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POPULATION STATUS AND RECENT TRENDS IN CANADIAN RAPTORS: A REVIEW

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Abstract
We examined population trends and status in 37 taxa of Canadian raptors using Breeding Bird Survey (BBS) data (1966–1994 and 1985–1994) for the whole of Canada and seven ecozones separately, continent-wide Christmas Bird Counts (CBC) (1959–1988), migration counts from 12 hawkwatches (various dates) and specific research projects. According to the primary sources reviewed, many raptor populations increased since the early 1970s, coinciding with reductions in use of organochlorine pesticides (OCs). Species that increased included osprey Pandion haliaetus, *bald eagle* Haliaeetus leucocephalus *(BBS and CBC) and peregrine falcon* Falco peregrinus anatum *(1995 peregrine falcon survey). Red-tailed hawk* Buteo jamaicensis, *American kestrel* Falco sparverius *and merlin* Falco columbarius *also generally increased or were stable, but results differed according to source, time period and ecozone (both red-tailed hawk and American kestrel showed short-term decreases in the Mixedwood Plains BBS). Significant declines were found for burrowing owl* Speotyto cunicularia *(BBS), short-eared owl* Asio flammeus *and long-eared owl* Asio otus *populations (BBS and CBC). Golden eagle* Aquila chrysaetos *may be declining in some areas (CBC, four migration counts) but results were equivocal; there was some evidence to suggest that broad-winged hawk* Buteo platypterus *may also be declining. Long-term BBS data indicated that Swainson's hawk* Buteo swainsoni *populations were stable, but significant short-term declines were found in the Prairies ecozone, corresponding with decreases in productivity measured in long-term breeding studies. Sharp-shinned hawk* Accipiter striatus *apparently increased in number according to the overall long-term BBS, but may be declining according to some eastern migration count data. While no evidence of declines was found for prairie falcon* Falco mexicanus, *the Canadian population is small and vulnerable to habitat change that could reduce prey populations. Four species that reach their greatest abundance in, or are restricted to, the Prairies and Boreal Plains ecozones are declining there (northern harrier* Circus cyaneus, *Swainson's hawk, burrowing owl and short-eared owl). Although causal factors vary, our analysis suggests the possibility that large-scale phenomena such as human activity (pesticide use or habitat modification) and perhaps climate are affecting populations of some Prairie raptors. Research on endangered species is being conducted under the auspices of national recovery plans. We recommend that research be instigated to examine critically productivity failures in Swainson's hawks, and possible declines in golden eagle breeding populations. In view of the increasingly widespread impact of forestry on northern forests in Canada, we further recommend that special surveys be set up, and breeding densities, productivity and occupancy rates be determined in different forest types for accipiters, broad-winged hawk, as well as forest owls (particularly barred owl* Strix varia, *boreal owl* Aegolius funereus *and northern saw-whet owl* Aegolius acadicus brooksi*). We caution that the BBS and other national surveys may be inadequate for monitoring populations of many raptor species in Canada, particularly forest-dwelling accipiters, some owls and buteos. Special monitoring or sampling programs are needed for these species. However, taken together, multiple sources can provide inferential evidence for population trends and status. © 1997 Elsevier Science Ltd*

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INTRODUCTION

During the 1960s and early 1970s, drastic declines in some North American and European raptor populations were attributed to bioaccumulative organochlorine pesticides (OCs) that caused widespread reproductive failures, particularly in peregrine falcons, ospreys, bald eagles and some accipiters (Snyder *et al.*, 1973; Newton, 1979; Cade *et al.*, 1988; Court *et al.*, 1990; Noble *et al.*,

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1993; scientific names are given in Appendix). Since the 'DDT and cyclodiene era' (1946–1972), these raptor populations have recovered and are currently stable or increasing (e.g. Ewins, 1992; Newton and Wyllie, 1992; White, 1994; Holroyd and Banasch, 1996, in prep.). In addition, some species have adapted to urban and other human-disturbed environments (e.g. osprey, merlin; see references in Bird *et al.*, 1996). However, new-generation pesticides such as carbamates and organophosphates, by-products like polychlorinated biphenyls (PCBs) and other factors may now affect some raptor populations (Mineau, 1993; Noble *et al.*, 1993; Elliot, 1995; Mineau *et al.*, 1996). There is evidence to suggest that, as a result of pesticide use, several Canadian populations are still declining (e.g. burrowing owl; Fox *et al.*, 1989) or reproduction is inhibited (e.g. bald eagles on the southern Great Lakes; Bowerman, 1993; Hunter and Baird, 1995). However, declines in habitat suitability, due to timber harvest, agricultural intensification or urban development are now probably the main factors linked with decreases in several raptor species (e.g. Cadman, 1991; Dunbar and Blackburn, 1994; see papers in National Wildlife Federation, 1988, 1989*a*,*b*, 1990, 1991; Meyburg and Chancellor, 1994). Therefore, assessments of the population status of raptors are important for conservation (Fuller, 1996).

Raptors pose special problems for the estimation of population status and trends (Fuller and Mosher, 1987; Titus *et al.*, 1990) because they are usually dispersed and/or secretive species that nest at low densities and because their populations may fluctuate cyclically in relation to prey abundance. For example, many standard avian surveys do not adequately sample forest raptors, do not penetrate the remote regions where they breed or do not take place at the appropriate season to survey breeding pairs adequately (Fuller and Mosher, 1981). Additionally, many Canadian raptors migrate southward for the boreal winter and there mix with populations from elsewhere in the Americas, making specific estimates of Canadian populations on the non-breeding grounds impossible. Defining a Canadian raptor population is also contentious because pairs of some species may breed in one region one year, while in the next they may breed hundreds of kilometres away; thus, some raptor species that breed in Canada are part of continental populations that intermix with breeding populations in the United States (e.g. great gray owl; Duncan, 1992). We define populations here in a geographical sense only, as those breeding and/or wintering in Canada. We do not include species that are rare visitors or transients in Canada (e.g. black vulture *Coragyps atratus*).

There are few data on sizes, trends or the productivity of many Canadian raptor populations. The limited availability of information is related to the vast size of Canada coupled with the low density and southern distribution of human populations, making adequate sampling of remote areas incomplete. However, Canada probably holds a substantial proportion of the North American, or indeed world, populations of some species (e.g. osprey, tundra peregrine, gyrfalcon, northern hawk-owl and boreal owl).

In this paper, we present current information on population trends in Canadian raptors and point to gaps in knowledge. Apart from recent, brief overviews (Holroyd, 1993; Noble *et al.*, 1993; Kirk *et al.*, 1995) there has been no overall assessment of raptor populations in Canada since Fyfe (1976, 1977). Fyfe (1976, 1977) based his assessments on anecdotal reports from experts for each species. While we rely to some extent on communications from research specialists, we draw extensively on large data sets, analyses of which have become increasingly sophisticated over the last 20 years (see Sauer *et al.*, 1991, 1996; Hussell and Brown, 1992). One valuable source, the Christmas Bird Count (CBC), has only recently become available for analyses. While we recognize the limitations of the use of standard national avian surveys to monitor raptors (see Fuller and Mosher, 1987), in many cases these provide the only data available. Similar reviews of raptor status were made by Fuller (1996) for North American forest raptors and Fuller *et al.* (1995) for the United States; a series of reports produced by the National Wildlife Federation also examined the status of raptors in different parts of the United States (National Wildlife Federation, 1988, 1989*a*,*b*, 1990, 1991). Raptor status has also recently been reviewed in Finland (e.g. Saurola, 1985) and Central and South America (Bierregaard, 1995).

Our objectives here are threefold: (1) to assess the status of Canadian raptors; (2) to identify patterns of population trends in species and suggest species that might be considered for listing by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or require specific research to determine underlying causes of local or regional declines and (3) to identify species for which the main data sources are inadequate and for which basic information on breeding densities and population trends is lacking.

METHODS

To evaluate current trends in Canadian raptors we used six main sources; (1) the Breeding Bird Survey (BBS), (2) CBC, (3) migration counts, (4) breeding bird atlases, (5) l'Étude des populations d'oiseaux du Québec (ÉPOQ) and (6) results of species-specific surveys. In addition, we examined COSEWIC reports which contain summaries of status and trends as well as providing useful anecdotal observations. To estimate population sizes, we examined migration count data and breeding bird atlases. We also interviewed 10 raptor biologists (see Acknowledgements), some of whom gave estimates for their study species and others who provided population estimates for all species. While some of these estimates are best 'guesstimates' of population size (number of breeding pairs) and are therefore likely to be accurate only to an order of magnitude, others are quite precise and are based on extensive and detailed surveys (see Appendix). We believe that these estimates are useful starting points for discussion and are relevant to our evaluation of status and trends (see Saurola, 1985).

The BBS is a roadside count that was initiated in 1966 (Robbins *et al.*, 1986) and can be useful for monitoring some raptor species populations (e.g. Fuller *et al.*, 1987; Sauer *et al.*, 1991). A recent power and sample size analysis by J. R. Sauer (1970–1995) indicated that power was 80% or greater for the following species; turkey vulture, black vulture, northern harrier, northern goshawk, red-tailed hawk, red-shouldered hawk, Swainson's hawk, broad-winged hawk, American kestrel and great horned owl (J. R. Sauer, unpubl. data). We used analyses of BBS data for the whole of Canada to provide an overall picture of raptor populations. Because there are frequently regional differences in bird species population trends (Peterjohn and Sauer, 1993) and species vary in their distribution and abundance patterns, we also examined BBS trends for seven ecozones separately for which sufficient routes were available. Data were prepared by classifying the physiographic strata used in the BBS (Robbins *et al.*, 1986) into ecozones (Downes and Collins, 1996); these were the Pacific Maritime, Montane Cordillera, Prairies, Boreal Plains, Boreal Shield, Mixedwood Plains and Atlantic Maritime (Ecological Stratification Working Group, 1996; see Fig. 1).

Two separate analyses were performed: from 1966 to 1994 (hereafter 66–94 period) and a recent 10-year period, 1985–1994 (hereafter 85–94 period; Downes and Collins, 1996; C. M. Downes, pers. comm.). Because 50 or 100 routes are recommended for regional- or continental-scale trend analyses respectively (B. Peterjohn, pers. comm.), caution should be used in interpreting trends for some raptor species (14 species had over 50 routes in the long-term analysis for the whole of Canada). Species for which analyses were based on fewer than 14 routes or 40 individuals were omitted

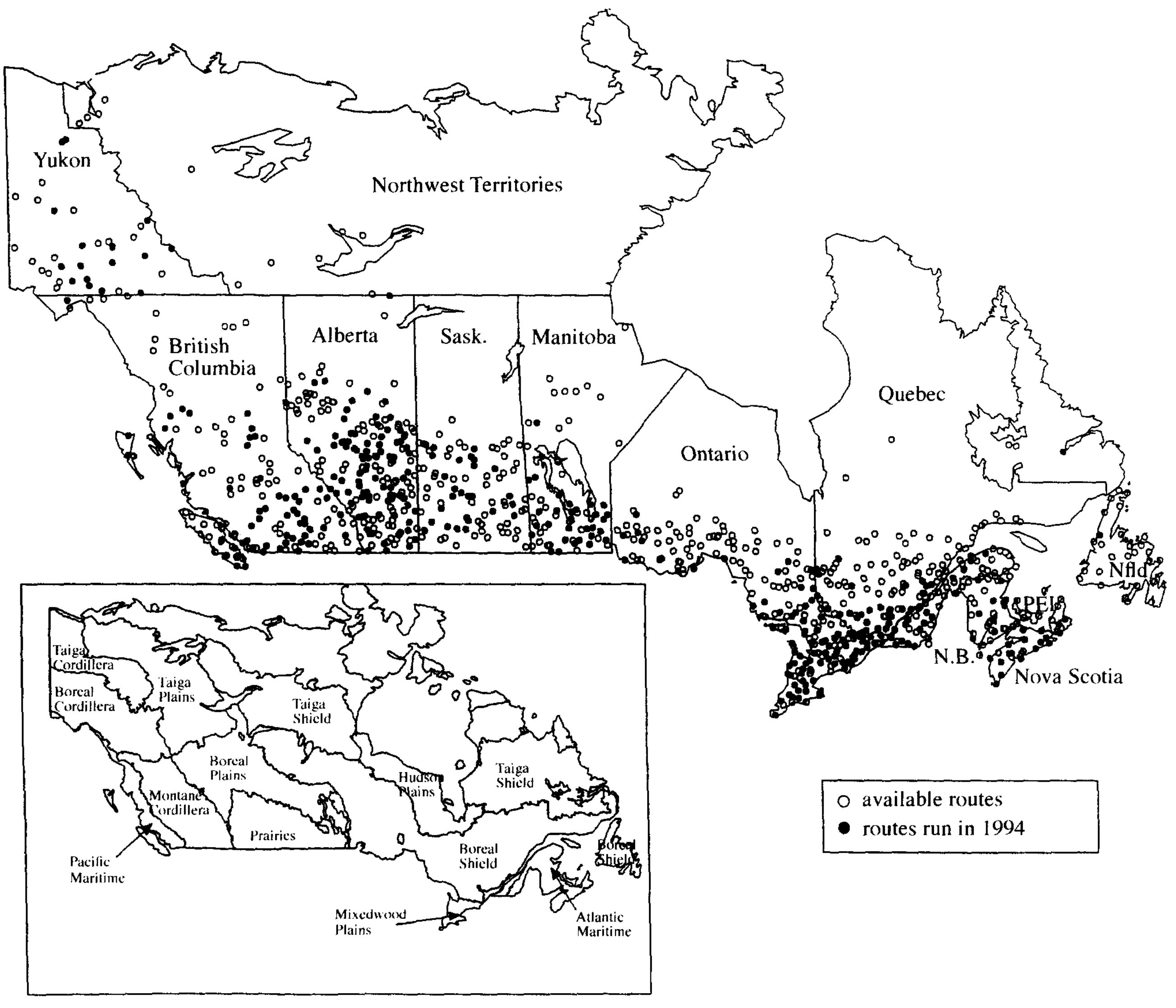

Fig. 1. Map showing ecozones of Canada (courtesy of C. M. Downes, Canadian Wildlife Service).

from the tables, as recommended by the Canadian Wildlife Service (CWS), BBS protocol (Downes and Collins, 1996). Too few individuals were recorded for trend analyses to be statistically valid for some raptor species, particularly when data were subdivided at the provincial level or even smaller areas (B. Peterjohn, pers. comm.). For species whose abundance (mean number recorded per route) is less than 1·0, there can be a positive bias associated with the analysis, and both increasing and decreasing trend estimates should be viewed with caution (Sauer *et al.*, 1991; Link and Sauer, 1994). One reason for this is that the size of the constant added to low or zero counts prior to log-transformation can have a profound effect on the trend analyses; another problem is the infrequency of positive counts (Link and Sauer, 1994). However, this does not mean that the trend estimates are invalid, CWS has tested the effects of adding different constant values (Collins, 1990) and estimating equations analyses perform well on species with low abundance (Link and Sauer, 1994). We caution that statistical techniques used for BBS trend analyses differ between the United States Biological Service (USBS) and the CWS and that these may give different results (Thomas and Martin, 1996), especially for species recorded at very low abundance levels (i.e. most raptors); currently, the USBS is developing estimating equations for the analysis of population trends (Link and Sauer, 1994), whereas the CWS uses an earlier form of route regression, while correcting for observer differences (Collins, 1990). We used current CWS protocol to be consistent with previous analyses of CWS, BBS data (Downes and Collins, 1996).

Moreover, there are at least three fundamental methodological problems in the use of the BBS for raptors: (1) BBS routes are concentrated in southern Canada, and there are few in the Boreal and Arctic regions. (2) Large raptors like bald eagles, ospreys and buteos in open landscapes have large, conspicuous stick nests, often in trees or favoured perch sites, with which surveyors are familiar. Thus, there is a relative difference in the reliability of BBS results between these species and small species, including accipiters and ground- or cavity-nesting raptors, which have more concealed nests and are more secretive. (3) Another bias is that many raptors have bred by the time of the BBS in June; for example, counts of great horned owls may measure productivity rather than breeding densities.

The CBC is the largest and oldest wildlife survey in the world and provides useful information for some raptor species (Butcher, 1990). An analysis of CBC data was recently performed for the entire continent by Sauer *et al.* (1996). Separate analyses by province or ecozone might be useful for some species (e.g. rough-legged hawk, snowy owl, great horned owl and long-eared owl). However, because many Canadian raptors migrate to the United States in the boreal winter depending on weather (temperature and snow depth) and fluctuations in food supply (e.g. Kerlinger *et al.*, 1985), continental trend estimates are most appropriate for comparisons with other data sources.

Many raptors migrate southwards to spend the boreal winter in the United States, Mexico and Central or South America. Because some of these birds follow topographic features such as mountain ridges, coastlines and lake peninsulas (Mueller, 1967) and therefore numbers are concentrated in a visible migration, hawk lookouts have functioned as convenient counting sites since early this century (Kerlinger, 1989, for review; Hussell, 1985; Bednarz and Kerlinger, 1989). Many, perhaps most, hawks counted at lookouts in the northern Great Lake states are of Canadian origin. For example, the Hawk Ridge overlook at Duluth, Minnesota probably samples large numbers of birds from northwestern Ontario, Manitoba and possibly elsewhere (Hussell and Brown, 1992). Cape May Point in New Jersey counts raptors from Québec and the Maritimes, as well as the northeastern United States (Clark, 1985).

We examined recent analyses of data from eastern hawk count sites at Hawk Mountain, Pennsylvania (Bednarz *et al.*, 1990), Niagara Peninsula Hawkwatch near Grimsby, Ontario, and Hawk Ridge, Duluth, Minnesota (Hussell and Brown, 1992); a combined analysis from Hawk Ridge (Duluth), Minnesota; Whitefish Point, Michigan; Derby Hill, New York; Hawk Mountain, Pennsylvania; Sandy Hook, New Jersey; and Cape May Point, New Jersey (Titus and Fuller, 1990); and four western sites: the Wellsville mountains, Utah; the Goshute mountains, Nevada; the Manzano mountains, New Mexico; and the Sandia mountains, New Mexico (Hoffman, *et al.*, 1992, unpubl. data). Other eastern Canadian hawkwatch sites (e.g. Tadoussac and Montréal in Québec; Aubry and Bannon, 1996; or Cranberry Marsh, Ontario, Ridout, 1995) had too few years of data for analyses but should provide useful future trend information. Unfortunately, no rigorous statistical analyses have been made of count data from other sites in Ontario, such as Hawk Cliff and Holiday Beach (Ridout, 1995, 1996 for two recent autumn season totals). No long-term data were available from migration count sites in western Canada. Until recently, migration routes for raptors in the west were poorly known, but there was a recent discovery of a major flyway at Mount Lorette, near Calgary, Alberta (>6000 golden eagles have been observed in the autumn; P. Sherrington, pers. comm.), that should prove useful for future trend analyses. The same is true for other count sites in Alberta such as Windy Point and Barrier Lake (Koes and Taylor, 1995, 1996).

Few owl species are counted at migration stations (e.g. Duffy and Kerlinger, 1992) but banding stations in the Great Lakes region provide some data, particularly for boreal owl (Carpenter, 1987; Grigg, 1990, 1993) and northern saw-whet owl (e.g. Holroyd and Woods, 1975; Weir *et al.*, 1980; T. C. Erdman, D. L. Evans, pers. comm.). Banding stations in the northern United States (e.g. Hawk Ridge at Duluth, Minnesota, and Whitefish Point, Michigan) also probably sample large numbers of Canadian owls (Shepherd, 1992). Unfortunately, lack of standardization makes these data somewhat problematic for trend analysis.

While breeding bird atlases cannot provide information on population trends, because they represent only a fixed period in time (usually atlases are conducted over a 5–10-year period), they provide data on the distribution and relative abundance of raptor species for areas surveyed. However, they are biased by uneven coverage (usually more complete in areas closest to human population centres) and they do not adequately reflect abundances in more northerly and remote areas. Moreover, effort and observer skills vary greatly during collection of atlas data. Therefore we used atlases only to support conclusions from other data sources and for species lacking information from other sources, such as several owl species.

Checklist data collected over a period of 20 years (1969–1989) for the province of Québec were analyzed using linear regression by Cyr and Larivée (1995). These trends were based on the frequency of checklists in which the species were recorded (Cyr and Larivée, 1995).

For many raptors, none of these sampling methods is adequate to discern accurate trends. For these species, we used population data from long-term or short-term research projects. Such data on breeding densities and productivity are extremely important supplements or substitutes to information from the main data sources. Examples of such sources are the peregrine falcon surveys for 1990 and 1995 (Holroyd and Banasch, 1996, in prep.), gyrfalcon surveys in Yukon and the Northwest Territories (Mossop and Hayes, 1994; Shank and Poole, 1994), northern spotted owl surveys in British Columbia (Dunbar and Blackburn, 1994), the Manitoba Nocturnal Owl Survey (Duncan and Duncan, 1994) and theses on bald eagles (Elliot, 1995), sharp-shinned hawks (Meyer, 1987), prairie falcons (Hunt, 1993), barn owls (Andrusiak, 1994), great horned owls (Rohner, 1994), flammulated owls (van Woudenberg, 1992) and barred owls (Elderkin, 1987).

To investigate the significance of patterns of increase or decrease in raptors as a group we used a binomial test (Zar, 1984). Data from the BBS and CBC were analyzed using route regression (Downes and Collins, 1996; Sauer *et al.*, 1996). Analyses of migration count data varied depending on the source; note that the method of analysis may have an important effect on the results. Analyses that emphasize vigorous standardization (e.g. Bednarz *et al.*, 1990; Hoffman *et al.*, 1992) or consider sources of variation (e.g. Hussell, 1985) may be more reliable than others. A second caveat to consider is the danger of comparing trends among data sources that cover different periods. For example, the starting point for most surveys is entirely arbitrary, so trend estimates made for species whose populations were already low or high at the initiation of the survey may largely reflect reactions of populations to events prior to the survey (e.g. species that were adversely affected by DDT and its derivatives). Statistical tests were considered significant at $p < 0{\cdot}05$. However, we also discuss marginally significant results ($0{\cdot}05 < p < 0{\cdot}1$).

RESULTS

Overview

When BBS data were pooled for the whole of Canada, sufficient information was available to comment on the trends for 21 diurnal raptors and owls (Table 1). More species showed positive (14) rather than negative regression coefficients (or % annual changes) (7) according to the BBS during the 66–94 period (Binomial test, ns; Table 1). However, during the 85–94 period, only 10 species showed positive regression coefficients (7 significant), while seven were negative (2 of these were significant; Binomial test, ns; Table 1).

Species summaries

According to the BBS, the turkey vulture is increasing significantly both in the overall analysis for Canada (Table 1) and for the Boreal Shield and Mixedwood Plains ecozones separately (Tables 2 and 3). Although the CBC does not sample the huge numbers of turkey vultures that migrate south to spend the nonbreeding season in Latin America (Kirk and Mossman, in press), the analysis for the whole continent also demonstrated increasing populations (Table 4). Similarly, significant increases were found in four out of six migration count analyses (Table 5), and Québec's ÉPOQ also indicated a significant increase in this species (Table 6).

Osprey increased significantly on the countrywide BBS (Table 1), and there were also significant increases in the Boreal Shield and Atlantic Maritime ecozones during the 66–94 period, but these were not apparent over the 85–94 period (Tables 2 and 3). Six migration count analyses showed significant increases in osprey numbers, and the remaining analyses indicated that populations were stable (Table 5). In Québec, populations were stable according to ÉPOQ (Table 6).

Increases in bald eagle populations were indicated by the countrywide BBS and for the Pacific Maritime ecozone during the 66–94 period (Tables 1 and 2). However, over the 85–94 period populations were apparently stable at the ecozone level (Table 3); similarly the CBC (and ÉPOQ in Québec) suggested that populations were stable (Table 4). While bald eagle counts increased significantly at Niagara Peninsula, Hawk Ridge and the combined analysis of six eastern lookouts and were stable at western lookouts, they showed a significant long-term decline at Hawk Mountain. Analysis of counts from a more recent period at Hawk Mountain, however, indicated an increase (Table 5).

Whereas northern harrier appeared to be stable according to the BBS for Canada (Table 1) and most

Table 1. Breeding Bird Survey results for the whole of Canada for long-term (1966–1994) and short-term (1985–1994) trends for diurnal raptors and owls (C. M. Downes, pers. comm.)

Species	1966–1994			1985–1994		
	% Change[a]	n^b	Abundance[c]	% Change[a]	n^b	Abundance[c]
Turkey vulture	4·34***	43	0·378	10·90***	68	0·547
Osprey	2·00*	158	0·396	9·53**	97	0·507
Bald eagle	6·88*	91	0·378	12·48***	64	0·518
Northern harrier	−0·40	310	0·592	0·38	231	0·617
Sharp-shinned hawk	0·69*	137	0·294	−0·45	92	0·323
Cooper's hawk	0·28	83	0·296	4·97*	50	0·334
Northern goshawk	0·13	75	0·280	0·09	42	0·319
Red-shouldered hawk	0·35	38	0·285	−0·94	19	0·319
Broad-winged hawk	0·50	143	0·348	−3·33+	85	0·439
Swainson's hawk	1·25	117	0·985	−5·01*	86	1·376
Red-tailed hawk	2·65***	355	0·668	5·17***	282	0·908
Ferruginous hawk	5·57**	25	0·473	8·87+	17	0·577
Golden eagle	−0·75	20	0·282			
American kestrel	1·12+	405	0·653	−1·28	296	0·803
Merlin	1·08*	163	0·314	3·50*	106	0·352
Great horned owl	−0·21	212	0·415	−3·18	142	0·490
Burrowing owl	−2·19*	16	0·462			
Barred owl	0·61+	64	0·288	1·51	34	0·357
Great Gray owl	−0·11	17	0·411			
Long-eared owl	−0·98*	16	0·313			
Short-eared owl	−2·57***	83	0·386	−3·51	29	0·407

[a]% change, mean annual percent change. Statistical significance: $+0{\cdot}05 < p < 0{\cdot}1$, $*p < 0{\cdot}05$, $**p < 0{\cdot}01$, $***p < 0{\cdot}001$.
[b]n, number of routes used in analysis.
[c]Abundance, average relative abundance of the species on routes (n) calculated from annual indices. Note that species recorded on fewer than 14 routes and with < 40 individuals are omitted (Downes and Collins, 1996).

ecozones (with a significant increase in the Maritimes), it showed a significant decline over the 66–94 period in the Boreal Plains ecozone (Table 2). However, no significant trends were found for this species over the 85–94 period (Table 3). Migration counts also suggested that populations were stable, but significant increases were found at both Niagara Peninsula and Hawk Mountain (1934–1986; Table 5); there was also a significant increase in this species according to ÉPOQ in Québec (Table 6).

The significant increase in sharp-shinned hawks in the 66–94 period according to the BBS for Canada was not evident in the more recent years 85–94 (Table 1), nor at the ecozone level (Tables 2 and 3). However, the positive regression coefficient for the Boreal Shield ecozone was marginally significant. Sharp-shinned hawks also increased significantly according to the continent-wide CBC (Table 4). None of the hawkwatch analyses we summarize reveal the declines in sharp-shinned hawk documented for Cape May Point (included in the combined analysis by Titus and Fuller, 1990), and in fact three sites (Niagara Peninsula, Hawk Mountain, 1934–1986 and Goshute Mountains) had significant increases (Table 5). Part of the reason for this is that declines at hawkwatches in the eastern United States did not take place until after the period of published analyses (up to 1987 in Titus and Fuller, 1990 and up to 1986 in Bednarz *et al.*, 1990). Nonetheless, declines at Cape May Point from 1979–1992 are statistically significant (Viverette *et al.*, 1996). Yet sharp-shinned hawks have increased according to Québec's ÉPOQ (Table 6).

Although Cooper's hawk was stable over the 66–94 period for the BBS for Canada, there was a significant increase in this species over the 85–94 period (Table 1). At the ecozone level, populations were apparently stable in the Prairies according to the BBS (Tables 2 and 3). CBC data indicated a marginally significant increasing trend in Cooper's hawk (Table 4). Significant increases were found for Cooper's hawk according to analyses of Niagara Peninsula, six eastern lookouts, Hawk Mountain (1971–1986), and Goshute Mountain counts; however, the long-term analysis for Hawk Mountain showed a marginally significant decline (Table 5). There was also a significant decrease in this species in Québec's ÉPOQ (Table 6).

According to the BBS for Canada, northern goshawk was stable (Table 1). However, not surprisingly, the species was counted on few routes; no analyses met our criteria for either period at the ecozone level, and in any case there were no significant trends. The CBC also suggested that populations were stable over the long-term (as did ÉPOQ; Tables 4 and 6). However, the migration count analyses for northern goshawk were equivocal. They showed mostly negative regression coefficients; significant decreases were recorded for Hawk Mountain (1971–1986), the Wellsville mountains and Sandia mountains (and marginally negative trends for the Goshute and Manzano mountains), but these analyses cover short time periods (Table 5) and may simply reflect cyclic irruptions. More recent analyses confirm the possibility of decreases at the Wellsville

Table 2. Percentage annual change in Canadian raptors between 1966–1994 according to Breeding Bird Survey by ecozone (Downes and Collins, 1996; C. M. Downes, pers. comm.)

Species	Pacific Maritime		Montane Cordillera		Prairies		Boreal Plains		Boreal Shield		Mixedwood Plains		Atlantic Maritime	
	% Change[a]	n^b	% Change[a]	n^b	% Change[a]	n^b	% Change[a]	n^b	% Change[a]	n^b	% Change[a]	n^b	% Change[a]	n^b
Turkey vulture									5·09***	34	6·31**	28		
Osprey			1·16	38					2·88*	44			2·91*	43
Bald eagle	10·15**	19	2·84	24									0·61	15
Northern harrier					−0·14	90	−2·23*	48	−1·46	49	2·95	40	1·40	46
Sharp-shinned hawk									0·89+	39				
Cooper's hawk					0·21	28								
Red-shouldered hawk											−0·16	19		
Broad-winged hawk									0·83	73			0·46	33
Swainson's hawk					1·59	89	0·04	19						
Red-tailed hawk	5·07**	15	3·16*	48	3·57***	79	2·79+	66	1·26+	51	−0·83	40	0·39	31
Ferruginous hawk					5·27**	26								
American kestrel			0·29	48	1·70**	62	0·54	68	2·27**	90	−0·19	42	0·63	57
Merlin					1·76*	43	−0·10	33	2·09+	41				
Great horned owl					2·75+	70	−4·15	45	−1·76*	19	0·30	29	0·29	23
Burrowing owl					−2·02*	16								
Barred owl													1·38*	28
Short-eared owl					2·92**	44	−4·12***	19					1·38%	

[a]% Change, mean annual percent change. Statistical significance: $+0{\cdot}05 < p < 0{\cdot}1$, $*p < 0{\cdot}05$, $**p < 0{\cdot}01$, $***p < 0{\cdot}001$.
[b]n, number of routes used in analysis. Note that species recorded on fewer than 14 routes and with < 40 individuals are omitted (Downes and Collins, 1996).

Table 3. Percentage annual change in Canadian raptors between 1985–1994 according to Breeding Bird Survey by ecozone (C. M. Downes, pers. comm.)

Species	Montane Cordillera		Prairies		Plains Boreal Plains		Boreal Shield		Mixedwood Plains		Atlantic Maritime	
	% Change[a]	n[b]	% Change[a]	n[b]	% Change[a]	n[b]	% Change[a]	n[b]	% Change[a]	n[b]	% Change[a]	n[b]
Turkey vulture							10·36**	31	12·63*	23		
Osprey	8·54	28					14·55	21			7·11	30
Bald eagle			−1·67	15								
Northern harrier	0·08	72	−1·85	37	−1·40	32	0·23	33	3·64	30		
Sharp-shinned hawk							−0·90	23				
Broad-winged hawk							−4·35	46			−3·07	19
Swainson's hawk			−5·88**	71								
Red-tailed hawk	0·33	38	7·70***	68	5·15+	54	4·05	32	−6·43+	35	0·31	18
Ferruginous hawk			4·15	18								
American kestrel	−0·85	37	−3·02	46	1·24	55	0·54	56	−10·20*	37	3·02	39
Merlin			5·72	32	−1·40	28	12·88**	19				
Great horned owl			−1·65	57					−1·20	18		
Short-eared owl			−5·38	15								

[a]% change, mean annual percent change. Statistical significance: $+0{\cdot}05 < p < 0{\cdot}1$, $*p < 0{\cdot}05$, $**p < 0{\cdot}01$, $***p < 0{\cdot}001$.
[b]n, number of routes used in analysis. Note that species recorded on fewer than 14 routes and with < 40 individuals are omitted (Downes and Collins, 1996).

Table 4. Christmas Bird Count trends (1959–1988) for North America (Sauer *et al.*, 1996)

Species	% Change[a]	n[b]	Abundance[c]
Turkey vulture	2·6**	885	3·53
Bald eagle	0·0	1295	1·20
Northern harrier	−0·4	1712	1·88
Sharp-shinned hawk	1·4**	1709	0·26
Cooper's hawk	0·8+	1624	0·23
Northern goshawk	0·2	1007	0·11
Red-shouldered hawk	0·8+	1168	0·45
Red-tailed hawk	2·1**	1936	2·90
Ferruginous hawk	3·9**	383	0·28
Rough-legged hawk	−0·1	1551	1·16
Golden eagle	−1·0+	722	0·41
American kestrel	0·8+	1909	2·59
Merlin	0·4	1067	0·13
Peregrine falcon	0·0	666	0·05
Gyrfalcon	1·9**	117	0·09
Prairie falcon	1·5**	448	0·28
Barn owl	0·5	718	0·13
Eastern screech-owl	3·0**	1142	0·24
Western screech-owl	2·1**	206	0·07
Great horned owl	1·7**	1835	0·72
Snowy owl	−0·4	540	1·58
Northern hawk-owl	−1·3*	71	0·10
Northern pygmy owl	0·5	235	0·16
Burrowing owl	0·2	240	0·13
Northern Spotted owl	0·2	47	0·05
Barred owl	0·7	1166	0·25
Great gray owl	0·5	59	0·14
Long-eared owl	−1·6*	709	0·11
Short-eared owl	−1·8**	958	0·20
Northern saw-whet owl	0·3	472	0·04

[a]% Change per year calculated by route regression. Statistical significance: $+0{\cdot}05<p<0{\cdot}1$, $*p<0{\cdot}05$, $**p<0{\cdot}01$.
[b]n, number of circles where species detected.
[c]Abundance is mean abundance/circle.

mountains (Hawkwatch International, 1996; Hoffman *et al.*, unpubl. data).

Red-shouldered hawk was stable according to the BBS for Canada (Table 1); similar conclusions were reached from the ecozone-level analysis (Table 2). A marginally significant increase was found on the CBC for this species (Table 4). Migration counts at eastern hawkwatches also suggested that populations were stable or showed negative regression coefficients that were not significant, as did ÉPOQ (Tables 5 and 6).

Long-term BBS data for Canada and the ecozones suggested that the broad-winged hawk is stable (Table 1 and Table 2); however, during the 85–94 period, there was a significant decline in nationwide counts (Table 1). Also, the regression coefficient for the Boreal Shield for the 85–94 period approached marginal statistical significance (Table 3). Four out of five regression coefficients from migration count analyses for the broad-winged hawk were negative, one of them being marginally significant (Table 5).

Swainson's hawk was stable according to the BBS in the 66–94 period for Canada and the Prairies and Boreal Plains ecozones separately (Tables 1 and 2). However, there was a significant decline over the 85–94 period, both for the country-wide BBS and Prairies ecozone (Tables 1 and 3). Although there were only nine routes sampled in the Boreal Plains ecozone and this result was therefore excluded by our criteria, the regression coefficient was also significantly negative for the 85–94 period. The recent decline in the Prairies ecozone is entirely consistent with declines in productivity recorded in Saskatchewan and Alberta (see Discussion). Analyses of migration count data for Swainson's hawk were conflicting; although there was a marginally negative trend at the Manzano mountains hawkwatch, none of the other trends was significant, and there was a positive, but not statistically significant, regression coefficient for the combined analyses for four western hawkwatches (Table 5). However, it should be noted that these analyses cover a relatively short period and involve very low numbers of hawks. Migration counts for this species may not be useful in the United States since the Swainson's hawk migrates on a broad front, but would be more effective where hawks concentrate (e.g. Panama, Smith, 1985; or central Veracruz, Mexico, where 448,000 birds were counted in the autumn of 1994; Ruelas Inzunza *et al.*, 1996).

Almost all BBS data indicate that the red-tailed hawk is increasing; significant increases were found for Canada (both 66–94 and 85–94 periods) and also for five of seven ecozones during the 66–94 period (Tables 1–3). Increases were highly significant in the Prairies ecozone for both periods; however, during the 85–94 period, there was a marginally significant decline in the Mixedwood Plains ecozone. The CBC indicated an increase in this species, supporting most of the BBS analyses (Table 4). Although most hawkwatch analyses suggested that the red-tailed hawk is stable, two indicated significant declines: Hawk Ridge (marginally significant) and Hawk Mountain (1971–1986; Table 5). These results may not be inconsistent, and in fact there may have been a recent decline in this species in parts of eastern Canada (see Discussion).

Ferruginous hawk increased significantly according to the BBS for the 66–94 period (for Canada and the Prairies ecozone separately; Tables 1 and 2). This increase was only marginally significant for the 85–94 period (BBS Canada; Table 1). The CBC provided supportive evidence for a significant increase in this species (Table 4). According to western migration counts ferruginous hawk populations were stable, but there was a marginal increase between periods in the Wellsville mountains (Table 5).

The rough-legged hawk breeds almost entirely to the north of BBS routes, but the CBC suggested that populations were stable (Table 4). There was a significant negative trend at Hawk Ridge for the rough-legged hawk, but counts at other sites suggested that populations were stable (Table 5).

Golden eagle populations were stable according to the BBS for Canada (the 66–94 period; Table 1).

Table 5. Annual percent change in migration counts for eastern and western North America

Species	Niagara Peninsula hawkwatch, Grimsby, Ontario[a] 1975–1990	Hawk Ridge hawkwatch, Duluth, Minnesota[a] 1974–1989	Six eastern hawk look-outs[b] 1972–1987	Hawk Mountain, Pennsylvania		Wellsville mountains, Utah (1977–1979) vs (1987–1990)[d]	Goshute mountains, Nevada[e] (1983–1990)	Manzano mountains, N. Mexico[e] (1985–1990)	Sandia mountains, N. Mexico[e] (1985–1991)	Four western lookouts[f] (1983–1991)
				1934–1986[c]	1971–1986[c]					
Turkey vulture	8·0**	3·6+				0·38↓	0·035**	1·351	0·057	18·33*
Osprey	6·8**	5·5**	8·94*	0·131***	0·181	1·83↑	0·013**	0·003	0·004	7·04*
Bald eagle	13·5**	18·7**	13·47***	−0·018***	0·011+	0·71↓	0·001	0·035	−0·008	−1·40
Northern harrier	6·0**	−3·3	5·09	0·029***	0·023	0·06↑	0·001	0·003	−0·004	−2·91
Sharp-shinned hawk	4·3*#	−0·7	0·38	1·420**	1·940	1·14↑	0·09**	−1·495	−0·033	4·63
Cooper's hawk	5·4**	−1·2#	7·75*	−0·049+	0·335*	0·07↓	0·081*	−0·996	0·032	7·51
Northern goshawk			−3·76	0·023	−0·303*	5·48↓**	−0·010+	−0·093+	0·004*	−4·36
Red-shouldered hawk	−0·5		0·87	−0·005	0·023					
Broad-winged hawk	−2·9	−3·1	−2·74+	2·421	−12·054					
Swainson's hawk						1·39↑	0·029	−0·213+	−0·002	8·28
Red-tailed hawk	−1·8	−4·4+#	−0·04	−0·264	−2·033**	1·32↑	0·03	−1·075	0·003	0·65
Ferruginous hawk						2·47↑+	0·004	−0·015	0·001	2·36
Rough-legged hawk	−0·8	−8·7*	1·11	0·004	−0·010					
Golden eagle	10·8*	−7·4+	2·98	−0·010***	−0·071	8·23↓***	−0·002	−0·469*	−0·044*	−6·10
American kestrel	0·7	0·0	0·43	0·190***	−0·518**	0·91↓	−0·114***	−1·038	0·017	8·13
Merlin	9·4*	13·2**	14·24***	0·003	0·034	1·38↑	0·006*	0·021	0·0008	4·80
Peregrine falcon	27·8*#	6·1*	15·30*	−0·093***	0·004	4·90↑**	0·001	−0·057	0·003	−0·21
Prairie falcon						0·12↓	0·002	−0·002	−0·001	1·40

Statistical significance: $+0·05 < p < 0·1$, $*p < 0·05$, $**p < 0·01$, $***p < 0·001$, # = trend non-linear. All counts in autumn except Hawk Ridge, Grimsby, Minnesota and Sandia mountains, New Mexico.
[a]Trend calculated by logistic multiple regression (Hussell and Brown, 1992).
[b]Trend calculated by parametric route regression; see text for details of hawkwatch sites (Titus and Fuller, 1990).
[c]Trend calculated by linear regression (Bednarz *et al.*, 1990).
[d]Student *t* value comparing numbers between 1977–1979 and 1987–1990 (Hoffman *et al.*, 1992).
[e]Trend calculated by linear regression; Goshutes, Sandia mountains corrected for observer effort (Hoffman *et al.*, 1992).
[f]Trends calculated by linear regression, combined analysis from Goshute, Manzano, Sandia, Wellsville mountains (Hoffman *et al.*, 1992). Goshute and Sandia Mountains adjusted for number of observers.

Table 6. Percentage annual change in raptor populations (1969–1989) according to linear regression analysis of bird checklist data in Québec (l'étude des populations d'oiseaux du Québec [ÉPOQ]; source Cyr and Larivée, 1995)

Species	% Annual change	Correlation coefficients	Number of records
Turkey vulture	0·144***	0·73	873
Osprey	0·019	0·32	6741
Bald eagle	−0·008	−0·16	877
Northern harrier	0·013**	0·60	10,802
Sharp-shinned hawk	0·072*	0·53	4430
Cooper's hawk	−0·015*	−0·50	467
Northern goshawk	0·005	0·31	1510
Red-shouldered hawk	−0·003	−0·12	1,516
Broad-winged hawk	0·008	0·07	3,819
Red-tailed hawk	0·136**	0·64	4,968
Golden eagle	0·010	0·31	388
American kestrel	−0·020*	−0·49	15,734
Merlin	0·014	0·78	3,501
Peregrine falcon	0·011	0·57	1,296
Gyrfalcon	−0·011	−0·17	495

Statistical significance: $*p<0{\cdot}05$; $**p<0{\cdot}01$; $***p<0{\cdot}001$.

Although the regression coefficient over the 85–94 period was negative and marginally significant ($p=0{\cdot}08$), it was based on only 12 routes and was excluded by our criteria. At the ecozone level, a negative regression coefficient was found for the Montane Cordillera ecozone, but the same cautions apply as above. Interestingly, golden eagle also showed a marginally negative decline according to the CBC (Table 4). Golden eagle apparently increased at Niagara Peninsula, but at Hawk Mountain (1934–1986), the Wellsville mountains, Manzano mountains and Sandia mountains there were significant declines; the decline at Hawk Ridge, Duluth, was also marginally significant (Table 5). More recent analyses (up to 1995 or 1996) by Hawkwatch International indicate that slight declines have occurred only at the Wellsville mountains (Hawkwatch International, 1996). Given the 50-year count period, the decline at Hawk Mountain is especially notable. However, the evidence for declines is not supported by long-term breeding studies of Canadian populations or more recent eastern migration count data (see Discussion).

American kestrel is apparently stable or increasing (the BBS for the 66–94 period was marginally significant; Table 1). At the ecozone level, significant increases were found for the Prairies and Boreal Shield ecozones (the 66–94 period); however, there was a significant negative trend in the Mixedwood Plains ecozone for the 85–94 period (Tables 2 and 3). A marginally significant increase was found on CBC counts (Table 4). Migration count analyses were somewhat equivocal; the species increased significantly at Hawk Mountain over the long-term and also at the Goshute Mountains, but there was a decline at Hawk Mountain over the more recent period (1971–1986; Table 5). Interestingly, there was also a significant decline for American kestrel in Québec according to ÉPOQ, suggesting the possibility of declines in parts of eastern Canada (Table 6).

Merlin is increasing significantly judging by the BBS for Canada (Table 1); significant increases were evident for the 66–94 period in the Prairies ecozone, and there was a marginally significant increase in the Boreal Shield ecozone (Table 2). In the 85–94 period, the increase in the Boreal Shield ecozone was significant, but results for other ecozones indicated stable populations (Table 3). The CBC also suggested that populations are stable (Table 4), as did most migration counts (Table 5). However, there were significant increases at Grimsby, Hawk Ridge, the combined analysis of six eastern hawkwatches and the Goshute mountains in the west. Merlin is also stable in Québec (ÉPOQ; Table 6).

There are several special studies that have been initiated on raptor species that have low population numbers, on species that are declining or on species affected detrimentally by certain forestry or agricultural practices. Such studies provide some of the best data on their current local and sometimes regional population trends. The 1990 and 1995 peregrine falcon surveys indicated that populations of all subspecies are increasing or stable (Holroyd and Banasch 1996, in prep.). Surveys conducted once every five years, however, may miss the dramatic variability in occupancy rates and productivity typical of many northern peregrine falcon populations (Court *et al.*, 1990; G. S. Court, pers. comm.). The prairie falcon population is probably stable according to the continent-wide CBC and western migration counts. Long-term studies of gyrfalcons (Mossop and Hayes, 1994; Shank and Poole, 1994) suggest that populations are stable and that distribution and productivity fluctuate according to variation in prey availability.

There were relatively few data for owls compared to other raptors. As a result of research on barn owls in British Columbia, Andrusiak (1994) suggested that unless traditional grasslands (hay meadows) were retained in the lower mainland, there would be declines in populations. Recent research on flammulated owls has described the habitat requirements of the species, provided breeding density estimates and suggested that breeding success, and perhaps numbers, increase when there are high densities of a major prey species, the western spruce budworm (*Choristoneura occidentalis*) (van Woudenberg, 1992; D. Lowe, pers. comm.). Great horned owl was stable according to the Canada-wide BBS; there was a significant increase in the Prairies ecozone, but a significant decline in the Boreal Shield ecozone over the 66–94 period (Table 2). This species is increasing according to the CBC (Table 4). Northern hawk-owl showed a significant decrease on the CBC (Table 4). Burrowing owl decreased significantly over the 66–94 period for the BBS for Canada (Table 1); this decline was almost entirely attributed to the Prairies ecozone (Table 2), where studies have demonstrated a dramatic decline (Wellicome and Haug, 1995).

Although the CBC indicated that burrowing owl was stable (Table 4), this survey does not monitor Canadian owls that spend the boreal winter in Latin America. The BBS for Canada and continent-wide CBC indicated that barred owl was increasing (Table 1) or stable (Table 4); there was a significant increase in the Atlantic Maritime ecozone during the 66–94 period according to the BBS (Table 2). The great gray owl was stable over the long-term (BBS Canada and CBC; Tables 1 and 4). However, there was a highly significant decline in short-eared owl in the 66–94 period (BBS for Canada and in the Prairies and Boreal Plains ecozones separately; Tables 1 and 2). Interestingly, the CBC also indicated a significant long-term decline in this species (Table 4). The long-eared owl decreased significantly (BBS for Canada and CBC continent-wide; Tables 1 and 4). According to spring banding data from Whitefish Point, the proportion of boreal owls that migrate each year fluctuates (W. Grigg, pers. comm.), making it difficult to establish long-term trend estimates. Captures of northern saw-whet owls suggest that the species is abundant; recent use of broadcasts of conspecific vocalizations has resulted in up to 1000 owls caught each season at Little Suamico at Stevens Point in Wisconsin (T. C. Erdman, pers. comm.) and similar results have been found at Hawk Ridge, Duluth in Minnesota (D. L. Evans, pers. comm.). As in boreal owls, the proportion of individuals that migrate southwards may vary for different sex classes, depending on food availability and weather.

BBS analyses by ecozone

Below, we summarize BBS results by ecozone to investigate whether particular regions had patterns of declines or increases. There were few data for any species for the Pacific Maritime ecozone; both bald eagle and red-tailed hawk populations increased significantly in the 66–94 period (Table 2). During the 85–94 period, there were insufficient routes for any species to complete trend analyses.

Of the four species for which there were sufficient routes in the Montane Cordillera ecozone during the 66–94 period, all appeared to be stable, and none showed significant trends, except for the red-tailed hawk, which increased significantly (Table 2). There were data for only three species during the 85–94 period and all of these showed non-significant regression coefficients (Table 3).

In the Prairies ecozone, data were available for 10 species during the 66–94 period (Tables 2 and 3). Two diurnal owl species had significant negative trends. Red-tailed hawk showed a highly significant increase over the 85–94 period, but none of the other species that had significant trends during the 66–94 period did so during the 85–94 period. Strikingly, there was a highly significant negative trend in Swainson's hawk counts in the 85–94 period, corresponding with the recent productivity decline in long-term studies (see Discussion).

Of the seven species for which data are presented in the Boreal Plains ecozone in the 66–94 period, only the red-tailed hawk showed a marginally significant increasing trend (Table 2). However, two open country birds, the northern harrier and short-eared owl, showed significant long-term declines in this ecozone. Of the four species counted with sufficient routes in the 85–94 period, regression coefficients approached significance only for the red-tailed hawk (positive trend; Table 3). Although based on only nine routes and therefore excluded by our criteria from inclusion in the tables, there was a highly significant negative trend for the Swainson's hawk for the Boreal Plains ecozone during the 85–94 period ($-13{\cdot}94\%$ annual change, $p = 0{\cdot}0005$).

Of the nine species analyzed for the Boreal Shield ecozone in the 66–94 period, three increased significantly (turkey vulture, osprey and American kestrel; Table 2). Three other species showed statistically marginal increases ($0{\cdot}05 < p < 0{\cdot}1$); these were sharp-shinned hawk, red-tailed hawk and merlin. In only one species, great horned owl, were trends significantly negative. For the 85–94 period, both turkey vulture and merlin increased signficantly; the remaining six species were apparently stable (Table 3).

Apart from the turkey vulture, which increased significantly, all seven species in the Mixedwood Plains ecozone were apparently stable over the long-term (Table 2). While turkey vulture also increased significantly over the 85–94 period, there was evidence for decreases in red-tailed hawk (marginally significant decline) and American kestrel (significant decline) over the same period (Table 3).

Finally, of the eight species counted on sufficient routes in the Atlantic Maritime ecozone during the 66-94 period, regression coefficients were significantly positive for two: Osprey and barred owl (Table 2). All five species analyses for the 85–94 period for this ecozone indicated stable populations (Table 3).

DISCUSSION

We caution that there are considerable limitations to the data sources we have used. For example, the BBS provides limited quantities of data for assessing breeding raptor status (Fuller and Mosher 1987; Fuller *et al.*, 1987). Evans (1982) suggested that migration counts sometimes do not reflect real declines when these are known to have occurred, but this assessment was prior to the recent generation of migration count trend analyses; however, migration counts are confounded by numerous variables (Hussell, 1985). CBC data are essentially unstandardized, in terms of both coverage and observer numbers, and there are problems in determining the scale at which to conduct trend analyses. However, there are few sources of data, and we must rely on them to draw the preliminary conclusions presented below and in Appendix. We also suggest that despite the deficiencies of each monitoring method, taken together these sources may provide a useful indication of the status and population trends of many Canadian raptor species.

For an overview of the status of Canadian raptors, the population sizes presented are only coarse estimates, accurate only to an order of magnitude for all but the best-known species. According to the experts that we polled most raptor species in Canada number 10,000–50,000 pairs. The most abundant and widespread species likely number in the hundreds of thousands, whereas several species have populations of 5000 or fewer pairs (Appendix). Some of the smaller Canadian populations reflect their limited distribution in Canada (e.g. barn owl, flammulated owl, northern spotted owl), while others have reduced populations due to habitat loss (e.g. red-shouldered hawk, ferruginous hawk) or contaminants (e.g. peregrine falcon).

There is strong evidence for increases in turkey vulture populations from almost all data sources. These increases reflect the expansion in range of this species in northeastern North America during this century which is attributed to a variety of factors (see Appendix). However, the number of turkey vultures that breed in Canada is unknown and expansion areas may not involve successful reproduction (Kirk and Mossman, in press).

Osprey populations are increasing in most of Canada or stable in western and boreal regions. Evidence from long-term study populations in the Great Lakes also indicates that populations are increasing (Appendix). While artificial nest sites have aided this recovery (Houston and Scott, 1992; Ewins, 1996) and survey efforts have increased (Ewins, 1992), the ban on the use of OCs in North America since the early 1970s has facilitated most of the recovery in osprey populations.

Bald eagle populations showed long-term increases or stable populations. While the long-term analysis at Hawk Mountain was significantly negative, the more recent increase (1971–1986) is attributed mainly to immatures, suggesting that productivity recovered after the DDT era (Bednarz *et al.*, 1990). Although breeding populations have become re-established in southern Ontario, productivity is still low in these pairs because of industrial contaminants (Bowerman, 1993; Hunter and Baird, 1995). While productivity in parts of British Columbia is limited by food supply, exposure to contaminants may be contributing to low productivity in one area (Elliot, 1995). At Besnard Lake in northern Saskatchewan, where bald eagles were unaffected by OCs, populations have been stable over a 24-year period (Gerrard *et al.*, 1992).

Some northern harrier populations fluctuate in relation to microtine vole cycles (MacWhirter and Bildstein, 1996), so overall trends are difficult to detect. The species appears stable over the long-term according to most migration counts, but declines were evident for the Boreal Plains ecozone for the 66–94 period from the BBS. This supports impressions of naturalists of a decline in northern harrier in this ecozone in Alberta (Alberta Government, 1996). These declines may be related to the extent and intensity of agricultural changes, especially drainage of wetlands (Cadman, 1991).

Most results suggested that sharp-shinned hawk populations are increasing or stable. However, precipitous declines began at the Cape May Point hawkwatch in about 1986 (92% decline in hourly passage rates between 1979–1992), and less marked declines at Hawk Mountain in 1990 (23% decrease, 1979–1992) (Viverette *et al.*, 1996). Declines have also been found at other eastern hawk watch sites (Kellogg, 1993; Kerlinger, 1993), but not west of the Great Lakes (Chartier, 1994). Furthermore, because band recoveries indicate considerable geographic overlap between birds captured along Appalachian and coastal flyways and because Cape May Point birds include mostly juveniles (Clark, 1985), Goodrich and Struve (1993) suggested that declines in reproduction could be widespread in the source area of these flyways. Because sharp-shinned hawks feed largely on avian prey, they are vulnerable to contamination by OCs (Evans, 1982; Noble *et al.*, 1993). Interestingly, DDE levels in sharp-shinned hawk tissue samples collected from eastern migration count sites are higher than those found in western sites (Bohall Wood *et al.*, 1996). OCs and PCBs are present in adult sharp-shinned hawks (Bohall Wood *et al.*, 1996), and DDE is approaching the 15% critical level in some eggs collected from nests in the Bay of Fundy National Park (% Ratcliffe thinning, mean −11·01, range −5·3–18·3; Meyer, 1987; Woodley *et al.*, in prep.). The question of whether real declines have occurred or whether there has been a geographic shift in migration routes or changes in wintering distribution remains unresolved (Viverette *et al.*, 1996).

Most data sources suggest that Cooper's hawk is stable. Populations of this species were affected by DDT, and they have recovered since the 1970s. However, in the absence of long-term breeding studies from continuous forest and fragmented landscapes in different parts of Canada, it is difficult to assess trends or the status of this species. Rosenfield *et al.* (1991) believed that studies of breeding densities, productivity and reoccupancy rates were essential to establish the status of Cooper's hawk and suggested that national avian surveys such as the BBS do not give reliable results. In parts of its range, Cooper's hawk breeds in suburban habitats (Rosenfield and Bielefeldt, 1993), but these habitats may be suboptimal and breeding success may be low elsewhere (Bosakowski *et al.*, 1993). In Alberta, Cooper's hawks may breed much further north in the boreal mixedwood forest zone than previously believed (G. S. Court, pers. comm.; see Semenchuk, 1992).

Over most of Canada, northern goshawk populations fluctuate on an 8–11-year cycle in response to fluctuations in prey populations (Doyle and Smith, 1994; Boutin *et al.*, 1995). Thus data are needed over many cycles to distinguish long-term from short-term trends. If the populations of goshawks migrating through western hawk lookouts are cyclic then the short-term decreases in migration counts found by Hoffman *et al.* (1992) may reflect natural lows in populations. However, a more recent analysis over longer periods also shows a decrease in counts (Hoffman *et al.*, unpubl. data). Goshawks exhibit geographic variation in the extent of their movements; they are considered sedentary in the western United States (Palmer, 1988), but most Canadian and northern U. S. populations are cyclic and hawks migrate or die when prey populations crash (Doyle and Smith, 1994; Erdman *et al.*, in press; see Kirk, 1995*a* for review). There is concern over the Queen Charlotte Goshawk *A. g. laingi* because of its small population size and because it is vulnerable to loss of preferred old-growth habitat (Crocker-Bedford, 1994; Duncan and Kirk, 1995).

Although they are at the northern limit of their range in southern Canada, red-shouldered hawks are apparently stable according to all sources. However, they are affected negatively by timber harvest and fragmentation of landscapes, so special consideration must be given to them when planning timber harvests (Szuba *et al.*, 1991).

Broad-winged hawks may be declining according to some sources (e.g. some BBS data Table 3; migration counts, Table 5). However, it is unlikely that the BBS can adequately monitor the northern populations of a forest raptor such as the broad-winged hawk, although recent power analyses of continental BBS data suggest that the BBS is useful for this species (J. R. Sauer, unpubl. data). Evidence from the impressions of raptor banders in Alberta indicates declines in broad-winged hawk in aspen parklands, which are increasingly fragmented by agriculture and suburban development (Alberta Government, 1996). Mature aspen stands are important for broad-winged hawk in the boreal mixedwood region and optimal habitat is predicted to decrease by 88% within the next 300 years in the AlPac Forest Management Area according to timber supply simulations (Cumming *et al.*, 1994). Loss of optimal habitat and forest fragmentation as a result of logging may have detrimental consequences on broad-winged hawk populations elsewhere in North America and on the nonbreeding grounds (Goodrich *et al.*, 1996).

Whereas the long-term BBS analyses indicated that Swainson's hawks were stable, those for the 85–94 period indicated a highly significant decline in populations over the whole of Canada and for the Prairies ecozone. These results are not contradictory and agree closely with the timing of productivity declines in the prairies. Long-term breeding studies indicate dramatic declines, both in productivity and sometimes in adult breeding populations. During eight consecutive years, reproductive success fell well below average (1988–1995) and adult breeding numbers declined near Kindersley, Saskatchewan (Houston and Schmutz, 1995). The fact that these declines have also been recorded in another study in Saskatchewan, where occupancy of breeding territories has declined by 60% (W. C. Harris, pers. comm.), and near Hanna, Alberta—three widely separated populations (Kirk and Houston, 1995) is a cause for concern. While drought, declining ground squirrel (*Spermophilus* spp.) numbers, and agricultural intensification are doubtless contributory factors, pesticide poisoning on the nonbreeding grounds in the pampas of Argentina is strongly implicated in recent declines. In 1994, 702 dead Swainson's hawks were recovered at one roost in Argentina (Woodbridge *et al.*, 1995), and in January 1996 there was a kill of 4100 birds (Goldstein *et al.*, 1996). The total kill was estimated at over 20,000 and of 12 banded hawks, nine were from Canada. Interestingly, intensive pesticide use for grasshopper control in Argentina began in 1985 just prior to the productivity declines observed in Canadian hawks (P. Mineau, pers. comm.). It is possible that adult mortality during the austral summer has resulted in high turnover rates and increasingly younger, and therefore more inexperienced, breeders occupying territories and accounting for the subsequent low productivity (Kirk, in prep.).

Most data sources suggest that red-tailed hawk populations are increasing or stable. However, there was a marginally significant decline in the BBS in the Mixedwood Plains ecozone in the 85–94, period and there were conflicting trends in migration counts. Bednarz *et al.* (1990) proposed that conversion of pasturelands to residential development or intensive row-crop agriculture could explain declining counts at Hawk Mountain; another possible explanation is that increasing numbers are wintering in southern Ontario (Freedman and Riley, 1980). Red-tailed hawks may be increasing because of deforestation and agricultural intensification. In the Prairies, though, red-tailed hawk increased in the past because of planting of shelterbelts (Houston and Bechard, 1983), and this was reflected in the BBS for the Prairies ecozone.

The long-term BBS data and specific studies show that ferruginous hawk populations were stable or increasing in the Prairies ecozone. However, the populations are limited by available habitat, native pasture, which is decreasing in area and fragmented by intensive agriculture (Schmutz, 1984, 1993; Schmutz *et al.*, 1992). If habitat is indeed limiting, then perhaps the BBS is monitoring nonbreeding birds.

It is difficult to monitor populations of rough-legged hawk because the species breeds in the Arctic region; the number that winter in southern Canada is probably variable and depends on prey populations, snow cover and temperature. Numbers of breeding birds also fluctuate greatly from year to year (Mindell *et al.*, 1987; Mindell and White, 1988); when prey populations crash in Labrador, rough-legged hawks may breed in unusually high numbers in forest clear-cuts in the Western Newfoundland Model Forest (Whitaker *et al.*, 1996). Long-term data on breeding densities and productivity from the Northwest Territories suggest that populations are stable (C. C. Shank, unpubl. data).

Analyses of long-term migration count data from Hawk Mountain suggest that golden eagle populations may have declined in parts of eastern North America, despite the recent discovery of breeding birds in northern Québec (Morneau *et al.*, 1994) and the Labrador peninsula (J. Brazil, pers. comm.). Possible increases in Québec have been linked to increases in the caribou herd (Aubry and Bannon, 1995) but are more likely due to expanded coverage of the northern breeding areas, rather than actual population increases. Some western hawkwatches and the CBC suggest a decline, but at Hawk Mountain there has been an increase in the number of immatures. However, most eastern North American migration counts show recent increases in golden eagles on autumn migration. At Holiday Beach, Ontario, there were 145, 199 and 230 birds recorded for the years 1990, 1991 and 1992, respectively (Weir, 1991, 1992) and a record high fall combined total of 234 birds was made on all hawk stations across the province of Ontario in 1995 (Ridout, 1996). Some of these birds could be derived from western populations, as suggested for Hawk Mountain (Bednarz *et al.*, 1990). Somewhat contrary to the main data sources presented here, long-term productivity studies of golden eagles in the Northwest Territories indicate that populations were stable over a 14 year period (C. C. Shank, pers. comm.). The Yukon holds some of the highest numbers of golden eagles in North America (900–1000 pairs; D. H. Mossop, pers. comm.) and populations here are also stable; similarly, studies of 30 nests in southwestern Saskatchewan indicate little change in populations (W. C. Harris, pers. comm.). These studies suggest that, contrary to national surveys and some migration counts, Canadian populations are likely stable.

The American kestrel is one of the most common raptors in Canada, especially in the boreal forest (Bortolotti, 1994). While the reasons for the short-term decline in the BBS for the Mixedwood Plains ecozone and Québec's ÉPOQ remain uncertain, it is possibly due to loss of preferred old field and pasture habitats or perhaps afforestation (Bednarz *et al.*, 1990). Declines in migration counts may be attributed to the recent trend for more kestrels to winter further north, as for the red-tailed hawk (Freedman and Riley, 1980). Apparent declines in southern interior valleys in British Columbia remain unexplained (Bowling, 1995).

Merlin populations are also apparently healthy and increasing; this species has adapted well to urban habitats, where colonization began in the late 1960s or early 1970s (see references in Sodhi *et al.*, 1992, 1993). Although breeding densities in urban centres are now very high, local populations may be affected detrimentally by agricultural practices on the Great Plains (Sodhi *et al.*, 1993).

Apart from the long-term decrease at Hawk Mountain, migration counts suggest that American and tundra peregrine falcons are stable or increasing (differentiating the subspecies on migration counts is not reliable). Numbers of occupied sites in Canada have increased for both subspecies according to the most recent (1990 and 1995) peregrine falcon surveys (Holroyd and Banasch, 1996, in prep.). However, at least for tundra peregrine falcons, it is important to note that coverage, intensity of effort and timing of surveys have changed since the mid-1960s, when surveys began. For example, at Rankin Inlet, the area surveyed has expanded; thus, apparent increases in numbers of occupied territories in the early 1980s are due to coverage rather than an actual increase in breeding populations. However, since then, the study area and population have been relatively stable. Populations of tundra peregrine falcon have again begun to breed on the north slope of the Yukon. Peale's peregrine falcon populations are stable; however, the reduced seabird populations on the west coast of British Columbia may be currently limiting falcon populations, since they have not attained historical levels in some locations (e.g. Langara Island; Nelson, 1990; R. W. Nelson, pers. comm.).

Prairie falcon also appears to have stable populations, but habitat change, specifically loss of native grassland to agricultural cropland, may have caused population decreases in some areas (Fyfe *et al.*, 1969, 1976; Kirk and Banasch, 1996). Ground squirrels, which are a major prey item of prairie falcons, have declined recently because of loss of native grassland (Hunt, 1993). The prairie falcon is at the northern limit of its range in Canada, and populations are small (Appendix). Finally, long-term studies of gyrfalcon in the Yukon and Northwest Territories indicate that populations are stable (Mossop and Hayes, 1994; Shank and Poole, 1994). CBC data suggested a continent-wide increase in this species but this may be due to increased monitoring effort.

Few owls are well surveyed by the BBS or by migration counts. The best information comes from research on individual species, banding stations, CBCs and historical information contained in breeding bird atlases. While numbers of barn owls increased from the 1940s to the 1980s in British Columbia, due to mild winters and expansion of suitable agricultural habitat, they are expected to decline with increasing development (Appendix; Campbell and Campbell, 1984; Andrusiak, 1994). Any loss of habitat would exacerbate population decreases due to severe winters, which are an important mortality factor in British Columbia (Andrusiak, 1994). Previously thought to be very rare (McCallum, 1994), flammulated owl populations may currently be at high levels because of habitat suitability (old growth Douglas-fir [*Pseudotsuga menziesii*] with thickets of young trees and open grassy areas; van Woudenberg, 1992); however, this habitat may decline in quality because its existence is dependent on the fires that have been suppressed as part of modern forest policy (Appendix D. Lowe, pers. comm.). The species may be limited by nest site availability and suitable open old growth interspersed with young forest habitat. Flammulated owl apparently breeds in clusters of pairs, which has profound implications for its conservation (McCallum, 1994). Little is known about the status of the western screech-owl; although CBC data indicate an increase and data from British Columbia suggest it is stable (Campbell *et al.*, 1990), the species has possibly declined in coastal British Columbia and the Okanagan Valley because of habitat loss from commercial timber harvest or an expanding barred owl population (R. J. Cannings, pers. comm.; Cannings *et al.*, 1987; Kirk, 1995*b*).

Although we present few data for eastern screech-owl, the species appears to be common but frequently overlooked, and adapting to a variety of habitats in much of its range (Gehlbach, 1995); historically expansions in range have occurred in Ontario (Weir, 1987*a*). However, in Ontario, declines may have occurred in the south because of clearance of mature deciduous forest (Weir, 1987*b*). In Québec, the species was more abundant in the last century and is thought to have declined locally over the last 20 years due to loss of old orchards, loss of nesting sites (old trees) and possibly pesticide spraying in orchards (Ainley, 1995); eastern screech-owls are particularly susceptible to rodenticides (e.g. Hegdal and Colvin, 1988). The great horned owl is one of the few owl species that is recorded in any numbers on the BBS and appears to be stable or increasing; fluctuations in some provinces occur in relation to snowshoe hare (*Lepus americanus*) populations (Rohner, 1994; Houston and Francis, 1995). A large proportion of the population may be secretive floaters, which are not detected by most survey methods (Rohner, 1996).

Apart from the CBC, little information exists for several northern owl species whose populations fluctuate in relation to small rodent population cycles. For example, snow cover and food supply may determine the number of snowy owls wintering in the Great Plains, as suggested by Kerlinger *et al.* (1985) and Kerlinger and Lein (1988). Population trends for the northern hawkowl are almost impossible to determine, not only because of the remoteness of its northern breeding grounds, but also because of cyclic population fluctuations (Rohner *et al.*, 1995). However, anecdotal evidence suggests that compared with the numbers that moved southwards during periodic invasions in the 1800s and early 1900s, counts are now much reduced (perhaps due to shooting and incidental trapping; Duncan, 1991; Austen *et al.*, 1994), suggesting an overall decrease in Canadian populations. One hobby bander in Alberta, who has been banding hawk-owls for 20 years, also reported decreases over a 10 year period in his study area (Duncan, 1991). Very little is known about the northern pygmy-owl, which in Canada is almost entirely restricted to British Columbia (some also occur in Alberta); it is sometimes seen in numbers on CBCs (Campbell *et al.*, 1990). The burrowing owl is now listed by COSEWIC as endangered because of continued declines and the greatly reduced population (Wellicome and Haug, 1995; Haug *et al.*, 1993). Although coverage has increased the number of known northern spotted owl pairs in British Columbia, there is evidence that the population is much reduced from historical levels; the lack of old-growth forest at low elevations may have forced many pairs to breed in high elevation suboptimal habitat (Dunbar and Blackburn, 1994). There is further concern that breeding pairs are isolated and fragmented; Thomas *et al.* (1990) and Lamberson *et al.* (1994) suggested that units of 20–25 pairs are necessary for northern spotted owl populations to be viable.

It is difficult to determine trends for the great gray owl because of its multi-annual migrations in response to crashes in vole populations. However, some of the highest densities in North America occur in Manitoba (Duncan, 1992). Timber harvest has positive effects on foraging habitat but may have reduced nesting habitat (Duncan, 1992; Duncan and Hayward, 1994). Barred owl populations are stable or increasing according to most sources. In parts of the barred owl's range, it has been suggested that they prefer old mixedwood forests and so might be impacted negatively by timber harvest (e.g. Saskatchewan, James, 1993; Alberta, G. S. Court in Hannon *et al.*, 1995); in the Maritimes, however, where there was a positive increase on the BBS, they are apparently found in younger forest types (Elderkin, 1987). Very little is known about the long-eared owl in Canada; the species is probably more widespread than believed, since it is so secretive (e.g. in the Maritimes, Erskine, 1992), yet both the long-term BBS for Canada and the continent-wide CBC suggest significant declines in long-eared owl. Henderson and Barnhurst (1995) suggested that although the species may have declined because of agricultural practices causing the loss of woodlots and hedgerows over the last 40 years, tree plantations have been beneficial. CBC data (1956–1986) from New Jersey also suggested a decrease in the numbers of long-eared owls using traditional roosts (Bosakowski *et al.*, 1989).

On the other hand, the short-eared owl is definitely decreasing in much of its North American range and significant declines were found for the BBS in the Prairies and Boreal Plains ecozones. These ecozones are considered the core of the species' range in Canada by some authors (e.g. Cadman, 1993), but little is known about the northern population (J. R. Duncan, pers. comm.). Once an uncommon summer resident in the grasslands of Saskatchewan, the short-eared owl is now rare in most areas, other than, for example, Last Mountain-Quill Lakes (Smith, 1996). Similarly, CBC data over a 16-year period (1972–1987) indicate a decline in peak numbers in the lower mainland of British Columbia (Campbell *et al.*, 1990). However, fluctuations in numbers of owls that occur during both winter and summer because of prey cycles could partially obscure population trends in this species (Holt and Leasure, 1993). Boreal owl breeding densities fluctuate in relation to vole populations, making trends difficult to determine (Kirk, 1995*c*). Because the species prefers old and mature forest types elsewhere in its range (e.g. Idaho, Hayward and Hayward, 1993), studies are needed of breeding densities and reproductive success in different forest types to determine their habitat requirements (Kirk, 1995*c*). Unfortunately, boreal owls have not been enticed to use nest boxes on a large scale as they do in Finland, presumably because natural cavities are not limiting (S. Bondrup-Nielsen and J. R. Duncan, pers. comm.). Standardized data from banding stations, particularly Whitefish Point in Michigan, could be very useful in examining long-term trends (Carpenter, 1987; Grigg, 1990, 1993). This is also true for the northern saw-whet owl, which is banded in very large numbers at Great Lakes banding stations and in the eastern United States.

The significance of population changes

Distinguishing long-term trends in raptor population size from yearly variation and fluctuation is a major obstacle for assessing status. For many species, the available data include so much variability that they preclude determining population size and trend. Detailed, long-term breeding studies (>20 years in duration), such as those on the bald eagle (Gerrard *et al.*, 1992), Swainson's hawk (Houston and Schmutz, 1995) and northern goshawk (Erdman *et al.*, in press), are useful for identifying sources of variability. Although shorter-term initiatives (10 years or less) such as those at the Kluane Lake Boreal Forest Ecosystem project in the Yukon (Krebs *et al.*, 1992) and those that are part of model forest projects (e.g. Bay of Fundy, New Brunswick, or the Foothills Model Forest in Alberta) were not initiated to examine population trends of raptors, they provide useful information on breeding densities and abundance patterns, particularly of species whose populations fluctuate cyclically. For such species, long-term data are needed to assess whether the magnitude of highs and lows in the population has declined. Clearly, a long-term decline in golden eagle populations over a 50-year period would be a cause for concern, whereas a five-year decline in a great horned owl population would probably reflect cyclic fluctuations in response to snowshoe hare abundance. A second factor to consider in relation to the significance of population change is the species' body size, which is generally inversely related to its breeding densities. Because larger raptors tend to have lower breeding densities, take longer to reach the age of first breeding, take longer for each successful breeding attempt and produce fewer eggs and young (Newton, 1979), they might take longer to recover from population declines. Although many of these species probably have large populations, the potential for declines in 'common' species may be just as great as in rare ones (e.g. European sparrowhawk *Accipiter nisus*; Newton, 1986). From the perspective of monitoring, a more important point is that it might be more difficult to detect a population decline in these species.

CONCLUSIONS AND RECOMMENDATIONS

We caution that, for at least one-third of raptors, there are inadequate population data for Canada. These species include the accipiters, broad-winged hawk and most owl species. Of the 21 diurnal raptor taxa examined (merlin subspecies were combined in this analysis), eight have apparently increased since the 1970s, while nine more appear stable over the long-term (Appendix 1). Burrowing and short-eared owls declined, and possible evidence for decline was found for three other species: Sharp-shinned hawk, broad-winged hawk and Swainson's hawk. Northern harrier declined in the long-term BBS for the Boreal Plains ecozone, and red-tailed hawk and American kestrel for the short-term BBS for the Mixedwood Plains ecozone. In addition, the Queen Charlotte Goshawk is on the red list in British Columbia (Harper *et al.*, 1994), has a very low population (75 pairs), is threatened by loss of preferred old growth habitat (BC Ministry of Environment, Lands and Parks Ministry of Forests, 1994) and has been designated 'vulnerable' in Canada (Duncan and Kirk, 1995).

It is almost 20 years since Fyfe's (1976) summary of Canadian raptors. Several species that Fyfe reported as declining (e.g. bald eagle and red-shouldered hawk in Ontario and southern Québec) have undoubtedly increased or are stable. The recovery of the *anatum* peregrine falcon subspecies is a remarkable success; it was listed as extirpated (Maritimes, Ontario and southern Québec) or declining (Prairies, Yukon and NWT) by Fyfe (1976). However, a number of other species that Fyfe suggested were declining or stable have since continued to decline (e.g. Swainson's hawk and burrowing owl in the prairies). In total, we suggest that of the 37 Canadian raptor species and subspecies examined here, 17 are increasing or stable. However, three species are declining, six species are declining or stable, two species show decreases in parts of their ranges but are generally increasing, and nine species are fluctuating or possibly stable. For many species (at least five diurnal raptors and eight owl species) there is insufficient information to be confident about population trends, and for some of the remaining species data may be inadequate (Appendix). Special monitoring efforts may need to be instigated for species not sampled adequately by multiple sources, in particular accipiters, forest-dwelling buteos (especially broad-winged hawk) and owls. We believe that contaminants in sharp-shinned hawk, possible declines in broad-winged hawk and productivity declines in Swainson's hawk merit serious attention by researchers and managers. It is important that research be carried out to identify factors contributing to declines in Swainson's hawk. In particular, the effects of agricultural change and increased applications of new pesticides, which have both lethal and sublethal effects, need to be investigated for raptors in the Prairie provinces. This is important for all species that are declining in the prairie grasslands (i.e. burrowing owl, short-eared owl) and Boreal Plains ecozone (i.e. northern harrier). Given the extensive impact of timber harvesting in the vast boreal region of Canada (e.g. Court and Hannon, 1995), we recommend that further monitoring research be initiated on forest raptors that might be affected by logging (e.g. northern goshawk, red-shouldered hawk, broad-winged hawk, barred owl, boreal owl, northern saw-whet owl). There is sufficient evidence that timber harvest has negative impacts on some of these species elsewhere in their ranges (Cannings, 1993; Hayward and Hayward, 1993; James, 1993; Duncan and Kirk, 1995; Kirk, 1995*a*), so research and monitoring is needed on these species in Canada. Finally, and in some cases equally importantly, we recommend that studies be initiated on distribution, numbers, habitat use and prey populations of 'Canadian' subpopulations on their nonbreeding grounds in Mexico, Central America and South America (Senner and Fuller, 1989). To identify nonbreeding areas techniques such as satellite radiotelemetry will likely prove invaluable.

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APPENDIX

Table A1. Summary of population status and trends for 37 Canadian raptors

Species	Population size (pairs) and trend[a]	COSEWIC status	General comments	Fyfe's (1976) assessment[b]
Turkey vulture *Cathartes aura*	5,000–20,000 Increasing or stable		Expanding range in northeastern North America likely due to increased availability of roadkills, increase in white-tailed deer *Odocoileus virginianus* populations, deterioration of habitat in southern range or climatic change (Wilbur, 1983; Kirk and Mossman, in press)	
Osprey *Pandion haliaetus*	10,000–12,000 Increasing or stable		Annual increase 15·1% in Georgian Bay area (1974–1991); Kawartha Lakes 10·3% (1981–1991); Osprey populations generally recovering after OC era (Ewins, 1992)	Stable
Bald eagle *Haliaeetus leucocephalus*	15,000–20,000 Increasing or stable?	Not at risk 1984	Most populations increasing or stable, but southern Great Lakes (SW Ontario) birds still affected by contaminants (Bowerman, 1993) and some populations in British Columbia (Elliot, 1995)	Stable Decline ONT, southern QUÉ
Northern harrier *Circus cyaneus*	20,000–50,000 Stable or declining?	Not at risk 1991	Declining in one of strongholds in Boreal Plains ecozone probably due to agricultural intensification (Cadman, 1991) Increase in Québec (ÉPOQ)	Fluctuating; stable ONT, QUÉ; decline MAR
Sharp-shinned hawk *Accipiter striatus*	500,000–1,000,000 Increasing (BBS) or stable or declining (hawkwatches)?	Not at risk 1986	Possible declines in Atlantic Canada (eastern United States) attributed to budworm cycles affecting prey, acid rain reducing primary production, insect abundance, causing decreases in passerine prey and thus reducing productivity of hawks, OC contamination or changes in geographic winter distribution. Migration count data contradictory; eastern look-out with largest concentrations showed long-term declines since 1986, also declines at other hawk watches (Viverette *et al.*, 1996), elsewhere increasing or stable (Grimsby, Ont., western hawkwatches)	Stable or unknown (NWT), slight decline or stable (ONT, PQ)
Cooper's hawk *Accipiter cooperii*	10,000–50,000 Stable?	Not at risk 1996	Data suggest populations stable; increasingly breeds in suburban or other disturbed habitats (Rosenfield and Bielefeldt, 1993), but in some areas this may reflect lack of suitable habitat, not that species is doing well in these habitats (Bosakowski *et al.*, 1993)	Stable or unknown (MAR); slight decline or stable (ONT, QUÉ)
Northern goshawk *Accipiter gentilis*	10,000–50,000 Fluctuating, stable?	Not at risk 1995 *laingi* vulnerable	Populations cycle with prey abundance thus populations trends are difficult to track. Few data on nesting densities, productivity, re-occupancy rates (but see Doyle and Smith, 1994); *laingi* subspecies may be affected by forestry (Duncan and Kirk, 1995)	Cyclic, fluctuating (NWT, YUK), stable BC MAR
Red-shouldered hawk *Buteo lineatus*	2000–5000 Stable	Not at risk 1996	Probably stable according to migration counts, BBS; special surveys by Ontario Ministry of Natural Resources in Ontario provide best information on trends but as yet few years available	decline (ONT, QuÉ) unknown (MAR)
Broad-winged hawk *Buteo platypterus*	500,000–1,000,000 Declining or stable?		Some evidence that the species is declining; most migration counts were negative. Possibly declines because of timber harvest; study needed of impact of forest cutting. Melanistic form in Alberta vulnerable; could be used to monitor western Canadian boreal populations at hawkwatches (G. Court, pers. comm.)	Stable (PRA, ONT, QUÉ, MAR)

Swainson's hawk *Buteo swainsoni*	20,000–50,000 Declining		Productivity (ratio young produced per successful nest) decreased 1988–1993 in southern Saskatchewan and near Hanna, Alberta (Houston and Schmutz, 1995). BBS for Prairies ecozone shows highly significant decrease during 1985–1994	Decline or stable (PRA), unknown (BC)
Red-tailed hawk *Buteo jamaicensis*	500,000+ Increasing (declines in parts east?)	Not at risk 1995	Increasing due to forest clearance (Preston and Beane, 1993); increases in prairies due to afforestation (Houston and Bechard, 1983). Possible decreases in parts of east (Mixedwood Plains ecozone)	Stable or increasing (ONT, QUÉ)
Ferruginous hawk *Buteo regalis*	2000–4000 Stable	Threatened 1988	Probably stable or increasing in available habitat (Schmutz, 1993), but this habitat may be decreasing in suitability	Stable
Rough-legged hawk *Buteo lagopus*	10,000–25,000 Fluctuating, stable?		Numbers fluctuate with prey populations	Fluctuating (NWT, YUK)
Golden eagle *Aquila chrysaetos*	2000–10,000 Stable or declining?	Not at risk 1996	Some data sources suggest declines (e.g. two eastern and 3 western hawkwatches); however, recent increases in eastern hawkwatches and large numbers near Calgary, Alberta (6000 + birds on fall migration; P. Sherrington pers. comm.). Long-term productivity data from Northwest Territories, Yukon and Saskatchewan show no decline (C. Shank, D. Mossop, W. Harris, pers. comm.). Recent discovery of 20 nesting areas Hudson Bay, northern Québec (Morneau *et al.*, 1994, 28 pairs Labrador peninsula (J. Brazil pers. comm.). In BC may increase due to forest cutting (Campbell *et al.*, 1990)	Stable Unknown (ONT, QUÉ, MAR)
American kestrel *Falco sparverius*	500,000 + Stable or increasing (declines in parts east?)		Very common raptor, especially in boreal forest and to a lesser extent prairies. May be increasing in boreal forest as a result of clear-cutting (e.g. Whitaker *et al.*, 1996). Possible declines in parts of east (Mixedwood Plains) and west	Stable increasing (BC)
Merlin *Falco columbarius* (*F.c. columbarius*, *F.c. richardsonii*, *F.c. sucklei*)	10,000–100,000 Stable or increasing	Not at risk 1985	This species is increasing and adapting to urban habitats (Sodhi *et al.*, 1993; P. James, pers. comm.)	*F.c.c.* unknown (NWT, YUK), decline or stable (ONT, QUÉ); *F.c.r.* increasing (PRA); *F.c.s.* unknown (BC)
American peregrine falcon *F.p. anatum*	400–800 Stable or increasing	Endangered 1978	Increase in number of known nesting sites 1970–1990 (Holroyd and Banasch, 1996, in prep.). May still be at risk from OCs on migration and wintering areas.	Declining Extirpated (ONT, QUÉ, MAR), unknown (BC)
Tundra peregrine *F.p. tundrius*	800–2000 Stable or increasing	Vulnerable 1996	Populations increased since 1980s in northern Québec and Canadian Arctic (Bird and Weaver, 1988; Bromley, 1988). Apparent increase Rankin Inlet population 1980–1990 (Holroyd and Banasch, 1996, in prep.) due to increased coverage; less than half area surveyed in 1980 compared to 1990. Birds subject to disturbance. Coppermine and Hope Bay there have been significant increases in occupied territories (Shank *et al.*, 1993)	Declining

(*Continued*)

Table A1—*continued*

Species	Population size (pairs) and trend[a]	COSEWIC status	General comments	Fyfe's (1976) assessment[b]
Peale's peregrine falcon *F.p. pealei*	50–100 Stable or increasing	Vulnerable 1978	Population on Langara Island, British Columbia, stable (Nelson, 1990), probably limited by seabird prey populations, which have declined (e.g. Ancient Murrelet *Synthliboramphus antiquus*) (R. W. Nelson, pers. comm.)	Slight decline
Gyrfalcon *Falco rusticola*	1500–3000 Stable	Not at risk 1987	Breeds in remote Arctic regions not badly affected by habitat loss or pesticides. Recent 10 year study (1982–1991) in NWT showed no change in population trends or productivity (Shank and Poole, 1994). 1986–1991, nest chronology in Yukon advanced possibly due to climatic change (Mossop and Hayes, 1994)	Stable
Prairie falcon *Falco mexicanus*	500 Stable?	Not at risk 1996	Small, stable or possibly increasing population of this species in Canada (Semenchuk, 1992). Study of occupied nests along the Bow River in Alberta (1974–1989) indicated nonsignificant decrease from 18 to 13 pairs coincident with an increase in the areas of cultivated land surrounding nest sites (Hunt and Holroyd, unpubl. data). Species is on red list in British Columbia (Harper *et al.*, 1994)	Decline (BC), stable or increasing (BC)
Barn owl *Tyto alba*	250–750 Stable or fluctuating?	Vulnerable 1984	Main population in BC vulnerable to agricultural intensification, main mortality due to severe winters; also high roadkill mortality (Andrusiak, 1994). Possibly 6 pairs in Ontario atlas, 13 sites reported to Ontario Rare Breeding Bird Program (ORBBP), most from Carolinian forest region; decreases in numbers of owls since 1980s in Winsor-Hamilton brought to rehabilitation centres (Austen, *et al.*, 1994)	Unknown or expanding locally (BC)
Flammulated owl *Otus flammeolus*	1500 Stable?	Vulnerable 1988	Western spruce budworm *Choristoneura occidentalis* outbreaks may increase fledging success and perhaps local numbers (D. Lowe, pers. comm). Dense thickets of regenerating Douglas-fir *Pseudotsuga menziesii* required for security against predators adjacent to open areas for foraging; also large trees with Pileated Woodpecker *Dryocopus pileatus* or Northern Flicker *Colaptes auratus* cavities (Howie, 1987; van Woudenberg, 1992; D. Low, pers. comm.)	Unknown
Eastern screech-owl *Otus asio*	10,000–50,000 Stable	Not at risk 1986	Common and adaptable species (Gehlbach, 1995) occurring in eastern and central Canada. Second most abundant species on CBC 1980–1990 in Ontario (1·85 owls/party hour, total of 358 owls; Shepherd, 1992). May have declined locally in Ontario (Weir, 1987) and in Québec (Ainley, 1995)	Stable (ONT, QUÉ)
Western screech-owl *Otus kennicottii*	1000–2000 Stable?	Insufficient information 1995	Little known about this species but may have declined (R. Cannings, pers. comm.). Declined in SW states due to loss of riparian habitat (Johnson-Duncan *et al.*, 1988 in Johnsgard, 1988)	Stable
Great horned owl *Bubo virginianus*	100,000–500,000 Fluctuating or increasing		Generally abundant and increasing species. Most abundant species recorded on CBC in 1989–1990 in Ontario (2·40 owls/party hour; total owls 465; Shepherd, 1992)	Stable, stable or increasing (ONT, QUÉ)
Snowy owl *Nyctea scandiaca*	10,000–30,000 Fluctuating	Not at risk 1995	Breeding densities fluctuate according to Arctic prey populations. Variation in numbers on wintering grounds due to snow cover and food supply (Kerlinger *et al.*, 1985). CBCs (1961–1984) > 2·25 owls per count, recorded on 75% of all years (Kerlinger *et al.*, 1985; Kerlinger and Lein, 1988)	Fluctuating

Northern hawk-owl *Surnia ulula*	10,000–50,000 Fluctuating, stable	Not at risk 1991	Population status and trends almost impossible to determine because of remoteness of breeding habitat from human populations and cyclic fluctuations/irruptive movements (Duncan, 1991; Duncan and Duncan, in press). Numbers of birds involved in invasions declined (e.g. 1962–1963, 1991–1992; Duncan, 1991). Shooting probably greatest threat (e.g. Ontario; Austen *et al.*, 1994)	Fluctuating Unknown (MAR)
Northern pygmy-owl *Glaucidium gnoma*	2000–10000 Stable?		Very little known about population status or trends (Reynolds *et al.*, 1989). Only 5 nests found in British Columbia; total 23 breeding records, 1576 nonbreeding records (Campbell *et al.*, 1990). Alberta atlas found 25 nests, with 9 confirmed breeding (Semenchuk, 1992). May be dependent on old-growth forests (Lehmkuhl and Ruggiero, 1991)	Stable
Burrowing owl *Speotyto cunicularia*	1000 Declining	Endangered 1995	Population continues to decline, ultimate reasons uncertain. High adult mortality indicated by banding returns. Habitat not limited in some parts breeding range. Overwintering mortality in Mexico and South America may be contributing factor (Wellicome and Haug, 1995)	Declining Stable (PRA) declining MAN
Northern spotted owl *Strix occidentalis*	10–100 Declines from historical levels	Endangered 1986	Most recent surveys (1989–1993) indicate there were 39 active sites in 892·7 km^2, total population for BC estimated at 100 pairs (Dunbar and Blackburn, 1994). May have declined at Squamish and Whistler. High-elevation forest inhabited because of lack of old-growth at lower elevations. Threat from increasing Barred owl population (Dunbar and Blackburn, 1994)	Declining
Barred owl *Strix varia*	10,000–50,000 Stable or increasing		Sedentary species, breeding densities fluctuate in relation to prey (Elderkin, 1987). Preference for mature or old-growth forests for nesting in parts of range, thus populations possibly affected by timber harvests (e.g. Alberta—G. Court, pers. comm.; Saskatchewan, James, 1993)	Unknown or Increasing (ONT, QUÉ) Stable (MAR)
Great Gray owl *Strix nebulosa*	10,000–25,000 Fluctuating, stable	Not at risk 1996	Multi-annual migrations in response to crashes in vole *Microtus* spp. populations cause apparent population cycles (Duncan, 1992). Trends difficult to determine. Breeding density varies greatly from 1·88 owls km^2 in Manitoba (Duncan, 1992) to 0·74 or 1·72 km^2 in Oregon (Bull and Henjum, 1990)	
Long-eared owl *Asio otus*	10,000–20,000 Stable or declining?		Numbers fluctuate cyclically with vole *Microtus* populations, so population status and trends difficult to determine. Breeding bird atlases indicate low density of this species Erskine, 1992; Weir, 1987*b*; Austen *et al.*, 1994; Henderson and Barnhurst, 1995), but frequency at Great Lakes banding station and winter roosts of 50–75 birds (Shepherd, 1992) indicate more abundant. Breeding population estimated 219–370 pairs in Ontario (Austen, *et al.* 1994). Special surveys of calling young in June and July have met with great success in Quebec (Savard *et al.*, 1995)	Unknown (BC) Fluctuating
Short-eared owl *Asio flammeus*	20,000–40,000 Declining	Vulnerable 1994	Population status and trends difficult to determine due to cyclic fluctuations in relation to vole abundance (Cadman, 1993). However, all data point to long-term decline, including breeding bird atlases and provincial bird accounts. Declines occurring in one population centre in prairies (Semenchuk, 1992; Smith, 1996)	Fluctuating
Boreal owl *Aegolius funereus*	20,000–100,000 Fluctuating, stable?	Insufficient information 1995	Population status and trends difficult to assess because of cyclic fluctuations and irruptive movements in response to prey (Lane *et al.*, 1993). Few data on breeding densities (e.g. Bondrup-Nielsen, 1976; Duncan and Duncan, 1994). Analysis of standardized banding data from Whitefish Point (W. Grigg, unpubl. data) could provide population trends. Cutting of old mixedwoods in boreal forest is a concern (G. Court and J. Duncan, pers. comm.)	Unknown (BC), fluctuating

(Continued)

Table A1—*continued*

Species	Population size (pairs) and trend[a]	COSEWIC status	General comments	Fyfe's (1976) assessment[b]
Northern saw-whet owl *Aegolius acadicus*	50,000–150,000 Fluctuating, stable?		Irregular movements occur in response to fluctuations in food supply, making estimates of population status or trends difficult. Analysis of standardized banding data from Duluth, MN, may contribute to trend estimates. Breeding studies needed. *A. a. brooksi* subspecies in Queen Charlotte Islands, British Columbia was found only in pockets of old growth; may be vulnerable (Cannings, 1993; R. Cannings, pers. comm.)	Stable Unknown (ONT, QUÉ)

[a]See Methods. This represents best estimate of number of breeding pairs according to authors, based on available data; for all species consensus estimate reached with exception of following; Osprey (Poole, 1989); Ferruginous hawk (Schmutz, 1993); Peale's peregrine falcon—counts of nest sites (R. W. Nelson, pers. comm.); Barn owl (count of nest sites; Andrusiak 1994, Austen *et al.*, 1994); Flammulated owl (extrapolation from sampled area, British Columbia; D. Lowe, pers. comm.); Burrowing owl (Burrowing Owl Recovery Team; Wellicome and Haug, 1995); Northern spotted owl (Dunbar and Blackburn, 1994).

[b]MAR = Maritimes; QUÉ = Québec; ONT = Ontario; PRA = Prairies; BC = British Columbia; YUK = Yukon; NWT = Northwest Territories.

[c]'Species to watch' were considered 'not at risk' by COSEWIC but have small populations and/or some evidence for declines (Sharp-shinned hawk, Cooper's hawk, Red-shouldered hawk, Golden eagle, Prairie falcon, Northern hawk-owl, Great gray owl).