Spatial and temporal correlates of mass bird mortality in oil sands tailings ponds[1]

A report prepared for Alberta Environment by

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Executive Summary

On October 25 and 26, 2010, 547 dead birds were recovered and recorded by operators in the oil sands region of Alberta. These deaths exceeded the occasional mortalities that are reported by operators in a typical year and resulted in an investigation by Alberta Environment. As part of that investigation, Cory McLaughlin, an investigating officer with Alberta Environment, asked me to address the questions that follow. More information on the context of that request and subsequent discussions is included in the cover letter to Cory that accompanies this report. I address each of the questions below and conclude each with a set of conclusions. I provide additional synthetic conclusions and recommendations at the end of the report. Three appendices follow the report detailing weather and GIS information. Answers to my questions include several additional tables and figures that are referenced within the text.

The main conclusions of my analyses are as follows:

1. Adverse weather conditions undoubtedly contributed to the recoveries recorded on October 25 and 26, 2010. Adverse conditions included strong and variable winds, precipitation, dense cloud cover, and darkness. There is no evidence that the recovered birds were in ill health, but the positions of deterrents and artificial lights may have influenced where birds landed and, hence, the probability of encountering bitumen (below).

2. Based on prior information, it would have been difficult to predict the precise landing locations on October 25 and 26. However, synthesizing the available literature would have anticipated the potential and approximate roles of adverse weather, lower deterrent densities, and proximity to the Athabasca River. The analyses in this report combined with analyses of both past and future landing events of smaller magnitude will make it possible to increase the predictability of landing events in space and time. No one has

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[1] Adjustments to this report were completed in July 2012 in response to new information about the locations and numbers of birds that were recovered in the days following October 25, 2010. Further minor changes were made on 13 September 2012 to accommodate a review of FOIPP regulations. Original and tracked changes versions of this document are available upon request.

[2] Habib and Shore assisted in the GIS and weather analysis, respectively, and will be authors on a related publication. This report is written in first person singular to reflect the methodological ideas and opinions for which St. Clair is responsible.

previously anticipated the combination of poor weather, geography, bird physiology, and the positions of deterrents, artificial lights, and bitumen that may best predict the specific locations of landings in this event.

3. Detailed analyses of the spatial correlates of bird recoveries in the October 25 and 26 landing event indicated that they were more likely:
    a. On ponds that were closer to the Athabasca River with lower deterrent density or larger areas of shoreline that were unprotected by audio deterrence of 80 dB or greater,
    b. Within 200 m of shorelines on the down wind side of ponds, and
    c. In the vicinity of anthropogenic light stations that support mining operations.

4. More information is needed to assess the importance of both spatial and temporal variables, but several recommendations for research and mitigation are offered. Data of particular relevance include the distribution of both bitumen and anthropogenic light in the oil sands and the responses of birds to lights of different colours, intensities, and distributions. For more immediate use, the mitigation with the greatest promise includes use of green light instead of white, containment of bitumen, and the provision of alternative landing sites when periods of extreme weather and migration coincide.

Detailed report on the questions posed by Alberta Environment

Alberta Environment Question 1: What is the most reasonable explanation as to why migratory birds landed on tailings ponds north of Fort McMurray on October 25/26, 2010?

Late October comprises the very end of the fall migratory period for waterfowl in northern Alberta. Waterfowl there and elsewhere in North America typically migrate south to their wintering grounds throughout the late summer and fall of each year. Shorebirds and passerines begin migrating in August of each year. Waterfowl species, which are usually among the last to leave, may stay on breeding and staging areas as late as the middle of October. Although the fall migration period is usually protracted and much less synchronized than spring arrivals both within and among species, migration of waterfowl through the oil sands region was historically over by October 25 and 26.[3]

Within-species variation in migratory timing is associated with bird age, breeding status, breeding success, and body condition. In general, birds that bred or were produced late in the season and birds in poorer body condition leave for the wintering grounds later. Because food is typically abundant in the late summer at northern latitudes, birds without sufficient reserves to migrate stay as long as the weather remains favourable. The lesser reliance on photoperiod in the fall increases the importance of temperature as a cue to initiate migration (Newton 2007). The sudden drop in temperature that occurred shortly before October 25 (see below) would be expected to prompt movement by any late migrants that remained in more northern staging areas.

Once migration is initiated, two main circumstances cause birds to land or 'stop-over' before reaching their final destinations. One is the predictable need to rest and refuel at periodic intervals, and the other is adverse weather conditions that make flight too costly to maintain. I discuss below each of these causes for stop-overs and their consistency with conditions on October 25 and 26.

The frequency and duration of refueling rest stops is generally not well known and varies among species, individuals, seasons, and weather patterns (reviewed by Faaborg *et al.* 2010). Large-bodied birds such as ducks can store substantial body fat to fuel their migration and likely stop less frequently than do smaller birds. Typical stop-over frequency during fall migration for waterfowl appears to vary between a few hours to a few days (Morris 1996, Newton 2007). Variation among both species and flocks would be expected in the timing and duration of stop-overs induced by the need to refuel.

The birds that landed on Mildred Lake Settling Basin on October 25 and on surrounding areas on both October 25 and October 26 had likely recently departed from the Peace-Athabasca Delta. The importance of that wetland complex is well-established as a staging area for water birds in both spring and fall migrations. In fall, birds would forage there to accumulate the fat reserves that would sustain them on their southward migration. An unusually warm October in 2010 was likely the reason some migratory birds were still in the area on October 25.

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[3] McLaren M. A. and McLaren, P. L. 1985. Bird migration watches on crown lease 17, Alberta, Fall 1984. Report prepared by LGL Limited for Syncrude Canada, Ltd.

Because the Peace-Athabasca Delta is just 200 km north of the oil sands region, it is unlikely that birds, even late migrants, would have been exhausted by a long flight and depleted of fat reserves by the time they landed at Mildred Lake. This assumption is confirmed by the necropsies that were performed by the Environment Canada toxicology laboratory in Saskatoon. Those reports described six ducks of four species (2 Mallards, 2 Northern Shovelers, 1 Lesser Scaup, and 1 Gadwall) that were recovered on 30 October 2010; three individuals were collected from roads at each of Suncor and Kearl sites. Five of the six birds were described as being in excellent condition (no comment on the 6th) as revealed by subcutaneous and visceral fat deposits. Several had been squashed and dismembered, suggesting they had been hit by a vehicle after landing and then were scavenged by other animals. In addition to their external injuries, several birds had internal hemorrhages, fractures, broken bones and other evidence of blunt trauma from impact with the ground. Nothing in the report suggests that the birds were suffering from starvation or malnutrition as an explanation for their landings.

The second major reason that birds put down during migration, adverse weather, seems more likely to apply to the circumstances on October 25 and 26. Very high rates of landing and mortality are especially likely during storm events (reviewed by Newton 2007). Precipitation has been associated with bird landings in the oil sands region for decades (Gulley 1980, Golder 2000), but strong, unfavourable winds may be even more important causes of stop-overs[4]. Unfavourable winds include those that blow against the direction of migration and those that generate strong downdrafts, which dramatically increase the cost of flight. During fall migration in Alberta, those winds would be from the south and east, and downdrafts would form most strongly where large air masses collide[5].

At the time of the landings on October 25, several individuals on the ground reported recent freezing rain in the area. The Ft. McMurray weather station did not report precipitation for this time period, but it is likely that precipitation occurred over part of the period during which or shortly before landings occurred. At least one bird recovered on land at Suncor was described as being 'frozen' when it landed at the Suncor Coke Pit,[6] which might be indicative of heavy freezing precipitation at higher altitudes. Regardless of the degree and type of precipitation, all observers agreed that there was a storm event in the area in the days prior to landing. Several reports suggest that birds crashed in the vicinity of ponds over the same time period.[7]

Question 1 Conclusions. What is the most reasonable explanation as to why migratory birds landed on tailings ponds north of Fort McMurray on October 25/26, 2010?

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[4] Personal communication, Jean-Michel DeVink, Population Management Biologist, Canadian Wildlife Service

[5] Personal communication, Bill McMurtry, Environment Canada, Calgary

[6] Suncor incident report provided by Alberta Environment.

[7] Two other incident reports from Suncor described birds that were found incapacitated on the ground that were released upon recovery a short time later; one was a bird near Pond 4G that had not contacted oil and appeared to be healthy and one was found on land near STP that had small amounts of oil on the bill and head.

It seems apparent that adverse weather prompted birds to land on October 25 and 26. The weather during, and especially preceding, the landings included a major storm event with high wind speeds and changing wind directions (see below), exactly the conditions that hinder migration. It does not seem likely that low fat reserves caused the landings because (a) it was early in the migration journey for birds that were within 200 km of an area where they had likely refueled extensively, (b) the landings were by large-bodied birds that carry substantial body fat, (c) the necropsied birds were healthy with no indication of starvation, and (d) the landings involved multiple species and were highly synchronized in time and concentrated over space.

Alberta Environment Question 2: Would the incident on Oct. 25/26 have been reasonably foreseeable by oil sands facilities north of Fort McMurray?

There are two aspects of the incident on October 25 and 26, 2010 that might have been anticipated: the landings and the mortalities and I address them separately below. Anticipating either event type with certainty will likely never be possible. Similarly, the infrequent nature of past events makes it almost impossible to evaluate the probability with which the landings occurred when and where they did. Comprehensive and standardized monitoring may make it possible to predict both temporal and spatial characteristics of landing events in future. With this information, additional deterrence effort and other forms of mitigation could be offered at the times and locations where it is most needed. Identifying such correlates is one of the objectives I have for the *Research on Avian Protection Project (RAPP)* that stemmed from the prosecution of the April 2008 landing event at Syncrude's Aurora Settling Basin[8].

A total of 457 birds were recovered dead or badly oiled (and subsequently euthanized) on October 25 and 26 at Syncrude's Mildred Lake Settling Basin. A total of 97 more birds landed at various other sites associated with ponds, 94 of which died.

Reasons for landing. Evidence suggests that all landings occurred during and immediately after an early winter storm, which followed a prolonged period of unseasonably warm weather. The April 28, 2008 landing of birds at Syncrude's Aurora Settling Basin had superficially similar characteristics; birds landed after unseasonably warm weather had been abruptly displaced by a late winter storm. I know of only one other record of a mass landing event in the tailings ponds, which occurred on May 15, 1979 at Suncor's Pond 1[9].

Predicting the effects on landings of the storm that occurred shortly before October 25 would require that oil sands operators could associate similar storms and landing events in the past. To explore the apparent similarity of weather preceding these mass landing events, I requested of my research assistant, Bryon Shore, a summary of the weather conditions recorded at the ground surface at Ft. McMurray in the two weeks preceding these three landing events. His document is contained unaltered in Appendix A. Although I requested this work well in advance of the invitation by Alberta Environment to address the questions contained in this report, its contents are highly relevant to gauging the extent to which the landing might have been anticipated. I

[8] Described in the Court Order stemming from *R. vs. Syncrude*.
[9] Data provided by John Gulley, Golder Associates.

included all three landing events to facilitate the comparisons they offer. The summary includes temperature, wind speed, wind direction, and barometric pressure for each of the landing events. Trend lines in the associated graphs are coded by event: blue = 2008, red = 2010, and green = 1979. In each graph, the red bar indicates the approximate timing of landing.

A comparison of these weather variables is suggestive of commonality, but does not offer a precise cue for landing events. Temperatures had declined in the days prior to the landings in both October 2010 and April 2008, but not in May 1979. These drops occurred 5 (2010) to 10 (2008) days prior to the landing event. Wind speeds peaked at 60 km/h at the time of the storm onset in 2008, but wind speeds in the preceding few days were variable and comparable to speeds at several other times in the two-week period. In 2010, wind speeds peaked at 30 km/h on October 25, but winds as high as 40 km/h had occurred several times in the preceding weeks. For the 1979 event, wind speeds were very low. Wind direction was consistently from an easterly direction in the 24-h period prior to the landing events in 2008 and 2010, unlike other winds recorded in both of the preceding two-week periods. This pattern is also apparent in 1979, albeit with lesser magnitude and duration. In that year, there was a period of persistent easterly winds several days earlier. The sine of wind direction, which standardizes an easterly wind to a value of 1, accentuates these patterns in an additional set of graphs (Appendix A). These demonstrate that winds were predominantly easterly in the 24-h period prior to all three landing events. Moreover, the wind speed of easterly winds (obtained by multiplying wind speed by the sine of wind direction) reached its maximum value within 24 h prior to the landing events in both 2008 and 2010. Barometric pressure dropped precipitously the day before both the 2008 (1.1 kPa) and 2010 (1.3 kPa) landing events, but these drops were not remarkable in the two-week period for their severity; there was a very slight drop in 1979.

A summary of Bryon’s weather information suggests that landings might be more likely

- for up to several days following storm events,
- following persistent easterly winds, and
- during or following drops in barometric pressure

Because weather conditions on the ground can be very different from those at the altitudes at which birds migrate, I requested additional weather information from Bill McMurtry, a warning preparedness meteorologist with Environment Canada. That information is summarized in Appendix B.

Bill’s summary of the weather during and preceding the three storm events is qualitatively similar to my own. There is nothing particularly similar or outstanding about the weather prior to and during the three landing events, but all were accompanied by easterly winds. The weather on October 25, 2010 was typical of a storm event and Bill corroborated the observations of several individuals that there was precipitation in the area on October 25. He mentioned the potential importance of a low cloud ceiling, something I had not previously considered. Low cloud might lessen the ability of birds to detect either fresh water or the presence of bitumen on the water surface as they prepared to land.

Although Bill explained that easterly winds would generally be expected of a low pressure system arriving from the west — this is because winds blow from areas of high to low pressure

— he described the system on October 25 as a deepening low moving across the prairies towards the north west. The arrival of the low pressure system should have caused an equally abrupt change in wind direction from east to northwest. Bill emphasized that colliding air masses generally produce highly unstable winds with strong updrafts and downdrafts. Bryon's graphs reveal that wind direction changed abruptly immediately before the October 25 landing event. Wind directly was highly variable immediately before or during the 1979 and 2008 events as well.

Reasons for mortality. There are abundant observations of birds landing in tailings ponds without apparent ill effects (personal observation, multiple personal communications). Several experienced toxicologists have told me that the process-affected water on the surface of tailings pond water has negligible effects on birds that land for short periods, provided that the effluent was deposited at least 24 hours previously and that the birds do not come in contact with bitumen and other hydrocarbons. The mixing with air that occurs near the pond surface oxidizes the PAHs (polycyclic aromatic hydrocarbons) that are otherwise highly toxic to birds (Hwang and Cutright 2004, Albers 2006).

Hydrocarbons, including bitumen, can kill birds in many ways. Birds that ingest large amounts of them are poisoned (Butler *et al.* 1986, Leighton 1993, Troisi *et al.* 2006), and eggs that subsequently come in contact with even small amounts of bitumen on the brood patch of incubating parents die when volatile components enter the egg during gas exchange (Albers 1980, Finch *et al*. 2011. Disruption to feather structure is the more common reason that adult birds die from contact with bitumen (Jenssen and Ekker 1991, O'Hara and Morandin 2010). This is because bird feathers possess a microscopic zipper-like structure that knits the barbs of the feathers together to provide excellent thermal insulation and waterproofing. Water birds generate additional waterproofing by preening with the secretions of post-anal oil glands (Giraldeau 2010). Without this waterproofing, birds can succumb to hypothermia within hours if ambient temperatures are near freezing (Boag and Lewin 1980, Gulley 1980, Ramirez 2010).

Eyewitness reports confirm that the birds that died on Mildred Lake Settling Basin had contacted bitumen and their deaths were presumably caused directly (found dead) or indirectly (euthanasia) by this contact. Other birds, such as those sent for necropsy (above) appear to have died from blunt trauma after colliding with the ground. Newspaper and eyewitness reports described birds as 'falling from the sky,' onto parking lots and highways[10]. It is conceivable that birds targeted pavement as landing sites because the dark night, low cloud cover, and recent precipitation would have caused those surfaces to reflect what little light was available, much as water does. It appears that most, if not all, of the birds that landed on tailings ponds died because they contacted bitumen. No systematic searches were made of the birds dying in other locations and so the proportion of bird mortality caused by bitumen vs. blunt trauma cannot be estimated. I address the predictability of mortality given particular landing sites in question 3 below.

Conclusions for Question 2: Could the landings have been anticipated? Not with high precision or accuracyy based on prior knowledge of causation.

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[10] Darrell Martindale, Shell Environment, personal communication

Abundant literature indicates that migrating birds are more likely to land when there is precipitation, storm events that produce unpredictable downdrafts, and unfavourable winds (reviewed by Newton 2007). Each of these factors occurred in the days leading up to the landings on October 25 and 26 and so operators should have anticipated a generally higher probability that birds would land. However, I do not believe it would not have been possible to predict exactly where and when the birds would have landed.

Greater specificity of prediction for a mass landing event on October 25 is not supported by the infrequent history of mass landing events or by a specific weather signal that occurred during each of the previous events. Because severe storms occur in virtually every migration season, it seems that either mass landings have occurred quite frequently without being detected or reported, or mass landings do not generally result in mass mortalities. I believe the second explanation is more likely.

Future work may uncover a more useful weather signal on which to base subsequent predictions. Of particular importance may be easterly winds and the conditions that produce very strong downdrafts, which would dramatically increase the cost of flight to cause birds to 'drop from the sky.' Overcast conditions, precipitation, strong winds, and anthropogenic light (see also below) have all been associated with mass landing events by birds in the past (reviewed by Evans-Ogden 1996, Newton 2007).

Regardless of the degree to which the storm event might have predicted landings, none of the bird protection programs stipulate changes to deterrent strategies as a function of any short-term characteristic, including weather. Provincial regulations do not require such anticipation. Thus, although individuals familiar with the problem of avian deterrence in the oil sands should have anticipated a higher probability of birds landing on October 25, 2010, no existing protocols or practices stipulate that this should have changed pre-existing deterrent configurations or densities. The conclusions of this report may encourage changes in the distribution of deterrents and the mitigation of anthropogenic light, but these conclusions were not available prior to the landing event.

Alberta Environment Question 3: Would increased deterrent density, or other factors, at Syncrude and Suncor have prevented the landing of birds and the subsequent deaths of migratory birds at the tailings ponds?

Because my response to this question is lengthier and more complex than the previous two, I separate it into methods, results and discussion sections.

Methods

I examined a series of files provided by Alberta Environment of mortalities reported on October 25 and the subsequent days and compared the characteristics associated with 40 ponds on oil sands lease sites (Table 1). No birds were found dead on 35 of these ponds (87.5%). Almost all of the dead birds (457 / 551 or 83%) were recovered from Syncrude's Mildred Lake Settling Basin. An additional 5 birds were recovered on the adjacent Recycle Water Pond. Dead birds were also found at 4 of Suncor's ponds including Ponds 2/3 (64 birds) 7 (22 birds) 6 (2 birds) and South Tailings Pond (1 birds). Across all ponds with mortalities, most of the recovered birds were lesser scaup (415 / 551 or 75%), but greater scaup (4.7%) and bufflehead (4.5%) were also abundant (Table 2). A total of 19 species was recorded (Table 2).

To examine the variables that might predict the locations of dead birds, I coded those ponds with mortality as 1 and those without mortality as 0. I created two such dependent variables: one that identified all 6 tailings ponds at which dead or badly oiled birds were recovered, and one that identified only those three ponds at which many birds died. As a source for comparison for these ponds, I used the 21 ponds in the region with process-affected water where deterrents are present to mitigate the risk to birds. Hereafter, I considered these 21 ponds to be 'dangerous' ponds. The remaining 19 ponds in the region are very small (< 1 ha) and/or do not contain process-affected water.

Addressing the question of whether or not increased deterrent density could have prevented the landings requires a comparison of deterrent density and efficacy among the dangerous ponds. Such comparisons are difficult because many different deterrent types are used, including human effigies (Shell, Suncor, Syncrude), acoustic cannons (all operators), and electronic speakers with short- (Suncor and Shell) and long-range (CNRL) capabilities.

To standardize deterrent measurements for the purposes of analysis, I focused exclusively on auditory deterrents, which are generally more effective than visual deterrents (Reilly *et al.* 1997, Harris and Davis 1998, Conover 2001), particularly at night when the landings occurred at Mildred Lake. As one measure of deterrence density, I summed the number of auditory deterrents, regardless of type, and divided that sum by pond area and called this value 'deterrent density.' As a second measure of deterrence density, I attempted to accommodate different auditory capacities by creating an arbitrary, but relevant, standard using the manufacturer's estimate of sound intensity for a single acoustic cannon[11] at its source and, by square root extrapolation, at a distance of 200 m. I chose 200 m because that is half of the spacing between adjacent cannons (i.e., 400 m) that was recommended by an operator-commissioned report on oil sands deterrents (Golder 2000). At a distance of 200 m with ideal transmission conditions, a single acoustic cannon would be expected to generate a sound intensity of 80 dB. Thus, I applied 80 dB as an acoustic standard to other device types.

My research assistant, Tom Habib, converted this conceptual standard to a spatial one by identifying in a GIS the area that would be exposed to sound intensity of ≥ 80 dB around each of the acoustic devices in each pond (Figure 1). He then summed the 80 dB buffers around the

[11] The caption to Figure 1 provides information on manufacturer specifications.

deterrent devices to determine the area of the pond that was protected by the standard and compared this sum to total pond area. These differences generated non-nested measures for the area that was unprotected vs. protected by the 80 dB standard on October 25. Because the locations of recovered birds were concentrated at the edges of ponds (Figure 1), I had Tom additionally calculate these measures within 200 m of shore for each pond.

Several other factors may also be important to landing probability and may co-vary with measures of pond area and deterrence. I considered relevant variables to be pond size, pond age, and distance to the Athabasca river, measured both from the center of ponds and from the shore nearest the river. Larger ponds may be more attractive as stop-over sites for migrating birds or they may simply be more visible. Older ponds contain higher concentrations of bitumen and toxins, which might increase the probability of mortality. Proximity to the river is important because it is a known migratory corridor through the region.

I considered the effect of anthropogenic light descriptively (see results), but did not include this variable in any analyses because light information was available for only five of the six ponds where *any* mortalities were recorded and it was not recorded for all of the other 15 dangerous ponds.

To complement the analyses of whole ponds, I examined the locations of particular landing sites. Tom calculated the distance from each landing to the pond centre and to the nearest shore. Additionally, he obtained the azimuth from the pond centre to each landing location and from each landing to the nearest shore. These calculations were based on the precise location of each landing at Suncor, but no such coordinates were available from the 457 landings at Syncrude's MLSB. I estimated the Syncrude locations by dividing the total equally among the three locations where dead birds were observed being recovered from the water[12]. The area in which these birds are assumed to have died is depicted by a 300 x 720 m rectangle. As a final measure of deterrent density, I had Tom replicate that rectangle and overlay adjacent rectangles along the shorelines and then through the open water portions of the ponds at the highest possible density. Then I compared the number of deterrents – a single cannon – in the rectangle with the 457 mortalities to the number of deterrents in other rectangles that were both within Mildred LSB and the other 20 dangerous ponds in the region (Figure 2).

Statistical Analysis

I used the statistical package SPSS version 19[13] for analyses. I based my analyses of the binary response variables for *any* dead and *many* dead birds using a sequential model-building approach (Hosmer and Lemeshow 2000). In brief, I conducted t-tests to identify liberally significant variables ($P < 0.10$), retained only the stronger predictors among highly correlated variables ($r > 0.6$), and combined these variables to evaluate their significance with likelihood ratio tests. To these reduced models, I added biologically-plausible two-way interactions and again used likelihood ratio tests to assess their significance. I assessed model fit with Nagelkerke's

[12] Cory McLaughlin, Alberta Environment Investigator, personal observation
[13] IBM SPSS 19. http://www-01.ibm.com/software/analytics/spss/products/statistics/

approximation of r^2 and the Hosmer-Lemeshow statistic, each of which indicates a better fit with higher values.

To examine the azimuth between pond centre and recovery sites for the ponds with many mortalities, I used the V-test (Zar 1999) to test determine the probability that the observed distribution was random with respect to the apparent direction of landings (Figure 1). I compared observed locations to a bearing of south for the landings at Suncor's Pond 2/3 and Syncrude's MLSB, and southeast for Suncor's Pond 7.

Results

At the time of the bird landings in October 2010, the 40 tailings ponds in the oil sands region varied dramatically in their surface area, proximity to the Athabasca River, and deterrent density (Table 1). Relative to the other ponds, the 21 dangerous ponds were an average of 4 years older, almost 30 times larger and 4 km closer to the Athabasca River ($t \geq 2.73$ $P \leq 0.029$ for each comparison). The 21 dangerous ponds varied enormously in the area protected by the 80 dB acoustic standard (Figure 1); long range acoustic devices (LRAD) extended that standard for several km beyond the pond perimeter, whereas some ponds with other devices achieved less than 50% protection with that criterion.

Among the 21 dangerous ponds, those with *any* dead birds (n = 6) were best predicted in univariate tests by the uncorrelated variables of (shorter) distance to the Athabasca River and (lower) density of acoustic deterrents (Figure 3). Only deterrent density was retained in the final model ($\times^2 = 20.1$, df = 2, $P < 0.001$) with a moderate fit to the data (Nagelkerke's $r^2 = 0.20$, H-L test $P = 0.80$) that was not improved by interaction terms.

Ponds with *many* dead birds (n = 3) were best predicted by the area within 200 m of shore that was unprotected by the 80 dB standard (-2LL = 7.8, $P = 0.005$) and the interaction between unprotected shoreline and distance to the river (-2LL = 7.1, $P = 0.026$; Figure 3). The negative coefficient of this relationship indicates that ponds were more likely to have *many* dead birds if they were both close to the river and had large areas of unprotected shorelines. This model ($\times^2 =$ 8.0, df = 2, $P = 0.02$) provided a very good fit to the data (Nagelkerke's $r^2 = 0.56$, H-L test $P =$ 0.97).

Examining the locations within ponds where dead birds were recovered suggested three striking patterns (Figure 1). Most obviously, the distribution of bird recoveries was highly clumped for the three ponds that recorded *many* deaths. A second pattern is that bird recoveries were concentrated near the shore opposite the wind direction that prevailed on the night of October 25, 2010. For ponds where *many* birds died, the directions of recoveries relative to the centroids of ponds were consistently south (Syncrude's Mildred LSB: $V = 1.06 \times 10^6$, $P < 0.001$; Suncor's Pond 2/3: $V = 1.30 \times 10^2$, $P < 0.001$) or southeast (Suncor's Pond 7: $V = 1.06 \times 10^3$, $P < 0.001$). For the five ponds where 56 distinct recovery locations were known, birds were found an average of only 92.7 m ± 92.0 from shore. Only 8 (14%) of these locations were more than 200 m from shore (max = 351 m). A third visual pattern in recovery locations is that dead birds were more prevalent (n = 376) in areas that were outside the 80 dB acoustic standard, relative to locations inside that standard (n = 167). However, this apparent effect of protection status cannot be distinguished from one generated by the proportion of unprotected area for each of the six ponds where mortalities occurred (mean observed mortalities = 49 ± 111 SD vs. expected mortalities = 56 ± 108 SD; paired $t = 1.2$, df = 6, $P = 0.29$).

Two of the ponds with *many* mortalities contained light stations (Syncrude's Mildred LSB and Suncor's Pond 2/3) and it appears that bird mortalities were concentrated near these stations, particularly at Mildred LSB (Figure 1). No light stations were present at the other pond with *many* mortalities (Suncor's Pond 7), but most (14/22) of those mortalities were reported along the south east shore of the pond, which is adjacent to Suncor's light-emitting main plant (Figure 1). For the 3 ponds with few mortalities, light information was provided only for Suncor's STP Pond and the single bird there was recovered between two light stations.[14] The location of recoveries is not known for Syncrude's RCW pond, but this small pond is positioned amid dense mine operations and close to the light station that was positioned at the south end of Mildred LSB. No light information was available for Suncor's pond 6 where the final two recoveries occurred. Overall, the recoveries of 443 of 449 (99%) birds where light information was known appear to have occurred within a few hundred m of intense anthropogenic light.

To complement analyses of ponds and landing sites (above), I examined rectangles of (300 x 720 m) that emulated the recovery site of the first 452 birds that were reported at Mildred LSB. This comparison revealed that the recovery site was not less protected than other areas on the same pond. Indeed, the single cannon in that 300 x 720 m (21.6 ha) rectangle corresponded to a density of cannons of 0.046 deterrents / ha (Table 1, Figure 1), which was more than the mean of all 35 rectangles on that pond (mean = 0.60 cannons / rectangle; Binomial one sample test $t = 3.1$, $P = 0.004$). This single cannon also afforded a higher value than the average of the 16 other rectangles that were positioned along shorelines on Mildred LSB (mean = 0.31 cannons / rectangle; Binomial $t = 5.6$, $P \leq 0.001$).

A different pattern emerged from the rectangle analysis among ponds. One-sample tests showed that Mildred LSB had fewer shore-based deterrents than the other 20 dangerous ponds in the region (Table 1 *vs.* group mean = 0.52 ± 0.34 SD; $t = 2.4$, $P = 0.027$). This difference from the other ponds was also apparent in the shore area of Mildred that was unprotected by the 80 dB acoustic standard (Table 1 *vs.* group mean = 95.7 ± 71.8 SD; $t = 7.9$, $P \leq 0.001$). No similar differences were apparent between Mildred LSB and the other ponds in the distance to the Athabasca River, whole-pond measures of deterrent density, or the total pond area protected by the 80 dB standard ($t < 1.5$, $P > 0.16$ for each).

Discussion and Conclusions for Question 3

There are several challenges in answering the question, "Would increased deterrent density, or other factors, at Syncrude and Suncor have prevented the landing of birds and the subsequent deaths of migratory birds at the tailings ponds?" The primary limitation is the small sample size contained by a single event in which only three of 21 dangerous ponds exhibited substantial bird

[14] In addition to the bird found dead on STP, one of the two land-based mortalities reported by Suncor was found near the same location; adjacent to STP beside the light station. This bird was discovered with a broken wing and was euthanized.

mortality. Nonetheless, three variables and an interaction between two of them significantly predicted the ponds with bird recoveries. Closer attention to these variables, in addition to the effects of weather (above) and light (below) during future landings of any sort will make it more likely that landing events with substantial bird mortality can be predicted and avoided.

Logistic regression models of ponds with *any* dead birds revealed that mortality was more likely to occur in ponds with lower densities of acoustic deterrents. Ponds with *many* dead birds were best predicted by the amount of unprotected shore area, in addition to the combination of close proximity to the Athabasca River and large areas of unprotected shore.

The combination of unprotected shore area and distance to the river provided a remarkably complete prediction of the ponds with mortalities in late October 2011. With the single exception of Syncrude's RCW pond (13.4 ha), which is immediately adjacent to MLSB, no birds were recovered on ponds with less than 95 ha of unprotected shoreline or that were more than 3.5 km from the river. Four other ponds at Syncrude have unprotected shore areas exceeding 95 ha, but they are all at least 5 km from the river (Figure 3). Only one of the six dangerous ponds in the oil sands region that is within 3.5 km of the river, Suncor's Pond 8B, exceeded the 95 ha threshold for unprotected shoreline yet did not record bird mortality.

Additional information about the characteristics of ponds with mortality is potentially provided by differences among and within operators. All of the birds died at ponds managed by Suncor and Syncrude, the two companies that protected birds from dangerous ponds in Fall 2010 primarily with acoustic cannons deployed individually on pre-set firing intervals. This deployment method may reduce the responsiveness of birds owing to habituation (Conover 2000, Ronconi and St. Clair 2006). By contrast, the tailings ponds at CNRL and Shell are protected by on-demand deployment mechanisms triggered by the approach of birds. More work will be needed to determine the importance of deployment method across the region, but it cannot alone explain the differences in landing probability within sites at Syncrude and Suncor. For those ponds, the amount of unprotected shoreline and distance to the river provides the best spatial explanation for landing propensity, but a closer look at the sites of recovered birds may identify additional variables.

Although ponds with many mortalities were best predicted by larger areas of unprotected shoreline, this result did not apply to the specific sites of bird recoveries within ponds. The number of birds landing within vs. outside the 80 dB acoustic standard did not differ from the number that would be predicted to land there randomly based on area alone. On Mildred LSB, the single cannon in the landing zone offered a higher deterrent density than comparably-sized areas along the shoreline or across the entire pond, even though the average density of deterrents on Mildred LSB was lower than the other dangerous ponds.

Landing positions were not predicted by specific deterrent locations, but nor were they randomly distributed; almost all the birds were recovered within 200 m of south or south east shores of ponds. Birds may have landed at these locations because they preferred them or because the northwest winds that began abruptly on October 25 pushed them there, either before or after landing. The landings of birds in bays on each of Syncrude's Mildred LSB and Suncor's Pond 7 suggests that these birds may have targeted sheltered areas, which is predictable behaviour for birds seeking refuge from stormy weather.

The tightly clumped distribution of the birds suggests that they landed as flocks.[15] Although waterfowl tend to migrate in groups, it is especially prevalent among lesser scaup, which create flocks of several hundred, even thousands, of birds and are among the most abundant species of North American waterfowl. Lesser scaup are also among the latest of the fall migrants, leaving their staging areas only with the arrival of winter weather and then migrating mainly during the darkest part of the night. Like lesser scaup, bufflehead are diving ducks that leave late in the fall. However, unlike scaup, bufflehead are relatively rare, rely more strongly on favorable winds to migrate and avoid open water, particularly during storms. The timing of the October landings is surprisingly late for greater scaup, the third species with many recoveries. However, greater and lesser scaup are notoriously difficult to distinguish, particularly for females, which migrate later than males.

Wind, shelter, and species-specific behaviours appear to have contributed to the locations of landings within ponds, but I suspect anthropogenic light played an additional, and perhaps more important, role. This possibility is supported by the close proximity of light stations and recovery locations on the two ponds with the most mortalities (457 birds at Syncrude's Mildred LSB and 64 birds at Suncor's Pond 2/3; Figure 1). Anthropogenic light was also likely abundant at most of the recovery locations on Suncor's Pond 7 at two landing locations at Suncor's STP Pond, and for the five landings at the Mildred Lake RCW pond, summing to 99% of the recovery loctions where light information was available.

Intensified deterrents may counteract the attracting effects of light. Interestingly, there were two deterrents at the light station on the south shore of pond 8B, the single pond that did not record bird mortality yet was within 3.5 km of the river and had more than 95 ha of unprotected shore area (Figure 1). Many other ponds without mortality also contained light stations but these either had small areas of unprotected shoreline or were farther from the river. Light information is not available for all of these ponds.

It would not be surprising if anthropogenic light is an important, but hitherto unappreciated, contributor the mortality of birds in tailings ponds during the event of October 25 and on other occasions. Numerous studies have documented the fatal attraction of migrating birds to anthropogenic light (reviewed by Longcore and Rich 2004, Longcore *et al.* 2008), whether it is emitted by office buildings, communication towers, offshore drilling platforms, or any other source. Birds, like most animals, exhibit positive phototaxis (a tendency to orient towards light) when all else is equal. Over evolutionary time, light would have been a highly informative and reliable tool for navigation via the illumination afforded by the sun, moon, and stars. The ability for water to reflect light is likely the reason migrating birds so often follow river courses as landmarks. Birds presumably use the river as a migratory corridor because it provides a consistent landmark of reflected light, even at very low light levels. Although positive phototaxis is ubiquitous in animals including birds, it does not explain why it results in collisions

[15] Information in this paragraph is synthesized from the Birds of North America and the references therein (http://bna.birds.cornell.edu).

and mortalities. Understanding that phenomenon requires knowledge of the mechanisms by which birds navigate.

Birds use at least six different kinds of information to navigate during migration, including the position of celestial bodies, patterns of polarized and reflected light, landmarks on the Earth's surface, olfactory cues, and magnetism (reviewed by Cuthill 1999). Only some of these mechanisms are available to nocturnal migrants during storm events when visibility is close to zero. Then, birds would rely heavily on their ability to sense magnetic fields. There is little question that birds can sense the Earth's magnetic field, but there is controversy as to whether it is the retina, bill, or inner ear that is primarily responsible for this sense (reviewed by Wu and Dickman 2012). If the retina is involved in magnetic navigation, it may be compromised by anthropogenic light because of the long wave lengths such light contains.

Wiltschko *et al.* (2010) offer a series of intriguing hypotheses that I paraphrase and expand here. They suggest that nocturnally-migrating birds see the Earth's magnetic field in the shorter UV through green wave lengths, which excites particular kinds of cone receptors in their retinas. By moving their heads from side to side and with the aid of a specialized region of the brain, nocturnal migrants may equate the pattern of molecular excitation received by these visual cues to a map of the magnetic field, providing a highly accurate compass for orientation. Importantly, these receptors are dramatically more sensitive to light in the UV range, making it possible for birds to use UV light to see magnetism even when there is almost no ambient light available. Birds use this mechanism sparingly, perhaps because the excitation of these molecules occurs through the formation of covalent bonds that generate negative ions, otherwise known as free radicals. An accumulation of free radicals over time is associated with cancer in people and other animals. The use of magnetic vision is possible only when light from the red and yellow wavelengths – which is abundant in all bright or white light – is absent. Although the receptors continue to receive the information in the green through UV wavelengths, this light appears to overwhelm the neural centre that processes the magnetic information and it ceases working abruptly. This simple neurological switch may exist to prevent birds from using their magnetic sense except when it is absolutely necessary: under conditions of near-complete darkness like the ones that prevail on stormy nights.

Whatever the mechanism by which birds see magnetism, related research by Wiltschko and others clearly demonstrates that red, yellow, and white light causes disorientation in birds under laboratory conditions whereas blue, green, violet and UV light do not (Appendix C). These laboratory observations prompted Dutch researchers to replace red lights on offshore drilling platforms with green ones, which led to a corresponding decrease in the abundance of birds near the stations on overcast nights (reported by Poot *et al.* 2008; Appendix C). The Dutch researchers had already observed that attraction was more prevalent when visibility was poor, presumably because birds lacked access to additional visual cues. The same observation has been made repeatedly at other kinds of features with anthropogenic light: birds are more likely to be disoriented and to die in collisions with anthropogenic features like windows during the darkest parts of heavily overcast nights (reviewed by Evans-Ogden 1996).

I speculate that the bird species that are most vulnerable to collisions in the vicinity of anthropogenic light might also be those that are most reliant on UV light in other aspects of their natural history. An important clue about this reliance is provided by the tendency to migrate at night (above), but another clue may be provided by plumage coloration. The presence on breeding males of feathers that look black to us, but possess feather structure that reflects light to create a kaleidoscope of greens, blues, and violets to birds. Black and white feathers in ducks may mean that mate choice in these species is especially informed by light in the UV spectrum. We perceive something of this effect with particular lighting intensity and angles, but birds can see these refracted hues plus additional ones at much lower light intensities because of their ability to see in the UV wavelengths. All three of the species that were abundant in the October 2010 recoveries have black and white breeding plumage with light-dependent patterns of iridescence on their heads (Appendix C).

Synthesis of questions 1, 2 and 3

When the effects of artificial light, weather, tailings ponds, inconsistent deterrence, and bird behaviour are combined, it is easy to appreciate how some birds might experience a ‘perfect storm’ in the oil sands region. It was literally stormy conditions that preceded the landings in both April 2008 and October 2010 and most of these landings seem to have occurred at night. Although a majority of bird species are less likely to migrate during stormy weather (Newton 2007), lesser scaup and bufflehead, which together comprised almost 80% of the recovered birds, must encounter these conditions often because their fall migration is cued by the arrival of winter weather. The black and white coloration of these birds and their tendency to migrate in the darkest part of the night suggest that they are especially reliant on light in the shorter wave lengths (green through UV) because they can perceive it at much lower intensities and use it for magnetic orientation. This reliance may also mean that they are more likely than other species to track the river course closely because of the small amounts of light it would still reflect in near complete darkness. For birds with these adaptations, the positive phototaxis of high-intensity artificial light in the vicinity of the river may be a particular liability.

There are hundreds of high intensity lights in the oil sands region, which can be seen from a distance of several km. It is clear that light intensity increases the positive phototaxis with which birds respond to light (Evans-Odgen 1996). Birds might also be disproportionately likely to travel in the direction of light that is associated with less intense acoustic stimuli. As birds approach this artificial light, they presumably exceed some threshold of illumination in the longer-wavelength spectra (yellows and reds), which causes the collapse of the eye-brain mechanism that is responsible for magnetic orientation and, potentially, also their ability to see anything in the affected wavelengths. On a very dark night, disorientation would be expected to occur immediately when this mechanism is lost.

Migrating birds that are disoriented by light are vulnerable to collisions with tall structures (Evans-Ogden 1996), which may explain the otherwise-perplexing observation that incidental dead birds have been recovered by some operators amidst mine infrastructure approximately as often as they are recovered from the surface of tailings ponds (St. Clair and Ronconi 2010), even though the latter occupy dramatically more surface area on lease sites. Disoriented water birds would presumably attempt to land on water and this may explain why so many birds were reported to be ‘falling from the sky’ on roads and parking lots during the storm of October 25-26,

2010. Diving ducks, which comprised a majority of the birds recovered during this event, would be especially dedicated to landing on water because they have such limited mobility on land. When wet, these surfaces would reflect whatever light was available and their greater sensitivity to UV wavelengths would assist birds to find those areas. Undoubtedly, hundreds and perhaps thousands of birds landed on water, process-affected and otherwise, during the storm. Those that were lucky enough to land on water without bitumen likely simply flew away when light levels increased.

Anthropogenic light may pose multiplicative dangers to birds when it is combined with bitumen and this may bear on the distribution of mortalities in October 2010. Because bitumen is one of the few substances that absorbs UV light completely,[16] regions with large bitumen mats could offer considerably less reflected light in the UV spectra than would clean water, which can reflect much of the UV light that it receives. This difference must be particularly important to strongly nocturnal migrants like lesser scaup. Absorption of UV light may also make it harder for birds that have landed to see and avoid bitumen when they dive or surface. These effects would be exacerbated by the need for high-intensity night lighting at the sites of active mining where residual bitumen is deposited along with naphthenic acids, polycyclic aromatic hydrocarbons (PAHs), heavy metals, and salts. Sites away from active mining should be less dangerous to birds because many of these toxic compounds sink, evaporate, or oxidize as the tailings age.[17] However, bitumen rises to the surface when it mixes with methane and other gases in the sediment. Once on the surface, these globules may be blown by wind into thick mats along shorelines even in areas that are not sites of active mining. During storm events, strong winds would tend to push both birds and bitumen to the same areas creating a second type of danger zone for birds.

In sum, it appears that the effects of visibility, weather, artificial light, bitumen, and bird behaviour interact to increase the risk of both landing and mortality for birds migrating through the oil sands region on dark, stormy nights relative to migratory birds under other conditions. In addition to an increased probability of encountering stormy weather, birds that migrate very early in spring, very late in fall, and in the darkest part of the night may possess adaptations that make them particularly vulnerable to anthrpogenic light. Managing light may thus promote greater protection of avian species than can the provision of long-range audio deterrents, which comprise the majority of the current tools to prevent avian mortality in the oil sands.

In this report, I have identified several factors, both anthropogenic and natural, that appear to have contributed to the distribution of bird recoveries following the landings on October 25 and 26, 2010. However, I believe the synchronicity and magnitude of the landings suggests that landings *per se* could not have been prevented. Furthermore, I believe that fatal landings will continue to occur and they may occur with higher frequency in future because:

1. the proximity of the Peace-Athabasca Delta and the Athabasca River exposes over a million birds annually to tailings ponds,
2. some weather conditions – particularly those with strong winds, precipitation, and poor visibility – force birds to land abruptly in large numbers,

[16] Murray Gray, Chemical Engineer, University of Alberta, personal communication
[17] Summarized by Patrick Welsh, Undergraduate Project, 2011.

3. climate change is increasing the variability of weather patterns and causing more severe storm events, and
4. ongoing development in the region is rapidly increasing the spatial footprint of both tailings ponds and artificial light in the region.

These factors make the goal of preventing landings in tailings ponds untenable; I believe a better goal is to prevent mortalities. More information is needed to achieve that goal, but logical possibilities include:

1. Increased documentation of all bird landings and mortalities in the region to include all of the spatial and temporal variables identified above. This would determine the generality of the mechanisms suggested by the analyses in this report. An excellent start occurred with the implementation of the Standardized Monitoring Program in Spring 2011.
2. Verification of the common belief that water birds are not harmed by landing in tailings ponds if they do not encounter fresh tailings or bitumen.
3. Experimentation with and potential elimination of skyward pointing lights and replacement of white light with green lights wherever tall structures or bitumen occur. Much information on environmentally-friendly lighting that limits skyward glare is available on the internet and the provision of green shields above lights may provide a cost-effective means of experimentation and retrofitting.
4. Immediate development of remote-sensing systems to monitor the distribution of both bitumen and anthropogenic light in real time. Aerial photography already provides excellent maps of bitumen distribution and satellite images could be used to describe the distribution of light.
5. Increased consistency and intensity of deterrence effort within 200 m of shore where most mortalities occur.
6. Increased deterrence intensity, particularly in early spring and late fall when storms are more likely, in areas with intense lighting, fresh tailings, and wind-accumulated bitumen.
7. Comprehensive ecological analyses of the cost-benefit ratios of large-scale audio deterrents that extend several km into adjacent, physically undisturbed habitat.
8. Provision of ‘safer’ landing areas, which might be central parts of tailings ponds or adjacent fresh water ponds, particularly in the early spring and late fall when storm events are forecasted. Use of decoys could further increase the attractiveness of these areas and their efficacy can be enhanced with UV reflecting paint and automated motion
9. Avoidance of new tailings ponds within 3.5 km of the river and construction of very large tailings ponds with shorelines that cannot be accessed to deploy deterrents.
10. Avoidance of attempts to capture or haze diving birds that land during storm events. The diving behaviour of these birds increases the likelihood that they will emerge in bitumen even if they avoid landing on it, particularly if chases or hazing occurs in the vicinity of bitumen, during low light, or over prolonged time periods.

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Table 1. Pond ID, operator, name, and characteristics for each of the 40 ponds inventoried by Alberta Environment following the recoveries of dead birds on October 25 and 26, 2010.

Pond ID	Operator	Pondname	Age	Danger	Any Dead	Many Dead	Area (ha)	Distance to river from shore	Dead Birds	Number Deterrents	Deterrent Density	Floating Deterrents	Shore Deterrents	Unprotected area (ha)	Percent unprotected	Unprotected shore area	Protected shore	Deterrents / Rectangle	Deterrents / shore rectangle
1	CNRL	Coke Runoff	2	0	0	0	1	.	0	0	0.00	0	0	0	1.00	0	.	0.0	0.0
2	CNRL	Dyke 10	2	0	0	0	5	.	0	0	0.00	0	0	5	1.00	0	.	.	.
3	CNRL	Extraction Dump	2	0	0	0	1	.	0	0	0.00	0	0	1	1.00	0	.	.	.
4	CNRL	Froth Emerg	2	0	0	0	1	.	0	0	0.00	0	0	1	1.00	0	.	.	.
5	CNRL	Mine Dump	2	0	0	0	0	.	0	0	0.00	0	0	0	1.00	0	.	.	.
6	CNRL	OPP Train 1	2	0	0	0	0	.	0	0	0.00	0	0	0	1.00	0	.	.	.
7	CNRL	OPP Train 2	2	0	0	0	0	.	0	0	0.00	0	0	0	1.00	0	.	.	.
8	CNRL	R-1 Distributor	2	0	0	0	0	.	0	0	0.00	0	0	0	1.00	0	.	.	.
9	CNRL	R-1 Tailings	2	0	0	0	0	.	0	0	0.00	0	0	0	1.00	0	.	.	.
10	CNRL	R2 Dump	2	0	0	0	0	.	0	0	0.00	0	0	0	1.00	0	.	.	.
11	CNRL	Recycle Water	2	0	0	0	18	5.7	0	0	0.00	0	0	18	1.00	18	0	.	.
12	CNRL	Sulphur Runoff	2	0	0	0	1	.	0	0	0.00	0	0	1	1.00	0	.	.	.
13	CNRL	Storm Water	2	0	0	0	8	3.0	0	0	0.00	0	0	8	1.00	8	0	.	.
14	CNRL	Tailings Pond	2	1	0	0	642	11.8	0	32	0.05	0	0	0	0.00	0	306	0.4	0.4
15	Shell	External Tailings Facility	7	1	0	0	343	1.3	0	39	0.11	0	0	118	0.34	67	81	1.0	0.2
16	Shell	In-Pit	7	0	0	0	97	7.0	0	0	0.00	0	0	97	1.00	81	0	0.0	0.0
17	Shell	Recycle Water	7	0	0	0	5	7.1	0	0	0.00	0	0	5	1.00	5	0	.	.
18	Shell	Seep Collection	2	0	0	0	8	1.3	0	0	0.00	0	0	8	1.00	8	0	.	.
19	Shell	South Extension Area	2	1	0	0	47	1.2	0	13	0.28	0	0	21	0.46	20	25	1.5	1.5
20	Suncor	Pond 1A	8	1	0	0	49	1.3	0	2	0.04	0	0	40	0.82	33	9	0.7	0.7
21	Suncor	Pond 2/3	8	1	1	1	260	2.2	64	6	0.02	0	0	238	0.92	107	22	0.5	0.5
22	Suncor	Pond 4G/4G2	8	0	0	0	61	1.0	0	0	0.00	0	0	61	1.00	60	0	0.0	0.0
23	Suncor	Pond 5	8	1	0	0	152	2.6	0	7	0.05	0	0	124	0.81	84	10	0.4	0.4
24	Suncor	Pond 6	8	1	1	0	274	1.3	2	14	0.05	0	0	241	0.88	95	33	1.1	1.1
25	Suncor	Pond 7	9	1	1	1	391	0.5	21	6	0.02	0	0	353	0.90	155	15	0.4	0.2
26	Suncor	Pond 8A	9	1	0	0	139	1.2	0	7	0.05	0	0	132	0.95	73	7	0.6	0.6
27	Suncor	Pond 8B	8	1	0	0	707	2.3	0	20	0.03	0	0	627	0.89	144	58	0.7	0.5
28	Suncor	PAW	9	0	0	0	13	.	0	0	0.00	0	0	13	1.00	0	.	.	.
29	Suncor	South Tailings Pond	6	1	1	0	795	3.3	1	35	0.04	0	0	758	0.95	227	14	0.5	0.4
30	Syncrude	Aurora In-Pit	.	1	0	0	175	11.1	0	21	0.12	0	0	102	0.58	56	48	1.2	0.8
31	Syncrude	Aurora Recycle Water	.	1	0	0	5	9.0	0	3	0.61	0	1	0	0.00	0	5	.	.
32	Syncrude	Aurora Settling Basin	9	1	0	0	504	11.7	0	47	0.09	0	0	297	0.59	124	57	1.0	0.4
33	Syncrude	CIBA test	9	0	0	0	20	.	0	0	0.00	0	0	20	1.00	0	.	.	.
34	Syncrude	Mildred Lake Effluent	9	1	0	0	5	6.2	0	2	0.43	0	0	0	0.00	0	5	.	.
35	Syncrude	Mildred Lake Settling Basin	33	1	1	1	852	3.5	452	41	0.05	0	0	667	0.77	220	71	0.6	0.3
36	Syncrude	Mildred Recylce Water	.	1	0	0	13	5.8	0	1	0.07	0	0	8	0.59	8	5	1.0	0.5
37	Syncrude	Southeast In-Pit	.	1	0	0	140	4.3	0	12	0.09	0	0	64	0.45	53	41	.	.
38	Syncrude	Southwest In-Pit	8	1	0	0	264	9.5	0	17	0.06	0	0	170	0.64	97	59	1.1	0.5
39	Syncrude	Southwest Sand Storage	15	1	0	0	829	15.2	0	34	0.04	0	0	761	0.92	228	15	0.4	0.3
40	Syncrude	West In-Pit	9	1	0	0	698	5.8	0	45	0.06	0	0	340	0.49	159	98	1.3	0.5

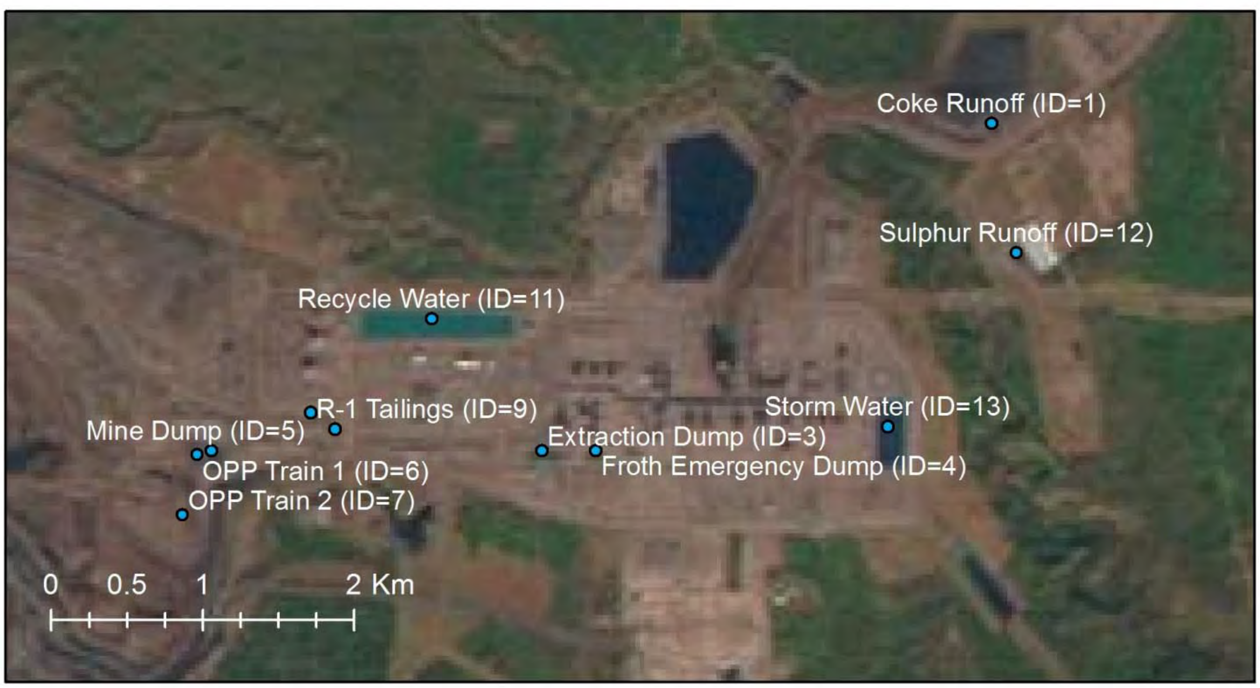
Table 2. Number of individual birds recovered dead or partially oiled on tailings ponds at Syncrude (MLSB and RCW) and Suncor ponds (all others) in late October 2010.

Species		MLSB	RCW	Pond 2/3	Pond 6	Pond 7	STP	Total	percent
American Coot	*Fulica americana*	13	1	.	.	1	.	15	2.72
American Wigeon	*Anas americana*	.	.	2	.	.	.	2	0.36
Bufflehead	*Bucephala albeola*	25	.	.	.	.	.	25	4.54
Canada Goose	*Branta canadensis*	2	.	.	.	.	.	2	0.36
Canvasback	*Aythya valisineria*	3	.	3	.	1	.	7	1.27
Common Goldeneye	*Bucephala clangula*	1	.	1	.	.	.	2	0.36
Greater Scaup	*Aythya marila*	24	.	2	.	.	.	26	4.72
Green-winged teal	*Annas crecca*	1	.	.	.	.	.	1	0.18
Hooded Merganser	*Lophodytes cucullatus*	.	.	1			.	1	0.18
Lesser Scaup	*Aythya affinis*	345	4	48	2	16	.	415	75.32
Mallard	*Anas platyrhynchos*	14	.	1	.	2	.	17	3.09
Northern Pintail	*Anas acuta*	.	.	2	.	.	.	2	0.36
Northern Shoveler	*Anas clypeata*	8	.	2	.	.	1	11	2.00
Red-breasted Merganser	*Mergus serrator*	2	.	.	.	1	.	3	0.54
Red-Necked Grebe	*Podiceps grisegena*	3	.	.	.	.	.	3	0.54
Ring-necked Duck	*Aythya collaris*	4	.	.	.	.	.	4	0.73
Ruddy Duck	*Oxyura jamaicensis*	8	.	.	.	.	.	8	1.45
Tundra Swan	*Cygnus columbianus*	.	.	1	.	1	0	2	0.36
Unknown		4	.	1	.	.	.	5	0.91
TOTAL		457	5	64	2	22	1	551	

Figure 1. Series of maps showing tailings ponds and process-affected water bodies on each oil sands operator's mine site. All maps are presented at a 1:50,000 scale. Background imagery is a Landsat 5 composite image captured on November 4, 2010 and obtained from the United States Geological Survey. Each process-affected water body considered in our analysis is labelled with a blue marker, and each deterrent location is indicated with a red marker. Deterrent locations were provided by each operator based on positions on October 26, 2010.

The effective acoustic radius around each deterrent was based on Golder (2000), which recommended a density of one propane cannon per 13 ha, corresponding to a 200-m radius around each cannon. The 200-m radius of this circle is expected to produce a sound level of 80 dB based on a propane cannon's maximum sound level of 125 dB at the cannon and under ideal conditions (www.zoncannon.com). To make it possible to compare acoustic deterrents of different types, we designated 80 dB as the threshold for deterrent efficacy and then calculated the effective radii (*i.e.* the distance corresponding to a sound level of 80 dB) for LRAD and Phoenix Wailers, again assuming ideal conditions. The LRAD is capable of producing 153 dB (www.lradx.com) for a maximum effective radius of 4500 m, and the Phoenix Wailer is capable of producing 119 dB (www.phoenixagritech.com) for a maximum effective radius of 90 m. Because the directionality of each deterrent was not known, we extended the effective radius a full 360° to obtain their effective area.

Yellow triangles describe the position of birds recovered on October 25 and 26. When many birds were recovered at a single site, that number is given adjacent to a larger triangle. Green triangles indicate birds that were recovered but released alive. Orange circles identify the location of light stations on eleven ponds for which that information was available. Red circles surrounded by greenish buffers identify the locations of cannons (or LRADs at CNRL, or Phoenix Wailers at Suncor) and greenish buffers identify the spatial extent of the 80 dB standard for acoustic deterrents of different types.

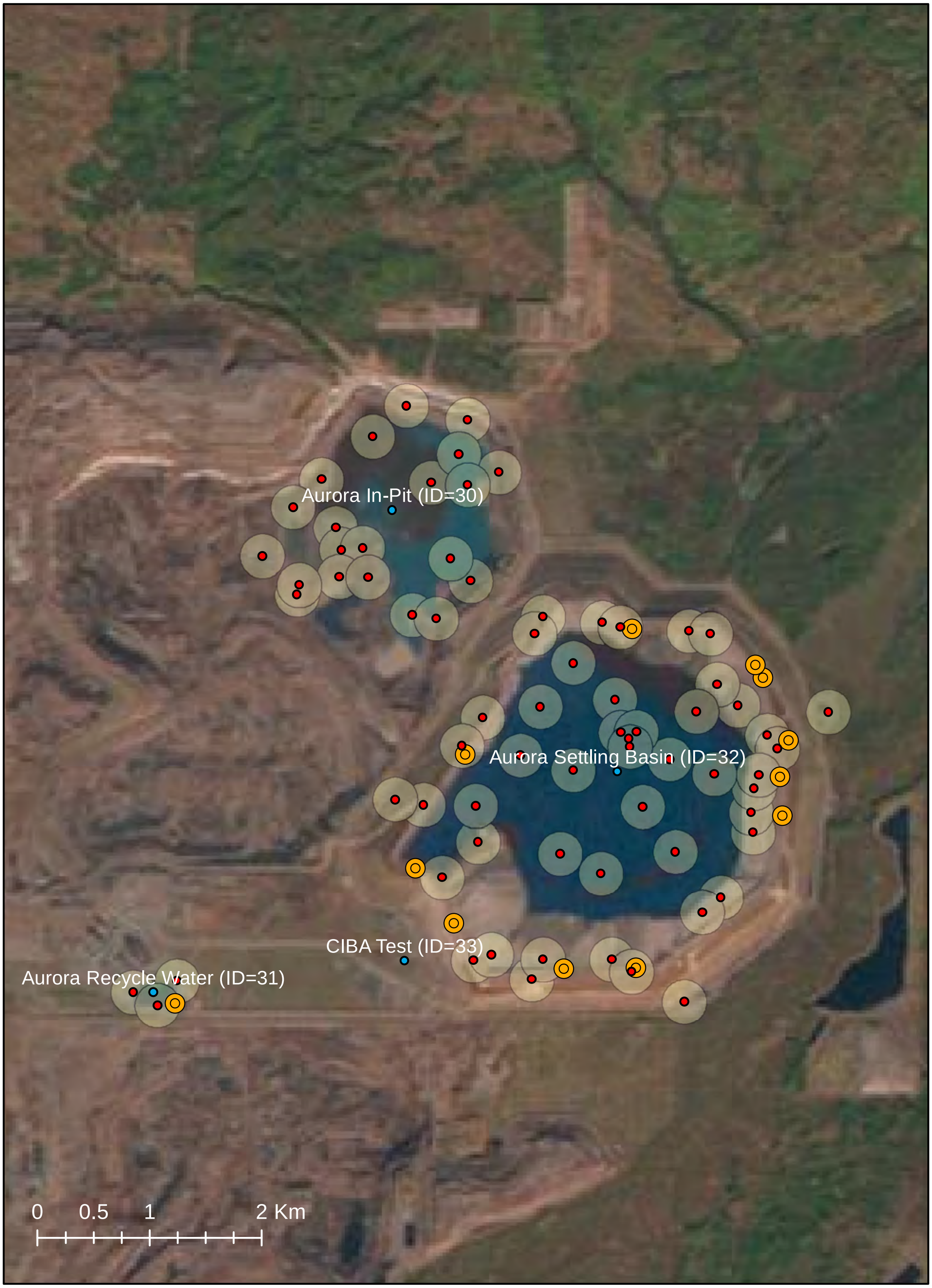



Dyke 10 (ID=2)
R2 Dump (ID=10)
Tailings Pond (ID=14)
0
0.5
1
2 Km

In-Pit (ID=16)
Recycle Water (ID=17)
External Tailings Facility (ID=15)
South Extension Area (ID=19)
Seep Collection (ID=18)
0
0.5
1
2 Km


Pond 6 (ID=24)
Pond 5 (ID=23)
Pond 4G/4G2 (ID=22)
Pond 2/3 (ID=21)
Pond 1A (ID=20)
Pond 7 (ID=25)
4
10
19
4
3
0
0.5
1
2 Km


Pond 8B (ID=27)
Pond 8A (ID=26)
PAW (ID=28)
South Tailings Pond (ID=29)
0
0.5
1
2 Km


Aurora In-Pit (ID=30)
Aurora Settling Basin (ID=32)
CIBA Test (ID=33)
Aurora Recycle Water (ID=31)
0 0.5 1 2 Km


Southwest Sand Storage (ID=39)
0
0.5
1
2 Km

Mildred Lake SB (ID=35)
151*
151*
150*
5
Mildred Lake Recycle Water (ID=36)
Mildred Lake Effluent (ID=34)
0
0.5
1
2 Km


151*
151*
150*
5
Mildred Lake Recycle Water (ID=36)
Mildred Lake Effluent (ID=34)
Southeast In-Pit (ID=37)
West In-Pit (ID=40)
Southwest In-Pit (ID=38)
0 0.5 1 2 Km

Figure 2. Schematic outlining three methods of calculating acoustic deterrent coverage on tailings ponds, shown for two example ponds (Mildred Lake Settling Basing on left; Shell Muskeg River External Tailings Facility on right). In all panels, the extent of open water is depicted with a blue line. Panels in each horizontal row were produced at the same scale. The approximate recovery locations of ducks on Mildred Lake Settling Basing are indicated by yellow triangles.

Deterrent density was calculated at the scale of the entire pond (Panels A and B) for each of shore-based deterrents (red dots) and floating water deterrents (orange dots), as well as total deterrent density.

The open water area within 200m of the shoreline (light blue area in Panels C and D) was calculated for each pond, and we drew a buffer (depicted in yellow) around each deterrent corresponding to a minimum of 80 dB sound level, which is approximately 200 m for a propane cannon under ideal conditions. The shoreline area not afforded protected by these buffers was then calculated in hectares and as a percentage of total shoreline area.

Large ponds were sub-sampled at a scale of 720 x 300m rectangles (Panels E and F). Rectangles were placed first along the shoreline (green rectangles), and subsequently to cover the open water area (orange rectangles). All deterrents are shown in red. The average deterrent density per rectangle was calculated for each pond.

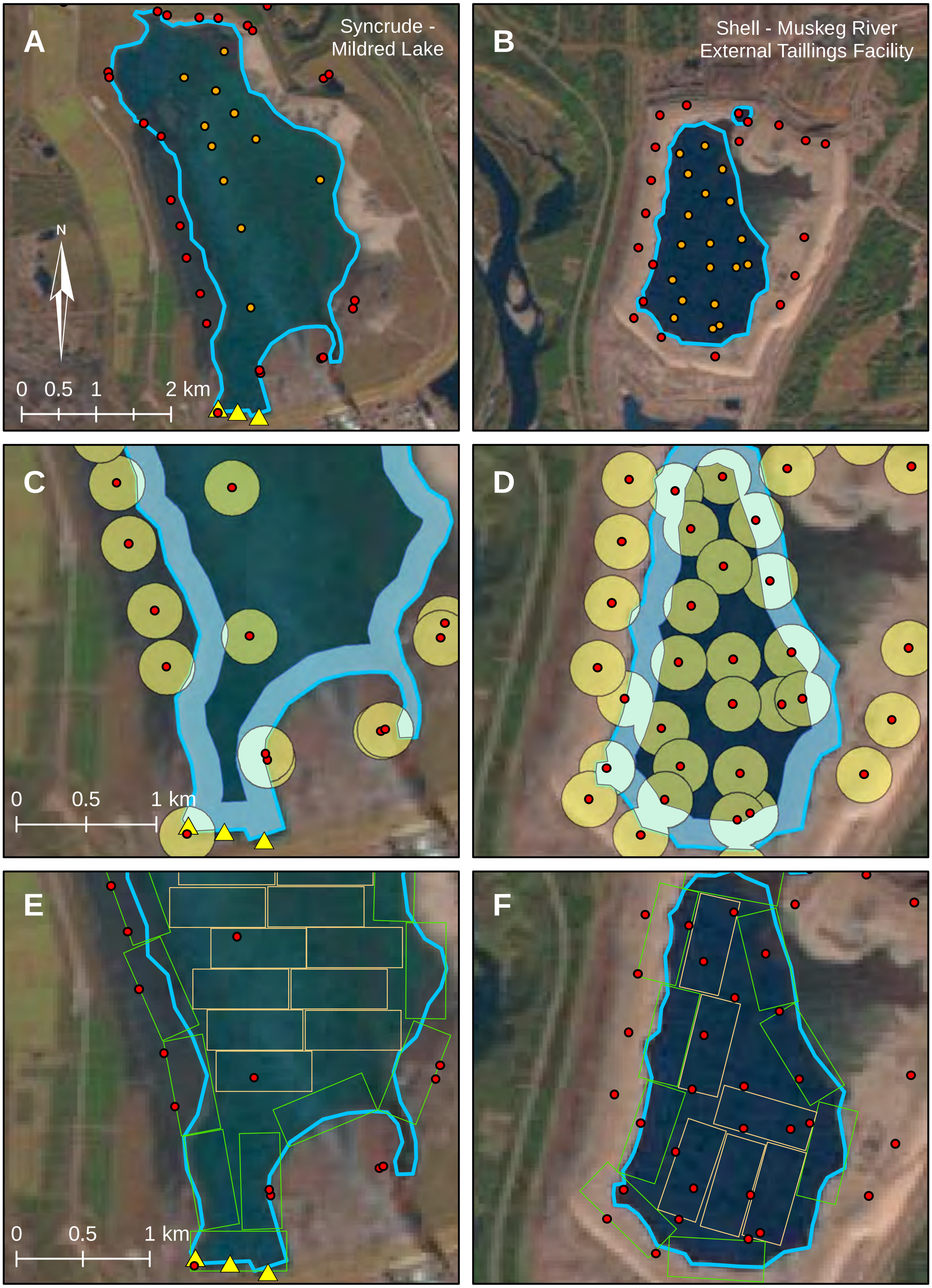
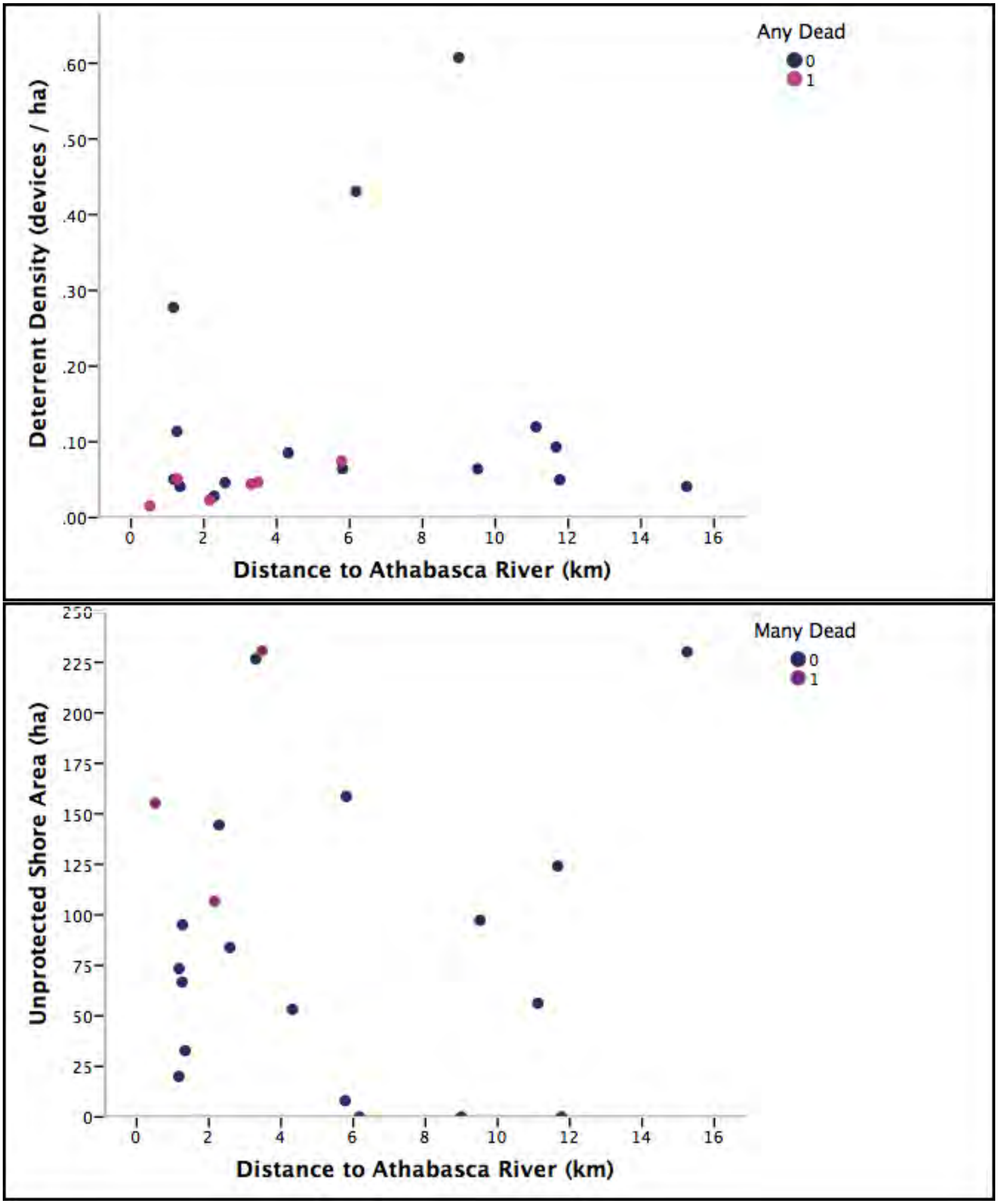

A
Syncrude -
Mildred Lake
N
0 0.5 1 2 km
B
Shell - Muskeg River
External Taillings Facility
C
0 0.5 1 km
D
E
0 0.5 1 km
F

Figure 3. Relationships for ponds in the oil sands region on the days following October 25, 2010 describing the distance to the Athabasca River from the nearest shoreline and (top panel) deterrent density where *any* dead birds were recovered and (bottom panel) the area of unprotected shoreline where many dead birds were recovered.



Appendix A

Weather summary for the two week periods preceding the April 28, 2008; October 25, 2010; and May 15, 1979 bird landings at oil sands tailings ponds

Created 15-Nov-2010
Updated 07-Dec-2010

Bryon Shore, M.Sc.

Summary

Weather data for Fort McMurray-area weather stations for the two week periods preceding and including April 28, 2008; October 25, 2010; and May 15, 1979 were downloaded from the Environment Canada National Climate Data and Information Archive. Hourly temperature, wind speed, wind direction, and barometric pressure were plotted for each of these two periods. Both April 28, 2008 and October 25, 2010 were immediately preceded (in the 24 hours prior to each date) by 10-20 km/h, sustained, easterly winds, and 1.1-1.3 kPa pressure drops. Of these trends, only wind direction appeared unusual relative to weather during the rest of each two-week period. North-south components of wind speed were either negligible, or would have acted as a tail wind relative to migration direction.

In contrast to the other two dates, May 15, 1979 was preceded by 0-15 km/h winds and a minor pressure drop (0.3 kPa). The wind was largely from an easterly direction (the sine of 24/48 hourly wind direction readings from May 14 and 15 was 0.5 or greater), though direction fluctuated throughout both days. North-south wind components were less than 10 km/h.

Data Source

Data for the Fort McMurray A, AWOS A, and CS weather stations were accessed from the Environment Canada National Climate Data and Information Archive website on November 11, 2010 (April 2008, October 2010) and December 7, 2010 (May 1979). Data for April 2008 were available from both the Fort McMurray A and CS stations, while data for October 2010 were available from the Fort McMurray AWOS A and CS stations. Data for May 1979 were only available from the Fort McMurray A station. Hourly temperature, dew point, relative humidity, wind speed, wind direction, barometric pressure, visibility, wind chill and weather data were available from both the Fort McMurray A and AWOS A stations, but not the Fort McMurray CS station (temperature, dew point, and relative humidity only). Precipitation was available on a daily, but not an hourly, basis. No precipitation was recorded on or immediately preceding either April 28, 2008 or October 25, 2010, however a weather condition of 'snow' was reported for the hours of 21:00 on October 24 and 0:00, 2:00, and 3:00 on October 25 (corrected for daylight savings time). Nine millimeters of precipitation (rain) were recorded on May 14, 1979, with rain showers reported at 18:00 and a thunderstorm at 12:00.

April 2008 Data:

http://www.climate.weatheroffice.gc.ca/climateData/bulkdata_e.html?timeframe=1&Prov=XX

&StationID=2519&Year=2008&Month=4&Day=28&format=csv&type=hly

http://www.climate.weatheroffice.gc.ca/climateData/bulkdata_e.html?timeframe=1&Prov=XX&StationID=27216&Year=2008&Month=4&Day=28&format=csv&type=hly

October 2010 Data:
http://www.climate.weatheroffice.gc.ca/climateData/bulkdata_e.html?timeframe=1&Prov=XX&StationID=31288&Year=2010&Month=10&Day=25&format=csv&type=hly

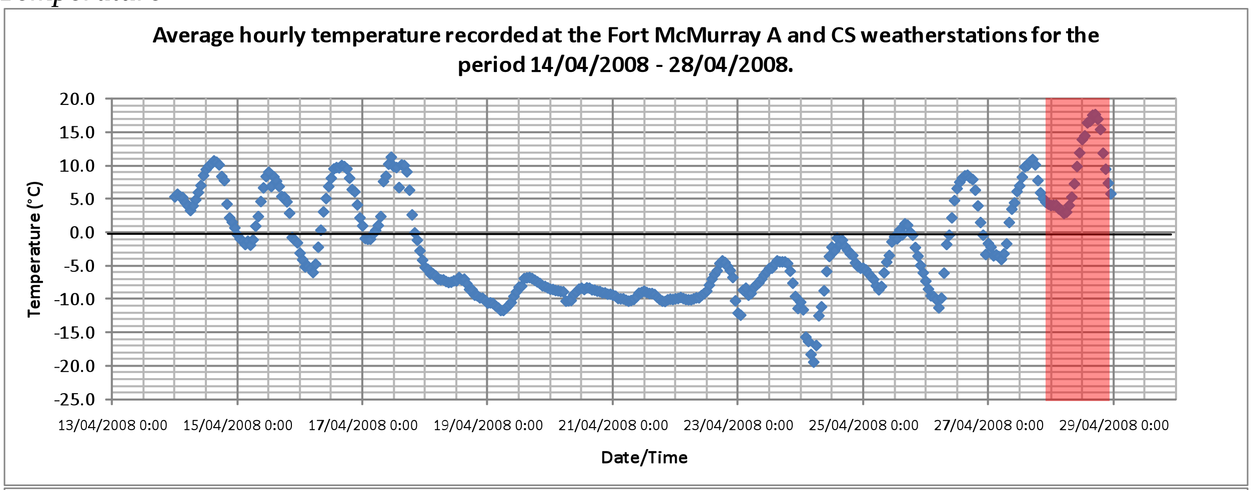
http://www.climate.weatheroffice.gc.ca/climateData/bulkdata_e.html?timeframe=1&Prov=XX&StationID=27216&Year=2010&Month=10&Day=25&format=csv&type=hly

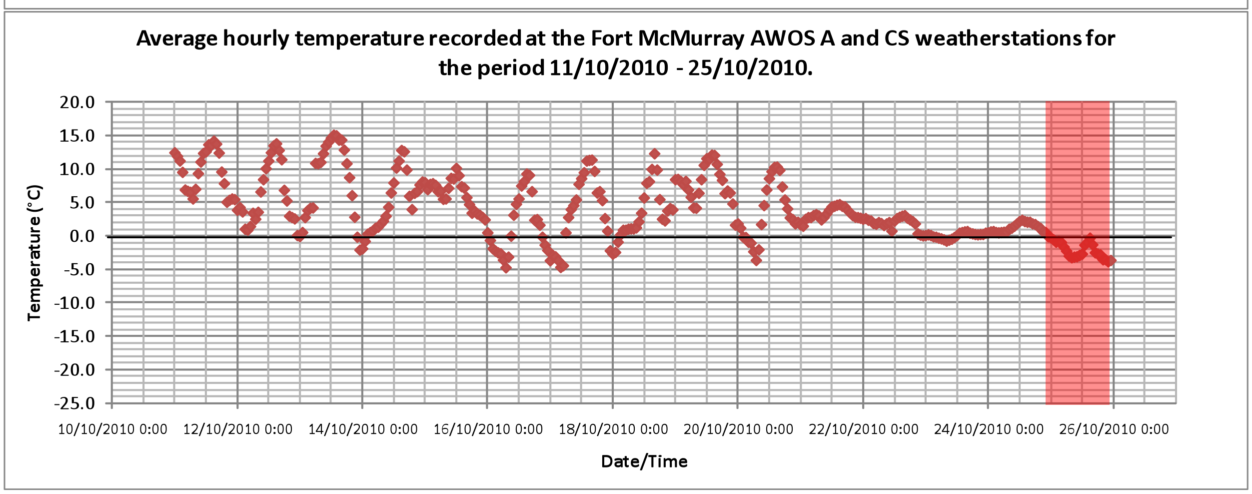
May 1979 Data:
http://www.climate.weatheroffice.gc.ca/climateData/bulkdata_e.html?timeframe=1&Prov=XX&StationID=2

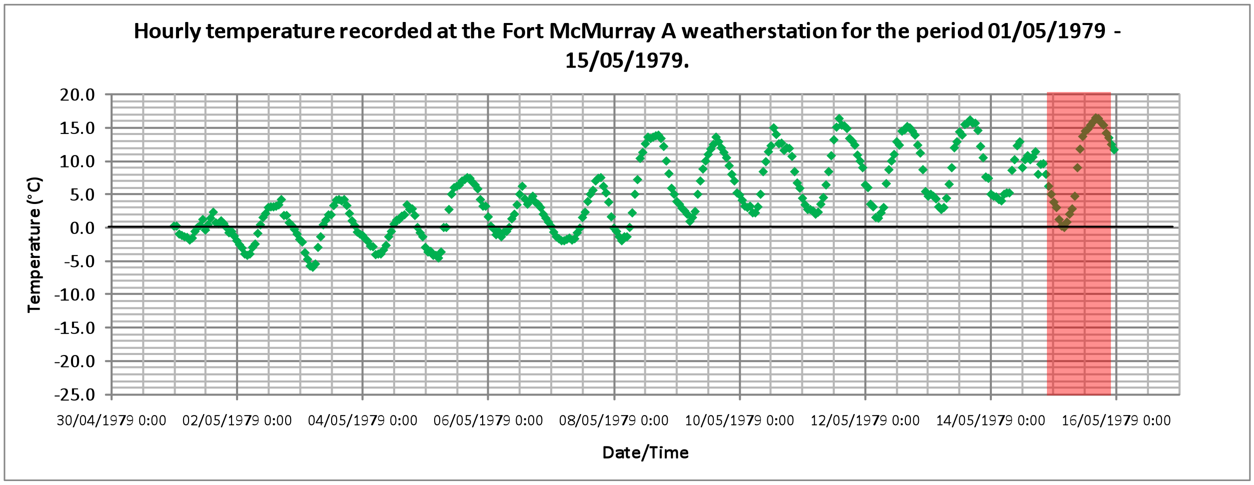
Graphs

The red-shaded portion of each graph corresponds to either April 28, 2008; October 25, 2010; or May 15, 1979, whichever is applicable. Times were not corrected for daylight savings time, as a one-hour shift was deemed unlikely to be important relative to a two-week trend.

Temperature

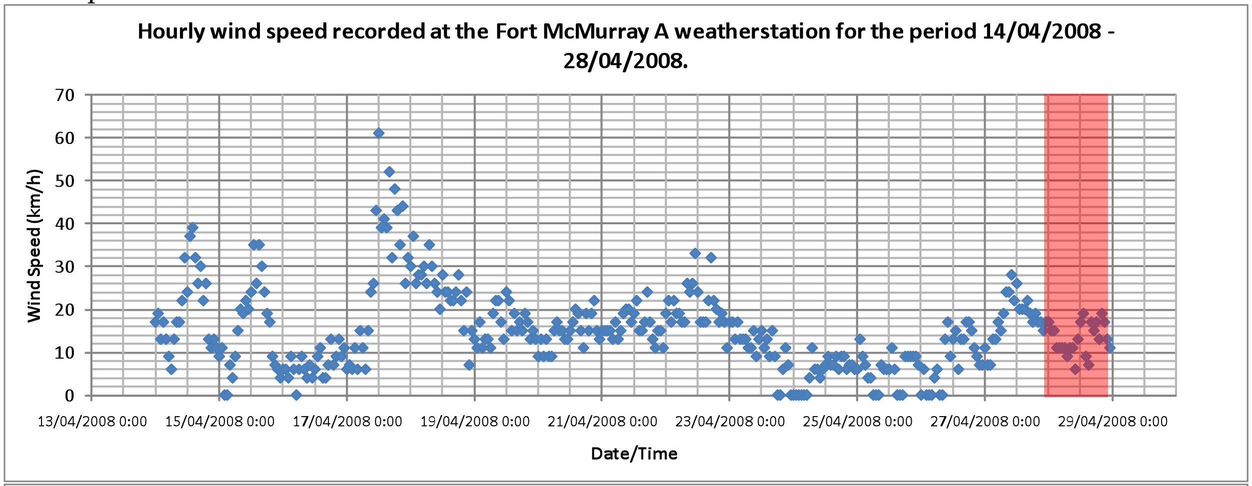


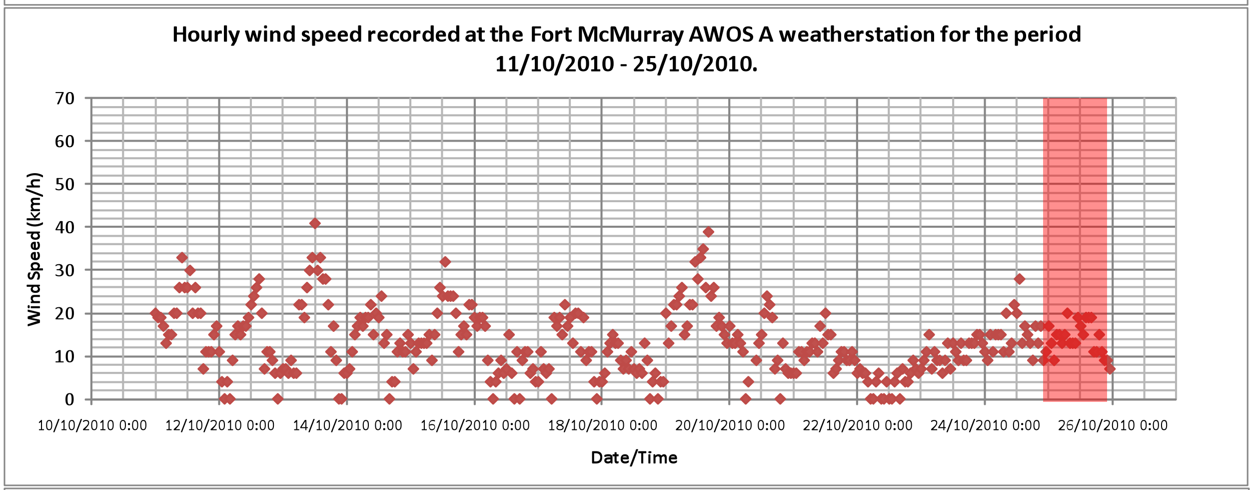


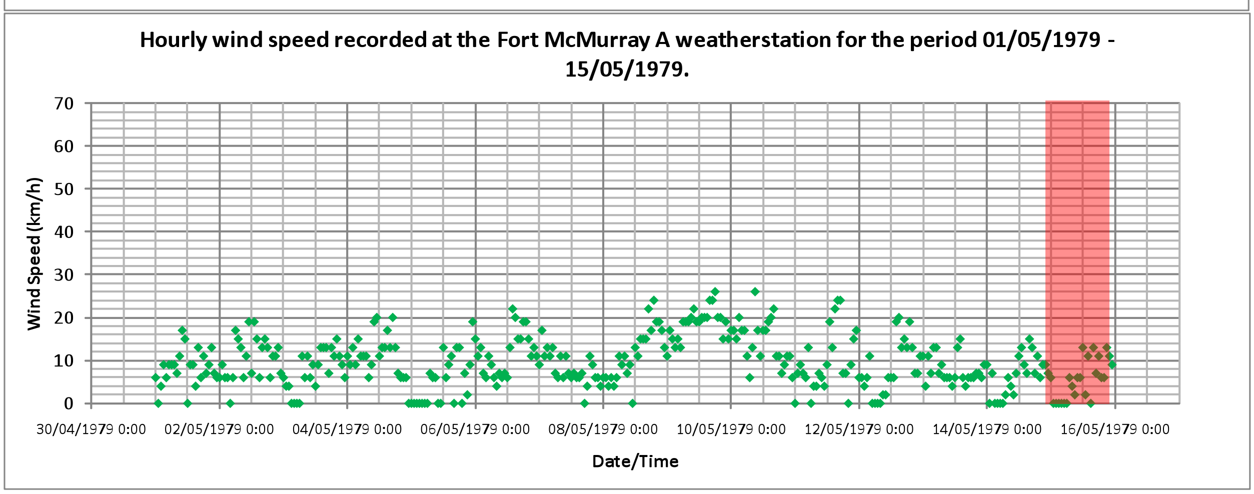


There are no obvious similarities in temperature among the dates. There is an upswing in average temperature in late April 2008 and May 1979, with regular day-night temperature cycles. Average temperature for both dates was approximately 10°C. In contrast, there was a slight decrease in average temperature in late October 2010, with little variation between day and night. Average temperature for October 25 was approximately -2°C.

Wind Speed

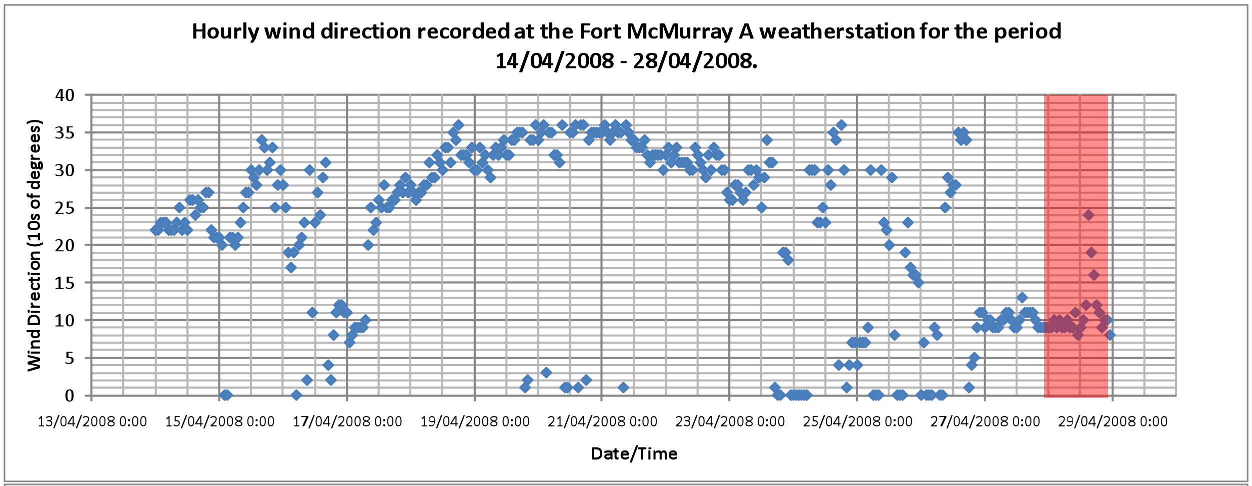


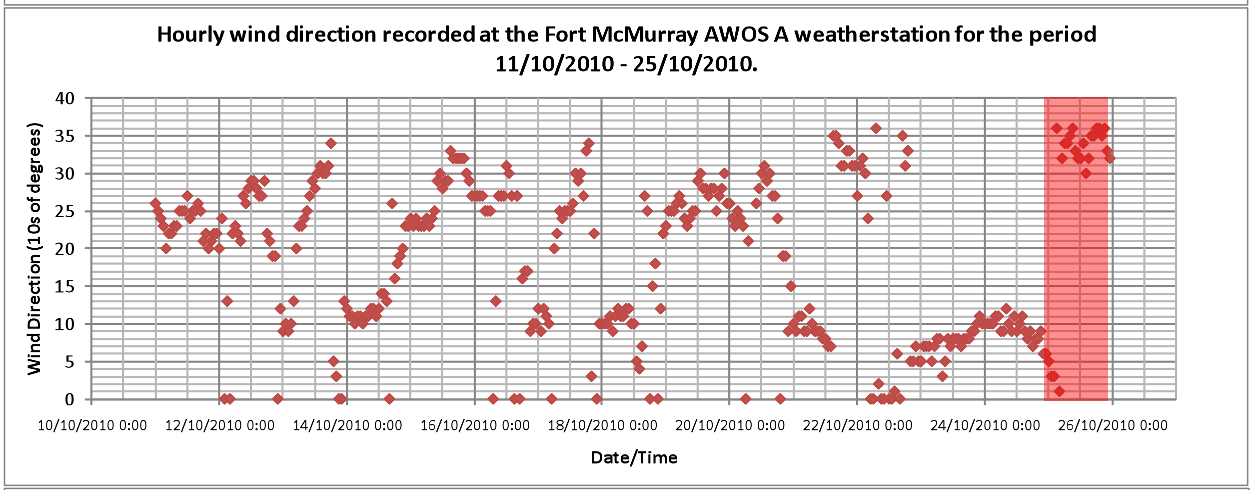


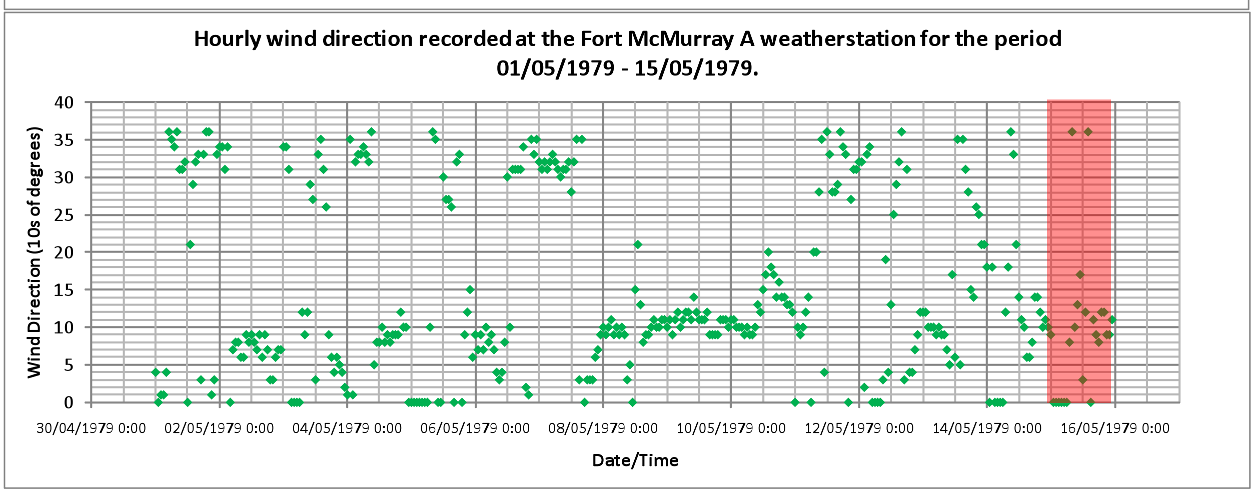


Wind speed was similar on and preceding April 28, 2008 and October 25, 2010. Winds ranged 10-20 km/h, with gusts near 30 km/h. Winds were lighter on and preceding May 15, 1979, ranging 0-15 km/h.

Wind Direction

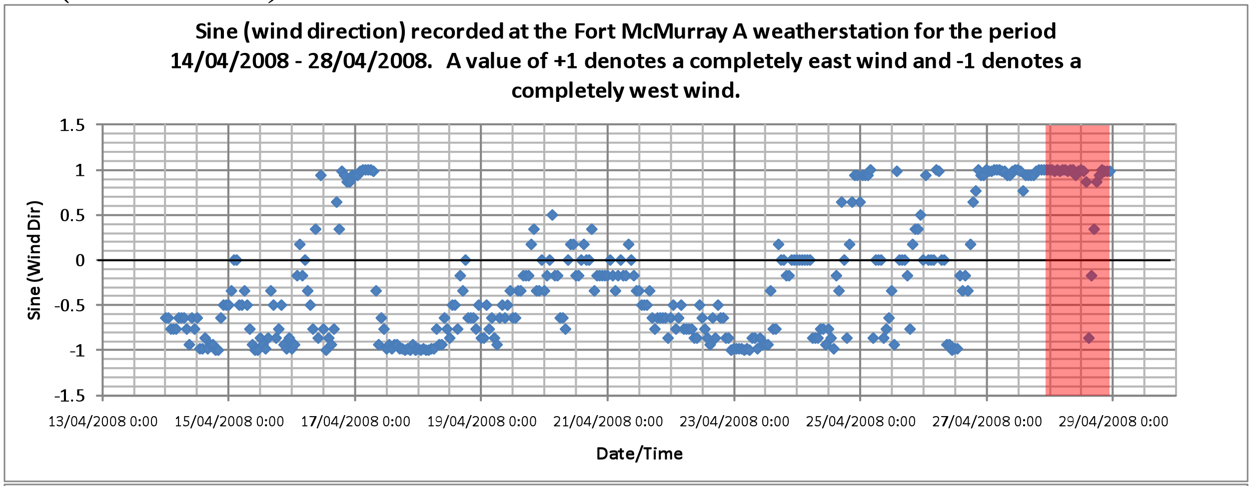


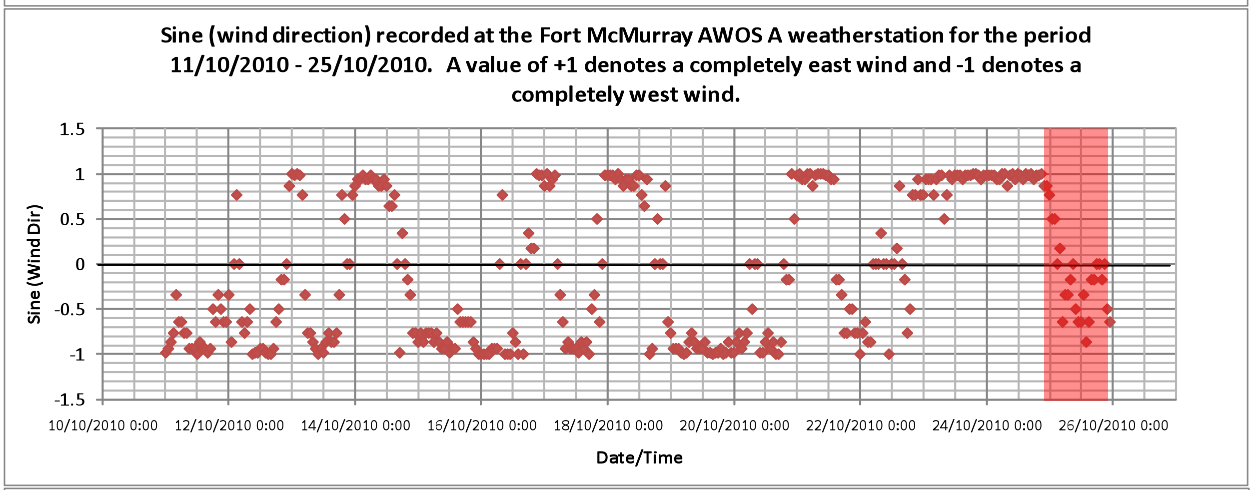


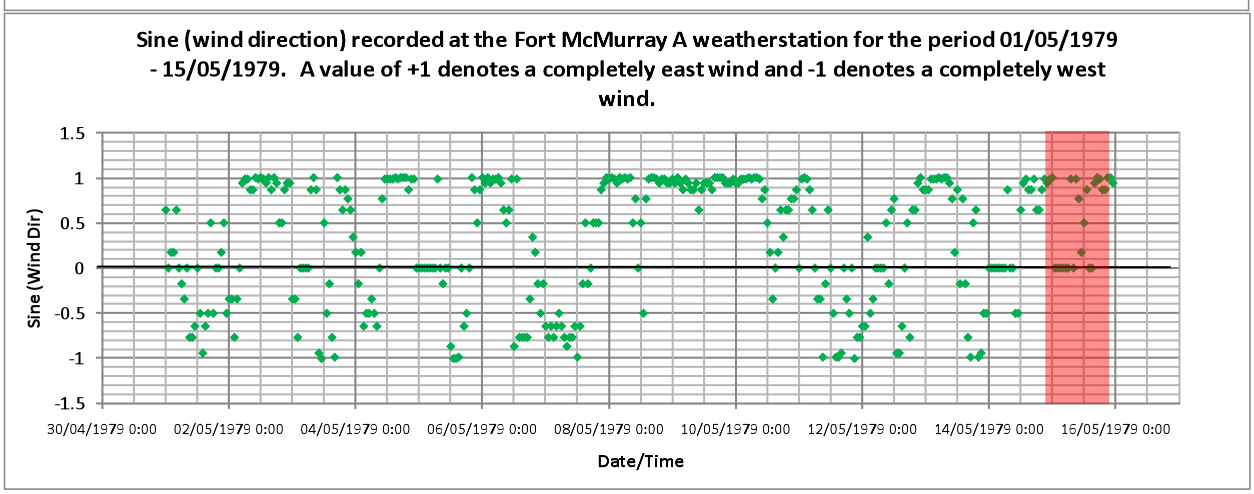


Both April 28, 2008 and October 25, 2010 were preceded by 24-48 hours of sustained east winds (100°). These were the only times on either chart where east winds prevailed for more than approximately 12 hours. In contrast, wind readings on/before May 15, 1979 were largely easterly, but the direction was not sustained. There was however, a period of sustained easterly winds May 8-10, 1979.

Sine (Wind Direction)



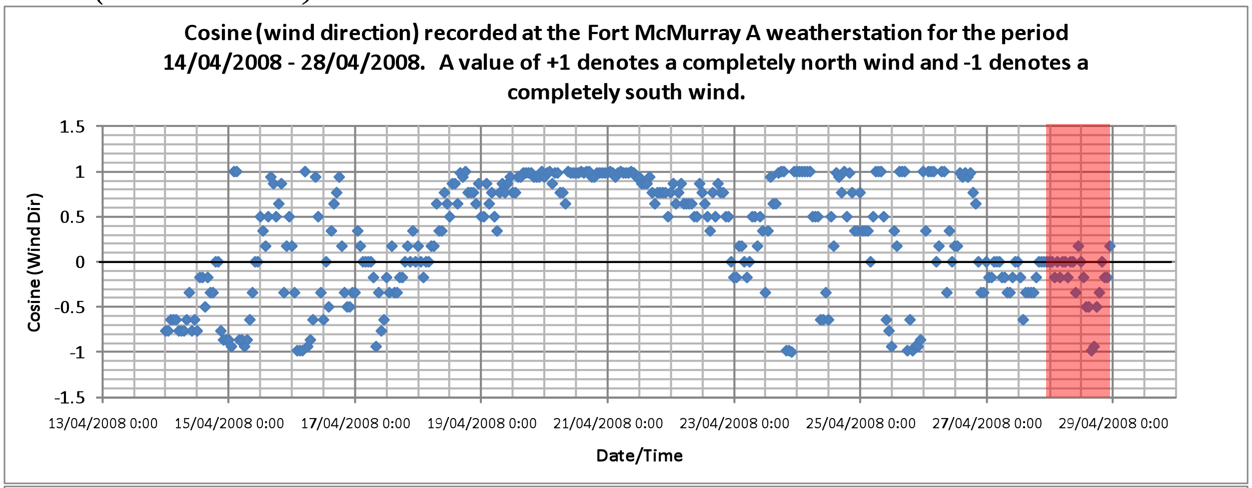


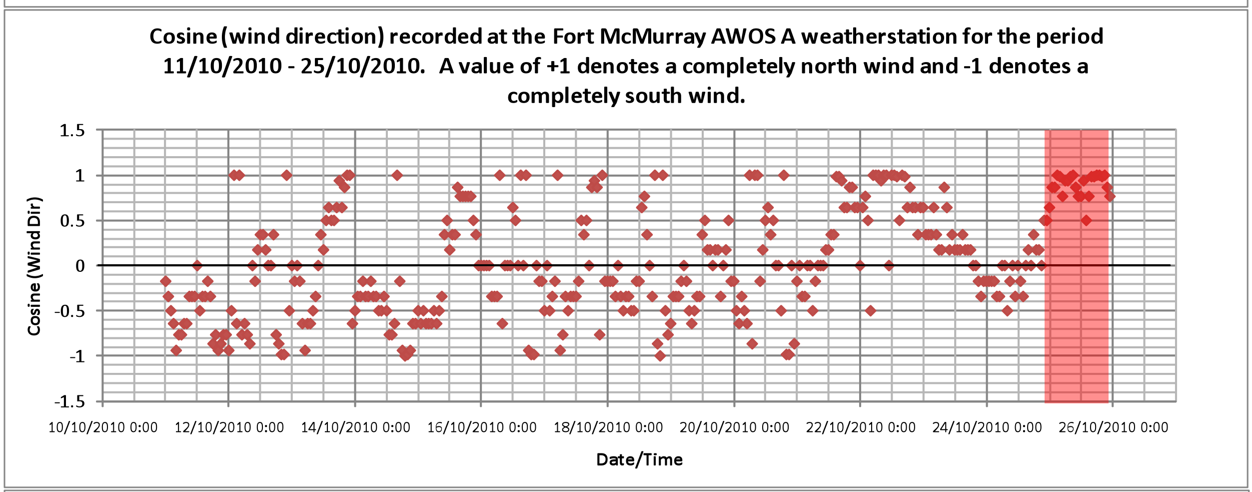


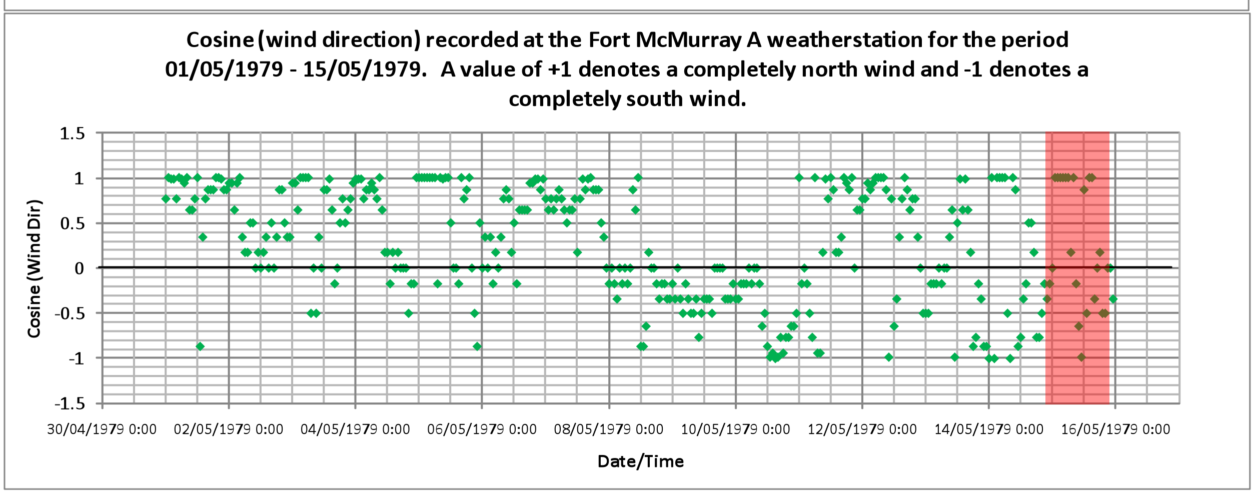
Similar to the last set of graphs, this set shows the prolonged period of easterly winds immediately preceding April 28, 2008 and October 25, 2010, as well as the largely (but not sustained) easterly winds on May 15, 1979.

Note: Taking the sine of the wind direction highlights the east-west component of wind direction, with a value of +1 denoting a completely easterly wind and a value of -1 a completely westerly wind.

Cosine (Wind Direction)



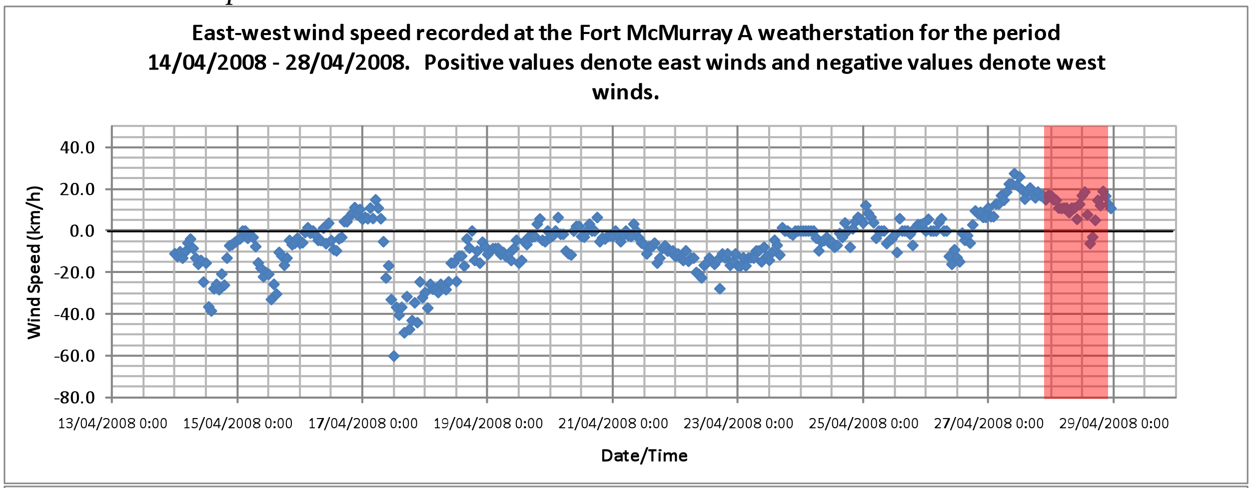




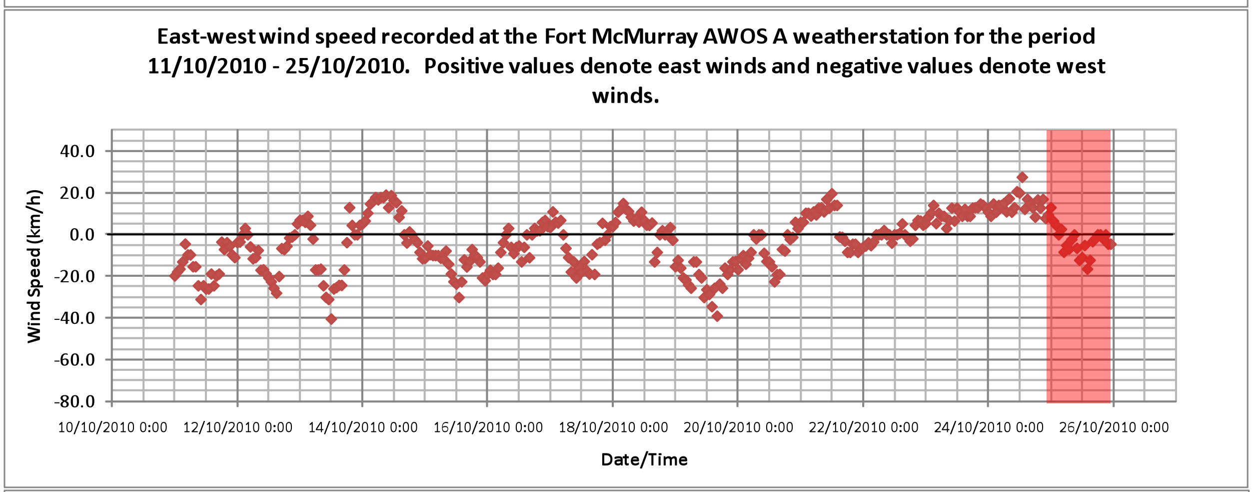
There were minimal north-south components to the wind directions during the 24-hour periods preceding both April 28, 2008 and October 25, 2010. The wind shifted to include a moderate southerly component on April 28, 2008, however winds on October 25, 2010 were nearly completely northerly. Wind was nearly completely northerly for approximately 10-hour periods on both May 14 and 15, 1979, with intermittently southerly winds on both dates as well. In contrast to the other two dates, the north-south components of the May 14-15 winds would have largely opposed the direction of migration.

Note: Taking the cosine of the wind direction highlights the north-south component of wind direction, with a value of +1 denoting a completely northerly wind and a value of -1 a completely southerly wind.

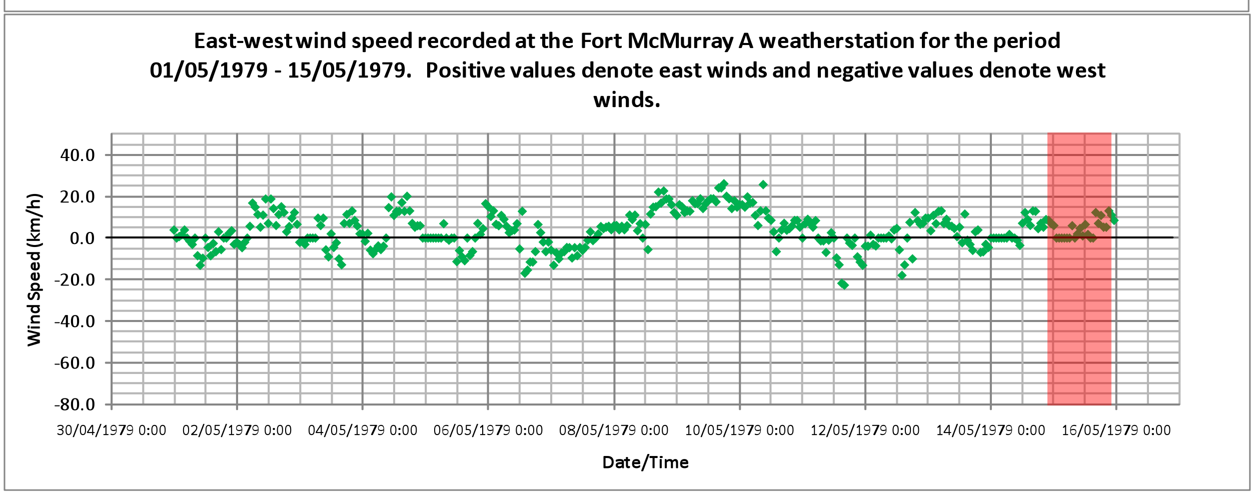
East-West Wind Speed



East-west wind speed recorded at the Fort McMurray A weatherstation for the period 14/04/2008 - 28/04/2008. Positive values denote east winds and negative values denote west winds.



East-west wind speed recorded at the Fort McMurray AWOS A weatherstation for the period 11/10/2010 - 25/10/2010. Positive values denote east winds and negative values denote west winds.

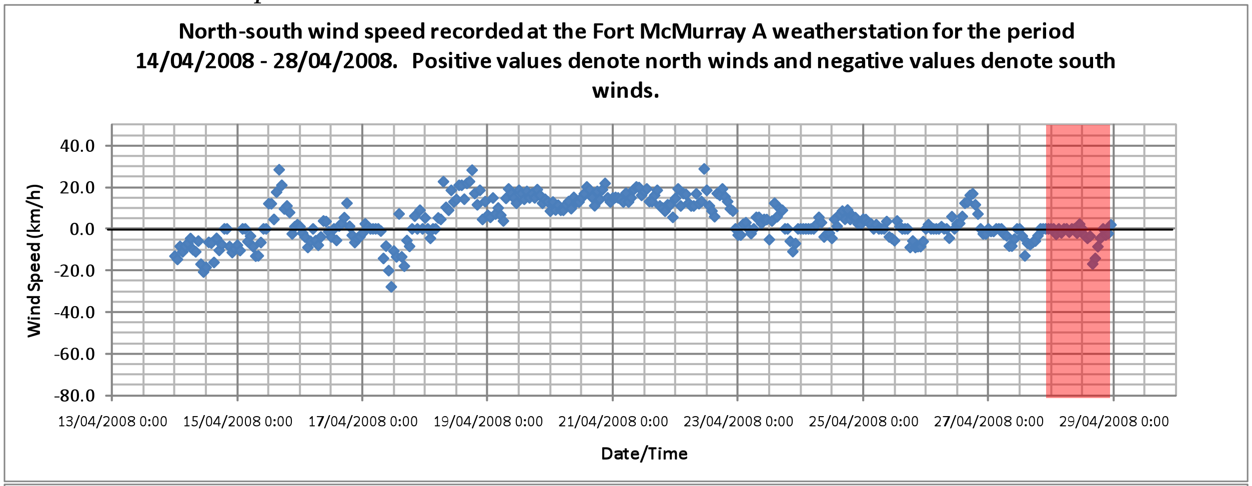


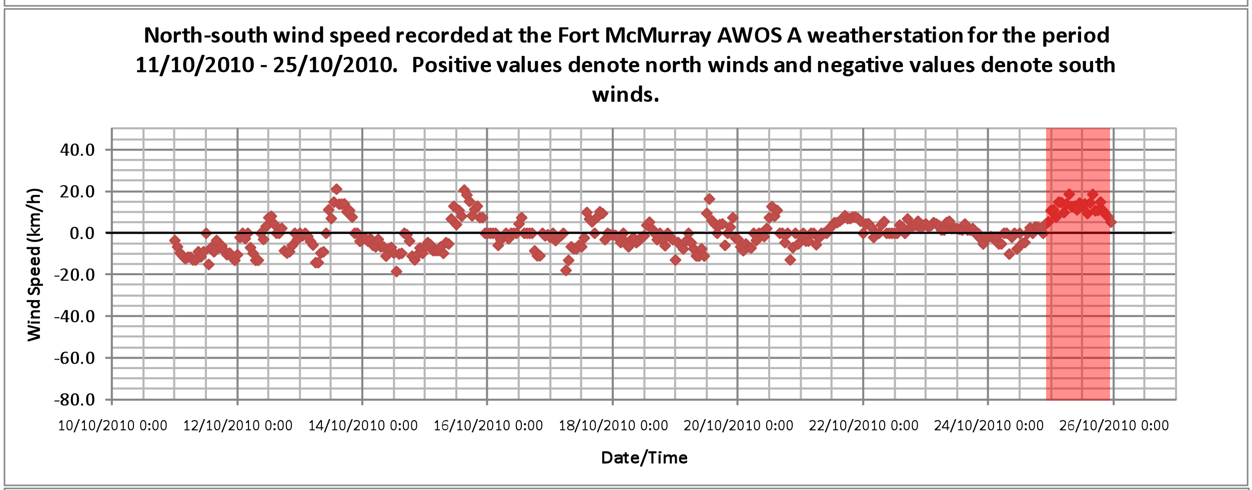
East-west wind speed recorded at the Fort McMurray A weatherstation for the period 01/05/1979 - 15/05/1979. Positive values denote east winds and negative values denote west winds.

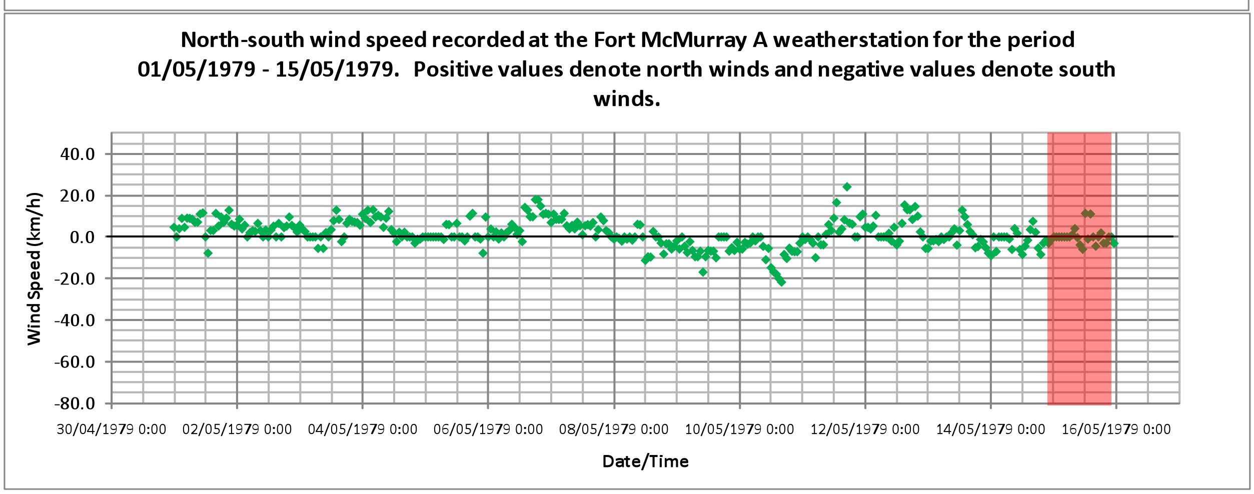
There were sustained 15-20+ km/h easterly winds during the 24-hour periods preceding both April 28, 2008 and October 25, 2010, however these winds diminished or switched directions on these dates. East-west winds on May 15, 1979 were lighter than those on the other two dates (0-15 km/h).

Note: These values were calculated by multiplying the recorded wind speed by the sine of the wind direction. Positive values denote east winds and negative values denote west winds.

North-South Wind Speed

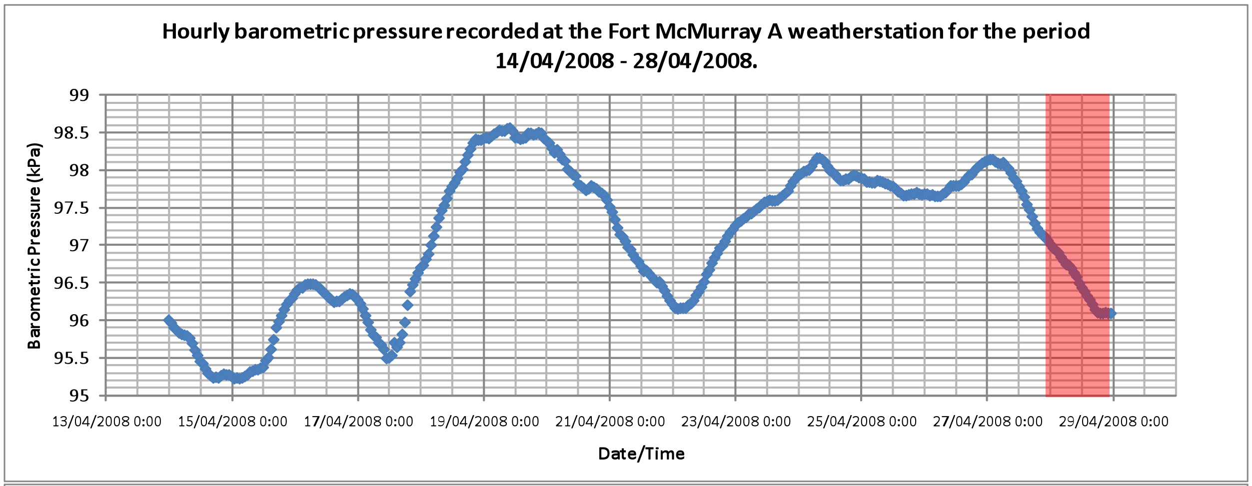


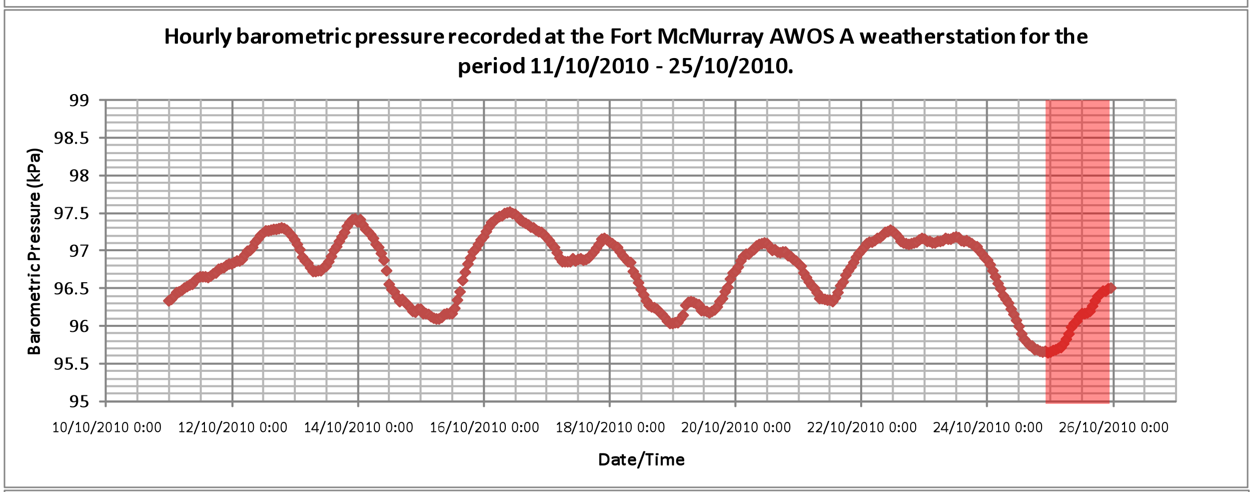


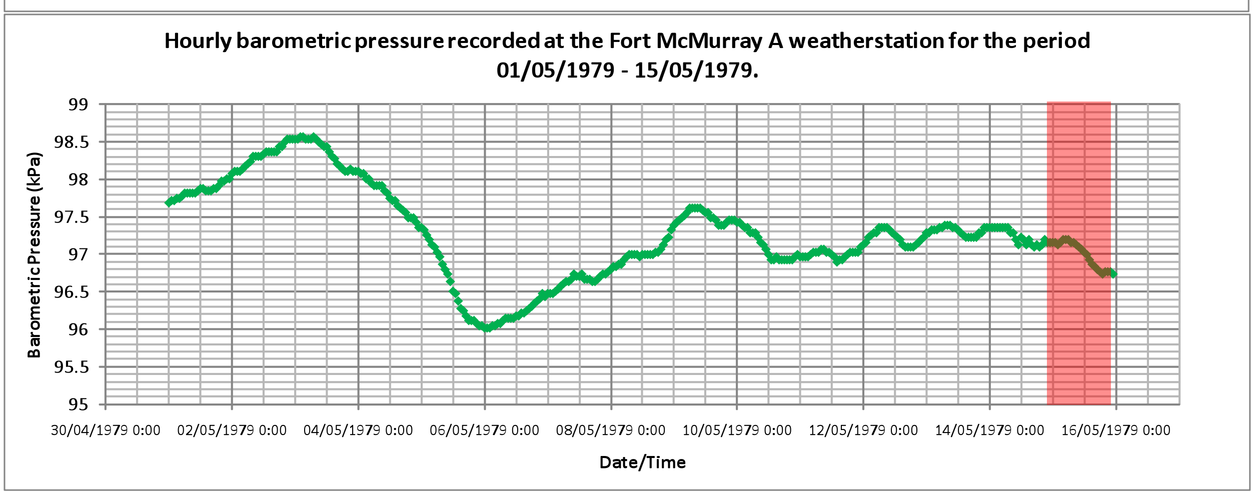


There were minimal (generally <10 km/h) north-south winds during the 24-hour periods preceding all three dates. A slightly stronger south wind developed in the afternoon of April 28, 2008, while a stronger northerly component developed on October 25, 2010.
Note: These values were calculated by multiplying the recorded wind speed by the cosine of the wind direction. Positive values denote north winds and negative values denote south winds.

Barometric Pressure







Both April 28, 2008 and October 25, 2010 were preceded by abrupt pressure drops (1.1-1.3 kPa in the preceding 24 hours). In comparison with pressure trends over the preceding two weeks, however, these drops were not unusual in their severity. There was a minimal pressure drop on May 14, 1979 (0.3 kPa), with a slightly larger drop on May 15, 1979 (0.5 kPa; 0.7 kPa total over the two days).

Appendix B

General Weather Overview for Fort McMurray and Area

Provided in April 2011 by Environment Canada

General Comments With Respect to Weather Interpretation

- The weather observations at the Fort McMurray Airport are technically for a 6 mile (~10 km) radius around the airport and weather conditions beyond that radius may vary greatly
- Weather chart interpretation is simply that, an interpretation
- Weather radar is an important tool to use to interpret weather conditions. Environment Canada weather radar is not available for areas north of Fort McMurray (beyond the usable limits of the closest available radar, Jimmy Lake radar)

May 15, 1979 (Spring)

Surface Field (Fort McMurray Observations, Station Elevation 369 metres above sea level)

- Light and variable winds (<10 km/h) in the morning, light east to south-easterly winds (~10 km/h) in the afternoon
- High humidity early in the morning, possibility of fog in the area early in the morning
- Daytime High 17 degrees Celsius (Normal 16.2)
- Surface pressure ~997 MB

850 MB Field (~1350m to 1500m ASL)

- Light and variable winds increasing to easterly 15 to 25 km/h in the afternoon as 850 MB low forms vicinity Alberta-British Columbia provincial border elbow
- Temperature warming to +4 degrees Celsius

700 MB Field (~2850m to 3100m ASL)

- Light and variable winds (~15 km/h)
- Slight warming throughout the day (2 to 3 degrees Celsius)
- Temperature around minus 6 degrees Celsius

500 MB Field (~5250m to 5600m ASL)

- Fairly weak westerly upper flow (~30 km/h)
- Slight warming in upper levels throughout the day

Satellite Imagery

- Not available to view

Other weather elements and comments for May 15, 1979

- Unsettled weather observed during the previous day (brief midday thunderstorms and brief late afternoon showers with 9 mm rain measured at Fort McMurray airport)
- Zero snow on the ground measured and reported at the Fort McMurray Airport on May 15

- Fairly benign weather observed at Fort McMurray Airport on May 15 (seasonal temperatures, light winds)
- Based on surface temperature and dew point temperature spreads measured at Fort McMurray Airport, estimated bases of afternoon cloud should have been fairly high (7000 to 9000 feet ASL)
- Fairly seasonal temperatures for the 7 day period leading up to May 15. Daytime heating creating some late day instability on a couple of days

April 28, 2008 (Spring)

Surface Field (Fort McMurray Observations, Station Elevation 369 metres above sea level)

- Winds east to southeast 10 to 20 km/h
- Trough of low pressure approaches from the west
- Daytime high 18 degrees Celsius (Normal 12.7)
- Surface pressure ~ 996 MB.

850 MB Field (~1350m to 1500m ASL)

- Identifiable baroclinic zone (horizontal temperature gradient) over north-eastern Alberta
- Winds appear to be light and variable (Stony Plains winds northwest 35 knots, may be suspect)
- Warm air advection
- Temperature +5 degrees Celsius

700 MB Field (~2850m to 3100m ASL)

- Light west wind
- Peak of building upper ridge
- Temperature minus 6 degrees Celsius

500 MB Field (~5250m to 5600m ASL)

- West wind 25 km/h.
- Sharp upper ridge

Satellite Imagery

- Organized large band of cloud moved in over the area overnight and remained over area throughout most of the day. Clearing in the afternoon. Precipitation possible under the organized band of cloud

Other weather elements and comments

- Two large scale weather systems brought snow to the area earlier in the month (April 18 to 19 and April 20 to 23)
- Snow on the ground did not appear to be measured at the Fort McMurray Airport
- Mainly cloudy in the morning, clearing in the afternoon
- Based on surface and temperature dew points, estimated base of overnight and early morning clouds around 5000 feet ASL
- Daytime high temperatures were well above normal
- Warmer than seasonal weather on April 28
- Previous two days saw temperatures rise from below normal to near normal then to above normal on April 28

October 25, 2010 (Fall)

Surface Field (Fort McMurray Observations, Station Elevation 369 metres above sea level)

- Deep low pressure system (and deepening) moving across the southern prairies
- Light to moderate easterly winds at the surface (15 km/h) very early in the morning, snow likely north of Fort McMurray. Winds shifting to light to moderate northwesterly (15 to 20 km/h) by early morning
- Likely some snow the night of the 24^{th} and into the early hours of the 25^{th}
- Potential for low based clouds
- Surface ridge of high pressure build in from the north late in the day
- Daytime high zero degrees Celsius (Normal 5.7)
- Surface pressure ~996 MB

850 MB Field (~1350m to 1500m ASL)

- Deepening 850 MB low over southern Saskatchewan
- Moderate easterly flow (25 km/h)
- Temperatures cooling throughout the day (falling about 3 degrees Celsius)
- Temperature minus 6 degrees Celsius

700 MB Field (~2850m to 3100m ASL)

- Deepening 700 MB low western Saskatchewan
- Moderate north-easterly flow (25 km/h) becoming northerly throughout the day
- Temperature minus 9 degrees Celsius

500 MB Field (~5250m to 5600m ASL)

- 500 MB low near Lloydminster
- Winds light northwest (20 km/h) increasing to moderate northwest 35 km/h
- Slack wind flow to the south

Satellite Imagery

- The northern cloud edge of a very large storm system to the south is in the Fort McMurray region

Other weather elements and comments

- Very deep low pressure system moving across the southern prairies
- Daytime temperatures below normal
- Snow on the ground did not appear to be measured at the Fort McMurray Airport
- Based on the temperature and dew point temperature measured at the Fort McMurray Airport, there was the potential for low based cloud in the area on October 25
- Several days of below normal temperatures and rain and snow leading up to and including October 25.

<u>Weather Commonalities between all 3 identified events</u>

- There were no obvious weather commonalities between the 3 identified events
- The weather on May 15, 1979 appeared to be benign. The weather on April 28, 2008 seemed to have been fairly benign however satellite imagery showed morning cloud and perhaps a slight potential for some precipitation. The October 25, 2010 event had a slightly greater potential for some active weather around the area
- Based on weather chart interpretation, there was no indication of very strong or very significant winds during any of the 3 identified days
- The barometric pressure measured during all three events were 996 to 997 MB (probably more of a coincidence than anything)
- All 3 events had an easterly component to the winds either the day of or leading up to the day of the identified event
- Only during one of the identified days did the observations at the Fort McMurray airport identify precipitation (October 25, 2010), however clouds shown on the satellite imagery indicated that precipitation may have been possible on April 28, 2008
- Both Spring events had temperatures that were seasonal to above seasonal values
- The Fall event had temperatures that were below seasonal values

Other Identified Questions;

Q.) Would you suggest looking for other kinds of meteorological information than what is summarized here?

A.) There are many other meteorological elements or processes that potentially may have played a role. Unfortunately, many of these elements or processes are either impossible or are almost impossible to examine or quantify. Other identified items would require assumptions and a significant amount of work to analyze. By identifying other types of meteorological information to consider, Environment Canada is not offering to provide any further weather analysis. Here are just a few additional meteorological related items for consideration;

- Certain weather conditions can vary greatly between short distances (fog, low cloud ceilings, drizzle or freezing drizzle, snow, etc.).
- Weather observations 50 to 100 kilometres away may not be sufficient to identify weather conditions at another specific location
- What was the stability of the air mass at the time and location of the event (model upper air analysis)?
- What were the speeds of the vertical updrafts and downdrafts at the time and location of the event (impossible to know)?
- What was the height of the base of the cloud at the time and location of the event?
- What was the horizontal and vertical visibility at the time and location of the event?
- Was there precipitation at the time and location of the event?
- Was there freezing precipitation at the time and location of the event?
- Did local topography have an effect on the local weather conditions at the time and location of the event?
- What affects do thunderstorms have on migratory birds?
- Weather conditions may not have been the primary factor for the event?
- Were all of the water bodies in the area (sloughs, lakes, rivers, etc.) completely frozen at the time of the event?

Q.) Are easterly winds especially likely during cold fronts in Northern Alberta?

A.) Wind directions are a result of the pressure gradient pattern. Typically in Alberta, easterly winds will occur when a low pressure system approaches from the west (winds blow from high pressure to low pressure). If the low pressure system passes to the south of an identified location, the winds tend to back from an easterly component to a northerly component as the low moves eastward or southeastward and the associated cold front may sweep down from the north. Cold frontal passages generally provide a moderate to strong northerly component to the surface and low level winds.

Q.) Are winds less predictable following a storm than before?

A.) Winds tend to be more erratic during a weather disturbance. Weather disturbances that involve air mass instability can produce big variations in wind over small areas. Unstable air masses can tap stronger winds aloft and bring them down to the surface as wind gusts. Also in unstable air masses, buoyant air that rises can produce updrafts. Downdrafts tend to be much stronger than updrafts. Winds before a storm and after a storm tend to be more consistent with pressure gradients.

Q.) Is there any way to predict the degree of updraft when winds are measured in horizontal directions?

A.) Not that I am aware. Updraft and downdraft wind speeds are generally associated with air mass instability.

Appendix C

Slides to support interpretation of the effects of anthropogenic light on bird navigation offered in

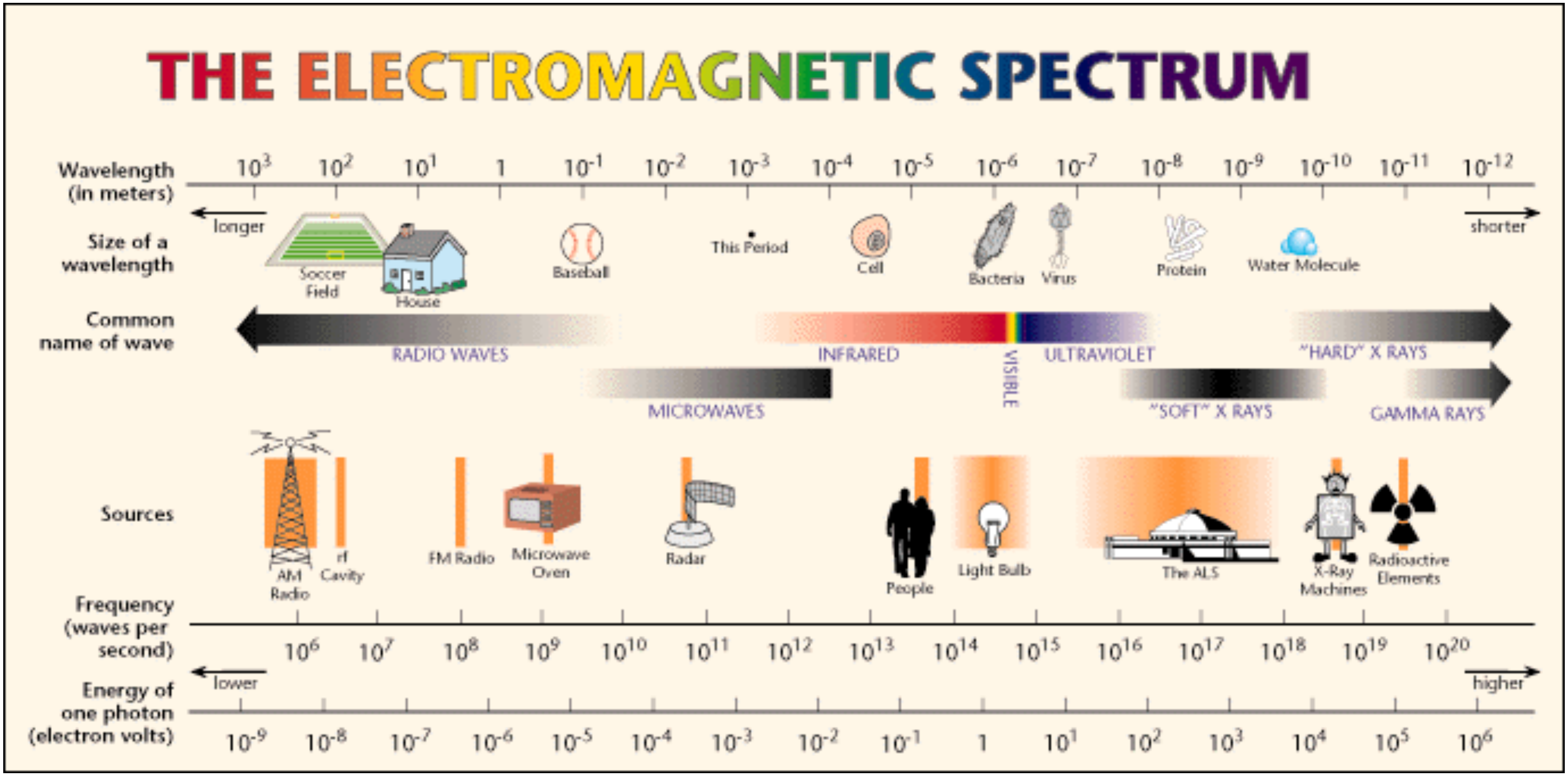
Spatial and temporal correlates of mass bird mortality in oil sands tailings ponds

A report prepared for Alberta Environment by

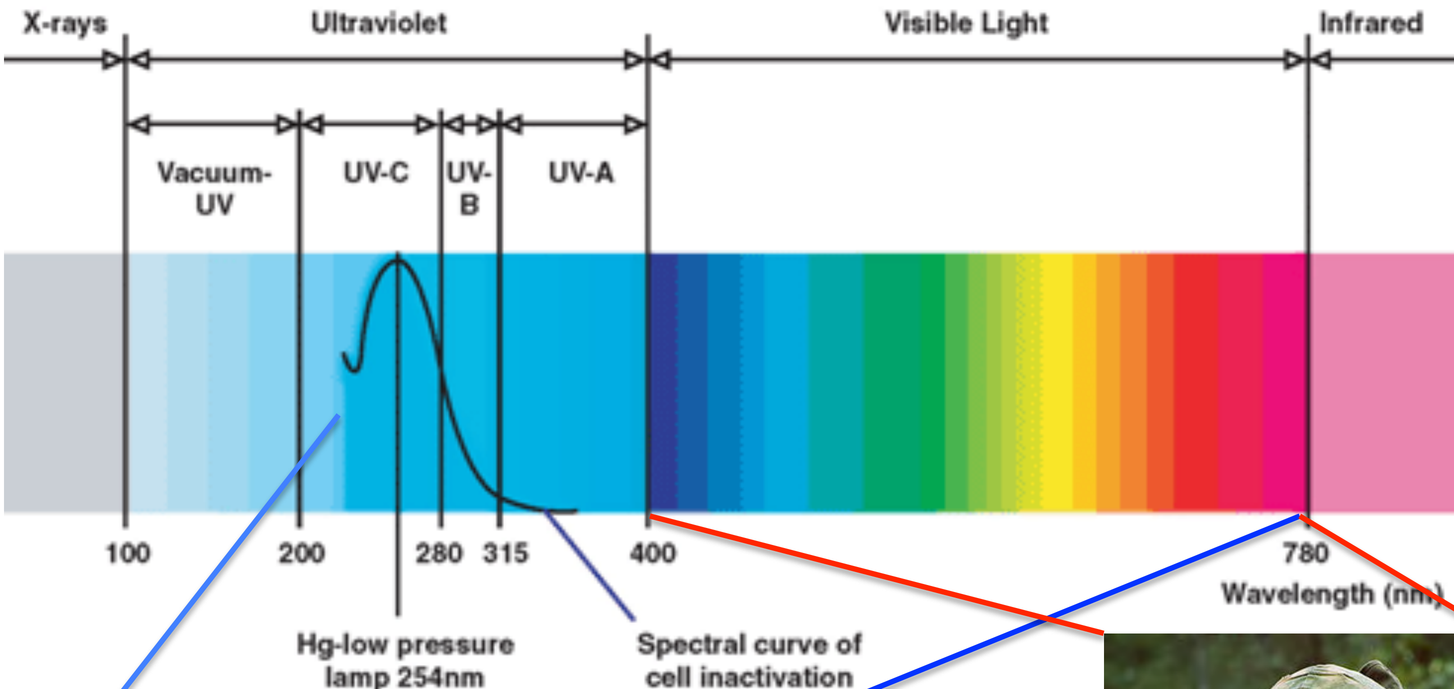
Colleen Cassady St. Clair, Thomas Habib, and Bryon Shore,
10 November 2011

Department of Biological Sciences, University of Alberta,
Edmonton, Canada T6G 2E9

All light is part of a much larger electromagnetic spectrum, which provides some logic to the suggestion that birds sense magnetism, as least partially, with specialized cells in their retinas.



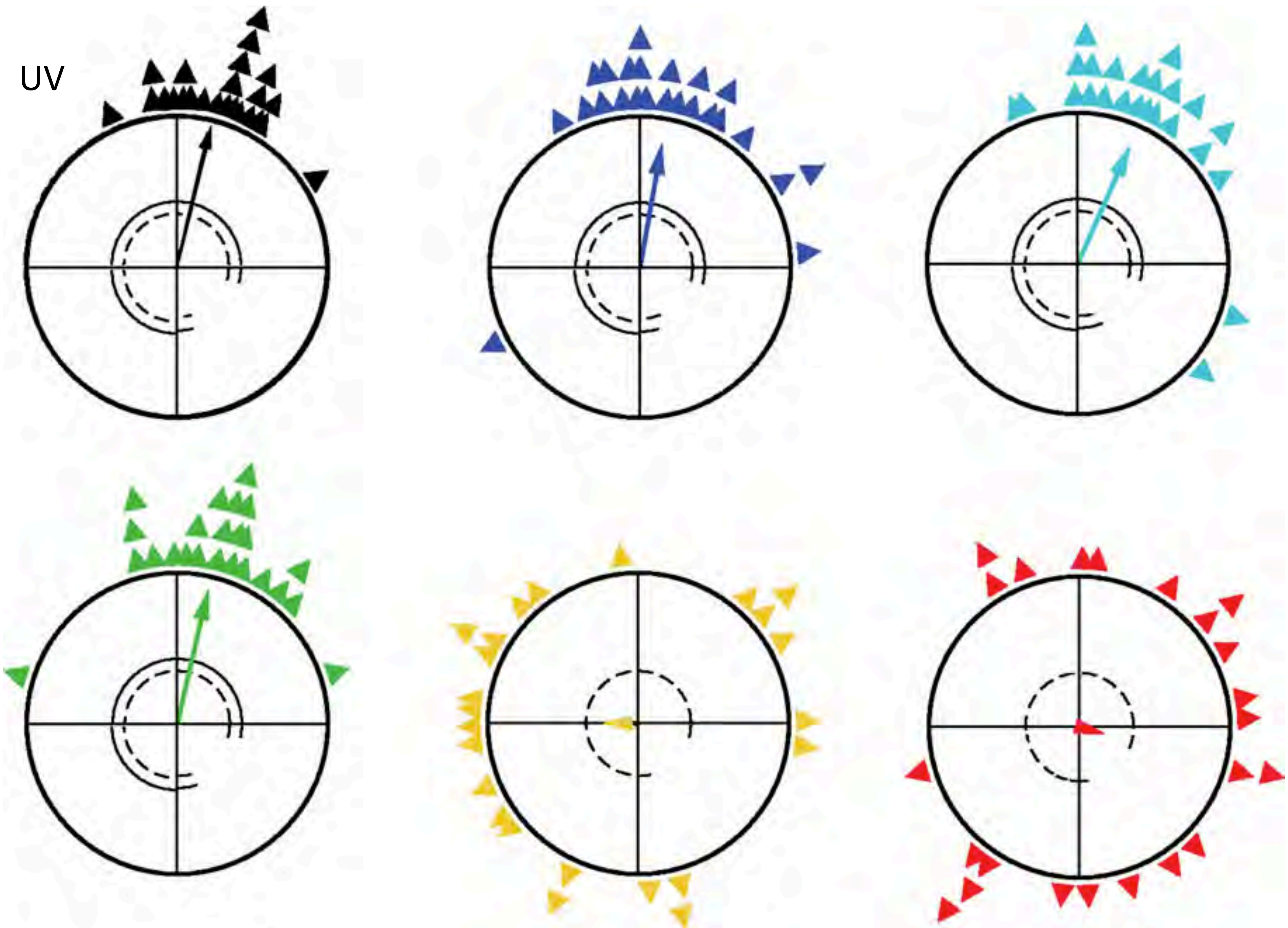
The Electromagnetic Spectrum



Birds see well into the UV range with specialized cone cells.

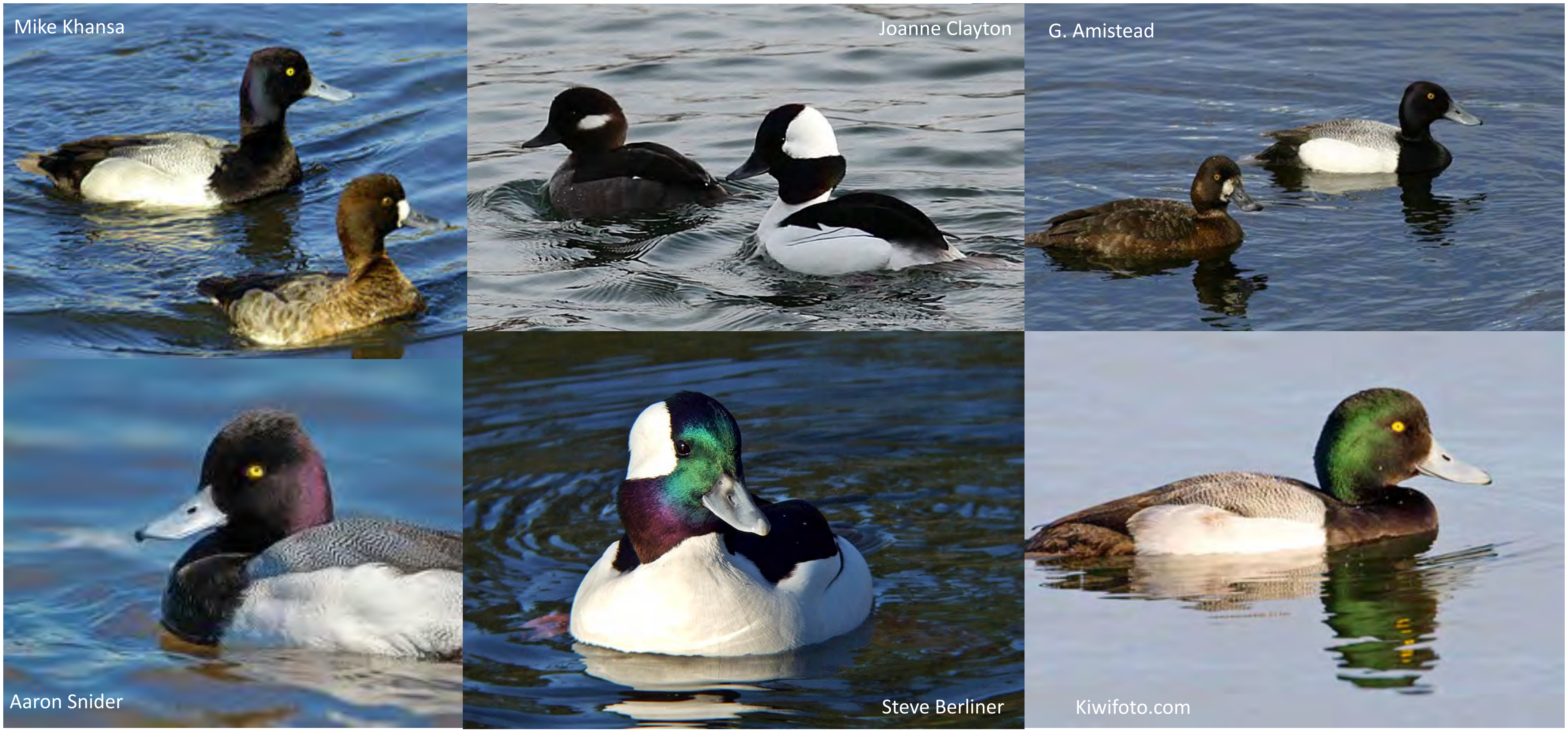
Red-green colour blind marines make much better sharp shooters, perhaps because it encourages greater use of shorter wave lengths.

Wiltschko *et al*. 2010 showed that caged migratory birds can orient appropriately (depicted by the arrow) when exposed to UV, blue and green light, but not when they are exposed to yellow and red light, which all anthropogenic light contains.



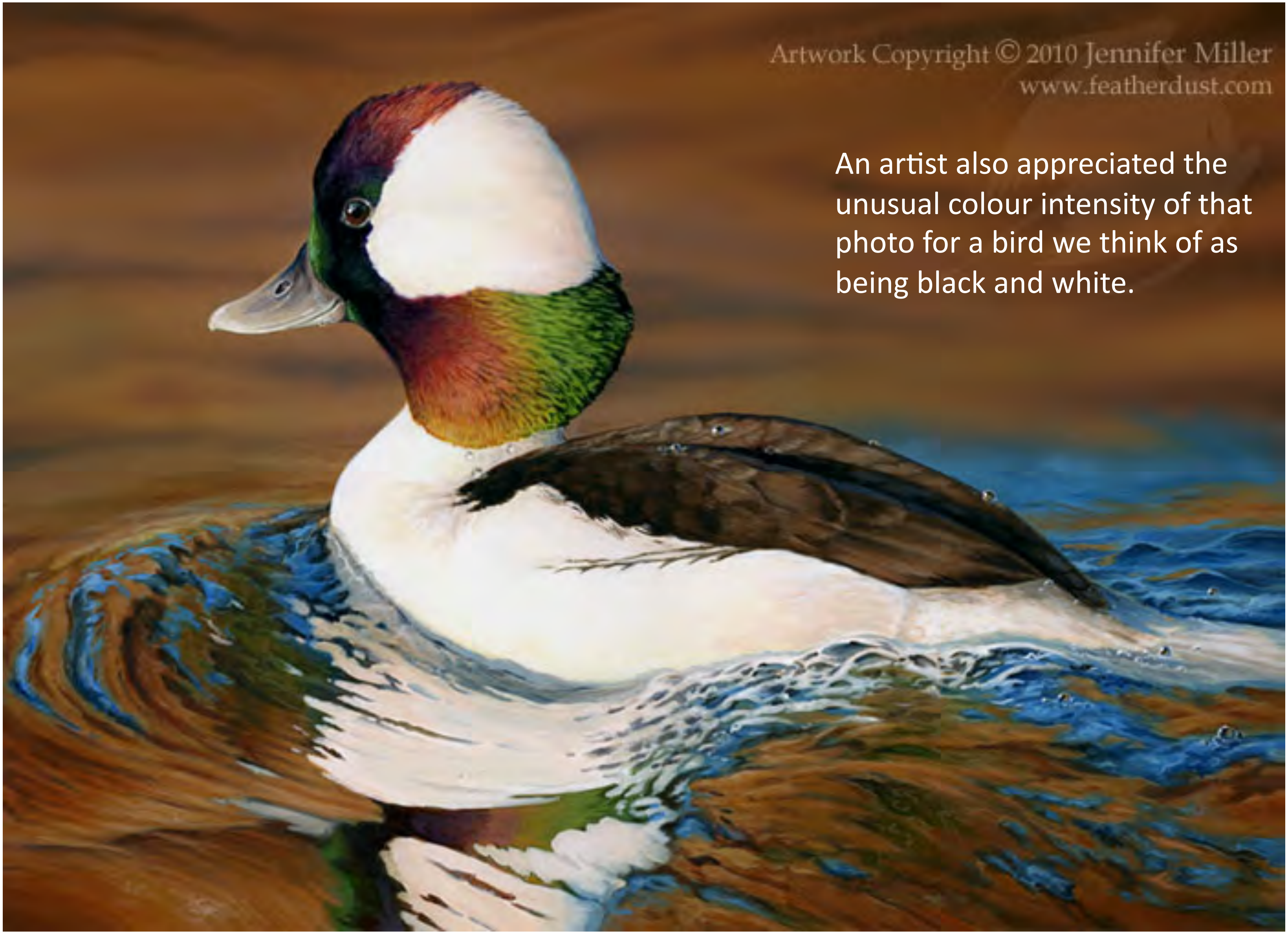

Poot et al. 2008

Birds that look black and white to us (top panel) display striking colour with refracted light (bottom panel).
Refracted light occurs mainly in the short wavelengths.



Lesser Scaup Bufflehead Greater Scaup


This photo was described as having 'poor' lighting by the photographer, but it likely reveals something closer to what female buffleheads see when they look at male buffleheads.
G. Dahlman



An artist also appreciated the unusual colour intensity of that photo for a bird we think of as being black and white.