Toronto & Region Remedial Action Plan

BUI Status Re-designation Document:
Bird or Animal Deformities or Reproductive Problems

December 2011

TORONTO & REGION
REMEDIAL ACTION PLAN

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The Toronto and Region Remedial Action Plan is managed by representatives from Environment Canada, Ontario Ministry of the Environment, Ontario Ministry of Natural Resources and Toronto and Region Conservation Authority.

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Summary

In 1987, when Toronto was designated an AOC there were concerns that contaminants in sediment and water might be causing bird or animal deformities and reproductive problems. At the time, there was insufficient evidence to designate a status for the associated Beneficial Use Impairment, *Bird or Animal Deformities or Reproductive Problems,* without additional research (Metro Toronto & Region RAP, 1994).

The present report provides current evidence on the status of the *Bird or Animal Deformities or Reproductive Problems* Beneficial Use Impairment (BUI) in the Toronto and Region Area of Concern (AOC) using top predator aquatic-feeding species known to be sensitive to the effects of contaminants. Results are based on two primary studies conducted by the Toronto and Region Conservation Authority and Environment Canada between 2001-2005. The first study examined reproductive success, morphological deformities and contaminants in eggs of five colonial waterbird species, the ring-billed gull (*Larus delawarenis*), common tern (*Sterna hirundo*), Caspian tern (*Sterna caspia*), black-crowned night-heron (*Nycticorax nycticorax*) and double-crested cormorant (*Phalacrocorax auritus*), in Tommy Thompson Park, a significant natural area of ecological importance located within the AOC. The second study examined wildlife health effects relating to reproduction and/or deformities in two indicator species, the herring gull (*Larus argentatus*) and the common snapping turtle (*Chelydra serpentina*), which feed within the AOC.

Overall, levels of contaminants in eggs of colonial birds from Tommy Thompson Park in 2004 were below thresholds associated with adverse effects on reproductive success in avian species. While morphological deformities were found in chicks of two of five colonial waterbird species, rates were low (i.e., below 0.33%) and the types observed were not consistent with contaminant-related deformities. Overall, contaminant-induced effects such as decreased reproductive success and elevated morphological deformities do not appear to be limiting factors at the population level for colonial waterbirds feeding in and around the AOC. Reproductive success of tern species and night-herons appeared to be limited by external factors such as predation, competition and/or habitat deterioration; these factors had little influence on nesting ring-billed gull and cormorant populations. Embryonic development appeared good in snapping turtles from the Humber River from 2002-2004 where hatching success was high in eggs (92.8%) and the rate of morphological deformities was low in hatchlings (9.5%). Finally, endpoints associated with impaired reproduction and deformities in wildlife including egg viability, clutch volume, intraclutch egg volume, and sex ratio in herring gulls and hatching success and hatchling deformities in turtles, were similar between the AOC and selected lower Great Lakes non-AOC reference sites.

Based on the evidence presented here, a recommendation is made that the classification of the *Bird or Animal Deformities or Reproductive Problems* BUI in the Toronto and Region AOC be changed from *Requires Further Assessment* to *Not Impaired*.

BUI Re-designation Criteria

BUI Status (Stage 1 Report; 1989):

Requires further assessment

Toronto and Region RAP Goals (Stage 2 Report; 1994):

The incidence rates of deformities and reproductive problems in “sentinel” wildlife species are the same as, or less than, background levels in populations in uncontaminated systems.

BUI Re-designation Goal (2011):

The incidence rates of deformities and reproductive problems in “sentinel” wildlife species are the same as, or less than, background levels in populations in uncontaminated systems.

Applied BUI Criteria (2011): Sentinel species within the Area of Concern (AOC) do not present anomalous rates of contaminant-mediated morphological deformities; indicators of the reproductive health of sentinel species such as egg viability, clutch characteristics, embryonic development, sex ratios, and hatching rates are not significantly different (worse) than those observed at comparable non-AOC reference sites.

Status of AOC Against BUI Criteria

Comparison of AOC conditions to Applied BUI Criteria

Endpoints associated with impaired reproduction and deformities in wildlife including egg viability, clutch volume, intraclutch egg volume, and sex ratio in herring gulls and hatching success and hatchling deformities in turtles, were similar between the Toronto and Region and selected lower Great Lakes non-AOC reference sites.

While morphological deformities were found in chicks of two of five colonial waterbird species, rates were low and the types observed were not consistent with contaminant-related deformities. These findings were consistent with the observation that contaminant concentrations in the eggs of colonial birds from Tommy Thompson Park were below thresholds associated with adverse effects on reproductive success in avian species. Accordingly, contaminant-induced effects such as decreased reproductive success and elevated morphological deformities do not appear to be limiting factors at the population level for colonial waterbirds feeding in and around the AOC.

Have the BUI Criteria for non-impairment been met?

Yes. There was no evidence of deformities and reproductive problems in sentinel wildlife species in the Area of Concern (AOC), nor was there evidence of deformity or reproductive differences in sentinel wildlife species between Toronto and Region and non-AOC reference sites.

Recommended Status of the Beneficial Use:

Not Impaired

Ongoing Actions

There are no actions underway for the express purpose of addressing the *Bird or Animal Deformities or Reproductive Problems* Beneficial Use.

Future Monitoring or Actions Required

There are no planned future activities, monitoring or otherwise, to expressly address the *Bird or Animal Deformities or Reproductive Problems* Beneficial Use.

Research Results

Introduction

This report addressed the Toronto and Region Area of Concern Beneficial Use #5 *Bird or Animal Deformities or Reproductive Problems*; the information herein is taken from the report *Update on the status of the reproduction and deformities Beneficial Use Impairment in the Toronto and Region Area of Concern* (Hughes 2011).

In the 1970s, studies documented elevated levels of contaminants, decreased reproductive success and elevated incidence of morphological abnormalities in some colonial waterbird species nesting in the Toronto and Region Area of Concern (AOC) (Gilbertson *et al*. 1976; Morris *et al*. 1976; Weseloh *et al.* 1989). In the 1980s, populations appeared to be reproducing normally however more recent data were lacking (especially pertaining to animal deformities) and accordingly, a status of "Requires Further Assessment" was designated for this BUI (Metro Toronto and Region Remedial Action Plan 1994; Waterfront Regeneration Trust 2002). Noteworthy is that evidence of reproductive impairment and morphological deformities were not limited to the Toronto and Region AOC but were found in fish-eating colonial waterbird species from a number of Great Lakes locations where contaminants such as p,p'-DDE and PCBs were associated with severe reproductive failures and population declines (e.g., Gilbertson 1974; Weseloh *et al*. 1983).

Two primary studies were conducted to address the "Requires Further Assessment" designation for the *Bird or Animal Deformities or Reproductive Problems* BUI and to provide a current status assessment of this BUI in aquatic wildlife in the Toronto and Region AOC. In 2004, the Toronto and Region Conservation Authority examined reproductive success, morphological deformities and contaminants in fish-eating colonial waterbird species nesting in Tommy Thompson Park, a significant natural area of ecological importance located within the AOC (TRCA 2006). Fish-eating wildlife, such as colonial waterbirds, are important as indicators of exposure to persistent contaminants in the aquatic environment (Fox and Weseloh 1987). As top predators, they occupy the highest trophic level in the aquatic food web and therefore may accumulate appreciably high levels of contaminants which may in turn adversely affect their reproductive health and development (see Grasman *et al*. 1998 for a review in colonial waterbirds). Colonial waterbirds nest in high numbers in Tommy Thompson Park and this has facilitated studies of their breeding populations and non-lethal collections of eggs for contaminants monitoring.

In addition, Environment Canada initiated studies in 2001, as part of the Fish and Wildlife Health Effects and Exposure Study, to systematically assess Canadian AOCs, including the Toronto and Region AOC, for the occurrence of wildlife health effects associated with contaminants in the aquatic environment. Two aquatic-feeding wildlife species, the herring gull (*Larus argentatus*) and the snapping turtle (*Chelydra serpentina*), have been commonly used as indicators to evaluate contaminants and their effects on wildlife health in Great Lakes AOCs (e.g., de Solla *et al*. 2007, 2008; Weseloh *et al*. 2006; Fox *et al*. 2007). The herring gull is a long-lived, primarily fish-eating colonial waterbird that, from the time it reaches breeding age, is resident year-round resident in the Great Lakes basin (Mineau *et al*. 1984). This species, whose Great Lakes populations have been extensively studied, usually feeds within a few kilometres (up to 10-12 km) of its nesting colony and is therefore an indicator of regional contaminant conditions. The common snapping turtle is a long-lived reptile with a predominately fish-based diet that commonly inhabits Great Lakes shorelines (with the exception of the north shore of Lake Superior; Fox 2001). With a relatively small home range, this species is a useful indicator of local sources of contaminants (Bishop *et al*. 1998; de Solla *et al*. 2007). Snapping turtle eggs are generally easily located and collected allowing for artificial incubation of eggs in the laboratory and an assessment of hatchlings and congenital deformities in wild populations.

The purpose of this report is to provide current evidence on the status of the *Bird or Animal Deformities or Reproductive Problems* BUI in the Toronto and Region AOC based on the results of these two studies which employ top predator aquatic wildlife species known to be sensitive to the effects of contaminants. In combination with observed contaminant loads and population trends examined in these species, these results will provide an accurate measure of the extent of reproductive and development impairment in aquatic wildlife in the AOC.

Methods

Description of Tommy Thompson Park

Tommy Thompson Park, also known as the Leslie Street Spit, is a 500 hectare (approximate), man-made peninsula extending into Lake Ontario at the foot of Leslie Street on the City of Toronto waterfront (TRCA 2008). Initially constructed in 1959, the site continues to grow through the placement of clean fill and dredged sand and silt which, over time, has created a variety of habitats and attracted significant numbers and species of birds and other wildlife. More than 400 plants, 314 birds, 19 mammal and 12 herpetile species have been recorded at the site. In addition, the site has provided habitat for significant colonies of waterbirds including ring-billed gull (*Larus delawarensis*), common tern (*Sterna hirundo*), Caspian tern (*Sterna caspia*), herring gull, great egret (*Ardea alba*), black-crowned night-heron (*Nycticorax nycticorax*) and double-crested cormorant (*Phalacrocorax auritus*). The presence of these colonies has contributed to the site being identified as an Environmentally Significant Area (ESA) and, more recently, as a globally significant Important Bird Area (IBA).

Reproductive Success of Colonial Waterbird Species

Monitoring of reproductive success and morphological deformities in five nesting colonial waterbird species, the ring-billed gull, double-crested cormorant, black-crowned night-heron, Caspian tern and the common tern, was conducted by the TRCA in Tommy Thompson Park in 2004 (TRCA 2006). Nests were marked and monitored by performing regular nest checks and recording the nest contents including numbers of eggs which were hatched, unhatched, damaged or lost and numbers of fledglings produced per nest. Reproductive success was measured by calculating hatching success as the number of eggs hatched divided by the number of eggs laid (1), adjusted hatching success, which eliminates the eggs which were damaged, predated or had disappeared to evaluate hatchability (2), and productivity, as the number of chicks to reach approximate fledging age (i.e., 4 weeks of age), per nest (3). These were calculated according to the following formulas:

$$\text{Hatching Success (\%)} = \frac{\text{Number of Eggs Hatched}}{\text{Total Number of Eggs Laid}} \times 100 \qquad (1)$$

$$\text{Adjusted Hatching Success (\%)} = \frac{\text{Number of Eggs Hatched}}{\text{Number of Eggs of Known Outcome*}} \times 100 \qquad (2)$$

$$\text{Productivity} = \frac{\text{Number of Chicks to Reach Fledging Age (i.e. 4 weeks)}}{\text{Total Number of Active Nests}} \times 100 \qquad (3)$$

* Number of Eggs of Known Outcome = Total Number of Eggs Laid - Total Number of Eggs Damaged, Predated, or Disappeared

Reproductive success in herring gulls was not examined in this study due to recent declines in nest numbers in the Park and concerns that monitoring could adversely affect their nesting success for the season. This work was done in conjunction with ongoing TRCA colonial waterbird population monitoring in the Park. In addition, for each of the five colonial waterbird species, three replicates of five eggs each were collected from 15 randomly selected nests, one per full clutch. Eggs were refrigerated until they were sent to the laboratory for contaminant analysis (see below).

A brief description of the monitoring methodology used in this study is provided below. A more detailed description of the methodology employed at individual sites including photos of enclosures in the Park is described in TRCA (2006) and is provided in Hughes (2011, Appendix 1).

Ring-billed gulls: Two enclosures were constructed for ring-billed gull monitoring using fencing on peninsulas A and B on April 28. Each enclosure contained 25 nests located in the centre of the colony. Two additional unenclosed areas containing 25 nests each were also selected in peninsulas A and B for monitoring. Individual nests were marked and nest contents monitored every few days until hatch at which point they were monitored daily (May 16-21). Following hatch the total number of chicks was counted every few days until the approximate age of fledging (4 weeks, June 28 and June 30 in the two peninsulas). Total number of fledglings could be determined only in the two enclosed areas; chicks in the two unenclosed areas were both mobile and uncontained and nest origin could not therefore be determined.

Double-crested cormorants: Two areas containing a total of 62 double-crested cormorant ground nests were sectioned off on Peninsula B with nylon rope on May 28. Nests were marked and contents were recorded daily during the hatching period from June 1-11 and then every few days afterward until approximate fledging age (4 weeks).

Black-crowned night-herons: Thirty arboreal nests on peninsulas B and C were selected for black-crowned night-heron monitoring between May 25-28. Due to the height and size of the trees, it was not possible to determine clutch size or hatching success of eggs since the nests were either too high to use the mirror pole or the trunk was too small to be climbed. Fledging rates was determined using binoculars and a spotting scope once chicks were large enough to be viewed from the ground.

Caspian terns: Two unenclosed areas on the Endikement Tip each consisting of 20 marked nests were randomly selected for Caspian tern monitoring beginning on June 2. Nests were marked and contents monitored daily until hatch and then every few days until fledging (4 weeks, June 28). The total number of nests in the tern colony was counted at peak nesting on June 4 and the total number of fledglings counted on June 28 to determine fledging success (i.e., productivity).

Common terns: Two of four common tern rafts in the Park, raft B in cell 2 and raft D in embayment D, were randomly selected for monitoring. Raft B was visited by canoe and raft D was visited by wading. Nests were assigned a numbered tile and nest contents recorded on May 27. The total number of nests was counted on June 1. Nest contents were monitored until hatch and then every few days until the approximate age of fledging (3-4 weeks, June 30).

Morphological Deformities in Colonial Waterbird Species

Chicks of all ground-nesting species were randomly selected from each of the colonies and fully inspected both visually and by feeling for abnormalities. Black-crowned night-heron chicks in arboreal nests were examined visually using either a mirror mounted on an extendible pole or binoculars. In addition to ground nests, cormorant chicks from 50 randomly selected arboreal nests on peninsulas A and B were also examined using a mirror pole. For species which were examined on multiple days, chicks were marked on the webbing of the foot with a permanent marker in order to minimize recounts. Numbers of chick and dates of inspection were as follows: ring-billed gulls: 2000 chicks, June 18; cormorants: 1500 chicks, June 18-24; black-crowned night-herons: 50 chicks, June 25-30; Caspian terns: 40 chicks, June 18-24, and; common terns: 300 chicks, June 8-11. Chicks were released at the same location they were caught.

Eggs that remained unhatched in monitored nests for five days after sibling eggs had hatched were checked for a heartbeat with a “Buddy” heart rate monitor. Live eggs were returned to the nest while dead eggs were collected and opened to determine fertility and deformities.

Herring Gull Egg Viability

Contaminant-induced early embryonic mortality was an important factor contributing to the low reproductive success observed in Great Lakes herring gulls during the 1970s (see Grasman *et al*. 1998). Non-destructive surveys of herring gull egg viability were conducted using an electronic device, the embryonic viability detector (EVD) (Hebert *et al.* 2001). The EVD detects vibrations associated with embryonic movement and heartbeat. These vibrations are turned into sound waves allowing a determination of whether an egg is alive or dead. Following assessment with the EVD, live eggs were returned to their nests and dead eggs were collected for further analysis. EVD data were only reported for 3-egg clutches. This compensated for inter-nest differences in parental quality and experience, since females in poorer condition may lay only two or even one egg. Clutches that contain fewer than 3 eggs exhibit higher egg mortality and have higher proportions of dead eggs (C.E. Hebert, CWS unpublished data). By using data only from 3-egg clutches, inter-nest variability that may be related to parental quality was reduced, thereby standardizing the results and ensuring the appropriateness of inter-colony comparisons. Eggs from the Tommy Thompson Park herring gull colony were examined in 2004 and 2005. Egg viability was calculated as the proportion of live eggs in a 3-egg clutch and compared to egg viability at a reference site, Scotch Bonnet Island, in eastern Lake Ontario. Scotch Bonnet Island was selected as an appropriate reference site because it is outside of a designated AOC and it is located within the Lake Ontario basin.

Egg measurements, such as the length and breadth of individual eggs, were also recorded in 3-egg clutches from the Tommy Thompson Park herring gull colony in 2003 and 2004. These data were used to calculate egg volume (based on the formula: 0.000476 x length x breadth^2, in centimetres), clutch volume (as the total volume of the three eggs in the clutch, in cubic centimetres), and intraclutch variation in egg size (the difference in volume between the largest and smallest egg in the clutch divided by the largest egg size and multiplied by 100). As no data were available for Scotch Bonnet Island for the 2003 and 2004 study years, Snake Island, also in the eastern basin of Lake Ontario, was selected as the non-AOC reference site for egg parameter comparisons.

Egg viability was arcsine transformed prior to analysis. Student t-tests were conducted for two site comparisons where conditions of homogeneity of variance and normality were met. The Mann-Whitney U test was employed as the non-parametric test when these conditions were not satisfied. All results were considered significant at $p<0.05$.

Sex Determination of Young Herring Gulls at Hatch

To examine if there was differential (possibly chemically mediated) mortality of males or females during *in ovo* development, blood samples from herring gull chicks were taken in 2004 for genetic sex determination. Samples were collected from gull chicks at both Tommy Thompson Park and Scotch Bonnet Island and were taken by toe clipping usually within 24 hours of the last (of three) chicks hatching (i.e., from complete clutches and when the third chick was still wet). Estimated dates of hatch of herring gull eggs were made by marking nests at the two egg stage during egg-laying and projecting ahead 26+ days. Nests were re-visited and those having three chicks were sampled.

Blood from the toe clip of each chick was collected on to a clean filter paper. Sex determination was by polymerase chain reaction (PCR) amplification of the chromo-helicase-DNA-binding (CHD) genes (CHD-Z in males and CHD-Z and CHD-W in females) according to the methods of Griffiths (1991) and Griffiths *et al.* (1998). Sex ratio bias was assessed statistically using a chi-squared analysis and examining for deviations from the expected 1:1 male:female sex ratio.

Hatching Success and Deformity Rates in Hatchling Snapping Turtles

Snapping turtle eggs were collected from two main collection sites on the Humber River, a large tributary located at the western end of the Toronto and Region AOC which drains into Lake Ontario. The majority of eggs were collected approximately 2 to 2.5 kilometres north of Lake Ontario at two sites near Bloor Street in the City of Toronto. The other main collection site was further up in the Humber River watershed at the Claireville Reservoir near Indian Line Road and close to the junction of Highway 407 and Highway 50. Eggs were also collected from the Upper Canada Bird Sanctuary, a non-AOC reference location on St. Lawrence River. This reference location is the closest non-AOC location in the Great Lakes where contaminants data for snapping turtles were available for comparison purposes.

Entire clutches of eggs were collected within 48 h of oviposition. For contaminant analysis, a subset of eggs (usually five) was selected within each clutch and the contents were pooled and frozen in hexane-cleaned amber glass jars at –20°C (see below). The remaining eggs from each clutch were placed in plastic containers containing moistened vermiculite, then stored at approximately 18-24°C at the Canada Centre for Inland Waters in Burlington, Ontario. Within two weeks of collection, all eggs were then placed in incubators under constant temperature conditions of 27.5±1°C. Water loss through evaporation was replaced every two to three days as required to maintain relatively constant moisture. Eggs were maintained under these conditions until hatching.

Hatchling turtles were assessed for gross morphological deformities of the carapace scutes, eyes, head, limbs and tail. Hatching success and deformities were calculated for each clutch as the proportions of eggs incubated and eggs hatched, respectively, and then arcsine transformed prior to statistical analysis.

Organochlorine Contaminant Analysis of Eggs

Chemical analyses of colonial waterbird eggs for organochlorine contaminants were conducted at the National Wildlife Research Centre (NWRC) in Hull, Québec. Organochlorine contaminants measured included: p,p'-DDE (dichlorodiphenyldichloroethylene), *p,p'*-DDT, *p,p'*-DDD (dichlorodiphenylethane), oxychlordane, dieldrin, OCS (octachlorostyrene), mirex, hexachlorobenzene (HCB), heptachlor epoxide (HE) and sum PCBs, determined as the total sum of 62 individual PCB congeners. Chemical analytical methods have been described by Simon and Wakeford (2000) and Won *et al*. (2001). Samples underwent neutral extraction, removal of lipids and biogenic compounds by gel permeation chromatography, followed by further cleanup using florisil column chromatography. Quantitative analysis of organochlorines and PCBs was performed using capillary gas chromatography, coupled with a mass selective detector (GC/MSD) operated in selected ion monitoring mode. The first injection was designed to determine organochlorines using an external standard method on the basis of ion response factors in a standard solution containing 21 organochlorines. The second injection was performed to determine PCBs using an external standard method with a standard mixture of Arochlor 1242:1254:1260 (1:1:1). Eggs were also analyzed for total mercury using the Advanced Mercury Analyzer (AMA-254).

Snapping turtle eggs were shipped to the Great Lakes Institute of Environmental Research (GLIER) at the University of Windsor for contaminant analysis. Eggs collected in 2001 and 2002 were quantified using gas chromatography-electron capture detection (GC-ECD) while eggs collected in 2003 and 2004 were analysed using gas chromatography-mass spectrometry (electron ionization) (GC-MSD (EI)). Sum PCB concentrations consisted of all 34 congeners that were common to both GC-ECD and GC-MSD. For polybrominated diphenyl ether (PBDE) flame retardants, all egg samples were analysed using GC-mass spectrometry-electron capture negative ionization (GC-MS(ECNI)) and sum PBDEs reported are based on the sum of nine PBDE congeners which include BDE-28, -47, -99, -100, -138, -153, -154, -183, and -209. Further details of chemical analyses are provided in de Solla *et al*. (2007). Statistical analyses of organochlorine pesticide, PCB and PBDE data were tested for homogeneity of variances using Levene's test and then ln transformed (where necessary) to meet conditions of parametric testing. Student t-tests were performed to examine differences in hatching success, hatchling deformity rates, and contaminant levels in snapping turtle eggs collected from the Toronto and Region AOC (Humber River) and UCBS, the non-AOC Great Lakes reference site.

Results

Reproductive Success of Colonial Waterbird Species

Reproductive success varied greatly among the five nesting species examined at Tommy Thompson Park in 2004 (Table 1; see TRCA 2006 for further details of reproduction at individual areas monitored).

Ring-billed Gulls: Of the 100 ring-billed nests monitored on peninsulas A and B, 280 eggs were produced resulting in an average clutch size of 2.80 eggs per nest. A total of 210 chicks hatched from these eggs producing a hatching success rate of 75%. A total of seventy eggs disappeared (presumably due to predation) or did not hatch, the majority of which were from the unenclosed areas (67%). The adjusted hatching success rate and the number of young fledged were determined using nests in the two enclosures only since chicks were mobile in the two unenclosed areas and may have been miscounted leading to the potential for inaccuracies. An adjusted hatching success rate which includes only those eggs of known outcome in the two enclosures was calculated as 94.4% (119 eggs hatched/126 eggs of known outcome). A total of 66 fledglings were counted at approximately four weeks of age resulting in a productivity value of 1.32 young per nest.

Double-crested cormorants: Sixty-two double-crested cormorant grounds nests were monitored in two areas of Peninsula B producing a total of 195 eggs and an average clutch size of 3.15 eggs per nest (Table 1). A total of 158 chicks hatched from these eggs yielding a hatching success rate of 81.0%. After accounting for the 32 eggs which had disappeared, the adjusted hatching success rate was high at 96.9% (158 eggs hatched/163 eggs of known outcome) since only five of 195 eggs did not hatch. A total of 118 chicks were counted in the two areas four weeks after the approximate average hatch date resulting in a productivity of 1.90 chicks fledged per nest. Since the counting of chicks was difficult due to their high mobility at this time, the fledging rate should be considered an estimate. While the average time for cormorant chicks to fledge is 35-40 days, it is assumed that chicks reaching 4 weeks of age will fledge as the risk of predation decreases with increased chick size. Older chicks, however, may be susceptible to starvation, trampling and exposure.

Black-crowned Night-Herons: Thirty arboreal black-crowned night-heron nests on peninsulas B and C were selected for monitoring and observed using binoculars at the approximate time of fledging to determine the number of chicks present. A total of 50 chicks were observed resulting in a productivity rate of 1.67 chicks fledged per nest (Table 1). Average clutch size and hatching success could not be determined for this species due to the height of nests and the difficulty and disturbance associated with examining nest contents.

Caspian Terns: Forty Caspian tern nests were monitored in two unenclosed areas on the Endikement Tip producing a total of 96 eggs and an average of 2.40 eggs per nest (Table 1). Hatching success was low at 47.9% with 46 of 96 eggs hatching. Fifty of these eggs were lost due to predators, weather and/or disturbance. No eggs

Table 1. Hatching success, reproductive output and incidence of morphological deformities in colonial waterbirds in Tommy Thompson Park in 2004. See text for details of terms. Species include: ring-billed gull (RBGU), double-crested cormorant (DCCO), black-crowned night-heron (BCNH), Caspian tern (CATE) and common tern (COTE). Productivity threshold(s), as the number of young fledged per nest, are presented with associated references for comparison purposes.

Species	No. of Active Nests	Total N. of Eggs Laid	Average Clutch Size	Hatching Success (%)	Adjusted Hatching Success+ (%)	No. Deformed Chicks/ N. of Chicks Examined	No. Young Fledged++	N. Young Fledged/ Active Nest	Productivity Threshold(s)
RBGU	100/50+++	280	2.80	75.0	94.4	5/2000 (0.25%)	66	1.32	0.6*
DCCO	62	195	3.15	81.0	96.9	0/1500 (0%)	118	1.90	1.2 - 2.4**
BCNH	30	NA	NA	NA	NA	0/50 (0%)	50	1.67	1.5 - 2.7***
CATE	40/289+++	96	2.40	47.9	100	0/40 (0%)	39	0.13	0.6****
COTE	220	564	2.56	34.2	NA	1/300 (0.33%)	98	0.45	1.1*****

+ Includes only eggs of known outcome (i.e., those that were not damaged, predated or had disappeared).
++ Number of chicks of fledging age of 4 weeks for all species.
+++ Indicates numbers of active nests used to determine hatching success and number of young fledged/active nests, respectively.
* Required for stable population; Ludwig (1967)
** General fledging rate; Hatch and Weseloh (1999)
*** Considered for good population; Tremblay and Ellison 1980; Custer et al. 1983; Rattner et al. 2001
**** Required for stable population; Ludwig (1965)
***** Required for stable population; Nisbet (1978)

were infertile or dead. Therefore after accounting for eggs of known outcome, 100% (46/46) of Caspian tern eggs hatched. There was evidence of predation in these areas as seven chicks were found dead and partially eaten. Since chicks were mobile at the approximate time of fledging (i.e., 4 weeks), the total number of young was counted in the 289 nest-colony to determine Caspian tern productivity in the Park. Thirty-nine chicks were counted resulting in a productivity rate of 0.13 young fledged per nest.

Common Terns: The two common tern rafts monitored, raft B in cell 2 and raft D in embayment D, had a combined total of 220 nests (Table 1). The average clutch size was 2.56 eggs per nest based on a total of 564 eggs laid. Hatching success was low at 34.2% as 193 eggs hatched of 564 eggs laid. At the approximate age of fledging at 4 weeks, 98 chicks were counted on the two rafts resulting in an overall productivity rate of 0.45 young fledged per nest.

Morphological Deformities in Colonial Waterbird Species

In 2004, physical deformities were found in chicks of two of five colonial waterbird species in Tommy Thompson Park (Table 1). Five of 2000 ring-billed gull chicks examined (0.25%) were deformed. These included four chicks with swollen ankles and/or feet which likely were the result of injury or infection and one chick with a curled appearance likely due to underdeveloped neck muscles which rendered it unable to lift its head. One of 300 common tern chicks examined (0.33%) was also deformed with a curled appearance likely due to underdeveloped neck muscles. There were no physical deformities found in any of the 1500 double-crested cormorant, 40 Caspian tern or 50 black-crowned night-heron chicks examined.

Seven dead eggs were collected from the monitored ring-billed gull nests. Of those, five were infertile and two were cracked and therefore empty. Five dead eggs were collected from the double-crested cormorant nests and, of those, three were infertile, one was cracked and one had a chick with no obvious deformities that had died mid-hatch. There were no whole or unhatched Caspian tern eggs as all eggs had either disappeared or were broken and empty. Unhatched eggs from common tern nests were too small for the “Buddy” heart rate monitor and therefore were not tested. Due to the height of the nests it was not possible to examine unhatched black-crowned night-heron eggs.

Contaminants in Eggs of Colonial Waterbird Species

Mean contaminant concentrations of five compounds, sum PCBs, p,p’-DDE, mirex, mercury, and 2,3,7,8-TCDD, in eggs of five colonial waterbird species in 2004 are shown in Figure 1. For comparison purposes, mean contaminant data are also provided for single pools of 13 herring gull eggs collected annually from 2003-2007 at Tommy Thompson Park. Of all contaminants, sum PCBs were found in the highest concentrations in eggs of five species, the double-crested cormorant, Caspian tern, common tern, black-crowned night-heron and herring gull, which feed on almost

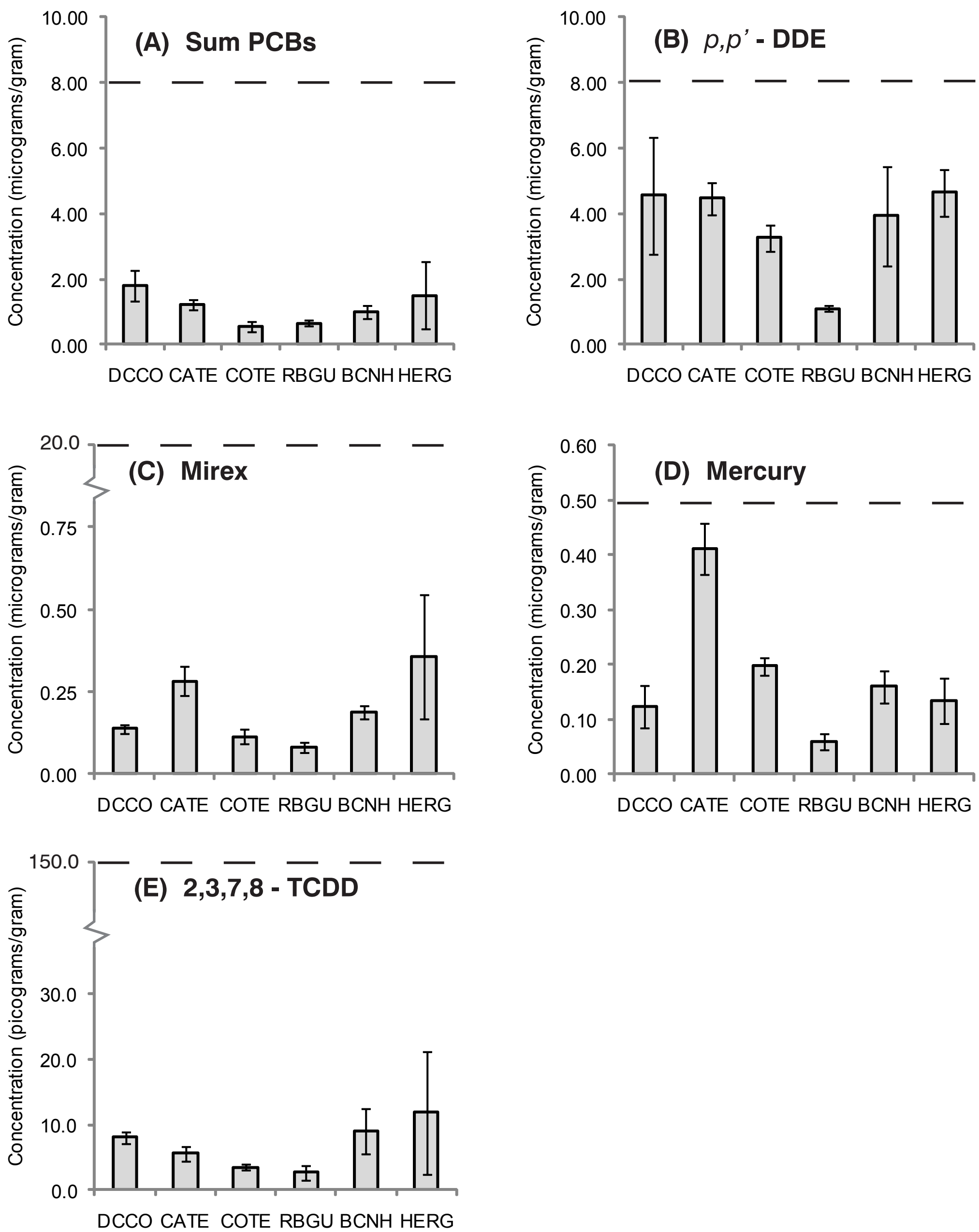

Figure 1. Mean concentrations (±SD) of sum PCBs (A), p,p'-DDE (B), mirex (C), mercury (D), and 2,3,7,8-TCDD (E) in eggs of five colonial waterbird species collected from Tommy Thompson Park in the Toronto and Region AOC in 2004 (wet weights). Mean contaminant concentrations are also shown for herring gulls based on single pools of eggs for years 2003-2007. Species names are: double-crested cormorant (DCCO), Caspian tern (CATE), common tern (COTE), ring-billed gull (RBGU), black-crowned night-heron (BCNH) and herring gull (HERG). The dashed line indicates the threshold associated with a variety of reproductive effects in avian species, with the exception of Mirex, which is plotted at lowest concentration threshold where *no* effect on reporduction was found (see text for details).

exclusively on fish and other bird species (range (±SD) in means=3.26±0.39 μg/g - 4.65±0.72 μg/g) while the ring-billed gull had the lowest mean sum PCB level in eggs due to its more terrestrial-based diet (1.10±0.09 μg/g; Figure 1a). Similar to the pattern observed in 1981 (Weseloh *et al*. 1989), higher levels of contaminants in eggs of Caspian terns compared to common terns in 2004 may be due to Caspian terns exploiting proportionately different species of fish, as well as larger fish. Based on a broad literature review of PCB effects in birds, Hoffman *et al*. (1996) concluded that sum PCB concentrations in the range of 8 to 25 μg/g in eggs were associated with decreased hatching success for terns and cormorants. Sum PCB levels in all pools of eggs were below the lowest 8 μg/g threshold. Of note, with the exception of the herring gull which is a resident year-round in the Great Lakes, all of the assessed species are migratory and thus contaminant burdens may reflect exposure on wintering grounds. To this end however, Ryckman *et al*. (1988) found spatial similarities in the relative contaminant loads between Great Lakes herring gulls and cormorants suggesting that exposure on wintering grounds contributes little to the overall contaminant burden in cormorants during the breeding season.

Of all organchlorine pesticides, *p,p'*-DDE in eggs was found at the highest concentrations with means (±SD) in eggs ranging from 0.57±0.16 μg/g in common terns to 1.80±0.49 μg/g in double-crested cormorants (Figure 1b; see Hughes (2011, Appendix 2) for complete listing of other pesticides). Concentrations of p,p'-DDE in eggs were below threshold levels associated with significant effects on reproductive success as reported in black-crowned night-herons (8 μg/g; Henny *et al*. 1984) and cormorants (10 μg/g; Pearce *et al*. 1979). Mirex levels in eggs were also high relative to levels of other pesticides with Caspian tern eggs (mean (±SD)=0.28±0.04 μg/g) and herring gull eggs (0.36±0.19 μg/g) having the highest concentrations and ring-billed gull eggs having the lowest mean concentration (0.08±0.02 μg/g; Figure 1c). Reproduction of mallards (*Anas platyrhynchos*), Japanese quail (*Coturnix japonica*), and northern bobwhites (*Colinus virginianus*) was unaffected when mirex residues in eggs averaged 20 μg/g, 90 μg/g and 150 μg/g, respectively (Wiemeyer 1996). Mirex levels in all pools of eggs were well below the lowest 20 μg/g threshold of this range.

Mean mercury concentrations (±SD) were also highest in Caspian tern eggs and lowest in ring-billed gull eggs (equal to 0.41±0.05 μg/g and 0.06±0.01 μg/g, respectively; Figure 1d). All pools of eggs were below the threshold level of 0.5 μg/g typically associated with adverse reproductive effects in birds (Thompson 1996). It is unclear what effect the relatively higher levels of mercury in Caspian tern eggs may have on the productivity of this species although there was no evidence of infertile eggs or embryonic mortality and nests were found in record numbers in the Park in 2004. The apparent tolerance to high levels of mercury exhibited by this species may be influenced by levels of selenium (which was not measured in this study) and which may be an important in mitigating the toxic effects of methylmercury.

Mean concentrations of 2,3,7,8-TCDD (±SD) in eggs ranged from 2.71±1.05 pg/g in ring-billed gulls to 11.84±9.41 pg/g in herring gulls (Figure 1e). There was considerable variation in levels of 2,3,7,8-TCDD in herring gull eggs among years 2003 to

2007 accounting for the large variation observed. All pools of eggs were well below the threshold of 150-250 pg/g associated with decreased embryonic growth and edema in herons (Hoffman *et al*. 1996).

Egg Viability, Egg Parameters and Sex Ratio in Herring Gulls

Egg viability (±SD) in herring gulls from Tommy Thompson Park in the Toronto and Region AOC was equal to 85.0±19.8 % in 2004 and 100.0±0% in 2005 (Figure 2). No significant difference was found in mean egg viability in herring gulls from Tommy Thompson Park and Scotch Bonnet Island, the non-AOC reference colony in eastern Lake Ontario in 2004 ($t(42)=0.75$, $p=0.46$). In 2005, mean egg viability, equal to 100% in all six clutches examined, was significantly higher than egg viability in gulls from Scotch Bonnet Island (t-test with separate variance estimates, $t(21.0)=3.02$, $p=0.006$).

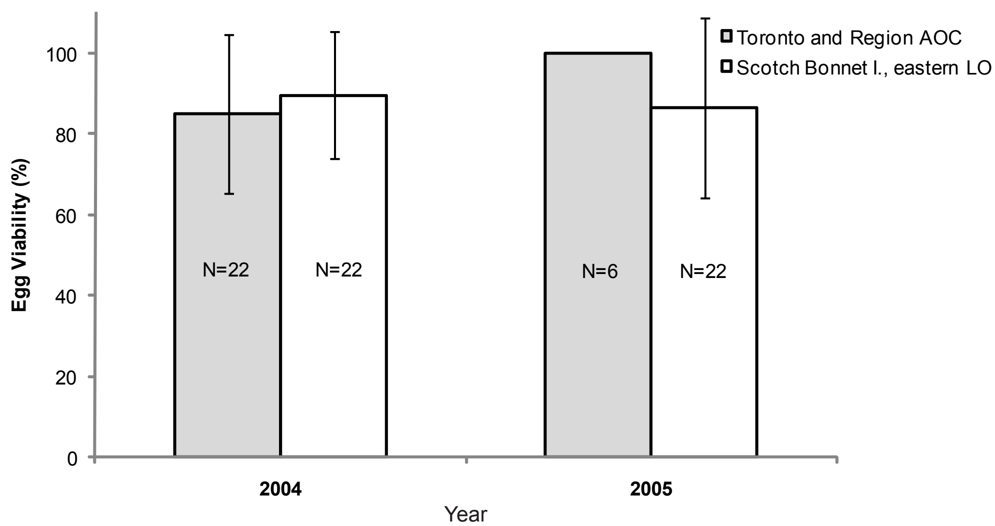

Figure 2. Mean percentage (±SD) of viable herring gull eggs in 3-egg clutches from Tommy Thompson Park in the Toronto and Region Area of Concern (AOC) and Scotch Bonnet Island, the non-AOC reference site in eastern Lake Ontario (LO), in 2004 and 2005. N denotes the number of clutches examined.

Mean clutch volume (±SD) in herring gull eggs from Tommy Thompson Park was equal to 253.3±13.94 cm^3 in 2003 and 248.3±22.14 cm^3 in 2004 (Figure 3a). In 2003, no significant difference in mean clutch volume was found between the two colonies in the Toronto and Region AOC and Snake Island, the non-AOC reference site in eastern Lake Ontario ($t(37)=0.86$, $p=0.40$). In 2004, one clutch from the Toronto colony was notably very small in volume (175 cm3) compared to the other twenty-two clutches from this colony where total clutch volume ranged from 211 cm^3 to 260 cm^3. This clutch contributed to the large variation observed among clutches in Toronto for that year, resulting in a non-normal distribution of data and necessitating the use of non-parametric statistics for subsequent analysis. Overall, no significant difference in mean clutch volume was found in gulls from Toronto and Region AOC and Snake Island in 2004 ($U=225$, $p=0.07$). Intraclutch egg size variation, as a measure of the difference between the largest and smallest egg in the clutch, was equal to 7.8±4.8% and 10.1±7.4% in 2003 and 2004, respectively (Figure 3b). No significant differences in intraclutch egg size variation were found between the Toronto AOC and Snake Island colonies in either 2003 or 2004 ($t(37)=0.04$, $p=0.97$ and $t(49)=1.24$, $p=0.22$, respectively).

To investigate differential (possibly chemically mediated) mortality of males or females during *in ovo* development, herring gull chicks from Tommy Thompson Park and Scotch Bonnet Island were blood sampled in 2004 to determine genetic sex. Of the thirty chicks examined at the Toronto colony, 53.3% of chicks were male (16/30) and 46.7% were female (14/30). Of the 29 chicks examined at Scotch Bonnet Island, 62.1% were male (18/29) and 37.9% (11/29) were female. Overall, no significant deviations from the 1:1 sex ratio were found at either colony in 2004 ($X^2<1.69$, $p>0.25$).

Hatching Success and Deformity Rates in Hatchling Snapping Turtles

Mean hatching success (±SD) of snapping turtle clutches collected from 2002 to 2004 on the Humber River in the Toronto and Region AOC was equal to 92.8 ± 9.1% (N=14 clutches; Figure 4a; de Solla *et al.* 2008). Mean hatching success was statistically comparable to hatching success at Upper Canada Bird Sanctuary (UCBS), the non-AOC reference location on the St. Lawrence River (88.4 ± 13.6%, N=10 clutches; $t(22)=0.88$; $p=0.39$). Mean deformity rate of hatchling snapping turtles from the Humber River was equal to 9.5 ± 15.4% (N=14 clutches; Figure 4b). The mean hatchling deformity rate at UCBS was somewhat elevated (equal to 18.3 ± 10.0%, N=10 clutches) and was significantly higher than the rate observed in turtles from the Toronto and Region AOC ($t(22)=2.14$; $p=0.04$).

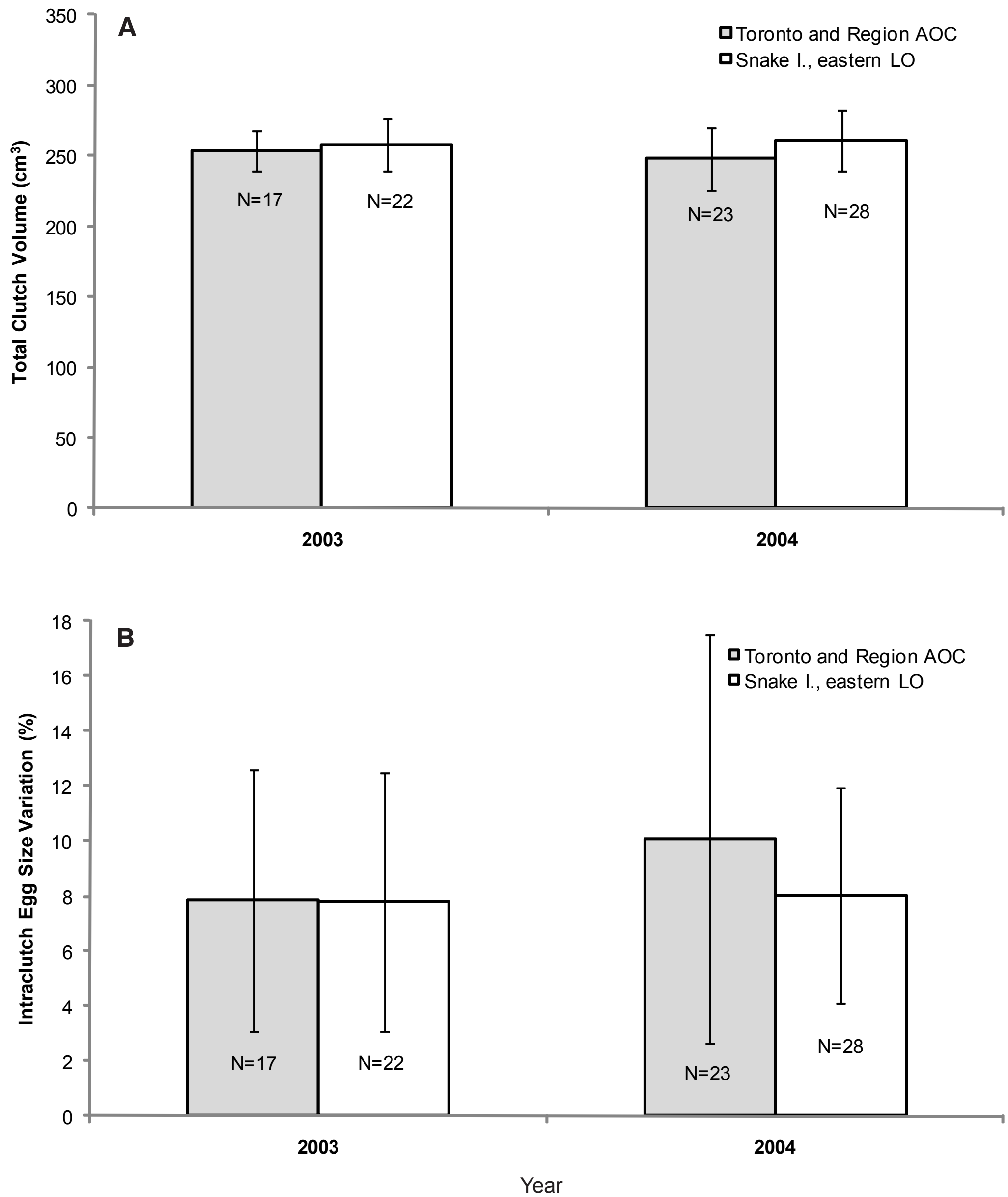

Figure 3. Mean clutch volume (±SD), shown in (A), and intraclutch egg size variation (±SD), shown in (B), in 3-egg herring gull clutches from Tommy Thompson Park in the Toronto and Region Area of Concern (AOC) and Snake Island, the non-AOC reference site in eastern Lake Ontario (LO), in 2003 and 2004. N denotes the number of clutches examined.

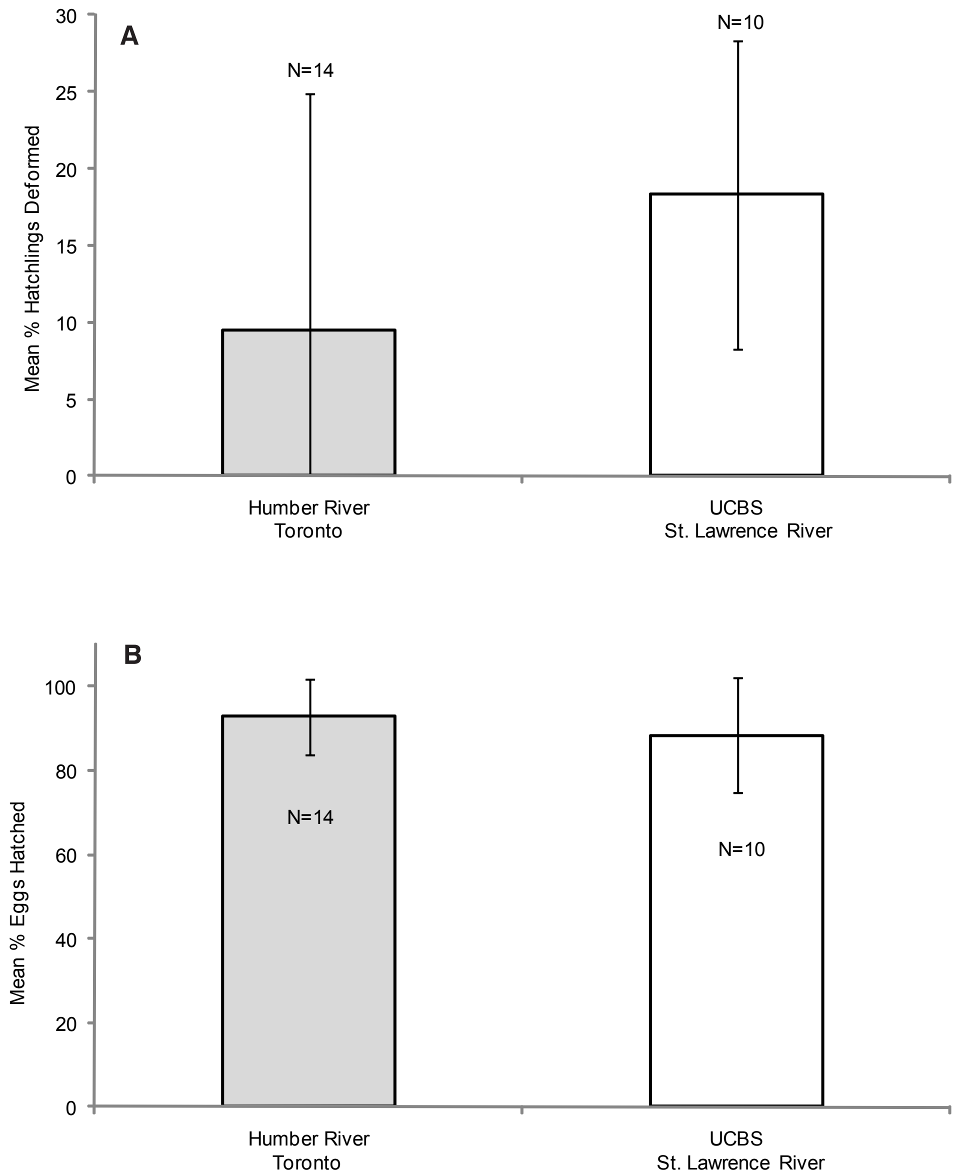

Figure 4. Mean hatching success (±SD) of snapping turtle eggs (A) and mean deformity rate (±SD) of hatchlings (B) collected from the Humber River in the Toronto and Region AOC and the Upper Canada Bird Sanctuary (UCBS), the non-AOC lower Great Lakes reference site on the St. Lawrence River, from 2002-2004 (de Solla et al. 2008). N denotes the number of clutches collected.

Contaminants in Snapping Turtle Eggs

Of all compounds examined, sum PCBs were found at the highest concentrations in eggs collected from the Humber River in the Toronto and Region AOC from 2001 to 2004 where the mean sum PCB concentration was equal to 517.3 ± 86.2 ng/g (Table 2; de Solla *et al*. 2007). Concentrations of *p,p'*-DDE, mirex and sum chlordane were the highest of all organochlorine pesticide compounds. Overall, concentrations of sum PCB and four pesticides including sum chlordane, dieldrin, hexachlorobenzene (HCB) and heptachlor epoxide (HE) were significantly higher in eggs from the AOC than in eggs from the non-AOC reference site, UCBS ($t>2.62$; $p<0.02$). Levels of p,p'-DDE, mirex and octachlorostyrene (OCS) in eggs were not significantly different between the AOC and UCBS. Sum PBDEs were also high relative to pesticides with a mean concentration equal to 65.4 ± 48.9 ng/g in eggs from the Humber River and where they were found at levels significantly higher than the UCBS reference site ($t(13)=4.81$; $p=0.0003$). Mercury levels in eggs were low and not statistically different between the AOC and non-AOC sites. Mean concentrations of *p,p'*-DDE in eggs from both the Humber River and UCBS exceeded the total DDT tissue residue guideline for the protection of the wildlife consumers of aquatic biota equal to 14.0 ng/g (CCME 2001).

Contaminants in Colonial Waterbirds

The following discussion of reproduction and deformities in colonial waterbirds will proceed on a species-by-species basis with reference to: 1) overall general colonial waterbird population trends observed using nest counts in the AOC and Lake Ontario as part of the Great Lakes decadal surveys conducted by the Canadian Wildlife Service (Blokpoel 1977; Blokpoel and Tessier 1996, 1998; CWS unpublished), and 2) specific population trends observed using annual nest counts in Tommy Thompson Park as part of monitoring by the Toronto and Region Conservation Authority (TRCA unpublished data). A more detailed population trend analysis of nesting species in Tommy Thompson Park is reported in Hughes *et al*. (2010).

Ring-billed Gulls: Ring-billed gulls are by far the most abundant nesting species in the Toronto and Region AOC with nearly 30,000 nests counted in Tommy Thompson Park alone in 2008 (Table 3). In this study, average clutch size of 2.8 eggs/nest and hatching success of 75% in 2004 were within ranges reported for these parameters in ring-billed gulls nesting at the Leslie Spit (Tommy Thompson Park) in 1977 (range of means=2.7-3.0 eggs/clutch and 64.3%-90.9% in gulls of known age, respectively; Haymes and Blokpoel 1980). Hatching success and fledging rate, reported here as 1.3 chicks fledged per nest, were also similar to values reported at two Lake Huron ring-billed gull colonies where nest location and density were examined as variables contributing to breeding success in 1972 (ranges=45%-82% and 0.68-1.89 chicks per nest, respectively; Dexheimer and Southern 1974). High hatching success and fledging rates of 83% and 2.20 chicks per nest, respectively, in early-started clutches contributed to the high reproductive success reported on Gull Island in 1977 (Chardine 1978). In this study, ring-billed gulls produced over two times the number of chicks required to maintain a stable population, as estimated by Ludwig (1967) to be equal to 0.6 chicks per nest (pair).

Table 2. Mean (±SD) sum PCB, organochlorine pesticide, and sum PBDE concentrations (ng/g, wet weight) in snapping turtle eggs from the Humber River in the Toronto and Region Area of Concern and the reference site, Upper Canada Bird Sanctuary (UCBS) from 2001-2004. Mean mercury (±SD) concentrations are also provided in ng/g, dry weight. N represents the number of clutches sampled. Similar uppercase letters between sites for a given compound are not significantly different ($p>0.05$).

	Chemical	Concentration at Toronto and Region AOC (Humber River) (ng/g)	Concentration at Upper Canada Bird Sanctuary Reference Site (ng/g)
Organochlorines	Sum PCB's	517.3 (86.2) **A**	112.9 (49.0) **B**
	p,p'-DDE	28.0 (7.89) **A**	16.8 (15.1) **A**
	Sum Chlordane	37.4 (3.57) **A**	4.65 (3.01) **B**
	Mirex	25.6 (3.91) **A**	11.6 (6.89) **A**
	Dieldrin	3.16 (0.43) **A**	0.49 (1.33) **B**
	Hexachlorobenzene	0.73 (0.11) **A**	0.36 (0.24) **B**
	Octachlorostyrene	0.40 (0.12) (N=15) **A**	0.42 (0.43) (N=11) **A**
	Sum PBDEs	65.4 (48.9) (N=13) **A**	6.37 (4.44) (N=5) **B**
	Heptachlor epoxide	1.42 (0.16) (N=15) **A**	0.25 (0.32) (N=11) **B**
Metals	Mercury	0.18 (0.08) (N=14) **A**	0.26 (0.13) (N=9) **A**

Table 3. Census data of colonial waterbird nests (=pairs) in the Toronto and Region Area of Concern during the 1st (1976), 2nd (1990/91), 3rd (1997-2000) and 4th (2008) Great Lakes decadal surveys (Blokpoel 1977; Blokpoel and Tessier 1996, 1998; CWS unpublished). Annual rates of change are for the 3rd to 4th decadal surveys. NC denotes rates cannot be calculated.

Species	Census Year				Annual Rate of Change (%)
	1976	1990-1991	1997-2000	2008	
Ring-billed Gull	14,267	49,356	59,453	29,873	-7.4
Double-crested Cormorant	0	3	1,727	7,144	+13.8
Black-crowned Night-Heron	56	792	1,265	567	-9.5
Common Tern	1,246	128	336	357	+0.6
Herring Gull	57	103	111	30	-11.8
Great Egret	0	0	0	6	NC
Caspian Tern	7	0	3	0	-100
Great Black-backed Gull	0	0	1	0	100
Total	**15,633**	**50,282**	**62,896**	**37,977**	**-**

While predation of ring-billed gulls was noted at the colony, the effects appear to be minimal. The ring billed gull's opportunistic foraging behaviour and ability to nest in high densities in a wide variety of habitats has contributed to its success as the most abundant nesting colonial waterbird species in the AOC as well as Lake Ontario in 2008 (Table 3; Hughes *et al*. 2010). Overall, the observed decline in nest numbers at an annual rate of 7.4% between the third and fourth surveys in 1999 and 2008 is consistent with that observed throughout Lake Ontario between the two surveys and is likely due to an overall decrease in food availability and/or habitat loss associated with availability of nesting sites.

Double-crested Cormorants: The breeding population of double-crested cormorants has steadily increased in Tommy Thompson Park from three nests when this species first colonized the Park in 1990 to over 9,400 nests in 2010 (Figure 5A; TRCA unpublished data). Similarly, a high annual rate of growth of 13.8% was found in the AOC between the third survey in 1997 and the fourth decadal survey in 2008 (Table 3). As expected, clutch size (3.15 eggs/nest), hatching success (81.0%) and fledging success (1.90 chicks fledged per nest) of double-crested cormorants in this study are consistent with good overall productivity (Hatch and Weseloh 1999). Fledging success was within the range found in lakes Superior, Huron and Ontario colonies from 1980 to 1991 (1.7-2.4 chicks per nest) during a period of rapid growth in the Great Lakes (Weseloh *et al*. 1995). The dramatic increase in the breeding population of double-crested cormorants in the AOC is similar to the explosive pattern observed on Lake Ontario from the early 1970s to early 1990s when decreased contaminant

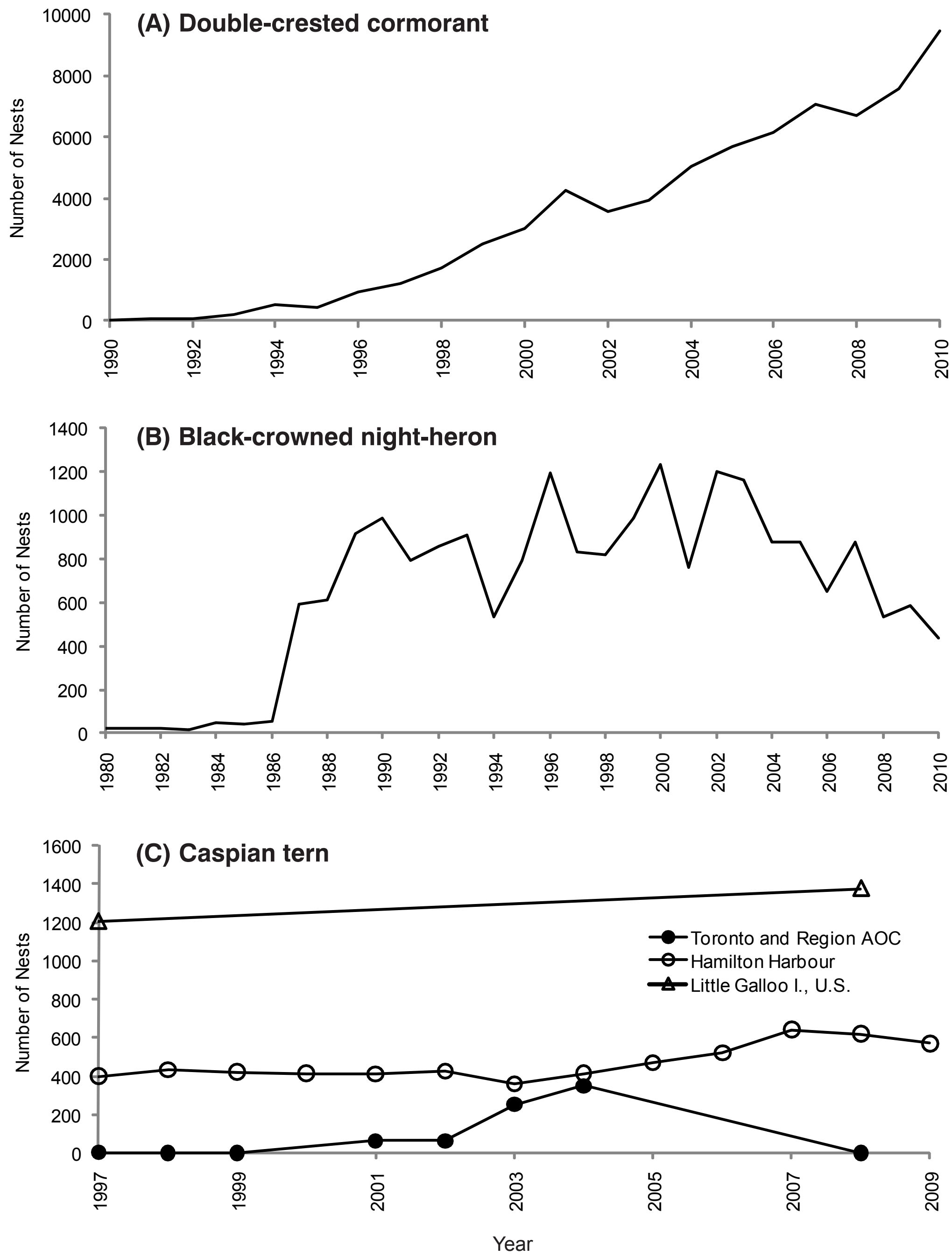

Figure 5. Annual nest counts of double-crested cormorants (A) and black-crowned night-heron (B) in Tommy Thompson Park in the Toronto and Region AOC from 1990-2010 (TRCA unpublished data) and annual nests counts of Caspian terns in Tommy Thompson Park in the Toronto and Region AOC and Hamilton Harbour (C) from 1997-2008 (TRCA unpublished data; CWS unpublished data). Nest counts for Little Galloo Island in the eastern basin of U.S. Lake Ontario are also shown for two years, 1997 and 2008 (C) (Cuthbert and Wires 2008).

loads and an increased abundance of forage fish contributed to the success of this species (Weseloh and Ewins 1994). Since 1990, the steady increase in numbers of nesting cormorants in the AOC is similar to that observed at some other Lake Ontario sites, including Hamilton Harbour, as well as Lake Ontario-wide (Hughes *et al*. 2010).

All of the nests monitored in this study were ground nests since most of the arboreal nests were too high to monitor effectively. As a result, cormorant productivity may be underestimated because ground nests are typically the last to be colonized and therefore may be occupied by less fit and/or juvenile birds. The large influx of cormorants to the Park has created concerns relating to forest habitat and the potential for conflicts with other species, such as the black-crowned night-heron, for nesting habitat. A cormorant management strategy was implemented in 2009 in specific areas of the Park to mitigate potential adverse effects on vegetation and other wildlife species by, in part, encouraging cormorants to nest on the ground rather than in trees (TRCA 2009). Within the last three years ground nesting locations have become the preferred nesting location for this species in the Park (R. Toninger, TRCA, pers. comm.).

Black-crowned Night-Herons: Sixty-eight percent of the Canadian Lake Ontario breeding population of black-crowned night-heron nested in Tommy Thompson Park in 2008 underscoring the importance of this nesting site on the Great Lakes (Hughes *et al*. 2010). The fledging rate of black-crowned night-heron in Tommy Thompson Park, equal to 1.67 chicks per nest in this study, is similar to rates found in other studies in the St. Lawrence Estuary in 1975 (two colonies, 1.5 and 2.1 chicks per nest; Tremblay and Ellison 1980), and New England in 1975 and 1979 (range=2.1-2.7 chicks per nest, age of chicks 15 days cmp. to 28 days here; Custer *et al*. 1983) where reproduction was considered to be normal. Relatively lower fledging rates, ranging from 0.46-1.27 chicks per nest, were found in black-crowned night-heron from Alcatraz Island in San Francisco where factors including predation, interspecific competition and habitat deterioration largely contributed to low reproductive success observed from 1990-2002 (age of chicks 15 days; Hothem and Hatch 2004). Night-heron from Baltimore Harbour, Maryland, produced a higher average of 2.05 chicks per nest (age of chicks 15 days; Rattner *et al*. 2001).

While population trends of black-crowned night-herons based on annual nest counts show some fluctuations from year-to-year in the Park, the total population of nesting night-heron has steadily decreased in size from its maximum of 1,235 nests in 2000 to 434 nests reported in 2010 (Figure 5B; TRCA unpublished data). This is likely due to the steady influx of nesting cormorants which has resulted in these birds moving elsewhere in the Park and/or nesting in less suitable marginal habitat such as in smaller trees and/or high disturbance areas. Reproductive success of night-herons may vary with habitat quality in the Park as birds nesting in better locations may produce more chicks (R. Toninger, TRCA, pers. comm.). Habitat deterioration, interspecific competition with cormorants, predation and human disturbance are factors which likely influence chick survival in the Park. Raccoon (*Procyon lotor*) predation may also be significant in the Park where between 4% and 28% of black-crowned night-heron nest failure was attributed to raccoon activity in a sub-sample of nests in trees in Peninsula C in 2010; other factors such as weather and lack of coordination between members of a pair of birds also likely contributed to nest failure in this year (Fraser *et al*. 2011). While night-heron appeared to show a reasonable rate of productivity in 2004, there are clearly a number of factors which contribute to the reproductive success of this species and continued monitoring and management is required to ensure that this important Great Lakes population continues to breed successfully in the Park.

Caspian Terns: The average clutch size of Caspian tern nests at 2.40 eggs/clutch in 2004 was similar or higher relative to mean clutch sizes for early-nesting terns on the Eastern Headland in 1979-1981 (range in means=2.07-2.30 eggs/clutch; Fetterolf and Blokpoel 1983) and terns from colonies on Lake Michigan, Lake Huron and Lake Ontario in 1991 (range in means=1.75-2.24 eggs/clutch; Ewins *et al*. 1994). However, hatching success and fledging rates in this study at 47.9% and 0.13 young fledged per nest, respectively, were lower than corresponding rates at the Eastern Headland in 1980 and 1981 (76.9% and 0.71 young per nest; Fetterolf and Blokpoel 1983). Similarly, relatively higher hatching success and fledging rates were found at Caspian tern colonies elsewhere on the Great Lakes in 1991 (47%-85% and 0.7-1.61 young fledged per nest; Ewins *et al*. 1994). Overall, the low number of Caspian tern young fledged per nest in 2004 is below the calculated reproductive output of 0.6 young fledged per nest required to maintain a stable population on the Great Lakes (Ludwig 1965).

Caspian terns nesting in Tommy Thompson Park are impacted by a number of stressors which may have contributed to the low reproduction success observed in 2004 and the subsequent abandonment of the colony in 2008 (Figure 7). The location of the tern colony on the Endikement Tip is situated on the mainland and as such was accessible to mammalian predators, such as raccoons, feral cats, skunks, and rats, observed in the Park. In addition, the colony was also in close proximity to nesting ring-billed gulls which, upon disturbance, were observed to eat exposed tern eggs when adult terns lifted off their nests. Intensive management activities implemented to discourage nesting ring-billed gulls in the Endikement Area in the early 2000s may have also left the tern colony exposed and more susceptible to predation. Human disturbance during incubation can also influence reproductive success (Fetterolf and Blokpoel 1983). Caspian terns which abandoned the colony in 2008 may have relocated to other areas of Lake Ontario such as Hamilton Harbour and Little Gallo Island on the U.S. side of Lake Ontario where recent increases in nesting numbers have been observed (Figure 5C). The construction of six new islands in embayment D in 2011 will provide new tern nesting habitat in the Park and offer increased protection from humans and avian and mammalian predators. This might encourage their expansion back to Toronto which previously had supported a large Caspian tern population of 350 nests in 2004 (Figure 5) and as well as improve their long-term stability and reproductive success in the Park. The low reproductive success at this colony in 2004 appears to be largely related to the effects of predators and not contaminants, as also suggested by the large clutches and high adjusted hatching rate (100%) observed in the monitored areas.

Common Terns: In Tommy Thompson Park, annual numbers of breeding pairs of common terns have declined from over 1,200 nests in the mid-1970s/early 1980s to approximately 400 nests in the early 2000s to, more recently, 300 nests in the late 2000s (TRCA unpublished data). Mean clutch size in 2004, equal to 2.56 eggs/clutch, was within the range found at two colonies on Mugg's Island (Toronto Harbour) in the AOC in 1972 (range=2.47-2.77 eggs/clutch; Morris *et al*. 1976). In 2004, however, the number of young fledged per pair at 0.45 was approximately one-half of that reported as the mean reproductive success of several colonies of common terns in the lower Great Lakes from 1972 to 1977 (Courtney and Blokpoel 1983). In 2008, a study of common tern productivity by York University researchers in the Park estimated the number of young fledged per nest as 0.56, a similar value to that found in this study (Lakfard and Fraser 2009). Population studies of common terns in Massachusetts have determined that an annual production of 1.1 chicks per pair is necessary for population stability (Nisbet 1978). However this rate of production is seldom seen on the Great Lakes and is well above that found in Tommy Thompson Park.

Many factors can negatively impact breeding success of common terns including loss of suitable nesting habitat, displacement by gulls, predation by mammalian and avian species, human disturbance and weather. While the installation of five artificial nesting platforms (i.e., rafts) have been largely successful in attracting breeding common terns to the Park and mitigating the effects of some of these factors, predation from birds (e.g., black-crowned night-heron) and aquatic animals (e.g., turtles, mink), human disturbance (e.g., recreational boaters), and weather likely contribute to the variability and fluctuations in nest numbers and reproductive success often evident between years. The influence of these factors is not specific to the AOC - the Canadian Lake Ontario breeding population of common tern has also declined from 1,205 nests in 1998 to 655 nests in 2008 (Hughes *et al*. 2010). The Port Colborne common tern colony on eastern Lake Erie is a historically important site for nesting terns which has slowly decreased in size since 1988 due to gull encroachment and predation by birds and mammals (Morris 2009). While the construction of new islands in embayment D of the Park will be important in providing additional tern habitat in the Park, continuing conservation efforts including ongoing management and public education will be required for protecting these important nesting colonies.

In summary, while a 40% decline in total nest numbers of all species combined was found in the AOC (Table 3), large declines were also found in Canadian Lake Ontario (22%) and Lake Ontario-wide (26%) (Figure 6; total nest numbers as reported in Hughes *et al*. 2010).

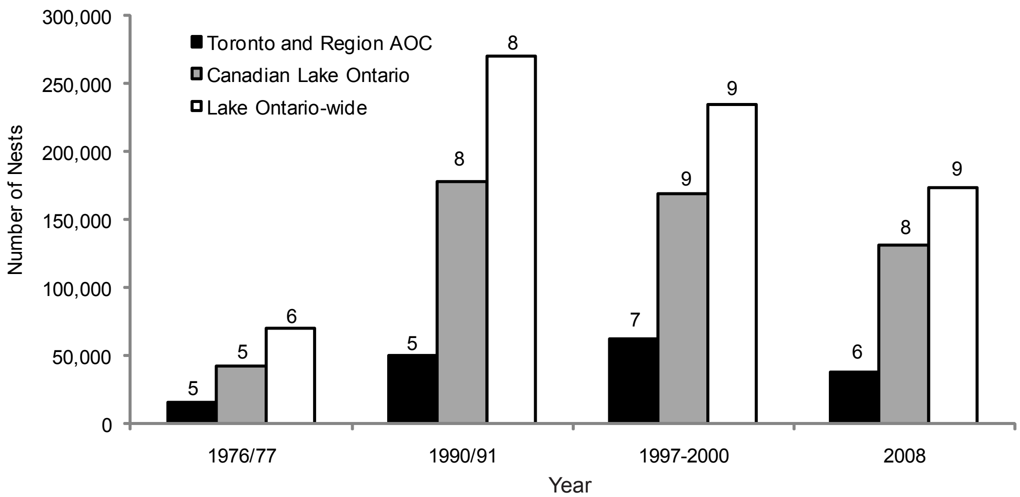

Figure 6. Census data of colonial waterbird nests in the Toronto and Region Area of Concern, Canadian Lake Ontario, and Lake Ontario-wide during the 1st (1976), 2nd (1990/91), 3rd (1997-2000) and 4th (2008) Great Lakes decadal surveys (Blokpoel 1977; Blokpoel and Tessier 1996, 1998; Scharf and Shugart 1998; Cuthbert *et al*. 2001; Cuthbert and Wires 2008; CWS unpublished). Numbers above bars indicates the number of nesting species.

Herring Gulls: Despite the decrease in the herring gull breeding population in the AOC and Canadian Lake Ontario (Table 3; Hughes *et al*. 2010), reproduction appears to be good and not related to contaminant stressors or stressors specific to the Toronto and Region AOC. Of the reproductive parameters examined in herring gulls in this study, egg viability was high at over 85% in 2004 and 2005. Factors that may affect egg viability are varied and may include toxic substances, bacterial and viral pathogens, and nutritional deficiencies. Gross nutritional deficiencies were not evident since egg size parameters (i.e., clutch volume, intraclutch variation in size) were within the range associated with good productivity (Hebert *et al*. 2002). In addition, egg viability and egg size parameters were statistically similar to the two respective reference sites, Scotch Bonnet Island and Snake Island, in two study years. There was also no significant bias in the sex ratio in gulls from Toronto Harbour indicating no differential (possibly chemically mediated) mortality of males or females during *in ovo* development.

Morphological Deformities in Colonial Waterbirds

During the 1970s when reproductive failure was observed in some Great Lakes colonies of birds, a relatively high incidence of congenital deformities, such as crossed bills, was also observed. In 1972, the overall deformity rate in common tern chicks from Mugg's Island (Toronto Harbour) was equal to 1.2% (of 420 chicks examined) and the most common deformity found was crossed bills (Gilbertson *et al*.1976). During a 1973 survey of a ring-billed colony on Mugg's Island, approximately 0.8% of chicks had a deformity (i.e., more than 20 of about 2500 chicks) with a leg deformity as the primary deformity type found (Gilbertson *et al*. 1976). Deformities were also found in cormorant chicks from some Lake Ontario colonies during the periods 1979-1987 (0.07%, 2 of 2882 chicks; Fox *et al*. 1991) and 1988-1994 (0.008%, 3 of 38898 chicks; Ryckman *et al*. 1988). The Toronto and Region AOC colony was not among the Lake Ontario colonies visited in either survey.

In 2004, morphological deformities in colonial waterbird chicks were found in two of five species examined, the ring-billed gull and common tern, at rates equal to 0.25% (5 of 2000 chicks) and 0.33% (1 of 300 chicks), respectively. Deformities reported in chicks of these two species were lower with respect to rates of incidence in the 1970s reported by Gilbertson *et al*. (1976), and, of particular note, were not consistent with contaminant-related physical deformities. In this study, no deformities were found in chicks of cormorants, Caspian terns or black-crowned night-herons. Anecdotally, researchers and TRCA staff have not reported or found unusual deformities in colonial waterbirds in the Park (R. Toninger, TRCA, pers. comm.).

Snapping Turtles

While effects on reproductive success and development of snapping turtles have been found in some Canadian Great Lakes AOCs (de Solla *et al*. 2008), these were not evident in snapping turtles from the Humber River where hatching success was high (92.8%), hatchling deformity rate was low (9.5%) and both parameters were statistically similar (or better) relative to the non-AOC Great Lakes reference site, UCBS. Although contaminant levels in eggs were significantly higher relative to the reference site for a number of compounds including PCBs, the biological significance of such elevated levels with respect to embryonic development is unclear. It is important to mention that effects examined in this study were limited to impacts on hatchability of snapping turtle eggs and hatchling deformities only. Elevated levels of compounds such as PCBs may result in other potential adverse effects on reproduction and development not examined in this study. Relative to other Great Lakes sites, mean sum PCBs in eggs from the Humber River were similar to levels in snapping turtles from the Bay of Quinte AOC and approximately one-half of that found in sites in the Hamilton Harbour AOC, Niagara River and Detroit River (de Solla *et al*. 2007).

Polybrominated diphenyl ethers (PBDEs), similar in structure to PCBs and also of toxicological concern, were also found in eggs of snapping turtles and herring gulls from the AOC and their respective reference site locations (Table 2; de Solla *et al*. 2007; Hughes *et al*. 2010). Elevated PBDE exposure in wildlife has been associated with heavily and urbanized regions (Norstrom *et al*. 2002; de Solla *et al*. 2007) such as that in Toronto and surrounding area. While toxicological studies of PBDE exposure in experimental animals reveal impacts on reproduction, neurological development, as well as immunotoxicity (Darnerud *et al*. 2001), it is not known what health effects associated with PBDE exposure might be evident in turtles and gulls foraging in the AOC.

Contaminants

Current levels of contaminants in eggs of colonial birds from Tommy Thompson Park in 2004 were below thresholds associated with adverse effects on reproductive success in avian species (Pearce *et al*. 1979; Henny *et al*. 1984; Hoffman *et al*. 1996; Thompson 1996; Wiemeyer 1996). In contrast, early studies of Great Lakes colonial waterbirds in the early 1970s showed near total reproductive failure in Lake Huron colonies of double-crested cormorants in 1972 where levels of *p,p'*-DDE and PCBs (as Arochlor 1260) in eggs were at least seven times higher than in this study (Weseloh *et al*. 1983). Similarly, fledging rates were low in black-crowned night-heron from eastern Lake in 1972, 1973 and 1976 (range in means=0.5-1.4 μg/g) and where levels of *p,p'*-DDE and PCB levels (as Arochlor 1254:1260) were at least four times higher than in this study (Price 1977). These studies (and others, e.g., Gilbertson 1974) support the corollary of that found in this study, i.e., relatively lower levels of contaminant exposure are associated with increased reproductive success of nesting colonial waterbirds in the AOC.

Since the 1970s, dramatic declines in levels of contaminants have been reported in wildlife species in the AOC. Levels of contaminants in herring gull eggs for example have declined significantly from 1974 to 2007 with levels of PCBs and p,p'-DDE by over 93% and most other compounds including 2,3,7,8-TCDD by at least 73% (Figure 7). Similar large decreases in levels of many compounds have been found in black-crowned night-heron, common terns and ring-billed gull in the AOC from 1970s/80s to 2004 (Hughes *et al*. 2010). These trends provide evidence of decreased exposure to wildlife following federal restrictions and bans on the use of contaminants and the effectiveness of remedial actions in the AOC.

Conclusions

The content of Table 4 provides a summary of the reproduction and deformities data and corresponding current and long-term contaminants and population trends data collected for aquatic wildlife species used to evaluate the status of the reproduction and deformities BUI in the Toronto and Region AOC. The weight of evidence evaluation of the data pertaining to the assessment of this BUI in the AOC has demonstrated the following:

- Levels of contaminants in eggs of colonial birds from Tommy Thompson Park in 2004 were below thresholds associated with adverse effects on reproductive success in avian species.

- While morphological deformities were found in chicks of two of five colonial waterbird species, rates were low and the types observed were not consistent with contaminant-related deformities.

- Contaminant-induced effects such as decreased reproductive success and elevated morphological deformities do not appear to be limiting factors at the population level for colonial waterbirds feeding in and around the AOC.

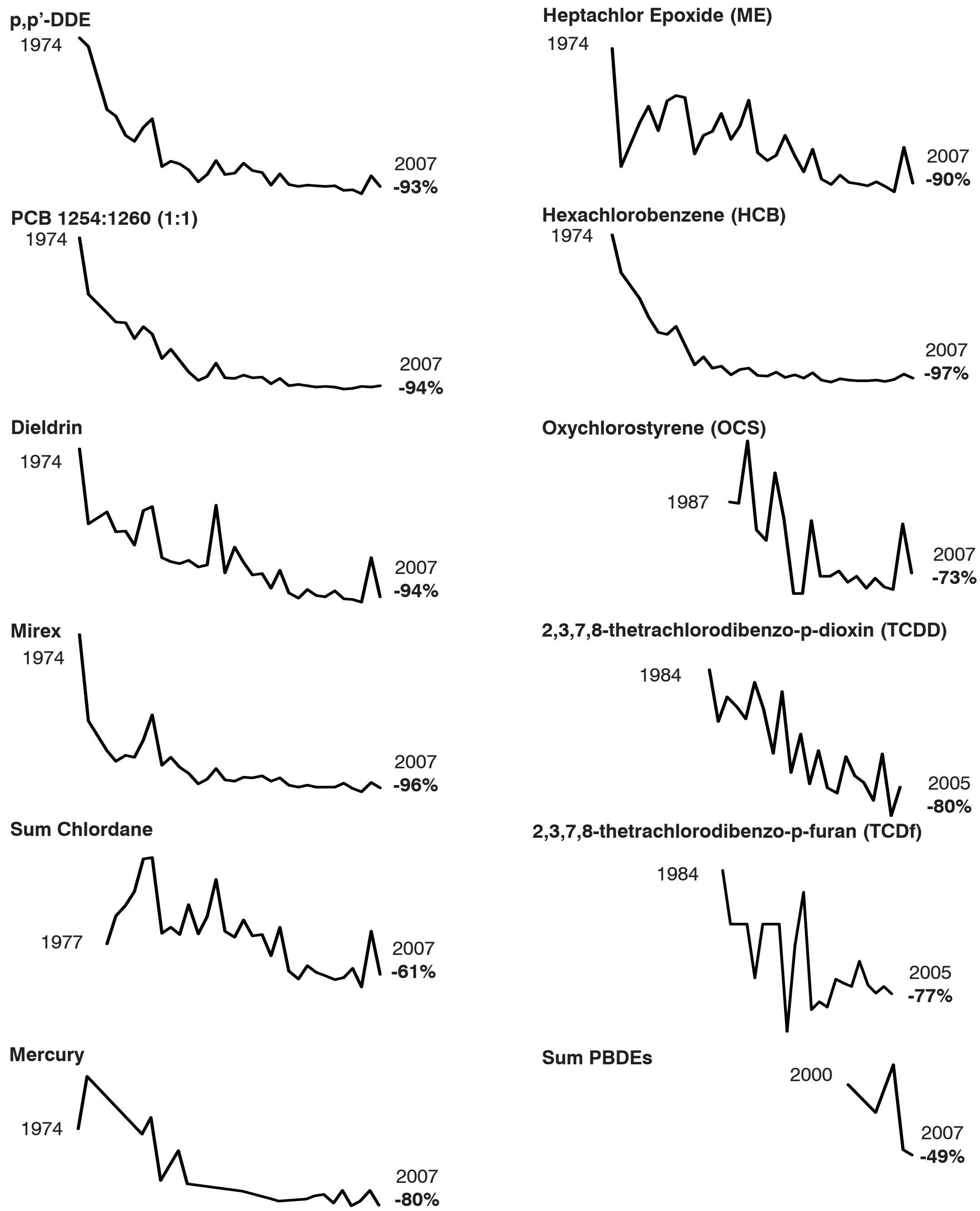

Figure 7. Percent decline in the concentrations of 12 contaminants in herring gull eggs from Toronto and Region AOC from the first year of analysis (to left of trace line) to the last year of analysis (to right of trace line). Trace line depicts contaminant concentrations in herreing gull eggs as measured in intermediary years (adapted from Hughes *et al*.- 2010).

Table 4. Reproduction and deformity parameters examined in wildlife species from the Toronto and Region Area of Concern from 2001-2005. Supporting data include current and long-term contaminant trends and population trends which are presented here or in further detail in Hughes *et al.* (2010).

Parameter	**Colonial Waterbirds**		**Snapping Turtles**
	Herring Gull	Ring-billed Gull Double-crested Cormorant Black-crowned Night Heron Common Tern Caspian Tern	
Egg Viability	✓		
Clutch Volume & Interclutch Egg Variation	✓		
Sex Ratio	✓		
Hatching Success		✓	✓
Fledging Success		✓	
Deformity Rates in Young		✓	✓
Supporting Data:			
Contaminants - Current Trends	✓	✓	✓
Contaminants - Long-term trends	✓	✓	
Population Trends	✓	✓	

- Reproductive success of tern species and night-herons appeared to be limited by external factors such as predation, competition and/or habitat deterioration; these factors had little influence on nesting ring-billed gull and cormorant populations.

- Based on parameters examined in this study, embryonic development appears good in snapping turtles from the Humber River from 2002-2004 where hatching success was high in eggs and the rate of morphological deformities was low in hatchlings.

- Endpoints associated with impaired reproduction and deformities in wildlife including egg viability, clutch volume, intraclutch egg volume, and sex ratio in herring gulls and hatching success and hatchling deformities in turtles, were similar between the AOC and selected lower Great Lakes non-AOC reference sites.

Based on the evidence presented here, a recommendation is made that the "bird or animal deformities or reproduction problems" BUI in the Toronto and Region AOC is considered as Not Impaired.

Recommendations

Specific to the reproduction and deformity BUI in the Toronto and Region AOC and based on the above recommendation, no additional work is required to assess or remediate this BUI.

- Future monitoring of reproduction of colonial waterbirds in Tommy Thompson Park would be valuable since this site represents a very important nesting location for breeding colonial waterbirds in Lake Ontario.

- Ongoing monitoring of colonial waterbird populations by the TRCA in Tommy Thompson Park will identify if new concerns relating to this BUI are noted at which time the Remedial Action Plan (RAP) team will be notified.

- Great Lakes programs such as the Herring Gull Monitoring Program should be continued to provide important information with respect to current exposure and long-term trends of contaminants in wildlife in the AOC.

- Additional collections of snapping turtle eggs from the same sites on the Humber River for contaminant analysis would prove beneficial for examining temporal trends since no additional years of data in the AOC are available.

- Continued partnerships with other agencies (e.g., government, academia) are also important for identifying issues and future concerns relating to this BUI.

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