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

Final report

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Abstract

The performance indicators, the satisfaction curve and the waterfowl dynamic model that have been developed allow to determine impacts of different water regimes on migrating and breeding waterfowl and represent key tools to define the least detrimental water regimes (scenarios). The performance indicators reveal that water levels will be an important limiting factor for migrating waterfowl present within the lake St. Pierre flooded plains especially when water levels registered at the Sorel gauge are under the 5,5 m elevation. Water rises could, on the other hand, represent some threat to nesting females through nest flooding, mainly if those increases take place during the most intensive nesting periods such as in June when nesting females are abundant and when chances of renesting are substantially reduced. Average water levels registered between April and October could be detrimental to the ducklings survival (productivity) if they are too high (reduction of emergent marsh acreage and then of escape cover; increase chances of nests flooding) or too low (development of botulism in birds; increase in predation).

Following comparison of the different water plans obtained with our performance indicators (one for the migration and two for the reproduction), it appears that no single plan is really more advantageous for the migrating and the breeding waterfowl present within the fluvial section of the St Lawrence River even though some allow a slightly better performance. The most effective plans are Plans A and E either during the migration or the breeding season. Differences between plans are however not statistically significant.

Some water plans are slightly more detrimental to the population dynamic of dabblers. Chances of extinction and probability of a 50% or even a 25% decrease during a 100 years simulation time period are nil or almost nil, no matter which plans are analyzed. However, the probability of a 10% decline in the population during the 100 years time period is different between plans. Plans E and A rank among the less detrimental and being statistically more performing than Plans 1958DD and D.

As all plans have a tendency to induce some impacts, mostly because they maintain lower water levels than required and allow water rises during critical periods of the nesting season, some recommendations (criteria) are proposed. Those recommendations include minimum water levels to maintain during the spring migration and the breeding season and the range of water rises authorized according to the breeding phenology and the water levels at the moment of the rises.

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1. Introduction

The flood plains of the lake St. Pierre area are considered as the most important staging area for waterfowl during the spring migration. Thousands of migrating waterfowl depend of this area each year. Appropriate water levels during April and early May therefore prevent that the flood plains become too small forcing the birds to concentrate in areas where available food could be a limiting factor and could increase inter and intra-specific stress. Such water levels also prevent the birds from being in poor physiological health due to poor nutrition which could potentially reduce their reproductive success significantly. Finally, optimal water levels maintain the economic spin-off related to aquatic bird observation, a very important activity in the sector.

The different archipelagos found within the fluvial section of the St. Lawrence River between Lake St. Louis and Trois-Rivières harbour some 2500 nests of dabbling ducks that will provide close to 500 flying broods in the fall. They host almost 50% of the total nesting dabbling duck population of the whole Saint-Lawrence. Some 25 islands of the 161 islands comprising the study area solely supports close to 60% of the total production of this section. The presence of such numbers of breeding ducks has an important local economic impact estimated at 10 million dollars annually, most of those expenses being made through hunting.

Nesting takes place between mid-April and the early August with a peak at mid-June. The brood rearing period lasts between mid-May and the third week of September with a peak at the end of July. Tall prairies are the preferred nesting habitat while deep emergent marshes are heavily used by broods. The archipelagos of Berthier-Sorel and Contrecoeur support 70% of all nests produced.

Eighty percent (80%) of the area of the most productive islands (25) and 35% of the area of all the islands (161) of the study sector are flooded with a two year recurrence. During the nesting period, water levels that are too high or too variable might make these sought after sites inaccessible but also flood and destroy the nests already established and compromise the reproduction of a certain number of females. Water fluctuations will induce important flooding of nesting habitats only when water reaches higher elevations.

Females raise their broods in deep marshes. Particularly high or low water levels during the brood rearing stages could reduce the areas of this type of marsh which is essential to the survival of the ducklings.

A substantial decrease in the production of ducks in the area could eventually induce an impact on the annual hunt. Most of the dabblers found in the hunters bag during the opening of the hunting season in the Montreal area, are effectively produced on islands influenced by water levels.

2. Objectives

- Modify the performance indicator on nest losses so to take into account the fact that early nesters may renest when their eggs are flooded.
- Develop a new performance indicator to relate productivity provided by the banding stations data on ratio of immatures and female adults with water levels.
- *Finalize the waterfowl dynamic model that integrates data on productivity and nest* losses, as provided with our performance indicators, for the plans analysis.
- Use the waterfowl dynamic model along with the existing performance indicators on the migrating waterfowl and the nest losses to determine *which* water plans could represent the least serious *threat* to the spring migrating and reproductive waterfowl population found in the St. Lawrence River between lake St. Louis and lake St. Pierre ;
- Recommend to the IJC the least detrimental plans and annual water management strategies (criteria) that could be used to improve the adopted future plan so to maintain a healthy population of waterfowl within our study area;

3. Results

3.1 Performance indicator on nest losses taking into account renesting

It is generally recognized in the literature that dabblers females which loose their nests during the early stages of the breeding season have a high propensity to renest. So, the disappearance of a nest early during the nesting season could not be automatically associated with a net lost, simply because the female could renest relatively rapidly, minimizing the real impact of the water levels on the local breeding population.

The average probability of renesting for the different species surveyed within the study area was estimated to be 45%, as determined by a literature review (table 1). Even though the capacity of renesting varies between species and that some of them, especially teals and the Black duck, have a lesser tendency to do so than the Gadwall or the Mallard, we have kept the 45% value to assess the renesting of the overall species; species having lesser chances being weakly abundant within our study area.

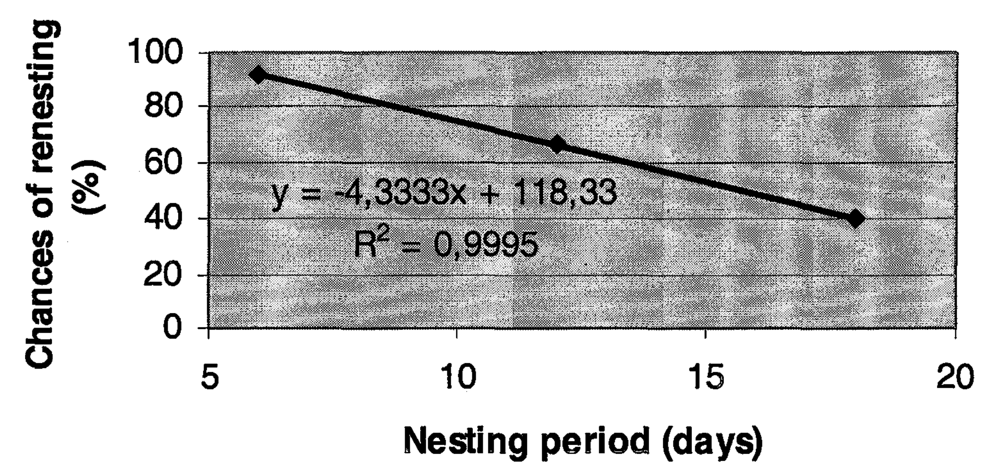
Many authors agree however that the probability of renesting varies with the stage of nesting. Thus, chances of renesting would be in the order of 100% when a female looses its nest during the first days of laying (Gates, 1962; Sowls, 1955), while those chances would gradually decrease during the following days, becoming equal or close to zero during the last days of the incubation. We have assumed that the average renesting probability of 45%, as determined by the literature, could be associated with the stage 3 of the incubation (13-18 days), which represents the middle of the overall nesting period (laying and incubation combined). The probability of renesting for the other phases of the nesting period has been determined with the data provided by Gates (1972) for the Gadwall and summarized in figure (1) and table (2). This author has documented the behaviour of 23 Gadwall females when their nests were destroyed at different stages of the incubation period. He noted that females loosing their nests during the first 6 days of the incubation period were successfully renesting in a proportion of 92%, while those having their nests destroyed between 7-12 days and 13-18 days after the initiation of the incubation, were successfully renesting in a proportion of respectively 67% and 40%.

Table 1 : Probability (%) of renesting of different dabblers species during the entire nesting period

Reference	**Species**					
	Gadwall	**Mallard**	**Shoveler**	**Pintail**	**Teals**	**Black duck**
Keith, 1961	82	100	75		55	
Esler and Grand 1994				31		
Rotella and al, 1993		80				
Grand and Flint, 1996				56		
Guyn et Clark, 2000				55		
Gates, 1962	74					
Sowls, 1978	25	32	21	35	15	
Stotts and Davis, 1960						36
Coulter and Miller, 1968		57				33
Dzubin and Gollop, 1972		50				
Stotts, 1968						16
Strohmeyer, 1967					20	
Dzubin and Gollop, 1972		30				
Average	**60**	**58**	**48**	**44**	**30**	**28**
Overall average	**45**					

Not only will the probablility of renesting vary according to the stage of reproduction, but the length of time required for a female to renest will also vary with the stage at which the first nests are destroyed. According to Sowls (1955), the farther advanced incubation is, the longer the hen waits before nesting again. This phenomenon is illustrated graphically in figure 2 and in table 2 as adapted from Sowls (1955).

Figure 1. Probability of renesting according to the incubation period



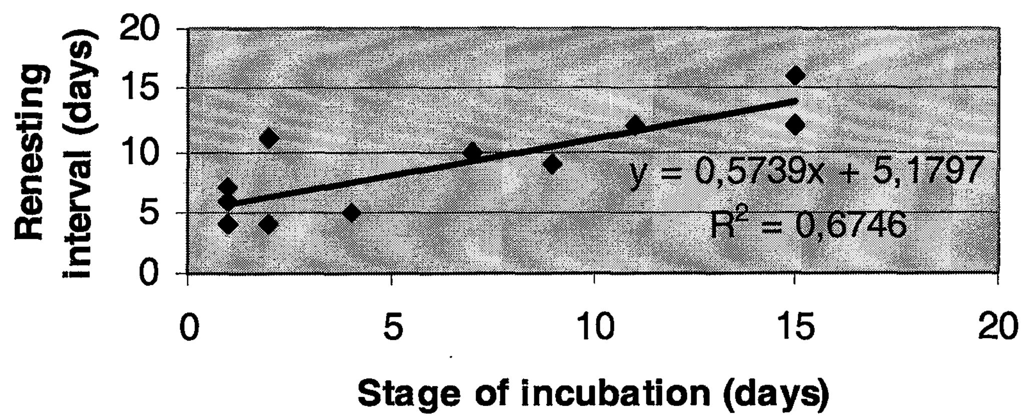
Adapted from Gates (1972)

Table 2. Probability (%), length and ultimate date of renest of dabbling duck species within our study area at different periods of the nesting season

Nesting period	Probability of renest (%)	Renesting interval (days)	Time lapse required to produce fully fledged broods (days)	Ultimate date of potential renesting to produce viable broods
Laying				
Stage 1 : 1-5 days	100	0	85	June 29th
Stage 2 : 6-10 days	95	3-5	89	June 25th
Incubation				
Stage 1 : 1-6 days	92	5-9	92	June 22th
Stage 2 : 7-12 days	67	9-12	95	June 19th
Stage 3 : 13-18 days	**45 (mean determined by literature)**	13-16	100	June 14th
Stage 4 : 19-24 days	14	16-19	102	June 12th
Stage 5 : > 24 days	5 or less	19 or more	104 or more	June 10th

Adapted from Gates (1972) and Sowls (1955)

Figure 2. Length of renesting interval at destruction of first nest during incubation



Sowls (1955)

Then, a female which would loose its nest late during the incubation period and late during the breeding season, would see its chances of renesting substantially decrease. We have estimated that broods should be fully fledged by the end of September, so to have some chances of survival. Table 2 therefore allows to determine ultimate dates of potential renesting for females according to the stage of nesting when loosing their eggs. According to that table, the ultimate potential date for renesting would be around the 29th of June.

Figure (1) and table (2) finally allow to estimate probable real nests losses through water rises according to the nesting stage. For example, a sudden rise of 100 cm of the water level when the water level registered at the Sorel station reaches the elevation 5.24 m and which would flood 378 nests during the third week of May while 50% of the females have reached the stage 1 of laying (1-5 days), 25% the stage 1 of incubation (1-6 days), and 25% the stage 4 of incubation (19-24 days), would then not induce a final impact of 378 nests lost, as estimated with **the previous performance indicator**, but rather a total lost of 81 nests measured as follows:

Probable nests loss:= 378 (number of flooded nests) x 0,5 (% of nests at stage 1 of laying) x 0 (% of females unable to renest) + 378 number of flooded nests) x 0,25 (% of nests at stage 1 of incubation) x 0,08 (% of females unable to renest) + 378 (number of flooded nests) x 0,25 (% of nests at stage 4 of incubation) x 0,86 (% of females unable to renest) = 0 + 8 + 73 = 81 nests really lost.

Appendix 3 shows the **new performance indicator** to assess the number of nest losses according to water rises during the nesting season and which now considers chances of renesting of females.

3.2 New performance indicator on productivity

Lehoux *et al.* (2004) have showed that the performance indicator developed to evaluate impacts of water levels on brood rearing habitat was inappropriate. They have demonstrated that during years when brood rearing marsh areas were insufficient, no impact on waterfowl productivity was noted. The productivity was even higher during years when acreage of brood rearing habitat was reduced. Among factors that could explain such poor correlation we have:

- the possibility that emergent marshes are not a limiting factor for broods within the fluvial section of the St. Lawrence simply because they have a greater support capacity than previously estimated;
- the possibility that broods rely on submerged vegetation when emergent marshes become scarcer;
- the possibility that the number of estimated broods produced in the study area was smaller than expected;
- the possibility that the relationship previously established between the mean annual water levels during plant growing season and the emergent marsh acreage is not appropriate.

For those reasons, the performance indicator dealing with the brood rearing habitat had to be abandoned. It has been replaced by a new one which directly relates hydrological parameters registered at the Sorel station during April-October between 1968-2002 and the **productivity** obtained by data provided on ratio of immatures and female adults following banding operations at the baie Lavallière station in the lake St. Pierre area during the same period (table 3). It was found that the productivity was influenced on one hand by the average water levels registered during the plant growing season (April till October) and on the other hand by the water rises which induced some nest losses to flooding. To be able to correctly correlate productivity with those two hydrological parameters and so to eventually have more pertinent tools to assess the value of different water plans, we had to follow the following step:

Discriminate the effects of both the average water levels and the water rises on the productivity so to be able to compare each water plan according to the two following approaches: impacts of the average water levels alone on productivity and impacts of both the average water levels + water rises on productivity.

Table 3. Productivity of dabblers breeding along the fluvial section of the St. Lawrence River between Lake St. Louis and Lake St. Pierre

Year	Average water levels at the Sorel station (m) (IGLD 85)	Seasonal nest losses to flooding	Estimated productivity with the banding data			Final productivity (without the effects of nest losses) (immatures/f.adult) Modified ratio²
			Immature	F. adult	Ratio¹	
1968	4.78	34	73	21	3.48	3.53
1991	4.87	27	165	33	5.00	5.31
1992	4.81	44	278	49	5.67	5.71
1993	5.19	187	438	82	5.34	5.40
1997	5.19	100	347	47	7.38	7.66
1998	4.98	143	830	97	8.56	8.74
1999	4.32	17	1557	398	3.91	4.00
2000	4.72	112	618	235	2.63	2.81
2001	4.28	16	1400	409	3.42	3.57
2002	4.94	264	781	275	2.84	3.05

ratio 1 = productivity as determined by data collected at the baie Lavallière banding station
ratio 2 = ratio 1 + (nest losses of the corresponding year x 0.0015) to compensate for the reduced productivity due to annual nest losses because of flooding

Productivity related to solely average water levels

The productivity determined by banding data was modified so to eliminate the effect of nest losses due to water rises which has also a tendency to decrease the overall productivity, especially when nest losses are important. It was estimated that each nest loss, or each female unable to nest, induced a decrease in the seasonal overall productivity of 0.0015 immature/adult female. In fact, we assume that each nesting female contributes to 1/5890 (total estimated population) x 9.0 (average number of immatures produced per clutch) of the overall productivity. Therefore, an annual loss of 500 nests due to flooding by water rises during a given year would reduced the productivity by 500 x 0.0015 or by 0.75 immature/adult female. In other words, the overall productivity would then be 8.25 immatures/adult female instead of 9.0, assuming that no other limiting factors were involved.

Knowing, with our performance indicator on nest losses, the number of nests that were flooded during some target years between 1968 and 2002, it was then possible to readjust our productivity for the corresponding years (table 3; ratio 2) Our *performance indicator* then only relates 10 years of productivity with the corresponding average water levels without the effects of water rises on nests (figure 3).

Figure 3. Performance indicator on the variations of the dabblers productivity (without the effects of nest losses) according to the water levels registered between April and October

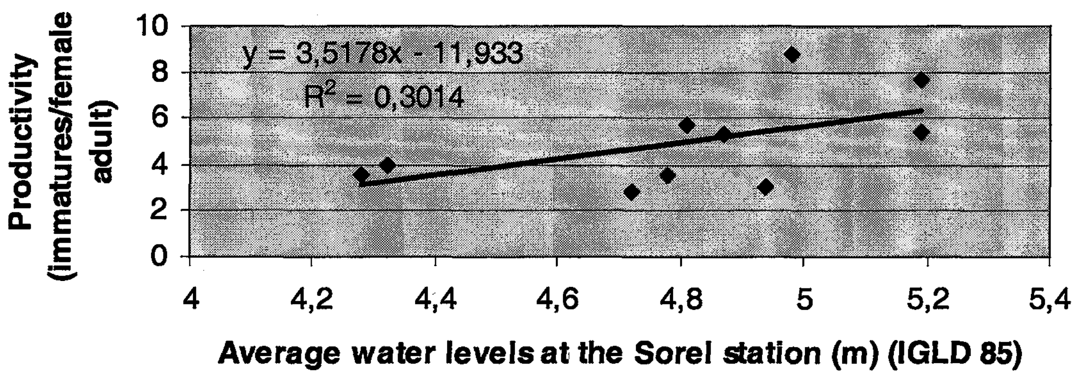
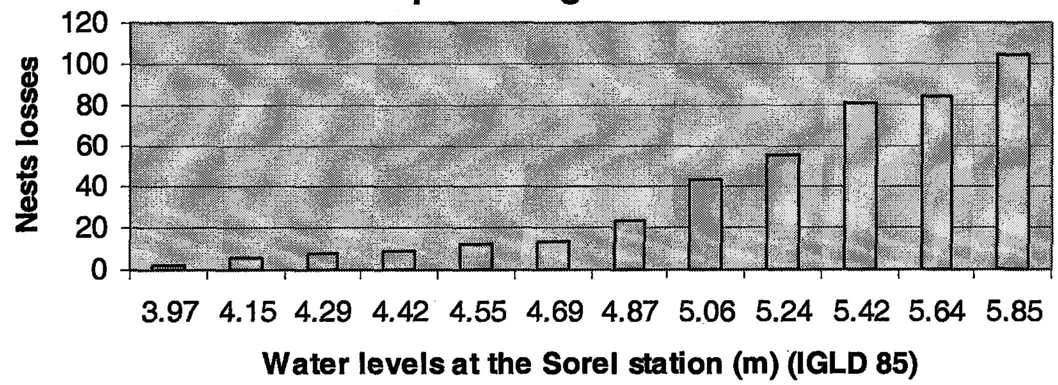


Figure 3 reveals that our model which correlates productivity and average water levels during the plant growing season (without the effects of water rises) is not highly significant ($r^2 = 0.30$). This poor correlation is probably due to the fact that only a small sample of years have been used to build the model. There is however a tendency to have higher productivity when average water levels are maintained at high levels. Productivity seems to decrease during years when average water levels are maintained too low. At lower levels, islands would become more easily accessible to mammalian predators, emergent marshes would become too dry preventing broods to have access to good quality escape cover and chances are that stagnant waters that favour the development of botulism in birds, would increase. However, when average water levels become too high (≥ 5.5 m), it is possible that the productivity could decrease again. At such levels, emergent marshes would become scarce preventing birds to have easy access to escape cover. Furthermore, nests will be more easily flooded following any sudden substantial increase of the water levels. Figure 4 reveals for instance that a rise of 20 cm occurring at the end of June when the water level at the Sorel station is at the elevation 5.42 m, will be almost 15 times more detrimental to the nests than the same rise occurring when the water level is at the elevation 4.15 m.

Figure 4. Expected nests losses following a 20 cm water rise at the end of June according to different prevailing water levels



Productivity related to both average water levels and water rises

In order to be able to measure the additional impact caused by water rises on productivity, that latter impact being tabulated through nest losses, we will use the performance indicator on nest losses (see appendix 3). The number of annual nests lost through water rises is determined on a weekly basis (quarter of month) and not on a daily basis. This procedure underestimates the real number of rises during the nesting season and then the real number of nest losses by an estimated factor of 28%. The additional impact of water rises on productivity will then be tabulated the following way:

Annual productivity as determined with our performance indicator <u>*minus*</u> ((annual nest losses determined with our performance indicator x 1.28 to compensate the fact that nest losses are measured for quarters of month and not on a daily basis) X 0.0015 to take into account the fact that each nest loss induced a decrease of productivity by a factor of 0.0015 immature/female adult as previously mentioned). The final equation is then:

Net productivity = Productivity – ((nest losses x 1.28) x 0.0015)

3.3 Population viability analysis

The population viability analysis is an approach which allows to determine the threats that a population has to face and to evaluate their risks. It is based on a dynamic population model in which, stochasticity could be implemented in order to simulate the natural variation and the uncertainty of the data.

The development of a waterfowl population dynamic model for the fluvial section of the St. Lawrence requires the following information:

An estimation of the breeding population within the study area

Field data collected between 1979 and 1994, a literature review and a theoretical model developed by Bélanger 1989 (see Lehoux *et al.,* 2003 for more details) revealed that the different archipelagos and the immediate terrestrial habitats within a radius of 5.6 km could support close to 6000 nests of breeding waterfowl. We then started the simulation with a population of 6000 females and assumed a stable age distribution among young and adults. We assumed that there was no massive immigration possible and no drastic changes in the survival rates. No density dependencies were modelled but it was estimated that the maximum support capacity could exceed 6000 nests without being greater than 10 000 nests. Therefore, the model never allowed a number of females higher than 10 000 females within the system.

The breeding success or the productivity defined by the number of young/breeding female which reach the fledging status

For the population dynamic model we used an age structure population model based on two age classes; young and adults. We assumed that immatures could breed the following year after hatching. We used only females adults and young females in the population modelling. The productivity provided by each water plan was determined, as previously mentioned, on an annual basis by our performance indicator which correlates productivity with average water levels during the plant growing season. The productivity was also adjusted to take into account the fact that annual nest losses (assessed by our performance indicator) could have a detrimental impact on that productivity; each nest loss decreasing productivity by a factor of 0.0015 young /female adult.

The survival of young and adults between the breeding seasons

The survival rates of female adults and young females present in our study area were estimated with data provided on Mallard by banding stations located along the fluvial section of the St. Lawrence River during the 1985-2003 period. The survival rate used in the model was 0.51 (± 0.017 sd) for adult female and 0.43 (± 0.346 sd) for young female.

The population dynamic was modelled with the help of the software RAMAS. The modeling was run for a 100 years time period. We have associated our estimates with standard deviation. It allows the use of a stochastic model. Such modeling has the advantage to take in account the natural environmental variation and the error sampling of the estimates generated by the various water plans.

Table 4. Data available to develop a population dynamic model for the waterfowl breeding within the fluvial section of the St. Lawrence River

Parameters	Value
Initial breeding population within the studied habitats of the fluvial section of the St. Lawrence River based on the support capacity of each nesting habitat	6 000 adult females (insular habitats + terrestrial habitats within a radius up to 5,6 km on each side of the River)
Productivity (immatures/female adult)	To be determined *annually* during 40 years for each water plan according to the following approach: Productivity as defined with our performance indicator which takes into account the average water level during the plant growing season (see figure 3) and Productivity as defined with our performance indicator which takes into account the average water level during the plant growing season (see figure 3) **minus** productivity loss through nests flooding (nest losses as defined with the appendix 3 + 28% x 0,015) = *number of immatures/female adult produced during a given year*
Survival of adult females (%)	51 ± 1.7 as defined with banding data
Survival of immatures females (%)	43 ± 3.5 as defined with banding data

3.4 Assessment of the impacts of the different proposed water plans on migrating and breeding waterfowl with the performance indicators

Each plan was compared with plan 1958DD (Plan X/Plan 1958DD) in terms of either the average annual number of migrating waterfowl during the migration or the average annual productivity of breeding dabblers; the best plans being those presenting the highest ratio. For instance, a ratio of 1.10 was an indication that the analyzed plan was 10% more performing than Plan 1958DD. On the other hand, a ratio of 0.90 revealed a plan presenting a 10% less impressive performance. For nest losses, the ratio was obtained by rather comparing 1958DD with other plans (Plan 1958DD/Plan X), simply to avoid to rank as a valuable plan, those which induce more severe nest losses.

3.4.1 Impacts on migration

Our performance indicator on migration reveals that only two water plans, during a 40 years time period, support in average less migrating waterfowl (approximately 10%) than Plan 1958DD (table 5). It is especially the case with Plans C and D. Plan 1958DD ranks fourth. The top plan for migration is Plan A, immediately followed by Plans E and B. However, differences between plans are not significant ($p<0.05$) (see appendix 2 for further details on the statistical analysis). It seems therefore that all plans roughly maintain the same water levels within the flood plains of the lake St. Pierre during the most intensive period of the spring migration.

Table 5. Comparison of the different impacts of each water plan on migrating waterfowl as determined with our performance indicator

Water Plan	Migration (sum of the average number of birds estimated for each week of the migration within the flooded plain of lake St. Pierre)	Ratio (1958DD/ plan
A	35 956	1.095
E	34 310	1.045
B	34 015	1.036
1958DD	32 824	1.000
D	30 112	0.917
C	30 073	0.916

3.4.2 Impacts on breeding waterfowl (productivity and nest losses)

Table 6 shows that *no water plan* has really a more detrimental or a more advantageous impact on the productivity (without the effect of nest losses) of the dabbling duck population of the St. Lawrence River after a 40 years period than Plan 1958DD. In fact, we found no statistical evidence (P<0.05) (see appendix 2 for details on the statistical analysis) that the average productivity could be particularly favoured with some of the water regimes. Plan E ranks first and Plan 1958DD ranks fourth, being only 2% less performing than Plan E. This result can be explained by the fact that the average water levels found between April and October do not differ from one water plan to another. Productivity being directly related to that factor, a non significant difference at that level between the different plans, will then automatically lead to a productivity which is relatively equivalent.

Table 6. Comparison of the different impacts of each water plan on the productivity of the breeding waterfowl as determined with our performance indicator

Water Plan	Productivity (average number of immatures/female adult on a yearly basis without impact of nest losses)	Ratio (plan/1958DD)
E	4.02	1.022
A	3.97	1.010
B	3.96	1.007
1958DD	3.93	1.000
C	3.90	0.992
D	3.87	0.984

It also seems that *no water plans* induces substantially more nest losses than Plan 1958DD. No statistical differences were noted between plans (p<0.05) (see appendix 2 for details on the statistical analysis).The worst plan is Plan C which averages close to 5% more nests flooding annually that Plan 1958DD, being again the less performing plan just like for migration. Plan A is the top ranked plan and Plan 1958 ranks second. Those results then suggest that water rises are probably of the same amplitude and happen at the same periods during the season no matter which plan is analyzed.

Table 7. Comparison of the different impacts of each water plan on waterfowl nest losses as determined with our performance indicator

Water Plan	Nest losses (average number of nest losses/year following water rises)	Ratio (1958DD/ plan
A	74	1.081
1958DD	80	1.000
E	81	0.987
D	81	0.987
B	82	0.975
C	85	0.941

3.4.3 Impacts on the population dynamic

Two series of analysis were made, one with the data set on productivity alone without the effects of nest losses and a second one including the effects of nest losses. We compared each water plan only on the probability that the population would get lower than 10% of the initial estimated number at least once during the 100 years time period. Chances that the population becomes extinct or decreases by 50% or even by 25% were found being nil or almost nil (p <0.001).

The probability of a 10% decline in the population during the 100 years time period is not really different from one plan to another no matter if the nest losses effect is considered and even if Plans E and A appear to be statistically different from Plans 1958DD an D. In the overall, the probability of a 10% decline is estimated to be less than 3% among plans even with the effects of nest losses (table 8 and 9). Table 9 ranks plans according to their probability of bringing a 10% decrease in the breeding population. Plans E and A remain the most performing plans as already underlined with our previous performance indicators analysis. while Plans 1958DD and D bring up the rear.

Table 8. Impacts of the different plans on the dynamic of the dabblers population (without nest losses) breeding within the fluvial section of the St. Lawrence River (results of 10 000 simulations)

Water plan	Probability of a 10% decline[1] (%)
	Without nest losses due to water rises
E	0.82 (0.00 – 1.71)
A	0.94 (0.05 – 1.83)
B	1.47 (0.58 – 2.36)
C	1.99 (1.10 – 2.88)
1958DD	2.24 (1.35 – 3.13)
D	2.41 (1.52 – 3.30)

1: probability that the population declines by 10% or more at least once during the simulation time period (100 years)

Table 9. Impacts of the different plans on the dynamic of the dabblers population (with nest losses) breeding within the fluvial section of the St. Lawrence River (results of 10 000 simulations)

Water plan	Probability of a 10% decline1 (%)
	With nest losses due to water rises
E	**1.45 (0.56 – 2.34)**
A	**1.71 (0.82 – 2.60)**
B	**2.93 (2.04 – 3.82)**
C	**3.39 (2.50 – 4.28)**
1958DD	**4.03 (3.24 – 5.02)**
D	**4.45 (3.56 – 5.34)**

1: probability that the population declines by 10% or more at least once during the simulation time period (100 years)

3.4.4 Final prioritisation of plans

In order to present a final prioritization of plans which allows to target those which seem to be slightly less detrimental to waterfowl either during the migration or the reproduction, we have decided to combine information provided by both the performance indicator on migration and the population dynamic model. We think that the assessment of the different water plans based on the population dynamic approach is better to assure an healthy population of breeding dabblers within the fluvial section of the St. Lawrence River than an assessment based solely on the performance indicators on productivity and nest losses. The first approach allows to really put aside plans that could potentially decrease the population on a long term basis.

Table 10 shows the final results. Plans are prioritized according to the summation of the ranks previously allocated for both migration and the population dynamic model. It appears that no matter how we treat the information, some plans remain at the top of the list while others rank at the bottom. Among the best plans we still have Plans E and A. The worst plans would include Plans D, C and 1958DD while Plan B would be classified as being moderately efficient.

Table 10. Prioritisation of plans according to the performance indicator on migration and the population dynamic model

Water plan	Ranking Performance indicator on migration	Ranking Population dynamic model	Ranking Waterfowl (Final)
E	2	1	**1**
A	1	2	**1**
B	3	3	**3**
1958DD	4	5	**4**
C	6	4	**5**
D	5	6	**6**

3.5 Conclusion and final recommended plans and management criteria

Following comparison of the different plans obtained with our three performance indicators (one for the migration and two for the reproduction) (see appendixes) and the population dynamic analysis, it appears that no single plan is really much more advantageous for the migrating and the breeding waterfowl present within the fluvial section of the St Lawrence River even though some allow a slightly better performance, notably Plans E and A. *In other words, no matter which plan is chosen, threats on the waterfowl should be relatively the same.*

All plans have a tendency to induce some impacts, mostly because they maintain lower water levels than required and because they all authorized some water rises. In order to decrease the impacts of the future proposed plan on waterfowl, we then recommend the following approaches.

The six most relevant recommendations (criteria) are summarized in table 11. They also take the form of a satisfaction curve and a satisfaction table (figure 5; table 13) that allow to identify in a comprehensive manner the least detrimental water levels as well as deviations that could be authorized without threatening the waterfowl population of the lower St. Lawrence.

Table 11. Summary of the principal recommendations (criteria) to favour in order to improve future management of the water plan for the benefit of waterfowl

1. During spring migration, between April 10 and May 7, maintain water levels at the Sorel station above the elevation 5.55 m in order to ensure a minimum occupation level of the flood plain by aquatic birds (> 20% of total birds);

2. During the plant growing season (April till October) maintain *average* water levels between the elevation 4.8 and 5.5 m at the Sorel station in order to ensure high productivity of birds in the area;

3. Throughout the intensive brood rearing period of August, never maintain *average* weekly water levels at the Sorel station under the 4.2 m elevation to ensure the presence of quality brood rearing marshes and also to avoid the presence of stagnant waters which favour the development of botulism in birds.

4. During the most intensive period of the nesting season (April 29-July 21) when at least 10-15% of females are active and when water levels registered at the Sorel station are above the 4.9 m elevation, avoid as a general rule all water increases greater than 40 cm between April 29 and May 5; greater than 20 cm between May 6 and the end of June and greater than 30 cm during the first three weeks of July. Increases of greater amplitude are permitted when water levels registered at the Sorel station are lower (see Table 12 to determine the detailed range of water level increases permitted).

5. If greater water level increases than those previously recommended (> 40 cm or > 20 cm) were really required between April 29 and May 19, favour rapid rises (< 7 days) of high amplitudes (> 10 cm/day) in order not to interfere unnecessarily with early nesting waterfowl species (Mallard, Northern Pintail and Black Duck). Up to the third week of May, most of the breeding active females (> 75%) are in the egg laying or in the early incubating phase. Nest losses at this precise period in reproduction would only affect females which can more easily renest when having lost their clutch. It would thus be best to have a rapid destruction of the nest instead of extending this destruction over several days. We would therefore prevent the females from spending important protein reserves unnecessarily to lay eggs which would irremediably be flooded or destroyed;

6. If more important water level increases than those previously recommended (> 20 cm or > 30 cm) were required later in the season, between May 20 and July 21, favour slow water increases (> 7 days) of low amplitude (< 7 cm/day). These water level increases should preferably be carried out in the absence of strong winds (< 25 km/h). This management approach would present numerous advantages for the females which are incubating at this time and which have fewer chances of renesting than the earlier nesters. These advantages being 1: leave more time for the females to complete nesting before the nests are flooded; 2: increase the delay during which the females can raise their nests with new material in order to avoid the effects of flooding and 3: prevent the nests from being moved or completely destroyed by a sudden and rapid water increase.

Table 12. Detailed recommended rises according to existing water levels and the nesting period

Nesting period	Elevation at Sorel (m)(IGLD 85)	Rise (cm)							
		<20	<30	<40	<50	<60	<70	<80	<100
April 29- May 5	> 5.5			X					
	5.0-5.5					X			
	4.5-4.9							X	
	< 4.5								X
May 6- May 19	> 5.5	X							
	5.0-5.5		X						
	4.5-4.9				X				
	< 4.5						X		
May 20-June 2	> 4.9	X							
	4.5-4.9				X				
	< 4.5						X		
June 3-June 30	> 4.9	X							
	4.5-4.9			X					
	< 4.5					X			
July 1- July 21	> 4.9		X						
	4.5-4.9				X				
	< 4.5						X		

FIGURE 5. Satisfaction curve for waterfowl within the lower St. Lawrence River

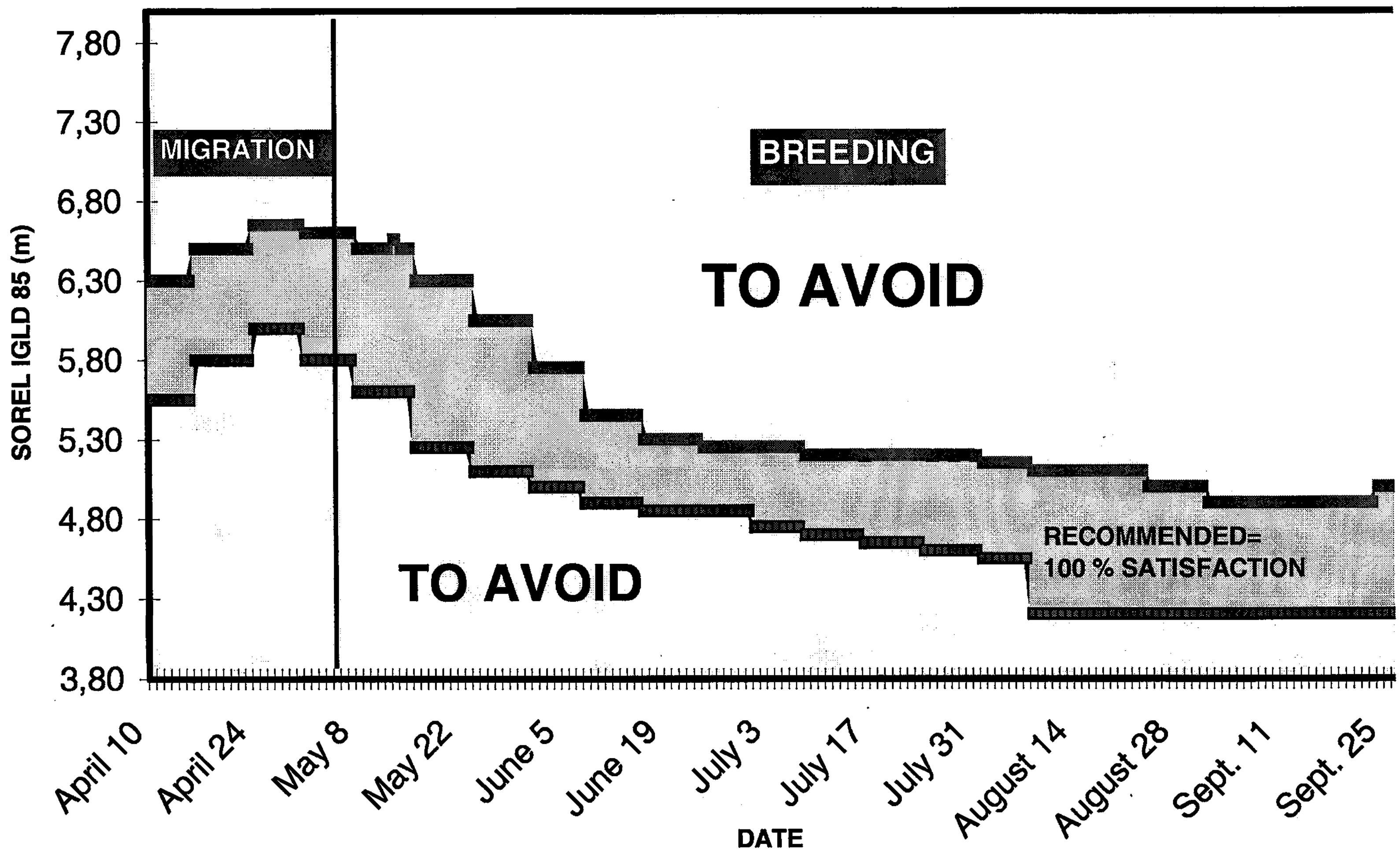


Table 13. Satisfaction table for migrating and breeding waterfowl in the fluvial section of the St. Lawrence River between Lake St. Louis/Lake St. Pierre

Activity	Period	Water level (min)	Water level (max)
Migration	10 April-17 April	5,75	6,84
	Avoid any rises (>40 cm) during the three following weeks. If rises were inevitable, favour rapid rises (< 7 days) of daily large scales (>10 cm/day)		
	18 April-30 April	6,00	6,84
	1 May-7 May	5,92	6,25
Nesting	Drawdown may start. Avoid any rapid rises (>20 cm) during the following weeks (till mid-July). If rises were inevitable, favour slow rises (>7 days) of daily small scales (< 7cm/day)		
	15-31 May	5,00	6,00
	June-10 July	4,50	5,50
Brood rearing	Rises allowed		
	11 July-end July	4,20	4,70
	August	4,20	4,60
	September	4,10	4,60

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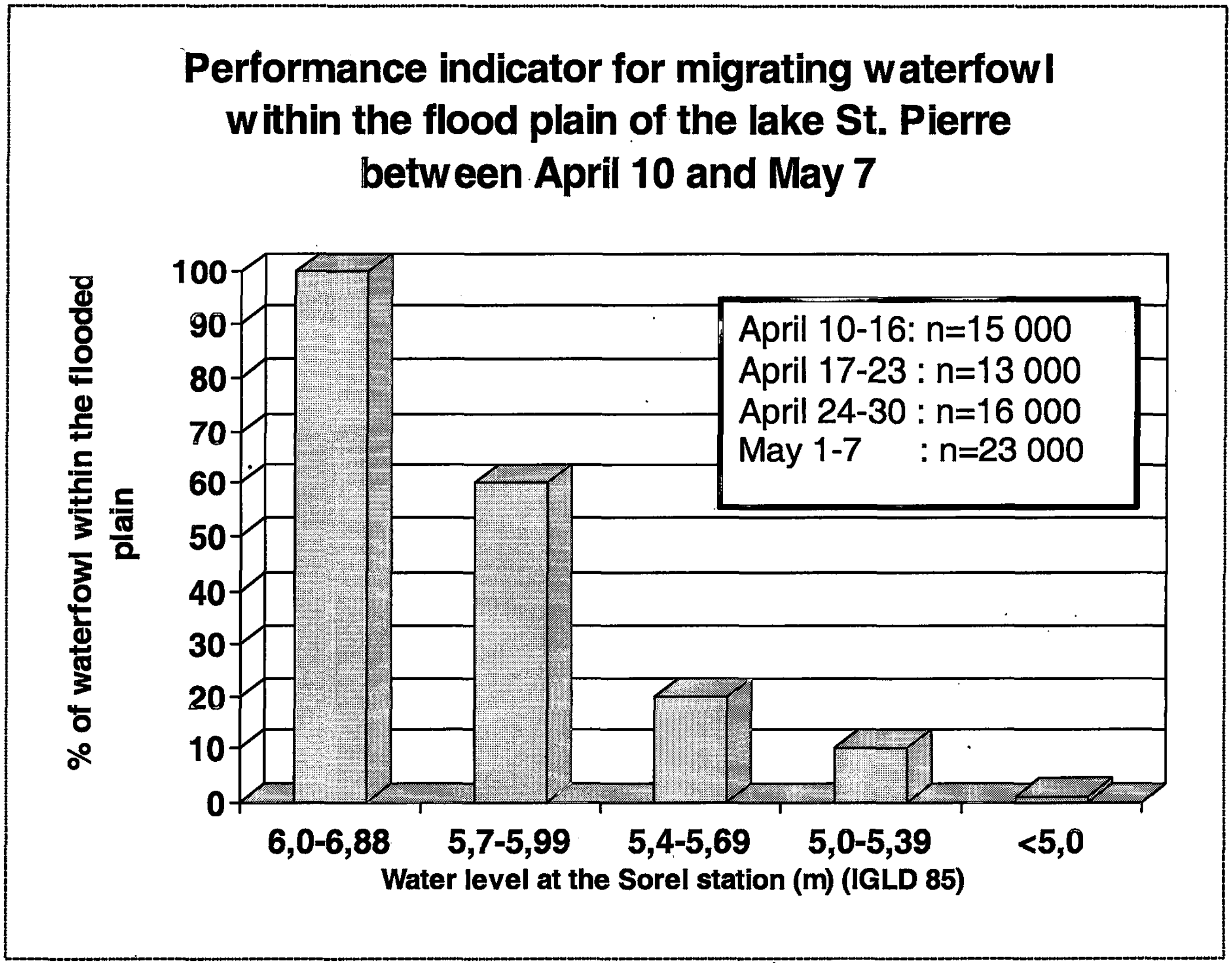
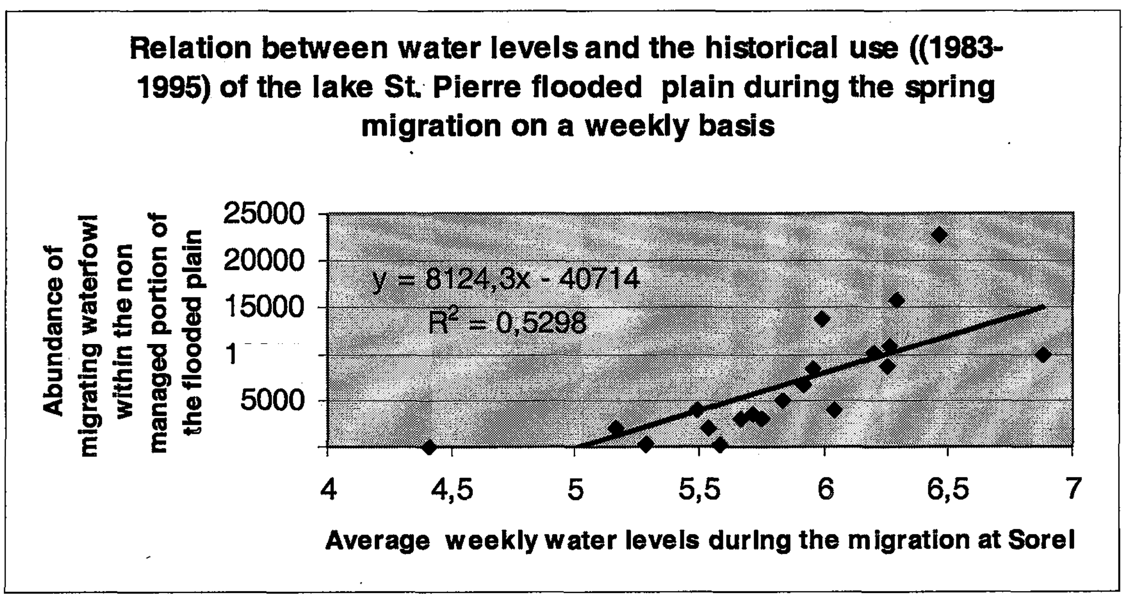
Appendix 1.

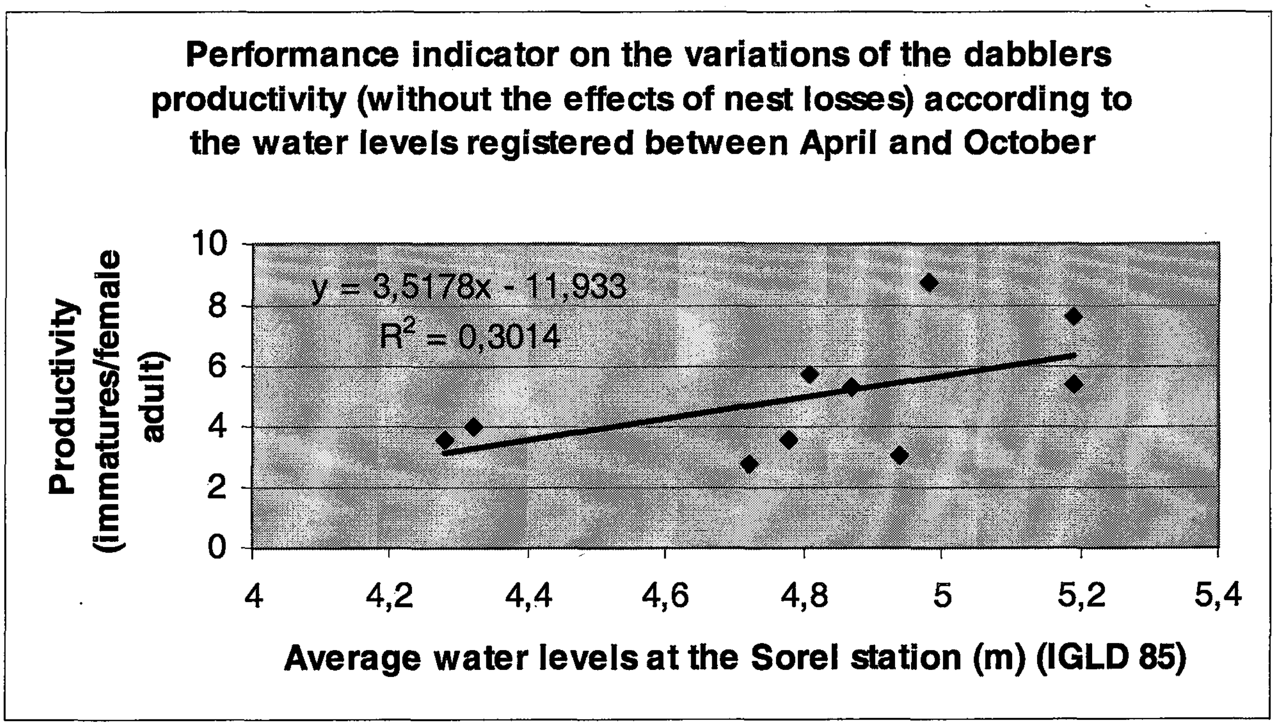
List of the performance indicators studied for waterfowl and general assessment of their value


Performance indicator for migrating waterfowl within the flood plain of the lake St. Pierre between April 10 and May 7
% of waterfowl within the flooded plain
100
90
80
70
60
50
40
30
20
10
0
April 10-16: n=15 000
April 17-23 : n=13 000
April 24-30 : n=16 000
May 1-7 : n=23 000
6,0-6,88
5,7-5,99
5,4-5,69
5,0-5,39
<5,0
Water level at the Sorel station (m) (IGLD 85)


Relation between water levels and the historical use ((1983-1995) of the lake St. Pierre flooded plain during the spring migration on a weekly basis
Abundance of migrating waterfowl within the non managed portion of the flooded plain
25000
20000
15000
5000
y = 8124,3x - 40714
R² = 0,5298
4
4,5
5
5,5
6
6,5
7
Average weekly water levels during the migration at Sorel

Performance indicator	Expected results	Presumed usefulness of the indicator	Efficiency
Migration	Evaluation of the impacts of low water levels on waterfowl numbers during the spring migration in the Lake St. Pierre flood plain.	This indicator helps to identify the water levels which : 1. ensure optimal aquatic bird distribution in the Lake St. Pierre flood plain (6.0 to 6.88 m at Sorel); 2. prevent that reductions cause the surface area of the flood plain to become too small forcing the birds to concentrate mainly in managed marshes where available food could be a limiting factor and increase inter and intra-specific stress; 3. prevent the birds from being in poor physiological health due to poor nutrition which could potentially reduce their reproductive success significantly (fewer females capable of reproduction, reduced clutch size, smaller eggs); 4. ensure that the most important flood plain of the fresh water portion of the St. Lawrence is sustained; 5. ensure that the most important migratory stopover of the St. Lawrence is sustained; 6. maintain the economic spin-off related to aquatic bird observation, a very important activity in the sector.	This indicator shows a good correlation between water levels and bird abundance in the non managed portion of the Lake St. Pierre flood plain (as demonstrated by survey data; r^2=0.52)

Performance indicator for the productivity



Performance indicator	Expected results	Presumed usefulness of the indicator	Efficiency
Productivity	Evaluation of the impacts of different average water levels during the plant growing season (April-October) on the productivity of dabblers (immatures/adult female).	This indicator helps to identify, for different average water elevations, the average water levels which : 1. would increase productivity of dabblers breeding in the fluvial section of the St. Lawrence River; 2. would maintain an healthy population of breeders in the study area; 3. could maintain the economic spin-off associated with hunting in the fresh water portion of the St. Lawrence (evaluated at 10 million dollars annually).	This indicator demonstrates that : 1. low water levels during the plant growing season might decrease the dabblers productivity especially because the nesting sites become readily available to terrestrial predators; 2. at very high level, a reduction of the productivity could also be expected because emergent marshes would become scarcer preventing birds to have easy access to escape cover and nests will be more easily flooded following any sudden substantial increase of the water levels 3. the relation between average water levels and productivity is poorly significant (r^2 = 0.30)

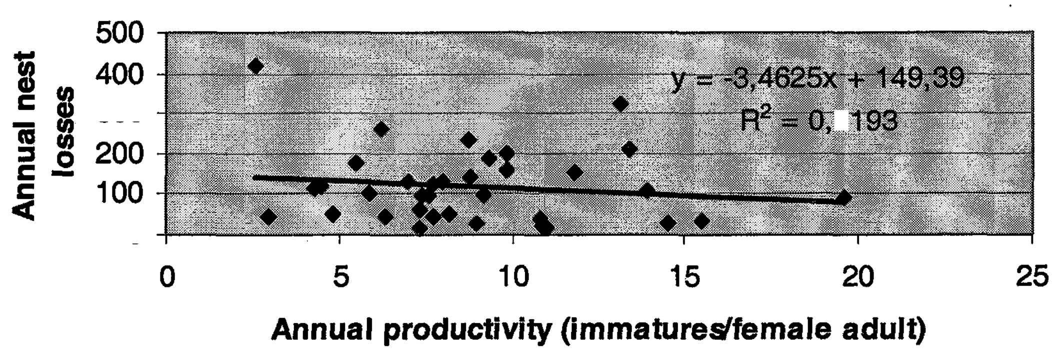
Performance indicator for nest losses

Example (for the more detailed performance indicator, see attached document)

May 26 - June 2: 541 non renesting females							
4.87 m[1]	**4.87m**	**5.06m**	**5.06m**	**5.24m**	**5.24m**	**5.42m**	**5.42m**
Magnitude of the rise (m)	Performance [2] indicator (%)	Magnitude of the rise (m)	Performance indicator (%)	Magnitude of the rise (m)	Performance indicator (%)	Magnitude of the rise (m)	Performance indicator (m)
0.19	97.94						
0.37	94.38	0.18	96.38				
0.55	89.64	0.36	91.56	0.18	95.03		
0.77	83.05	0.58	84.87	0.40	88.13	0.22	92.80
0.98	76.59	0.79	78.31	0.61	81.38	0.43	85.75
1.19	69.25	1.00	70.86	0.82	73.69	0.64	77.73
1.41	62.58	1.22	64.09	1.04	66.72	0.86	70.47
1.58	56.91	1.39	58.32	1.21	60.77	1.03	64.27
1.76	51.06	1.57	52.37	1.39	54.66	1.21	57.91

1: water level at the Sorel station (IGLD 85) at the moment of the rise
2: % of the 541 non renesting females not impacted by the water rise

Relation between the annual nest losses through flooding and the productivity of the breeding dabblers within the fluvial section of the St. Lawrence River



The productivity data provided by the wing bee have been used in that model

Performance indicator	Expected results	Presumed usefulness of the indicator	Efficiency
Nest flooding	Evaluation of the impacts of water level increases on nests (flooding) at different stages of the nesting period and thus on the overall productivity	This indicator helps to identify, for the different water elevations, the increase amplitudes which : 1. would reduce nest loss caused by floods; 2. would ensure the best annual waterfowl productivity in the study area; 3. could maintain the economic spin-off associated with hunting in the fresh water portion of the St. Lawrence (evaluated at 10 million dollars annually).	This indicator demonstrates that : 1. water level increases might cause nests to be lost every year. During some years we may expect very severe losses (up to 550 nests/year according to historical water level data (1968-2002)); 2. some females may renest especially if nests flooding occur early in the nesting season (before the end of June) 3. We have estimated that each nest lost through flooding induces an overall annual decrease in productivity of 0.0015 immature/adult female. It then means that even during years when severe nest losses are observed (± 500 nests historically), the overall impact on the annual productivity should not exceed 10%.

Appendix 2.

Results of the statistical analysis of the impacts induced by the different proposed water plans

Analysis of variance of the migration data generated by our performance indicator for the different water plans

Water plan	*Sampling size*	*Sum*	*Mean*	*Variance*
1958DD	41	1345800	32824,3902	670612390
A	41	1474200	35956,0976	617609024
B	41	1394600	34014,6341	595502780
C	41	1233000	30073,1707	624829512
D	41	1234600	30112,1951	624096598
E	41	1406700	34309,7561	588299402

ANOVA

Source of variation	*Sum of squares*	*degrees of freedom*	*Squared mean*	*F ratio*	*probability*
between groups	1161779390	5	232355878	0,37467189	0,8657938
within groups	1,4884E+11	240	620158285		
Total	1,5E+11	245			

Analysis of variance of the productivity data generated by our performance indicator for the different proposed water plans

Water plan	*Sampling size*	*Sum*	*Mean*	*Variance*
1958DD	41	160,958919	3,92582729	2,62315493
A	41	162,669829	3,9675568	2,13438292
B	41	162,178909	3,95558316	2,44118545
C	41	159,870171	3,89927247	2,49624794
D	41	158,47846	3,86532828	2,50393805
E	41	164,761443	4,01857177	2,14332939

ANALYSE DE VARIANCE

Source of variation	*Sum of squares*	*degrees of freedom*	*Squared mean*	*F ratio*	*probability*
between groups	0,59863694	5	0,11972739	0,05008732	0,99845166
within groups	573,689547	240	2,39037311		
Total	574,288184	245			

Analysis of variance of the nest losses data generated by our performance indicator for the different proposed water plans

Water plan	*Sampling size*	*Sum*	*Mean*	*Variance*
1958DD	41	3279,43409	79,9861973	10363,3824
A	41	3017,95783	73,6087276	9332,70515
B	41	3360,02093	81,95173	10273,3893
C	41	3491,469	85,1577804	10847,4919
D	41	3332,56404	81,2820498	10461,7854
E	41	3323,346	81,0572195	9357,55443

ANOVA

Source of variation	*Sum of squares*	*degrees of freedom*	*Squared mean*	*F ratio*	*probability*
between groups	2971,5916	5	594,318321	0,05880816	0,99772331
within groups	2425452,34	240	10106,0514		
Total	2428423,93	245			

Appendix 3.

Detailed description of the performance indicator on nest losses(see attached document)