**Calibration Data:** See wetland vegetation PI descriptions (by Wilcox and Ingram) for complete description of calibration data. Vegetation quadrat data (7 transects) and bathymetry/topography surveys for 8 open embayment (Hay Bay Marsh, Robinson Cove, South Bay Wolf Island-Button Bay, Braddock Bay, Black River Bay, The Isthmus, and Eel Bay) and 7 protected embayment (Parrott Bay, Hill Island East, Wolf Island-Bayfield Bay, Presqu’ile Bay Marsh, North Pond, Point Vivian Bay, and East Goose Bay) wetlands. Black River Bay South, an additional protected embayment site, was identified as an outlier and therefore excluded from the data analysis.

**Validation Data:** Wetland vegetation mapping from historical aerial photography of the study sites were used to validate wetland vegetation model predictions of general habitats (e.g. meadow marsh). No data is available to validate predictions of yellow rail breeding habitat.

**Documentation and Reference:** See the wetland vegetation PI descriptions (by Wilcox and Ingram) for documentation and references specific to the wetland vegetative model. Vegetation used as preferred breeding habitat was determined from peer reviewed published literature and databases (e.g. NHIC, NYNHP, and the NYSDEC Breeding Bird Atlas).


**Risk and Uncertainty Assessment:**

This PI is based on the following assumptions:

- Abundance and distribution of SAR are currently limited by available preferred or required habitat;
- Literature provides accurate information on life history and habitat needs and preferences;
- Habitat and/or vegetative structural type designations are comparable to the designation as determined from the vegetative sub-model;
- The vegetative sub-model allows us to predict quantitative changes in habitat for each water level scenario;
- Actual required habitat is a proportion of the predicted habitat;
- Evaluation of habitat change, as determined by change in the area of preferred or required habitat, is a valid method to assess positive or negative impacts to a SAR;

Some uncertainty is associated with all of the assumptions made in development of PIs. Despite this uncertainty, species-at-risk must be considered in the decision making process. Protecting the ecosystems of vulnerable, threatened, and endangered species is essential for the species survival and conservation and protection of biological diversity. The U.S. and Canadian federal governments, Province of Ontario, and State of New York have many laws written to protect wildlife and to prevent or minimize damage to critical
habitat. Any decline in the availability of habitat for species-at-risk is potentially significant in terms of the sustainability of the species or its habitat. The species-at-risk PIs will aide in evaluating the impact of proposed water level regulation scenarios on critical habitat.

Significance, Uncertainty and Sensitivity:

1) Significance Rating: Historically, yellow rail breeding distribution was throughout Ontario. Now, it is almost extirpated following extensive draining of wetlands in southern Ontario. There are three occurrences of yellow rail in wetlands found on the north shore of Lake Ontario. Although these occurrences are considered extant, no birds have been found in last five years. Yellow Rail which nests in large marshes with shallow or no standing water and has specific breeding habitat preferences. Yellow rail is listed as vulnerable by OMNR and special concern by COSEWIC (schedule 1) and Canada’s SARA.

2) Uncertainty: The uncertainty associated with each of our assumptions and includes (but is not limited to):
   - The suspected distribution of each species is only as good as available occurrence information;
   - We assume that species are currently limited by available habitat. Conversely, even if the IERM predicts a certain amount of available habitat for a given species, that species may only be able to occupy a portion of that habitat for a number of reasons (e.g. proximity to humans, wetland complexity, pollution, faunal wetland species composition and diversity, etc.);
   - Information on life history and habitat needs and preferences as determined from literature review may not be complete;
   - There may be uncertainty with how the forcing functions (i.e. water level) interact with habitat;
   - There are uncertainties associated with the vegetation sub-model, which is used to predict habitat availability (ha), and should be addressed by Wilcox and Ingram;
   - SAR are impacted by many factors in addition to habitat availability, including: habitat quality, prey quality and availability, weather, predation, inter- and intra-specific competition, etc. These factors likely interact with changes in water level (e.g. increased nest predation with decreases in water level).

3) Sensitivity: Yellow rail is retained as a key PI because its habitat is sensitive to alterations in water levels and flows.
**PI Name / Short Description**: King Rail (RAEL) - preferred breeding habitat coverage (Lake Ontario) [E11]

**Technical Workgroup**: Environmental TWG

**Researched By**: Lantry, Schiavone
**Modeled By**: LTI (DePinto, Redder)

**Performance Indicator Metric**: Basin level area estimate of the annual cover of preferred breeding habitat (ha).

**Ecological Importance/Niche**: King rail is designated as Threatened by New York State Department of Environmental Conservation (NYSDEC), Endangered by Ontario Ministry of Natural Resources (OMNR), the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; Schedule 1), and the Species at Risk Act (SARA). Protecting the ecosystems of vulnerable, threatened, and endangered species is essential for species survival and the conservation and protection of biological diversity.

**Temporal Validity**: 2nd quarter of May through end of July.

**Spatial Validity**: Valid for Lake Ontario, where appropriate breeding habitat exists. Annual preferred breeding habitat coverage is simulated for “typical” open and protected embayment wetlands. “Typical” open and protected embayment wetlands are characterized by bathymetry/topography and vegetative community responses that are intended to be representative of the entire collection of open and protected embayment wetlands on Lake Ontario (see calibration data). The generalized plant community and elevation models are assumed to be representative of all coastal wetlands of each geomorphic type located within all the Lake Ontario shore units and the Upper St. Lawrence RIV 1 shore unit (see Calibration Data). As such, the model outputs are extrapolated to a complete coastal wetland database for Lake Ontario and the Upper St. Lawrence River to obtain a basin level annual estimate of preferred breeding habitat.

**Hydrology Link**: Water level regulation could change the availability of preferred breeding habitat in open and protected embayments. Predictions of this PI are generated from the wetland plant model developed by Wilcox and Ingram. Wetland plant community evolution is strongly dependent on the hydroperiod (i.e., flooding and dewatering history) at a particular elevation.

**Algorithm**: The wetland plant model uses flooding and dewatering intervals at specific elevations based on a 0.05-meter interval between 73.25 and 75.75 (meters IGLD85) to assign vegetative structural types to elevations on an annual basis. The wetland plant model is based upon field sampling completed for the IJC study (see wetland vegetation PI descriptions and reports for additional details).

**Calibration Data**: See wetland vegetation PI descriptions (by Wilcox and Ingram) for complete description of calibration data. Vegetation quadrat data (7 transects) and
bathymetry/topography surveys for 8 open embayment (Hay Bay Marsh, Robinson Cove, South Bay Wolf Island-Button Bay, Braddock Bay, Black River Bay, The Isthmus, and Eel Bay) and 7 protected embayment (Parrott Bay, Hill Island East, Wolf Island-Bayfield Bay, Presqu’ile Bay Marsh, North Pond, Point Vivian Bay, and East Goose Bay) wetlands. Black River Bay South, an additional protected embayment site, was identified as an outlier and therefore excluded from the data analysis.

**Validation Data:** Wetland vegetation mapping from historical aerial photography of the study sites were used to validate wetland vegetation model predictions of general habitats (e.g. meadow marsh). No data is available to validate predictions of king rail breeding habitat.

**Documentation and Reference:** See the wetland vegetation PI descriptions (by Wilcox and Ingram) for documentation and references specific to the wetland vegetative model. Vegetation used as preferred breeding habitat was determined from peer reviewed published literature and databases (e.g. NHIC, NYNHP, and the NYSDEC Breeding Bird Atlas).


**Risk and Uncertainty Assessment:**

This PI is based on the following assumptions:

- Abundance and distribution of SAR are currently limited by available preferred or required habitat;
- Literature provides accurate information on life history and habitat needs and preferences;
- Habitat and/or vegetative structural type designations are comparable to the designation as determined from the vegetative sub-model;
- The vegetative sub-model allows us to predict quantitative changes in habitat for each water level scenario;
- Actual required habitat is a proportion of the predicted habitat;
- Evaluation of habitat change, as determined by change in the area of preferred or required habitat, is a valid method to assess positive or negative impacts to a SAR;

Some uncertainty is associated with all of the assumptions made in development of PIs. Despite this uncertainty, species-at-risk must be considered in the decision making process. Protecting the ecosystems of vulnerable, threatened, and endangered species is essential for the species survival and conservation and protection of biological diversity. The U.S. and Canadian federal governments, Province of Ontario, and State of New York have many laws written to protect wildlife and to prevent or minimize damage to critical habitat. Any decline in the availability of habitat for species-at-risk is potentially significant in terms of the sustainibility of the species or its habitat. The species-at-risk
PIs will aide in evaluating the impact of proposed water level regulation scenarios on critical habitat.

Significance, Uncertainty and Sensitivity:

1) Significance Rating: King Rail has declined dramatically in the northern part of its range (e.g. Great Lakes Region). This species has been reported from three wetland areas along the New York and Ontario shores of Lake Ontario. In Ontario, king rail seems to prefer shallow-water marshes with abundant vegetation that merge with scrubby swales. King rail is listed as endangered by OMNR, COSEWIC and SARA and as threatened by NYSDEC.

2) Uncertainty: The uncertainty associated with each of our assumptions and includes (but is not limited to):
   - The suspected distribution of each species is only as good as available occurrence information;
   - We assume that species are currently limited by available habitat. Conversely, even if the IERM predicts a certain amount of available habitat for a given species, that species may only be able to occupy a portion of that habitat for a number of reasons (e.g. proximity to humans, wetland complexity, pollution, faunal wetland species composition and diversity, etc.);
   - Information on life history and habitat needs and preferences as determined from literature review may not be complete;
   - There may be uncertainty with how the forcing functions (i.e. water level) interact with habitat;
   - There are uncertainties associated with the vegetation sub-model, which is used to predict habitat availability (ha), and should be addressed by Wilcox and Ingram;
   - SAR are impacted by many factors in addition to habitat availability, including: habitat quality, prey quality and availability, weather, predation, inter- and intra-specific competition, etc. These factors likely interact with changes in water level (e.g. increased nest predation with decreases in water level).

3) Sensitivity: King rail is retained as a key PI because its habitat is sensitive to alterations in water levels and flows.
**PI Name/Short Description:** Low Vegetation, 18C fish guild – spawning habitat supply (Upper St. Lawrence River) [E12]

**Technical Workgroup:** Environmental TWG

**Researched by:** Minns, Doka, (Chu, Bakelaar, Leisti)
**Modeled by:** Moore, LTI (DePinto, Redder)

**Performance Indicator Metric:** This performance indicator represents the annual habitat supply (weighted suitable area) for the LV18 guild spawning in the Upper River reach group located in the Upper River. Emergent vegetation, submergent vegetation, substrate composition, water levels, and reach elevations (used to calculate water depths) are used to compute habitat suitability and supply for the LV18 guild in the Upper River study area. Temperature is used to calculate the appropriate time window for the annual calculations.

**Ecological Importance/Niche:** The members of the LV18 guild occupy shallow water (<20 m) during their life histories and prefer spawning in low vegetation and 18-22 degrees C. The species that comprise the guild have been recorded in the Lake Ontario & St. Lawrence systems and their species-specific habitat requirements have been used to calculate weighed suitable areas in the appropriate part of the system. Specific habitat requirements used for calculations are available (see report section).

**Temporal Validity:** LV18 spawning habitat supply is computed on a daily basis and then summed over an appropriate thermal window to generate annual habitat supply results (in units of hectare-days). Currently, a ratio of annual habitat supplies between baseline (1958DD) and proposed regulation plans is calculated annually and then the ratios are averaged and a coefficient of variation is calculated over the 101-year simulation period.

**Spatial Validity:** This LV18 habitat supply performance indicator is valid for a contiguous group of 1339 reaches and 335 wetlands that comprise the Upper River reach group. The weighted suitable area for different fish guilds, based on thermal and vegetation preference during spawning, are calculated for all reaches within the Upper River (see figure below).
Hydrology Link: Habitat suitability for the LV18 guild spawning, which is used to compute weighted suitable area in hectare-days, depends on the interaction between emergent vegetation, submergent vegetation, substrate composition, and water depth in the Upper River study area. Water depth inputs for the habitat suitability model are calculated daily, based on interpolated quarter-monthly water levels. WSAs can be combined across life stages, where appropriate, based on weightings determined by their responsiveness to hydrology.

Calibration Data: No specific calibration data are available, but relationships between habitat suitability and emergent vegetation, submergent vegetation, substrate composition, depth, and temperature are based on a large body of literature and information available on the habitat requirements of the LV18 guild spawning. Individual habitat components, such as shoreline substrate type and temperatures, have been calibrated with different sources of information.

Validation Data: No specific validation datasets are available for weighted suitable areas. Temperatures used in the habitat supply calculations have been validated using simulated data from different thermal models for Upper River or empirical datasets specific to the Upper River study area, when available.
Algorithm: Specific equations and algorithms used in the calculation of weighted suitable areas have been documented in IJC Lake Ontario – St. Lawrence Study reports (available at ftp://wtoftp.on.ec.gc.ca) and are too extensive to list here. The equations are part of a habitat supply submodel and database of the IERM for the LV18 guild in the Upper River.

Documentation & References: The documentation and details of the algorithms used to calculate this PI are summarized in:


Risk and Uncertainty Assessment: Currently cumulative uncertainties have not been estimated but errors and uncertainties exist at three levels of the habitat supply analysis: spatial habitat information, habitat models, weighted suitable area calculations based on their suitability and thermal windows. The scenarios should be equally affected by these cumulative uncertainties and also the relative differences used for comparisons. Therefore we are confident in the relative habitat supply effects and predictions.
**PI Name/Short Description:** High Vegetation, 24C fish guild – spawning habitat supply (Upper St. Lawrence River) [E13]

**Technical Workgroup:** Environmental TWG

**Researched by:** Minns, Doka, (Chu, Bakelaar, Leisti)

**Modeled by:** Moore, LTI (DePinto, Redder)

**Performance Indicator Metric:** This performance indicator represents the annual habitat supply (weighted suitable area) for the HV24 guild spawning in the Upper River reach group located in the Upper River. Emergent vegetation, submergent vegetation, substrate composition, water levels, and reach elevations (used to calculate water depths) are used to compute habitat suitability and supply for the HV24 guild in the Upper River study area. Temperature is used to calculate the appropriate time window for the annual calculations.

**Ecological Importance/Niche:** The members of the HV24 guild occupy shallow water (<20 m) during their life histories and prefer spawning in high vegetation and >=24 degrees C. The species that comprise the guild have been recorded in the Lake Ontario & St. Lawrence systems and their species-specific habitat requirements have been used to calculate weighed suitable areas in the appropriate part of the system. Specific habitat requirements used for calculations are available (see report section).

**Temporal Validity:** HV24 spawning habitat supply is computed on a daily basis and then summed over an appropriate thermal window to generate annual habitat supply results (in units of hectare-days). Currently, a ratio of annual habitat supplies between baseline (1958DD) and proposed regulation plans is calculated annually and then the ratios are averaged and a coefficient of variation is calculated over the 101-year simulation period.

**Spatial Validity:** This HV24 habitat supply performance indicator is valid for a contiguous group of 1339 reaches and 335 wetlands that comprise the Upper River reach group. The weighted suitable area for different fish guilds, based on thermal and vegetation preference during spawning, are calculated for all reaches within the Upper River (see figure below).
**Hydrology Link:** Habitat suitability for the HV24 guild spawning, which is used to compute weighted suitable area in hectare-days, depends on the interaction between emergent vegetation, submergent vegetation, substrate composition, and water depth in the Upper River study area. Water depth inputs for the habitat suitability model are calculated daily, based on interpolated quarter-monthly water levels. WSAs can be combined across life stages, where appropriate, based on weightings determined by their responsiveness to hydrology.

**Calibration Data:** No specific calibration data are available, but relationships between habitat suitability and emergent vegetation, submergent vegetation, substrate composition, depth, and temperature are based on a large body of literature and information available on the habitat requirements of the HV24 guild spawning. Individual habitat components, such as shoreline substrate type and temperatures, have been calibrated with different sources of information.

**Validation Data:** No specific validation datasets are available for weighted suitable areas. Temperatures used in the habitat supply calculations have been validated using simulated data from different thermal models for Upper River or empirical datasets specific to the Upper River study area, when available.
Algorithm: Specific equations and algorithms used in the calculation of weighted suitable areas have been documented in IJC Lake Ontario – St. Lawrence Study reports (available at ftp://wtoftp.on.ec.gc.ca) and are too extensive to list here. The equations are part of a habitat supply submodel and database of the IERM for the HV24 guild in the Upper River.

Documentation & References: The documentation and details of the algorithms used to calculate this PI are summarized in:


Risk and Uncertainty Assessment: Currently cumulative uncertainties have not been estimated but errors and uncertainties exist at three levels of the habitat supply analysis: spatial habitat information, habitat models, weighted suitable area calculations based on their suitability and thermal windows. The scenarios should be equally affected by these cumulative uncertainties and also the relative differences used for comparisons. Therefore we are confident in the relative habitat supply effects and predictions.
**PI Name/Short Description:** Low Vegetation, 24C fish guild – spawning habitat supply (Upper St. Lawrence River) [E14]

**Technical Workgroup:** Environmental TWG

**Researched by:** Minns, Doka, (Chu, Bakelaar, Leisti)

**Modeled by:** Moore, DePinto (LTI), Redder (LTI)

**Performance Indicator Metric:** This performance indicator represents the annual habitat supply (weighted suitable area) for the LV24 guild spawning in the Upper River reach group located in the Upper River. Emergent vegetation, submergent vegetation, substrate composition, water levels, and reach elevations (used to calculate water depths) are used to compute habitat suitability and supply for the LV24 guild in the Upper River study area. Temperature is used to calculate the appropriate time window for the annual calculations.

**Ecological Importance/Niche:** The members of the LV24 guild occupy shallow water (<20 m) during their life histories and prefer spawning in low vegetation and >=24 degrees C. The species that comprise the guild have been recorded in the Lake Ontario & St. Lawrence systems and their species-specific habitat requirements have been used to calculate weighed suitable areas in the appropriate part of the system. Specific habitat requirements used for calculations are available (see report section).

**Temporal Validity:** LV24 spawning habitat supply is computed on a daily basis and then summed over an appropriate thermal window to generate annual habitat supply results (in units of hectare-days). Currently, a ratio of annual habitat supplies between baseline (1958DD) and proposed regulation plans is calculated annually and then the ratios are averaged and a coefficient of variation is calculated over the 101-year simulation period.

**Spatial Validity:** This LV24 habitat supply performance indicator is valid for a contiguous group of 1339 reaches and 335 wetlands that comprise the Upper River reach group. The weighted suitable area for different fish guilds, based on thermal and vegetation preference during spawning, are calculated for all reaches within the Upper River (see figure below).
Hydrology Link: Habitat suitability for the LV24 guild spawning, which is used to compute weighted suitable area in hectare-days, depends on the interaction between emergent vegetation, submersent vegetation, substrate composition, and water depth in the Upper River study area. Water depth inputs for the habitat suitability model are calculated daily, based on interpolated quarter-monthly water levels. WSAs can be combined across life stages, where appropriate, based on weightings determined by their responsiveness to hydrology.

Calibration Data: No specific calibration data are available, but relationships between habitat suitability and emergent vegetation, submersent vegetation, substrate composition, depth, and temperature are based on a large body of literature and information available on the habitat requirements of the LV24 guild spawning. Individual habitat components, such as shoreline substrate type and temperatures, have been calibrated with different sources of information.

Validation Data: No specific validation datasets are available for weighted suitable areas. Temperatures used in the habitat supply calculations have been validated using simulated data from different thermal models for Upper River or empirical datasets specific to the Upper River study area, when available.
Algorithm: Specific equations and algorithms used in the calculation of weighted suitable areas have been documented in IJC Lake Ontario – St. Lawrence Study reports (available at ftp://wtoftpa.on.ec.gc.ca) and are too extensive to list here. The equations are part of a habitat supply submodel and database of the IERM for the LV24 guild in the Upper River.

Documentation & References: The documentation and details of the algorithms used to calculate this PI are summarized in:


Risk and Uncertainty Assessment: Currently cumulative uncertainties have not been estimated but errors and uncertainties exist at three levels of the habitat supply analysis: spatial habitat information, habitat models, weighted suitable area calculations based on their suitability and thermal windows. The scenarios should be equally affected by these cumulative uncertainties and also the relative differences used for comparisons. Therefore we are confident in the relative habitat supply effects and predictions.
PI Name/Short Description:  Northern Pike – young-of-year (YOY) recruitment index (Upper St. Lawrence River) [E15]

Researched by: Minns, Doka, (Chu, Bakelaar, Leisti), Casselman, Farrell
Modelled by: Moore, LTI (DePinto, Redder)

Performance Indicator Metric: This performance indicator provides an index of YOY recruitment for Northern pike in the Upper River Zones 1, 2, and 3 reach group located in the Upper River. A daily average of the temperatures within the Upper River Zones 1, 2 and 3 area is used to estimate daily growth of northern pike parameterized for specific life stages. In addition, WSA is used to apply density-dependent effects on growth and survival based on space requirements at different life stages. (See WSA PI documentation for additional information.)

Ecological Importance/Niche: Northern pike is an important top predator that is a recreationally important species, spawning in early spring and belonging to the cool water fish guild in nearshore systems.

Temporal Validity: Northern pike recruitment is computed on an annual basis and is affected by daily habitat supply results. Each year the total surviving recruits or young-of-the-year are tallied. Currently, a ratio of northern pike recruitment between baseline (1958DD) and proposed regulation plans is calculated annually and then the ratios are averaged and a coefficient of variation is calculated over the 101-year simulation period to generate two metrics for comparison.

Spatial Validity: This northern pike performance indicator is valid for a contiguous group of 959 reaches and 250 wetlands that comprise the Upper River Zone 1 reach group, and a contiguous group of 380 reaches and 85 wetlands that comprise the Upper River Zones 2 and 3 reach group. Each reach group was selected to represent temperature zones, sampled wetlands, and different geographic regions across Upper River. The size of the reach group area is adequate for supporting distinct northern pike populations. Population estimates can be combined across reach groups, where appropriate, based on weightings determined by responsiveness to hydrologic changes. The population modelling reach groups were selected based on habitat variables such as temperature zone, presence of sampled wetlands and represent general geographic zones across the lake. The size of the reach group area is adequate for supporting distinct northern pike populations. WSAs can be combined across reach groups with a region, where appropriate, based on weightings determined by responsiveness of the PI to hydrology.
**Hydrology Link:** Daily weighted suitable area, partly a function of hydrology, is used to calculate the density-dependent effects on growth and mortality of the appropriate life stages of northern pike in the Upper River Zones 1, 2, and 3 study area. In addition, a stranding factor is applied to the northern pike spawning component of the model. This factor simulates the mortality of developing eggs and hatchlings associated with catastrophic stranding events in wetland and nearshore habitats. A decrease in water level results in a proportional decrease in egg and hatchling survival.

**Calibration Data:** No specific calibration data are available for northern pike recruitment, but the bioenergetic and mortality rates used are based on a large body of literature and information available on the species in the Great Lakes. Bioenergetics parameters used in the northern pike model for early life stages were calibrated specifically for the IJC study area (Farrell).

**Validation Data:** No specific validation datasets are available for weighted suitable areas. Temperatures used in the habitat supply calculations have been validated using simulated data from different thermal models for Upper River or empirical datasets specific to the Upper River Zones 1, 2 and 3 study area, when available.

**Algorithm:** Specific equations and algorithms used in the calculation of weighted suitable areas have been documented in IJC Lake Ontario – St. Lawrence Study reports.
(available at ftp://wtoftp.on.ec.gc.ca) and are too extensive to list here. The equations are part of a habitat supply submodel and database of the IERM for northern pike in Upper River.

**Documentation & References:** The documentation and details of the algorithms used to calculate this PI are summarized in:


**Risk and Uncertainty Assessment:** Population models assume prey is abundant and growth is limited by density-dependent effects and temperature. Uncertainties exist in our density-dependent effects on growth, as currently growth decreases as densities increase. Currently cumulative uncertainties have not been estimated but errors and uncertainties exist at four levels of the analysis: spatial habitat information, habitat models, weighted suitable area calculations, and population models. The relative differences between scenarios should be equally affected by these cumulative uncertainties.
PI Name/Short Description: Largemouth Bass – young-of-year (YOY) recruitment index (Upper St. Lawrence River) [E16]

Technical Workgroup: Environmental TWG

Researched by: Minns, Doka, (Chu, Bakelaar, Leisti)
Modeled by: Moore, DePinto (LTI), Redder (LTI)

Performance Indicator Metric: This performance indicator provides and index of YOY recruitment for largemouth bass in the Upper River Zones 1, 2, and 3 reach groups located in the Upper River. A daily average of the temperatures within the Upper River Zones 1, 2, and 3 areas is used to estimate daily growth of largemouth bass parameterized for specific life stages. In addition, WSA is used to apply density-dependent effects on growth and survival based on space requirements at different life stages. (See WSA PI documentation for additional information.)

Ecological Importance/Niche: Largemouth bass is an important predator that is a recreationally important species, spawning in summer and belonging to the warm water fish guild in nearshore systems.

Temporal Validity: Largemouth bass recruitment is computed on an annual basis and is affected by daily habitat supply results. Each year the total surviving recruits or young-of-the-year are tallied. Currently, a ratio of largemouth bass recruitment between baseline (1958DD) and proposed regulation plans is calculated annually and then the ratios are averaged and a coefficient of variation is calculated over the 101-year simulation period to generate two metrics for comparison.

Spatial Validity: This largemouth bass performance indicator is valid for a contiguous group of 959 reaches and 250 wetlands that comprise the Upper River Zone 1 reach group, and 380 reaches and 85 wetlands that comprise the Upper River Zones 2 and 3 reach groups. Each reach group was selected to represent temperature zones, sampled wetlands, and different geographic regions across Upper River. The size of the reach group area is adequate for supporting distinct largemouth bass populations. Population estimates can be combined across reach groups, where appropriate, based on weightings determined by responsiveness to hydrologic changes. The population modeling reach groups were selected based on habitat variables such as temperature zone, presence of sampled wetlands and represent general geographic zones across the lake. The size of the reach group area is adequate for supporting distinct largemouth bass populations. WSAs can be combined across reach groups with a region, where appropriate, based on weightings determined by responsiveness of the PI to hydrology.
**Hydrology Link:** Daily weighted suitable area, partly a function of hydrology, is used to calculate the density-dependent effects on growth and mortality of the appropriate life stages of largemouth bass in the Upper River Zones 1, 2, and 3 study area.

**Calibration Data:** No specific calibration data are available for largemouth bass recruitment, but the bioenergetic and mortality rates used are based on a large body of literature and information available on the species in the Great Lakes.

**Validation Data:** No specific validation datasets are available for weighted suitable areas. Temperatures used in the habitat supply calculations have been validated using simulated data from different thermal models for Upper River or empirical datasets specific to the Upper River Zones 1, 2, and 3 study area, when available.

**Algorithm:** Specific equations and algorithms used in the calculation of weighted suitable areas have been documented in IJC Lake Ontario – St. Lawrence Study reports (available at ftp://wtoftp.on.ec.gc.ca) and are too extensive to list here. The equations are part of a habitat supply submodel and database of the IERM for largemouth bass in Upper River.

**Documentation & References:** The documentation and details of the algorithms used to calculate this PI are summarized in:
Risk and Uncertainty Assessment: Population models assume prey is abundant and growth is limited by density-dependent effects and temperature. Uncertainties exist in our density-dependent effects on growth, as currently growth decreases as densities increase. Currently cumulative uncertainties have not been estimated but errors and uncertainties exist at four levels of the analysis: spatial habitat information, habitat models, weighted suitable area calculations, and population models. The relative differences between scenarios should be equally affected by these cumulative uncertainties.
**PI Name / Short Description:** Northern Pike – young-of-year (YOY) net productivity (Upper St. Lawrence River - Thousand Islands area) [E17]

**Technical Workgroup:** Environmental TWG

**Researched By:** John M. Farrell, Jerry V. Mead, and Brent Murry

**Modeled By:** Jerry V. Mead, John M. Farrell, Brent Murry, LTI (DePinto, Redder)

**Performance Indicator Metric:** Relative YOY production (g/ha/year) is simulated for three habitats (drowned river mouths, and non-protected and protected bays, and shoals) from spring spawning to the late summer YOY period. A young-of-year (YOY) Northern pike production model is used as a performance indicator to assess effects of water level and temperature variation on critical early life stages. The growth and abundance (production) of YOY are known to be the primary forces in determining the strength of year classes that maintain northern pike populations. The performance indicator is a spatially explicit individual based model that integrates life stage specific (egg, fry, juvenile) growth, relative abundance, survival and production for three primary habitats. Spawning is simulated over the entire littoral gradient, spanning from seasonally flooded emergent vegetation in wetlands (drowned river mouth) and bays (open and protected) to permanently flooded submersed aquatic vegetation in bays and shoals (~0.2 to 6 meters water depth).

**Ecological Importance/Niche:** Northern pike are the dominant piscivore in littoral habitats for the upper St. Lawrence River and are a top predatory species with a strong influence on fish communities system wide. Northern pike influence both size and population dynamics of yellow perch, which dominate fish biomass, and many other fish species they consume. Northern pike are an excellent indicator species due to their role in the fish community, and their dependence and sensitivity to wetland habitats during spawning and early life history. Due to their sensitivity, Northern pike are a good indicator of system changes and their populations have experienced significant population declines.

**Temporal Validity:** The PI is representative of early life history processes occurring from early spring (March 1st) through summer (August 23rd). The model endpoint matches long-term monitoring data for YOY Northern pike that is used for model calibration and validation. Model predictions will be most accurate for the Post-Seaway era conditions for which data for model development were available.

**Spatial Validity:** The Northern pike YOY performance indicator is valid for the upper St. Lawrence River Thousand Islands Region. The PI was developed from field data collected in 16 study areas within this region. Bathymetric digital elevation models (DEM) were created specifically for these study sites with high resolution. Water depths from site specific gauging locations were used to test predictions of depth from DEMs.

**Hydrology Link:** Research indicates that springtime water levels that enhance northern pike spawning success were historically important, but today appear to be decoupled from age-0 production and subsequent year-class formation (Farrell 2001). This may be due to current water level management practices preventing access of spawners to preferred habitat types and potentially stranding eggs following spawning. A secondary effect of hydrologic management is long-term habitat changes, including the increase of cattail (Beland 2003; Farrell et al. 2003, Halpern et al. 2003), and the loss of sedge meadow habitats have likely influenced northern pike reproductive success. Post-Seaway year class strength models indicate greater importance for late summer/fall water levels, where low levels promote stronger year-classes, rate of spring warming (days until 8C is reached), and summer temperatures (#days>20C). These factors are
consistent with a post-Seaway habitat change and access scenario for spawning northern pike, and suggest deeper, later spawning and a stronger role of nursery habitat conditions.

**Algorithm:** Northern pike eggs are deposited using as a function of mean daily water temperature and vegetation coverage (grasses, sedge meadow, and submerged aquatic vegetation) with a Logistic regression probability model. Vegetation coverage in wetlands is predicted using the ETWG wetland submodel; for elevations less than 74.2 m (IGLD 1985) submerged aquatic vegetation was mapped by interpreting high resolution ortho-images of study sites taken in the spring of 2003 (NYS GIS Clearinghouse), and low elevation springtime aerial photographs (SUNY College of Environmental Science and Forestry). Loss of eggs and yolk larvae by stranding due to water level fluctuation is incorporated in model function. Rate of development and survival of eggs to swim up of larvae are simulated daily as a function of habitat specific water temperature and time (days) determined from laboratory trials (Farrell and Toner 2002). Growth of swim-up larvae, following complete yolk absorption and start of exogenous feeding, is simulated using a temperature and consumption driven bioenergetics model. A habitat specific proportion of maximum consumption achieved was fit with field estimates of northern pike growth. Habitat specific mean daily survival of YOY northern pike is predicted as a function of body length and was determined from field studies and literature values. Production for each habitat is the simulated product of growth and abundance for August 23.

**Calibration Data:** Calibration of the model is extensive including field egg density data collected over the three habitat types, egg development and mortality trials conducted to predict timing of swim-up of larvae, and a YOY bioenergetics model developed specifically for the period of first piscivory to emigration.

**Validation Data:** The northern pike spawning component of the model is validated by comparison of predicted observations to field data collected from independent historical data sampling for egg density. For egg deposition probability relationships to vegetation density and water temperature, 15% of the raw data is held out of model construction and used in validation. Predicted and observed growth and abundance data are compared for replicate study areas and temporal periods. Year class strength regression relationships to model predictions of YOY production are also used in model validation. A sensitivity analysis is performed on simulated northern pike production relationships with water temperature to assess the relative influence of major model components.

**Documentation & References:** The primary source of data collected in the field for development of this performance indicator originates from long term datasets on Northern pike from the SUNY College of Environmental Science and Forestry (ESF). ESF maintains field data on Northern pike in a partnership with NYS Department of Environmental Conservation. Important and unique datasets including field collections of naturally spawned eggs (Farrell 2001), monitoring of abundance of YOY northern pike, and completion of 12 related thesis and dissertation research projects. In addition, two recent studies completed for the Great Lakes Protection Fund involving coastal wetland habitats (Farrell et al. 2003a) and the use of spawning marshes (Farrell et al. 2003b) provides important data regarding northern pike and their critical habitats.


**Risk and Uncertainty Assessment:**

The major assumptions of the YOY production indicator are listed below:

- The 16 study areas in the upper river are representative of the entire upper St. Lawrence River.
- Egg and yolk-fry have 100% mortality if habitat suitability becomes zero.
- Variability in egg fertilization was assumed equal among habitats and over years.
- Spawning habitat area polygons in submersed vegetation types are of constant area and coverage in elevations less than 74.2 m (IGLD 1985).
- P value (the proportion of maximum consumption achieved) was a fixed, but estimated value for each habitat and does not exhibit interannual variation in prey availability.
- Precision of spatial simulations of water temperature (1d) will limit model performance.
- Conditions for which the model was developed are applicable to the temporal period being simulated.
PI Name / Short Description: Muskrat (*Ondatra zibethicus*) – house density in drowned river mouth wetlands (Upper St. Lawrence River – Thousand Islands area) [E19]

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 et 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 (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 (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:

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

where,

\[
WINTERWD_i = \text{the mean water depth during winter months (December, January, and February) for a geomorphic type (i) and,}
\]

\[
PROB_i = \text{the probability that geomorphic type (i) contains active muskrat houses (occupancy).}
\]

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 (PROBi) 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) 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.


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.
**PI Name/Short Description:** Golden shiner (*Notemigonus crysoleucas*) – suitable feeding habitat surface area (Lake St. Louis to Trois-Rivières) [E20]

**Technical Workgroup:** Environment TWG

**Researched by:** Mingelbier M. and J. Morin

**Modeled by:** Morin J., S. Martin and O. Champoux. Modeled using full 2D system and reduced to a simplified relationship to discharge.

**Performance Indicator Metric:** Hectares of habitat suitable for golden shiner feeding and living, relative to a particular water discharge measured at the Sorel gage.

**Ecological Importance/Niche:** Fish are a major component of the aquatic ecosystem, influenced at various degrees by the water discharge. The golden shiner, which is omnivorous, plays an important ecological role in the St. Lawrence River as a forage fish for the main sport fish such as large mouth bass and muskellunge. It is also used as bait by fishermen.

**Temporal validity:** Valid between August 1st and October 31st and computed from the QM33 to QM42

**Spatial validity:** Valid between Lake St. Louis and Lake St. Pierre (not Lachine Rapids and Laprairie Basin)

**Hydrology Link:** The golden shiner lives in shallow waters, which are sensitive to water level variations. Water discharge regulation may have adverse effects on habitat supply.

**Algorithm:** The algorithm is based on the mean value of discharge estimation at Sorel from QM33 to QM42. A fish habitat model was combined with a 2D physical model to compute the probability of presence and the surface of the feeding ground for six discharge scenarios. The habitat model was based on field measurements. Three hydrological attributes were used to model the feeding habitat of golden shiner:

1. Current velocity
2. Percent of Clay
3. Simulated vegetation density

**Calibration Data:** No data available

**Validation data:** Leave one out method with the 512 samples, cross validation between three sections of the St. Lawrence River, and historical data (when available) were used to validate the fish habitat model.

**Documentation and references:**


Mingelbier M., P. Brodeur and J. Morin (in prep. due by March 2005). First recommendations concerning fish and their habitat in the St. Lawrence River to improve current criteria used for regulating the Lake Ontario - St. Lawrence River system. Société de la faune et des parcs du Québec, Direction de la recherche sur la faune.

**Risk and Uncertainty Assessment:** We are confident that the present habitat model, which is based on data collected in the field (512 sites of gillnets and seines; 142 presences and 370 absences), accurately predicts the habitat suitable for golden shiner between August and October. The performance corresponded to $R^2 = 0.26$ and the goodness of fit (concordance between predicted and observed) was 77%. The present model was especially designed to evaluate the sensitivity of fish habitat to water discharge variations. It does not take into account any other confounding factors such as overfishing, anthropogenic habitat losses, agriculture impacts, toxics, etc.

Figure 1. Map of the suitable habitat (feeding and living) for the Golden shinner (*Notemigonus crysoleucas*) for an average discharge (9500 m$^3$/s at Sorel)
Transfers from 2D explicit models to 1D simplified SMV curves:

Figure 2. (a) Global relationship between “Surface area of suitable summer habitat” for NOCR and the discharge in Sorel; (b) suitable average summer habitat (ha) for the period 1900-2000, calculated with the 1958-DD and Pre-project Plans; (c) cumulated suitable habitat (ha) over time for the period 1900-2000; (d) difference in suitable habitat between the two scenarios 1958-DD and Pre-Project after 100 years.

Table 1. Best fit curves for the Golden shiner, for the five regions in the St. Lawrence River; QS= discharge at Sorel

<table>
<thead>
<tr>
<th>Regions</th>
<th>Best fit for: Golden shiner (Notemigonus crysoleucas = NOCR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake St. Louis (LSL)</td>
<td>0.000000034650<em>QS^3 - 0.00082669386</em>QS^2 + 6.309187523211*QS - 3930.594638713770</td>
</tr>
<tr>
<td>Montreal-Sorel</td>
<td>-0.00000001212<em>QS^3 + 0.00002061839</em>QS^2 + 0.273961784965*QS - 1.381076170031</td>
</tr>
<tr>
<td>Sorel archipelago</td>
<td>-0.00000005177<em>QS^3 + 0.00009356534</em>QS^2 - 0.423343675751*QS + 14.722725798660</td>
</tr>
<tr>
<td>Lake St. Pierre</td>
<td>0.000000057108<em>QS^3 - 0.001775099068</em>QS^2 + 16.774782070481*QS - 31.127376622406600</td>
</tr>
<tr>
<td>LSL 3-Rivières</td>
<td>0.000000086598<em>QS^3 - 0.002601389418</em>QS^2 + 23.431383597885*QS - 34.953469234567000</td>
</tr>
</tbody>
</table>
PI Name / Short Description: Wetland fish - abundance index (Lower St. Lawrence River) [E21]

Technical Workgroup: Environmental TWG

Researched By: de Lafontaine, Y., and F. Marchand
Modeled By: Jean Morin and LTI (DePinto, Redder)

Performance Indicator Metric: The metric is the summed abundance of a fish guild consisting of 8 fish species reproducing in the wetland habitats of the lower St. Lawrence River. The metric was derived from the annual catch of adult fish captured between May 15 and October 31 every year at the experimental fishery at St-Nicolas since 1975. The units of the metric are the total number of fish (composing that guild) captured in a given year. The 8 species are: bowfin, brown bullhead, northern pike, yellow perch, longnose gar, pumpkinseed, quillback, rock bass.

Ecological Importance/Niche: The metric represents a selected group of 8 fish species that are known to be closely dependent on the wetland habitats for their reproductive behavior and long-term population survival. Some of these fish species are commercially harvestable and others consist of forage fish which are thought to be important for top predators. Given the expected impact of water levels fluctuations on wetlands, this metric is considered an important indicator of the response at higher trophic levels within the ecosystem.

Temporal Validity: The metric uses daily captures records collected between May 15 and October 31 every year since 1975. The metric was significantly associated with water levels attributes during spring in the years preceeding the catch. This would suggest that water level fluctuations would affect fish species during spring spawning activity and during their first year of life.

Spatial Validity: The metric was developed in using fish captures made at an experimental fishery located at the downstream end of the lower St. Lawrence River. However, tagging study has demonstrated that fish collected at St-Nicoals exhibit seasonal migrations between Lake St-Pierre and Quebec City. It is therefore assumed that fish captures recorded at St-Nicolas are representative of populations inhabiting the river sector downstream of lake St-Nicolas Islands.

Hydrology Link: The metric was developed using statistical empirical evidence linking the metric values to attributes of water levels recorded at the Jetty#1 in Montreal. It is assumed that water levels fluctuations will affect the reproductive success of wetlands fish. While many factors are probably involved, no experimental study has searched to explain and validate the empirical relationship between the hydrology and the biological response.

Algorithm: The metric is positively linked to the spring water level and positively linked to the coefficient of variation of water level in spring. This indicates that higher
water level during spring would favor reproductive success of wetland fish and that high variability (high CV) in spring levels also represent favorable conditions. The total variance explained by the empirical model (using 3 dependent variables) is 65%.

**Calibration Data:** Data used to developed the PI metric were all obtained from daily catch records during 28 consecutive years.

**Validation Data:** The model can be tested in the future years by compiling and using catch data from the experimental trap fishery at St-Nicolas.

**Documentation & References:** Information relative to the Pi is found in: de Lafontaine, Y., and F. Marchand, 2004. *Hydrological fluctuations and productivity of freshwater fish in the St. Lawrence River.* Report presented to IJC.

**Risk and Uncertainty Assessment:** Unlike what was done for another PI “Total fish abundance” (de Lafontaine and Despatie, 2004), there has been no sensitivity analysis done with the “Wetland Fish” PI. The metric was developed using data available from 1975 to 2002. Extrapolation outside the range of water level variability observed during that time period should be done with caution and would not be recommended, since the linearity of the PI response is not proven.
PI Name/Short Description: Northern Pike (*Esox lucius*) – suitable reproductive habitat surface area (Lake St. Louis to Trois-Rivières) [E22]

Technical Workgroup: Environment TWG

Researched by: Brodeur P., M. Mingelbier and J. Morin

Modeled by: Morin J, S. Martin and O. Champoux. Modeled using full 2D system and reduced to relation with discharge.

Performance Indicator Metric: Suitable spawning habitat and potential mortality of N. pike. The calculation of this indicator includes (i) the number of hectares of habitat suitable for Northern pike spawning from which we subtract (ii) the number of hectares dewatered within the periods following the egg deposition. The reference water discharge gage is located at Sorel.

Ecological Importance/Niche: The Northern pike is an ecologically important top predator in the fluvial St. Lawrence River and is targeted by sport fishermen. The pike reproductive success is favoured by high water levels during the spawning period and stable levels during the incubation period. A water level lowering would have substantial impacts on the reproductive success while reducing the access to spawning grounds and increasing the potential mortality.

Temporal Validity: Valid for the period between the spawning time (egg deposition) and 30 days after (4 quarter months). The date of spawning varies from year to year between early April and late May. Therefore, the quarter-months included in the computation are based on the accumulated degree-days at Dorval.

Spatial Validity: Valid between Lake St. Louis and Lake St. Pierre (not including Lachine Rapids and Laprairie Basin).

Hydrology Link: During the springtime, the Northern pike spawns in shallow water of the St. Lawrence floodplain. The access to high quality spawning habitats is controlled by water level. There is potential fish mortality due to short-term or atypical water level variations (intra-annual) in the floodplain, particularly for young life stages. Northern pike, with shallow preferences for spawning, is vulnerable to dewatering after egg deposition – eggs may become dry reducing reproduction success, or rapid dewatering could trap larvae in the floodplain.

Algorithm: The algorithm is based on the mean value of discharge estimation at Sorel for the determined computing quarter-month. A habitat suitability index (HSI) was developed to estimate the spawning habitat quality. Three variables were used in the HSI: water temperature, water velocity and wetland type. The HSI was then coupled with a 2D physical model to compute, for eight different discharge scenarios, the weighted suitable area (WSA) calculated as the product between the suitable habitat surface and the HSI. For each discharge scenario, six scenarios of water level decrease after spawning were applied to estimate the potential mortality by subtracting the WSA where spawning grounds were dewatered. The annual chronology of pike spawning was determined using a predictive model based on air temperature.

Calibration Data: No calibration data available

Validation Data: The HSI was based on data from the field and the literature. Historical data on year class strength were used to validate the WSA. The predictive model of spawning chronology was validated with historical data (20 site-years).
**Documentation and References:**


**Risk and Uncertainty Assessment:** The present performance indicator was especially designed to evaluate the sensitivity of fish habitat to water discharge variations. It does not take into account any other confounding factors such as over fishing, anthropogenic habitat losses, biological interactions, agriculture impacts, toxics, etc. This indicator assumes that most of the reproduction occurs in the St. Lawrence River, not in the tributaries. This assumption comes from the geographical limits of the IJC study area and the 2D model.

Suitable spawning habitat of N. pike for an average spring discharge at Sorel (14 500 m³/s). Habitat losses corresponding to 0.5 m and 1 m water level drawdown after eggs deposition are presented for the lake St. Pierre area.
Transformation from 2D explicit models to 1D simplified SMV curves:

(a) Global relationship between “Surface area of suitable summer habitat” for ESLU and the discharge in Sorel; (b) suitable average summer habitat (ha) for the period 1900-2000, calculated with the 1958-DD and Pre-project Plans; (c) cumulated suitable habitat (ha) over time for the period 1900-2000; (d) difference in suitable habitat between the two scenarios 1958-DD and Pre-Project after 100 years.
Performance Indicator: Migratory waterfowl – floodplain habitat surface area (Lake St. Louis to Trois-Rivières) [E23]

Technical Workgroup: Environment TWG

Research by: Lehoux, Dauphin, Champoux & Morin.
Modeled by: Jean Morin

Performance Indicator Metric: Use of the non-managed flood plains of the Lake St. Pierre area by waterfowl (in terms of abundance of birds during the spring migration) according to different water levels. Water levels are those measured at the Sorel gage.

Ecological Importance/Niche: During spring, the Lake St. Pierre flood plains represent the most important migratory stopover of the whole St. Lawrence River for waterfowl. An economic spin-off is related to aquatic bird observation in the sector. The reproductive success of the birds could be reduced significantly if inappropriate conditions are encountered on staging areas.

Temporal validity: Valid between April 10th and May 7th.

Spatial validity: Lake St. Pierre flood plains

Hydrology Link: The use of the lake St. Pierre flood plains (the non-managed sector) reaches an optimum when the water levels at the Sorel gage is maintained between the elevation 6,0 and 6,88 m. The area is almost completely deserted at the elevation 5,0 m. Adequate water levels provide the following benefits:

- ensure optimal aquatic birds distribution in the Lake St. Pierre flood plains;
- prevent a too small flood plain acreage forcing birds to concentrate mainly in managed marshes where available food could be a limiting factor and increase inter an intra-specific stress;
- prevent birds from being in poor physiological health due to poor nutrition which could potentially reduce their reproductive success significantly;
- ensure that most important flood plain of the fresh water portion of the St. Lawrence is sustained;
- maintain the economic spin-off related to aquatic bird observation, a very important activity in the Lake St. Pierre sector.

Algorithm: The algorithm relies on the mean water level at Sorel from QM14 to QM17. The model is based on historical data and on a field study conducted in 2000. Historical data provided 7 years of bird surveys between 1983 and 1995, for a total of 20 surveys during the spring migration in the lake St. Pierre flooded plains. Flooded plains of lake St. Pierre become attractive to migrating waterfowl when water levels registered at the Sorel gage are higher than 5.4 m. Under the elevation 5.0 m the non managed portions of
the flooded plains are almost completely deserted. The abundance of migrating waterfowl can be determined with the following correlation: \( Y = 8124.3X - 40714 \)

**Calibration Data:** No data available

**Validation Data:** The model is based on survey data

**Documentation and References:**


**Risk and uncertainty Assessment:** This performance indicator shows an important correlation between water levels and bird abundance in the non-managed portion of the Lake St. Pierre flood plains (demonstrated by survey data; \( r^2 = 0.53 \)). Detailed impacts of non appropriate water levels within the flood plains during the spring migration on the physiological condition of birds remain however difficult to assess with accuracy. This performance indicator should however be considered as a significant indicator to assess impacts of the different plans mainly because the flooded plains of the lake St. Pierre represent the most important staging area for aquatic birds within the southern portion of the Province of Quebec. More than 500 000 waterfowl stop over during April and May.
Indicator evolution for 1958DD and PreProject plans:

Figure: Comparison of the Performance indicator for the 100 years discharge series: Plan 1958DD and PreProject.

Figure: Comparison of the temporally cumulated Performance Indicator for the 100 years discharge series: Plan 1958DD and PreProject.
PI Name/Short Description: Migratory waterfowl – productivity (Lake St. Louis to Trois-Rivières) [E25]

Technical Workgroup: Environment TWG

Researched by: Lehoux, Dauphin, Laporte, Champoux & Morin.

Modeled by: Jean Morin

Performance indicator Metric: Number of young/adult female annually produced according to different average water levels during the plant growing season (April-October) as measured at the Sorel gage.

Ecological Importance/Niche: The fluvial section of the St. Lawrence River (including the adjoining mainland) harbors some 6000 nests. It hosts almost 50% of the total nesting dabbling duck population of the whole St. Lawrence River. Inappropriate water levels could substantially decrease productivity, threaten the population and eventually reduce the economic spin-off associated with hunting in that area evaluated at 10 million dollars annually.

Temporal validity: Valid between April 1 and October 31.

Spatial validity: Valid for the Lower St. Lawrence between Lake St. Louis and Lake St. Pierre.

Hydrology Link: The productivity of waterfowl within the fluvial section of the St. Lawrence River is substantially reduced when the average water levels measured during the plant growing season (April-October) are maintained too low or too high. Inappropriate average water levels during the plant growing season induce the following impacts:
- low average water levels might decrease the dabblers productivity especially because nesting sites become readily available to terrestrial predators;
- low average water levels make the emergent marshes, which are the prime habitat during the brood rearing season, too dry and too dense preventing broods to have easy access to feeding sites and escape cover;
- at very high average water levels, a reduction of productivity is also expected because emergent marshes would become scarcer preventing birds to again have easy access to escape cover. Nests will also become more easily flooded following any sudden substantial increase of the water levels;

Algorithm: The algorithm relies on the mean water level at Sorel from QM13 to QM40. The model is based on 10 years of banding data collected between 1968 and 2002. The dabblers productivity (number of fledged ducklings/reproductive female) will be at its optimum when average water levels registered at the Sorel gage are maintained at levels
higher than 5.4 m. The annual productivity can be determined with the following correlation: \( Y = 3.5178X - 11.933 \)

**Calibration Data:** No data available

**Validation Data:** Historical water levels and productivity data, as provided by banding stations between 1968 and 2002, were used to make the appropriate correlation.

**Documentation and References:**

**Risk and Uncertainty Assessment:** We are confident that this model will accurately predict which average water levels, as recorded during the April-October period, will provide the best productivity of waterfowl within the fluvial section of the St. Lawrence River. The real impact on productivity of very high average water levels (>5,5 m) remains however less obvious. Data used to correlate the productivity and the water levels are somewhat limited. We only have 10 years of banding data collected mainly between 1990 and 2002 to do so. We have a relatively weak correlation between productivity and the average water levels registered during the plant growing season \( (r^2 = 0.30) \). However that performance indicator is one the rare indicator which correlates water levels and productivity. Long term inappropriate water levels during the breeding season could eventually have a serious threat on the dabbling ducks population found in the lower St. Lawrence and induce some important economic losses.
**PI Name/Short Description:** Amphibian species (frogs, toads, peepers) - reproductive habitat surface area (Lake St. Louis to Trois-Rivières) [E27]

**Researched by:** Armellin A., C.Plante, D. Rioux and J.Morin

**Modeled by:** Morin J., O. Champoux and S.Martin.
Modelled using full 2D system and reduced to relation with discharge.

**Performance indicator Metric:** Reproduction habitat of amphibians, including frogs, toads and peepers, in wetlands of the St. Lawrence River. Available surface area of reproduction habitat for different conditions in spring time.

**Ecological Importance/Niche:** The amphibians play an important role in the wetlands because of their position in the food chain and their important biomass. The vegetation of the floodplain (marsh, submerged vegetation, wet meadow, etc.) is an important part of amphibian’s habitat in their life cycle, they use both the aquatic environment and the terrestrial environment, making them very sensitive to water level variation. Water level fluctuations offer food and shelter against potential predators. The variation in water level can affect these habitats, therefore affecting frogs.

**Temporal validity:** This indicator is applied and computed to QM 14 to 23 (reproduction) and 23 to 30 (mortality) of each year.

**Spatial validity:** From Lake Saint-Louis to Trois-Rivières.

**Hydrology Link:** Amphibians prefer to spawn in wetland vegetation flooded by a depth of less than 50 cm. The flooding of St. Lawrence River wetlands is directly associated with spring flood amplitude and duration.

**Algorithm:** The 2-D algorithm is based on the mean discharge at Sorel from QM14 to QM23 for the reproduction period and from QM23 to QM30 for the mortality potential period. The high water level during spring time will favour frog reproduction in emergent vegetation. Following the spawning period, variation in water level will serve as a limiting factor in the survival of the eggs and tadpoles.

1) Vegetation types: Amphibians are known to use marsh areas to deposit their eggs. Terrestrial or aquatic vegetation are not utilized as spawning areas.

2) Water depth: Amphibians are not good swimmers, so they use shallow water near the shore to accomplish their reproduction.

3) Current velocity: reproduction takes place in standing water.

**Potential nesting habitat model (QM 14 to 23)**

Habitat is calculated over the entire domain (at nodes) with the following algorithm

\[
\text{Reproduction } HQI = (HQI_{Tv} \times HQI_{Zr} \times HQI_T)^{1/3}
\]

Where \( HQI_{Tv} \) (vegetation):

- in Wet meadow \( HQI_{Tv} = 0.8 \), in Shallow marshes \( HQI_{Tv} = 1.0 \), in Deep marshes \( HQI_{Tv} = 0.6 \), in Acquatic macrophytes \( HQI_{Tv} = 0.2 \), in Open water \( HQI_{Tv} = 0.0 \)

Where \( HQI_{Zr} \) (water depth):

[Graph showing HQI_Zr vs. Water Depth (m)]
Where HQIV(water velocity):  

**Mortality model (QM 23 to 30)**

From the resulting potential habitat, the mortality model removes all the nodes where the water level drop down to < 0.1 m during at least one of the considered QM.

A 2D habitat model computes the probability of the presence of safe habitat considering the water depths at a variety of flows. The term “safe” means that for each year, the model excludes the portion of potential habitat that can be adversely affected by water level fluctuations (resulting in mortality). The full 2D models are reduced to a simplified matrix that is function of flow and water level decrease.

**Calibration Data:** No data available

**Validation Data:** Occurrences of tadpole catch from field surveys.

**Documentation and References:**


This reference document is available at

ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/report/

**Risk and Uncertainty Assessment:** We are confident that this model will accurately predict which spring flows are better or worse for amphibian reproduction success. The PI can be used to distinguish a good year from a bad year, but further thought is required to distinguish a good 101 years from a bad 101 years. We recommend the average annual habitat be used to rank plans. The PI also does not reflect other important factors that affect amphibian population, such as water quality, availability of food or predation. In our expert opinion, this does not significantly diminish the value of this PI because we feel available spawning area is generally the factor that drives population.

Significance: 3

Uncertainty: 2

Sensitivity: 4
Figure 1. Map of the suitable reproduction habitat for amphibians (frogs, toads and peepers) for an average discharge (9500 m³/s at Sorel)

Figure 2. Comparaison of reproductive habitat surface area for the frog for Plan 1958DD and Plan PP
PI Name/Short Description: Muskrat (*Ondatra zibethicus*) – surviving houses (Lake St. Louis to Trois-Rivières) [E28]

**Researched by:** Ouellet V. and J.Morin

**Modeled by:** Ouellet, V., J.Morin and O.Champoux

**Performance Indicator Metric:** This indicator predicts the number of dwelling houses and their loss caused by water level fluctuations after ice-cover formation. Number of muskrat houses at a particular water level in November and the loss of houses after water level increases (20, 40, 60 and 300 cm) are incurred in January and February after ice-cover formation. Water levels are those predicted at the Sorel gauge.

**Ecological Importance/Niche:** Muskrat are herbivorous, eating shoots, roots, bulbs, tubers, stems and leaves of various hydrophytes, especially emergent species; therefore, muskrat populations have the potential to regulate wetland habitat structure. A primary function of the muskrat is to control the expansion of cattails, which serves as the preferred food supply and building material for this species. This indicator computes the density of dwelling houses for different water level increases in January-February relative to the mean water level for the previous November.

**Temporal validity:** The estimate of the number of houses built and successfully maintained each year is based on November (QM 40 to 44) mean water level of the current year compared to the maximum relative increase in water level during the following January and February (QM1 to QM8).

**Spatial validity:** Valid for the Lower St. Lawrence between Lake St. Louis and Lake St. Pierre (except Laprairie Basin).

**Hydrology Link:** The muskrats build houses during the fall in areas with adequate water levels (20 to 100 cm, with a preferred range of 30 to 70 cm deep), and these houses will remain active throughout the winter season unless drastic changes in environmental conditions occur. Significant changes in water level after house construction will potentially affect the winter survival of muskrats (e.g., flooding). This species is also dependant on the type of plant cover, which is determined primarily by water depth. The muskrats begin lodge construction in the last part of October and continue through November until ice cover formation. The indicator is based on the number of houses potentially built in November, and the predicted loss of houses as function of water level increases during the winter months.

**Algorithm:** The algorithm is based on the mean discharge at Sorel from QM40 to QM46 for the potential house-building period and from QM1 to QM8 of the next year for the potential mortality period. The principal hydrologic attribute known to have linkage with the establishment of dwelling houses is water level during house construction and fluctuations during the winter months. For this PI we consider:

1) The mean water level for the four quarter months of November, including the tidal signal, to determine the potential number of houses established.
2) The maximum water level in January and February to calculate the number of houses inundated by the increase of the water level.

Because the distribution of plant species is primarily determined by hydrological attributes of the system, it was possible to include probabilities of Typha in the model. We used a probabilistic model (logistic regression) for Typha latifolia developed by Turgeon et al., 2004. We used Typha sp. because it serves as the muskrat’s favourite emergent plant species for food and building material supplies, thus providing a good indicator of the potential of an area for muskrat lodge construction. The water depth and the probabilities of Typha sp. were integrated into a habitat suitability index (HSI). This allows the evaluation of the density of dwelling houses, which is then modified based on increases in water level after lodge establishment and the potential for the muskrat to modify his lodge by relocating the chamber for keeping the floor dry. The data used for model development are based on literature review and expert opinion.

The algorithm is:  

\[ \text{HSI}_{\text{establishment}} = (\text{HSI}_{\text{water depth}} + \text{HSI}_{\text{Typha}})^{1/2} \]

2) \( \text{Potential of adaptation} = \text{Height of lodge} - \text{height of chamber} - \text{dimension of chamber} - \text{minimum thickness of wall} \)

With this equation, we calculate the maximum value for the “potential of adaptation” of the chamber in the house. This serves to fix the upper limit (100 % of stressed houses) at 75 cm of water level increase. The lower limit (0 % of stressed houses) was fixed at 20 cm of water level increase because there are no impacts from smaller water level increases. Between the two limits, a linear interpolation is used to estimate the % of house impacted.

Based on these calculations we produced a matrix of results, which allow the calculation of the number of lodges established in November for any year and any water level and water level increase scenario. The matrix is composed of height scenarios water level (2.26 to 8.01 m) by three types of wetlands (1967, 1976 and 1984), which correspond to three different distributions of Typha sp. (low, medium and high). The resulting number of houses is then used to estimate the impact from relative increases in water level during the winter months:

1) If increases are under 20.0 cm, there is no impact on dwellings.
2) If increases are between 20.0 cm and 74.99 cm, the number of impacted houses is determined by: \( y = 0.083214x - 0.083038 \).
3) If increases are more than 75 cm, all houses are impacted.

**Calibration Data:** No data available

**Validation Data:** Data on muskrat houses are very rare. The Société de la Faune et des Parcs du Québec (FAPAQ) has one recorded observations of dwelling houses in some areas of Lake St. Pierre in 1988:

**Documentation and References:**


**Risk and uncertainty assessment:** The muskrat model allowed us to predict the density of dwelling houses for the mean water level of November and which portion of these houses are affected by subsequent water level fluctuations. We have very small data to estimate the error on predicted densities, which includes an inventory of dwelling houses for 1988. From the 1988 data set, the variation on the prediction compared to the aerial survey varied from 0.5 to 2 houses per hectare on average. We have limited confidence on the accuracy of the exact number of predicted houses. The impact for water level increase during the winter months is a relatively simple estimation that has a direct impact on the use of these houses. However, the impact of the loss of houses on the muskrat population is not well known, and we do not have sufficient data to estimate the exact impact. It is clear from the literature that the loss of houses increases the stress on the muskrat population.
PI Name/Short Description: Eastern Sand Darter (*Ammocrypta pellucida*) – reproductive habitat surface area (Lake St. Louis to Trois-Rivières) [E30]

Technical Workgroup: Environment TWG

Researched by: Sylvain Giguère and Pierre Laporte
Modeled by: Jean Morin, Olivier Champoux and Sylvain Martin

Performance Indicator Metric: The PI gives an annual value of the available safe potential surface area of spawning and egg development habitat (measured at the Sorel gage). The aggregated 100 year plan scenarios are expressed by the percent of time that the PI exceeds the first quartile value for plan 1958DD for the comparable water supply series (e.g. Historic, S1, S2, S3, etc). This metric will be used for plan evaluation by calculating a ratio of metrics between two plans.

Ecological Importance/Niche: The Eastern Sand Darter is a small (4 cm to 7 cm) sedentary percid fish. The Sand Darter is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed in the Schedule 1 of the *Species at risk Act*; the species and its critical habitat are legally protected under this Act. Critical habitat protection will be applied when it is identified within the Recovery Strategy or Action Plan. Spawning and egg development of the Sand Darter is influenced by hydraulic attributes.

Temporal validity: We measure the potential spawning habitat for the three last quarter month (QM) of June and the two first of July while we measure the risk to dry up eggs and larvae from the second QM of June until the third one of July.

Spatial validity: The PI is valid for the Lower St. Lawrence between Lake St. Louis and Lake St. Pierre (except Laprairie Basin). The total region is used to evaluate water regulation plans.

Hydrology Link: This PI is influenced by hydraulic attributes responsible for spawning habitat availability and eggs/larvae survival. More specifically, the PI was developed using 2D modeling based on the combination of hydrodynamic and substrate models. Three hydraulic variables were considered: *mean water depth, mean current velocity* and *water level decrease*.

The Sand Darter prefers to spawn in 15 cm to 120 cm of water with a current velocity less than 20 cm/s that create silt-free sandy bottoms. Water levels fluctuations have two known linkages to this fish reproduction:

1) Local flow velocity is a good indicator of what the river bottom substrate will be made up of.
2) Water level drops can dry up eggs and larvae.
Algorithm: The PI is made from the potential spawning and eggs/larvae development habitat model, from which the mortality model removes all portions where water levels fluctuations create “unsafe” conditions to the eggs/larvae development. The two models built to create the PI are presence / absence type models that are based on the parameters and values coming from literature review (more info in Giguère and al. (2005)).

Potential spawning habitat model (QM 22 to 26)
Habitat is considered as suitable if all the following features are present: presence of sand > 70% in the substrate polygon; current velocity > 0 m/s & < 0.2 m/s; water depth > 0.15 m & < 1.20 m.

Mortality model (QM 22 to 27)
From the resulting potential habitat, the mortality model removes all the nodes where the water depth became < 0.1 m during at least one of the considered QM.

Calibration Data: No data available

Validation Data: In the study area, there is no known recorded observation of Sand Darter during the reproduction period. However, this fish species has been observed in the Châteauguay River, Yamaska River and St. François River. The mouth of these rivers matches the habitat characteristics used for modeling its potential presence. In the St. Lawrence River, the species has been caught in the Chenal-aux-Ours, an area where all habitat characteristics appear to be suitable for spawning under certain flow conditions. The ministère des Ressources naturelles, de la Faune et des Parcs (MRNFP) has also recorded four observations during summer 2002. Considering that this poor swimmer possibly use similar habitat for reproduction than those observed during summer time, we have build a model that predicts its habitat availability based on summer observations. For the model, velocities, water depth and substratum were used. The comparison of observed locations with the predicted habitat is not very good with the 4 samples available.

Documentation and References:

Risk and Uncertainty Assessment:
This PI is based on the following assumptions:
- Spawning habitat supply and egg/larvae survival are significant factors influencing the size and integrity of Sand Darter populations.
- Predicted fish response to hydrologic conditions based upon literature review is valid.
- Quarter month hydrologic data is representative of real hydrologic conditions.
• Predicted fish response to hydrologic conditions based on statistical modeling is valid.
• Transformation from a 2D to 1D hydrologic model is correct.

**Confidence rating:** The PI allows for a relative comparison among alternate water regulation plans. This PI has been built with a “precaution” principle from a moderate amount of literature information that was available from outside of the region of interest. The potential habitat model has been validated with independent data. Some of them, that are general description, seem to match well the characteristics selected while other precise observations do not match well with the highlighted areas. The substratum map is responsible of this poor validation score. The substrate composition is applicable to large polygons of several km² in size while the sand darter can use very small patch of sand for spawning. This explains that all suitable micro habitats comprise in the large polygons have not been caught by the modeling effort. On the other hand, the four observations are coming from a survey where the predicted good habitats were not sampled. Therefore these areas are possibly good reproduction/living habitat. Even considering the coarse substratum map used, the model can be used to rank plans in a relative fashion. Obviously more work need to be done for managing properly this species.

Although hydrologic variables are strongly associated with habitat and Sand Darter occurrence, there is also a significant amount of variation not explained by hydrology. In order to assess 100 year water level scenarios, the predictive models necessarily ignore, or hold constant other important population variables (e.g. productivity, age and sexes distribution) and environmental variables (e.g. predation, food availability, siltation, exotic species) that can also impact reproductive success, and have an influence on regional Sand Darter populations. For these reasons the PI values should only be considered as relative measures between plans.

**Significance of the species:** The Sand Darter is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed in the Schedule 1 of the Species at risk Act; the species and its critical habitat are legally protected under this Act. Critical habitat protection will be applied when it is identified within the Recovery Strategy or Action Plan.

**Sensitivity to water levels management:** The scientific literature document the close association between Sand Darter occurrence, during spawning period, and specifics hydrological condition. Sand Darter PI is retained as a Key PI because it clearly shows an important vulnerability and sensitivity to alternations in water levels and flows, and is listed as a Species at risk. As such it should be used to evaluate potential environmental responses to alternative water regulation plans.
**PI Name/Short Description:** Spiny Softshell Turtle (*Apalone spinifera*) and Northern Map Turtle (*Graptemys geographica*) – reproductive habitat surface area (Lake St. Louis to Trois-Rivières) [E31]

**Technical Workgroup:** Environment TWG

**Researched by:** Sylvain Giguère and Pierre Laporte  
**Modeled by:** Jean Morin, Olivier Champoux and Sylvain Martin

**Performance Indicator Metric:** This PI addresses nesting and egg development of the Map Turtle, a 25 cm (maximum) aquatic turtle and Spiny Softshell, a 50 cm (maximum) aquatic turtle. The PI gives an annual value of the available safe potential surface area of nesting and eggs development habitat (measured at the Sorel gage). The aggregated 100 year plan scenarios are expressed by the percent of time that the PI exceeds the first quartile value for plan 1958DD for the comparable water supply series (e.g. Historic, S1, S2 S3, etc). This metric will be used for plan evaluation by calculating a ratio of metrics between two plans.

**Ecological Importance/Niche:**

The Spiny Softshell is a 50 cm (maximum) aquatic turtle designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This species is in the process of being added to schedule 1 of the Species At Risk Act as a Threatened Species. After listing, this species and its habitat will be protected under the Species At Risk Act, and a Recovery Strategy will be required within two years. Critical habitat protection will be required when the Recovery Strategy or Action Plan identifies this as a necessary step. The Spiny Softshell is designated as threatened by the Québec government under the Loi sur les espèces menacées ou vulnérables. Under this provincial act, individuals are protected. The indicator gives the available safe potential surface area of nesting and egg development habitat for different water discharge conditions.

**Temporal validity:** We measure the potential nesting habitat available for all of June and the two first quarter month (QM) of July while we measure the risk to drown eggs from the first QM of June until the last one of September.

**Spatial validity:** The PI is valid for the Lower St. Lawrence River between Lake St. Louis and Lake St. Pierre (except Laprairie Basin). The Lake St. Louis sub region is used to evaluate plans since Map Turtle has never been found anywhere else in the study area and Spiny Softshell observations are mainly coming from Lake St. Louis area.

**Hydrology Link:** This PI is influenced by hydraulic attributes responsible for nesting habitat availability and eggs/embryos survival. More specifically, the PI was developed...
using 2D modeling based on the combination of hydrodynamic model and shore substrate and vegetation database. Two hydraulic variables were considered: mean water depth and water level increase.

The Map Turtle and Spiny Softshell Turtle prefer to lay eggs in sand or gravel substrate, normally from 50 cm to 100 cm above the water level. Water levels fluctuations have three known linkages to this turtle reproduction:

1) Amplitude, duration and recurrence of flood are good indicators of the portion of banks / beaches available for nesting.
2) Amplitude, duration and recurrence of flood are good indicators of what the banks / beaches will be made up of (substratum and vegetation density).
3) Water level raises can drown eggs if submerged more than 48 hr.

Algorithm: The PI is made from the potential nesting and eggs development habitat model, from which the mortality model removes all portions where water levels fluctuations create “unsafe” conditions to the eggs/embryos development. The two models built to create the PI are presence / absence type models that are based on the parameters and values that were determined upon literature review and expert opinions. (more info in Giguère and al. (2005)).

Potential nesting habitat model (QM 21 to 26)
Habitat is considered as suitable if all the following features are present: water depth < 0; slope < 30°; one of the following shore polygon features.
- Beaches
- Top bank vegetation = beach or bare ground
- Bank vegetation = beach or bare ground
- Lower bank vegetation = beach or bare ground
- Top bank vegetation density < 5% + substratum = sand or gravel
- Bank vegetation density < 5% + substratum = sand or gravel
- Lower bank vegetation density < 5% + substratum = sand or gravel

Mortality model (QM 21 to 36)
From the resulting potential habitat, the mortality model removes all the nodes where the water level raises > 0 m during at least one of the considered QM.

Calibration Data: No data available

Validation Data: In the study area, Map Turtle has been found in one site during the reproduction period. This site does not fit the potential habitat highlighted by the modeling effort since the shore had not been fully characterised at this specific site. On the other hand, the Lake St. Louis has not been closely examined and other sites can be used by the Map Turtle. There is no known nesting site of Spiny Softshell in the study area. The Lake St. Louis potential habitat has been visited by Giguère and represents well these species needs in term of nesting habitat. Several traces of nesting activities have been seen (digging) without identification of the species (no individual have been seen).

**Risk and Uncertainty Assessment:**

This PI is based on the following assumptions:

- Nesting habitat supply and egg/embryos survival are significant factors influencing the size and integrity of Map Turtle and Spiny Softshell Turtle populations.
- Predicted turtles response to hydrologic conditions based upon literature review is valid.
- Quarter month hydrologic data is representative of real hydrologic conditions.
- Predicted turtles response to hydrologic conditions based on statistical modeling is valid.
- Transformation from a 2D to 1D hydrologic model is correct.

**Confidence rating:** This PI has been built from a moderate amount of literature information that was available from outside of the region of interest. Little information was available for the study area. The potential habitat highlighted by the modelling effort has also been visited in the Lake St. Louis and are representative of the species reproduction needs. A “precaution” principle has also been used in order to obtain a “conservative” type PI. Thus we are confident that the PI allows for an accurate relative comparison among alternate water level and flow regimes within the Lower St. Lawrence.

Although hydrologic variables are strongly associated with habitat and Map Turtle / Spiny Softshell occurrence, there is also a significant amount of variation not explained by hydrology. In order to assess 100 year water level scenarios, the predictive models necessarily ignore, or hold constant other important population variables (e.g. productivity, age and sexes distribution) and environmental variables (e.g. predation, food availability, pollution, human disturbance) that can also impact reproductive success, and have an influence on regional Map Turtle / Spiny Softshell populations. For these reasons the PI values should only be considered as relative measures between plans.

**Significance of the species:** The Map Turtle is designated as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed in the Schedule 1 of the *Species at risk Act*; the species, its residence (e.g. hibernacula) and its critical habitat are legally protected under this Act. Critical habitat protection will be applied when it is identified within the Recovery Strategy or Action Plan. The Map Turtle is also designated as Vulnerable by the Québec government under the *Loi sur les espèces menacées ou vulnérables*. Under this provincial act, individuals are protected.
The Spiny Softshell Turtle is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed in the Schedule 1 of the *Species at risk Act*; the species, its residence (e.g. hibernacula) and its critical habitat are legally protected under this Act. Critical habitat protection will be applied when it is identified within the Recovery Strategy or Action Plan. The Spiny Softshell is also designated as Threatened by the Québec government under the *Loi sur les espèces menaces ou vulnérables*. Under this provincial act, individuals are protected.

**Sensitivity to water levels management:** The scientific literature document the close association between Map Turtle and Spiny Softshell Turtle occurrence, during eggs laying period, and specifics hydrological conditions. Map Turtle / Spiny Softshell Turtle PI is retained as a Key PI because it clearly shows an important vulnerability and sensitivity to alternations in water levels and flows, and is listed as a Species at risk. As such it should be used to evaluate potential environmental responses to alternative water regulation plans.
**PI Name/Short Description:** Bridle Shiner (*Notropis bifrenatus*) – reproductive habitat surface area (Lake St. Louis to Trois-Rivières) [E32]

**Technical Workgroup:** Environment TWG

**Researched by:** Sylvain Giguère and Pierre Laporte  
**Modeled by:** Jean Morin, Olivier Champoux and Sylvain Martin

**Performance Indicator Metric:** Spawning and egg development of the Bridle Shiner, a small (6 cm maximum) feeder fish (fish eaten by larger fish). Units are hectares of river at a particular flow level with the characteristics preferred by the Bridle Shiner. Flows are those predicted at the Sorel gage.

The PI gives an annual value of the available safe potential surface area of spawning and egg development habitat (measured at the Sorel gage). The aggregated 100 year plan scenarios are expressed by the percent of time that the PI exceeds the first quartile value for plan 1958DD for the comparable water supply series (e.g. Historic, S1, S2 S3, etc). This metric will be used for plan evaluation by calculating a ratio of metrics between two plans.

**Ecological Importance/Niche:** The Bridle Shiner is designated as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed in schedule 1 of the Species At Risk Act. Under this Act, a management plan, including appropriate measures for the conservation of the species, is required for this species. Wherever it occurs in sufficient numbers, the Bridle Shiner is presumably an important forage fish for a variety of important game fish. This indicator computes the available safe potential surface area of spawning and egg development habitat for different water discharge conditions.

**Temporal validity:** We measure the potential spawning habitat availability for all of June and the two first quarter month (QM) of July while we measure the risk to dry up eggs and larvae from the first QM of June until the third one of July.

**Spatial validity:** The PI is valid for the Lower St. Lawrence River between Lake St. Louis and Lake St. Pierre (except Laprairie Basin). The Lake St. Pierre sub region is used to evaluate plans since the larger and healthiest bridle shiner population is found there.

**Hydrology Link:** The Bridle Shiner prefers to spawn in 60 cm to 120 cm of water in moderate to dense submerged vegetation. The presence of 15 cm to 45 cm of free water above the vegetation is important to reproduction activities of this species. Water levels fluctuations have two known linkages to this fish reproduction:

1) Flood and minimum flow amplitude, recurrence and duration are good indicators of the submerged vegetation composition and density.

2) Water level decreases can dry up eggs and larvae.
**Algorithm:** This PI is influenced by hydraulic attributes responsible for spawning habitat availability and eggs/larvae survival. More specifically, the PI was developed using 2D modeling based on the combination of hydrodynamic, substrate and submerged plants density models. Three hydraulic variables were considered: mean water depth, mean current velocity and water level decrease.

The PI is made from the potential spawning and eggs development habitat model, from which the mortality model removes all portions where water levels fluctuations create “unsafe” conditions to the eggs/larvae development. The two models built to create the PI are presence / absence type models that are based on the parameters and values coming from literature review (more info in Giguère and al. (2005)).

**Potential spawning and eggs development habitat model (QM 21 to 26)**
Habitat is considered as suitable if all the following features are present: substrate polygon contains > 10% of clay or silt or sand; current velocity > 0 m/s & < 0.15 m/s; water depth > 0.45 m & < 1.20 m; submerged vegetation density > 1.5

**Mortality model (QM 21 to 27)**
From the resulting potential habitat, the mortality model removes all the nodes where the water level drops > 0.15 m during at least one of the considered QM.

**Calibration Data:** No data available

**Validation Data:** In the study area, there is no known recorded observation of Bridle Shiner within the reproduction period. However, The ministère des Ressources naturelles, de la Faune et des Parcs (MRNFP) has several recorded observations for the summer period. Considering that this poor swimmer fish possibly use similar habitat during reproduction and summer time, the models has been run for a summer discharge similar to those recorded during the survey periods. 42 of 49 occurrences (79,7 %) matches the characteristics selected in this modeling effort.

**Documentation and References:**

**Risk and Uncertainty Assessment:**
This PI is based on the following assumptions:
- Spawning habitat supply and egg/larvae survival are significant factors influencing the size and integrity of Bridle Shiner populations.
- Predicted fish response to hydrologic conditions based upon literature review is valid.
- Wetland habitat models are providing an accurate, relative estimate of submerged plants density.
- Quarter month hydrologic data is representative of real hydrologic conditions.
- Predicted fish response to hydrologic conditions based on statistical modeling is valid.
- Transformation from a 2D to 1D hydrologic model is correct.

**Confidence rating:** This PI has been built from a moderate amount of literature information that was available from outside the region of interest. The potential habitat model has been validated with several independent field data that matches the characteristics selected. A “precaution” principle has also been used in order to obtain a “conservative” type PI. Thus we are confident that the PI allows for an accurate relative comparison among alternate water level and flow regimes within the Lower St. Lawrence.

Although hydrologic variables are strongly associated with habitat and Bridle Shiner occurrence, there is also a significant amount of variation not explained by hydrology. In order to assess 100 year water level scenarios, the predictive models necessarily ignore, or hold constant other important population variables (e.g. productivity, age and sexes distribution) and environmental variables (e.g. predation, food availability, pollution, exotic species) that can also impact reproductive success, and have an influence on regional Bridle Shiner populations. For these reasons the PI values should only be considered as relative measures between plans.

**Significance of the species:** The Bridle Shiner is designated as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed in the Schedule 1 of the *Species at risk Act*; the species and its critical habitat are legally protected under this Act. Critical habitat protection will be applied when it is identified within the Recovery Strategy or Action Plan. Wherever it occurs in sufficient numbers, the Bridle Shiner is presumably an important forage fish for a variety of important game fish.

**Sensitivity to water levels management:** The scientific literature document the close association between Bridle Shiner occurrence, during spawning period, and specifics hydrological condition. Bridle Shiner PI is retained as a Key PI because it clearly shows an important vulnerability and sensitivity to alternations in water levels and flows, and is listed as a Species at risk. As such it should be used to evaluate potential environmental responses to alternative water regulation plans.
APPENDIX B - IERM USER MANUAL
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1. INTRODUCTION

1.1 IERM FRAMEWORK OVERVIEW

The Integrated Ecological Response Model (IERM) was designed to analyze the ecological impacts of proposed regulation plans for the Lake Ontario – St. Lawrence River (LOSL) system. The IERM framework was developed as a collection of modules, class module, forms, and other objects in Microsoft Visual Basic 6.0 (VB6). The IERM application is comprised of two main components: a model simulation component and a visualization component consisting of a suite of graphical user interface (GUI) tools for viewing model results for hydraulics, ecological performance indicators, and hydrologic criteria.

This user’s manual provides detailed information on how to:

- Run IERM simulations for various regulation plans and supply scenarios;
- Link the IERM to the Shared Vision Model (SVM);
- Visualize results for hydraulics, performance indicators, and hydrologic criteria in the IERM; and
- Review documentation for “key” performance indicators and hydrologic criteria.

The simulation component of the IERM utilizes a suite of databases to store and transfer raw model input/output data during the runtime sequence. Quarter monthly hydraulic results and annual performance indicator and criteria evaluation results are transferred from the simulation component to the main IERM database (IERM_v5.mdb). Following the completion of one or multiple IERM simulations, the results stored in the main IERM database can be accessed and reviewed by navigating through the IERM visualization tools. The simulation and visualization components are decoupled within the IERM framework so that results from one or many simulations can be stored in the main IERM database for access by the visualization tools without re-running the IERM. The linkage between the two components is illustrated in Figure 1-1.
1.2 INSTALLATION

The latest version of the IERM (version 4) is available for download at http://www.limno.com/ierm. The self-extracting zip file should be saved to the user’s local hard drive, and its contents should be extracted to a local folder by double-clicking the executable and following the instructions. The IERM software setup package consists of 3 files: “IERM.cab”, “setup.lst”, and “setup.exe.” Prior to installation, the user should ensure that the installation machine meets the system requirements described in Section 1.2.1. In addition, any previous versions of the IERM software should be uninstalled by following the steps in Section 1.2.2 prior to installing Version 4.

1.2.1 System Requirements

The IERM software should be installed in the “C:\Program Files” folder located on the local hard drive of a machine meeting the following minimum requirements:

- **Operating System:** Windows 2000 or XP;
- **Processor:** Pentium class – 300 Mhz or faster
- **Available disk space:** 500 MB

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• **Memory**: 128 MB (256 MB recommended)

Note that the IERM software should never be installed on a machine running Windows 95 or 98; installing on either of these platforms could cause damage to the operating system.

**1.2.2 Uninstalling Previous IERM Versions**

Prior to installing the current IERM versions, the user should remove any existing IERM versions on the installation machine by following these steps:

1. Access the Windows Control Panel by clicking either: **Start > Settings > Control Panel** (Windows 2000) or: ; **Start > Control Panel** (Windows XP).

2. Double-click "Add/Remove Programs" and locate the "Integrated Ecosystem Response Model" item in the list;

3. Click “Change/Remove”, and select “Yes” when prompted about whether you want to remove the IERM; and

4. During un-installation, select the “Keep” option when asked about keeping shared components.

**1.2.3 IERM Software Installation**

After uninstalling all previous IERM versions and confirming that the installation machine meets the minimum requirements described above, the user may begin the installation process for Version 4 by double-clicking the “setup.exe” file and following the on-screen prompts. During the installation process, several prompts may inquire about keeping an existing version of a system file that is newer than the file that the setup program is attempting to install. In all cases, the user should select “Yes” in response to these prompts to prevent any future operating system problems. The installation process may take 10-15 minutes due to the size of the files that must be copied to the installation folder. After installation has completed, an “Integrated Ecological Response Model” folder should be available.

**1.2.4 Display Issues**

The IERM software will currently not function properly if system display fonts are set to “Large” or “Extra Large.” The setting for system fonts can be found by accessing the Windows Control Panel, clicking “Display”, and then “Appearance options. The Scheme option should NOT be set to a large or extra large setting. In addition, the “Screen Area” setting under the Settings tab should not be less 1024 x 768.
1.3 MAIN MENU

All functionality provided within the IERM can be accessed from the IERM Main Menu (Figure 1-2), which is shown when the user executes the IERM program (IERM.exe). The IERM Main Menu provides the starting point for performing the following major tasks:

- Running IERM simulations (“Run IERM”);
- Visualizing hydraulic results (“Visualize Hydraulics”);
- Visualizing performance indicator results (“Visualize PI Results”);
- Visualizing criteria results (“Visualize Criteria”);
- Managing plan release input data (“Manage Plan Data”); and
- Reviewing performance indicator documentation (“View PI Information”).

Detailed information regarding running an IERM simulation and using the visualization tools is provided in Sections 2 and 3, respectively. Additional features available from the IERM Main Menu include viewing a map of the LOSL study regions (“View Map”), exporting results to the Shared Vision Model (“SVM Export”), and viewing IERM version and contact information (“About IERM”). The “Exit IERM” button will close the IERM program and return the user to the Windows operating system.

Figure 1-2. IERM Main Menu
2. IERM SIMULATION MODEL

The IERM simulation component contains all code relevant to the hydraulic simulation, ecological sub-models and associated performance indicators, and the hydrologic criteria evaluation. Ecological sub-models provided by the ETWG were coded into standalone modules or class modules that could be accessed from the main IERM calling sequence. This modularized approach provides a great deal of flexibility in terms of adding and modifying the various sub-models. The simulation code interacts with a series of Microsoft Access databases that provide efficient storage and transfer of model input/output data using Microsoft’s Data Access Objects (DAO) library (Figure 1-1). The following sections provide detailed information on running an IERM simulation, including input data requirements and linking the IERM to the Shared Vision Model (SVM).

2.1 IMPORTING PLAN INPUT DATA

The IERM framework was designed to minimize the number of inputs required to run model simulations. This was accomplished by coding the SVM hydraulic algorithms directly into the IERM framework. Several different types of quarter-monthly input forcings are required to apply the regressions, including:

- Lake Ontario net total basin supply (NTS) rates;
- Tributary inflow rates for the Ottawa River and other major tributaries to the LSL;
- Ice factors at several locations in the USL and the LSL; and
- Releases at the Moses Saunders Dam associated with a given regulation plan.

Static quarter-monthly time series for total basin supply, tributary inflow rates, and ice factors are maintained within the main IERM database for 9 supply scenarios: historical, 4 stochastic scenarios, and 4 climate change scenarios. Because the SVM hydraulic algorithms are integrated directly into the IERM framework, the only “dynamic” input dataset required to run an IERM simulation is the quarter-monthly releases associated with the regulation plan of interest.

The IERM provides two options for importing quarter-monthly plan release data. First, the user may manually import release data manually from a spreadsheet using a plan import utility provided within the IERM. With this approach, plan releases are imported independently of launching an IERM simulation(s). Alternatively, the user may import plan releases from the Shared Vision Model (SVM) at runtime using a specially formatted worksheet in the SVM Post Processor file.
2.1.1 Importing Releases with the IERM Plan Utility

The IERM provides a plan import utility that allows the user to import plan releases directly from a Microsoft Excel spreadsheet. This utility can be accessed by clicking the “Manage Plan Data” button on the IERM Main Menu. The IERM plan utility interface provides an “Import Dam Release” tab (Figure 2-1), which allows the user to import releases for a new regulation plan or overwrite releases currently stored in the IERM database for an existing regulation plan.

![Figure 2-1. IERM Plan Import Utility](image)

The plan release import process is initiated by clicking the “Import Release Data” button in the upper left corner of the form and selecting a Microsoft Excel workbook that contains quarter-monthly release data in the required format (Figure 2-2). The import workbook must contain a worksheet for each plan that includes the plan name (cell “B1”), the plan description (cell “B2”), and the one or two-digit identifier associated with the supply scenario (cell “B3”):

- Historical Scenario: “H”;
- Stochastic #1-4: “S1”, “S2”, “S3”, “S4”; or
- Climate Change #1-4: “C1”, “C2”, “C3”, “C4”

The quarter-monthly plan release data, including year, month, quarter month (QM), and release rate (m³/s) should be provided beginning in row 5, with column headers (“Year”, “Month”, “QM”, “Release”) provided in row 4. Because model simulations cover a full 101-year period, exactly 4848 (101 years X 48 QM) rows of data must be provided in the cell range “A5:D4852”.

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2.1.2 Importing Releases from Shared Vision Model

As an alternative to importing releases using the plan import utility, the IERM provides the user with the option of importing quarter-monthly release data directly from a SVM Post Processor workbook. The SVM import option is available as a “runtime” option on the “IERM Simulation Builder” form, which is discussed in detail in Section 2.2.

Once a SVM Post Processor workbook has been opened in Excel, the user should navigate to the “IERM Import” worksheet (Figure 2-3). The “pick list” near the top of the sheet should contain the names of all plans that have been run through the SVM framework and exported to the SVM Post Processor. When the plan of interest is selected, the release data (year, QM, and release rate) contained in the range “B9:D4856” will be updated based on the release data available in appropriate plan worksheet.
The name of the SVM Post Processor workbook should contain some combination of 1) “SVM”, “Post”, “Processor” or 2) “Board”, “Room” so that the IERM can properly recognize the file during the import/export steps. These keywords are not case-sensitive, and they may occur anywhere within the filename. It should be noted that the plan selection procedure is identical regardless of the supply scenario that is being evaluated; however, it is important to remember that the appropriate scenario identifier (“H”, “S*”, or “C*”) must be appended to the SVM Post Processor filename. The IERM will use the supply scenario identifier to determine which set of supplies and ice factors to apply to the selected plan. The supplies and ice factors for all 9 supply scenarios are maintained in the main IERM database, so it is not necessary to import this information when running IERM simulations. Only one SVM Post Processor file should be open when linking release data to the IERM to ensure that the correct set of releases is imported into the IERM.

2.2 RUNNING IERM SIMULATIONS

An IERM simulation, or a batch of simulations, can be launched from the “IERM Simulation Builder” form, which can be accessed by clicking the “Run IERM” button on the Main Menu (Figure 2-3). The IERM Simulation Builder provides two options for running a simulation. If the “Run Plan Stored in the IERM” option is checked, the user may select one or more plans to run simulations for. If multiple plans are
selected, the plans will be run in a batch sequence. Note that existing regulation plans may be permanently deleted from the main IERM database by selecting the plan(s) and clicking the “Delete Plans” button.

![IERM Simulation Builder](image)

**Figure 2-4. IERM Simulation Builder**

Alternatively, the “Import Plan from the SVM” option allows the user to import releases and run a simulation for a new regulation plan from the SVM Post Processor. In order for the IERM to properly recognize the release series to be imported, the releases should be made available in the “IERM Import” worksheet in a single SVM Post Processor file. Specific requirements for this worksheet and the parent SVM Post Processor workbook are discussed in Section 2.1.2.

Regardless of whether the existing plan or SVM import option is selected on the “IERM Simulation Builder” form, the IERM simulation(s) can be launched by clicking the “Run IERM” and clicking “Yes” on the confirmation prompt. After the user confirms that the simulations should be launched, the IERM will import any necessary release data, launch a progress window, and initialize the simulation(s). The IERM progress form will provide updates for each sub-model and task as the simulation(s) progress. The total required simulation time for a regulation plan will be 1-2 hours depending on the specifications of the user’s machine. After all simulations have been completed, a completion message will be displayed. Clicking “OK” will return the user to the IERM Main Menu.

A single IERM simulation generates a large quantity of output for the hydraulic, performance indicator, and criteria evaluations. During the course of an IERM sub-model simulation, these results are stored internally in arrayed variables. After a sub-model simulation has been completed, the simulation results are transferred to the appropriate tables in the main IERM database (IERM_v5.mdb), as illustrated in
Figure 1-1. Output datasets transferred from the simulation code to the main IERM database include:

- **Hydraulics**: Quarter-monthly water levels and/or flows for Lake Ontario, Thousand Islands area, Ogdensburg, Cardinal, Montreal Harbor, and Sorel are stored in the “Reg_Hydraulics” table.
- **Performance Indicators**: Annual scores for each performance indicator metric are stored in the “PI_Results” table.
- **Hydrologic Criteria**: Number of years each criterion is successfully met and total deviations for years where the criterion is not met are stored in the “Criteria_Results” table.

At the end of simulation, the IERM computes the aggregate scores for all performance indicators. These scores are later used to compute PI ratios for display in the PI visualization tools. It is important to note that plan “1958DD” must always be run and present in the IERM for a given supply scenario (historical, stochastic, climate change) prior to running any other plans for that particular supply scenario. This is important because a number of PIs are “scored” relative to the 101-year results for 1958DD.

### 2.3 EXPORTING RESULTS TO SHARED VISION MODEL

Running an IERM simulation generates a complete set of performance indicator and criteria results and stores those results in the IERM main database. In order to export the PI and criteria results to the SVM, the user must click the “SVM Export” button on the IERM Main Menu, which will display the “Export IERM Results to SVM” form (Figure 2-5). After selecting the supply scenario of interest, the user may select one or multiple sets of IERM plan results to export. Clicking the “Export Results” button will copy the key PI and criteria evaluation results to the appropriate plan worksheets in an open SVM Post Processor workbook.

It is important to note that the IERM will export results to the first SVM Post Processor (or “Board Room”) workbook that meets the keyword criteria described in Section 2.1.2. If the user has multiple post-processing files open, the results may be exported to any one of the qualifying workbooks without the user knowing which file was used. Therefore, it is important that the user only have one SVM Post Processor (or “Board Room” workbook open when exporting IERM results to the SVM.
Figure 2-5. IERM Export to SVM
3. IERM VISUALIZATION TOOLS

The IERM visualization component contains all code relevant to graphical user interface (GUI) displays of the hydraulic, performance indicator, and criteria output generated by the simulation component. The IERM interface was designed using VB6 forms and controls and Giagsoft’s ProEssentials v5 graphics library. The IERM visualization component was designed to provide the user with a variety of tools for reviewing the simulation results. These visualization tools can be accessed by clicking on the appropriate “Visualize…” buttons on the IERM Main Menu (Figure 1-2). The following sections provide an overview of the IERM visualization capabilities for hydraulic, performance indicator, and criteria evaluation results.

3.1 VISUALIZING HYDRAULIC RESULTS

The hydraulic time series visualization (Figure 3-1) can be accessed by clicking the “Visualize Hydraulics” button on the IERM Main Menu or the “Plot Hydraulics” button on the PI Target diagram. This visualization tool allows the user to view quarter-monthly water levels and/or flow for key locations in the LOSL region, including Lake Ontario, Thousand Islands area, Ogdensburg, Cardinal, Moses Saunders Dam (i.e., releases), Montreal Harbor, and Sorel. The baseline and alternative regulation plan selections can be modified using the “pick lists” in the upper left-hand corner. The user may zoom in and out of the plot by using the controls in the upper right-hand corner of the window or by left clicking and dragging the mouse to create a window. After zooming in, the scrollbars may be used to scroll the plot vertically or horizontally. Quarter-monthly hydraulic data can be exported to Microsoft Excel spreadsheet format by clicking the “Export Data” button.
3.2 VISUALIZING PERFORMANCE INDICATOR RESULTS

The IERM provides a series of linked tools for visualizing performance indicator (PI) results. These tools provide a means for comparing the performance indicator responses to (user-defined) baseline and alternative plans at several levels of detail. At the top level, the PI target diagram provides an overview of the responses for all (or selected) PIs. The user may click on the individual PI points displayed on the target plot to “drill down” into more detail regarding the PI scores for the selected plans, including a plot of the annual PI scores. In addition, the IERM allows the user to plot PI results on a base map of the LOSL system, directly compare the response of a given PI for all regulation plans, and visualize weighted average ratios for the 3 PI regions and 6 PI groups. A schematic illustrating the various levels of PI evaluation and visualization is shown in Figure 3-1.
3.2.1 PI Target Diagram

The PI target diagram (Figure 3-3), which can be accessed by clicking the “Visualize PI Results” button on the Main Menu, provides the starting point for navigating to any of the PI visualization tools provided within the IERM.
Figure 3-3. PI Target Visualization

The target diagram is designed to allow the user to rapidly assess the relative response of a large number of PIs for the selected baseline and alternative plans. The red circle is always associated with a ratio of unity (1.0), which is indicative of zero change for the alternative plan relative to the baseline plan. The outer black circle is associated with the minimum PI ratio score, while the “bullseye” is associated with the maximum PI ratio score. Therefore, ratio points that fall inside the red circle score better for the alternative plan relative to the baseline plan, while ratio points that fall outside the red circle (inside the outer black circle) score worse. By default, the ratio values associated with the black circle and the bullseye are 0.0 and 2.0, respectively; however, these values can be adjusted by adjusting the slider bar in the “Target Scale” frame. In some cases, one or more PI ratios may fall below/above the minimum/maximum ratio values specified in the “Target Scale” frame. In these cases, the ratio points are plotted on the outer black circle or the bullseye point.

The target diagram is organized into multiple “slices”, which represent either the 3 LOSL regions or the 6 PI groups, depending on the option selected in the “Pie Slices” frame. The shape and color of a given PI ratio point indicates which LOSL region and PI group that particular PI belongs to. The 3 regions include Lake Ontario (circle), the upper St. Lawrence River (diamond), and the lower St. Lawrence River (triangle). The PI groups include vegetation (green), fish (orange), birds (blue),...
herptiles (purple), mammals (brown), and species-at-risk (red). Slices and associated PIs can be added or removed from the diagram by toggling the checkboxes provided in the “PI Display Regions” and “Display PI Groups” frames. Finally, the target plot can be limited to displaying only “key” PI ratios (“Key PIs” button) and/or the short PI names can be displayed (“Show Names” button). When an individual PI ratio point is single-clicked, a short description of the PI will be displayed in the status bar. Double-clicking the PI allows the user to “drill down” into more detail regarding the PI results for the selected plans (see Section 3.2.2 for more details).

In addition to modifying the display options for the 3 LOSL regions and 6 PI groups, the IERM provides the option of toggling the display on/off for individual PIs. The PI toggle display (Figure 3-4) can be accessed by clicking the “Toggle PIs” button on the PI target diagram. The display status of individual PIs can be viewed by selecting the appropriate region and group at the top of the form. A checked box for a given PI indicates that the display is toggled “on” for that indicator. The user can save changes to the PI display selections and return to the PI target form by clicking the “Save Changes” button. Alternatively, the user can discard any display changes and return to the PI target diagram by clicking the “Cancel” button.

![Figure 3-4. PI Toggle Display](image)

### 3.2.2 PI Output Summary & Time Series

The “IERM PI Output Summary” (Figure 3-5) provides a more detailed view of the PI aggregate and ratio results for the selected baseline and alternative regulation plans. This display can be accessed by double-clicking on a PI ratio point in the PI
target display. The PI output summary provides general information on the selected PI, including a short description and the region/group that the PI belongs to. The PI’s weight factor and weight percentage area also displayed; these values are associated with the weighting scheme described in Section 3.2.3. The “PI Aggregate Scores” frame provides the ratio score and the associated aggregate scores for the selected baseline and alternative regulation plans. In addition, this frame provides a description of the aggregation method that was applied to obtain the aggregate scores. (It should be noted that the aggregate scores are not actually used to compute the ratio when the aggregation method used for a given PI is the “average of annual ratios.” This only applies to fish habitat supply and population PIs for Lake Ontario and the upper St. Lawrence River.)

![PI Output Summary](image)

**Figure 3-5. PI Output Summary**

The complete PI time series output (Figure 3-6) can be accessed by clicking the “View Time Series” button on the PI output summary display. The PI time series visualization displays the selected regulation plans, a short description of the PI, and the ratio/aggregate scores at the top of the form. The time series graphic contains two separate plots. The upper plot displays the annual PI results for the selected baseline and alternative plans, while the lower plot displays the quarter-monthly hydraulic time series (water level or flow) that serves as the primary hydrologic/hydraulic forcing function for the PI. Similar to the hydraulic visualization, the tools available in the “Zoom” frame allow the user to zoom in/out of the two plots. Scrollbars can be used to navigate horizontally and vertically after zooming in on the plot(s). The “Export Results” button available in the “PI Tools” frame directs the user to the PI export interface, which is discussed in Section 3.2.6. The “PI Browser” button in this frame directs the user to the IERM PI Browser display, which is discussed in Section 4.
3.2.3 PI Weighted Averages

The IERM includes a feature that allows the user to visualize weighted average PI ratios for individual PIs, PI groups, and LOSL regions based on a user-defined weighting scheme. The user can review and modify the weighting scheme on the “PI Weighting Factors” display (Figure 3-7), which can be accessed by clicking the “Set Weights” button on the PI target form. The controls at the top of this display can be used to display different PIs, PI groups, and regions. Weighting factors can be adjusted in 0.05 increments on a scale of 0.00-1.00 by selecting a single bar and by adjusting the scrollbar in the “Modify Selected Weight” frame, or by using the up/down keyboard arrows. Pie charts that provide summary distributions for the various weighting factor can be displayed by clicking on the “View Summary” button.
Once the PI weighting scheme has been established, the user can view weighted average ratios by PI group (within the 3 LOSL regions), by LOSL region, or as an ETWG weighted average ratio. These various points can be displayed as white symbols on the PI target diagram (Figure 3-3) by selecting the 2\textsuperscript{nd} and 3\textsuperscript{rd} checkboxes found in the “General Options” frame. Similar to the individual PI ratios, these weighted ratio points can be single-clicked to obtain a brief description of the ratio, and double-clicked to view additional details regarding the ratio value. In the case of the weighted average ratios, double-clicking individual points displays the “EWTG Weighted Average Summary” (Figure 3-8) and highlights the ratio of interest. The weighted average summary provides an interactive “tree view”, which allows the user to explore the ratios and weighting factors that were used to calculate the weighted average ratios at the 3 levels: PI group averages, LOSL region averages, and the overall ETWG average.

The PI weighting scheme provided in the IERM (version 4) mirrors the weighting scheme used in the March/April 2005 version of the SVM Board Room to compute an overall index of ecological integrity for each plan.

Figure 3-7. IERM PI Weighting Factor Display
3.2.4 PI Map-Based Display

A geographic display of the PI results can be accessed by clicking the “View Map” button on the PI target diagram. This display allows the user to overlay individual PI ratio or group/region weighted average ratios on a base map of the LOSL system for the selected baseline and alternative plans (Figure 3-9). Individual PI results may be viewed by first selecting the associated LOSL region and PI group in the “Select Result” frame, and then selecting the PI of interest. Regardless of whether the PI or weighted average option is selected, the IERM will display two bars representing the ratios calculated for the baseline and alternative plans. The relative height of these bars will be proportional to the ratio values. When a bar is clicked, the actual ratio values will be displayed in the status bar at the bottom of the form. Text annotations shown on the map display (e.g., “Ottawa River”) can be toggled on or off using the check box in the lower left hand corner of the form.

Figure 3-8. IERM Weighted Average Summary
3.2.5 Plan Ranking

A majority of the visualization tools provided in the IERM are designed to compare just two plans (baseline and alternative) at a time. However, the “Compare Plans” button provided on the PI target diagram generates a bar chart (Figure 3-10) that compares the response of the selected performance indicator (PI) or region/group weighted average to all regulation plans that have been evaluated within the IERM framework. The Y-axis shows either the PI aggregate score or the ratio relative to the baseline plan (as specified on the target plot) depending on the radio button settings in the upper right-hand corner of the interface. The plans can be “ranked” from highest ratio (at the left side) to lowest ratio (at the right side) by selecting the “” option at the bottom of the form.
3.2.6 Exporting PI Results

The IERM provides options to export the annual, aggregate, and ratio results one or more PIs. The “IERM PI Result Export” (Figure 3-11) can be accessed by clicking the “Export Results” button, which is available on the PI target diagram and the PI time series visualization. The user has the option of exporting IERM results to a Microsoft Excel spreadsheet for any combination of regulation plans and PIs. The “Organize worksheets…” checkboxes can be used to define the format of the export workbook. The “organize by plan” option will produce a workbook with a worksheet for each selected regulation plan, while the “organize by PIs” option will produce a workbook with one worksheet per PI. The results for the selected plan(s) and PI(s) can be exported as raw annual scores (“Export Scores” button) or PI ratios (“Export Ratios” button).
3.3 VISUALIZING CRITERIA RESULTS

The IERM criteria visualization (Figure 3-12) can be accessed by clicking the “Visualize Criteria” button on the IERM Main Menu. Similar to the PI visualizations, this display allows the user to visualize the criteria evaluation results for selected baseline and alternative regulation plans. Three different graphics can be generated by modifying the selection in the “General Options” frame:

- **Number of Violations** – a bar chart displaying the number of years that each criterion was successfully met;
- **Deviation from Criteria** – a bar chart displaying the total deviation (i.e., sum of absolute deviations from target water level for 101-year simulation) for each criterion; and
- **Quadrant Comparison** – a two-dimensional plot combining the results displayed in the “violations” and “deviations” bar charts.

The quadrant comparison displays the criteria evaluation results using a “normalized ratio” approach. A normalized ratio is defined as the ratio of the alternative score to the baseline score minus a value of one. A normalized ratio of zero indicates that the scores for the two plans are identical, while a positive normalized ratio indicates that the alternative plan scores better than the baseline plan. In Figure 3-12, the X-axis is
associated with the number of times a criterion was successfully met, while the Y-axis is associated with the inverse of the total deviations calculated for the criterion. Therefore, each quadrant in the plot represents a specific condition, with the first quadrant representing the optimal condition:

- **Quadrant #1** – criteria are met more often, failures (i.e., deviations) are less severe;
- **Quadrant #2** – criteria are met less often, failures are less severe;
- **Quadrant #3** – criteria are met less often, failures are more severe; and
- **Quadrant #4** – criteria are met more often, failures are less severe.

It should be noted that total deviations/failures are not calculated for several criteria for which success/failure in meeting a water level condition is evaluated over a multi-year period.

![IERM Visualization for Hydrologic Criteria](image)

**Figure 3-12. IERM Visualization for Hydrologic Criteria**
4. IERM DOCUMENTATION

The IERM provides an abbreviated online HTML-based user’s manual to compliment this comprehensive user’s manual. The online IERM help can be accessed by clicking the “IERM Help” button on the Main Menu, or by clicking the “?” buttons provided on a majority of the IERM form displays. In addition, the IERM provides limited built-in documentation for performance indicators (and associated ecological sub-models) and hydrologic criteria. The following sections describe how to browse this built-in documentation.

4.1 PI DOCUMENTATION

The IERM includes a “PI Browser” display, which allows the user to view a full description for each PI (Figure 4-1). This display can be accessed by clicking the “View PI Information” button on the IERM Main Menu. In addition to these descriptions, the PI browser display provides links to external files that provide documentation for the key ecological PIs included in the final SVM analysis. The key PI documents are available in either Microsoft Word or Adobe PDF format, and can be accessed by selecting the key PI of interest and clicking the “View Docs” button located near the bottom of the display.

![Figure 4-1. IERM Performance Indicator Browser](image_url)
4.2 CRITERIA DOCUMENTATION

The IERM includes a “Criteria Browser” display (Figure 4-2), which allows the user to view a full description for each hydrologic criterion. This display can be accessed by clicking the “View Criteria Information” button on the IERM Main Menu.

![Figure 4-2. IERM Criteria Browser](image)

Figure 4-2. IERM Criteria Browser
Table C-1. Ecological Key PI Ratios for Historical Supply Scenario

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<th>Natural Y (“B”)</th>
<th>Benefits (“D”)</th>
<th>PreProject-ice (“E”)</th>
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### Development of an Integrated Ecological Response Model (IERM) for the Lake Ontario-St. Lawrence River Study

April 2005

**DRAFT**

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Limno-Tech, Inc.
Table C-2. Ecological Key PI Ratios for “S1” Supply Scenario

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<th>Natural Y (“B”)</th>
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### Table C-3. Ecological Key PI Ratios for “S2” Supply Scenario

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Limno-Tech, Inc.
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Table C-4. Ecological Key PI Ratios for “S3” Supply Scenario

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### Table C-5. Ecological Key PI Ratios for “S4” Supply Scenario

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Limno-Tech, Inc.