Population Assessment of the Northern Spotted Owl in British Columbia 1992-2001

Ian R. Blackburn, Ministry of Water, Land and Air Protection

Alton S. Harestad, Simon Fraser University

James N. M. Smith, University of British Columbia

Stephen Godwin, Ministry of Water, Land and Air Protection

Reed Hentze, B.C. Conservation Foundation

Carla B. Lenihan, Ministry of Sustainable Resource Management

Abstract

In 1997, the Spotted Owl Management Plan was implemented in British Columbia to prevent the extirpation of this Endangered species from Canada. This plan currently maintains an average 62% (+/- 15% SD, n = 101) suitable habitat for Spotted Owls within 101 Long-term Activity Centres distributed among 21 Special Resource Management Zones (SRMZs) totaling 363,000 ha in the Chilliwack and Squamish Forest Districts. The long-term goal of the Spotted Owl Management Plan is to maintain eventually a minimum of 67% suitable habitat within these Long-term Activity Centres and thus stabilize the owl population. We monitored the occupancy of Spotted Owls within 40 survey areas inside and outside SRMZs between 1992 and 2001. We compared the change in occupancy observed during the study with the slow population decline predicted by a spatially-explicit simulation model used to assess the Spotted Owl Management Plan. Within our survey areas, Spotted Owl occupancy declined by 49% between 1992 and 2001. The average annual rate of decline was -7.2% (+/- 1.7%, 90% C.I.). This rate of decline is 4.8 times faster than the rate predicted by the spatially-explicit model. The substantial decline in numbers of Spotted Owls between 1992 and 2001 has occurred despite protection of suitable habitat during a large portion of the 10-year study within 39 of the 40 survey areas and SRMZs. Our results suggest that this decline may have slowed in recent years, possibly in response to these habitat protection measures. If we assume that the study area is representative of the entire Spotted Owl population in B.C., then the number of Spotted Owls in B.C. is not stable, but has declined sharply over the past 10 years. We estimate that fewer than 50 breeding pairs of Spotted Owls occur within British Columbia. Despite the slowed population decline observed in recent years, our results suggest that the current suitable habitat levels protected in SRMZs under the Spotted Owl Management Plan are inadequate to stabilize the owl population, and we expect the population to decline further over the next few decades. Our results suggest that the Spotted Owl population in B.C. is at a greater risk of extirpation than originally anticipated. Additional management actions are necessary to prevent extirpation and conserve the Spotted Owl in Canada.

Introduction

The Northern Spotted Owl (*Strix occidentalis caurina*) is closely associated with old and mature forests in the Pacific Northwest from northern California to the southwestern mainland of British Columbia (SORT 1994). Loss of suitable habitat and forest fragmentation due to urbanization, industrial forest uses, and natural disturbances are thought to be the greatest threat to the Spotted Owl (SORT 1994). The historic (pre-European settlement) Spotted Owl population in B.C. may have been as many as 500 breeding pairs[1]. In 1991, less than 100 breeding pairs were estimated to occur within the province (Dunbar *et al.* 1991). Due to the small known owl population, the species' dependence on old and mature forests, and the continued loss of these forests, the Spotted Owl was designated as nationally Endangered in 1986 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2000). This designation means that the species is threatened with imminent extirpation throughout all or a significant portion of its range in Canada. The owl is also provincially Red-listed as a candidate species eligible for legal designation as Threatened or Endangered under the *B.C. Wildlife Act* (BC Conservation Data Centre 2001). In 1990, the Northern Spotted Owl was listed as Threatened under the *U.S. Endangered Species Act* throughout the species' entire range in the United States.

Adult Spotted Owls (>2 years old) are long-lived territorial birds that generally remain resident within the same geographic area throughout their lives. Based on demographic studies in the United States, female owls produce 2 juveniles on average every 2 years. About 25% of juveniles survive their first year. However, juvenile survivorship has been reported to be as low as 14% in some regions of Washington State (Franklin *et al*. 1999). Subadult owls (1 and 2 years old) usually join a pool of non-territorial "floater" owls, which search for vacant habitats as territorial owls die or move to other areas (USDI 1992).

In 1997, the B.C. Government approved the Spotted Owl Management Plan for the Chilliwack and Squamish Forest Districts (SOMIT 1997). The goal of the Plan is to provide a reasonable chance for the owl population to stabilize and possibly increase over the next 100 years. The Plan protects Spotted Owls and their habitat within 363,000 ha of forested land in 21 Special Resource Management Zones (SRMZs) that overlap existing protected areas and about 18% of the Timber Harvesting Land Area in the 2 forest districts. An objective of the Plan is to maintain or recruit a minimum target of 67% suitable habitat[2] within each of the 101 Long-term Activity Centres[3] in SRMZs. On average, Long-term Activity Centres currently comprise about 62% (+/- 15% SD, n = 101) suitable habitat. Forty-four Long-term Activity Centres are currently below the 67% suitable habitat target. Achieving the 67% suitable habitat target within these 44 Long-term Activity Centres will occur over the next 60 years as young forests naturally, or through habitat enhancements, mature and develop suitable habitat conditions (SOMIT 1999).

[1] Historic population estimate = [(total capable forested area below 1,380 m elevation in the Chilliwack and Squamish Forest Districts and Lower Mainland area)] / [(3,200 ha annual home range) x (75% to account for overlapping annual home ranges)]. This analysis assumes 60% - 67% historic levels of suitable habitat in these landscapes (Government of British Columbia 1995).
[2] Suitable habitat is defined as forests older than 100 years, taller than 19.3 m, and below 1,380 m in elevation.
[3] Each Long-term Activity Centre approximates the median 3,200-ha annual home range size of a pair of Spotted Owls.

The Spotted Owl Management Plan is based, in part, on the hypothesis that the Spotted Owl population will eventually stabilize and increase over the next 100 years as the amount of suitable habitat first stabilizes and then increases in SRMZs. A spatially-explicit simulation model was used to assess the Spotted Owl Management Plan. The model predicted that Spotted Owl numbers would decline over the initial 20-year period by about 25% at an average annual rate of -1.5% (Blackburn 1996). This anticipated decline is thought to be in response to further habitat loss inside and outside of SRMZs. After 20 years, the model predicted that Spotted Owl numbers would stabilize and then increase over the next 80 years as habitat recruitment occurs within SRMZs. The Spotted Owl Management Plan was assessed as providing a 60% chance of "stabilizing" the Spotted Owl population over the next 100 years (SOMIT 1997).

Demarchi (1998) used the same spatially-explicit simulation model and examined an alternative hypothesis that suggests the Spotted Owl Management Plan is not needed because the owl population will stabilize despite continued timber harvesting in the 2 forest districts. He suggests that the expected time for the species to recover is related to the level of timber harvest and that decreasing the annual rate of timber harvest will shorten the time required for the Spotted Owl to recover. However, he also points out that maintaining the annual rate of timber harvest without adjusting this rate to account for new habitat protection measures for Spotted Owls inside SRMZs will increase the loss of habitat outside SRMZs. As a result, this loss of habitat may decrease dispersal success of Spotted Owls and increase the time required to recover the species. Conversely, Hodum and Harrison (1997) suggest that the Spotted Owl Management Plan may be a prescription for extirpation of the species. Their conclusion is based on the small number of breeding owls maintained in SRMZs, the poor habitat connectivity between SRMZs, the high level of timber harvest activity allowed in SRMZs, and the lack of protection of Spotted Owls and their habitat outside SRMZs.

Our objectives are to report the current trend in numbers of Spotted Owls and to assess the initial effectiveness of the Spotted Owl Management Plan at stabilizing the owl population in British Columbia. It is hypothesized in the Spotted Owl Management Plan that protection of the minimum levels of suitable habitat in SRMZs will cause slow declines in owl numbers over the short-term, driven by continuing habitat losses inside and outside SRMZs. If the Spotted Owl Management Plan is working better than expected, owl numbers should have stabilized or be increasing. Alternatively, sharply declining owl numbers would suggest that the Spotted Owl Management Plan is not working as anticipated and is insufficient to stabilize the Spotted Owl population over the short-term.

Methods

Between 1992 and 2001, Spotted Owl surveys were conducted in the southwest mainland of British Columbia. Survey objectives and search effort varied from year to year depending on the funding and survey priorities. We visited 147 survey areas during this 10-year period; each survey area approximates the 3,200-ha median annual home range size of a pair of Spotted Owls. This variable survey effort and survey objectives resulted in some data gaps between years at survey areas.

Spotted Owl surveys were performed by experienced observers. Night visits involved visiting call playback stations spaced about every 500 m along a linear transect within each survey area (Blackburn and Lenihan 1995, RIC 1997). Spotted Owl calls were broadcast at each station to elicit territorial responses of Spotted Owls. Positive responses confirmed the presence of the species within the survey area. In general, only territorial owls respond to call playback; non-territorial owls (floaters) are rarely detected (Ward *et al*. 1991, USDI 1992, Raphael *et al.* 1996). Spotted Owls located during night or day visits were used to confirm presence. Owls are most vocal at night and are more detectable between March 1 and September 30, hence, we used only night visits during this period to determine absence of Spotted Owls.

In 2000, we chose 40 of the 147 survey areas to assess the current trend in numbers of Spotted Owls. The 40 survey areas were chosen using 2 criteria. First, only survey areas that were occupied at least once by a territorial Spotted Owl during the study were chosen. This ensured that the local habitat could support owls. Territorial Spotted Owl status was determined by one of the following criteria: 1) multiple responses by owls within the breeding period, 2) multiple responses of owls over 2 or more years in the same general area, 3) presence of an active nest, 4) observations of an adult owl with young, or 5) presence of a pair of owls roosting together (Blackburn and Lenihan 1995). Second, survey areas were chosen that had sufficient survey effort between 1992 and 1999 to assess changes in occupancy during the study. We assumed that survey effort at these 40 survey areas between 1992 and 1999 was not biased by the different survey objectives during this period. In 2000, we surveyed all 40 survey areas extensively (a minimum 24 hours of night search effort) to confirm presence or absence of Spotted Owls. In 2001, we re-surveyed 30 of the 40 survey areas. The survey areas chosen in 2001 were divided proportionally between the occupied and vacant survey areas in 2000.

The 40 survey areas (study area of about 118,000 ha) are distributed throughout the Chilliwack and Squamish Forest Districts (Figure 1). The study area is equivalent to about 8% of the estimated historic number of potential owl territories, 40% of the number of owl territories estimated by Dunbar *et al*. (1991), and 40% of the number of Long-term Activity Centres in SRMZs under the Spotted Owl Management Plan. These survey areas also represent 78% of the known Spotted Owl population found between 1985 and 2001 in the 2 forest districts, and, 86% of the known Spotted Owl population found within SRMZs.

The study area represents about 13% of the total potential suitable habitat available to Spotted Owls in the 2 forest districts (includes protected areas) and 37% of potential suitable habitats in SRMZs (includes protected areas). The amount of potential suitable habitat within the 40 survey areas was 62% of the total gross forested area. These habitats are assumed to have remained relatively stable during the study due largely to habitat protection measures initiated in 1993 to protect Spotted Owl habitat. The percentage of potential suitable habitat in the study area is similar to the non-study area portion of SRMZs (Figure 2). However, the study area contains 18% more potential suitable habitat than non-study areas found outside of SRMZs. Overall, the 2 forest districts contain about 50% potential suitable habitat. If we exclude SRMZs and study areas outside SRMZs, the percentage of potential suitable habitat in the Squamish and Chilliwack Forest Districts is 55% and 40%, respectively. Although the Chilliwack Forest

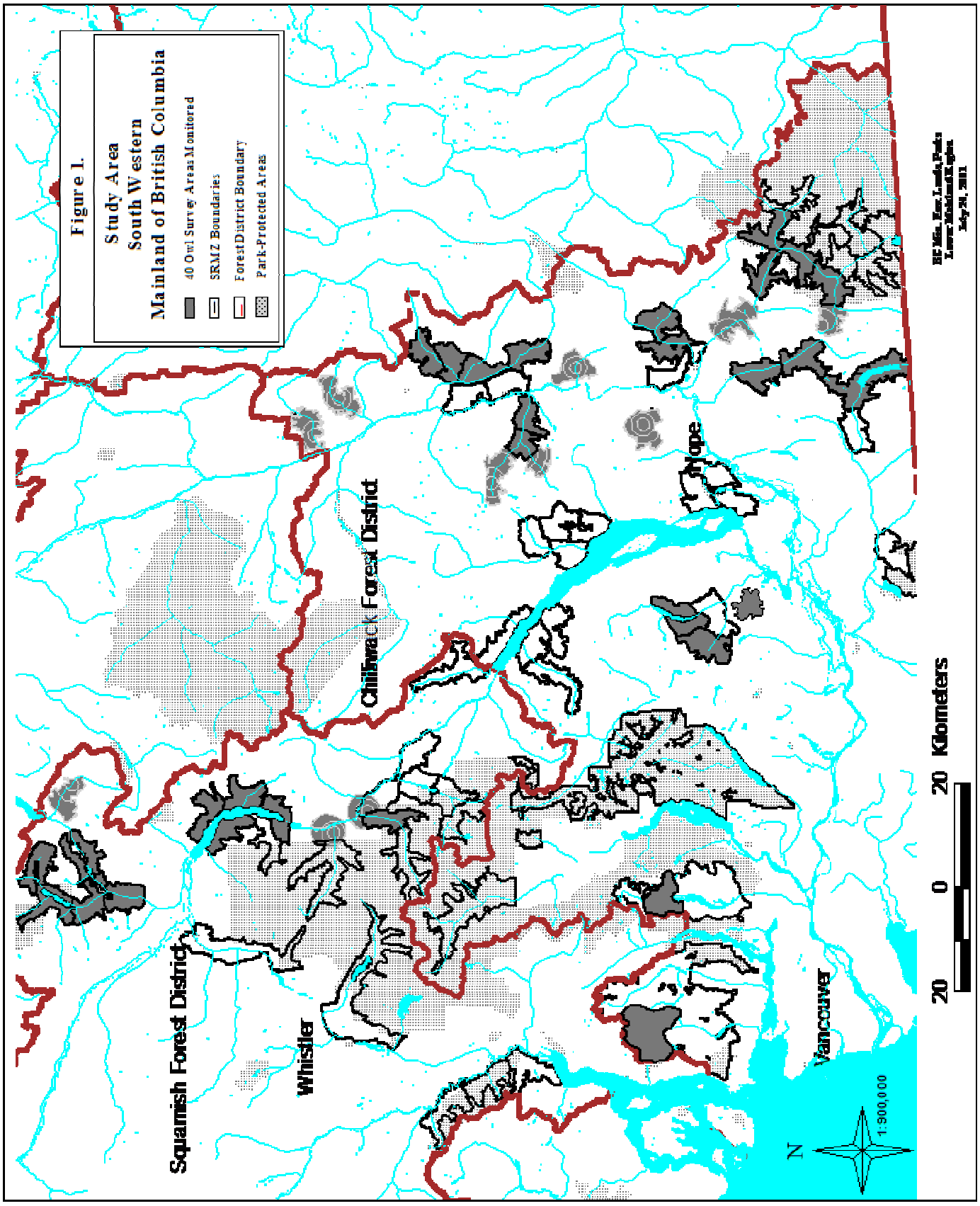
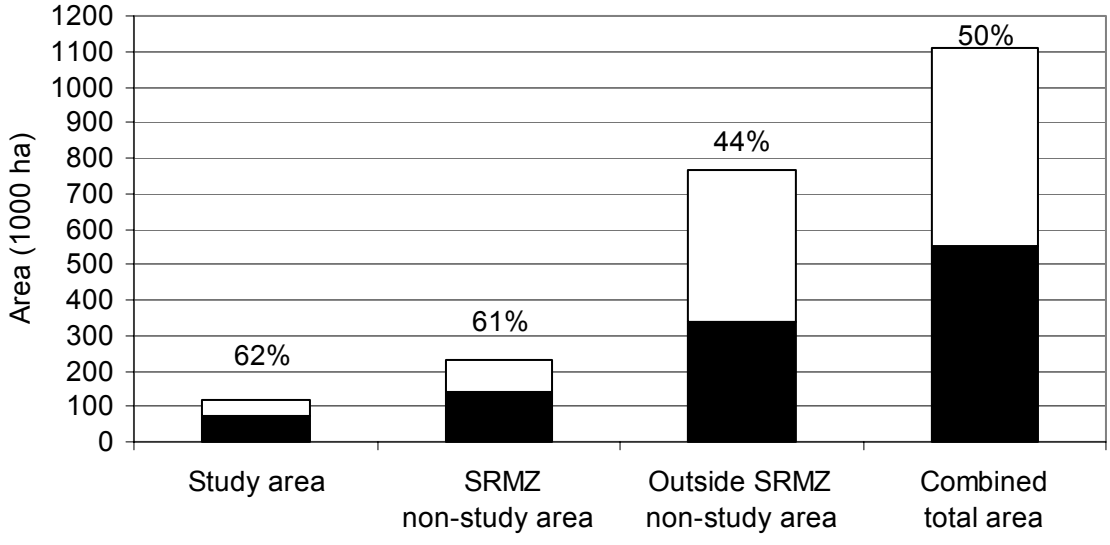


Figure 1.
Study Area
South Western
Mainland of British Columbia
40 Owl Survey Areas Monitored
SRMZ Boundaries
Forest District Boundary
Park-Protected Areas
Squamish Forest District
Whistler
Chilliwack Forest District
Hope
Vancouver
N
1:900,000
20 0 20 Kilometers

Figure 2. Estimated amount and percentage of potential suitable habitat within the study area, SRMZ non-study area, outside SRMZ non-study area, and combined total habitat in the 2 forest districts (data source: MSRM 2002).

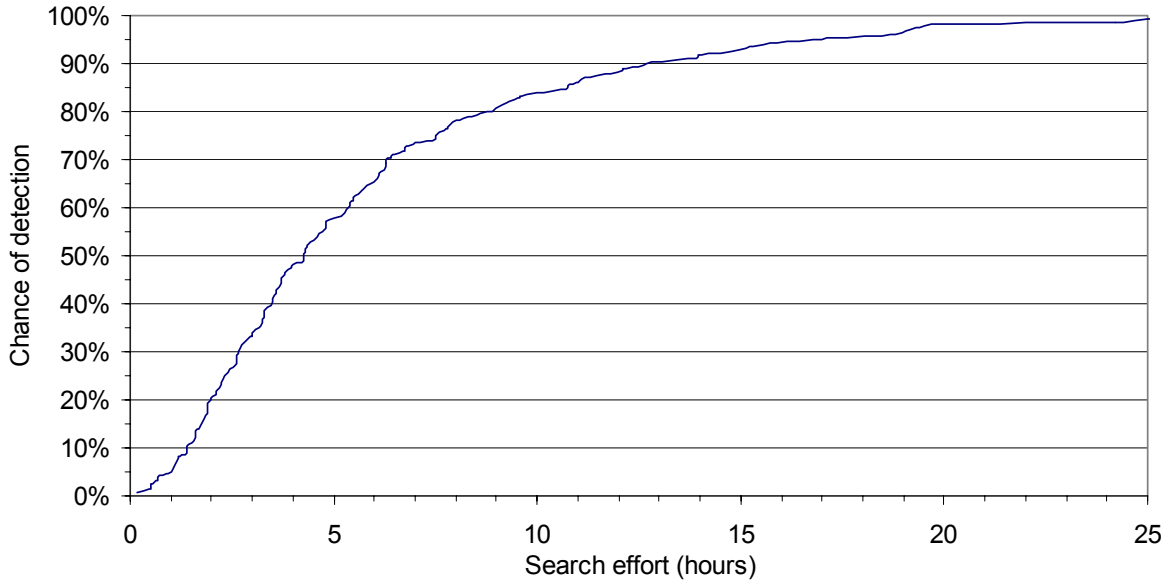


District contains a lower percentage of suitable habitat, this district is about twice the size of the Squamish Forest District, and therefore, contains more potentially suitable habitat.

We constructed a cumulative frequency distribution of the search effort required to detect the first Spotted Owl each year in the 40 survey areas between 1992 and 2000 (Figure 3). We used this distribution to determine a criterion for concluding that Spotted Owls were absent from other survey areas. Although detection rates of Spotted Owls differed slightly among survey years (single-factor ANOVA with log-transformed data, $F=2.061$; d.f. = 8,147; $P=0.04$), no outstanding year could be detected by post-hoc multiple comparisons. Our result indicates that 90% of all initial Spotted Owl detections each year between March 1 and September 30 occurred within 13 hours of total night search effort (n = 156). We therefore used a minimum 13 hours of unsuccessful night search effort to indicate a 90% chance that a surveyed area was vacant.

The population assessment is based on the presence or absence of Spotted Owls within the 40 survey areas. For each survey year, we classified the 40 survey areas as occupied, vacant, not-detected (surveyed, but less than a 90% chance of detecting an owl), or not-surveyed. For each survey area classified as not-detected, the amount of search effort was applied to the cumulative frequency distribution to calculate the percent chance of detecting a Spotted Owl if one was present. We assumed that all Spotted Owls detected were territorial owls, although some owls detected may have been floaters. The population assessment does not consider the reproductive status or density of Spotted Owls within each survey area.

Figure 3. Chance of detecting Spotted Owls if they are present. Chance of detection is a function of cumulative night search effort needed to initially detect a Spotted Owl each year in the 40 survey areas (1992 - 2000, n = 156).



For each survey year, we calculated the proportion of occupied survey areas in relation to the number of survey areas adequately sampled based on the total search effort in all 40 survey areas. To account for search efforts in not-detected survey areas, we divided the summed chance of detecting a Spotted Owl at all not-detected survey areas each year by the 90% chance needed to assess vacancy. The result provides an estimate of the number of "equivalent vacant survey areas", i.e., the number of additional survey areas that would be classified as vacant based on the minimum survey effort requirement of a 90% chance of detecting a Spotted Owl needed to assign a vacant status to a survey area. The number of survey areas adequately sampled was determined by:

Number of survey areas adequately sampled	=	Number of occupied survey areas	+	Number of vacant survey areas	+	Number of "equivalent vacant" survey areas

The proportion of occupied survey areas each year was then multiplied by the maximum sample size of 40 to estimate the number of occupied survey areas at the 40 survey areas each year. We assumed that data fitted a normal distribution, and hence used parametric statistical analyses. We assumed that there was an equal opportunity for Spotted Owls to occupy any one of the 40 survey areas each year between 1992 and 2001. We calculated 90% confidence intervals (C.I.) for each survey year and weighted these C.I.'s based on a maximum sample size of 40.

We used a linear-multiplicative model to estimate the average annual change of occupancy (β) between 1992 and 2001 (Thomas 1996, RIC 1998):

$$N_y = N_i\beta^{(y-i)}$$

where: N_y is the number of occupied survey areas in year y,
N_i is the number of occupied survey areas in the initial (i) year,
β is the estimated average annual change in occupancy.

We calculated the 90% C.I. for the annual change in occupancy between 1992 and 2001 by calculating the maximum and minimum slopes of the 95% C.I. for the estimated number of occupied survey areas in 1992 and 2001. The 95% C.I. was used because both years' estimates have error that when analyzed together, the error estimates are multiplied (95% C.I. x 95% C.I. = 90% C.I.).

The management and conservation consequences of accepting a false null hypothesis (Type II error) that the Spotted Owl population is stable when it is actually declining are severe, because the current small population size leaves little margin for recovery from incorrect management decisions (Taylor and Gerrodette 1993). Statistical power analysis provides a method to estimate the probability of accepting a false null hypothesis. The program MONITOR was used to determine the statistical power (Gibbs 1995). A statistical power of 80% or greater is recommended to detect a trend reliably (Bart and Robson 1995, Gibbs 1995).

Results

Between 1992 and 2001, over 3,000 hours of night search effort was expended at owl call playback stations among the 40 survey areas. The sampling design provided for a maximum of 400 occupied or vacant records (40 survey areas x 10 years = 400 potential records). Over the 10-year period, 197 (49%) records were classified as occupied and 61 (15%) records were vacant (Table 1). Not-detected was classified for 142 (36%) records. Of these 142 not-detected records, the combined survey effort was equivalent to the effort that would have to been required to adequately assess vacancy at 37 survey areas. Using these results, the estimated number of occupied survey areas was determined for each year (Table 2).

No surveys were performed for 86 of the potential 400 records. Sixty (71%) of these not-surveyed records occurred between 1992 and 1995 when survey objectives were largely to determine the range and distribution of the owl. During this 4-year period, Spotted Owls were discovered for the first time at 24 of the 40 survey areas in the study. Spotted Owls were already known to occupy the other 16 survey areas prior to 1992.

Because Spotted Owls were known to occupy 16 of the 40 survey areas prior to 1992, there is a potential bias to over-estimate the number of occupied survey areas at the beginning of the 10-year study. This potential bias would be caused by the high likelihood that these 16 survey areas would be occupied after 1992, the initial year of the study, due

Table 1. Survey results and amount of search effort applied among the 40 survey areas. Survey areas are arranged top to bottom from most occupied to least occupied during the study period.

Survey area	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1*				?						
2*			?							
3*			?	?						
4	?	?						?		?
5*		26%	?	?						
6	33%	?	?							
7	53%		?	?						
8	?	75%								
9	?							83%		
10*		?	?	?		52%		?		
11	?						67%	?		?
12*			?							
13*			?							
14*			?							?
15*			?		61%			65%		
16	?			46%						
17		27%	?	?		64%		?		?
18	?	?	33%		?					
19	?	?	?					37%		?
20	?	?						?		
21	?	?	?					33%		
22	?	?								
23*			?	35%				87%		
24										
25	31%			89%				?		?
26	?		?	?	87%		67%	?		
27*			?	?		?	78%	?		
28	?	?					83%	?		?
29*		21%	?					40%		?
30*			?		74%	78%		?		
31	?									89%
32	?						?	?		
33*			?		?			65%		
34			?	?	42%	73%		54%		87%
35	?	?	?					39%		88%
36*			?	47%	82%	78%	83%	38%		
37*			22%	35%	26%	84%		38%		89%
38	48%			85%	83%		72%	?		?
39	?			33%						?
40	?		?	?	?	82%	52%	89%		89%

Occupied

Vacant

? Not-surveyed

% Not-detected - with percent chance of determining status

* Identifies the 16 survey areas known to be occupied prior to 1992.

Table 2. The estimated number of occupied survey areas among the 40 survey areas each year based on the proportion of observed occupied survey areas in relation to the number of survey areas that were adequately sampled each year.

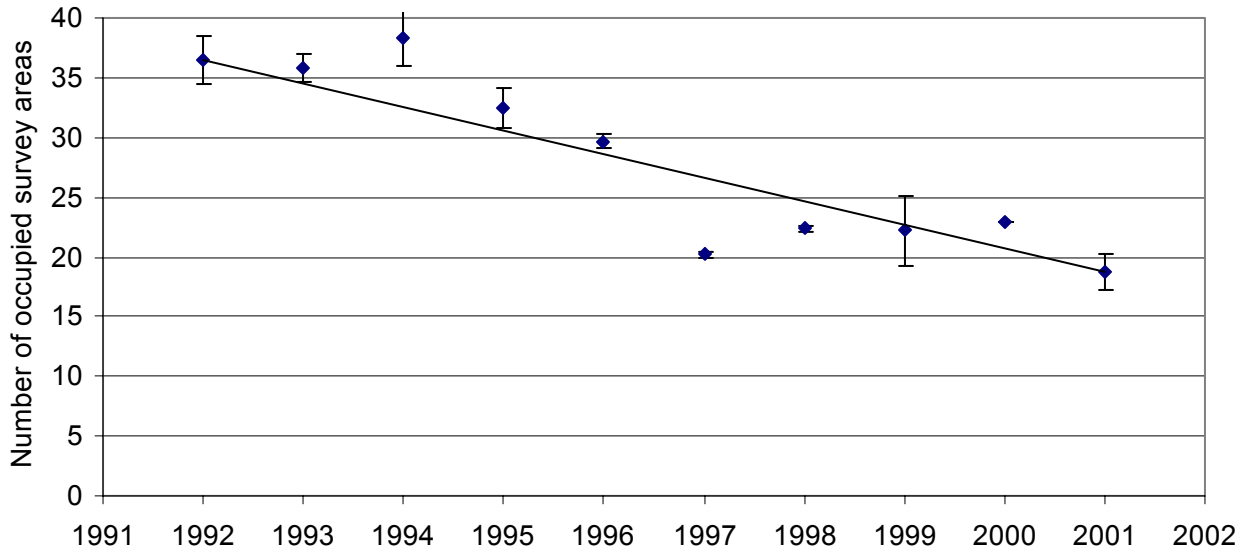
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Number of occupied survey areas	19	25	15	22	26	19	21	13	23	14
Number of survey areas adequately sampled	20.8	28	15.6	27.1	35.1	37.7	37.6	23.4	40	29.9
Proportion of survey areas occupied	0.91	0.89	0.96	0.81	0.74	0.50	0.56	0.56	0.58	0.47
Estimated number of occupied survey areas	36.5	35.8	38.4	32.5	29.7	20.2	22.4	22.2	23.0	18.7

to the longevity of Spotted Owls, their territorial behaviour, and their tendency to remain resident within the same geographic area throughout their lives. Conversely, there is also a potential bias to under-estimate the number of occupied survey areas if these 16 survey areas became vacant sooner due to age-specific factors (e.g., old birds) than newly discovered occupied survey areas that may be occupied by young owls. If these biases are occurring, we expected to detect differences in survey area occupancy each year and population trends between the 16 previously occupied survey areas and the 24 newly discovered survey areas. We conducted linear regressions on the observed occupancy of survey areas during the 10-year study period at the 16 previously occupied survey areas and at the 24 newly discovered survey areas. The percentage data were arcsine square root transformed and then we used a General Linear Model (SPSS 2001) to compare slopes of the 2 regressions. We found no significant difference between the slopes of the 2 regressions (ANOVA, $F=0.48$, d.f.=1, $P=0.50$). We conclude that the 16 previously known occupied survey areas did not influence the number of occupied survey areas or the trend of the owl population any greater than the 24 newly discovered survey areas. Hence, we combined both data sets for the population assessment.

Applying a Linear Multiplicative model to the estimated number of occupied survey areas each year, occupancy among the 40 survey areas declined by 49% (range 40% to 57% for 90% C.I.) between 1992 and 2001 (Figure 4). The average annual rate of decline was -7.2% (+/- 1.7% for 90% C.I.). The estimated number of occupied survey areas each year suggests owl numbers were relatively stable between 1992 and 1994, declined quickly between 1994 and 1997, and stabilized again between 1997 and 2000, and declined again between 2000 and 2001. Our power analysis indicated that we could have detected a declining trend as small as -2% per year over the 10-year period with a statistical power $\geq$ 80%.

During the year 2000, the percentages of suitable habitat in occupied survey areas (mean = 62% +/- 13% SD) and vacant survey areas (mean = 62% +/- 11% SD) were not significantly different (t-test, $t = 0.1$, d.f. = 35, $P = 0.92$).

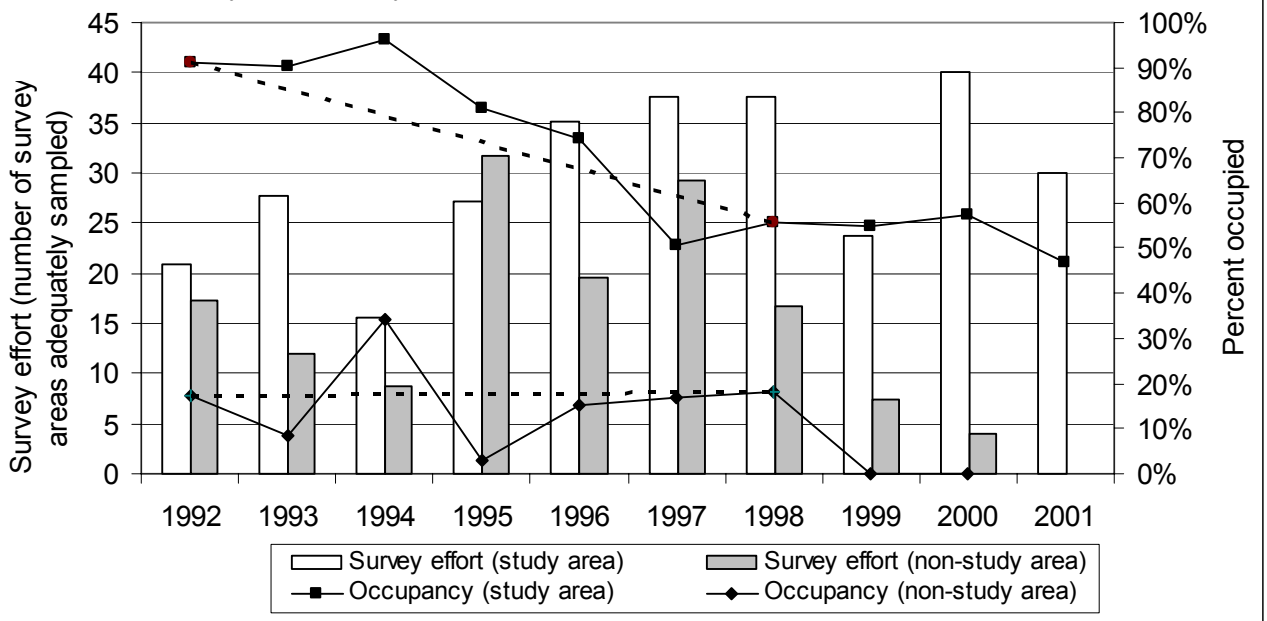
Figure 4. Estimated number of occupied survey areas among the 40 survey areas from 1992 to 2001 (with 90% C.I.). The Linear Multiplicative model suggests the number of occupied survey areas declined by about 49% at an average annual rate of -7.2%.



In southwestern B.C. where we conducted our study, we estimate that there are about 200 potential 3,200-ha survey areas containing greater than 50% suitable habitat. This estimate omits the Squamish and Whistler corridor because Spotted Owls have not been detected in this area since 1979 despite considerable search effort at 23 survey areas in the early 1990's. Between 1992 and 2001, 124 of the 200 potential survey areas were sampled with various levels of search effort. Of the 124 survey areas visited, 40 survey areas (20% of the 200 potential survey areas) were used in the population assessment. A comparison of the total search effort and occupancy (percent occupied) between the study and non-study areas each year is provided in Figure 5.

Spotted Owls are not known to change their territories frequently. However, if Spotted Owls did change their territories frequently, and/or, if territories are not occupied by other owls quickly after the resident owls die or move to other areas, then we expected a bias that would over-estimate the decline. The 40 survey areas would exhibit a steeper decline than the "true" population trend. This is due to attrition as the 40 survey areas return to a state of equilibrium with the owl population. If this bias was occurring, we expected the occupancy of owls in the non-study areas to increase as the occupancy of owls within the study area decreased to reflect a stable or increasing owl population. A comparison of the 1992 to 1998 results suggests that the occupancy in the non-study area did not increase, but remained relatively stable, while the study area decreased (Figure 5). This comparison omitted data from 1999 to 2001 due to the low sample size in the non-study area during this period. The results suggest that Spotted Owls are not differentially leaving the study area and re-establishing in the non-study area. Therefore, we conclude

Figure 5. Survey effort and occupancy of Spotted Owls each year in the study area (n=40) and non-study area (n=84). Dotted line is the trend in owl numbers from 1992 to 1998 for the study and non-study areas.



that the declining trend among the 40 survey areas is a reliable representation of the status of the entire "true" Spotted Owl population in British Columbia.

Discussion

Between 1992 and 2001, the occupancy of Spotted Owls among the 40 survey areas declined by about 49% at an average annual rate of -7.2%. If the study area is representative of the entire Spotted Owl population in B.C., the number of Spotted Owls in B.C. is not stable, but has declined sharply over the past 10 years. Using the number of breeding pairs of Spotted Owls estimated by Dunbar *et al*. (1991), the observed decline suggests that the current Spotted Owl population in B.C. is fewer than 50 breeding pairs. This decline is not exclusive to British Columbia. A range-wide population decline of -3.9% per year (+/- 3.6% for 95% C.I.) between 1985 and 1998 has been observed in the United States in 15 mark-recapture studies (Franklin *et al.* 1999).

Our population assessment is based on the presence or absence of Spotted Owls within a survey area, but does not consider the density or reproductive status of the owls. Furthermore, we assumed that all Spotted Owls detected were territorial owls, although some owls detected may have been floaters that were moving through the survey area. Using presence or absence may bias our results by including transient individuals, or if more than 1 Spotted Owl territory occurs in a survey area. More importantly, presence or absence does not provide information on the status of the population. If all survey areas

occupied in 2001 contained pairs of Spotted Owls, then there is a greater chance that the population will recover than if most survey areas occupied in 2001 contained single owls. The greatest concern is that we may infer a more stable population from presence or absence data, when only single owls occupy the survey areas. If true, the population may become extirpated abruptly as owls succumb to old age and there is no recruitment.

It is possible that Spotted Owls have become habituated to repeated owl call playbacks and therefore have responded less frequently in later portions of our study. This would generate an apparent decline when numbers were stable. This hypothesis predicts that the time to detect owls at occupied sites should have increased over time. We did not observe this pattern. Owls remained equally detectable at survey areas where they persisted from year to year.

Adult survivorship and reproductive success may be directly related to the proportion of suitable habitat found within an owl's territory (Bart and Forsman 1992). In our study, the population decline was estimated from a sample of owls whose territories contained on average 62% suitable habitat. However, the amount of suitable habitat in the 2 forest districts found outside SRMZs and protected areas contains on average 44% suitable habitat; 18% lower than the study area (Figure 2). The amount of habitat within the study area remained relatively stable during the 10-year study compared to other portions of the 2 forest districts that were subjected to timber harvesting and natural disturbances. The higher percentage of suitable habitat and the more stable habitat conditions in the study area may have buffered impacts and the decline of Spotted Owls outside the study area may be steeper than we observed. Furthermore, as owls are faced with habitat loss from their territories, they may become non-territorial floaters and seek vacant territories, or displace existing territorial owls to establish new territories. This may contribute to "packing" of owls into remaining suitable habitats (McKelvey *et al.* 1993, Raphael *et al*. 1996). Hence, our results may exhibit a more stable population if owls displaced outside of the study area established new territories in the study area. However, the observed population decline and the large number of vacant survey areas observed during the study suggest low numbers of floaters and low recruitment of owls into available territories.

Possible Explanations for the Population Decline

The Canadian Spotted Owl Recovery Team identified 5 threats to Spotted Owls that may cause the population to decline and become extirpated (SORT 1994). These 5 threats include reduced habitat availability and connectivity, random environmental events, low genetic variability, mortality from predators, and the effects of competition with Barred Owls. Raphael *et al.* (1996) identified 3 hypothetical scenarios in their population assessment of Spotted Owls in the United States: a) the Spotted Owl population decline is part of a natural, long-term fluctuation in numbers; b) Spotted Owl numbers will eventually stabilize at a lower level in response to stabilizing habitat levels; c) the Spotted Owl population is declining to extirpation. We examine these scenarios to assess the future of the Spotted Owl in British Columbia.

Spotted Owl populations exhibit natural, long-term fluctuations

Animal populations are seldom stable, but grow during favourable conditions and decline during unfavourable conditions. Natural fluctuations in numbers may be related to stochastic environmental and demographic events, but rarely influenced by the amount and distribution of suitable habitats. The observed decline in the Spotted Owl population may be a short-term phenomenon in a population that fluctuates but remains relatively stable over the long term. Because of this possibility, population trends for long-lived animals, such as Spotted Owls, require many years of monitoring to detect natural patterns in population size (USDI 1992).

It is possible that the demography of Spotted Owls may change due to the effects of environmental conditions (Zabel *et al.* 1996, Franklin *et al*. 2000). Zabel *et al.* (1996) found a significant negative correlation between precipitation during the nesting season and reproductive success of Spotted Owls. The large decline in Spotted Owl numbers between 1996 and 1997 coincides with seasonal (i.e., spring, summer, fall, winter) precipitation on average 60% greater than normal between the fall of 1996 and fall 1997, and with below normal seasonal temperatures (-2^{o}C) in the fall of 1996 (Environment Canada 2001). Perhaps the wetter and cooler temperatures than normal may have decreased owl numbers and reproductive success. However, the observed decline in Spotted Owl numbers between other years does not appear to coincide with above or below normal seasonal temperatures and precipitations.

Another cause of poor demographic performance might be during periods of low prey populations making it more difficult for Spotted Owls to find food. This may decrease nesting attempts and reproductive success, and increase adult mortality as individuals succumb to starvation. The low numbers of Spotted Owls observed between 1997 and 2001 may stem from reduced nesting and territorial behaviour of the owls. Changes in demography of Great Horned Owls (*Bubo virginianus)* occur during periods of low prey abundance (Rohner 1996, 1997). However, other species in the genus *Strix* exhibit stable populations in the face of large fluctuations in the abundance of their principal prey (Southern 1970, Brommer *et al*. 1998). Numbers of Northern Flying Squirrel (*Glaucomys sabrinus*), which comprise 41% of the Spotted Owl's diet in B.C. (Horoupian *et al.* 2000), remained relatively stable between 1996 and 1999 within portions of the owl's range in British Columbia (Ransome 2001). This relatively stable prey population between 1996 and 1999 coincides with the relatively stable owl population observed between 1997 and 2000.

To support the hypothetical scenario of a stable, but naturally fluctuating Spotted Owl population, the observed population decline between 1992 and 2001 must be offset by future years of population increase. However, no cyclical or fluctuating patterns in Spotted Owl population size have been reported in the United States (USDI 1992, Raphael *et al*. 1996). There is no obvious reason to expect the population dynamics of Spotted Owls in British Columbia to differ from that in the United States.

Spotted Owl populations will stabilize in response to stabilizing habitat levels

The Spotted Owl Management Plan is based in part on the hypothesis that the population will stabilize and increase as the amount of suitable habitat initially stabilizes and then increases naturally, or through habitat enhancements, in SRMZs. In comparison to the spatially-explicit simulation model used to assess the Spotted Owl Management Plan (Blackburn 1996), our observed population decline of -7.2% per year between 1992 and 2001 is 4.8 times faster than the annual rate predicted by the model. This sharp decline does not support the suggestion of Demarchi (1998) and Blackburn (1996) that the owl population is stabilizing. Instead, the Spotted Owl population in B.C. appears to be at a greater risk of extirpation than originally anticipated.

Between 1993 and 1995, 39 of the 40 survey areas and the majority of all SRMZs became protected and were managed to maintain or recruit the minimum target of 67% suitable habitat. The relatively stable number of occupied survey areas observed between 1997 and 2000, combined with the decline observed between 2000 and 2001, suggests a slowed declining trend by the population in recent years, possibly in response to these stabilizing habitat conditions within areas protected for the owl. If true, then this supports the thought that the amount of suitable habitat available to the Spotted Owl is a major limiting factor that influences population numbers. Despite this apparent slowed decline in recent years, the sharp decline in owl numbers between 1992 and 2001 suggest that current levels of suitable habitat protected in SRMZs under the Spotted Owl Management Plan are inadequate to stabilize the Spotted Owl population. This may be attributed to some SRMZs currently functioning below their optimal recovery potential (i.e., the 44 Long-term Activity Centres currently below the 67% suitable habitat target).

The Spotted Owl Management Plan identifies the importance of dispersal habitat outside of SRMZs to facilitate owl movements from one SRMZ to another. Habitats outside of SRMZs were not stable during our study, but were subject to timber harvesting and natural disturbances. Annual rates of timber harvest (Annual Allowable Cut) were not adjusted for Spotted Owl habitat protection measures initiated in 1993 until April 1999 and October 2000 for the Chilliwack and Squamish Forests Districts, respectively. As a result, increased timber harvesting was applied to the remaining forest land outside SRMZs and other areas protected for Spotted Owls during the study. The increased rate of harvest outside of SRMZs may have accelerated displacement of territorial owls, decreased habitat connectivity between owl territories, and decreased success of displaced adults and dispersing juveniles at finding suitable habitats more than originally anticipated, a concern raised by Demarchi (1998).

At present, SRMZs are at their lowest potential for recovering the Spotted Owl population. The potential for Spotted Owl recovery should increase as habitat quantity and quality improves to the minimum 67% suitable habitat target over the next 60 years, and as habitat management strategies to maintain large suitable habitat patches and habitat connectivity within Long-term Activity Centres are expressed on the landscape. Despite the apparent slowed population decline in recent years, the owl population will likely decline further until past habitat loss inside SRMZs and continuing habitat loss inside and outside SRMZs are offset by habitat recruitment.

Spotted Owl population will decline to extirpation

Small populations are vulnerable to extinction through factors such as random fluctuations in environmental conditions and demographic structure, loss of genetic variability, inter-specific competition, and amount and dispersion of habitat (Krebs 1984, USDI 1992, Raphael *et al*. 1996).

The proportionately large decline in number of owls between 1996 and 1997 may have been exacerbated by inclement weather. Although the number of owls may stabilize at this lower level, the population may be unable to increase to former levels due to its current small population size and sparse distribution of individuals. This diminished population could remain stable but low until another event results in further declines. Such events could contribute to a step-wise pattern in population trend.

Under current forest management regimes, suitable habitat for Spotted Owls outside of SRMZs will continue to decline due to industrial forest uses and urbanization. As well, habitat loss will occur in Long-term Activity Centres where timber harvesting of suitable habitat is allowed down to the 67% target. Natural disturbances, such as forest fires and forest pests, inside and outside SRMZs will also cause further losses of suitable habitat. As a result, the lower amount and fragmented distribution of habitats over the next few decades may further displace owls and hinder reproductive success, constrain owl movements and lower dispersal success. Extirpation may occur if Spotted Owls cannot find suitable habitat or available mates in suitable habitat (Lamberson *et al*. 1992).

Northern Barred Owls (*Strix varia varia*) and Spotted Owls have co-existed for about 40 years in southwestern B.C., since the Barred Owl began to colonize the Spotted Owl's range (Taylor and Forsman 1976). Barred Owl numbers are increasing in the Pacific Northwest of the United States (Pearson and Livezey 2001), and its range is expanding southward. Barred Owls are more abundant in southwestern B.C. than Spotted Owls and may be out-competing and displacing Spotted Owls for food and habitat. A preliminary analysis of Barred Owl occupancy within the 40 survey areas between 1992 and 2001 suggests that they have declined by a proportion similar to that observed for Spotted Owls (Shawn Hilton, pers. comm.). The Spotted Owl, however, is more vulnerable to extirpation by stochastic events due to its small population size, while the abundant Barred Owl is not necessarily at risk. To assess the Barred Owl's influence on Spotted Owls, further analysis is needed for data from the other 84 non-study survey areas visited during 1992-2001. If Barred Owl occupancy remained stable or increased at these non-study survey areas, then the trends observed in the study area may indicate both species are competing for the same resources. If Barred Owl occupancy declined at these non-study survey areas then both species may be responding jointly to the same limiting factors.

Over the past decade, numbers of Spotted Owls in B.C. has declined and become further isolated. We do not know if the Spotted Owl population in B.C. is currently below a viable population threshold and will become extirpated (Lamberson *et al.* 1992, Raphael *et al.* 1996), or if the population can sustain further declines and still maintain its capacity to recover. We expect the population to decline further due to future habitat losses and stochastic events. If habitats within SRMZs do not facilitate an increase in the Spotted Owl population to levels resilient to these stochastic factors, then extirpation will likely occur.

Management Considerations

The current Spotted Owl population is very small and extremely vulnerable to stochastic events that could cause population decline and extirpation. Increasing the population size increases the stability and resilience of the population to these stochastic events. Fortunately, suitable, but unoccupied, habitats exist within SRMZs that would allow Spotted Owls to establish new territories and increase the current population size. Hence, management actions should be implemented quickly to conserve and increase the number Spotted Owls, but be applied cautiously given the high risk of extirpation for this species.

Increased monitoring

At minimum, annual monitoring of a large sample of survey areas (occupied and unoccupied) is essential to provide better estimates of the population trend. An assessment of the reproductive status at occupied survey areas is also needed to facilitate informed management decisions and recovery actions. Monitoring should also assess survivorship of individuals, movements, as well as, the age and sex structure of the population.

Increased habitat protection for Spotted Owls

Habitat models in the United States suggest that large clusters of 15 or more owl territories, spaced close together to facilitate dispersal between clusters, provides a high likelihood of stabilizing the population (Thomas *et al.* 1990, USDI 1992, Lamberson *et al*. 1994). The findings of Blackburn (1996) and Demarchi (1998) also suggest that increasing the amount of habitat protection in SRMZs, or reducing the rate of timber harvest, would increase the likelihood of stabilizing and recovering the owl population. In B.C., SRMZs are located, on average, 15 km apart, and will eventually maintain about 5 potential owl territories. Despite the slowed decline in Spotted Owl occupancy between 1997 and 2001, our results suggest that current habitats protected in SRMZs under the Spotted Owl Management Plan are inadequate to stabilize the Spotted Owl population. This may be attributed to some SRMZs currently existing below their optimal recovery potential. Waiting 60 years or more for habitat and owl population recruitment in SRMZs to occur and then determine whether the provisions of the Spotted Owl Management Plan are sufficient is not advisable given the current population decline and risk of extirpation. If the amount of habitat available is a major limiting factor to the Spotted Owl, then increasing the amount of suitable habitat protected inside and outside of SRMZs should further slow, if not stop, the decline and increase the chance for the owl population to recover. Spotted Owls may still decline if other factors are influencing the population size or if the population is already below the extirpation threshold. However, further slowing or stopping the population decline provides additional time and opportunities to understand and remedy the cause(s) of the decline.

Accelerate Spotted Owl habitat recovery in SRMZs

At present, SRMZs are at their lowest potential for recovering the Spotted Owl population due to the low amount of suitable habitat in 44 of the 101 Long-term Activity Centres. Increasing the amount of suitable habitat to the minimum target of 67% within these Long-term Activity Centres will increase the recovery potential and chance of stabilizing the owl population. Applying silviculture treatments (e.g., thinning) in SRMZs that create and enhance suitable habitat, as identified in the Spotted Owl Management Plan, has the potential to reduce the time required naturally to increase the amount and quality of suitable habitat in SRMZs. All silvicultural treatments should be applied judiciously because if there is loss of habitat due to failed forest stand treatments (e.g., loss due to subsequent blowdown), it will lower the recovery potential and increase the risk of extirpation. Therefore, monitoring and evaluation are critical to assess the effectiveness of silviculture treatments intended to create and enhance suitable habitat.

Direct manipulations of Spotted Owls

Hands-on manipulations of individual owls may increase Spotted Owl numbers. These manipulations include: translocation of individual birds to establish potential reproductive pairs, captive breeding and release programs, and food supplementation for breeding individuals. These actions must focus on increasing reproductive success and survivorship of juveniles and subadults, because there are limited opportunities to increase adult survivorship of these long-lived birds. Unfortunately, little is known about the feasibility of these actions for the Spotted Owl, and implementing such actions may inadvertently make conditions worse for the species. For example, translocations require a healthy source population from which to take the owls, but most populations are declining. These actions have not been attempted for Spotted Owls in the United States and there are no clear protocols to follow. Continuing attempts to use a breeding program to re-establish the extirpated Burrowing Owl (*Athene cunicularia*) in B.C. have met with limited success to date. Generally, such direct interventions are used as a last resort once all other recovery efforts have failed.

Conclusion

Populations of Spotted Owls have declined substantially in Canada and the United States over the last decade. The contributions of various known factors that have lead to this decline are unknown, but habitat loss is likely foremost among these factors. Although the habitat provision of the Spotted Owl Management Plan may have slowed the population decline in recent years, our results suggest that these provisions are inadequate to stabilize the population. Over the next few decades, habitat loss is expected to continue inside and outside SRMZs and habitat recruitment will occur slowly inside SRMZs. Combined, we expect these habitat processes to contribute to further declines in numbers of Spotted Owls. Additional management actions are necessary to reduce the

risk of extirpation and recover the Spotted Owl in British Columbia. Unfortunately, many factors influencing Spotted Owl numbers cannot be controlled (such as natural disturbances and environmental conditions) or efforts to control them may be futile and may lead to greater environmental problems (such as removal of predators and competitors). The future conservation of the Spotted Owl in B.C. is not solely a biological issue, but is complicated by social and economic values. Unless society supports these management actions to conserve the Spotted Owl, the species will likely be extirpated soon in Canada.

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