The Canadian Field-Naturalist

Volume 120, Number 1 January–March 2006

Predicting Bird Oiling Events at Oil Sands Tailings Ponds and Assessing the Importance of Alternate Waterbodies for Waterfowl: a Preliminary Assessment

ROBERT A. RONCONI

Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9 Canada
Present address: Department of Biology, University of Victoria, P.O. Box 3020 Station CSC, Victoria, British Columbia V8W 3N5 Canada; e-mail: rronconi@uvic.ca

Ronconi, Robert A. 2006. Predicting bird oiling events at oil sands tailings ponds and assessing the importance of alternate waterbodies for waterfowl: a preliminary assessment. Canadian Field-Naturalist 120(1): 1-9.

Tailings ponds are an integral part of oil sands mining development in northeastern Alberta, but waterfowl and shorebirds often land in these ponds during spring migration where they may become covered with oil. For decades, managers have developed and implemented methods for deterring birds from landing in these ponds, yet no deterrent strategy is fully effective. Therefore, to enhance deterrence strategies, it will be important to understand the environmental conditions that influence bird use of tailings ponds. This study quantified waterfowl flights over, and use of, tailings ponds and compared this use to waterfowl activity at natural waterbodies in the region over a single spring migration period. Results suggest that waterfowl are most likely to land on tailings ponds before lakes have thawed, after which migratory ducks appeared mainly to use natural waterbodies for migratory stopover sites. Very high numbers of waterfowl were observed on one waterbody, Kearl Lake, suggesting that this lake may be of greater importance to spring staging waterfowl than previously thought. A small sample of birds oiled at tailings ponds were examined in relation to spring weather conditions. Logistic regression analysis demonstrated that the probability of birds being oiled tended to increase with precipitation levels. Results of this study suggest that (1) preservation of natural waterbodies may play an important role in minimizing bird use of tailings ponds, and (2) future bird deterrence efforts should especially aim to deter birds during rainy weather conditions when birds may be more likely to become oiled. These results were from a small sample size, are preliminary in nature, and should be interpreted with caution. A concerted and careful effort to collect and thoroughly analyze long-term records of oiled birds may reveal important environmental effects predicting bird oiling events.

Key Words: waterfowl, oil sands, mining, tailings ponds, lakes, weather, migration, radar, conservation, Alberta.

In northeastern Alberta, oil sands development has grown considerably over the past several decades. This industry promises to grow into the 21st century since recent oil reserve estimates have placed Canada second on the world list of oil reserves with 175 billion barrels of oil in oil sands deposits (CAPP 2003*). Although most of these reserves are extractable with new drilling technologies, an estimated 20% are recoverable only with open pit mining practices (CAPP 2003*). One of the primary environmental concerns stemming from oil sands mining is the existence of tailings ponds which have oil floating on the surface. Birds landing on these ponds might become covered in oil and die. This problem has been recognized since the initial development of oil sands mining (SCL 1973; Schick and Ambrock 1974*; Ward et al. 1976*; Hennan and Munson 1979) and significant effort has been dedicated to researching the conditions that promote and prevent birds from becoming oiled (Boag and Lewin 1980; Gulley 1980; Yonge et al. 1981*; Ronconi and St. Clair 2006; also see review by Golder Associates 2000*). Nevertheless, birds still continue to be oiled and oil sands companies carry on their search for better means of reducing these incidents.

Previous oil sands research recommended the creation of uncontaminated waterbodies in close proximity to tailings ponds, allowing birds alternate landing sites (Gulley 1980; Golder Associates 2000*). Moreover, research in other industrial contexts indicates that birds can be deterred from an area more effectively when alternate roosting sites (including ponds) are available (Martin and Martin 1984; Gosler et al. 1995; Stevens et al. 2000). Yet others have argued that such diversionary ponds would only draw more birds to the region (Allen 1990). Instead, the preservation of naturally occurring waterbodies may be an optimal solution to provide alternate landing sites for birds, particularly if these alternative bodies are already used by migrating birds in the region. Comprehensive surveys of waterfowl at the major waterbodies in the vicinity of Alberta's oil sands were conducted prior to oil sands development (Hennan and Munson 1979), but the current status of these waterbodies and their use by migratory birds are unknown. Moreover, subsequent surveys of waterbird numbers at natural waterbodies (Shortt 1985*; Van Meer and Arner 1985*) did not compare levels of bird activity between these natural ponds and nearby tailings ponds. Such information would make it possible to assess the importance of alternative waterbodies as stopover sites during migration, and to assess temporal changes within seasons in the attractiveness of tailings ponds to waterfowl.

In addition to information about the alternative stopover sites for migrating birds, researchers and managers have also sought to understand the conditions under which birds become oiled on tailings ponds. Over a three-year period, Gulley (1980) identified three main conditions as determinants of the numbers of birds that were killed each year. First, more birds were oiled when more birds were migrating (Gulley 1980), though the synchrony of migration is not fully predictable and tends to vary among both years and species (Bellrose 1976). Second, cold spring weather and delayed ice break-up correlated with bird oilings. Finally, greater than average seasonal rainfall has been correlated with higher rates of oiled birds. In contrast, other studies failed to observe any environmental (wind, temperature, precipitation) effects on the probability of bird landings in tailings ponds (Ronconi and St. Clair 2006). Yet neither analysis examined the frequency of bird oiling events in relation to daily weather patterns and this information may be most likely to reveal the causes of variation.

The study is situated at one of more than 10 oil sands tailings ponds operating in northeastern Alberta (Golder Associates 2000*), all of which are situated along a major migratory flyway for waterfowl traveling to the Peace-Athabasca Delta, an internationally significant staging area (Bellrose 1976; Hennan and Munson 1979). The objectives in this study were three-fold. First, I examined the seasonal abundance and direction of migratory bird movements over tailings ponds. Second, I compared numbers of waterfowl that landed at tailings ponds with numbers of birds at natural ponds in a broader region and with historical data. Finally, I assessed potential correlations between daily weather conditions and the frequency of oiled birds found during April and May of 2003. Because data were available only for a single season, I present these as preliminary results and encourage future researchers to investigate these findings over longer time periods.

Methods

The study was undertaken at the Muskeg River Mine (MRM), Albian Sands Energy Ltd., located approximately 75 km north of Fort McMurray, Alberta (Figure 1). During April and May 2003, the mine was beginning initial oil production stages. The tailings pond complex consists of three ponds totaling ~ 740 ha of surface area when full, but water coverage during this study period was approximately 530 ha. Natural waterbodies were selected for surveys based on accessibility, size, and proximity to the MRM tailings ponds. These included two lakes near the mine, four lakes south of the mine near other oil sands development, and eight lakes north of the mine that were isolated from development (Figure 1). As these lakes were situated along a North-South axis relative to the MRM, all lakes were potentially usable by waterfowl migrating along this corridor.

Airport radar systems have been used to study bird migration patterns in Alberta (Richardson and Gunn 1971), and marine radar has been used by ornithologists to study various aspects of bird activity (Cooper et al. 1991; Burger 1997; Bertram et al. 1999; Gauthreaux and Belser 2003). In this study, marine type radar was used to assess spring migratory activity over the MRM tailings ponds between 3 and 29 May 2003. Migratory activity was measured by the groups of birds flying over the study area (groups rather than individuals are identifiable by radar) and the direction of flight. Radar observations were made from 0.5 hours before sunrise to 4 hours after sunrise. This period was considered a high migratory period in northeastern Alberta (Richardson and Gunn 1971). Owing to some technical difficulties, directional data were not recorded for the first four days of this period, and data collection was not possible on six other days because of heavy precipitation that obscured radar observations.

Tailings pond and lake surveys were conducted from fixed observation points using binoculars and spotting scopes. Tailings ponds were surveyed regularly from 18 April to 29 May, and lakes were surveyed 9 to 28 May as most lakes were still completely or partially frozen during the first week of May. Observers counted individual ducks, gulls, coots, loons, and grebes on the water. No more than two or three geese were observed during any lake count; therefore, goose counts were omitted from the results. Because of the large size of McCleland Lake, all portions of it were not simultaneously visible, thus counts were only a minimum estimate of bird numbers on that lake. Kearl Lake was surveyed more often than the other natural waterbodies because it was nearest to the MRM tailings ponds and thus most likely to offer an alternate landing site for migratory birds. During the mid-1970s Mildred Lake was dammed, converting most of the lake into a tailings pond and leaving only a portion of the lake in its semi-natural state. Surveys of Mildred Lake included only the semi-natural portion. When applicable, results were compared to previous surveys (see Hennan and Munson 1979 for detailed waterfowl surveys in the region).

Reports of oiled birds on the tailings ponds were collected from 10 April to 29 May, inclusive. Although systematic searches for oiled birds were not conducted, observers spent 4 to 8 hours observing waterfowl at the tailings ponds on most days thus ensuring some consistency in effort throughout this period. Weather data for wind speed and direction, temperature, and rainfall were recorded from meteorological stations on site, and snowfall events were converted into rainfall equivalency. Mean temperature is reported here as the daily mean of maximum and minimum temperatures. Wave conditions on the ponds and percent cloud cover were recorded by observers. All occurrences of oiled birds are reported (below); however, analyses of weather effects were conducted only on oiled birds that were still alive when found, an assumption that those birds became oiled either the day they were found or the previous night. For analysis by logistic regression, oiled birds were the dependent variable (1 = days with oiled birds; 0 = days with no oiled birds). Days when observers were not present on site were excluded from analyses. Weather data were the independent variables (wind, temperature, precipitation, wave conditions, % cloud cover). Except for wave conditions, analyses of weather effects were assessed for three time periods: date of oiled bird finding, one day prior (i.e. previous 24 hour conditions), and two days prior (i.e. previous 24-48 hour conditions). Wave condition was only analyzed for the first two time periods since it was considered likely that rough water effects would not persist for as long as two days. Logistic regression analysis (SPSS 11.5) was used to assess weather effects and to build a model for predicting their effects on the probability of birds being oiled. Owing to small sample sizes of data from a single season, a liberal alpha value (0.10) was used for logistic regression analysis. Tests were conducted for inter-

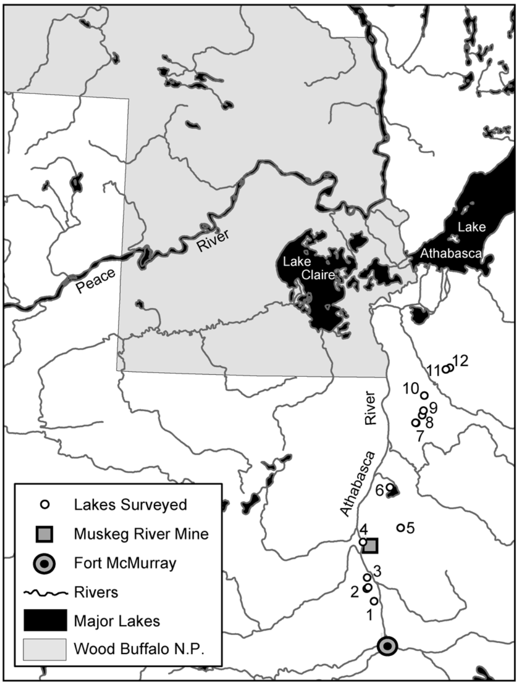

FIGURE 1. Map of study area showing the location of the Muskeg River Mine and surrounding natural waterbodies surveyed in 2003. Lake names are as follows: (1) Poplar, (2) Ruth and Crane, (3) Mildred, (4) Isadore's, (5) Kearl, (6) McCleland, (7) Unknown Lakes, (8) Go Go, (9) Herb, (10) Six Lakes, (11) Larocque, and (12) Net.

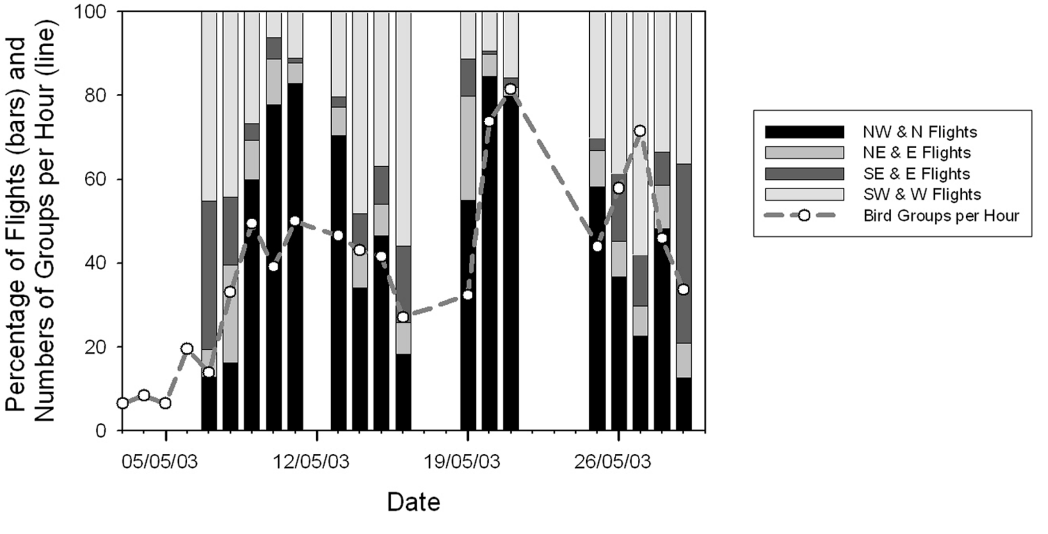

FIGURE 2. Migration patterns from radar data at the Muskeg River Mine tailings ponds, 3-29 May 2003. Bird groups were the unit of measure because group size could not be inferred from radar images. Gaps in the data set resulted from days of heavy precipitation which obscured radar observations.

TABLE 1. Numbers of waterfowl at the Muskeg River Mine (MRM) and surrounding natural waterbodies, 2003.

Location	Date	Coordinates	Distance (km) Lake from MRM	Size[1]	Gulls	Ducks	[2]Other Water birds
Muskeg River Mine							
Tailings Ponds	18 April	57°13'47"N, 111°35'10"W	0		0	35	3
	20 April				0	8	0
	23 April				0	32	0
	24 April				0	13	0
	25 April				4	13	0
	26 April				0	22	4
	27 April				5	55	0
	03 April				0	86	0
	04 April				0	90	0
	05 April				0	16	0
	06 May				0	166	58
	07-29 May				0-14	≤ 28	≤ 2
Near Muskeg River Mine							
Kearl Lake	09 May	57°18'08"N, 111°15'06"W	19	>	15	104	11
	15 May				300	2700	present
	19 May				440	859	9
	30 May				2	8	9
Isadore's Lake	26 May	57°13'43"N, 111°36'29"W	1	=	66	102	2
North of Muskeg River Mine							
McCleland Lake[3]	23 May	57°30'35"N, 111°21'16"W	32	>>	12	645	5
Unknown Lake	23 May	57°50'25"N, 111°06'29"W	72	<	4	0	0
Unknown Lake 2	23 May	57°50'28"N, 111°06'46"W	72	<	0	4	2
Go Go Lake	23 May	57°52'48"N, 111°02'56"W	77	<	0	0	2
Herb Lake	23 May	57°54'13"N, 111°02'11"W	80	=	0	5	1
Six Lakes	24 May	57°58'50"N, 111°01'45"W	88	=	0	0	3
Net Lake	24 May	58°07'23"N, 110°46'55"W	108	=	0	5	3
Larocque Lake	24 May	58°06'51"N, 110°49'11"W	107	=	3	0	1
South of Muskeg River Mine							
Mildred Lake	25 May	57°02'45"N, 111°33'52"W	18	=	0	0	0
Crane Lake	25 May	56°59'45"N, 111°33'12"W	24	<	0	158	present
	28 May				0	106	5
Ruth Lake	25 May	56°59'22"N, 111°34'06"W	25	>	19	306	present
	27 May				12	350	12
Poplar Reservoir	27 May	56°55'32"N, 111°29'50"W	32	=	0	15	2

[1] Relative to Muskeg River Mine tailings ponds = (approximately equal), > (larger), < (smaller).
[2] Includes coots, loons, grebes.
[3] Entire lake was not observable, therefore counts are minimum numbers of birds.

actions and confounding variables. For detailed description of the model-building approach see Ronconi and St. Clair (2006) and Hosmer and Lemeshow (1989).

Results

Counts of bird groups by radar provided an indication of overall bird activity relative to the numbers of birds landing at tailings ponds. The radar system was operational from 3 – 29 May, during which two peaks in migratory activity were observed (Figure 2). Peaks in migratory flights (NW & N flights) coincided with two peaks in bird activity (bird groups per hour). However, a third peak in groups per hour on 27 May showed no corresponding peak in NW & N flights. Notwithstanding the three peaks, these data document high migratory volumes over most of May when counts of waterfowl on lakes were conducted. However, the numbers of ducks that also landed on the tailings ponds (Table 1) were consistently low over this same period with no comparable peaks.

Counts of birds at tailings ponds and natural waterbodies showed much variability and peaks occurred at different times for different lakes. Counts of ducks and other waterbirds at the MRM tailings ponds (Table 1) showed peaks in activity from 26 April through to 6 May, after which activity dropped considerably and remained low throughout May. Conversely, high counts of birds on surrounding lakes were observed in May (Table 1), though comparable counts from April were not possible because the natural waterbodies were still frozen at that time. In particular, Kearl Lake showed a peak around mid May with an estimated 2700 ducks and 300 gulls on 15 May. As numbers were low at Kearl Lake in early May, these data, in combination with low May counts at tailings ponds, suggest that bird use of tailings ponds may have shifted to natural waterbodies for much of May. North of MRM, counts showed very low numbers except for McCleland Lake with over 600 ducks on 23 May. This high count suggests that McCleland was still being used as a migratory stopover at this time, but lakes farther north were likely only occupied by small numbers of breeding pairs. Between 25 and 27 May, counts of lakes south of MRM had higher numbers than maximum counts at MRM tailings ponds throughout April or May, but by this date many of these birds may have been resident breeders.

Although duck use of tailings ponds appeared low in comparison with natural waterbodies, overall duck numbers for this region were higher than historical surveys reported. Comparisons with Hennan and Munson's (1979) surveys showed several changes (Table 2). Duck numbers at McCleland Lake fell within the range of historical counts and were higher than four of the five years surveyed between 1973-1977, even though McCleland was only censused once in 2003. The highest count at Kearl Lake in 2003 was 4.6 times the maximum recorded by once annual surveys between 1973 and 1977. South of the MRM, Mildred Lake showed no use in 2003, in contrast to abundant use in previous surveys, whereas numbers were higher at Ruth Lake than were recorded during the 1970s. Due to inconsistencies in data collection methods and dates of surveys, we can not speculate on trends or changes in waterfowl abundance since the 1970s. However the dramatically high count of ducks on Kearl Lake suggest that this lake may be more heavily used as a migratory stopover site than might have been suspected from earlier surveys.

Fifteen oiled birds were observed at the MRM tailings ponds during the study period (Table 3), nine of which were alive when found. Of these, four Lesser Scaup (*Aythya affinis*) were lightly oiled and able to fly, making it probable that these were non-fatal oiling events. The remaining live oiled birds included one goose, one shorebird, one gull and two ducks. Days when live oiled birds were found were plotted in relation to weather variables (Figure 3). A logistic regression analysis was conducted on 47 days of observations, six of which had reported live oiled birds. This analysis found no effect of temperature, sea-state, wind direction, or cloud cover. Univariate analyses found date ($P = 0.160$) to be marginally significant, and rainfall ($P = 0.086$), rainfall during the previous 24 hours ($P = 0.066$), and wind speed during the previous two days ($P = 0.050$) as significant variables affecting the probability of birds being oiled. However, when combined in a multivariate analysis no variables retained significance but the two rainfall variables were only

TABLE 2. Comparisons of spring 2003 duck counts with historical counts from 1973-1977 (Hennan and Munson 1979).

Location	Maximum Number of Ducks Recorded During Spring Migration					
	1973	1974	1975	1976	1977	2003
MRM Tailings Ponds	–	–	–	–	–	166
Kearl Lake	529	586	24	37	140	2700
McCleland Lake[1]	194	1154	225	360	195	645
Mildred Lake[2]	246	313	136	17	–	0
Ruth Lake	113	20	26	11	–	350
Poplar Reservoir	–	–	16	1	14	15

[1] For 2003 surveys the entire lake was not observable; therefore, count is a minimum estimate of ducks
[2] ca. 1975 most of Mildred Lake was converted into a tailings pond. Surveys in 2003 checked only the portion of Mildred Lake that remains in its natural state.

TABLE 3. Summary of oiled birds found at the Muskeg River Mine tailings ponds, April and May 2003.

Date	Common Name	Scientific Name	Group Size	Status	Oiled Status
26 April	goose spp.	unknown	1	Live	heavy – >80%
03 May	Common Goldeneye	*Bucephala clangula*	1	Live	heavy – 80%
19 May	Lesser Scaup	*Aythya affinis*	4	Live	light < 10%[1]
20 May	Bonaparte's Gull	*Larus philadelphia*	1	Live	heavy – 70%
21 May	small shorebird	*Calidris* spp.	1	Live	heavy – 60%
21 May	Lesser Yellowlegs	*Tringa flavipes*	1	Dead	moderate – 30%
26 May	Northern Shoveler	*Anas clypeata*	1	Live	heavy > 50%
26 May	Northern Shoveler	*Anas clypeata*	1	Dead	heavy – 100%
26 May	small Shorebird	unknown	1	Dead	heavy – 100%
26 May	medium passerine	unknown	1	Dead	heavy – 90%
26 May	large shorebird	unknown	1	Dead	heavy – 100%

[1] Lightly oiled but able to fly.

marginally non-significant ($P = 0.107$ and 0.105). To examine the apparent, though non-significant, effect of rainfall on birds being oiled, the cumulative rainfall was summed for the day of plus day before oiled birds were found and this had a significant effect (*Wald* = 4.973, d.f. = 1, $P = 0.026$) on the probability of birds being oiled. The positive coefficient of this variable indicated that the probability of a bird becoming oiled increased with higher rainfall. With the cumulative rainfall variable, the model was significant (*-2LL* = 30.264, *model* $\chi^2 = 5.636$, d.f. = 1, $P = 0.018$), but the model fit was weak (*Nagelkerke's* $r^2 = 0.212$, *Hosmer and Lemeshow test* $\chi^2 = 1.330$, d.f. = 1, $P = 0.095$). Small sample size likely contributed to the marginal significance of variables and the poor fit of the model, yet the persistence of rainfall effects indicate that precipitation was related to birds being oiled this year and this may be true more generally.

Discussion

Timing of Spring Migration

Although the radar system was not operational in April, visual observations suggested that migration activity in the study area was fairly low in April and early May and that migration peaked in mid-May. The radar was also not in operation (due to weather) for six days in May near peak migration (Figure 2); therefore, migration records presented here may have missed some critical portions of the migration. Nevertheless, the results on migration timing agree with other studies in northeastern Alberta. Richardson (1969) reported peak spring migration over east-central Alberta in May. Aerial surveys of lakes in this region during 1972 and 1973 reported peak numbers on 15 May and 25 May, respectively (SCL 1973). Likewise, Schick and Ambrock (1974*) showed peak migration to occur in middle and end of May in 1973. During aerial surveys in 1976/1977, Hennan and Munson (1979) reported peak spring migration for ducks in early May, with most abundant species being scaup (*Aythya* sp.), Ring-necked Ducks (*Aythya collaris*), Buffleheads (*Bucephala albeola*), and to a lesser extent Mallards (*Anas platyrhynchos*). Annual variation in timing of spring migration is likely to vary with timing of ice break-up of the Athabasca River and also the Peace-Athabasca Delta (Schick and Ambrock 1974*).

Although the timing of migration in northeastern Alberta is relatively well known, the composition and numbers of birds passing through the area are less well known. During the same time period of this study in 2003, Ronconi and St. Clair (2006) reported the following numbers of birds flying over the tailings ponds: 1140 ducks, 2132 shorebirds, 11 339 geese, 218 swans, 965 gulls, 56 terns and 205 others (loons, grebes, cranes, herons, cormorants, coots). These numbers give some indication of guild composition during migration but should be used cautiously as such because these were visual, daytime observations and many birds in Alberta migrate at night and at high altitudes (Richardson 1971; Blokpoel 1973; Blokpoel and Burton 1973). Hennan (1972) reported hundreds of thousands of waterfowl using the Peace-Athabasca Delta as a spring staging area, thus providing some indication of the volume of birds that may pass over the tar sands area each year. Nevertheless, many individuals of some waterfowl species may also take alternate migration routes to Alaska or nest in southern Canada (Miller et al. 2005).

Finally, in this study area we may also be observing resident as well as migratory waterfowl. This study makes no distinction between the two groups; however, the high proportions of northwesterly and northerly flights (Figure 2) suggest that most of the birds observed were migrants. It is likely that the small numbers of birds observed on the tailings ponds in May and on some lakes in late May were residents rather than stopover migrants. Surprisingly, the ecology of waterfowl at staging and stopover areas is fairly poorly understood (Arzel et al. 2006).

Numbers of Birds on Ponds and Lakes

Despite the apparent peak in migration around mid-May, the numbers of ducks on the tailings ponds peaked sooner than this. Working in a nearby area, Gulley (1980) found that duck dependence on tailings ponds was higher when spring ice break-up was delayed. In 2003, ice break-up on the nearby Athabasca River began 23 April and was finished by 1 May, yet many of the nearby lakes remained at least partially frozen through the first week of May. Duck surveys at Kearl Lake showed low numbers on 9 May when this lake was still partially frozen, but numbers grew by 23 times only one week later when the lake was ice-free. These results are mainly qualitative, but they support the hypothesis of others (Gulley 1980; D. Martindale, personal communication) that duck use of tailings ponds is highly dependent on the availability of open water elsewhere. After 9 May, duck numbers at the MRM tailings ponds were seldom above 10 individuals, while thousands of individuals were using Kearl Lake less than 20 km away. Nevertheless, these conclusions about seasonal change in dependence on tailings (early spring) to natural waterbodies (mid to late May) are tenuous due to several inconsistencies in survey methodology: (1) Kearl Lake was the only natural water body surveyed more than twice, (2) most natural waterbodies were surveyed only in late May and might have missed peak migration, and (3) lack of personnel did not allow for simultaneous surveys of tailings ponds and natural waterbodies. Bird movements between wetlands may have been a concern; however, the extremely low numbers of ducks at the tailings ponds after 7 May suggest little, if any, movement between artificial and natural ponds after this date. Finally, no data are available on wetland characteristics, which were beyond the scope of this project but may have had significant influence on waterfowl use of waterbodies.

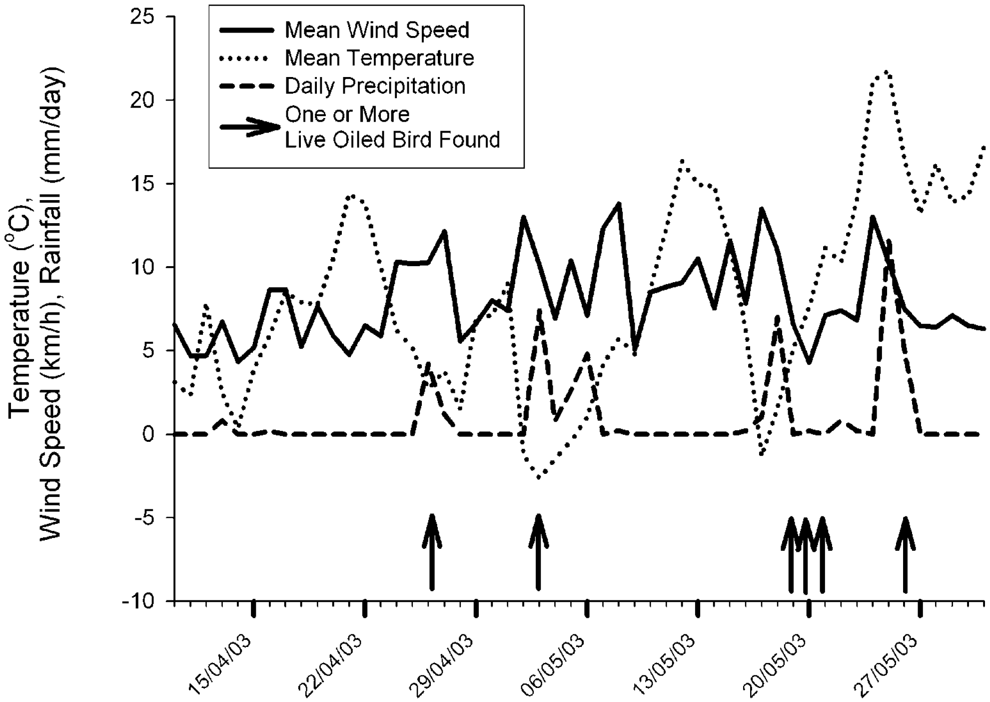

FIGURE 3. Weather patterns with respect to dates when live oiled birds were found at the Muskeg River Mine tailings ponds, April and May 2003.

Comparisons with census results from the 1970s suggest some changes in lake use. However, duck activity levels can vary widely within seasons, as was indicated in our results and other studies (e.g. SCL 1973; Gulley 1980; Van Meer and Arner 1985*; Shortt 1985*). The maximum counts between 1973 and 1977 were typically based on only one or two surveys during May, making them similarly prone to high variability. Although qualitative and tenuous, these comparisons reinforce the belief (SCL 1973; Schick and Ambrock 1974*; Ward et al. 1976*; Hennan and Munson 1979) that some lakes are important as stopover sites for migratory ducks, though not as major staging areas. As with our results, censuses from 1973 to 1977 ranked McCleland and Kearl lakes among the most important stopover sites for ducks (Hennan and Munson 1979). Other lakes in the region with high numbers included Little McCleland, Mildred, Horseshoe, and Saline lakes (Hennan and Munson 1979). The lack of ducks on Mildred Lake in 2003 is not surprising considering only a small portion of the lake remains in its natural state. The lack of ducks on remote lakes north of McCleland Lake was not surprising given the relatively small size of the lakes surveyed. Nonetheless, Hennan and Munson (1979) identified other remote lakes with high waterfowl densities, though these were not accessible for surveys by land in 2003.

Generally the oil sands region is not recognized as an important staging area for migratory waterfowl (SCL 1973; Schick and Ambrock 1974*; Ward et al. 1976*; Hennan and Munson 1979), although some staging does occur nearby. The Peace-Athabasca Delta, north of oil sands regions, has been recognized as an internationally significant staging area for hundreds of thousands of waterfowl (Hennan 1972). Further south of Fort McMurray, Gordon Lake was previously recognized as an important waterfowl staging area with spring numbers greater than 5600 in 1973 and 1974 (Hennan and Munson 1979). The count of 2700 waterfowl at Kearl Lake in 2003 suggest that this lake may bear greater importance as a staging area than might have been concluded from those earlier surveys, but further surveys may be needed to verify annual variation in waterfowl use of this lake. Surveys of other natural waterbodies also revealed that smaller ponds support small populations of birds throughout the spring and summer (Shortt 1985*). Because availability of natural waterbodies may minimize duck dependence on tailings ponds, further investigations of waterfowl use of these waterbodies is merited. Should it continue to appear that they are important to waterfowl, future oil sands developers may consider conserving these locations and avoiding the establishment of tailings ponds in close proximity to them.

Probability of Oiling

Logistic regression analysis of several weather variables found wind speed and precipitation to be the only variables that might predict the few observations of oiled birds in 2003. Strong winds may mix waters and spread oily films over wider areas, hence creating greater risk of oiling, but with consistent winds oily sheets may also be pushed to one shore of the pond. Thus any link between winds and oiling may be complicated. A two-day cumulative rainfall measure best predicted days with oiled birds, but rainfall the day of an oiling event and rainfall from the previous 24 hours showed some possible predictive ability. These uncertain results, along with small sample size, suggest only a potential effect of precipitation. Results of this study support a previous analysis across years (Gulley 1980) which showed that precipitation levels affected numbers of waterfowl deaths. Although Ronconi and St. Clair (2006) found no correlation between weather and bird landings on tailings ponds, the more important factor may be whether or not birds become oiled when they land.

If precipitation increases the frequency of birds being oiled, as these results cautiously suggest, I speculate that it may be caused by two possible mechanisms. First, poor weather conditions such as rain, strong winds, headwinds, and cold temperatures can delay migration, cause changes or a temporary reversal in migration direction, and cause migratory birds to be temporarily grounded (Richardson 1978; Elkins 1983). Waterfowl in particular appear to be erratic in their migratory behaviour which may be influenced by break-up of ice cover (Pöysä 1996), temperatures (Austin et al. 2002), weather fronts (Custer et al. 1997), and especially wind patterns (Bergman 1978; Liechti 1993; Bruderer 1994; Alerstam and Gudmundsson 1999). The significance of precipitation as a predictor of oiling may be due to correlations between rainfall and other weather changes, which may together be affecting bird movements and halting of migrations. The more frequently migratory waterfowl are forced to move and stop during migration, the greater the risk of encountering oil sands ponds and oil on the water surface in these ponds.

Second, precipitation may additionally increase oiling probabilities through birds experiencing reduced visibility during landings under rainy and snowy conditions. Without clear views of the water, they may be more likely to land in patches of oil which might otherwise be avoided. Reduced visibility as a causal mechanism may also explain the non-significance of wind speed, wind direction, and temperature since these variables should be less likely to affect the visibility of oil patches. Snow could affect in-flight visibility of birds, and on two of six days with oiled birds, the precipitation that occurred was a mix of rain and snow. Moreover, for three of the remaining days with oiling events (19, 20, and 21 May), heavy snow had fallen for two days previously (17 and 18 May). Although fog was not measured in this study, fog may also limit visibility and thus influence oiling events (Gulley 1980). Careful collection and thorough statistical analyses of long-term oiled bird records at tailings ponds may reveal important trends and weather association. These data could be valuable to improving the effectiveness of bird deterrent strategies, and I encourage oil sands companies to standardize collection protocols and pool their data for such an investigation.

Conclusions

As the development of oil sand mines continues in the 21st century, tailings pond and bird oiling problems will persist, and findings from current and previous studies will become more relevant to managers seeking a solution to this issue. Findings from this study suggest the importance of maintaining natural waterbodies in the region, especially those that are already used as migratory stopover sites for waterfowl. The significance of rainfall affecting numbers of birds being oiled suggests that bird deterrence efforts could benefit from enhancement on rainy days, and future deterrent development should pursue strategies that are effective during rainy weather more so than during clear conditions. With decades of data on oiled birds, and 30 years of research on bird deterrence, the oil sands industry in northern Alberta is positioned to offer significant insight into waterfowl management issues for future development here and at other sites of industrial development.

Acknowledgments

Logistical support and funding was provided by Albian Sands Energy Ltd., with additional logistical support from the University of Alberta, Edmonton. I thank Colleen Cassady St. Clair for support and guidance throughout this study and for reviewing drafts of this manuscript. I am grateful for support from Darrell Martindale, excellent field assistance from Andrew Forrest and Sarah Wong, and technical support from Will Neagle and Peregrine Systems Inc. Field work for this project was made possible with the help of Albian Sands employees Christine Theriault, Maurice Kay, Bob McKenzie, Thor Einarson, Brian Kean, and others on the Tailings and Site Services Teams. This manuscript was improved by comments from A. J. Erskine and one anonymous reviewer.

Documents Cited (marked * in text)

CAPP. 2003. Canadian crude oil… increasing energy security. Canadian Association of Petroleum Producers [Online] 2 pages. Available: http://www.capp.ca/default.asp?V_DOC_ID=175.

Golder Associates Ltd. 2000. Oil sands tailings pond bird deterrent systems – a review of research and current practices. Prepared for Suncor Energy Inc., Oil Sands, Syncrude Canada Ltd., and Albian Sands Energy Inc. November 2000. Calgary, Alberta.

Schick, C. D., and **K. R. Ambrock.** 1974. Waterfowl investigations in the Athabasca tar sands area. Canadian Wildlife Service, Edmonton.

Shortt, R. 1985. Bird use of alternate waterbodies in the Syncrude Canada Ltd. area. Prepared for Syncrude Canada Ltd., Wildlife Protection Division.

Van Meer, T., and **B. Arner**. 1985. Bird surveillance and protection programme, summary of 1984 and 1985 activities. Syncrude Canada Ltd.

Ward, J. G., G. R. Dyke, and **P. L. Sharp.** 1976. Bird migration watches on Crown lease number 17, Athabasca oil sands, 1975. LGL Ltd. Environmental Research Associates for Syncrude Canada Ltd.

Yonge, K. S., M. L. Christiansen, H. P. Samoil, J. A. Smith, and **T. Van Meer**. 1981. Syncrude Bird Surveillance Program: a methodology for assessing bird activity and bird losses associated with the tailings pond. Syncrude Canada Ltd., Edmonton, Alberta.

Literature Cited

Alerstam, T., and **G. A. Gudmundsson.** 1999. Migration patterns of tundra birds: Tracking radar observations along the northeast passage. Arctic 52: 346-371.

Allen, C. H. 1990. Mitigating impacts to wildlife at FMC Gold Company's Paradise Peak Mine. Pages 67-71 Proceedings of the Nevada Wildlife/Mining Workshop.

Arzel, C., J. Elmberg, and **M. Guillemain.** 2006. Ecology of spring-migrating Anatidae: a review. Journal of Ornithology 147: 167-184.

Austin, J. E., D. A. Granfors, M. A. Johnson, and **S. C. Kohn.** 2002. Scaup migration patterns in North Dakota relative to temperatures and water conditions. Journal of Wildlife Management 66: 874-882.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Second Edition. Stackpole Books, Harrisburg, Pennsylvania.

Bergman, G. 1978. Effects of wind conditions on autumn migration of waterfowl between White Sea area and Baltic region. Oikos 30: 393-397.

Bertram, D. F., L. Cowen, and **A. E. Burger.** 1999. Use of radar for monitoring colonial burrow-nesting seabirds. Journal of Field Ornithology 70: 145-282.

Blokpoel, H. 1973. Bird migration forecasts for military air operations. Canadian Wildlife Service Occasional Paper 16, Ottawa, Canada.

Blokpoel, H., and **J. Burton.** 1973. Weather and height of nocturnal migration in east-central Alberta: a radar study. Bird-Banding 46: 311-328.

Boag, D. A., and **V. Lewin.** 1980. Effectiveness of three waterfowl deterrents on natural and polluted ponds. Journal of Wildlife Management 44: 145-154.

Bruderer, B. 1994. Nocturnal bird migration in the Negev (Israel): a tracking radar study. Ostrich 65: 204-212.

Burger, A. E. 1997. Behaviour and numbers of Marbled Murrelets measured with radar. Journal of Field Ornithology 68: 208-223.

Cooper, B. A., R. H. Day, R. J. Ritchie, and **C. L. Cranor.** 1991. An improved marine radar system for studies of bird migration. Journal of Field Ornithology 62: 367-377.

Custer, C. M., T. W. Custer, and **P. J. Zwank.** 1997. Migration chronology and distribution of redheads on the lower Laguna Madre, Texas. Southwestern Naturalist 42: 40-51.

Elkins, L. 1983. Weather and bird behaviour. T&AD Poyser Ltd., Calton.

Gauthreaux, S. A., Jr., and **C. A. Belser.** 2003. Radar ornithology and biological conservation. Auk 120: 266-277.

Gosler, A. G., R. E. Kenward, and **N. Horton.** 1995. The effect of gull roost deterrence on roost occupancy, daily gull movements and wintering wildfowl. Bird Study 42: 144-157.

Gulley, J. R. 1980. Factors influencing the efficacy of human effigies in deterring waterfowl from polluted ponds. M.Sc. thesis, University of Alberta, Edmonton, Alberta.

Hennan, E. G. 1972. Status of waterfowl in the Peace-Athabasca Delta. Ducks Unlimited (Canada), Winnipeg, Manitoba.

Hennan, E. G., and **B. Munson.** 1979. Species distribution and habitat relationships of waterfowl in northeastern Alberta. Prepared for Alberta Oil Sands Environmental Research Program by Canadian Wildlife Service. AOSERP Report 81.

Hosmer, D. W., and **S. Lemeshow.** 1989. Applied logistic regression. John Wiley & Sons Inc., New York.

Liechti, F. 1993. Nocturnal autumn migration over southern Germany: winddrift and compensation. Journal für Ornithologie 134: 373-404.

Martin, L. R., and **P. C. Martin.** 1984. Research indicates propane cannons can move birds. Pest Control 52: 52.

Miller, M. R., J. Y. Takekawa, J. P. Fleskes, D. L. Orthmeyer, M. L. Casazza, and **W. M. Perry.** 2005. Spring migration of Northern Pintails from California's Central Valley wintering area tracked with satellite telemetry: routes, timing, and destinations. Canadian Journal of Zoology 83: 1314-1332.

Pöysä, H. 1996. Population estimates and the timing of waterfowl censuses. Ornis Fennica 73: 60-68.

Richardson, W. J. 1969. Temporal variations in the volume of bird migration: a radar study in Canada. Pages 323-335 *in* Proceedings of the World Conference of Bird Hazards to Aircraft. *Edited by* V. E. F. Solman. Kingston, Ontario.

Richardson, W. J. 1971. Spring migration and weather in eastern Canada: a radar study. American Birds 25: 684-690.

Richardson, W. J. 1978. Timing and amount of bird migration in relation to weather: a review. Oikos 30: 224-272.

Richardson, W. J., and **W. W. H. Gunn.** 1971. Radar observations of bird movements in east-central Alberta. Pages 35-68 *in* Studies of bird hazards to aircraft. *Edited by* V. E. F. Solman. Canadian Wildlife Service Report 14.

Ronconi, R. A., and **C. C. St. Clair.** 2006. Efficacy of a radar-activated on-demand system for deterring waterfowl from oil sands tailings ponds. Journal of Applied Ecology 43: 111-119.

SCL. 1973. Migratory waterfowl and the Syncrude tar sands lease: a report. Syncrude Canada Ltd. Environmental Research Monograph 1973-3.

Stevens, R. G., J. Rogue, R. Weber, and **L. Clark.** 2000. Evaluation of a radar-activated, demand-performance bird hazing system. International Biodeterioration and Biodegradation 45: 129-137.

Received 17 February 2004
Accepted 17 May 2006