Technical report RT-137

Selected Performance Indicators of the Environment Technical Working Group (Lower St. Lawrence)

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Environment Canada (MSC, CWS, CSL) and MRNFP

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Selected Performance Indicators of the Environment Technical Working Group (Lower St. Lawrence)

Introduction to the document

The Environment Technical Work Group (TWG) have build several Performance Indicators (PI) that are aiming at quantify/qualify the impacts of discharge regulation on fauna and flora. The indicators presented herein are the key indicators selected from a total of 241 environmental indicators developed for the Lower St. Lawrence River. In the actual document, we present a general methodology that was used to produce the indicators and we briefly document the 18 key indicators selected for the "October 2004-PFEG Workshop", with the following structure: 1) the workgroup 2) activity represented by the indicator, 3) links with water levels, 4) his biological importance 5) performance indicator metric 6) the temporal and spatial validity 7) the links with hydrology (variables used in models), 8) validation data, 9) documents and references and finally 10) the risks and uncertainties associated with the PI. For some spatially explicit models, we present a map of the spatial distribution of the indicator for an average discharge the comparison between the 2D model results and their approximation for the SVM, and the comparison between calculations of the performance indicator based on two different discharge series: 1958DD and PreProject.

General methodology:

The PIs were developed over several years of study within the Env TWG, 2 general types of models were used for the Lower St. Lawrence:

1) Statistical relations with long term data series (1D)
2) System wide, spatially explicit model (physical variable driven) (2D)
    - A) Data driven models
    - B) Data calibrated habitat models
    - C) Knowledge-based habitat models

The first type of model, "one-dimensional statistical approach" is based on relationship between water level temporal series at one station and biological data. Several statistical variables are derived from water level such as median water level over a period, standard deviation for another time step period. Seasonal variability of water level pattern is included in relationships. The only performance indicator presented herein and developed with this methodology is the fish global indicator.

The third type of model, the two-dimensional system-wide model is based on the combination of several numerical models that describes change in physics associated with change in discharge. This system includes results from hydrodynamic model (water level, current velocities, depth and specific discharge), wind waves model (wave energy and wave shear stress) and eulerian transport-diffusion model (water masses spatial distribution, index of suspended matter concentration, index of light penetration, index of deposited material). The system is using large amount of data: high-resolution bathymetry and topography, substratum maps, aquatic macrophytes distribution and floodplain emerging plants that are also used in specific models.

These data were temporally interpolated for conditions present during biological sampling and used for the calibration of statistical models (Data calibrated habitat models; Fish feeding habitat, submerged plants, wetland type and part of wetland birds). For the data driven models, precisely interpolated water level, predicted wetlands and biological data from the field are combined for calculating a performance indicator (Migratory and part of wetland birds). The "Knowledge-based habitat models" are combining precise spatial variables and models to produce habitat model for species or guild from which we have little or no data (Rare species and frog models).

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I Fish "feeding ground" habitat models

1. Performance indicator: Fish feeding habitat; Surface (ha) of potential habitat for Golden shiner (NOCR) *Notemigonus crysoleucas* (FR: "Méné jaune")

Technical Workgroup: Environment TWG

Research by: Mingelbier M. and J.Morin

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

Activity represented by this indicator: Suitable feeding and living habitat of golden shiner.

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

Importance: Fish is 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's also largely used as bait by fishermen.

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

Temporal validity: Valid between August 1st and October 31st and computed from the QM33 to QM 42

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

Links with hydrology used to create the PI 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. % of Clay
3. Simulated vegetation density.

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 2004. Preliminary recommendations concerning fish and their habitat in the St. Lawrence River to assess and evaluate the current criteria used for regulating the Lake Ontario - St. Lawrence system. Société de la faune et des parcs du Québec, Direction de la recherche sur la faune. 124 p. ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports.

Mingelbier M. and J. Morin (2004). Modelling the occurrence of fish species in a large river using 2D numerical habitat, the St. Lawrence River, Canada. Vth International Symposium on Ecohydraulics, September 2004, Madrid, Spain.

Mingelbier M. and J. Morin (in press). Modélisation numérique 2 D de l'habitat des poissons du Saint Laurent fluvial pour évaluer l'impact des changements climatiques et de la régularisation. Naturaliste Canadien.

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 predict 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.

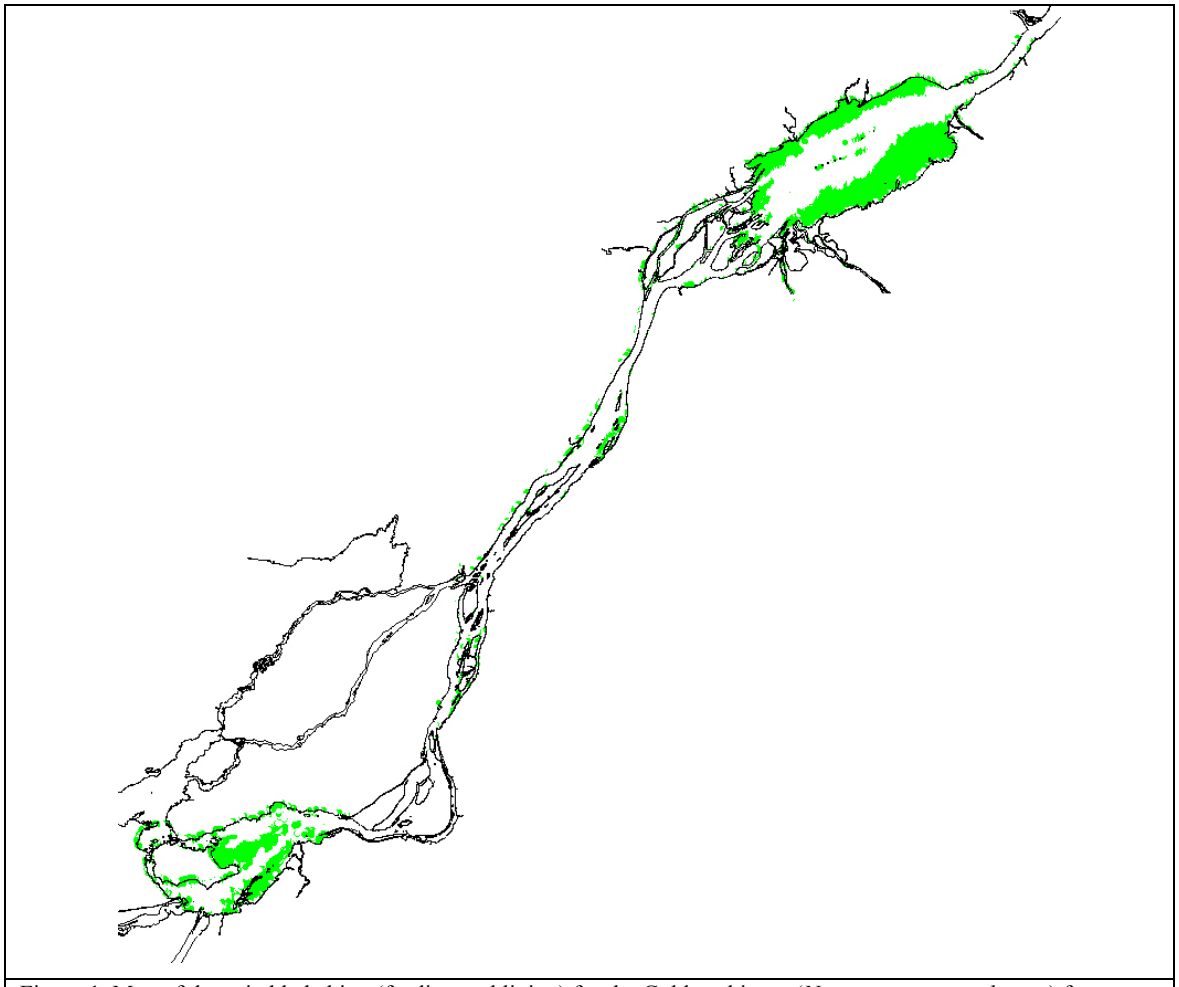


Figure 1. Map of the suitable habitat (feeding and living) for the Golden shinner (*Notemigonus crysoleucas*) for an average discharge (9500 m³/s at Sorel)

Transfers from 2D explicit models to 1D simplified SMV curves:

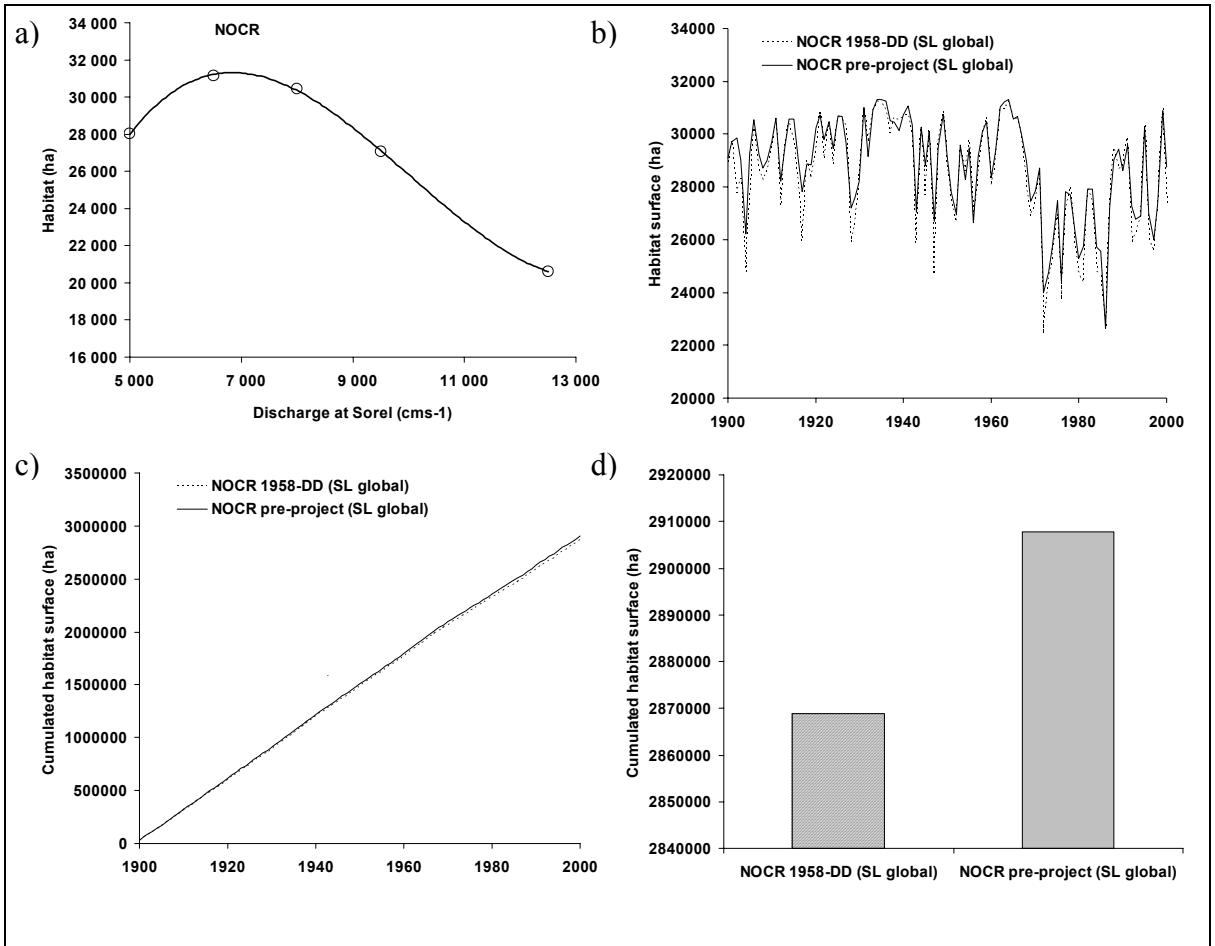


Figure 2. (a) Global relationship between "Surface area of suitable summer habitat" for NOCR and the discharge in Sorel; (b) suitable average summer habitat (ha) for the period 1900-2000, calculated with the 1958-DD and Pre-project Plans; (c) cumulated suitable habitat (ha) over time for the period 1900-2000; (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

Regions	Best fit for: Golden shiner (Notemigonus crysoleucas = NOCR)
Lake St. Louis (LSL)	0,000000034650*QS^3 - 0,000882669386*QS^2 + 6,309187523211*QS - 3930,594638713770
Montréal-Sorel	-0,000000001212*QS^3 + 0,000002061839*QS^2 + 0,273961784965*QS - 1,381076170031
Sorel archipelago	-0,000000005177*QS^3 + 0,000099356534*QS^2 - 0,423343675751*QS + 1474,272275798660
Lake St. Pierre	0,000000057108*QS^3 - 0,001775099068*QS^2 + 16,774782070481*QS - 31127,376622406600
LSL_3-Rivières	0,000000086598*QS^3 - 0,002601389418*QS^2 + 23,431383597885*QS - 34953,469234567000

2. Performance indicator: Fish feeding habitat; Surface (ha) of potential habitat for Walleye (STVI) *Stizostedion vitreum* (FR: "Doré jaune")

Technical Workgroup: Environment TWG

Research by: Mingelbier M. and J.Morin

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

Activity represented by this indicator: Suitable feeding and living habitat of walleye.

Links to water level: The walleye lives in turbid waters, which are sensitive to water discharge variations (light and temperature). Water discharge regulation may have adverse effects on habitat supply.

Importance: Fish is a major component of the aquatic ecosystem, influenced at various degrees by the water discharge. The walleye plays an important ecological role as top predator in the food chain. This species has a high economical value in the St. Lawrence River.

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

Temporal validity: Valid between August 1st and October 31st and computed from the QM33 to QM 42

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

Links with hydrology used to create the PI 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. Two hydrological attributes were used to model the feeding habitat of walleye:

1. Incidental light available at the bottom;
2. Bottom slope.

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 2004. Preliminary recommendations concerning fish and their habitat in the St. Lawrence River to assess and evaluate the current criteria used for regulating the Lake Ontario - St. Lawrence system. Société de la faune et des parcs du Québec, Direction de la recherche sur la faune. 124 p. ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports

Mingelbier M. and J. Morin (2004). Modelling the occurrence of fish species in a large river using 2D numerical habitat, the St. Lawrence River, Canada. Vth International Symposium on Ecohydraulics, September 2004, Madrid, Spain.

Mingelbier M. and J. Morin (in press). Modélisation numérique 2 D de l'habitat des poissons du Saint Laurent fluvial pour évaluer l'impact des changements climatiques et de la régularisation. Naturaliste Canadien.

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; 263 presences and 249 absences), accurately predict the habitat suitable for walleye between August and October. The performance corresponded to $R^2 = 0.36$ and the goodness of fit (concordance between predicted and observed) was 80%. 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.

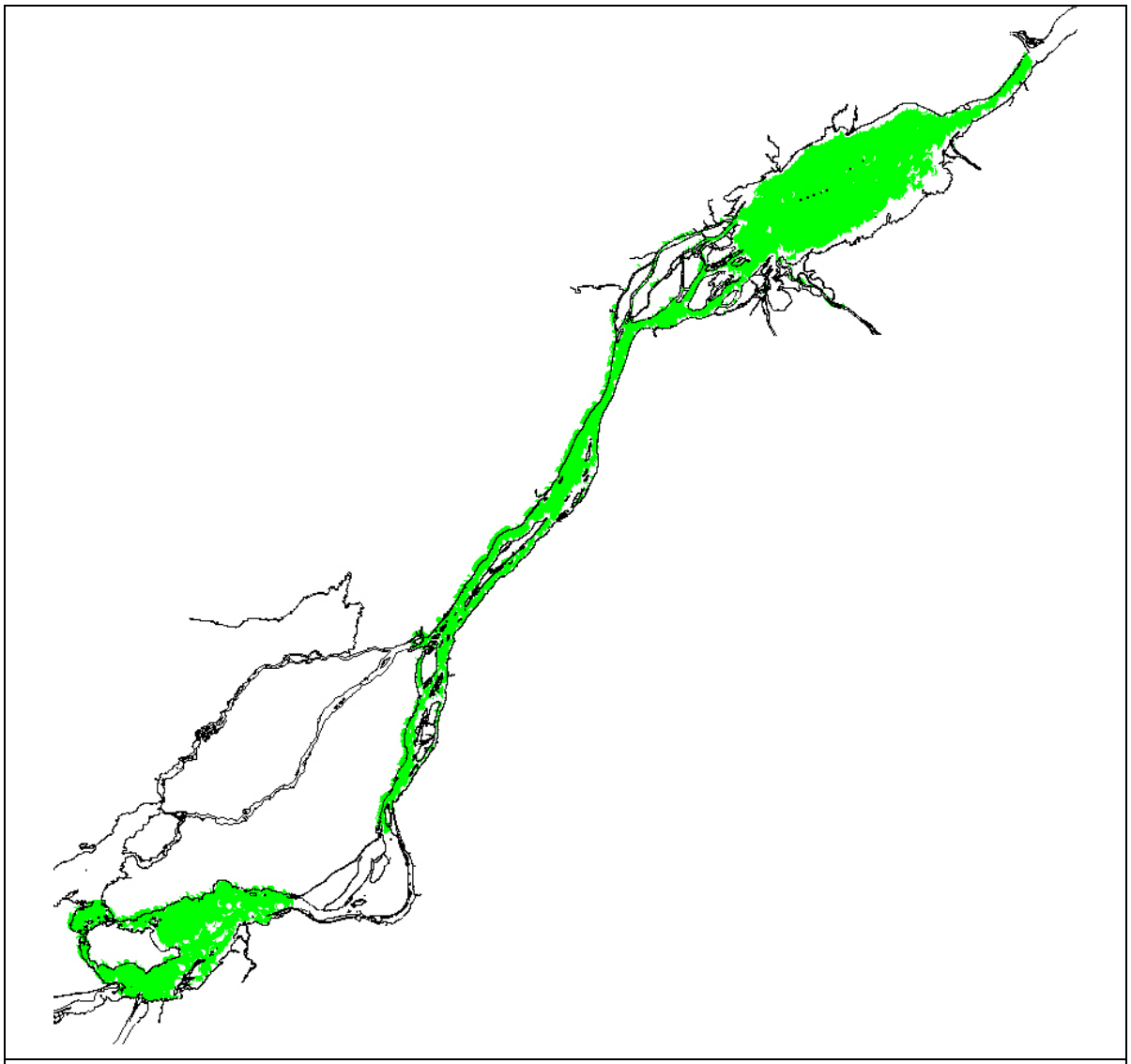


Figure 3. Map of the suitable habitat (feeding and living) for the Walleye (*Stizostedion vitreum*) for an average discharge (9500 m^3/s at Sorel)

Transfers from 2D explicit models to 1D simplified SMV curves:

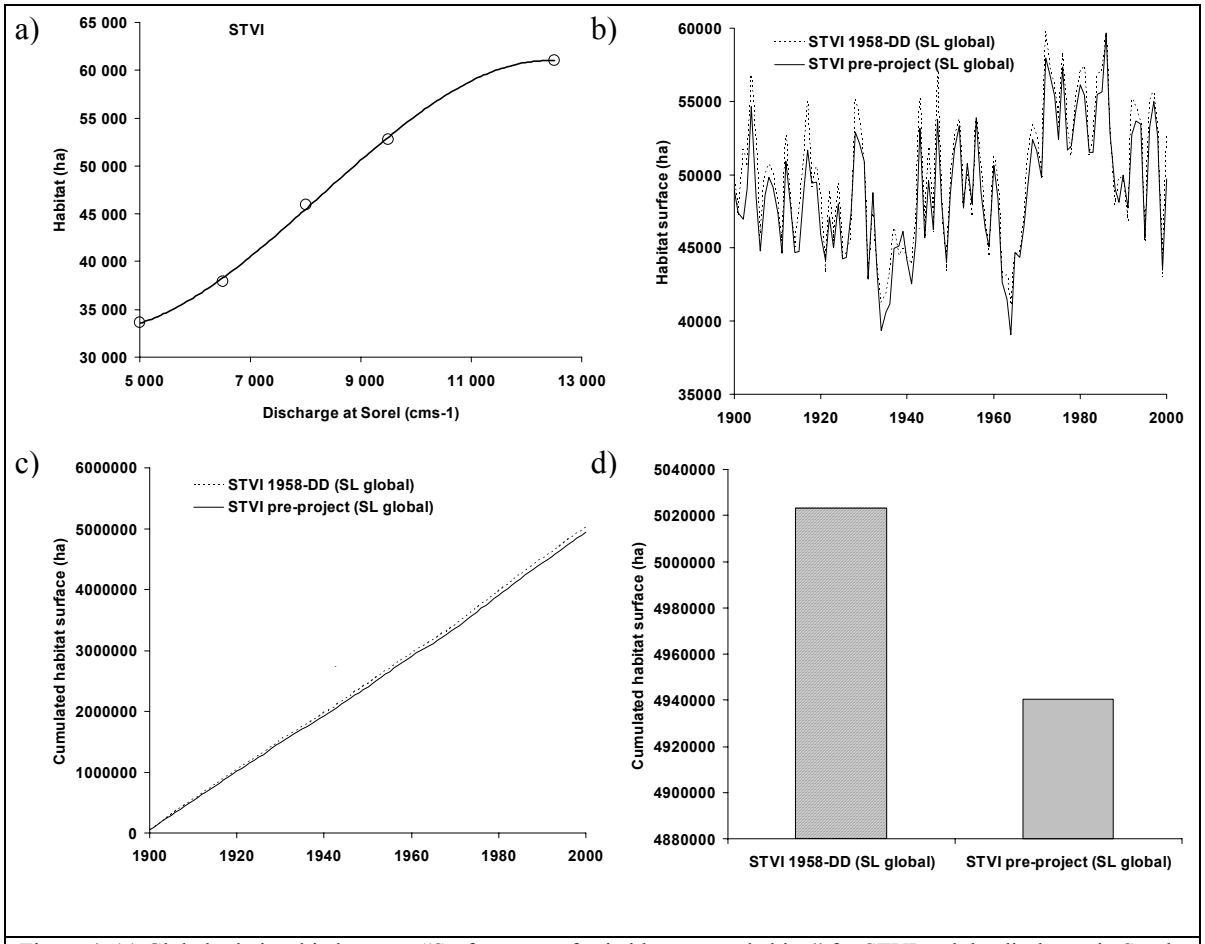


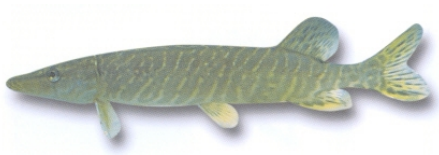
Figure 4. (a) Global relationship between "Surface area of suitable summer habitat" for STVI and the discharge in Sorel; (b) suitable average summer habitat (ha) for the period 1900-2000, calculated with the 1958-DD and Pre-project Plans; (c) cumulated suitable habitat (ha) over time for the period 1900-2000; (d) difference in suitable habitat between the two scenarios 1958-DD and Pre-Project after 100 years.

Table 2. Best fit curves for theWalleye, for the five regions in the St. Lawrence River; QS= discharge at Sorel

Regions	Walleye (Stizostedion vitreum = STVI)
Lake St. Louis (LSL)	0,000000002163*QS^3 - 0,000182551319*QS^2 + 3,639520707597*QS - 6510,012576749920
Montréal-Sorel	0,000000005891*QS^3 - 0,000160486086*QS^2 + 1,892058891884*QS + 947,580600980769
Sorel archipelago	-0,000000011924*QS^3 + 0,000329982965*QS^2 - 2,649174291705*QS + 10072,412131378700
Lake St. Pierre	-0,000000100068*QS^3 + 0,002581371157*QS^2 - 18,899103524013*QS + 56877,891861183900
LSL_3-Rivières	-0,000000102087*QS^3 + 0,002532585333*QS^2 - 15,775192104628*QS + 61862,724586098600

II Fish "spawning ground" habitat model

3. Performance indicator: Suitable spawning habitat and potential mortality for Northern pike (*Esox lucius*).



Technical Workgroup: Environment TWG

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

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

Activity represented by this indicator: Suitable spawning habitat and potential mortality of N. pike.

Links to water level: During the spring time, 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 dry reducing reproduction success and too rapid dewatering can trap larvae in the floodplain.

Importance: 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.

Performance Indicator Metrics: 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.

Temporal validity: Valid for the period between the spawning time (egg deposition) and 30 days after (4 quarter of month). The date of spawning varies from year to year between early April and late May. The computing quarter-month period is driven by the accumulated degree-days at Dorval.

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

Links with hydrology used to create the PI 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 by a predictive model based on air temperature.

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:

Mingelbier M., P. Brodeur et J. Morin 2004. Recommandations préliminaires concernant les poissons du Saint-Laurent et leurs habitats pour la révision des critères de régularisation du système lac Ontario-Saint-Laurent. Société de la faune et des parcs du Québec, Direction de la recherche sur la faune. 124 p. ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports.

Brodeur P., M. Mingelbier et J. Morin 2004. Impact des variations hydrologiques sur les poisons des marais aménagés du Saint-Laurent fluvial. *Nat. Can.* 128-2: 66-77.

Brodeur P., M. Mingelbier et J. Morin 2004. Impact of water discharge on fish reproduction using 2D numerical habitat in the St. Lawrence River, Canada. Proceedings of the 5th International Symposium on Ecohydraulics. Aquatic Habitats: Analysis and Restoration. Sept. 2004. Madrid, Spain.

Brodeur P., M. Mingelbier et J.Morin. *in press*. Impact du débit sur la disponibilité des habitats de reproduction des poissons de la plaine inondable du Saint-Laurent, mesuré avec un modèle numérique 2 D. *Nat. Can.*

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.

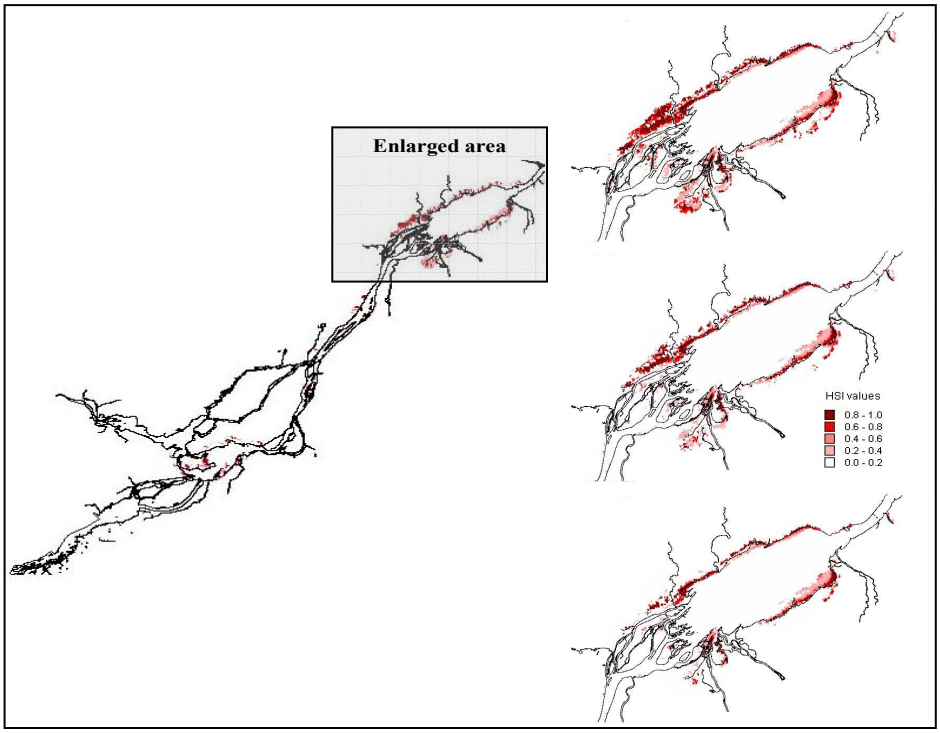


Figure 5. Suitable spawning habitat of N. pike for an average spring discharge at Sorel (14 500 m³/s). Habitat losses corresponding to 0.5 m and 1 m water level drawdown after eggs deposition are presented for the lake St. Pierre area.

Transfers from 2D explicit models to 1D simplified SMV curves:

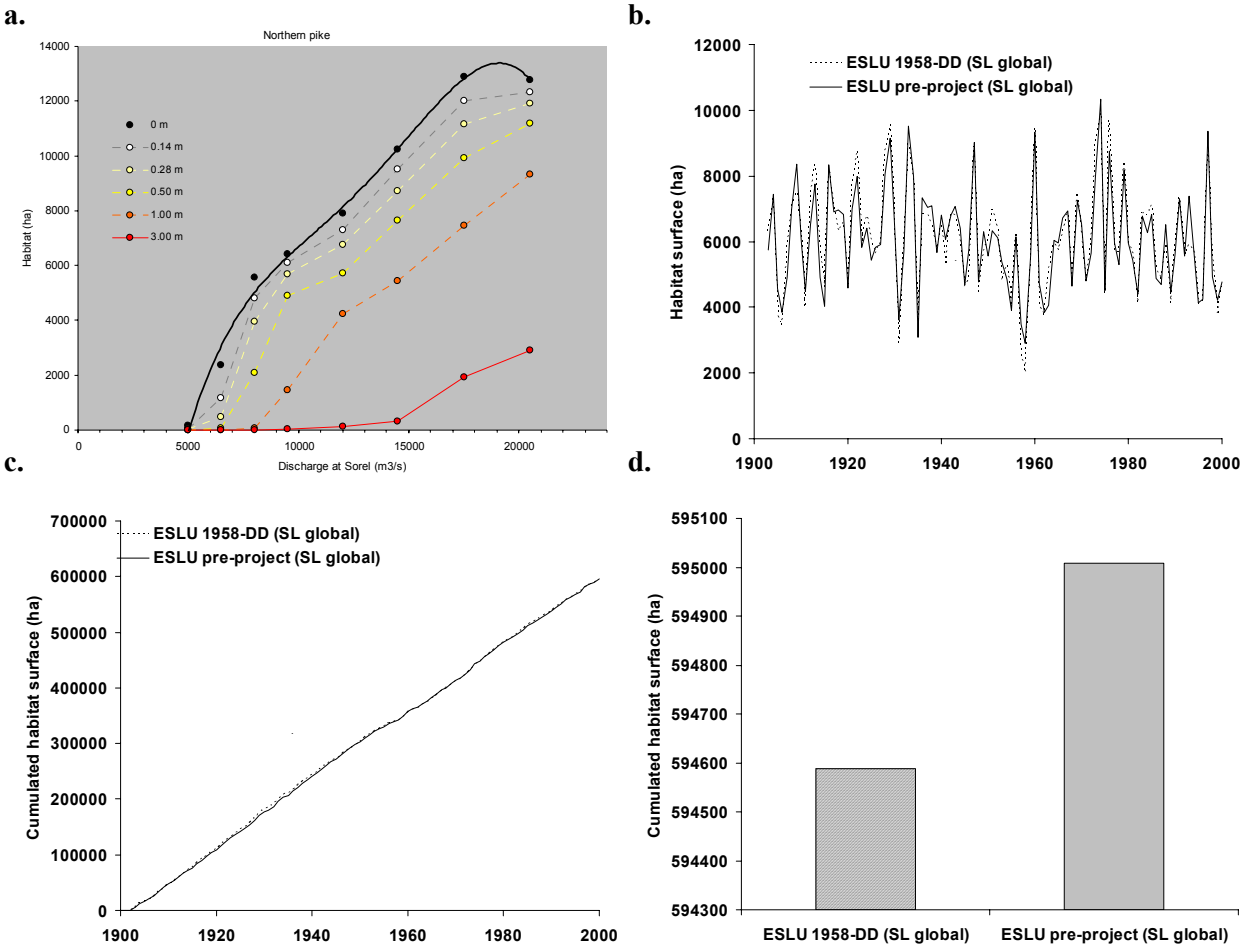


Figure 6. (a) Global relationship between "Surface area of suitable summer habitat" for ESLU and the discharge in Sorel; (b) suitable average summer habitat (ha) for the period 1900-2000, calculated with the 1958-DD and Pre-project Plans; (c) cumulated suitable habitat (ha) over time for the period 1900-2000; (d) difference in suitable habitat between the two scenarios 1958-DD and Pre-Project after 100 years.

III Herptile habitat models: reproduction and hibernation

4. Performance indicator: Frogs reproduction habitat

Research 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.

Activity represented by this indicator: Reproduction habitats of Amphibians: frogs, toads and peepers, in wetlands of St. Lawrence River

Links to water level: Amphibians prefer to spawn in wetland vegetation flooded by less that 50 cm depth. The flooding of St. Lawrence River wetland is directly associated with spring flood amplitude and duration.

Importance: 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 sensible to water level variation in the ecosystem. Water level fluctuations offer food and shelters against the predators. The variation in water level can affect these habitats, therefore affecting frogs.

Performance indicator Metrics: The indicator gives the available surface area of reproduction habitat for different conditions in spring time.

Links with hydrology used to create the PI algorithm:

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.

Links with used to create the PI algorithm:

The algorithm is based on the mean value of discharge estimation at Sorel from QM14 to QM23 for the reproduction period and from QM 23 to 30 for the mortality potential period.The high water level during spring time will favour the frog reproduction in the emergent vegetation. Then the variation of water level will be a limiting factor in the survival of the eggs and tadpoles.

1) Vegetation types: Amphians are known to use marsh to lay down their eggs. Terrestrial or aquatic vegetation are known to be avoided as a spawning ground.

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.

The 2D Algorithm (spatial)

<u>Potential nesting habitat model (QM 14 to 23)</u>

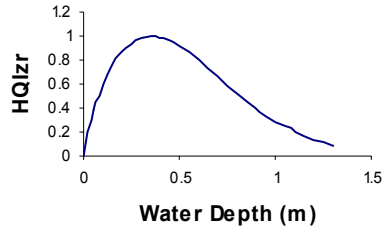
Habitat is calculated over the entire domain (at nodes) with the following algorithm

Reproduction $HQI = (HQI_{Tv} * HQI_{Zr} * HQI_{V})^{1/3}$

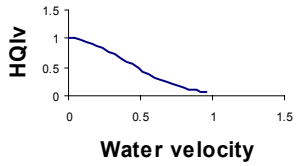
Where $HQI_{Tv\ (vegetation)}$:

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 $HQI_{Zr(\text{water depth})}$:



Where $HQI_{V(\text{water velocity})}$:



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 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 (mortality). The full 2D models are reduced in simplified matrix that is function of flow and water level decrease.

Validation: Occurrences of tadpole catch from field surveys.

Documentation and References:

Armellin, A et C. Plante (mars 2004) Diversité et abondance des amphibiens et Reptiles des milieux humides du Saint-Laurent (*Diversity and Abundance of Amphibians and Reptiles of St.Lawrence river's Wetlands*) IJC Report.

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 Amphibians spawning. 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 determine Amphibians 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.

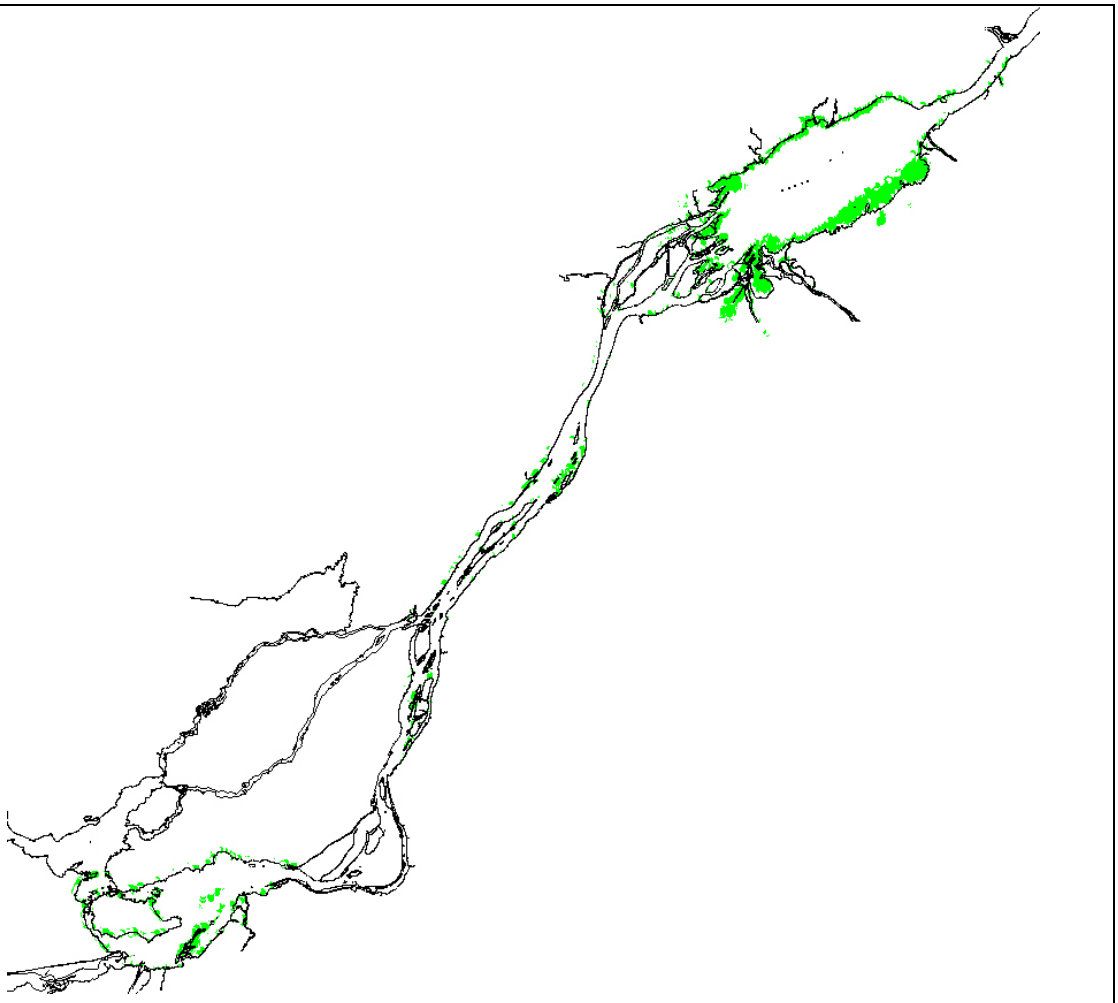


Figure 7. Map of the suitable reproduction habitat for of amphibians (frogs, toads and peepers) for an average discharge (9500 m³/s at Sorel)

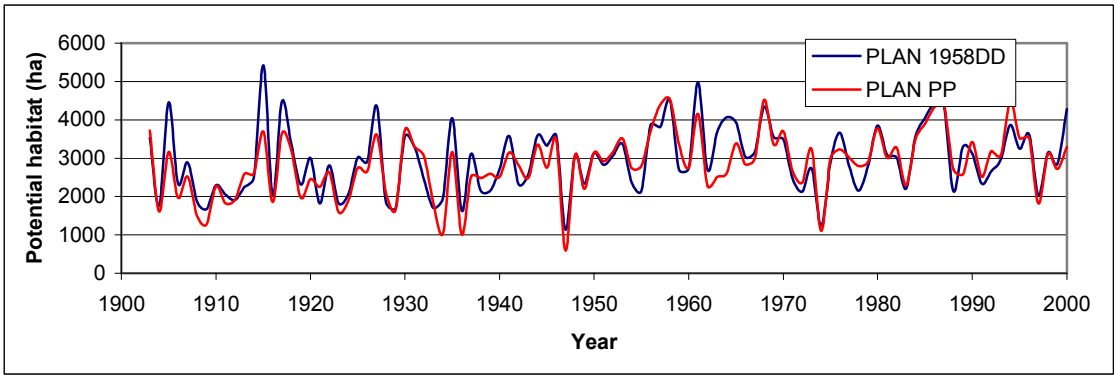


Figure 8. Comparaison of reproductive habitat surface area for the frog for Plan 1958DD and Plan PP

IV Large wetlands classes models: wetlands distribution (presence/absence)

5. Performance indicator: Surface area (ha) covered by open water

Technical Workgroup: Environment Technical Workgroup

Research by: Turgeon K., J. Morin and O.Champoux

Modeled by: Turgeon K., J. Morin, S.Martin and O.Champoux by use of logistic regression (SYSTAT 10.0) in a full 2D model and a 2D Vegetation Succession Model developed by J.Morin, Turgeon K, and S.Martin

Open water (Lake Saint-Pierre)

Activity represented by this indicator: Distribution (surface area in hectares) of open water in the St. Lawrence River floodplain.

Link to water levels: Open water is strongly dependent of water levels fluctuations, i.e. high water levels is associated with an increase of surface covered by open water.

Importance: Open water in the proximity of wetlands is used by fish (feeding and reproduction habitat) and by bird communities (particularly waterfowl). Open water is colonized by floating leaves (*Nymphea and Nuphar sp*.) and by submerged macrophytes which provide shelters and feeding sites for juveniles of fish and for macroinvertebrates.

Performance Indicator Metrics: Area covered by open water (ha) in the St. Lawrence River floodplain.

Temporal validity: From April to October (during the growing season of emergent species colonizing wetlands) and computed from the QM13 to QM 42.

Spatial validity: Valid for the lower St. Lawrence River from Lake St. Louis to Trois-Rivières (except Laprairie Basin). Models were built in the Lake Saint-Pierre.

Links with hydrology used to create the PI algorithm:

Open water was modeled using simulated 2D hydrodynamics variables:

1) Water depth has been used to model open water distribution in the Saint-Lawrence River floodplain.

The Algorithm: Linear regression equation (discharge vs area):
Surface covered by open water (ha) =2.26129E+04 + 3.401539372* ANNUAL MEAN DISCHARGE (MEAN OF THREE PRECEDENT YEARS). The algorithm is based on the mean value of discharge estimation at Sorel from QM14 to QM23 for each of the three years.

Validation: Logistic regression model was built on 869 presences and 10674 absences (prevalence = 0.075). Models were validated with internal validation (2 fold-partitioning technique using 10% of the data for validation) and external validation on other sections of the St. Lawrence River floodplain (Lake Saint-Louis islands and fluvial reach

archipelagos). Model was also tested for their temporal inertia on data in 2002 (IKONOS image with dominant emergent species). Logistic regression model representing open water (McFadden R^2 =0.6904) was accurate and seem to represent well the distribution of this wetlands class in the St Lawrence floodplain.

Documentation and References:

Turgeon K., O. Champoux, S. Martin et J. Morin 2004. Modélisation des milieux humides de la plaine inondable du Saint-Laurent, du lac Saint-Pierre au lac Saint-Louis. *Rapport scientifique RS-104*. Environnement Canada, SMC-Hydrologie, Sainte-Foy, 62 pages.

Turgeon K., O. Champoux, S. Martin et J. Morin. 2004. Modélisation des grandes classes de milieux humides de la plaine inondable du fleuve St-Laurent : considérer la succession des communautés végétales. *Rapport scientifique - RS-107.* Environnement Canada, SMC-Hydrologie, Sainte-Foy, 86 pages.

Turgeon K., O. Champoux, S. Martin et J. Morin. 2004. Modelling large wetlands classes in the St. Lawrence River, from Lake Saint-Pierre to Lake Saint-Louis. Vth International Symposium on Ecohydraulics, September 2004, Madrid, Spain.

Risk and uncertainty assessment: This model predicts accurately the distribution of open water during the growing season of emergent species (p value < 0.0001). Risks associated with the use of this model are very low because the correct classification rate (presences and absences correctly predicted) of open water was high (calibration = 91.7%; internal validation (10% of the data set) = 91.6%). The external validation on other sections of the Saint-Lawrence River gives good qualitative results and model applied on data in 2002 (IKONOS satellite image) produced high correct classification rate (90%), suggesting a high spatial and temporal transferability potential. The use of the Vegetation Succession Model allows integrating temporal inertia and stability in model predictions. Thus, this PI is stable over spatial and temporal scales and is strongly associated with water levels.

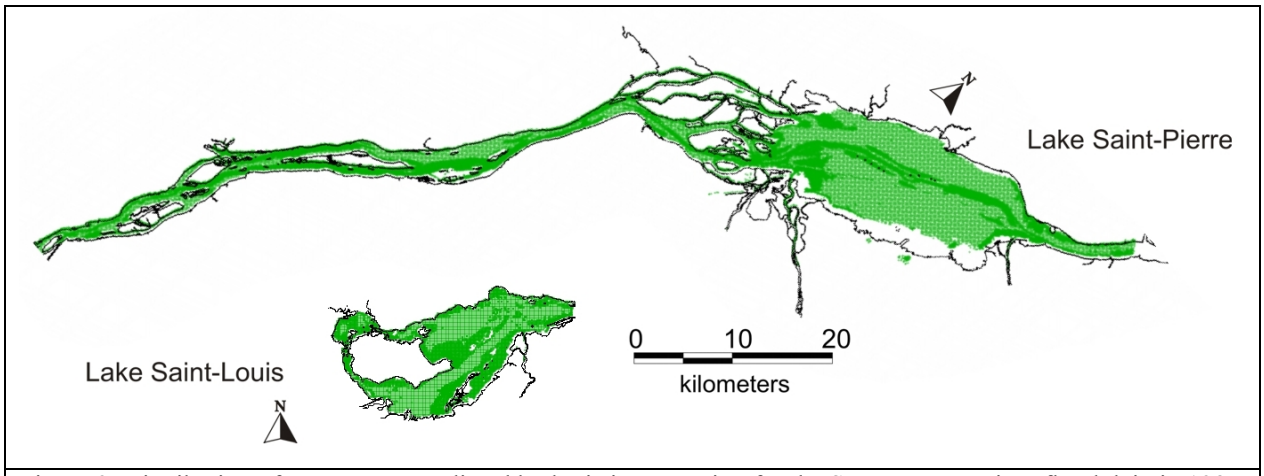


Figure 9. Distribution of open water predicted by logistic regression for the St. Lawrence River floodplain in 1985 (mean discharge = 11503 $m^3 \cdot s^{-1}$)

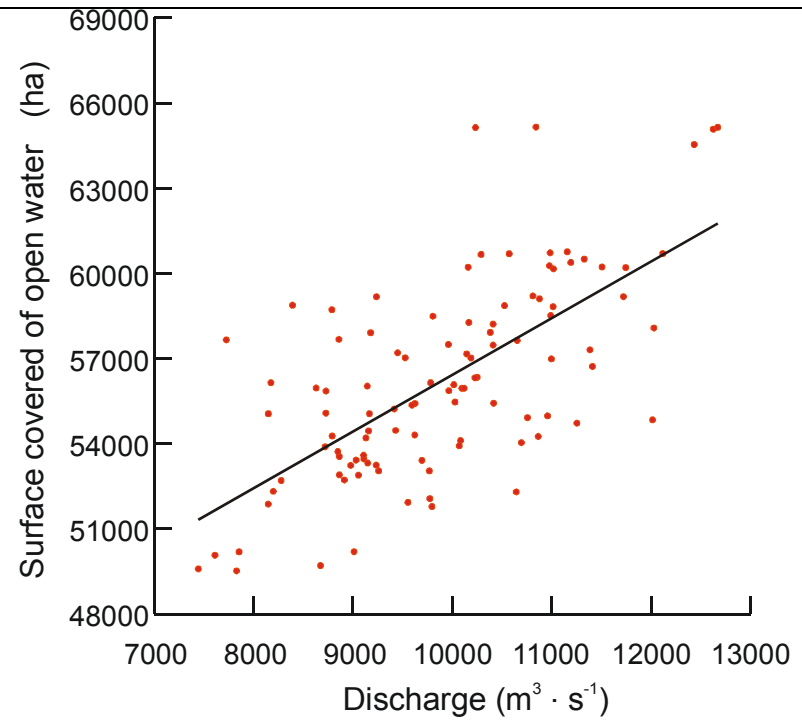


Figure 10. Relationship between estimated surface covered by open water (logistic regression) and discharges in the Saint-Lawrence River from 1900 to 2000.

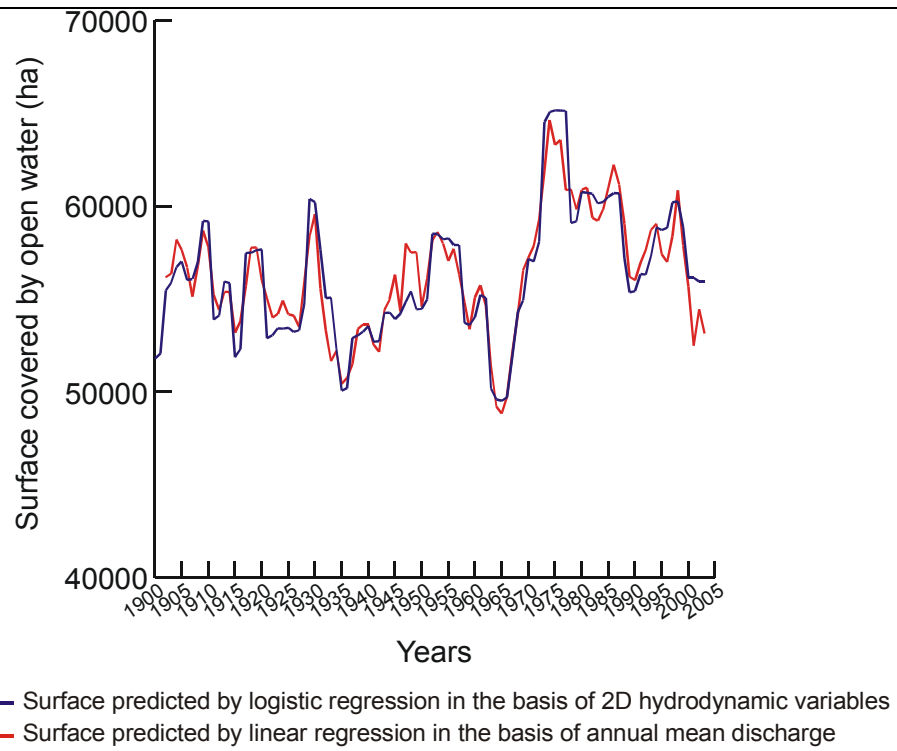


Figure 11. Relationship between surface covered by open water (ha) from 1900 to 2000.

6. Performance indicator: Surface area (ha) covered by forested swamp

Technical Workgroup: Environment Technical Workgroup

Research by: Turgeon K., J. Morin and O.Champoux

Modeled by: Turgeon K., J.Morin, S.Martin and O.Champoux by use of logistic regression (SYSTAT 10.0) in a full 2D model and a 2D Vegetation Succession Model developed by J.Morin, Turgeon K and S.Martin

Activity represented by this indicator: Distribution (surface area in hectares) of forested swamps in the St. Lawrence River floodplain.

Forested swamps dominated by *Acer saccharinum*

Link to water levels: Emergent species colonizing forested swamps need to be flooded during their early growing season but did not tolerate flooding during all their growing season. Ground need to be dry during the summer (good drainage). Emergent species in forested swamps respond, in average, 30 years after water levels fluctuations. Thus, the time lag is long between water levels fluctuation event and the modification in forested swamps distribution in the floodplain.

Importance: Wetlands are essential components of the ecosystem integrity. They play key roles in retention and purification of freshwater, in carbon recycling, in pollutants absorption and in the conservation of flora and fauna. Forested swamps were characterized by relatively high biodiversity (high canopy and underbrush). Dominant species are: *Acer saccharrinum, Fraxinus pennsylvanica, Onoclea sensibilis* and *Impatiens capensis.* They provide habitat of quality for birds (waterfowl, passerine and reproduction area for the Great blue heron), for micro- and macro mammals and for many amphibians.

Performance Indicator Metrics: Area covered by forested swamps (ha) in the St. Lawrence River floodplain.

Temporal validity: From April to October (growing season of emergent species colonizing wetlands) and computed from the QM13 to QM 42.
Spatial validity: Valid for the lower St. Lawrence River from Lake St. Louis to Trois-Rivières (except Laprairie Basin). Models were built in the Lake Saint-Pierre.

Links with hydrology used to create the PI algorithm:

Forested swamps were modeled using simulated 2D hydrodynamics variables:

1) Forested swamps need to be flooded during a small part of their growing season (spring and early summer) and the ground need to be dry in summer, (low slight field slope and good drainage);
2) Forested swamps did not tolerate high water velocity, waves exposure and cycles of flood/drought

The Algorithm: Linear regression equation (discharge vs surface):

Surface covered by natural wet meadows (ha) = 2.96895E+04 -1.838422560*ANNUAL MEAN DISCHARGE (MEAN OF THIRTY PRECEDENT YEARS). The algorithm is based on the mean value of discharge estimation at Sorel from QM14 to QM23 for each of the three years

Validation: Logistic regression models were built on 3410 presences and 8133 absences (prevalence = 0.295). Models were validated with internal validation (2 fold-partitioning technique using 10% of the data for validation) and external validation on other sections of the St. Lawrence River floodplain. We used the Cohen's Kappa to evaluate if model differ of what would be expected by chance. Model was also tested for their temporal inertia on wetlands data in 2002 (IKONOS image). Logistic regression model representing forested swamps (McFadden R^2 =0.4201) was relatively accurate and seem to represent well the distribution of this wetlands class in the St Lawrence floodplain.

Documentation and References:

Turgeon K., O. Champoux, S. Martin et J. Morin 2004. Modélisation des milieux humides de la plaine inondable du Saint-Laurent, du lac Saint-Pierre au lac Saint-Louis. Rapport scientifique RS-104. Environnement Canada, SMC-Hydrologie, Sainte-Foy, 62 pages.

Turgeon K., O. Champoux, S. Martin et J. Morin. 2004. Modélisation des grandes classes de milieux humides de la plaine inondable du fleuve St-Laurent : considérer la succession des communautés végétales. *Rapport scientifique - RS-107.* Environnement Canada, SMC-Hydrologie, Sainte-Foy, 86 pages.

Turgeon K., O. Champoux, S. Martin and J. Morin. 2004. Modelling large wetlands classes in the St. Lawrence River, from Lake Saint-Pierre to Lake Saint-Louis. Vth International Symposium on Ecohydraulics, September 2004, Madrid, Spain.

Risk and uncertainty assessment: This model predicts accurately the distribution of forested swamps during the growing season of emergent species (p-value < 0.0001). Risks associated with the use of this model are low because the correct classification rate (presences and absences correctly predicted) of deep marshes was relatively high (calibration = 80.6%; internal validation (10% of the data set) = 79.2%). The external validation on other sections of the Saint-Lawrence River gives good qualitative results and model applied on data in 2002 (IKONOS satellite image) produced high correct classification rate (87.4%), suggesting a high spatial and temporal transferability potential. The use of the Vegetation Succession Model allows integrating temporal inertia and stability in model predictions. Thus, this PI is stable over spatial and temporal scales and is strongly associated with water levels.

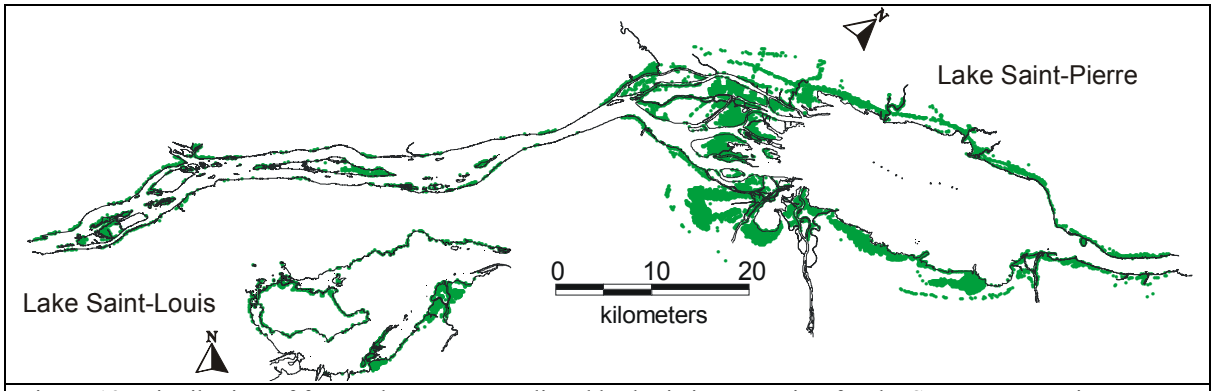


Figure 12. Distribution of forested swamps, predicted by logistic regression for the St. Lawrence River floodplain in 1985 (mean discharge = 11503 $m^3 \cdot s^{-1}$)

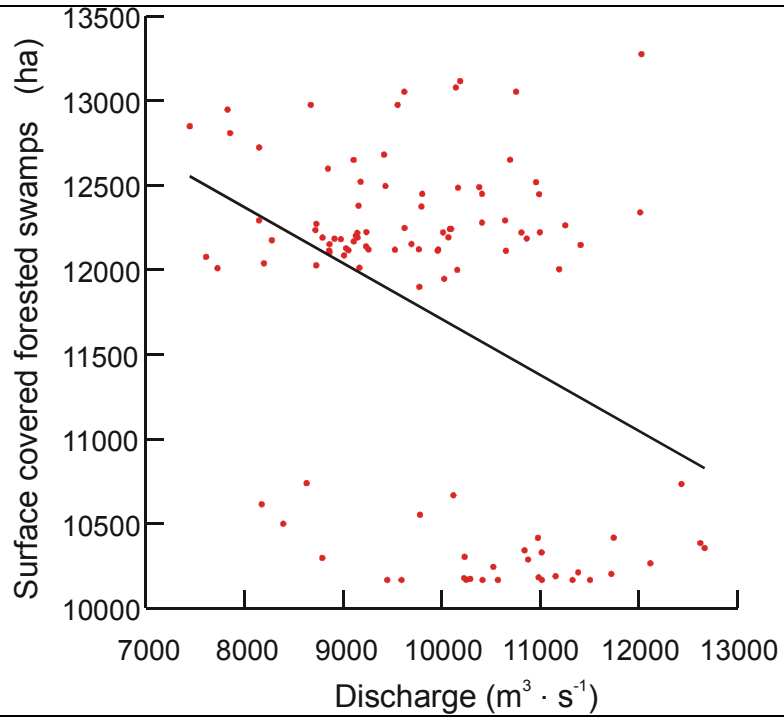


Figure 13. Relationship between estimated surface covered by forested swamps (logistic regression) and discharges in the Saint-Lawrence River from 1900 to 2000.

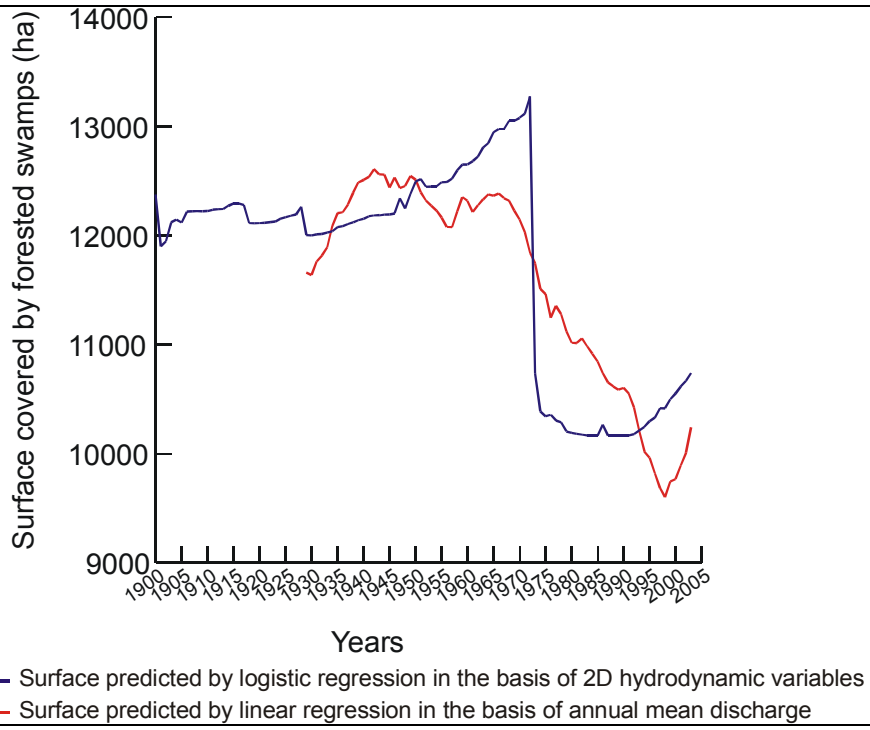


Figure 14. Relationship between surface covered by forested swamps (ha) according to years from 1900 to 2000.

V Rare and endangered species: reproduction habitat

7. Performance indicator: Rare and Endangered bird species; Available surface area for nest initiation of Least Bittern (IXEX) *Ixobrichus exilis* (FR: "Petit blongios")


Clodin Roy

Research by: Giguère, S., J. Ingram, B. Drolet, J.-L. DesGranges and P. Laporte

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

Activity represented by this indicator: It represent an index of reproductive potential in emergent marsh during the breeding season, based on the carrying capacity (an annual estimate of the number of potential breeding pairs in emergent marsh weighted by water depth and water level increase) multiplied by the rate of nest success (an annual rate of nest success based on the probability that a breeding female will successfully hatch a nest, according to the magnitude of water level change.

Link to water levels: This bird nests in the emergent vegetation 20 cm to 80 cm above to water surface. Water depth beneath the nest ranged from 35 cm to 80 cm. Water level fluctuations have three known effect one reproduction: 1) flood amplitude, recurrence and duration are good indicators of the composition and location of emergent marshes; 2) raises of water levels can drown eggs and chicks and 3) drops of water levels can increase nest predation.

Importance: The Least Bittern 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 protected under this Act. Critical habitat protection will be required when the Recovery Strategy or Action Plan will identify it. The North American Bird Conservation Initiative (NABCI) considers the Lower Great Lakes / St. Lawrence plain (BCR 13) as critical to the natural cycle of the Least Bittern.

Performance Indicator Metrics: The PI response will be evaluated using the number of years the PI index is above the median of the PI values associated with 1958DD.

Temporal validity: Valid for the Least Bittern breeding season from last quarter month of May to end of July (QM 19 - QM28).

Spatial validity: Valid for the Lake Ontario - Lower St. Lawrence between Lake Ontario and Lake St. Pierre (except lake Saint-François and Laprairie Basin) where emergent marsh exists.

Links with hydrology used to create the PI algorithm: The algorithm is based on the mean value of discharge estimation at Sorel from QM19 to QM28
This PI is influenced by hydraulic attributes responsible for emergent marsh surface area. More specifically, its algorithm was developed using Lower St. Lawrence hydrologic values based on a 2D water level and topographic model and upon Ontario and Québec nest record data of nesting chronology, nest heights and water depths below the nest. Tree

hydraulic attributes were considered: *mean water depth*, the maximum *water level increase* and the maximum *water level decrease*, and one habitat attributes: the *occurrence of Thypha spp*.

The Algorithm: The reproductive index PI is made from the multiplication of the Potential nesting habitat values and nest success rate.

Potential nesting habitat algorithm:
Presence of water beneath the nest and the presence of emergent vegetation are the two obligate habitat features needed for nesting. Those parameters were weighted upon expert opinion. We built a suitability curve for the water depth feature (pIXEX). For the vegetation component, it is documented that *Typha* species are largely preferred to build the nest (pTYPHA_L and pTYPHA_A). *Carex*, *Scirpus*, *Sagittaria*, *Cephalantus* can also be used (pMp) in deep marshes.

Sub PI 1 : Least Bittern potential nesting habitat
presIXEX=(power(pIXEX,0.5)*power(pTYPHA_A,0.2)*power(pTYPHA_L,0.2*power(pMp,0.1))

Where: pIXEX = ((1/0.248*sqrt(2*π)))*exp(-0.5*(power(((depth-0.598)/0.248),2))))/1.6086

Nest success:
The subPI-2 algorithm is based on nest initiation estimates, nest height and water depth below nest data. Nest height data was adjusted to account for Least Bittern specific nest resilience to flooding. Probability of nest loss estimates due to water level increases or decreases were determined based upon a statistical relationship between magnitude of water level change and probability of nest flooding or stranding. Water level change over a nest exposure period was calculated as the maximum water level increase and decrease from the quarter month of nest initiation over the subsequent five quarter month period. Either the probability of flooding or stranding was used depending of which had the higher probability value. The other reproductive variables included in the annual nest success equation, baseline nest success (in the absence of hydrologic impact) and the probability that a female will renest if the first nest attempt is unsuccessful (re-nesting rate) were held constant.

SubPI-2: Least Bittern nest success = $n_1 + [(1- n_1) * rr * n_2]$

Where: n_1 or n_2 = nest success attempt 1 or 2 where n_i = BN * (1-PF) <u>or</u> BN * (1 - (PS * PSF)

BN = Baseline nest success = 0.6; PF = Prob. of nest flooding (see table A); PS = Prob. of nest stranding (see table A); PSF = Prob. of nest failure due to stranding = 0.5; rr = renest rate = 0.6

Table 1: ***Lest Bittern's nest flooding/stranding probability (PF/PS)***

Rise of water level (RW; cm)	Decrease of water level (DW; cm)	Black Tern flooding/stranding probability
If RW <= 20	and RW > DW	PF = 0
If RW > 20 and RW < 82	and RW > DW	PF = -5E-05 * RW^2 + 0.0159 * RW
If RW > 82	and RW > DW	PF = 1
If RW < DW	and DW <= 29	PS = 0
If RW < DW	and DW > 29 and DW < 1.09	PS = 0.7461 * Ln(DW) – 2.4948
If RW < DW	and DW > =1.09	PS = 1

Validation: For Sub PI 1, potential nesting habitat model, external validation was done existing data. 80% of the 50 recorded observations available match predicted potential nesting habitat occurrence. No internal or external validation was performed for nest success sub PI 2.

Documentation and References:

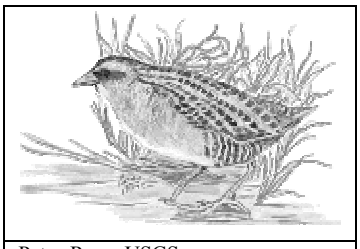
Giguère, S. et P. Laporte (2003) Évaluation des impacts des fluctuations hydrologiques sur les espèces en péril. Tronçon fluvial du Saint-Laurent (Cornwall – Pointe-Du-Lac). Le développement d'indicateurs de performance. Rapport final - Année 3 (2003 - 2004). IJC

DesGranges, J.-L., Ingram, J., Drolet, B., Savage, C., Morin, J., Borcard, D. and Agin, P. (2003) Lake Ontario- St. Lawrence river water level regulation review: Use of wetland breeding bird evaluation criteria within an integrated environmental response model. IJC final wetland bird technical report (2000-2004).

Risk and uncertainty assessment: We recommend that the Least Bittern reproductive index be used to rank plans. We are confident that this index allows for an accurate comparison (in relative terms) between different flows regimes. This PI necessarily ignores important ecological variables that could have an influence on Least Bittern nesting success (predation, food availability, pollution, etc). Despite these gaps and the appreciable noise in some of our response functions, we believe that our PIs clearly show an important vulnerability to water level for that species.

The Least Bittern is a typical K strategist species. This type of species relies more on the number of nesting attempts during their adult life than on the size of their annual progeny. Our index lends us to believe that this species will normally be able to maintain its populations in the LOSL system (without immigration from elsewhere) if it benefits of at least one good reproductive summer every alternate years. Two consecutive bad nesting years can induces a significant decline in their populations in the absence of external recruitment.

8. Performance indicator: Rareand Endangered bird species; Available surface area for nest initiation of Yellow Rail (CONO) *Coturnicops noveboracensis* (FR: "Râle Jaune")



Patsy Renz, USGS

Technical Workgroup: Environment TWG

Research by: Giguère S., P.Laporte, O.Champoux and J.Morin

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

Activity represented by this indicator: Nesting of the Yellow Rail, a small (60 g) secretive marsh bird.

Link to water levels: The Yellow Rail nests directly on the saturated ground of the wet meadows. Water levels fluctuations have two known linkages to this bird reproduction:

1) Amplitude, recurrence and duration of flooding are good indicators of the composition and location of the wet meadow.
2) Raises of water levels can drown eggs and chicks.

Importance: Canada comprises about 90% of the world Yellow Rail breeding range. This bird species is designated as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed as Species of special concern in the schedule 1 of the Species At Risk Act. Under this Act, a management plan, including appropriates measures for the conservation of the species, is required for this species. This species is protected under the Migratory Birds Convention Act, 1994. Yellow Rail is one of the most sought-after birds by bird-watcher in North America. The indicator gives the available safe potential surface area of nesting habitat for different water discharge.

Performance Indicator Metrics: Hectares of wet meadow at a particular flow level with the characteristics preferred by the Yellow Rail. Flows are those measured at the Sorel gage.

Temporal validity: We measure the potential nesting habitat available for the two last quarter month of May (QM18 to QM20) while we measure the risk to drown eggs and chicks from the last quarter month of May until the third one of June (QM20 to 23).

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

Links with hydrology used to create the PI algorithm: The algorithm is based on the mean value of discharge estimation at Sorel from QM18 to QM20 for the nesting period and from 20 to 23 for the mortality potential period

The two models built to create the PI are presence / absence type models. These models are based on the parameters and values coming from literature review and expert's opinions (more info in Giguère and Laporte 2002-2003 final report).

<u>Potential nesting habitat model (QM 18 to 20)</u>

Habitat is considered as suitable if all the following features are present: water depth ≤ 0 m; soil utilization polygon = natural, old field or pasture land; wetland type = wet meadow.

Mortality model (QM 20 to 23)

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

A 2D habitat model computes the probability of 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 (mortality). The full 2D models are reduced in simplified matrix that is function of flow and water level decrease.

Validation: Environment Canada – Canadian Wildlife Service has three recorded observations of this rare species. Two of the three observations match the characteristics selected in this modeling effort. The 1958DD time series is also behaving well since the safe potential habitat available change a lot from a year to year. This feature is realistic considering the nesting characteristics of the species (nest on the ground very close to the water).

Documentation and References:

Alvo, R. and Robert, M. (1999) Status Report on the Yellow Rail, *Coturnicops noveboracensis*. Committee on the Status of Endangered Wildlife in Canada (COSEWIC), 72 pp.

Giguère S. and P.Laporte 2003. Évaluation Des Impacts Des Fluctuations Hydrologiques sur Les Espèces En Péril. Tronçon Fluvial Du Saint-Laurent (Cornwall – Pointe-Du-Lac). Le développement d'indicateurs de performance. Rapport final - Année 3 (2003 - 2004). IJC Report.

The latest reference document includes a complete literature review of the species nesting habitat and period and is available at: ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports

Risk and uncertainty assessment: We are confident that this model will accurately predict which end of May and June flows are better or worse for Yellow Rail nesting. The predicted area should be close to the reality since the natural wet meadows model is rather precise. Even if the predicted area is not exactly correct, this error will be essentially constant over the range of flows, so they will not undermine the usefulness of the model for ranking plans. 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 safe potential nesting habitat to be used to rank plans. The PI also does not reflect other important factors that determine Yellow Rail population, such as availability of wintering habitat. In our expert opinion, this does not significantly diminish the value of this PI because we feel available safe nesting area is generally the factor that drives population.

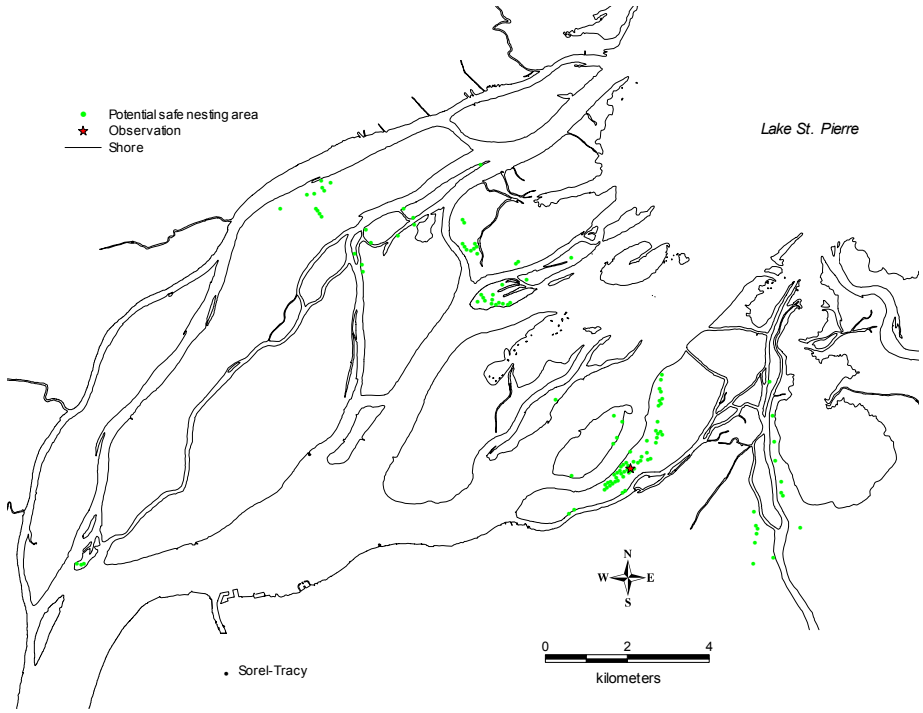


Figure 15. Map of the indicator (Yellow rail) for Lake St. Pierre archipelago area for 1991 designated quarter month

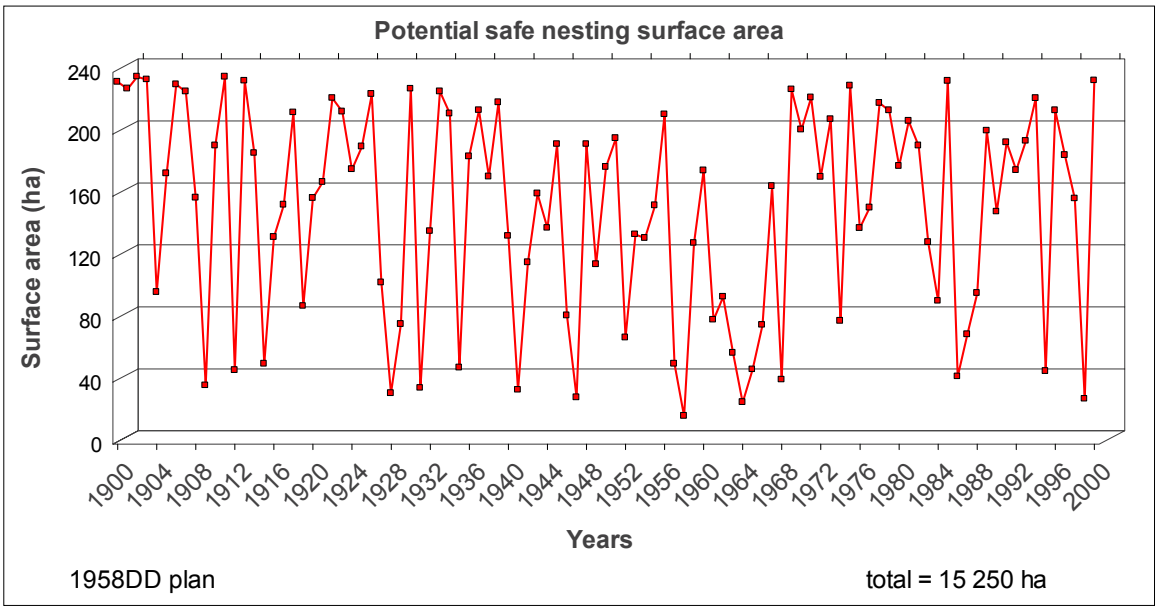
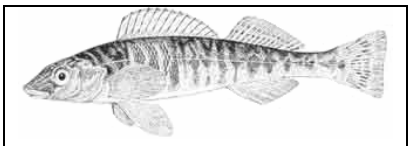


Figure 16. Potential safe nesting area for the Yellow rail over 100 years (from 1900 to 2000) with the 1958 DD plan.

9. Performance indicator: Rare and Endangered fish species; Available spawning surface area for Channel Darter (PECO) *Percina copelandi* (FR: "Fouille-roche gris")



Redpath Museum / McGill University

Technical Workgroup: Environment TWG

Research by: Giguère S., P.Laporte, O.Champoux and J.Morin

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

Activities represented by this indicator: Spawning and egg development of the Channel Darter, a small (averaging 4 cm) benthic percid fish.

Link to water levels: The Channel Darter prefers to spawn in 30 cm to 150 cm of water with current velocity creating silt-free sand, gravel and/or rocky bottoms. Water levels fluctuations have three 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, which is a very important parameter.
2) High water levels tend to mean cooler water temperatures; temperature controls reproduction activities (migration, courtship, spawning) and larvae development.
3) Drop of water levels can dry up eggs and larvae.

Importance: The Channel Darter is unique in Canada to the province of Ontario and Quebec and it contributes to the biodiversity of aquatic ecosystem. The species is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed as threatened in schedule 2 of the Species At Risk Act, and is now in the process of consultation before listing under schedule 1. At this time, this species will be protected under the Species At Risk Act. A Recovery Strategy will be required within two years. Critical habitat protection will be required when the Recovery Strategy or Action Plan will identify it. The indicator gives the available safe potential surface area of spawning and egg development habitat for different water discharge.

Performance Indicator Metrics: Hectares of river bed at a particular flow level with the characteristics preferred by the Channel Darter. Flows are those measured at the Sorel gauge.

Temporal validity: We measured the potential spawning habitat available for the two last quarter months of June (QM 23 to 28) and all of July (QM 23 to 29) while we measured the risk to dry up eggs and larvae from the second quarter month of June until the first one of August.

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

Links with hydrology used to create the PI algorithm: The algorithm is based on the mean value of discharge estimation at Sorel from QM23 to QM28 for the potential spawning period and from 23 to 29 for the mortality potential period.

The two models built to create the PI are presence / absence type models. These models are based on the parameters and values coming from literature review and expert's opinions (more info in Giguère and Laporte 2002-2003 final report).

Potential spawning habitat model (QM 23 to 28)

Habitat is considered as suitable if all the following features are present: substrate polygon contains > 0% of gravel or pebble; water depth > 0.45 m and < 1.50 m.

Mortality model (QM 23 to 29)

From the resulting potential habitat, the mortality model removes all the nodes where the water depth < 0.15 m during at least one of the considered QM.

A 2D habitat model computes the probability of 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 (mortality). The full 2D models are reduced in simplified matrix that is a function of flow and water level decrease.

Validation: The Société de la Faune et des Parcs du Québec (FAPAQ) has two recorded observations of this rare species within the reproduction period. These occurrences match the characteristics selected in this modeling effort.

Documentation and References:

Phelps, A. and Francis, A. (2001) Update COSEWIC Status Report on Channel Darter (*Percina copelandi*). Committee on the Status of Endangered Wildlife in Canada, Ottawa, 27 p.

Winn, H.E. (1953) Breeding Habits of the Percid Fish *Hadropterus copelandi* in Michigan. Copeia 1953, no. 1, pp. 26-30.

Giguère S. et P.Laporte 2003. Évaluation Des Impacts Des Fluctuations Hydrologiques sur Les Espèces En Péril. Tronçon Fluvial Du Saint-Laurent (Cornwall – Pointe-Du-Lac). Le développement d'indicateurs de performance. Rapport final - Année 3 (2003 - 2004). IJC Report.

The latest reference document includes a complete literature review of the species spawning habitat and period and is available at:ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports

Risk and uncertainty assessment: We are confident that this model will accurately predict which flows are better or worse for Channel Darter spawning period. The predicted area may differ by a factor of 2 with the actual area because we do not have square meter by square meter data on the nature of substrate, but these errors will be essentially constant over the range of flows, so they will not undermine the usefulness of the model for ranking plans. Another uncertainty is that there is little information available to build the model and there are very few recorded observations (2) to validate the model. Indeed, the FAPAQ had never put effort in the St. Lawrence to catch this migratory fish species during the reproduction period. The conservatively built model can also overestimate the real amount of suitable habitat but as in the case of the substrate database, if overestimation errors are effectively present, these errors will be constant over the range of flows and will not

undermine the capacity of the model to rank plans. 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. The PI also does not reflect other important factors that determine Channel Darter population, such as water quality, availability of food, predation or competition with exotic species (i.e. round goby). 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.

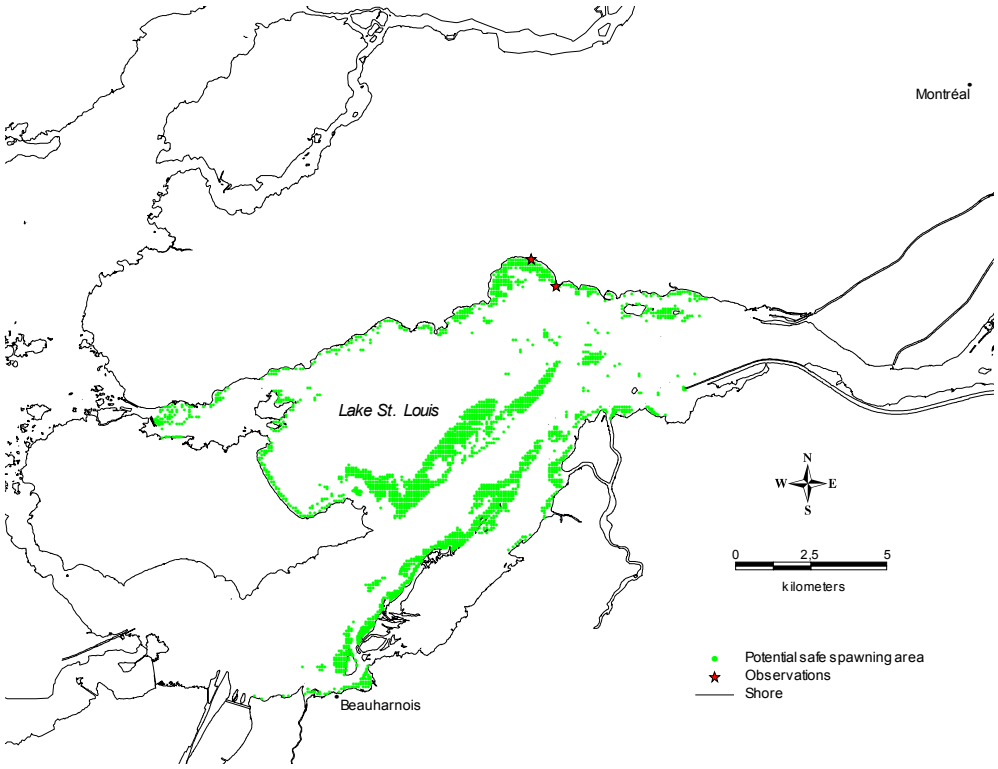


Figure 17. Maps of the indicator (Channel darter) for Lake St. Louis area for 1999 designated quarter month

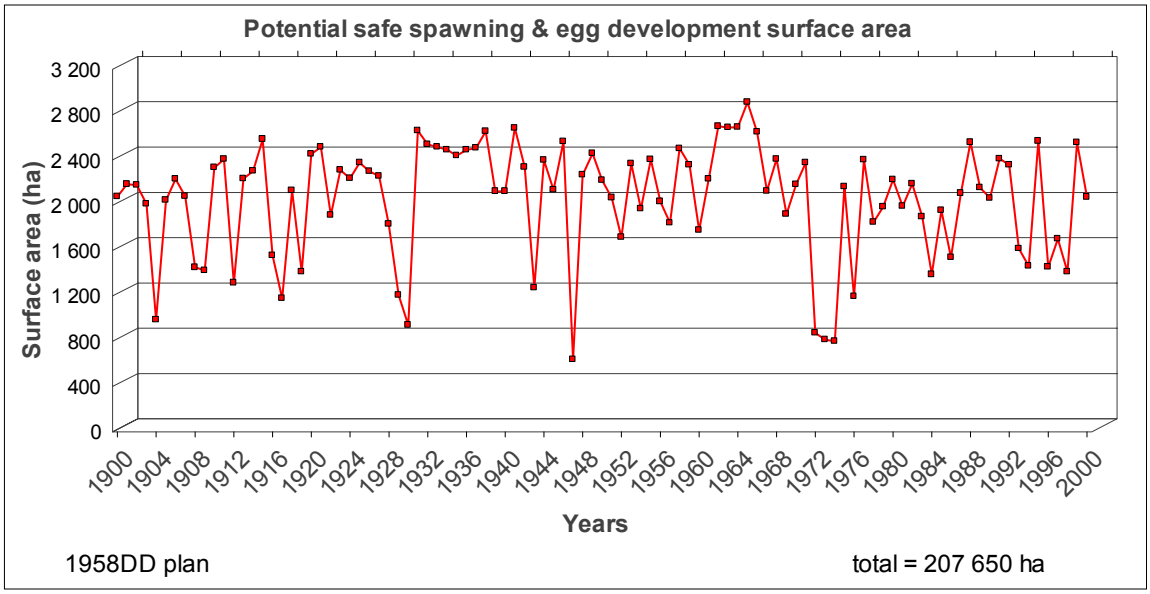
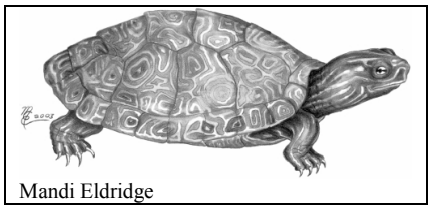


Figure 18. Potential safe spawning and egg development surface area for the Channel darter over 100 years (from 1900 to 2000) with the 1958 DD plan.

10. Performance indicator: Rare and Endangered fish species; Potential safe egg laying/development habitat available for the Northern Map turtle (GRGE) *Graptemys geographica* (FR: "Tortue géographique"

Technical Workgroup: Environment TWG

Research by: Giguère S., P.Laporte, O.Champoux and J.Morin


Mandi Eldridge

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

Activities represented by this indicator: Egg laying and development of the Map Turtle, a 25 cm (maximum) aquatic turtle.

Link to water levels: The Map Turtle prefers to lay eggs in sand / gravel substrate, normally from 50 cm to 100 cm above the water level. During nesting, the female keeps a visual contact with the water. Water level fluctuations have three known linkages to this turtle reproduction:

1) Amplitude and duration of flood is a good indicator of the portion of banks / beaches available.
2) Amplitude, duration and recurrence of flood is a good indicator of what the banks / beaches will be made up of (substratum and vegetated or not).
3) Increased water levels can drown eggs if submerged more than 48 hr.

Importance: The Map Turtle is designated as Special Concern 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 species of Special Concern. At this time, a management plan, including appropriate measures for the conservation of the species, will be required. The indicator gives the available safe potential surface area of nesting and egg development habitat for different water discharge.

Performance Indicator Metrics: Hectares of river bank / beach at a particular flow level with the characteristics preferred by the Map Turtle. Flows are those measured at the Sorel gauge.

Temporal validity: We measured the potential nesting habitat available for all of June and the two first quarter months of July (QM 21 to 26) while we measure the risk to drown eggs from the first quarter month of June until the last one of September (QM 21 to QM 36).

Spatial validity: Valid for Lake St. Louis. We could possibly calculate this PI for all the Lower St. Lawrence between Lake St. Louis and Lake St. Pierre (except Laprairie Basin) but since the species has never been found anywhere else in the study area except in the Lake St. Louis and because a population occurs in the Lake des Deux-Montagnes (near Lake St. Louis), it is more representative to only include this section.

Links with hydrology used to create the PI algorithm: The algorithm is based on the mean value of discharge estimation at Sorel from QM21 to QM26 for the potential nesting period and from 21 to 36 for the mortality potential period. The two models built to create the PI are presence / absence type models. These models are based on the parameters and

values coming from literature review and expert's opinions (more info in Giguère and Laporte 2002-2003 final report).

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; and one of the following shore polygon features:

- Beaches
- Top bank vegetation = beach or denuded ground
- Bank vegetation = beach or denuded ground
- Lower bank vegetation = beach or denuded ground
- Top bank vegetation density < 5% + substratum = sand or gravel
- Bank vegetation < 5% + substratum = sand or gravel
- Lower bank vegetation < 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 to > 0 m during at least one of the considered QM.

A 2D habitat model that computes the probability of 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 (mortality). The full 2D models are reduced to a simplified matrix that is a function of flow and water level decrease.

Validation: There is no known nesting site of Map Turtle in the study area. On the other hand, the study area has not been examined closely and a population occurs in the Lake des Deux-Montagnes, which is directly connected to Lake St. Louis. The highlighted sites shown on the above map were visited by Giguère and match very well the characteristics selected in this modeling effort. Several traces of nesting activities were seen (digging) without identification of the species (no individuals were seen). The 1958DD time series is also behaving very well, allowing more surface area in the low water levels periods (i.e. beginning of 1960's) and less habitat in the high water levels period (i.e. mid 1970's). This is very coherent since a low water level leads more banks and beaches while a high water levels have the opposite effect.

Documentation and References:

Roche, B. (2002) Status report on the Northern Map Turtle, *Graptemys geographica*, in Canada, Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Ottawa, 34 pp.

Giguère S. and P.Laporte (2003) Évaluation Des Impacts Des Fluctuations Hydrologiques sur Les Espèces En Péril. Tronçon Fluvial Du Saint-Laurent (Cornwall – Pointe-Du-Lac). Le développement d'indicateurs de performance. Rapport final - Année 3 (2003 - 2004). IJC Report.

The latest reference document includes a complete literature review of the species egg laying and development habitat and period and is available at: ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports

Risk and uncertainty assessment: The model used to build this PI is exactly the same that for the Spiny Sofshell because both of the species used the same type of habitat in the same period of the years. We are confident that this model will accurately predict which June to September flows are better or worse for Map Turtle nesting and egg development. The predicted area should be close to the reality since the database used to build the PI his quite precise. Even if the predicted area is not exactly correct, this error will be essentially constant over the range of flows, so they will not undermine the usefulness of the model for ranking plans. 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 determine Map Turtle population, such as water quality, availability of food or human disturbance. In our expert opinion, this does not significantly diminish the value of this PI because we feel available nesting and egg development area is generally the factor that drives population. Is it also mentioned in the literature that water level management during this period can explain a part of the species status.

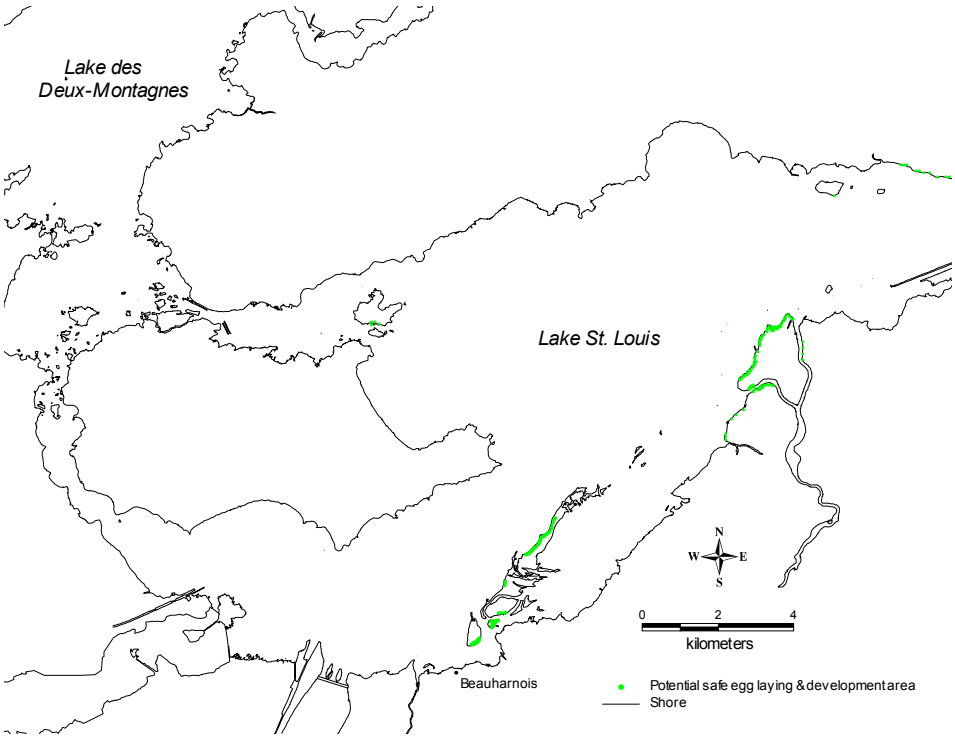


Figure 19. Map of the 2D habitat model for the Northern map turtle, in Lake Saint-Louis (1999 designated quarter month)

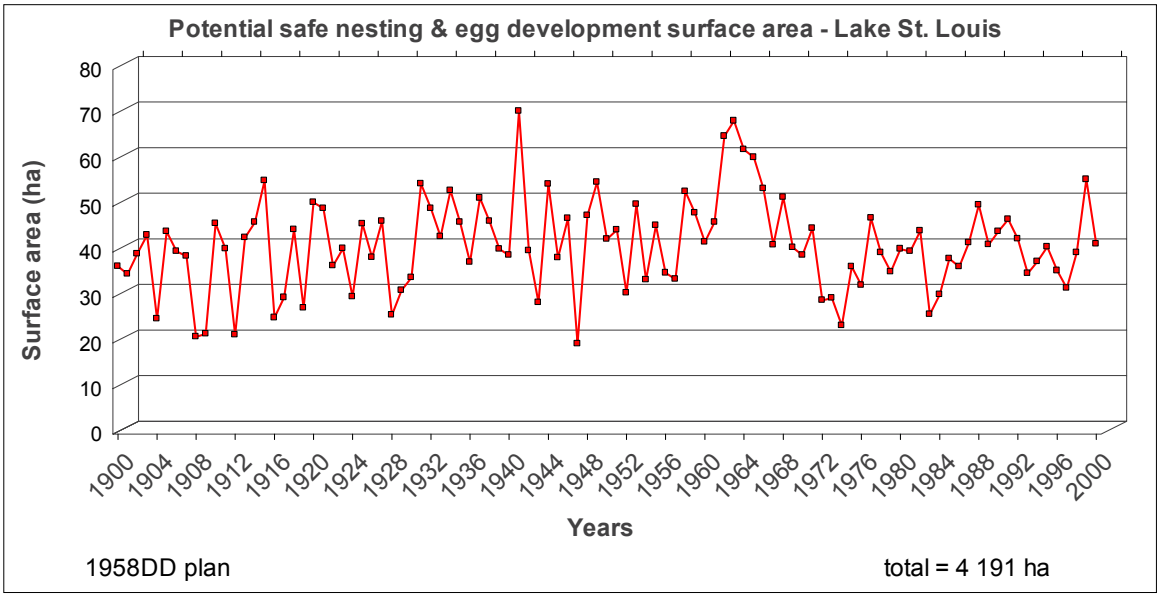


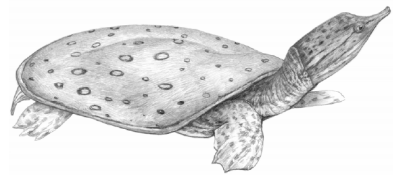
Figure 20. Potential safe spawning and egg development surface area for the Northern map turtle over 100 years (from 1900 to 2000) with the 1958 DD plan.

11. Performance indicator: Rare and Endangered fish species; Potential safe egg laying/developement habitat available of the Spiny Softshell turtle (APSP) *Apalone spinifera* (FR: "Tortue molle à épines")

Technical Workgroup: Environment TWG

Research by: Giguère S., P.Laporte, O.Champoux and J.Morin

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



Judie Shore

Activities represented by this indicator: Egg laying and development of the Spiny Softshell, a 50 cm (maximum) aquatic turtle.

Link to water levels: The Spiny Softshell prefers to lay eggs in sand / gravel substrate, normally from 50 cm to 100 cm above the water level. The female always keeps a visual contact with the water during nesting. Water levels fluctuations have three known linkages to this turtle reproduction:

1) Amplitude and duration of flood is a good indicator of the portion of banks / beaches available.
2) Amplitude, duration and recurrence of flood is a good indicator of what the banks / beaches will be made up of (substratum and vegetated or not).
3) Increased of water levels can drown eggs if submerged more than 48 hr.

Importance: The Spiny Softshell is 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 the 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. A Recovery Strategy will be required within two years. Critical habitat protection will be required when the Recovery Strategy or Action Plan will identify it. 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.

Performance Indicator Metrics: Hectares of river bank / beach at a particular flow level with the characteristics preferred by the Spiny Softshell. Flows are those measured at the Sorel gauge.

Temporal validity: We measured the potential nesting habitat available for all of June and the two first quarter months of July while (QM21 to QM 26) we measured the risk to drown eggs from the first quarter month of June until the last one of September (QM 21 to QM 36).

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

Links with hydrology used to create the PI algorithm: The algorithm is based on the mean value of discharge estimation at Sorel from QM21 to QM26 for the potential nesting

period and from 21 to 36 for the mortality potential period. The two models built to create the PI are presence / absence type models. These models are based on the parameters and values coming from literature review and expert's opinions (more info in Giguère and Laporte 2002-2003 final report).

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 denuded ground
- Bank vegetation = beach or denuded ground
- Lower bank vegetation = beach or denuded ground
- Top bank vegetation density < 5% + substratum = sand or gravel
- Bank vegetation < 5% + substratum = sand or gravel
- Lower bank vegetation < 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 to > 0 m during at least one of the considered QM.

A 2D habitat model that computes the probability of 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 (mortality). The full 2D models are reduced to a simplified matrix that is a function of flow and water level decrease.

Validation: There is no known nesting site of Spiny Softshell in the study area. In the 1980's, two individuals were observed in the northern part of Lake St. Louis and in 1999, one specimen was observed in the western part of Lake St. Pierre. The highlighted sites shown on the above map were visited by Giguère and match very well the characteristics selected in this modeling effort. Several traces of nesting activities have been seen (digging) without identification of the species (no individuals were seen). The 1958DD time series is also behaving very well, allowing more surface area in the low water levels periods (i.e. beginning of 1960's) and less habitat in the high water levels period (i.e. mid 1970's). This is very coherent since a low water level leads more banks and beaches while a high water levels have the opposite effect.

Documentation and References:

Fletcher, M. (2002) Update COSEWIC status report on the Spiny softshell turtle, *Apalone spinifera*, in Canada. Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Ottawa, 17 pp.

Giguère S. and P.Laporte (2003) Évaluation Des Impacts Des Fluctuations Hydrologiques sur Les Espèces En Péril. Tronçon Fluvial Du Saint-Laurent (Cornwall – Pointe-Du-Lac). Le développement d'indicateurs de performance. Rapport final - Année 3 (2003 - 2004). IJC Report.

The latest reference document includes a complete literature review of the species egg laying and development habitat and period and is available at: ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports

Risk and uncertainty assessment: The model used to build this PI is exactly the same that for the Northern Map Turtle because both of the species used the same type of habitat in the same period of the years. We are confident that this model will accurately predict which June to September flows are better or worse for Spiny Softshell nesting and egg development. The predicted area should be close to the reality since the database used to build the PI is quite precise. Even if the predicted area is not exactly correct, this error will be essentially constant over the range of flows, so they will not undermine the usefulness of the model for ranking plans. 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. The PI also does not reflect other important factors that determine Spiny Softshell population, such as water quality, availability of food or human disturbance. In our expert opinion, this does not significantly diminish the value of this PI because we feel available nesting and egg development area is generally the factor that drives population. However, there is a big uncertainty linked to the real presence of the species in the study area. On the three recorded observations, two are old (1982 and 1987) while the most recent one (1999) can be an exotic specimen (found with another individual of an exotic species not living in Québec province). The species has been actively searched during the last decade. Facing this risk but keeping in mind the precautionary principle, we recommend merging this PI with the Map Turtle one in order to provide a Turtle at risk PI. The fact that the Map Turtle PI is only valid for Lake St. Louis does not diminish the ability of the resulting PI since Lake St. Louis area and entire area have exactly the same behavior (see graphs).

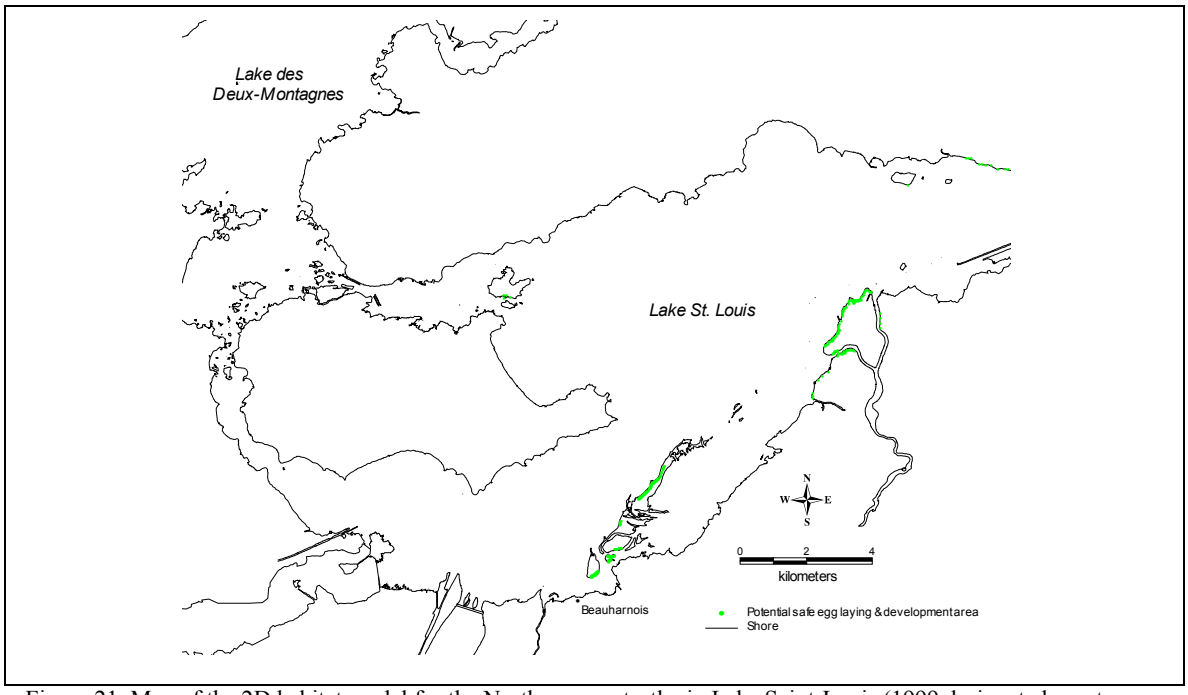


Figure 21. Map of the 2D habitat model for the Northern map turtle, in Lake Saint-Louis (1999 designated quarter month)

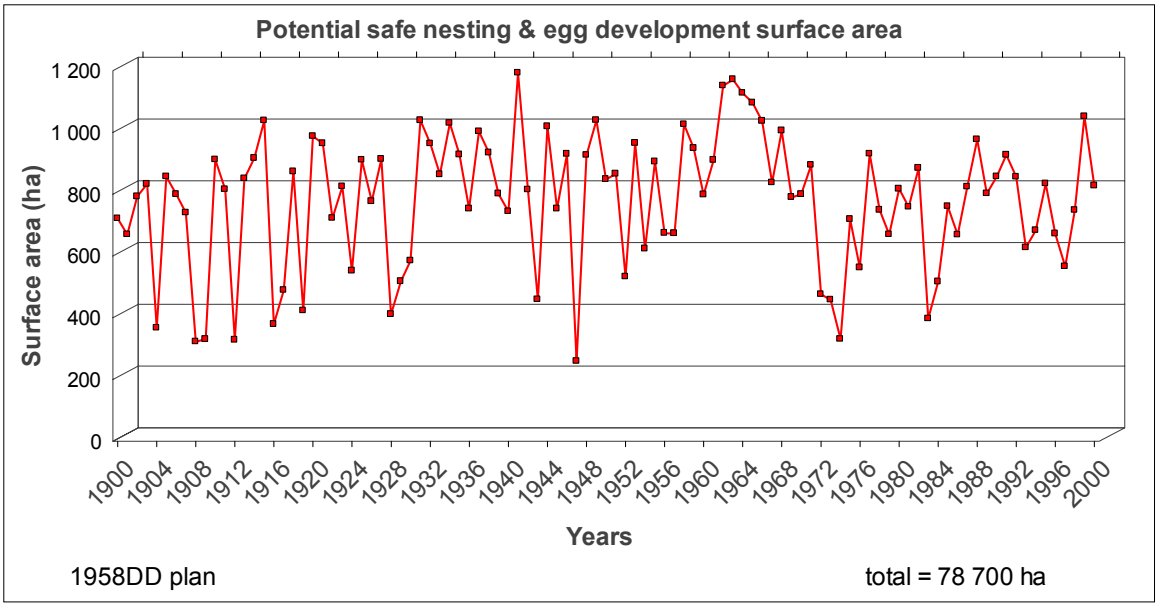
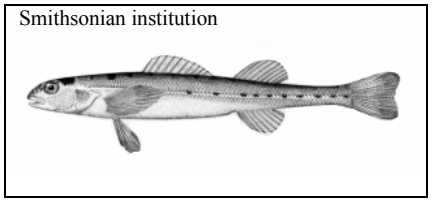


Figure 22. Potential safe spawning and egg development surface area for the Northern map turtle over 100 years (from 1900 to 2000) with the 1958 DD plan.

12. Performance indicator: Rare and Endangered fish species; Potential safe spawning and egg development habitat available of the Eastern Sand darter (AMPE) *Ammocrypta pellucida* (FR: "Dard de sable")



Technical Workgroup: Environment TWG

Research by: Giguère S., P.Laporte, O.Champoux and J.Morin

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

Activities represented by this indicator: Spawning and egg development of the Sand Darter, a small (4 cm to 7 cm) sedentary percid fish.

Link to water levels: The Sand Darter prefers to spawn in 15 cm to 120 cm of water with a current velocity less than 20 cm/s that creates silt-free sandy bottoms. Water level fluctuations have three 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, which is the most important parameter.
2) High water levels tend to mean cooler water temperatures; temperature controls spawning and larvae development.
3) Drop of water levels can dry up eggs and larvae.

Importance: The Sand Darter is considered as a species at risk all over its distribution range. It is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed as threatened in the schedule 1 of the Species At Risk Act; the species and its habitat are protected under this Act. A Recovery Strategy is required for this species and critical habitats should be identified. Critical habitat protection will be required when the Recovery Strategy or Action Plan will identify it. Since this fish is also classified as Threatened in the United States, it can be concluded that the genetic diversity, expressed in behavior, ecology, and morphology is in jeopardy. The indicator gives the available safe potential surface area of spawning and egg development habitat for different water discharge.

Performance Indicator Metrics: Hectares of river bed at a particular flow level with the characteristics preferred by the Sand Darter. Flows are those measured at the Sorel gauge.

Temporal validity: We measured the potential spawning habitat for the three last quarter months of June and the two first of July (QM22 to 26) while we measured the risk to dry up eggs and larvae from the second quarter months of June until the third one of July (QM 22 to 27).

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

Links with hydrology used to create the PI algorithm: The algorithm is based on the mean value of discharge estimation at Sorel from QM22 to QM26 for the potential spawning period and from 22 to 27 for the mortality potential period The two models built

to create the PI are presence / absence type models. These models are based on the parameters and values coming from literature review and expert's opinions (more info in Giguère and Laporte 2002-2003 final report).

Potential spawning habitat model (QM 22 to 26)

Habitat is considered as suitable if all the following features are present: presence of sand in the substrate polygon > 70%; current velocity > 0 m/s and < 0.2 m/s; water depth > 0.15 m and < 1.20 m; submerged vegetation density < 3.

Mortality model (QM 22 to 27)

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

A 2D habitat model computes the probability of 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 (mortality). The full 2D models are reduced to a simplified matrix that is a function of flow and water level decrease.

Validation: There is no known recorded observation for the Sand Darter within the reproduction period. However, The *Société de la Faune et des Parcs du Québec (FAPAQ)* has five recorded observations of this rare species in the study area. Considering that this sedentary fish does not seem to move a lot to reach its spawning ground, these observations were used to validate the model and match the characteristics selected in this modeling effort (3/5 observations fit the model).

Documentation and References:

Holm, E. and Mandrak, N. E. (1994) Status Report on the Eastern Sand Darter, *Ammocrypta pellucida*, in Canada. Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Ottawa, 18 pp.

Giguère S. et P.Laporte 2003. Évaluation Des Impacts Des Fluctuations Hydrologiques sur Les Espèces En Péril. Tronçon Fluvial Du Saint-Laurent (Cornwall – Pointe-Du-Lac). Le développement d'indicateurs de performance. Rapport final - Année 3 (2003 - 2004). IJC Report.

The latest reference document includes a complete literature review of the species spawning and egg development habitat and period and is available at: ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports

Risk and uncertainty assessment: We are confident that this model will accurately predict which June-July flows are better or worse for Sand Darter above mentioned activities. The predicted area may differ by a factor of 2 with the actual area because we do not have square meter by square meter data on the nature of substrate, but these errors will be essentially constant over the range of flows, so they will not undermine the usefulness of the model for ranking plans. 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 determine Sand Darter 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.

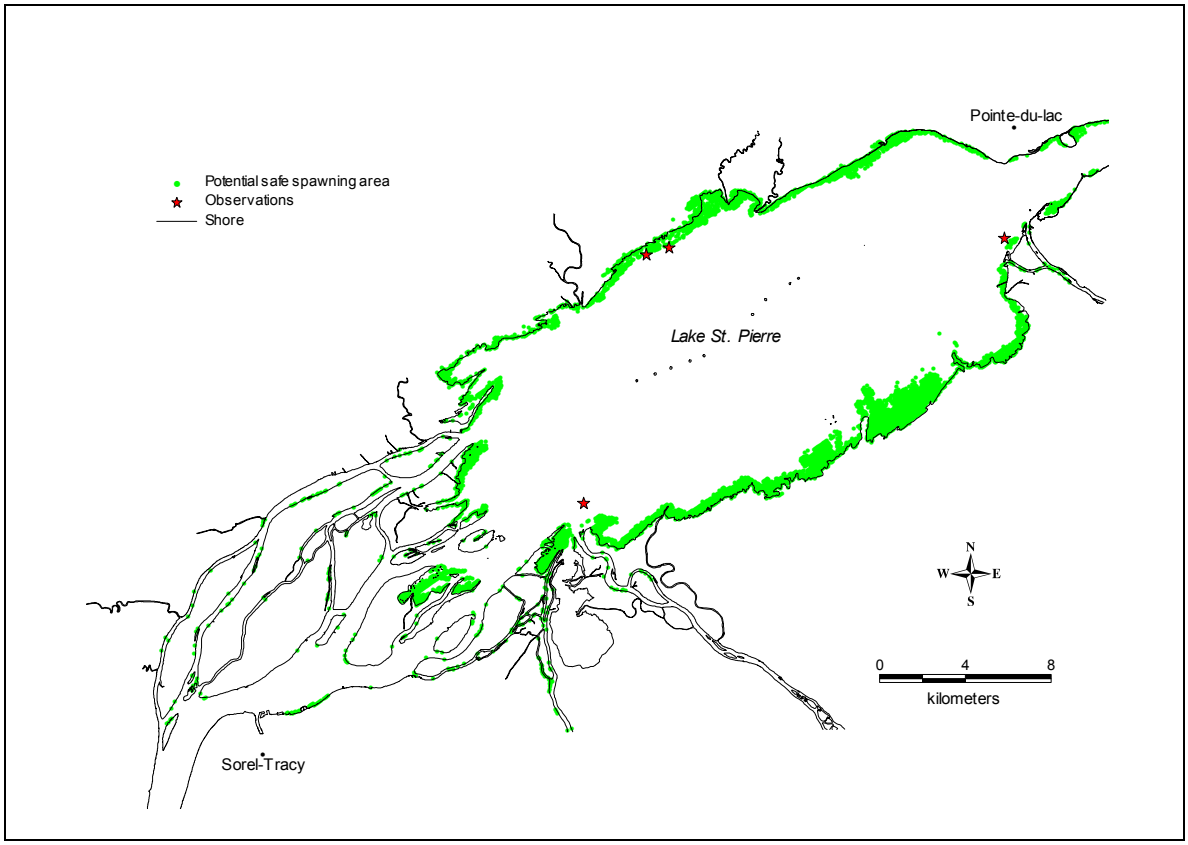


Figure 23. Map of the 2D habitat model for the Sand darter, in Lake Saint-Pierre (2002 designated quarter month)

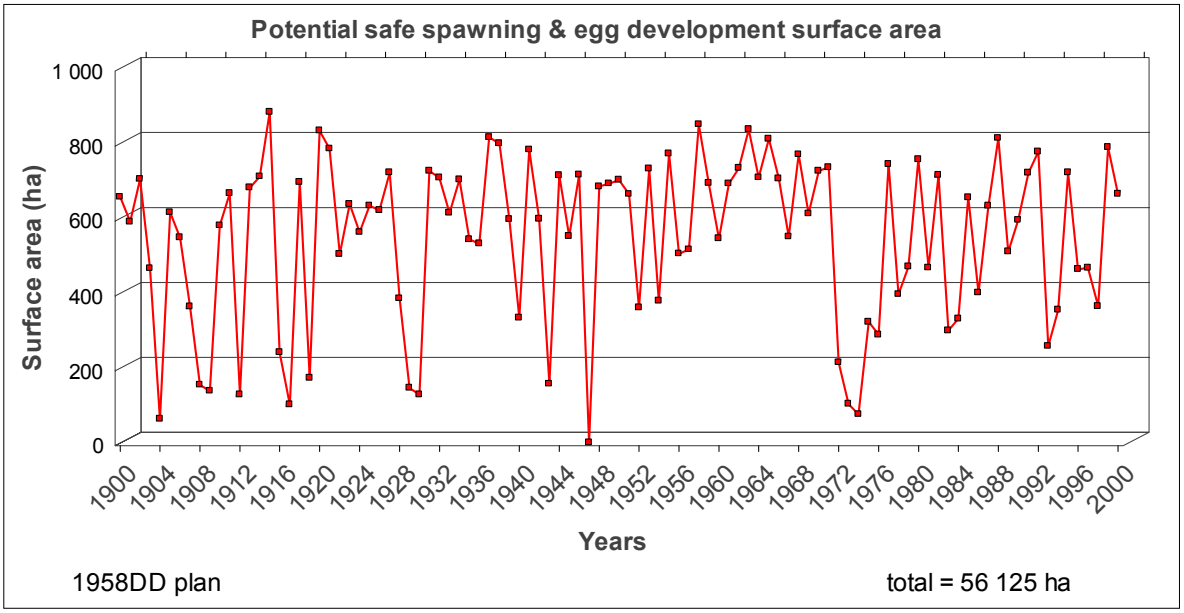
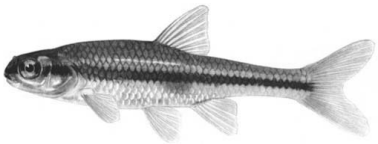


Figure 24. Potential safe spawning and egg development surface area for the Sand darter over 100 years (from 1900 to 2000) with the 1958 DD plan.

13. Performance indicator: Rare and Endangered fish species; Potential safe spawning and egg development habitat available of the Bridle Shiner turtle (NOBI) *Notropis bifrenatus* (FR: "Méné d'herbe")



Technical Workgroup: Environment TWG

Research by: Giguère S., P.Laporte, O.Champoux and J.Morin

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

Activities represented by this indicator: Spawning and egg development of the Bridle Shiner, a small (6 cm maximum) feeder fish (fish eaten by larger fish).

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

1) Hydrological characteristics are good indicators of the submerged vegetation composition and density, and the presence of this submerged vegetation is the most important parameter.
2) High water levels tend to mean cooler water temperatures; is controls spawning timing and larvae development.
3) High water levels can drag submerged vegetation containing eggs and larvae.
4) Drop of water levels can dry up eggs and larvae.

Importance: 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. Under this Act, a management plan, including appropriate measures for the conservation of the species, is required. Wherever it occurs in sufficient numbers, the Bridle Shiner is presumably an important forage fish for a variety of important game fish. The indicator gives the available safe potential surface area of spawning and egg development habitat for different water discharge.

Performance Indicator Metrics: Hectares of river at a particular flow level with the characteristics preferred by the Bridle Shiner. Flows are those measured at the Sorel gauge.

Temporal validity: We measured the potential spawning habitat available for all of June and the two first quarter months of July (QM21 to QM26) while we measured the risk to dry up eggs and larvae from the first quarter month of June until the third one of July (QM21 to QM27).

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

Links with hydrology used to create the PI algorithm: The algorithm is based on the mean value of discharge estimation at Sorel from QM21 to QM26 for the potential spawning period and from 21 to 27 for the mortality potential period. The two models built to create the PI are presence / absence type models. These models are based on the parameters and values

coming from literature review and expert's opinions (more info in Giguère S. and P.Laporte 2002-2003 final report).

Potential spawning habitat model (QM 21 to 26)

Habitat is considered as suitable if all the following features are present: substrate polygon contains > 0% of clay or silt or sand; current velocity > 0 m/s and < 0.15 m/s; water depth > 0.6 m and < 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.

A 2D habitat model computes the probability of 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 (mortality). The full 2D models are reduced to a simplified matrix that is a function of flow and water level decrease.

Validation: There is no known recorded observation for the Bridle Shiner within the reproduction period. However, The Société de la Faune et des Parcs du Québec (FAPAQ) has several recorded observations of this rare species for Lake St. Pierre and its archipelago for the summer period. Considering that this poor swimmer fish does not move a lot to reach spawning ground, these observations were used to validate the model and match pretty well the characteristics selected in this modeling effort.

Documentation and References:

Holm, E., Dumont, P., Leclerc, J., Roy, G. et Crossman, E.J. (1999) COSEWIC Status of the bridle shinner, Notropis bifrenatus. Comité sur la situation des espèces en péril au Canada, Ottawa, 21 p.

Scott, W.B. and Crossman, E.J. (1973) Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184, 1026 p.

Giguère S. and P.Laporte 2003. Évaluation Des Impacts Des Fluctuations Hydrologiques sur Les Espèces En Péril. Tronçon Fluvial Du Saint-Laurent (Cornwall – Pointe-Du-Lac). Le développement d'indicateurs de performance. Rapport final - Année 3 (2003 - 2004). IJC Report.

The latest reference document includes a complete literature review of the species spawning habitat and period and is available at:
ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports

Risk and uncertainty assessment: We are confident that this model will accurately predict which spawning period flows are better or worse for Bridle Shiner spawning. The predicted area should be close to reality since the submerged vegetation models used in this modeling are very close to the reality. On the other hand, this potential habitat model used a substrate database that does not have square meter by square meter data on the nature of substrate. However, the errors that follow from this parameter will be essentially constant over the range of flows, so they will not undermine the usefulness of the model for ranking plans. 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. The PI also does not reflect other important factors that determine Bridle Shiner population, such as predation rate, water quality or food availability. 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.

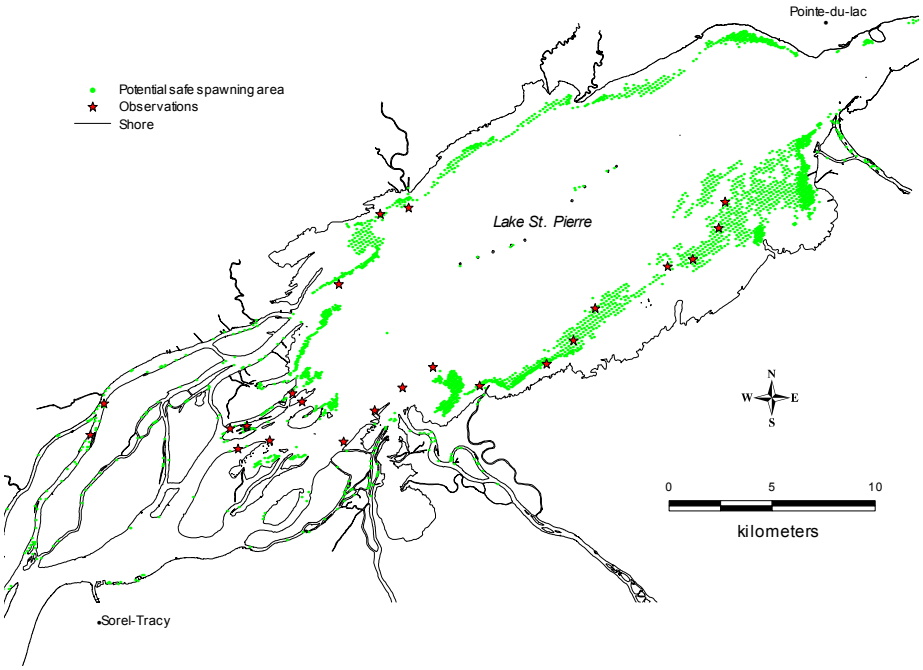


Figure 25. Map of the 2D habitat model for the Bridler shiner, in Lake Saint-Pierre (1995 designated quarter month)

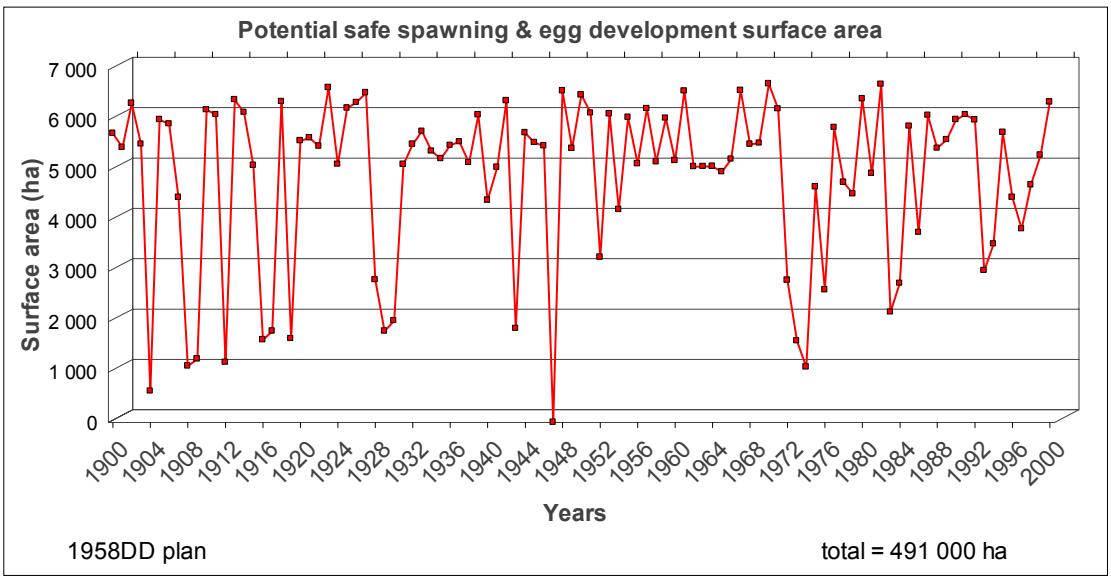


Figure 26. Potential safe spawning and egg development surface area for the Bridler shiner over 100 years (from 1900 to 2000) with the 1958 DD plan.

VI Migratory birds

14. Performance indicator: Waterfowl nest losses after flooding event

Technical Workgroup: Environment TWG

Research by: Lehoux D., D.Dauphin, P.Laporte, O.Champoux and J.Morin.

Modeled by:, Champoux, O., J. Morin and Dauphin D., with regression model based on a 2D estimation of available habitat.

Activity represented by this indicator: Impacts of increased water levels on annual waterfowl nest losses.

Link to water levels: Waterfowl nests are more susceptible to flooding when sudden increases (>20cm) occur during prevailing high water levels (>5,0 m).

Importance: The fluvial section of the St. Lawrence River (including the adjoining mainland) harbours some 6000 nests. It hosts almost 50% of the total nesting dabbling duck population of the whole St. Lawrence River. Inappropriate water level increases during the nesting season could increase nest losses, threaten the population and eventually reduce the economic spin-off associated with hunting in that area evaluated at 10 million dollars annually.

Performance Indicator Metrics: Number of nests lost to flooding according to the amplitude of the water level increases, at different water levels and at different periods of the nesting season. Water levels and increases in these levels are those measured at the Sorel gauge.

Temporal validity: Valid between April 13 and July 28 and computed from the QM15 to QM 29.

Spatial validity: Valid for the Lower St. Lawrence between Lake St. Louis and Lake St. Pierre including the adjoining mainland (up to 5,6 km on each side of the River in the lake St. Pierre area and up to 1 km for the other sections).

Links with hydrology used to create the PI algorithm:

The algorithm is based on the mean value of Water level at Sorel from QM15 to QM29

Inappropriate water level increases during the nesting season could induce the following impacts:

1. Increased nest losses cause by floods;
2. An increased nest loss during a given year will have a direct impact on the waterfowl productivity.

Validation: Historical data on productivity (1968-2000) as provided by banding stations were used to make correlation with nest losses.

Documentation and References:

Lehoux, D., D. Dauphin, P. Laporte, J. Morin and O. Champoux, 2004. Recommendation of water plans and final management criteria less detrimental to breeding and migrating waterfowl along the St. Lawrence River within the lake St. Louis and lake St. Pierre area. Environment Canada, Canadian wildlife service.

Risk and uncertainty assessment: This performance indicator shows a very strong correlation between *nest losses* and the *number of water level increases* when the water level was higher than 5,0 m and when water rises were higher than 20 cm (r^2=0,97). Even if there is no doubt that important nest losses during a given year could seriously impede productivity, the correlation between nest losses and productivity was relatively difficult to determine with historical data and only for a short set of data (1968-1980).

VII Wetlands birds

15. Performance indicator: Black Tern (CHNI) reproductive index in emergent marshes.

Research by: Drolet, B., J. Ingram, J.-L. DesGranges

Modeled by: Morin J. , S.Martin, O.Champoux, B.Drolet, J.Ingram and T.Redder with full 2D (LSL) and 1D (LO) model

Activity represented by this indicator: It represents an index of reproductive potential in emergent marsh during the breeding season, based on the carrying capacity (an annual estimate of the number of potential breeding pairs in emergent marsh weighted by water depth and water level increase) multiplied by the rate of nest success (an annual rate of nest success based on the probability that a breeding female will successfully hatch a nest, according to the magnitude of water level change.

Link to water levels: It nests on floating vegetation in emergent marsh vegetation, and prefers marsh habitat that is flooded. The breeding habitat is directly linked to long term water level fluctuations (see Wetland Habitat PI). The percentage of marsh habitat flooded or stranded, and the rate of water level change (rise > 20cm) are important annual factors.

Importance: The North American Bird Conservation Initiative (NABCI) considers the Lower Great Lakes/St. Lawrence plain (BCR 13) critical to its natural cycle. Black Tern is a surrogate species for Pied-billed Grebe (*Podilymbus podiceps*), as several wildfowl species that use emergent marshes as feeding and rearing habitats.

Performance Indicator Metrics: The PI response will be evaluated using the number of years the PI index is above the median of the PI values associated with 1958DD.

Temporal validity: Valid for the Black Tern breeding season from second week of May to the end of July (QM 18 to QM28). The PI does not consider cumulative effects from previous years.

Spatial validity: Valid for the Lake Ontario - Lower St. Lawrence between Lake Ontario and Lake St. Pierre (except lake Saint-François and Laprairie Basin) where emergent marsh exists.

Links with hydrology used to create the PI algorithm: This PI is influenced by hydraulic attributes responsible for emergent marsh surface area. More specifically, its algorithm was developed using Lower St. Lawrence hydrologic values based on a 2D water level and topographic model and upon Ontario and Québec nest record data of nesting chronology, nest heights and water depths below the nest. Three hydraulic attributes were considered: *mean water depth*, the maximum *water level increase* and the maximum *water level decrease*.

The Algorithm: Algorithm for the Black Tern reproductive index PI is made from the multiplication of the carrying capacity values and nest success rate.

Carrying capacity: The algorithm is based on water depth relationship weighted by water increase. The water increase indices were determined using 1) the highest increase of water level (in meters) between two quarter-month during the breeding periods, 2) the wetland transition before and after fluctuation and 3) the water depth after fluctuation (Tab. 1).

Sub PI 1: Black Tern carrying capacity = $(0.1074 + 0.3979 * WD - 0.0590 * WD^2) * B_{IN}$

Where: WD = water depth; B_{in} = Weighting factor for water increase index (IN)

If IN = 0; B_{in} = 1; if IN = 0.2 then B_{in} = 0.74; if IN = 0.4 then B_{in} = 0.09 and if IN = >0.4 then B_{in} = 0

Water depth algorithm lower and upper limits = -0.26 meter to 1.8 meters;

Null carrying capacity upper limits = 0.033 ind./0.64ha.

Table 1: ***Determination of water increase index (IN)***

Wetland transition	Increase of water level (meters)			
	0-0.2	0.21-0.50	0.51-0.70	>0.70
Wet-wet	0	0.4	0.4	0.6
Dry-wet	0.2	0.6	0.8	0.8
Dry-dry	0.6	0.8	0.8	0.8

Nest success: The subPI-2 algorithm is based on nest initiation estimates, nest height and water depth below nest data. Nest height data was adjusted to account for Black Tern specific nest resilience to flooding. Probability of nest loss estimates due to water level increases or decreases were determined based upon a statistical relationship between magnitude of water level change and probability of nest flooding or stranding. Water level change over a nest exposure period was calculated as the maximum water level increase and decrease from the quarter month of nest initiation over the preceding five quarter month period. Either the probability of flooding or stranding was used depending of which had the higher probability value. The other reproductive variables included in the annual nest success equation, baseline nest success (in the absence of hydrologic impact) and the probability that a female will renest if the first nest attempt is unsuccessful (re-nesting rate) were held constant.

SubPI-2: Black Tern nest success = $n_1 + [(1- n_1) * rr * n_2]$

Where: n_1 or n_2 = nest success attempt 1 or 2 where n_i = BN * (1-PF) <u>or</u> BN * (1 - (PS * PSF)

BN = Baseline nest success = 0.5; PF = Prob. of nest flooding (see table A); PS = Prob. of nest stranding (see table A); PSF = Prob. of nest failure due to stranding = 1; rr = renest rate = 0.5

Table 2A: ***SubPI-2: Black Tern's nest flooding/stranding probability (PF/PS)***

Rise of water level (RW; cm)	Decrease of water level (DW; cm)	Black Tern flooding/stranding probability
If RW <= 30	and RW > DW	PF = 0
If RW > 30 and RW < 69	and RW > DW	PF = 0.3277 * Ln (RW) – 0.3838
If RW > 69	and RW > DW	PF = 1
If RW < DW	and DW <= 36	PS = 0
If RW < DW	and DW > 36 and DW < 94	PS = -0.0002 * DW^2 + 0.0453 DW – 1.3473
If RW < DW	and DW > =94	PS = 1

Validation: No external or internal validation has been performed. Relationships between Black Tern and water level were verified with scientific literature and expert opinion.

Documentation and References:

DesGranges,J.L., J. Ingram, B. Drolet, C. Savage, J.Morin, D. Borcard and P.Agin (2003) Lake Ontario- St. Lawrence river water level regulation review: Use of wetland breeding bird evaluation criteria within an integrated environmental response model. IJC final wetland bird technical report (2000-2004).

Risk and uncertainty assessment: We are confident that the BT density PI allows for an accurate comparison (in relative terms) of BT nesting habitat availability between different flow regimes (see accuracy of Deep marsh PIs of various water depth). Nest loss is estimated using a non-linear regression model. It necessarily ignores important ecological variables that could have an influence on Black Tern nesting success (predation, food availability, pollution, etc). Despite these gaps and the appreciable noise in some of our response functions, we believe that our PIs for that species clearly shows an important vulnerability to water level. In our expert opinion, this proportion is large enough to assume that LOSL water fluctuations can have significant impacts on the nesting populations of Black Tern.

This species raises one brood per year. In favourable nesting conditions, only one young female is produced each year per adult female (1 brood/yr; mean fledgling success = 2 young/yr (1 male and 1 female)). If we consider that an adult female will probably reproduce during four years in her life time, this means that most females produce about 4.0 daughters during their reproductive life. Such reproductive traits are typical of K strategist species. This type of species relies more on the number of nesting attempts during their adult life than on the size of their annual progeny. Our "simplified" reproductive model leads us to believe that this species will normally be able to maintain its populations in the LOSL system (without immigration from elsewhere) if it benefits from at least one good reproductive summer every alternate year. Two consecutive bad nesting years can induce a significant decline in their population in the absence of external recruitment.

16. Performance indicator: Virginia rail reproductive index in emergent marshes.

Research by: Drolet,B., J. Ingram, J.-L. DesGranges

Modeled by: Martin S., J.Morin, O.Champoux, B.Drolet, J.Ingram and T.Redder with full 2D (LSL) and 1D (LO) model

Activity represented by this indicator: It represents an index of Virginia Rail reproductive potential in emergent marsh during the breeding season, based on the carrying capacity (an annual estimate of the number of potential breeding pairs in emergent marsh weighted by water depth and water level increase) multiplied by the rate of nest success (an annual rate of nest success based on the probability that a breeding female will successfully hatch a nest, according to the magnitude of water level changes.

Link to water levels: Virginia Rail nests on floating vegetation in emergent marsh vegetation, and prefers marsh habitat that is flooded, but will also breed in unflooded marsh vegetation. The breeding habitat is directly linked to long term water level fluctuations (see Wetland Habitat PI). The percentage of marsh habitat flooded or stranded, and the rate of water level change (rise > 20cm) are important annual factors.

Importance: The North American Bird Conservation Initiative (NABCI) consider the Lower Great Lakes/St. Lawrence plain (BCR 13) critical to the natural cycle.

Performance Indicator Metrics: The PI response will be evaluated using the number of years the PI index is above the median of the PI values associated with 1958DD.

Temporal validity: Valid for the Virginia Rail breeding season from second week of May to the end of July (QM 18 to QM 28). The PI does not consider cumulative effects from previous years.

Spatial validity: Valid for the Lake Ontario - Lower St. Lawrence between Lake Ontario and Lake St. Pierre (except Laprairie Basin) where emergent marsh exists.

Links with hydrology used to create the PI algorithm: This PI is influenced by hydraulic attributes responsible for emergent marsh surface area. More specifically, its algorithm was developed using Lower St. Lawrence hydrologic values based on a 2D water level and topographic model and upon Ontario and Québec nest record data of nesting chronology, nest heights and water depths below the nest. Three hydraulic attributes were considered: *mean water depth*, the maximum *water level increase* and the maximum *water level decrease*.

The Algorithm: Algorithm for the Virginia Rail reproduction index PI is made from the multiplication of the carrying capacity values and nest success rate.

Carrying capacity***:*** The algorithm is based on water depth relationship weighted by water increase and water decrease. The water increase indices were determined using 1) the highest increase and the highest decrease of water level (in meters) between two quarter-months during the breeding periods, 2) the wetland transition before and after fluctuation and 3) the water depth after fluctuation (Tab. 1).

Sub Pi 1 Virginia Rail carrying capacity = $(0.0690 + 0.3040 * WD - 0.1929 * WD^2) * B_{in}$

Where: WD = water depth; Bin = Weighting factor for increase and/or decrease water level index (IN).

If IN = 0 and DE = 0 then Bin = 1; If IN = 0.2 and DE = 0 then Bin = 0.92; if IN = 0.4 and DE = 0 then Bin = 0.33; if IN = 0 and DE = 0.2 then Bin = 0.86; if IN =0 and DE = 0.4 then Bin = 0.31, if IN = 0.2 and DE = 0.2 then Bin = 0.79; if IN = 0.4 and DE = 0.2 then Bin = 0.28; if IN = 0.2 and DE = 0.4 then Bin = 0.28; if IN = 0.4 and DE = 0.4 then Bin = 0.10 and if IN > 0.4 and DE > 0.4 then Bin = 0.

Water depth algorithm lower and upper limits = -0.1metre to 1meter;

Null carrying capacity upper limits = 0.0032 ind./0.64ha.

Table 1B: Determination of water increase index (IN)

Wetland transition	Increase of water level (meters)			
	0-0.2	0.21-0.50	0.51-0.70	>0.70
Wet-wet	0	0.4	0.4	0.6
Dry-wet	0.2	0.6	0.8	0.8
Dry-dry	0.6	0.8	0.8	0.8

Table 1C: Determination of water decrease index (DE)

Water depth after drop	Wetland transition	Decrease of water level (meter)			
		0-0.2	0.21-0.50	0.51-0.70	>0.70
> 0.45 meter	Wet-wet	0	0.2	0.2	0.4
< 0.45 meter	Wet-wet	0	0.4	0.4	0.6
N/A	Wet-dry	0.2	0.6	0.8	0.8
N/A	Dry-dry	0.6	0.8	0.8	0.8

Nest success: The subPI-2 algorithm is based on nest initiation estimates, nest height and water depth below nest data. Nest height data was adjusted to account for Virginia Rail specific nest resilience to flooding and stranding. Probability of nest loss estimates due to water level increases or decreases were determined based upon a statistical relationship between magnitude of water level change and probability of nest flooding or stranding. Water level change over a nest exposure period was calculated as the maximum water level increase and decrease from the quarter month of nest initiation over the preceding five quarter month period. Either the probability of flooding or stranding was used depending of which had the higher probability value. The other reproductive variables included in the annual nest success equation, baseline nest success (in the absence of hydrologic impact) and the probability that a female will renest if the first nest attempt is unsuccessful (re-nesting rate) were held constant.

SubPI-2: Virginia Rail nest success = $n_1 + [(1- n_1) * rr * n_2]$

Where: n_1 or n_2 = nest success attempt 1 or 2 where n_i = BN * (1-PF) <u>or</u> BN * (1 - (PS * PSF)

BN = Baseline nest success = 0.5; PF = Prob. of nest flooding (see table A); PS = Prob. of nest stranding (see table A); PSF = Prob. of nest failure due to stranding = 0.5; rr = renest rate = 0.4

Table 2A: SubPI-2: Virginia Rail's nest flooding/stranding probability (PF/PS)

Rise of water level (RW; cm)	Decrease of water level (DW; cm)	Virginia Rail flooding/stranding probability
If RW <= 20	and RW > DW	PF = 0
If RW > 20 and RW < 78	and RW > DW	PF = 0.4222 * Ln (RW) – 0.8359
If RW >= 78	and RW > DW	PF = 1
If RW < DW	and DW <= 12	PS = 0
If RW < DW	and DW > 12 and DW < 67	PS = 0.5853 * Ln (DW) – 1.4525
If RW < DW	and DW >= 67	PS = 1

Validation: No external or internal validation was performed for the Virginia Rail's reproduction index PI. Relationships between Virginia Rail and water level were verified with scientific literature and expert opinion.

Documentation and References: DesGranges, J.L., J. Ingram, B. Drolet, C. Savage, J.Morin, D. Borcard and P.Agin (2003) Lake Ontario- St. Lawrence river water level regulation review: Use of wetland breeding bird evaluation criteria within an integrated environmental response model. IJC final wetland bird technical report (2000-2004).

Risk and uncertainty assessment: We are confident that the VR density PI allows for an accurate comparison (in relative terms) of VR nesting habitat availability between different flow regimes (see accuracy of Deep marsh PIs of various water depth). Nest loss is estimated using a non-linear regression model. It necessarily ignores important ecological variables that could have an influence on Virginia Rail nesting success (predation, food availability, pollution, etc). Despite these gaps and the appreciable noise in some of our response functions, we believe that our PIs for this species clearly show an important vulnerability to water level for that species. In our expert opinion, this proportion is large enough to assume that LOSL water fluctuations can have significant impacts on the nesting populations of Virginia Rails.

This species usually raises one brood per year. In favourable nesting conditions, some 2.0 young females are produced each year per adult female (1 brood/yr; mean fledgling success = 4 young/yr (2 males and 2 females)). If we consider that an adult female will probably reproduce for three years (as for the Pied-billed Grebe) in her life time, this means that most females produce about 6.0 daughters during their reproductive life. Such reproductive traits are typical of "r" strategist species. This type of species relies more on the size of their annual progeny than on the number of nesting attempts during their adult life. Our "simplified" reproductive model lends us to believe that this species will normally be able to maintain its populations in the LOSL system (without immigration from elsewhere) unless it experiences two consecutive poor nesting years , in which case an entire cohort may not replace itself thus inducing a considerable population decline in the absence of external recruitment.

17. Performance indicator: Wetland obligate bird species richness in emergent marshes

Technical Workgroup: Environment TWG

Research by: Drolet B., J.-L.DesGranges and J.Ingram

Modeled by: Martin S., J.Morin, O.Champoux, B.Drolet, J.Ingram and T.Redder with full 2D (LSL) and 1D (LO) model **Activity represented by this indicator:** It represents the number of wetland obligate bird species that could be expected to occur in emergent marshes during nesting period.

Link to water levels: Wetland obligate bird species build their nests either on a floating platform over water, on the ground near the water edge or in robust vegetation slightly above water (Table 1).

	Names			Nesting strata		
Code	**Latin**	**English**	**French**	**Floating**	**Ground**	**Above water**
AMCO	*Fulica americana*	American Coot	Foulque d'Amérique	x		
BLTE	*Chlidonias niger*	Black Tern	Guifette noire	x		
COMO	*Gallinula chloropus*	Common Moorhen	Gallinule poule-d'eau	x		
PBGR	*Podilymbus podiceps*	Pied-billed Grebe	Grèbe à bec bigarré	x		
SORA	*Porzana carolina*	Sora	Marouette de Caroline	x	x	
VIRA	*Rallus limicola*	Virginia Rail	Râle de Virginie	x	x	
REDH	*Aythya americana*	Redhead	Fuligule à tête rouge	x	x	
AMBI	*Botaurus lentiginosus*	American Bittern	Butor d'Amérique		x	
AMWI	*Anas americana*	American Wigeon	Canard d'Amérique		x	
BWTE	*Anas discors*	Blue-winged Teal	Sarcelle à ailes bleues		x	
COSN	*Gallinago gallinago*	Common Snipe	Bécassine des marais		x	
GADW	*Anas strepera*	Gadwall	Canard chipeau		x	
MALL	*Anas platyrhynchos*	Mallard	Canard colvert		x	
NSHO	*Anas clypeata*	Northern Shoveler	Canard souchet		x	
SPSA	*Actitis macularia*	Spotted Sandpiper	Chevalier grivelé		x	
MAWR	*Cistothorus palustris*	Marsh Wren	Troglodyte des marais			x
LEBI	*Ixobrychus exilis*	Least Bittern	Petit Blongios			x
SWSP	*Melospiza georgiana*	Swamp Sparrow	Bruant des marais			x

The nests of these 18 species are susceptible to flooding due to storm events and rapid water level rises (>20 cm) during the breeding season. Water level rises will affect different subsets of marsh species depending on the number of nesting strata that happen to be flooded during the nesting season. It thus has a direct effect on the potential number of wetland bird species (i.e. species richness) that can successfully breed in a particular marsh. On the other end, neither water depth nor water stranding seem to affect species richness.

This PI represents the mean species richness computed from all nodes found in emergent marshes. It does not represent cumulative species richness and should be equal for all emergent marshes with still water (as in perched marshes and impoundments).

Importance: Species richness is often used as a proxy for biodiversity, and as such, can be seen as an indicator of ecosystem integrity. Being easily understandable, this PI can be used to insure that public opinion is sensitive enough to the environmental consequences of water regulation.

Performance Indicator Metrics: The ration between 1958DD mean richness and alternative plans.

Temporal validity: Valid from second week of May to the end of July (QM 18 to QM28). This PI does not consider cumulative effects from previous years.

Spatial validity: Valid for all emergent marshes, from Lake Ontario to Lake St. Pierre (except lake Saint-François and Laprairie Basin)..

Links with hydrology used to create the PI algorithm: It is influenced by hydraulic attributes that are responsible for emergent marsh surface area. More specifically, the algorithm was developed using Lower St. Lawrence hydrologic values (because of the greatest occurrence of the water fluctuation events), based on a 2D water level and topographic model. Only one hydraulic attribute showed direct linkages on bird species richness: the maximum *water level increase* (negative effect) between two consecutive quarter months during the breeding season. Water depth and water level decrease were not significant.

The Algorithm: The relationship with water increase index (IN) was determined by performing linear and non-linear regressions. The regression equation that 'best fit' the data from a statistical and biological standpoint was selected for modeling purposes (Fig. 1a). The water level increase indices were determined using 1) the highest increase of water level (in meters) between two quarter-months during the breeding period, 2) the wetland transition before and after fluctuation, and 3) the water depth after fluctuation (Tab. 2).

*Bird Richness = 8.1262 – 6.9571 * IN*
Wetlands type applicable = Emergent marsh;
Water depth algorithm lower and upper limits = [-0.33 metre to 1.8 metres];

Table 1B: Determination of water increase index (IN)

Wetland transition	Increase of water level (meter)			
	0-0.2	0.21-0.50	0.51-0.70	>0.70
Wet-wet	0	0.4	0.4	0.6
Dry-wet	0.2	0.6	0.8	0.8
Dry-dry	0.6	0.8	0.8	0.8

Validation: No external or internal validation was performed for the Bird Richness PI. However, statistical descriptors are given to assess model performance.

Documentation and References:

DesGranges, J.L., J. Ingram, B. Drolet, C. Savage, J. Morin, D. Borcard and P. Agin (2003) Lake Ontario- St. Lawrence river water level regulation review: Use of wetland breeding bird evaluation criteria within an integrated environmental response model. IJC final wetland bird technical report (2000-2004).

These reference documents are available at:
ftp://wtoftpa.on.ec.gc.ca/ijcstudy/environment/reports

Risk and uncertainty assessment: This section will be completed once this PI had been incorporated into the IERM, allowing for a comparison of the different water regulation plans for this PI.

VIII Fish global indicators

18. Performance indicator: Total number of fish in the river

Research by: Lafontaine and Marchand

Modeled by: Morin J. and O. Champoux in 1D model

Activity represented by this indicator: Indicator of annual abundance of various adult fish species

Links to water level: This indicator is based on the ratio of the intensity of the spring water level (flood) and the mean summer level.

Importance: (Need to be completed)

Performance Indicator Metrics: (Need to be completed)

Temporal validity: One value computed per year.

Spatial validity: Lower SLR between Sorel Islands and Quebec City. Data collected at one site, but fish migrate and populations are distributed between Sorel Islands and Quebec City.

Links with hydrology used to create the PI algorithm: This indicator is based on the ration of the intensity of the spring water level (flood) and the mean summer level. Daily water levels recorded at Jetty #1 (Montréal Harbour). The variables were used to calculate various descriptive parameters on a seasonal basis (For example: average water level during springtime).

Validation data: Catch data were obtained from a time series of daily fish records at the St-Nicolas experimental trap fishery. Daily catches were recorded from May 15 to November 1, each year since 1975 and were summed over the entire fishing season to derive the annual abundance index.

The algorithm: The algorithm uses the five year spring baseline on Montréal Harbour water level for QM 6 to QM 23

Total fish= 327776- 353253* Five year spring baseline at Montréal Harbour

Documentation and References: Lafontaine Y. and F. Marchand (2003) Hydrological fluctuations and productivity of freshwater fish species in the lower St. Lawrence River. Environment Canada, Montréal, 48p.

Risk and uncertainty assessment: (Need to be completed).

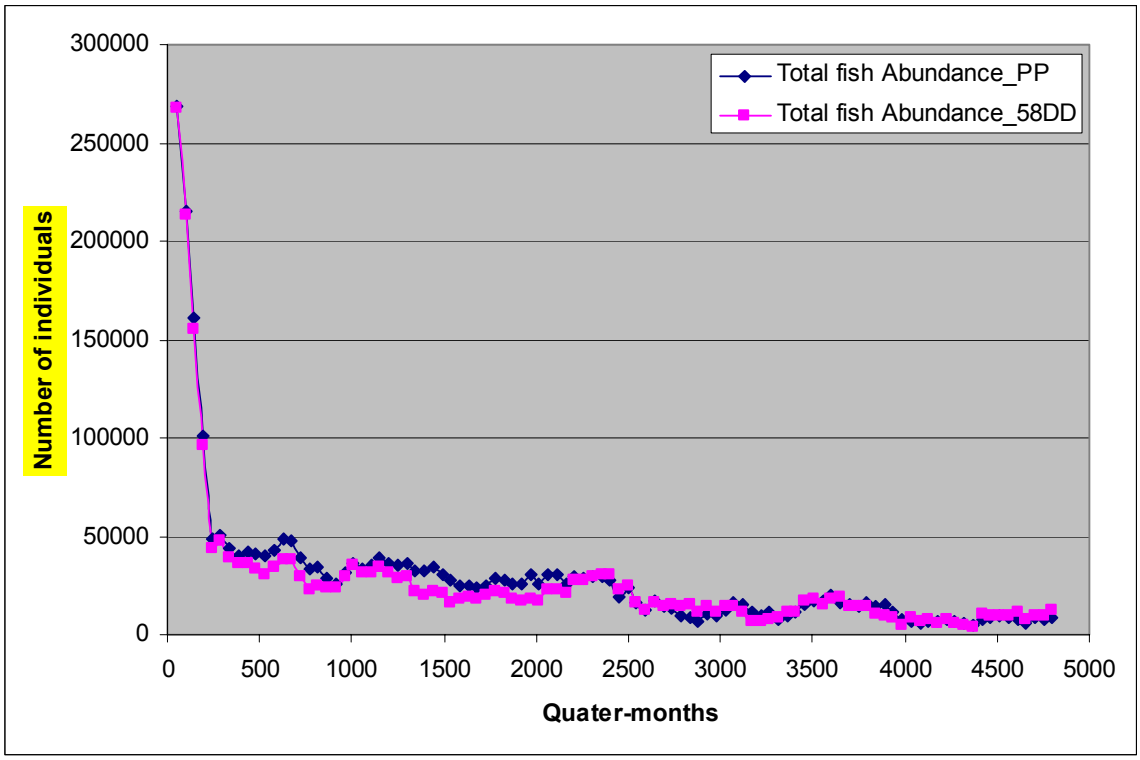


Figure 27. Comparison of the Performance indicator for the 100 years discharge series: Plan 1958DD and PreProject.

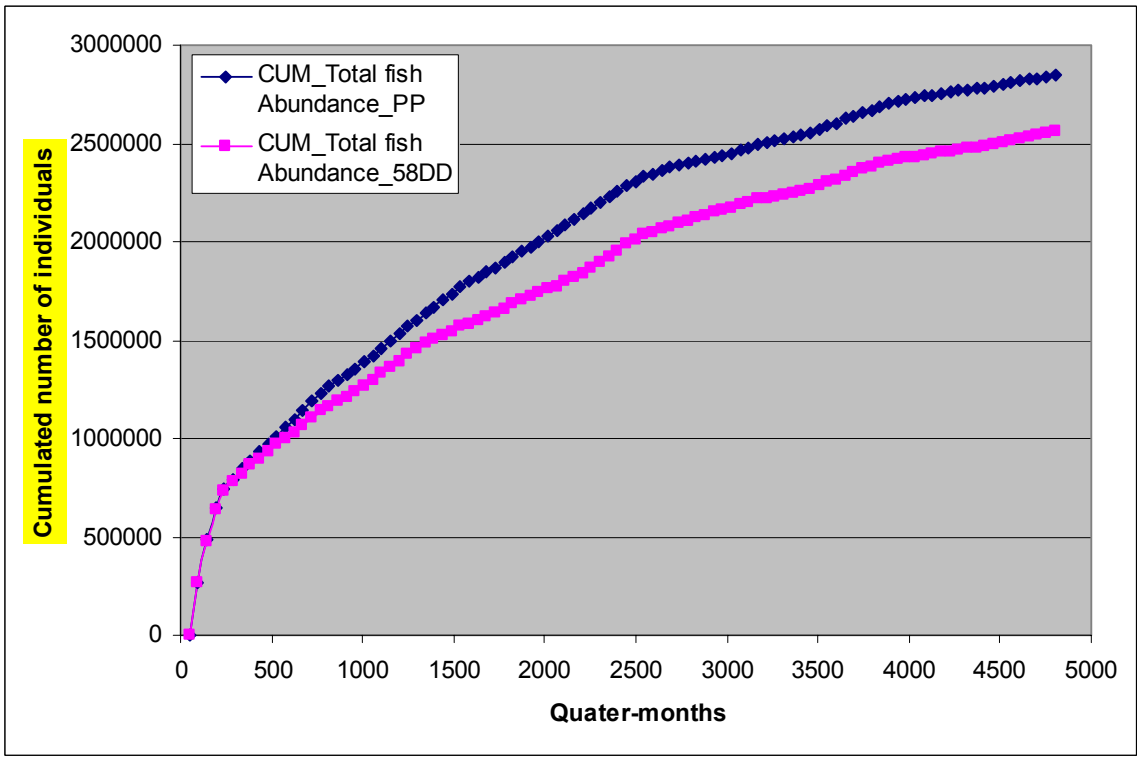


Figure 28. Comparison of the temporally cumulated Performance Indicator for the 100 years discharge series: Plan 1958DD and PreProject.

IX Muskrat winter habitat

19. Performance indicator: Numbers of dwelling houses of muskrats (*Ondatra zibethicus*) surviving to winter

© François Bourgeot

Research by: Ouellet, V. and J. Morin.

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

Activity represented by this indicator: Prediction of the number of dwelling houses and their loss caused by water level fluctuations after ice-cover formation.

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

Importance: Muskrat are herbivorous, eating shoots, roots, bulbs, tubers, stems and leaves of various hydrophytes, especially emergent species, therefore muskrat populations could potentially be regulating wetland habitat structure. This is mostly by controlling expansion of cattails, which is their preferred food supply and building material. The indicator gives the density of dwelling houses for different increases of water levels in January-February, relative to mean water level of November.

Performance Indicator Metrics: Number of dwellings at a particular water level in November and the loss of houses after water level increase (20, 40, 60 and 300 cm) in January and February. Water levels are those measured at the Sorel gauge.

Temporal validity: The estimation of the number of houses 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 (QM 1 to QM 8).

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

Links with hydrology used to create the PI algorithm: The algorithm is based on the mean value of discharge estimation at Sorel from QM40 to QM46 for the potential house building period and from QM 1 to 8 of the NEXT YEAR for the mortality potential period. The principal hydrologic attribute known to have linkages with the establishment of dwelling houses, is the water level and its subsequent fluctuations. For the PI we consider:

1) The mean water level for the four quarters 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.

Like the distribution of plant species is primarily determined by the hydrological attributes, it was possible to include probabilities of Typha into the model. We used a probalistic model (logistic regression) for *Typha latifolia*. This model was developed by Turgeon et al., 2004. We used *Typha* sp. because it's the muskrat's favourite emergent for food and material supplies, thus providing a good evaluator of the potential of an area for establishment of the lodges. The water depth and the probabilities of *Typha* sp. were integrated in a HSI (habitat suitability index). This allows the evaluation of density of dwelling houses, which is further recalculated regarding the increase in the water level after the establishment and the potential for the muskrat to modify his lodge by relocating the chamber to keep the floor dry. The data are from the literature review and expert's opinions.

The Algorithm: 1) $HSI_{establishment} = (HIS_{waterdepth} + HIS_{typha})^{1/2}$

2) *Potentiel of adaptation = Height of lodge – height of chamber dimension of chamber – 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 increase. Between the two limits, a linear interpolation is used to estimate the % of house impacted.

After calculations, we produced a matrix of results, which allowed us to calculated the number of lodges established in November for any years and for many scenarios of water levels and increases. 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 corresponds 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 increase in water level during the winter months:

3) If increases are under 20.00 cm, there is no impact on dwellings
If increases are between 20.00 cm and 74.99 cm, the number of impacted houses is determined by: $y = 0.083214x - 0.083038$
If increases are more than 75 cm, all houses are impacted

Validation: 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:

Ouellet, V., J. Morin and O. Champoux. 2004. Indicator of the number of dwelling houses surviving to increases in water levels during the winter. Environment Canada, SMC-Hydrology. Sainte-Foy. *In processing*.

Turgeon K., O. Champoux, S. Martin et J. Morin 2004. Modélisation des milieux humides de la plaine inondable du Saint-Laurent, du lac Saint-Pierre au lac Saint-Louis. *Rapport scientifique RS-104*. Environnement Canada, SMC-Hydrologie, Sainte-Foy, 70 pages.

Risk and uncertainty assessment: The model allowed us to predict the density of dwelling houses for the mean water level of November and which part of these houses are affected by the subsequent water level fluctuations. We have very few data to estimate the error on predicted densities. Only inventory of dwelling houses from 1988 is available. From the 1988 data set, the variation on the prediction compared to the aerial survey varied from 0.5 to 2 houses per hectare in average. We have limited confidence on the accuracy of the exact number of predicted houses. However, 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 data to estimate the exact impact. We know from the literature that the loss of houses increases the stress on the animals.