be a major food item, the benthic percentage is probably even higher and estimated to be as high as 95%. Data for the lower Hudson reported by LMS (1974) also support a high component of the diet as benthic in nature in that are large component was comprised of oligochaete worms. These organisms are digested more quickly that insects and crustaceans and are probably underrepresented in typical stomach content analyses. Fish are considered to be a minor component of the diet (less than 5%).

Range, Movement and Habitat

Brown bullhead, a freshwater demersal fish, resides in water conditions that are shallow, calm and warm. In the summer, bullheads can be found in coves with ooze bottoms and lush vegetation, especially water clover, spatterdock and several species of pond weed (Raney 1967). Carlson (1986) found that the vegetated backwaters and offshore areas are the most common habitats for brown bullheads. McBride (1985) found bullhead abundant in river canal pools. Brown bullhead prefer wetlands, embayments, and shallow habitats. Carlson (1986) found bullheads most frequently in backwaters, but also in other, deeper areas such as the channel border. This species prefers silty bottoms, slow currents, and deeper waters.

Reproduction

Brown bullhead reach maturity at two years and spawn for two weeks in the late spring and early summer. Smith (1985) noted that in New York, brown bullhead spawn when water temperatures reach 27°C in May and June.

They prefer to spawn among roots of aquatic vegetation, usually near the protection of a stump, rock or tree, near shores or creek mouths. Males, sometimes aided by females, build nests under overhangs or obstructions (Smith 1985). Eggs are guarded.

BELTED KINGFISHER (*Ceryle alcyon*)

The belted kingfisher is distinguished by a blue-gray dorsal plumage and mostly white underparts, a large, heavy bill, and a double peaked crest of feathers on the crown. It has a white throat and a broad white and blue-gray collar around the neck, a small white spot near the eye, and is spotted on the ventral portion of the wings and tail. The ventral side of the tail feathers remains distinctly barred with gray and white banding. The sole distinctive plumage characteristic between the sexes is the presence of a distinct rufous band crossing the chest in the female. Kingfishers have broad wing areas relative to their body size and fly with a wing beat characteristic of a deep and rapid irregular pace (Farrand 1983). Across their North American range adults are 31.0 to 36.0 cm total length (Farrand 1983), and weigh 136.0 to 155.0 gms (Brooks and Davis 1987; Dunning 1993; Poole 1938).

Habitat, Home Range, and Migration

Belted kingfishers are found along the shoreline of rivers, streams, ponds, and lakes, including both freshwater and brackish areas. The kingfisher diet is almost exclusively aquatic prey items and nesting usually occurs in close proximity to feeding areas. Preferred riparian areas include areas with mature woody vegetation with numerous overhangs above the water surface. The overhangs are critical for use as perching posts from which aquatic prey may be observed. Clear water conditions assist in prey capture (Bent 1940). Artificial perches for feeding include overhead wires above the water surface and bridges.

Typically the streams and rivers selected for feeding areas are larger (4 to >16 m) permanent lotic environments with a diverse assemblage of microhabitats (i.e., riffles, pools, runs etc.) of varying depths (0.17-0.50 m) (Brooks and Davis 1987). Banks can be steep or gradual in inclination and remain well vegetated. Feeding can occur in aquatic microhabitats with higher water velocities (i.e., riffles and runs) or more quiescent conditions (i.e., pools and runs). Generally feeding occurs in both lentic and lotic habitats, although lotic environments appear to be favored (Brooks and Davis 1987). Nesting always occurs in a cavity in close proximity to the feeding area. Nesting occurs in cavities that have been excavated in the steep, exposed banks of the shoreline or in riparian areas associated with the feeding habitat. Use of abandoned woodpecker holes and wood duck nests has been documented but are uncommon relative to earthen cavity sites (Andrle and Carroll 1988). The vertical inclination and height of the embankment slope appears to be a critical factor and may act as a deterrent to predators, allow for easy excavation, and prevent the nest from flooding during high flows. Brooks and Davis (1987) observed an average inclination of 55 to 89% and a height of one to two meters above the ground in nest embankments in Ohio and Pennsylvania populations. Eroded tracks at the base of the hole from the adults dragging their feet in flight when entering the nest cavity are characteristic of kingfisher nests. Embankments subject to severe erosion and rock outcrops are characteristics that may limit nest site selection. Suitable nest sites appear to be a limiting factor in the distribution of mating pairs (Brooks and Davis 1987). Home range is typically defined by length of shoreline defended by mated pairs (breeding territory) and feeding areas defended by solitary adults (non-breeding). Generally, breeding pairs defend a larger habitat than solitary individuals, although considerable overlap in size occurs. Davis (1982) reported that non-breeding individuals occupied an average home range of 0.39 km of shoreline and that breeding pairs defend an average home range of 1.03 km of shoreline in Pennsylvania and Ohio populations. NYS populations are expected to occupy similar home ranges.

The kingfisher is native throughout North America. In NYS, the kingfisher can be both a seasonal migrant or a resident species throughout the year. Migrations in the northeast are dependent upon the severity of the winter season, in particular the degree of ice cover on feeding waters. During severe conditions (i.e., persistent cold and continuous ice cover) northeast populations will migrate as far south as portions of the Carolinas and Virginia. Fall migration in NYS occurs from September through October and spring migration occurs from April through June (Bent 1940). During milder winters, the kingfisher can remain in NYS as long as a steady food supply is available and aquatic habitats remain free of ice (USEPA 1993b). Annual residence time of this species in NYS ranges from 245 days/year (migrants) to 365 days/year (full time resident).

Feeding Habits and Diet

Throughout their North American range belted kingfishers are opportunistic piscivores with smaller fish species dominating the diet and larger aquatic invertebrates like crayfish supplementing the diet. While amphibians, reptiles, and small mammals have been documented as occurring in the diet, wholly aquatic prey (fish and crayfish) are the principal diet components in northeast populations (USEPA 1993b).

Kingfishers locate aquatic prey by perching above the water surface and visual detecting the prey. All feeding occurs by sight with detection of prey being based upon movement. Capture of aquatic prey consists of the kingfisher diving from its perch into the water and physically seizing the prey with its bill. Prey detection and capture occurs within a few inches of the water surface (Davis 1982). Water turbidity is thought to contribute to feeding success. A reduction in feeding duration during peak or storm flow periods has been observed (Brooks and Davis, 1987). Diet studies of northeast and central North American populations (Michigan, New York, Pennsylvania, and Ohio) indicate that the typical diet of belted kingfishers ranges from 46-100% fish, 5-41% crayfish and other aquatic invertebrates, and 0-6% amphibians, reptiles or small mammals (USEPA 1993b). Stomach content analyses from 25 individuals from south-central NYS revealed an average diet of 72% fish, 22% crayfish/invertebrates, and 6% amphibian/reptiles (Gould, unpublished data cited in USEPA 1993b). Comparison of these data to the observed North American range shows the diets to be comparable. Fish consumed from NYS waters include salmonids, cyprinids, percids, ichtrarcids and centrarchids (USEPA, 1993b). Prey species selectivity appears to be based upon local abundance within in the aquatic community rather than species specificity. Davis (1982) observed that all fish captured by belted kingfishers in Ohio and Pennsylvania populations ranged from 4.0 to 14.0 cm in length. It is anticipated that NYS kingfisher populations would have similar size selectivity.

Reproduction

Males typically arrive prior to females and select and defend a breeding territory. Kingfishers are highly territorial and do not congregate in large numbers (Davis 1982). Because of limitations of suitable excavation/nest sites breeding pairs may nest some distance away from the foraging area (Andrle and Carroll 1988). The male and female excavate a cavity in an earthen tunnel for nesting. Tunnels are circular 8.9 to 10.0 cm wide and 7.6 to 8.9 cm high and can be excavated into the embankment up to 4.6 meters. Established breeding pairs often return to the same excavated nest cavities year after year. Excavations are often associated with other species that use earthen cavities to nest, including bank swallows (*Riparia riparia*) and rough winged swallows (*Steligidopteryx serripenniss*). Nests are devoid of nest lining material and eggs are laid on the earthen floor (Andrle and Carroll 1988). Although belted kingfishers prefer areas with as little disturbance as possible for nest site locations, they will tolerate human incursion and have been found nesting in roadway cuts and gravel and sand quarries (Hamas 1974). Eggs in NYS populations are laid from April to June and a single brood is common (Andrle and Carroll 1988). Five to eight eggs are generally laid in North American kingfishers (Peterson 1980). Incubation lasts approximately 17 to 24 days in NYS. Both male and female feed the nestlings. At hatching, nestlings typically weigh 10.0 to 12.0 gms and grow at a rate of five to six grams per day. At fledgling, generally occurring from July through August, individuals weigh 149 to 169 gms (Brooks and Davis 1987). The diet of nestlings and fledglings is comparable to the adult diet.

GREAT BLUE HERON (*Ardea herodias*)

The great blue heron is the largest heron species (order Ciconiiformes) indigenous to NYS. It is a common wading bird that inhabits both freshwater and estuarine portions of rivers throughout the state. The USFWS considers it a migratory, non-game avian species. NYS populations are monitored by the NYSDEC Non-game Species Program.

The sexes are similar in body size, wing span and coloration, although males are slightly larger in body mass and wing span than females (Peterson 1980). Body size ranges 104.0 to 132.0 cm with a wing span of 1.8 to 2.2 m and a height of 1.2 to 1.5 m (Farrand 1983). Dunning (1993) lists average body masses as 2,576 gms for males and 2,204 gms for females. Plumage in both sexes is identical. Adults have a white head with the sides of the crown and nape being black with short plumes projected to the rear; the neck is light gray, with a whitish ventral stripe; the bill is large and yellowish; the body is blue gray; and the legs are dark brown to black in coloration (Farrand 1983).

Habitat, Home Range, and Migration

Preferred habitats for feeding and breeding are riparian habitats along the shoreline of rivers, streams, lakes, and wetlands. These include both non-tidal and tidal portions of rivers and estuaries. When feeding along the shoreline of aquatic habitats, the great blue heron diet is composed almost exclusively of aquatic prey. It is semi-tolerant of human disturbance and is common along drainage ditches and river banks associated with human development, but will readily flush when approached on foot (Eckert and Karalus 1983). Heronries are typically located in standing trees and dead snags in secluded areas with minimal human disturbance (Andrle and Carroll 1988). Home range can be considered in terms of both distance traveled to feeding grounds from heronries and defended foraging areas used for feeding. USEPA (1993a) gives mean ranges of 3.1 to 8.0 km linear distance (max. 24.4 km). Unit areas for foraging varied by habitats with an average area of 0.6 ha in a Oregon freshwater marsh to 8.4 ha in an Oregon estuary (USEPA 1993a). No NYS home range data were available, but values are expected to be similar to those observed in other areas of the continental US.

In NYS, the great blue heron can be both a seasonal migrant or a resident species throughout the year as long as open water persists (Bull, 1998). Results of the Audubon Christmas Bird Count show that the great blue heron is an uncommon winter resident (CBC, 1999). Migrations in the northeast are highly dependent upon the severity of the winter season, primarily the degree of ice cover on feeding waters. During severe conditions (i.e., persistent cold and continuous ice cover) northeast populations will migrant south to portions of the Carolinas and Virginia. Fall migration in NYS populations remains unclear given the tendency of this species to linger or reside in summer grounds during the winter period. Fall migration may begin as early as mid-July. Spring migrants typically return to NYS habitats from late-March through early April (Bull 1998). Annual residence of this species in NYS can range up to 365 days/year for year-round residents.

Feeding Habits and Diet

The feeding behavior in great blue herons can be characterized as a stalking and ambush approach to prey capture (Eckert and Karalus 1983). Great blue herons are typically solitary hunters along shorelines of aquatic habitats. However, when prey is abundant (e.g., baitfish stranded in tidal mudflat shallows) great blue herons will congregate in large numbers to feed (Krebs 1974). Feeding typically occurs throughout the day with greatest activity occurring during dawn and dusk. Solitary feeding behaviors consists of a slow and deliberate pace in shallow water with prey being detected based upon visible movement. Maximum depth in which feeding occurs is approximately 1.5 to 1.6 m with firm bottom substrates (USEPA 1993a).

Stomach contents of adults and nestlings from a southwestern Lake Erie population were found to consist of 100% fish with most fish eaten being less than 20 cm total length (Hoffman 1978). Fish species indigenous to the Hudson River which were found in the Lake Erie study include: carp and minnows (Cyprinidae) 50% to 53%, perch (Percidae) 10% to 28%, sunfish and bass (Centrarchidae) 7% to 10%, drum (Sciaenidae) 4% to 10%, catfish (Ictaluridae) 0% to 5%, herrings and shad (Clupeidae) 0% to 5%, and aquatic invertebrates (crayfish, aquatic insects) 5% to 31% (USEPA 1993a). While herons prefer to feed on fish, amphibians/reptiles, small mammals and insects are taken on occasion (USEPA 1993a; Eckert and Karalus 1983).

Herons capture fish by impaling them with their bill. They realign fish in the beak and then swallow them whole. Fish up to 0.6 m long and up to one kilogram can be captured and swallowed (Eckert and Karalus 1983). Krebs (1974) found that smaller prey were selected more frequently because of greater abundance and less handling time. Through field observations, Krebs categorized fish size based upon comparative size of the fish captured to the length of the herons bill (assuming a 12.7 cm bill length) using the categories of small fish (< ½ bill length), medium fish (>½ to l bill length), and large fish (> l bill length). Results of the field investigation revealed a distribution in prey size of 73.4% small fish (<6.0 cm total length [TL]); 19.4 % medium fish (approximately 6.0-13 cm TL) and 7.4 % large fish (> 13.0 cm TL).

Reproduction

Great blue herons are colonial nesters and form heronries that in NYS range from less than 50 nests to up to 1,000 nests, given optimal nesting habitats (Bull 1998; Andrle and Carroll 1988). Confirmed heronries have been found throughout NYS (Andrle and Carroll 1988). Selection of nesting sites remains highly selective with the availability of densely distributed large trees or standing snags or dense scrub, a local foraging habitat and minimal human disturbance being three of the most critical characteristics for location of heronries (Eckert and Karalus 1983). Nests vary greatly in their dimensions from flimsy new platforms of sticks 0.5 m across to bulky older structures 0.9-1.2 m across. Nests are usually 7.6 to 30.5 m above the ground (Andrle and Carroll 1988). Mating occurs from late March through early April and eggs are laid between April 15 and June 9. The nestling stage extends for approximately 60 days after hatching and fledglings leave the nest by July in NYS (Andrle and Carroll 1988).

MINK (*Mustela vison*)

The mink is a small, opportunistic, carnivore found throughout the U.S. and Canada. It is indigenous to New York State where it is considered a furbearer species and its take is regulated by NYSDEC Division of Fish, Wildlife and Marine Resources. They are semi-aquatic in habit and frequent the shoreline and shallows of rivers, lakes, streams and wetlands. Mink are dark brown in color with a white chin patch and their fur is rich in guard hairs. Mink are sexually dimorphic in body size with males being larger than females. Males range from 33 - 43 cm total body length, 18 - 23 cm tail length. Females range from 30 - 36 cm body length; 13 - 20 cm in tail length (Burt and Grossenheider 1976). Body mass in adult mink from wild populations (from across the N.A. range) by sex range: 681 - 1,233 g. males; and 567 - 586 g. females (Burt and Grossenheider 1976, Mitchell 1961). Mitchell found adult male and female Montana mink to weigh an annual average of 1,150 g. for males and 600 g. for females. A total of twenty historical skins of this species from portions of the Hudson River Valley (Saratoga, Albany, Rensselaer, Greene, Columbia, Ulster and Dutchess Counties) are curated at the New York State Museum (NYSM) in Albany, New York. Unfortunately, morphological data recorded at the time of collection is only available for a single specimen. An adult, male mink collected from the Hudson River Valley weighed 1.1 Kg in body mass and was 59.0 cm in total length. Domestically raised mink are slightly larger in body mass for both sexes than individuals from wild populations. Hornshaw et al. (1983) reported body weights of 1,734 g. for male and 974 g. for female captive mink. The observed difference in body mass between wild and domestic populations appears related to nutritional enhancement in diets fed to captive individuals (Hornshaw et al. 1983).

Habitats and Home Range

Mink are found around stream banks, lake shores, and marshes. They tend to prefer areas where there is extensive cover and they defend large territories. In general, mink prefer wetlands and riparian habitat with irregular and diverse shorelines. They are reasonably tolerant of human disturbance but are sensitive to prey abundance which may drop in conjunction with human development (Allen 1986). Mink may also be limited by the availability of suitable den sites. In general, the upper New York State mink population size depends on the availability of wetlands and riparian habitats that are surrounded by dense woods and shrubs to provide adequate cover. Bulkheaded and channelized shorelines devoid of adequate cover are not considered significant mink habitat (Allen 1986). Regardless of the type of habitat utilized, mink dens are always associated with water and typically remain no more than 5-100 meters from a water body.

Depending upon the nature of habitat, (i.e., wetland vs. riverine), home range has been expressed either as per unit area of wetland or per length of river shoreline. Home range also varies by sex as male mink appear to defend a larger territory than females (Eagle and Whitman 1987). Gerell (1970) reported home range in for lotic environments to be 1.0 to 2.8 river Km for adult males and 1.0 to 2.8 river Km for adult females. Mitchell (1961) reported a home range for adult female mink from a Montana riverine population of 7.8 Ha in heavy riparian vegetation and 20.4 Ha in sparse riparian vegetation.

Habits and Diet

Mink are nocturnal in habit, and entirely carnivorous in diet. Like other members of the weasel family, they are solitary (with exception of mating and courtship), aggressive predators and actively seek prey within their home range. They are active year round and do not hibernate. Generally, mink are opportunistic in selection of prey in their feeding habits and will exploit select prey species during periods of abundance. Mink feed primarily on small aquatic and terrestrial animals, although feeding upon prey items larger than themselves (such as waterfowl and muskrats) has been documented (Sealander 1943). Principal prey items identified from various feeding studies include muskrats, voles, rabbits, fish, frogs, crayfish, salamanders, clams, and insects (DeGraaf and Rudis, 1987, Sealander 1963). Ingestion of vegetation/soil appears incidental to feeding behaviors on other organisms (Waller 1962; Sealander 1943). Diet composition appears to be linked to both habitat and prey abundance. Hunting in aquatic habitats occurs in shallow, near shore areas where aquatic prey is captured and then moved to the shore prior to consumption (Allen 1986, Doutt et al. 1977).

Riverine populations appear to have a greater aquatic prey fraction in the diet than wetland populations. In riverine populations sampled from Michigan rivers, diets were comprised of 85% fish, 4% crayfish, 3% amphibians, 6 % birds/mammals and 2% other matter/vegetation (Alexander 1977). Hamilton (1936) in a stomach content analysis study of a sample of seventy mink trapped from throughout New York State found the winter diet of NYS mink to consist in order of frequency: 54.1% mammals; 18.8 % fish; 16.5 % crayfish; 2.4% amphibians and 7.0 % insects. Hamilton (1940) reported that the summer diet for mink in Montezuma Marsh, New York on a percentage by bulk basis consisted of 42.7% mammals; 27.3% fish; 13.9% aquatic invertebrates; 9.1% birds and 4.5% reptiles/amphibians.

Based on field observations and scat analysis, Hamilton (1940) reported that the mink fed upon fish 7.6-10.5 cm TL. The dominant species fed upon was the most abundant forage fish in Montezuma Marsh, the golden shiner (*Notemigonus crysoleucas*) and the aquatic invertebrate fraction consisted almost entirely of adult forms of aquatic beetles belonging to the Family Dytiscidae. The apparent size selectivity for smaller fish species and food web niche (i.e., an abundant forage fish) of preferred fish prey species in the mink diet observed by Hamilton is supported by the study of Gilbert and Nancekivell (1982). Gilbert and Nancekivell found that the dominant fish prey species consumed by a Montana river mink population is the brook stickleback (*Culaea incostans*) which is an abundant, small (3.8 - 6.4 cm TL) forage fish species in the drainages studied. Both Hamilton (1940) and Gilbert and Nancekivell (1982) suggest that prey selectiveness for fish species in the mink diet are based upon abundance and size of forage species. Arnold and Fritzell (1987) found that in wetlands managed for waterfowl populations, waterfowl and muskrats appear to be the most important prey items for mink.

Mink capture aquatic prey and return to the shoreline to feed provides a mechanism for incidental ingestion of abiotic material. Ingestion of vegetation/soil appears incidental to feeding on other organisms by mink (Waller 1962; Sealander 1943). No quantitative dietary data regarding abiotic media ingestion by mink are available. Hamilton (1940) recorded minor quantities of sand (reported only as “trace”) in mink scat samples collected from Montezuma Marsh, NY. On average, the frequency of occurrence of sand in the samples is 1.33%. Hamilton (1936) found grasses to occur at a relative frequency of 1.18 % in mink stomachs from NYS and Alexander (1977) speculated that such finds are incidental material ingested during consumption of animal prey. Based upon the documented presence of sand and vegetation in mink diets, and the similarity in the diets of mink and raccoons, it is assumed that incidental ingestion by mink of non-prey related material approximates 9.4%.

Hibernation/Aestivation

Mink are active during all four seasons and do not asetivate nor hibernate (Doutt. et al. 1977; Alexander 1977). Populations within the study area will be active throughout the year.

Seasonal and Long Distance Migrations

Mink do not migrate on a seasonal basis, but occupy and defend a resident territory throughout the year. This excludes local movements for purposes of territoriality by adults and dispersal of sub-adults from resident populations (Allen 1986). Populations within the study area of the Hudson River Valley are year round residents.

Reproduction
Mink build their dens below ground under fallen trees or stumps, in hollow logs, muskrat lodges or other abandoned animal dens (Allen 1986, Doutt et al. 1977). They breed in the early Spring and have a gestation period of about 50 days but delay implantation of the embryos in order to give birth during the period of April to June across their range (Eagle and Whittman 1987). The kits are born naked and blind and An average litter contains an average of 3 or 4 kits (Burt and Grossenhieder 1976). Sexual maturity is typically reached by one year, although mating may occur as early as 10 months in captive populations (Burt and Grossenhieder 1976, Enders 1952). Mink have been shown to suffer reproductive failure at relatively low exposures to PCBs (Aulerich and Ringer 1977). Mink may also be limited by the availability of suitable den sites.

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