

# Effects of Forest Management Practices on Breeding Ospreys and Great Blue Herons in the Boreal and Great Lakes – St. Lawrence Forests of Ontario: Final Report Draft 2

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*Abstract* - We conducted a mensurative experiment to document the effects of forest management activities and the effectiveness of mitigative guidelines on the reproductive performance of ospreys and herons in central and northeastern Ontario. Occupancy and productivity were assessed during aerial survey flights of 300 nest sites in May through July 2001. Nest sites monitored varied widely in the proximity, amount, and timing of harvest, site preparation, tree planting, and tending activities conducted during the preceding 10 years. Forest management activities conducted during the nesting season did not appear to affect the long term occupancy or productivity of osprey or heron nest sites. There was also no relationship between proximity or extent of timber harvest, subsequent silvicultural activities, or permanent or temporary roads and any measure of reproductive performance assessed for ospreys. In contrast, the area of timber harvest within 250 to 500 m appeared to affect colony occupancy, colony size, and chick production in herons. Effects were insignificant when cuts were > 100 to 200 m from colonies, and were most pronounced for clearcuts. Chick production was also related to the area of tended cuts within 500 m of colonies. Moreover, the proximity and length of permanent roads appeared to affect colony occupancy, although effects appeared to be minimal at distances beyond 200 to 300 m. Spatial buffers currently prescribed appear to be effective in mitigating the impact of forest management activities. However, the provincial guidelines may be overly restrictive. The design of this study did not permit us to fully evaluate the effectiveness of temporal buffers currently prescribed.

## **Introduction**

Conservation of wildlife habitat and biological diversity has become a key element of sustainable forest management during the past decade (Hunter 1990, Freedman et al. 1994, CCFM 1997). One popular conservation paradigm promotes the use of a coarse filter approach that guides forest management activities so they emulate natural patterns and processes (Hunter 1993, Parminter 1998, McRae et al. 2001, OMNR 2001). However, a comprehensive approach to the integration of habitat and biodiversity concerns into forest management activities still requires the use of fine filters. Fine filters function within the broad direction of a coarse filter to maintain essential habitats required by species of special concern (Hunter 1990, Naylor 1994).

Ospreys (*Pandion haliaetus*) and great blue herons (*Ardea herodias*) are species of special concern in Ontario because they are considered to be sensitive to disturbance during the nesting season (Penak 1983, Bowman and Siderius 1984). On crown (i.e., public) lands, occupied nest sites must be identified as areas-of-concern (AOC) and protected by spatial and temporal buffer zones that are intended to mitigate the potential impacts of forest management activities associated with habitat alteration and direct disturbance.

Various guidelines have been proposed and used within the province. All guidelines prescribe reserves in which no forest management activities are permitted at any time of year and modified zones in which some activities are permitted outside the nesting season. Reserve

zones range from 150 to 300 m in radius around nest sites. Modified zones range from 150 to 700 m in radius beyond the reserve zone (Penak 1983, Bowman and Siderius 1984, Szuba and Naylor 1998)(Table 1).

These guidelines were based largely on literature review and expert opinion; their effectiveness has not been rigorously tested. Moreover, the impacts of forest management activities on occupancy and productivity of osprey and heron nest sites are poorly understood throughout the range of both species (Butler 1991a, Ewins 1997).

This study uses a mensurative experimental approach to describe the effects of forest management activities on occupancy and productivity of osprey and heron nest sites and evaluate the effectiveness of the different guidelines in mitigating these effects. Specifically, we test the hypotheses that 1) the proximity, extent, and timing of forest management activities has no effect on occupancy or productivity of nest sites and 2) that nest sites cut with or without the guidelines do not differ in occupancy or productivity when compared to uncut controls.

## **Study Areas**

Osprey and heron nest sites were studied in central and northeastern Ontario, Canada (Fig. 1). Half the nests studied were located in the North Bay, Parry Sound, and Sudbury administrative districts of the Ontario Ministry of Natural Resources (OMNR). These areas are found within the Great Lakes – St. Lawrence (GLSL) forest region (Rowe 1972). The GLSL region is characterized by forests of sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*), eastern hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), and red pine (*P. resinosa*) (Chambers et al. 1997) that are managed using selection and shelterwood silvicultural systems (OMNR 1998a,b). The remaining nest sites were within the Chapleau, Cochrane, and Timmins administrative districts of the OMNR. These areas are located within the boreal forest region (Rowe 1972). The boreal region is characterized by forests of jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), white spruce (*P. glauca*), balsam fir (*Abies balsamea*), trembling aspen (*Populus tremuloides*), and white birch (*Betula papyrifera*)(Taylor et al. 2000) that are managed using the clearcut silvicultural system (OMNR 1997a,b).

## **Methods**

### *Forest management history*

GIS-based spatial timber harvest databases were available for all districts. Each district database included information on location of cutover areas by year of activity and silvicultural system. In this study, we consider forest management history covering the period from spring 1991 to spring 2001. Spatial data available prior to this period were incomplete. The complete database was used for the selection of nest sites (see below). We verified harvest history (including AOC prescriptions) for all cutover areas within 2 km of nest sites selected for the study by reviewing OMNR and Sustainable Forest Licence (SFL) records and by interviewing staff. At the same time, we collected information on season of harvest and determined whether cutover areas had been mechanically site prepared (bulldozers with blades or skidder-mounted trenchers), planted, or tended (aerial or ground herbicide application).

GIS-based spatial Forest Resources Inventory (FRI) databases were also available. These databases provided details of forest cover (e.g., species composition, age, height, density), ownership patterns, and the distribution of waterbodies, wetlands, urban areas, and other

nonforested habitats. Spatial databases showing up-to-date location of roads (by class) were obtained from local OMNR or SFL offices.

### *Nest site selection*

Osprey and heron nest sites used in this study represent a stratified random sample of sites contained in OMNR's Natural Resource and Values Information System (NRVIS), a spatially-explicit database used for resource management planning. Nest sites listed in NRVIS were identified during aerial stick nest surveys conducted by OMNR staff (see Ranta 1998) or were opportunistically located by OMNR, SFL, or forest industry staff during field operations. We reviewed local district databases to confirm the existence of nests and acquire additional data on nest site characteristics and history prior to selecting study nests.

Nest sites surrounded by private land (> 10% private land within 1 km) were not selected because timber harvest records were only available for crown land. As well, nest sites with little adjacent forest cover (< 25% forested land within 1 km) were not selected because they were not likely to be affected by timber harvest (e.g., nests on small islands in large lakes). To the extent possible, we did not consider nest sites found before 1990 or for which there was no information on history of occupancy.

Using timber harvest maps, nest sites were stratified based on distance to the nearest cutover: 0-250 m, 251-500 m, 501-1000 m, 1001-2000 m, or > 2000 m. A total of 150 osprey and 150 heron nest sites was then randomly selected, approximately 30 from each harvest stratum. The number of nests sampled varied from 38 to 71 among districts. We tried to sample roughly equal numbers of nests within each harvest stratum within each district to minimize potential confounding effects of harvest treatment and geographic location.

### *Monitoring occupancy and productivity*

Occupancy and productivity surveys were conducted using either fixed-wing or rotary-wing aircraft during the summer of 2001. Surveys were generally conducted between 8:30 am and 5:00 pm EST on days without rain or high winds. Each survey session began in the south and finished in the north to account for latitudinal variation in the timing of reproductive events. During each flight, nest sites were located by navigating to known coordinates (UTM coordinates extracted from NRVIS) using an onboard global positioning system. When a nest site could not be located at the expected coordinates, potentially suitable nesting habitat within 300-500 m was searched for nests in case the original location had been digitized incorrectly. When a new site was located, its coordinates were identified and used in all subsequent surveys and analyses. When a nest site could not be located we considered it to be abandoned. We believe most nest sites not found had fallen down (see Poole 1989 for annual rate of nest loss in ospreys). A small number of nest sites not found may represent errors in the NRVIS database. During all surveys, every effort was made to minimize disturbance to the breeding birds. We typically maintained a distance of at least 50 m from nests and minimized time spent at each nest site.

Osprey nests were surveyed twice while heron colonies were surveyed once. Occupancy status of osprey nests was checked during survey flights using fixed-wing aircraft (Cessna 172) from May 14 to May 31 2001. This period coincides with the onset of the incubation period in Ontario (see egg dates in Peck and James 1983). Nests were considered occupied if an incubating adult or clutch of eggs was observed in the nest. Heron colonies were not checked during these

flights because they are reported to be very sensitive to disturbance at this time of year (Bowman and Siderius 1984).

Productivity of occupied osprey nests (and those nests for which status was uncertain) were rechecked during survey flights using rotary-wing aircraft (Bell Long Ranger) during the period June 25 to July 10 2001. Number of chicks was counted as a measure of productivity. Most osprey chicks were in their second down phase, and were thus only about 2 to 4 weeks of age (see Palmer 1988). Osprey chicks fledge at 7 to 8 weeks of age (Palmer 1988). Steenhof and Kochert (1982) proposed that surveys of fledging success in diurnal raptors should be conducted when young have reached 80% of their fledging age. Thus, our measure of productivity is clearly an overestimate of fledging success. However, in ospreys, the majority of lost production occurs during the incubation period (Swenson 1979, Levenson and Koplín 1984) and the maximum rate of chick mortality occurs 2 to 3 weeks after hatching (Hagan 1986). Thus, we believe our assessment is a reasonable relative measure of production.

Heron colonies were surveyed during the osprey productivity flights. Colonies were considered to be occupied if at least one nest showed evidence of breeding. Our estimate of occupancy rate is likely an underestimate because a colony that was abandoned during incubation would have been recorded as unoccupied. We also noted the number of occupied and unoccupied nests in each colony. Number of chicks was counted as a measure of productivity. Most heron chicks were large and fully feathered and some appeared to be close to fledging. However, it was not uncommon to observe wide variation in chick development within a colony; some nests contained downy chicks and a few nests even contained eggs. Thus, our measure of productivity is likely an overestimate of fledging success.

### *Measures of reproductive performance*

We assessed 3 measures of reproductive performance for each species: % of nests or colonies that were occupied (includes abandoned nest sites), mean number of nests occupied per colony (herons only), % successful nests (occupied nests with at least 1 chick; ospreys only), and mean number of chicks per successful nest. We compared each of the measures of reproductive performance between regions (boreal versus GLSL) using contingency analyses or *t*-tests.

### *Evaluating the effects of forest management activities*

For each nest site, we measured the distance to the nearest cutover (any silvicultural system), clearcut (includes conventional clearcuts, seed tree clearcuts, Harvesting with Regeneration Protection (OMNR 1997a), and strip, block, and selective clearcuts), shelterwood cut (includes all stages but most were seed cuts), selection cut (primarily single tree), summer cutover (any type of cut during the breeding season), site-prepared area, planted area, tended area, permanent (primary or secondary) road, temporary (tertiary) road, lake, or wetland. We had to pool selection and shelterwood cuts (referred to hereafter as partial cuts) because < 20% of nest sites had selection cutting within 2 km. We also measured the area (or length) of each of the silvicultural treatments, wetlands, waterbodies and types of roads within 0-250 m, 251-500 m, 501-1000 m, 1001-2000 m, and > 2000 m of each nest site. Nest sites were classified as wet sites (compared to dry sites) if nest trees were standing in water. All measurements were conducted using ArcView™ GIS (12.5 m cells for distance measurements, 50 m cells for area/length measurements).

To evaluate the effects of timber harvest activities, we used a combination of simple and multiple logistic, Poisson, and linear regression to model the relationship between each of the measures of reproductive performance and the distance to or area of each silvicultural treatment or habitat feature. Most statistical tests were conducted using SPSS (SPSS Inc. 1999). Poisson regression analyses were conducted using Statistix (Analytical Software 2000). All variables were transformed to meet assumptions of normality or homoscedasticity when appropriate. Statistical significance was accepted at the 5% level but we also report relationships when  $0.05 < P < 0.10$  if they appeared to be biologically meaningful.

### *Evaluating the effectiveness of the guidelines*

We evaluated the effectiveness of the GLSL guidelines only (Table 1) because they are less restrictive than the provincial guidelines. Thus, if the GLSL guidelines are effective, the provincial guidelines must also be effective.

All nest sites were grouped into 1 of 3 classes: 1) nest sites without cutting, other silvicultural activities, or roads within 1 km were considered controls; 2) nest sites with cutting or roads within 1 km but with no partial cuts or other silvicultural activities within 150 m and no clearcuts, summer cuts, or roads within 300 m were considered to meet the guidelines; and 3) nest sites with cutting or roads within 1 km and with partial cuts or other silvicultural activities within 150 m or with clearcuts, summer cuts, or roads within 300 m were considered to be exceptions to the guidelines. Nest sites were assigned to a class regardless of whether the nest site was actually known or occupied at the time of harvesting or subsequent silvicultural activities. Thus, we are testing the hypothesis that there is no significant difference among classes in measures of reproductive performance in 2001 based on the cumulative pattern of silvicultural activities during the past 10 years.

To evaluate effectiveness of the guidelines, we compared each of the 3 measures of reproductive performance among the 3 classes using either contingency analysis or ANOVA. We controlled for variation between regions when appropriate using log-linear analysis. Power analysis was conducted using PASS 2000 (Hintze 2000).

## **Results**

### **Ospreys**

For ospreys, 42.0% of the 150 nest sites were occupied. During the productivity survey, 66.7% of occupied nests had at least 1 chick. Overall, nests contained 1.94 chicks per successful nest.

### *Effects of forest management activities*

Table 2 summarizes the relationships between habitat features or forest management activities and reproductive performance of ospreys.

#### Nest occupancy

Nest occupancy did not vary between boreal (42.0%, 100 nests) and GLSL sites (42.0%, 50 nests) ( $P = 1.000$ ) or between wet (40.4%, 52 nests) and dry sites (42.9%, 98 nests) ( $P = 0.770$ ).

Proximity of lakes did not appear to affect nest occupancy when examined alone or in combination with other variables ( $P_s > 0.10$ ). However, nest occupancy was marginally related

(negative) to the area of lakes within 500 m ( $P = 0.051$ ). Moreover, this relationship was significant ( $P = 0.037$ ) when the length of permanent roads within 2 km was controlled. There was no relationship between proximity or area of wetlands and nest occupancy when wetland variables were examined individually or in combination with other variables ( $P_s > 0.10$ ).

Nest occupancy was positively related to the proximity ( $P = 0.032$ ) and length of permanent roads within 2 km ( $P = 0.019$ ). These relationships were still significant and positive when the area of lakes within 500 m was controlled ( $P = 0.035$  for proximity and  $P = 0.014$  for length). Nest occupancy was unrelated to the proximity of temporary roads when this variable was considered alone or in combination with other variables ( $P_s > 0.10$ ) but was marginally related (positive) to the length of temporary roads within 250 m ( $P = 0.093$ ). However, this latter relationship disappeared when the area of lakes within 500 m and the length of permanent roads within 2 km were controlled ( $P = 0.445$ ).

There was no relationship between the proximity or area of clearcuts, partial cuts, summer cuts, all cuts, site-prepared cuts, planted cuts, or tended cuts when variables were considered individually or in combination with other variables ( $P_s > 0.10$ ).

Overall, nest occupancy was best predicted ( $P = 0.002$ ,  $R^2 = 0.087$ ) by a model incorporating area of lakes within 500 m ( $P = 0.037$ ) and the length of permanent roads within 2 km ( $P = 0.014$ ).

#### Nest success

Nest success did not vary between boreal (65.8%, 38 sites) and GLSL sites (68.8%, 16 sites) ( $P = 0.833$ ) but did vary between wet (37.5%, 16 nests) and dry sites (78.9%, 38 nests) ( $P = 0.004$ ).

When site was controlled, nest success was not related ( $P_s > 0.10$ ) to either the proximity or the area/length of lakes, wetlands, permanent roads, temporary roads, clearcuts, partial cuts, summer cuts, all cuts, site-prepared cuts, planted cuts, or tended cuts when variables were considered individually or in combination.

#### Chicks per successful nest

Mean number of chicks per successful nest did not vary between boreal ( $2.00 \pm 0.50$ , 25 nests) and GLSL sites ( $1.82 \pm 0.60$ , 11 nests) ( $P = 0.352$ ) or between wet ( $1.83 \pm 0.75$ , 6 nests) and dry sites ( $1.97 \pm 0.49$ , 30 sites) ( $P = 0.582$ ).

Chick production was not related ( $P_s > 0.10$ ) to either the proximity or the area/length of lakes, wetlands, permanent roads, temporary roads, clearcuts, partial cuts, summer cuts, all cuts, site-prepared cuts, planted cuts, or tended cuts when variables were considered individually or in combination.

#### *Effectiveness of the guidelines*

Nest sites cut with or without the guidelines did not differ significantly from control sites in any of the 3 measures of reproductive performance (Table 3). This result did not appear to be a simple artifact of low statistical power. Nest sites cut without the guidelines tended to have a higher rate of occupancy and success than did control sites. Moreover, the probability of detecting a small difference (30%) in the number of chicks per nest was fairly high (74%).

## Herons

For herons, 29.3% of the 150 colonies had at least 1 occupied nest. A mean of 7.2 nests (range 1 – 43) was occupied per colony. We counted an average of 2.40 chicks per successful nest.

### *Effects of forest management activities*

Table 4 summarizes the relationships between habitat features or forest management activities and reproductive performance of herons.

#### Colony occupancy

Colony occupancy varied significantly between boreal (13.3%, 45 colonies) and GLSL sites (36.2%, 105 colonies) ( $P = 0.003$ ) and between wet (23.0%, 87 colonies) and dry sites (38.1%, 63 colonies) ( $P = 0.046$ ). Thus, all subsequent analyses controlled for geographic area and site effects.

Colony occupancy was not related to the proximity or area of lakes when lake variables were examined individually ( $P_s > 0.10$ ). However, area of lakes within 2 km appeared to have a negative effect on colony occupancy ( $P = 0.070$ ) when the length of permanent roads within 2 km and the proximity of all cuts were controlled. Neither the proximity nor the area of wetlands was related to colony occupancy when variables were examined individually or in combination with other variables ( $P_s > 0.10$ ).

Colony occupancy was negatively related to the proximity of permanent roads ( $P = 0.091$ ) and the length of permanent roads within 2 km ( $P = 0.041$ ). These relationships were slightly stronger when the area of all lakes within 2 km and proximity of cutting were controlled ( $P = 0.052$  for proximity and  $P = 0.022$  for length). Colony occupancy was marginally related to the length of temporary roads within 500 m ( $P = 0.078$ ) but was not related to proximity of temporary roads ( $P = 0.195$ ). However, when the area of lakes within 2 km, the length of permanent roads within 2 km, and the proximity of cuts were controlled, the length of temporary roads within 500 m was only weakly related to colony occupancy ( $P = 0.105$ ).

When cut variables were examined individually, only the proximity of all cuts ( $P = 0.040$ ) and the area of all cuts within 500 m ( $P = 0.084$ ) appeared to have a negative effect on colony occupancy. When area of lakes and length of permanent roads within 2 km were controlled, these relationships were slightly improved ( $P = 0.017$  for proximity of cuts and  $P = 0.063$  for area of cuts) and colony occupancy was also significantly related to the proximity of clearcuts ( $P = 0.041$ ). However, colony occupancy was only weakly related to the proximity of partial cuts ( $P = 0.126$ ) and was not related to the area of clearcuts or partial cuts ( $P_s > 0.10$ ). Neither proximity nor area of summer cuts was related to colony occupancy when variables were considered individually or in combination with other variables ( $P_s > 0.10$ ).

Colony occupancy was not related to the proximity or area of site-prepared, planted, or tended cuts when variables were examined individually or in combination with other variables ( $P_s > 0.10$ ).

Overall, the best model predicting colony occupancy ( $P = 0.000$ ,  $R^2 = 0.255$ ) included the distance to the nearest cut ( $P = 0.017$ ), the area of lakes within 2 km ( $P = 0.070$ ), and the length of permanent roads within 2 km ( $P = 0.022$ ).

Fig. 2 illustrates the functional relationship between colony occupancy and the proximity of permanent roads, all cuts, and clearcuts. Proximity of permanent roads clearly has a greater impact on colony occupancy than does the proximity of cutting. Proximity of the nearest cut of any type has less impact on colony occupancy than does the proximity of clearcuts, likely because the former includes partial cuts which showed no significant effect. All 3 logistic regression models suggest that colony occupancy consistently increases as proximity decreases. However, the form of these functions is partly an artifact of the model fit to the data. The slope of the curve for permanent roads is not significant for distances beyond 200 m ( $P = 0.153$ ) and is highly non-significant beyond 300 m ( $P = 0.293$ ). Similarly, the slopes of the curves for all cuts and clearcuts are not significant for distances beyond 100 m ( $P = 0.545$  for all cuts,  $P = 0.985$  for clearcuts).

#### Number of occupied nests per colony

Number of occupied nests per colony did not vary between boreal ( $8.33 \pm 7.89$ , 6 colonies) and GLSL sites ( $7.03 \pm 9.49$ , 38 colonies) ( $P = 0.449$ ) or between wet ( $8.65 \pm 10.70$ , 20 colonies) and dry sites ( $6.00 \pm 7.80$ , 24 colonies) ( $P = 0.234$ ).

Colony size was positively related to the proximity of lakes ( $P = 0.047$ ) and the area of lakes within 500 m ( $P = 0.001$ ). When proximity of all cuts was controlled, colony size was still positively related to the area of lakes within 500 m ( $P = 0.000$ ) but was no longer related to the proximity of lakes ( $P = 0.378$ ). Neither proximity nor area of wetlands appeared to have any effect on colony size when examined individually or in combination with other variables ( $P_s > 0.10$ ).

Proximity and length of permanent roads appeared to have no effect on colony size when examined individually or in combination with other variables ( $P_s > 0.10$ ). However, proximity ( $P = 0.098$ ) and length of temporary roads within 1 km appeared to have a marginally positive effect ( $P = 0.069$ ) on colony size. These latter relationships may have been spurious because they disappeared ( $P = 0.235$  for proximity and  $P = 0.224$  for length) when the area of lakes within 500 m was controlled.

Proximity and area of clearcuts, partial cuts, summer cuts, or all cuts was not related to colony size when variables were considered individually ( $P_s > 0.10$ ). However, the distance to all cuts ( $P = 0.077$ ) and the area of all cuts within 250 m ( $P = 0.055$ ) appeared to have a marginally negative effect on colony size when area of lakes within 500 m was controlled.

Proximity and area of planted and tended cuts was unrelated to colony size when examined individually or in combination with other variables ( $P_s > 0.10$ ). Area of site-prepared cuts within 2 km was marginally (positively) related to colony size ( $P = 0.088$ ) but this relationship was not significant when the area of lakes within 500 m was controlled ( $P = 0.240$ ).

Overall, the model best predicting colony size ( $P = 0.000$ ,  $R^2 = 0.447$ ) included the area of lakes within 500 m ( $P = 0.000$ ) and the distance to all cuts ( $P = 0.077$ ).

The functional relationship between colony size and proximity of all cuts is shown in Fig. 3. The slope of this function is not significant for distances beyond 100 m ( $P = 0.133$ ) and is highly non-significant for distances beyond 200 m ( $P = 0.593$ ).

## Number of chicks per occupied nest

Mean number of chicks per occupied nest was marginally greater at boreal ( $2.72 \pm 0.28$ , 6 colonies) than at GLSL sites ( $2.34 \pm 0.48$ , 35 colonies) ( $P = 0.066$ ). Mean number of chicks also varied between wet ( $2.18 \pm 0.46$ , 18 colonies) and dry sites ( $2.56 \pm 0.41$ , 23 colonies) ( $P = 0.008$ ). Thus, variation attributable to geographic area and site is controlled in subsequent analyses when appropriate. However, chicks per nest was not related to colony size ( $P = 0.579$ ) and thus this variable was not considered in subsequent analyses.

Chick production was not related to the proximity or area of lakes or wetlands ( $P_s > 0.10$ ) when variables were examined individually. However, there was a marginal ( $P = 0.055$ ) negative relationship between area of lakes within 250 m and chicks per nest when the area of partial cuts within 250 m and tending within 500 m was controlled.

Chick production was not related to the proximity or length of permanent or temporary roads ( $P_s > 0.10$ ) when variables were examined individually or in combination with other variables.

The proximity and area of clearcuts and summer cuts was unrelated to chick production when variables were examined individually or in combination with other variables ( $P_s > 0.10$ ). However, chick production appeared to be negatively related to the area of all cuts ( $P = 0.020$ ) and partial cuts ( $P = 0.002$ ) within 250 m. When the area of lakes within 250 m and tending within 500 m was controlled, these relationships were slightly improved ( $P = 0.017$  for all cuts and  $P = 0.001$  for partial cuts), and the proximity of partial cuts was marginally related to chick production ( $P = 0.052$ ).

Proximity of planted, site-prepared, and tended cuts did not appear to influence chick production when variables were considered individually or in combination with other variables ( $P_s > 0.10$ ). However, area of tending within 500 m appeared to have a negative effect ( $P = 0.039$ ) when the area of partial cuts and lakes within 250 m was controlled.

Overall, the best model predicting chick production ( $P = 0.000$ ,  $R^2 = 0.456$ ) included the area of partial cuts within 250 m ( $P = 0.001$ ), the area of tended sites within 500 m ( $P = 0.039$ ) and the area of lakes within 250 m ( $P = 0.055$ ).

The functional relationship between chick production and proximity of partial cuts is shown in Fig. 4. The slope of this function is not significant for distances beyond 100 m ( $P = 0.672$ ).

### *Effectiveness of the guidelines*

Colonies cut without the guidelines tended to have a lower rate of occupancy, smaller colony size, and produce fewer chicks per nest than did control colonies (Table 5). However, there were no significant differences in any of the 3 measures of reproductive performance between control colonies and those cut with or without the guidelines. But our ability to detect differences in colony occupancy and colony size was low; the probability of detecting a 50% difference between cut and control sites was only 49% and 31%, respectively. In contrast, the probability of detecting a 20% difference in chick production was 91%.

## Discussion

### *Effects of forest management activities*

Forest management activities may affect reproductive performance of birds such as ospreys and herons as a consequence of either direct disturbance or habitat alteration (Richardson and Miller 1997, Saurola 1997).

Disturbance during the nesting season associated with various human activities can have immediate effects on reproductive performance of both ospreys (Prevost et al. 1978, Swenson 1979, van Daele and van Daele 1982, Levenson and Koplín 1984, Saurola 1997) and herons (Parker 1980, Quinney 1983, Drapeau et al. 1984, Forbes et al. 1985, Parnell et al. 1988, Carlson and McLean 1996, Vennesland 2000, Skagen et al. 2001). Human disturbance may cause abandonment of nests, reduced attentiveness of incubating or brooding adults (with a resultant loss of eggs or chicks to predators or thermal stress), premature fledging of young, or reduced growth rate of nestlings (Poole 1981, Rodgers and Smith 1995, Richardson and Miller 1997).

However, accounts of the immediate effects of forest management activities on nesting ospreys and herons are limited and ambiguous. Melo (1975) and Adams and Scott (1979) described individual osprey nests that were cut to within 30 to 60 m during the nesting season but were apparently unaffected and fledged young. In contrast, Levenson and Koplín (1984) found that osprey nests that had experienced timber harvest within 500 m during the nesting season (actual proximity not specified) were less likely to fledge young than were nests in undisturbed areas. We could find no literature that describes the immediate effect of forest management activities during the nesting season on occupancy or productivity of herons.

Our design did not permit us to determine whether forest management activities conducted during the nesting season (summer cutting, planting, or site preparation) influenced reproductive performance in the year the activity was conducted. However, our results do suggest that proximity and extent of these activities were poor predictors of long term occupancy and productivity at nests of both ospreys and herons. Similarly, Agro and Naylor (1994) found no relationship between proximity of summer cuts and longevity of heron colonies. Our results suggest that any adverse effects of activities during the nesting season are either short-lived, or that long term effects, if they exist, are masked by other factors known to influence response to disturbance such as timing of disturbance within the nesting cycle, degree of habituation, or visibility of the disturbance (Parker 1980, Vana-Miller 1987, Butler 1991a, Ewins 1997, Richardson and Miller 1997).

Timber harvest at any time of year may alter habitat surrounding a nest site. Habitat suitability may be subsequently reduced if nests or perches are removed or if exposure of nests to wind, predators, or human disturbance is increased (Saurola 1997).

In this study, habitat alteration associated with timber harvest appeared to have little effect on occupancy or productivity of ospreys. Similarly, partial cutting (30 to 40% of BA removed) to within 30 to 60 m of the osprey nests described by Melo (1975) and Adams and Scott (1979) did not appear to affect long term occupancy (2-7 years). In his review of the effects of timber harvest on ospreys, Saurola (1997) suggested that as little as 50 m of uncut forest may be sufficient to protect osprey nests.

Our results suggest that habitat alteration associated with timber harvest can influence reproductive performance of herons. The amount of cutting within 250 to 500 m appeared to influence colony occupancy, colony size, and chick production. However, cutting more than 100 to 200 m from colonies appeared to have little impact. Type of harvest appeared to be important in determining this effect. Clearcutting had more effect than partial cutting on colony occupancy. In contrast, partial cutting had more effect on chick production than did clearcutting. However, this latter relationship may reflect the small number of occupied colonies that had experienced clearcutting (i.e., sites with clearcutting close to the colony were generally unoccupied).

Prior to this study, there had been little rigorous examination of the effect of habitat alteration associated with timber harvest on herons. In Montana, Parker (1980) cites an example of unrestricted cutting that appeared to cause a colony to relocate. Clearcutting along the edge of a large mixed species colony in Illinois during 4 successive winters led to a reduction in colony size from 820 to 332 nests (Bjorklund et al. 1975). In a study of 12 heronries in Oregon, clearcutting within 500 m of colonies (actual proximity not specified) apparently caused some colonies to relocate and resulted in a decrease in the proportion of nests occupied in other colonies (Werschkul et al. 1976). In contrast, in a study of 98 colonies in Ontario, Agro and Naylor (1994) found little relationship between proximity of cuts and colony longevity, although they had very few colonies with cutting within 150 m.

The amount of tending within 500 m of heron colonies appeared to influence the number of chicks produced per nest. Most tending activities involve aerial or ground application of herbicides in late summer (outside the nesting season). Thus, the observed relationship is likely not a consequence of direct disturbance of nesting birds by the tending operations. However, sites that receive tending have typically experienced a clearcut or shelterwood cut followed by mechanical site preparation and planting. Perhaps the cumulative effect of all these treatments has a negative effect on chick production.

### *Effects of roads*

Roads could negatively affect nesting ospreys or herons because roads alter habitat. Moreover, construction, traffic flow, and human activities associated with increased access represent potential sources of disturbance (see Trombulak and Frissell 2000).

Our study suggests little negative effect of permanent or temporary roads on occupancy or productivity of ospreys. In fact, nest occupancy was positively related to the length of permanent roads within 2 km. Melo (1975) and Adams and Scott (1979) reported successful fledging at individual nests that were approximately 30 m from active haul roads. Lind (1976) found no relationship between distance to the nearest 2 lane road and nest success. In contrast, Lanier and Foss (1989) described 1 osprey nest that was apparently adversely affected by pedestrian and vehicular activity on a moderately used unpaved road that was 250 m (and visible) from the nest. van Daele and van Daele (1982) found higher productivity at osprey nests > 1.5 km from well-traveled roads, human dwellings and associated human disturbance but were not able to isolate the effects of roads. The apparent positive relationship we noted may be spurious, or may reflect increased nesting opportunities associated with utility poles along permanent roads.

In contrast to ospreys, proximity and length of permanent roads did appear to affect colony occupancy in herons. Proximity of roads has been linked to the location (Watts and Bradshaw 1994, Gibbs and Kinkel 1997) and size of heronries (Parker 1980), but not to longevity (Agro and Naylor 1994). Corely et al. (1997) suggested that optimal nesting habitat was > 150 m from

unimproved roads in Oklahoma. Short and Cooper (1985) recommended that suitable nesting habitat had no roads within 250 m of a colony. Watts and Bradshaw (1994) reported that roads affected colonies in Virginia at distances of 400 to 800 m. In Montana, Parker (1980) suggested that ideal nesting habitat was > 750 m from a road. In some of these studies, it is difficult to separate the effect of roads from the effect of the human dwellings and other activities that tend to be associated with roads. In the relatively continuously forested and lightly developed landscapes we studied, permanent roads appeared to have little impact when further than 200 to 300 m from colonies.

### *Effects of lakes and wetlands*

In ospreys, nest site occupancy was negatively related to the area of lakes within 500 m. Moreover, nests in upland sites were about twice as successful as those in wet sites. This is surprising since osprey nest sites are typically associated with waterbodies (Peck and James 1983) and habitat suitability is generally thought to be affected by the supply of fish (Vana-Miller 1987). Numerous authors have noted a higher success rate at nests of ospreys built in stable structures (man-made structures such as artificial nesting platforms or utility poles) than in dead trees (see Poole 1989). However, this did not account for the difference we observed because upland and wet sites were equally likely to be in dead trees or artificial structures. The difference may be related to recreational disturbance. Nests close to lakes may be subject to disturbance by shoreline fishers and boaters (see Lind 1976, Swenson 1979, Saurola 1997). Sporadic human activity that occurs abruptly at critical periods after initiation of nesting (especially during incubation and early in the nestling period) can effect osprey production (Vana-Miller 1987).

In herons, lakes appeared to have a negative effect on colony occupancy and chick production and colonies in upland sites had a higher rate of occupancy and chick production than those in wet sites. Active heron colonies were significantly further from water than inactive colonies in Montana (Parker 1980). As with ospreys, these relationships may be at least partly explained by high levels of disturbance associated with recreational use of lakes and shorelines (Parker 1980). In contrast, colony size was positively related to the proximity and area of lakes. This relationship may be related to food supply. The littoral zone of lakes and rivers is a preferred foraging habitat for herons (Gibbs 1991) and numerous authors have noted a positive association between colony size and availability of foraging habitat (Gibbs et al. 1987, Butler 1991b, Gibbs 1991, Gibbs and Kinkel 1997).

It was surprising that neither the proximity nor area of wetlands was associated with occupancy or productivity in herons. In Maine and Illinois, heron colonies tend to be located near wetland complexes (Gibbs 1991, Gibbs and Kinkel 1997). Perhaps wetlands are not as important as the littoral zone of lakes as foraging habitat in central and northern Ontario. It is also possible that delineation of wetlands on Forest Resources Inventory maps is too crude to accurately represent the supply of wetlands suitable as foraging habitats.

### *Evaluating the guidelines*

The osprey and heron guidelines currently used appear to be effective in maintaining long-term occupancy and productivity of nest sites. Our results suggest that the provincial guidelines may be more conservative than necessary since the GLSL guidelines appear to be effective, even under boreal conditions. For ospreys, even the GLSL guidelines may be more restrictive than necessary since nest sites with a pattern of cutting at variance with these guidelines differed little from control sites. These results are not surprising since the proximity, timing, and extent of

forest management activities appeared to have little influence on occupancy or productivity of ospreys.

For herons, the GLSL guidelines may also be slightly more conservative than necessary; nest sites with a pattern of cutting at variance with these guidelines did not differ significantly from control sites. However, occupancy rate was almost 2 times greater at control colonies than at colonies cut without the guidelines. Moreover, reproductive performance was negatively effected by cutting within 100 to 200 m and permanent roads within 200 to 300 m of colonies.

While our results do suggest that the current temporal buffers are effective in maintaining the long term occupancy and productivity of nest sites, we caution that our study does not evaluate the effectiveness of the temporal buffers in mitigating immediate effects of harvesting or other silvicultural activities during the nesting season.

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Table 1. Summary of guidelines used to protect osprey and heron nest sites in Ontario.

<i>Guideline</i>	<i>Species</i>	<i>Source</i>	<i>Prescription</i>
Provincial	Osprey	Penak 1983	0 to 200 m - no cutting at any time 201 to 800 m – no clearcutting, road construction, or site preparation at any time (selective cutting permitted), no cutting during the nesting season
	Heron	Bowman and Siderius 1984	0 to 300 m – no cutting or road construction at any time 301 to 1000 m – no cutting, road construction, or site preparation during the nesting season
Great Lakes – St. Lawrence	Osprey & Heron	Szuba and Naylor 1998	0 to 150 m – no cutting at any time 151 to 300 m – no clearcutting at any time, no cutting during the nesting season, no road construction

Table 2. Summary of relationships between habitat features or forest management activities and reproductive performance in ospreys.

<b><i>Nest occupancy</i></b>	
<b><i>Variable</i></b>	<b><i>Relationship</i></b>
Lakes	Negatively related to area within 500 m ( $P = 0.037$ ) when length of permanent roads within 2 km controlled.
Wetlands	None
Permanent roads	Positively related to proximity ( $P = 0.035$ ) and length within 2 km ( $P = 0.014$ ) when area of lakes within 500 m controlled.
Temporary roads	None
All cuts	None
Clearcuts	None
Parital cuts	None
Summer cuts	None
Site preparation	None
Planting	None
Tending	None

<b><i>Nest success</i></b>	
<b><i>Variable</i></b>	<b><i>Relationship</i></b>
Lakes	None
Wetlands	None
Permanent roads	None
Temporary roads	None
All cuts	None
Clearcuts	None
Parital cuts	None
Summer cuts	None
Site preparation	None
Planting	None
Tending	None

<b><i>Chicks per successful nest</i></b>	
<b><i>Variable</i></b>	<b><i>Relationship</i></b>
Lakes	None
Wetlands	None
Permanent roads	None
Temporary roads	None
All cuts	None
Clearcuts	None
Parital cuts	None
Summer cuts	None
Site preparation	None
Planting	None
Tending	None

Table 3. Comparison of measures of reproductive performance for osprey nests subject to timber harvest within 1 km that did or did not match the pattern recommended by the GLSL guidelines (% or mean $\pm$ SD, sample size in brackets).

<i>Reproductive parameter</i>	<i>Matched guidelines?</i>		<i>Control</i>	<i>P</i>
	<i>No</i>	<i>Yes</i>		
% nests occupied	50.8 (63)	36.2 (58)	34.5 (29)	0.176
% successful nests	74.1 (27)	64.7 (17)	50.0 (10)	0.386
# chicks/successful nest	1.95 $\pm$ 0.51 (20)	1.82 $\pm$ 0.60 (11)	2.20 $\pm$ 0.45 (5)	0.423

Table 4. Summary of relationships between habitat features or forest management activities and reproductive performance in great blue herons.

<b><i>Colony occupancy</i></b>	
<b><i>Variable</i></b>	<b><i>Relationship</i></b>
Lakes	Negatively related to area within 2 km ( $P = 0.070$ ) when the length of permanent roads within 2 km and proximity of all cuts controlled.
Wetlands	None
Permanent roads	Negatively related to proximity ( $P = 0.052$ ) and length within 2 km ( $P = 0.022$ ) when area of lakes within 2 km and proximity of all cuts controlled.
Temporary roads	None
All cuts	Negatively related to the proximity ( $P = 0.017$ ) and area within 500 m ( $P = 0.063$ ) when area of lakes and length of roads within 2 km controlled.
Clearcuts	Negatively related to proximity ( $P = 0.041$ ) when area of lakes and length of roads within 2 km controlled.
Parital cuts	None
Summer cuts	None
Site preparation	None
Planting	None
Tending	None

<b><i>Colony size</i></b>	
<b><i>Variable</i></b>	<b><i>Relationship</i></b>
Lakes	Positively related to area within 500 m ( $P = 0.000$ ) when proximity of all cuts controlled.
Wetlands	None
Permanent roads	None
Temporary roads	None
All cuts	Negatively related to proximity ( $P = 0.077$ ) and area within 250 m ( $P = 0.055$ ) when area of lakes within 500 m controlled.
Clearcuts	None
Parital cuts	None
Summer cuts	None
Site preparation	None
Planting	None
Tending	None

<b><i>Chicks per occupied nest</i></b>	
<b><i>Variable</i></b>	<b><i>Relationship</i></b>
Lakes	Negatively related to area within 250 m ( $P = 0.055$ ) when area of partial cuts within 250 m and area of tending within 500 m controlled.
Wetlands	None
Permanent roads	None
Temporary roads	None
All cuts	Negatively related to area within 250 m ( $P = 0.017$ ) when area of lakes within 250 m and area of tending within 500 m controlled.
Clearcuts	None
Parital cuts	Negatively related to proximity ( $P = 0.052$ ) and area within 250 m ( $P = 0.001$ ) when area of lakes within 250 m and area of tending within 500 m controlled.
Summer cuts	None
Site preparation	None
Planting	None
Tending	Negatively related to area within 500 m ( $P = 0.039$ ) when area of lakes and partial cuts within 250 m controlled.

Table 5. Comparison of measures of reproductive performance for heron colonies subject to timber harvest within 1 km that did or did not match the pattern recommended by the GLSL guidelines (% or mean $\pm$ SD, sample size in brackets).

<i>Reproductive parameter</i>	<i>Matched guidelines?</i>		<i>Control</i>	<i>P</i>
	<i>No</i>	<i>Yes</i>		
% colonies occupied	21.7 (46)	30.7 (75)	37.9 (29)	0.224
# occupied nests/colony	7.00 $\pm$ 8.26 (10)	5.70 $\pm$ 6.88 (23)	10.55 $\pm$ 13.48 (11)	0.622
# chicks/occupied nest	2.19 $\pm$ 0.56 (10)	2.42 $\pm$ 0.45 (21)	2.55 $\pm$ 0.37 (10)	0.201



