Northern Goshawk Population Inventory for Vancouver Island, British Columbia, 1994–1998

Erica McClaren[1]
Wildlife Branch, British Columbia Ministry of Environment, Lands and Parks
2080A Labieux Road South, Nanaimo, BC, V9Y 6J9, Canada

ABSTRACT

Northern goshawk (Queen Charlotte subspecies: *Accipiter gentilis laingi*) inventory and research occurred on Vancouver Island, B.C. from 1994 to 1998. Broadcast surveys, the most effective inventory method known for goshawks, continue to be time-consuming and costly, with a relatively low number of goshawk detections and nest locations per unit of effort. Since 1994, approximately 2,912 broadcast stations resulted in 51 goshawk detections and the location of 19 nest territories. Twelve other goshawk territories were reported by forestry workers and members of the public, 3 were found using radiotelemetry, and another was discovered using the stand-watch inventory technique, increasing the number of currently known goshawk territories on Vancouver Island to 35. Territory occupancy rates appear to vary by year, and may relate to the seral stage of the nesting habitat and to the degree of fragmentation in the surrounding landscape. Research efforts on Vancouver Island have focused on describing the habitat characteristics of goshawk nest sites, nest stands, and home ranges, and on identifying their main prey items. As well, radiotelemetry is being used to gain information on goshawks' breeding and winter home range size and habitat use, territory and mate fidelity, breeding dispersal, and mortality rates. Future directions for goshawk research on Vancouver Island include: 1) testing the effectiveness of a new broadcast call for goshawk inventory; 2) testing the effectiveness of dawn vocalizations to determine territory occupancy and to locate active nest sites; and 3) examining nest productivity and territory occupancy in relation to the percent of old-growth and degree of fragmentation in goshawk breeding home ranges. This research aims to improve our ability to locate goshawk nest territories, gain a better understanding of population size on Vancouver Island, and increase our knowledge of habitat quality for goshawks. Using this information, current management strategies for goshawks may be refined to reflect the conclusions of local, scientific studies.

Key words: *Accipiter gentilis laingi,* inventory, northern goshawk, population, Vancouver Island.

Northern goshawks (*Accipiter gentilis*) are the largest member of the genus *Accipiter* in North America. Like other accipiters, such as the sharp-shinned hawk (*A. striatus*) and Cooper's hawk (*A. cooperii*), goshawks possess a long, rudder-like tail and relatively short, rounded wings, which provide them with both rapid acceleration and excellent maneuverability in their forested habitats. Regional variation among goshawks in British Columbia has resulted in 2 recognized subspecies: *A. g. atricapillus*, which occurs widely throughout British Columbia's mainland and North America; and *A. g. laingi*, referred to as the Queen Charlotte goshawk, which inhabits a much more localized range along the Pacific coast from Alaska to Washington (Squires and Reynolds 1997). Within British Columbia, Queen Charlotte goshawks, the focus of this study, appear to be isolated to the coastal islands, primarily Vancouver Island and the Queen Charlotte Islands (Campbell et al. 1990).

The conviction that northern goshawks require mature and old-growth forests to meet their life history requirements has placed them at the forefront of forest harvest and land-use conflicts in Europe (Kenward and Widen 1989, Tommeraas 1994, Widen 1997) and the United States (Crocker-Bedford 1990, Clark 1998) for over a decade and more recently in Canada (Duncan and Kirk 1995). However, goshawks are a difficult raptor to detect in their forested habitats due to their secretive behaviour, relatively low population densities, and large home range size (Kennedy and Stahlecker 1993, Joy et al. 1994, Bosakowski and Vaughn 1996). Consequently, there is a paucity of information regarding the impact of forest harvest and fragmentation on goshawk populations. Goshawks appear to select for habitat

[1] Present address: Fishery and Wildlife Biology, Colorado State University, Ft. Collins, Colorado
mcclaren@lamar.colostate.edu

based on structure rather than on type, typically nesting and foraging in mature and old-growth deciduous, coniferous, and mixed-wood forests characterized by large volume trees and closed canopies (Squires and Reynolds 1997, Daw et al. 1998). Goshawks prey upon a variety of species, occupying the role of a generalized, opportunistic hunter (Squires and Reynolds 1997), although structural characteristics of forests may dictate prey availability (Beier and Drennan 1997, Widen 1997).

Concerns regarding the population status of goshawks have resulted in petitions to list *A. g. atricapillus* populations west of the 100th meridian as threatened under the United States Endangered Species Act (ESA; Clark 1998). After reviewing the published scientific literature, Kennedy (1997) reported that there was no evidence to support the claim that goshawk populations were declining in the western United States. Kennedy (1997) stated that this result could be interpreted in 2 ways: 1) that goshawk populations are not declining; or 2) goshawk populations are declining but current sampling techniques are unable to detect this trend. Likewise, in 1998, the petition to list the goshawk under the ESA was rejected, due to insufficient evidence of population declines (Clark 1998).

More recently, conservation concerns have shifted to the Queen Charlotte goshawk. Petitions to list this subspecies as threatened or endangered under the American ESA, for similar reasons as described above for *A. g. atricapillus*, are still being debated in the courts. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designates the northern goshawk as Not at Risk and the Queen Charlotte goshawk as Vulnerable (Duncan and Kirk 1995). Within British Columbia, northern goshawks are not listed, whereas Queen Charlotte goshawks occur on the provincial Red List as a candidate for threatened or endangered status (B.C. MELP 1998). Furthermore, goshawks (both subspecies) are an Identified Wildlife Species under the British Columbia Forest Practices Code Act (Forest Practices Code of BC 1996) and Queen Charlotte goshawks are ranked by the provincial Conservation Data Centre as S2B, SZN (imperilled in British Columbia due to rarity and perceived threats to habitat). Due to the paucity of information on Queen Charlotte goshawk habitat requirements, it is unclear how habitat data collected on northern goshawks in the western United States apply to this subspecies (Daw et al. 1998).

Management guidelines have recently been developed in British Columbia for both subspecies of goshawks, in *Managing Identified Wildlife: Procedures and Measures, volume I* (B.C. MOF and B.C. MELP 1999) under the British Columbia Forest Practices Code Act (Forest Practices Code of B.C. 1996). However, these guidelines have been primarily developed from studies in the United States on *A. g. atricapillus*. Consequently, it is unknown how accurately these guidelines reflect the habitat requirements of Queen Charlotte goshawks on Vancouver Island. In order to gather more information on Queen Charlotte goshawks, the Wildlife Branch of the British Columbia Ministry of Environment, Lands and Parks (MELP) initiated goshawk research and inventory on Vancouver Island in 1994 and 1995, respectively. While there is often no clear distinction between inventory and research, these efforts have focused on: 1) distribution and breeding densities; 2) breeding and winter habitat associations, home range size, and movement patterns; 3) prey species composition; 4) territory occupancy and nest productivity in relation to the forest age class and the degree of fragmentation within home ranges; 5) nest site and mate fidelity; and 6) survivorship. Due to the length restriction of this paper, none of the above topics will be discussed in depth and some will not be discussed at all. Please refer to Ethier (1999) for a more detailed discussion of goshawk habitat associations and prey composition on Vancouver Island, and to McClaren (1999) for more information on other topics that are not included in this paper.

STUDY AREAS

Although inventory efforts have concentrated in the Woss/Sayward areas of Vancouver Island, inventory has also occurred in other areas, including Cowichan Lake, the Walbran Valley, Nanaimo Lakes, Port Alberni, Strathcona Park, Campbell River, Gold River, and parts of Quadra Island. Inventory also occurred on the Queen Charlotte Islands between 1995 and 1998, although this is currently organized by the Skeena region of MELP and, therefore, will not be discussed in this report. Inventory efforts have aimed to be unbiased by focusing equal effort in forests representing 3 silvicultural treatments: 1) largely uncut, continuous old-growth forests (>250 yrs); 2) largely uncut, continuous second-growth forests (40–140 yrs); and 3) largely cut, unconnected patches of old-growth and second-growth forests (defined here as fragmented). Since 1997, inventory between Campbell River and Woss has primarily focused on resurveying a 1.6-km radius around goshawk nest clusters within known territories to determine occupancy status and to locate active nest trees.

METHODS

Goshawk Inventory

Standardized inventory methods, outlined by the Resources Inventory Committee (RIC) in Ethier and McClaren (1997) were utilized for goshawk surveys on Vancouver Island. Two types of survey techniques were used in goshawk inventories: broadcast surveys and stand-watches. Kennedy and Stahlecker (1993) originally described broadcast survey protocol for conducting goshawk inventory in forests of the southwestern United States and stand-watches were suggested by Reynolds

(1983). All habitat data collection followed standards outlined in Luttmerding et al. (1990). Refer to McClaren (1999) for a more detailed description of these survey techniques.

Assessing Territory Occupancy and Nest Productivity

Known goshawk nest sites on Vancouver Island were revisited between 1995 and 1998 during the breeding seasons to assess their occupancy status and to gather nest productivity data. All known nests within each territory were assessed for activity using a spotting scope and tripod, to look for an incubating female or for fresh greenery and downy feathers around the nest's edge. Other clues that enabled us to assess occupancy at nest sites included goshawks calling, as well as fresh whitewash and plucking posts in the vicinity of known nest sites. If nests appeared to be inactive, calls were broadcast within a 1.6-km radius around known nest clusters to locate any unknown, alternate nests that may have been active within territories. Goshawk territories that appeared inactive in May and June were resurveyed during late July and early August to reassess the presence or absence of fledglings. If, after a minimum of 2 surveys (1 during the nestling phase, 1 during the fledgling phase), no goshawks were detected, territories were considered unoccupied. If after 2 surveys, 1 or more adult goshawks were detected within a territory but no active nest or fledglings were located, territories were considered occupied but inactive.

Nest productivity was recorded as the number of young observed in the nest approximately 1 week prior to fledging. This definition for nest productivity closely resembles recommendations by Steenhof (1987), who states 39 days after hatching is the appropriate age to determine the number of young successfully fledged from a goshawk nest. It is better to estimate the number of young that reach a certain size in the nest rather than count the number after fledging, since birds are easily missed after they fledge, resulting in lower estimates for nest productivity (Steenhof 1987). Additionally, nest failures were recorded when they occurred. This information will be used to examine differences in territory occupancy and nest productivity relative to forest age class and the degree of fragmentation within goshawk home ranges.

Trapping

Two methods of trapping were used to capture goshawks. One method, referred to as the dho-gaza trap, used a live, permanently injured, non-releasable great horned owl (*Bubo virginianus*) from a wildlife recovery centre, and a mist-net. The great horned owl was tethered to a perch below the mist-net near active goshawk nests. Goshawks' aggressive nature near their nests results in them swooping to scare the owl and getting caught in the net, without causing injuries to themselves or to the owl. Box traps, modified from the original design by Kenward and Marcstrom (1983), were the second method used to capture goshawks. Box traps, with rock doves (*Columba livia*) in the center compartment, lure goshawks into separate side compartments when they are trying to capture rock doves for food. Box traps were placed along roadsides or at clearcut edges next to forested stands where goshawk nests were known or were suspected to be located. Dho-gazas were used in June and early July to capture adults when they were most aggressive around their nests, whereas box traps were used in late July and August to capture young of the year before they dispersed.

Trapped goshawks were hooded and a series of morphometrics and health indicators were recorded (McClaren 1999). Wing and tail moults were also recorded, the birds were weighed and banded, and some were affixed with BIOTRACK® backpack radio-transmitters (BIOTRACK Ltd., UK). Radio-transmitters were affixed to adults; immatures were banded only. When other raptors were caught in box traps, morphometric and health data were recorded, and then they were released.

Radiotelemetry

Aerial telemetry, using helicopters and fixed-wing aircraft, was used to locate goshawks periodically throughout the breeding season and winter months, whenever finances and weather permitted. In May, an effort was made to relocate all tagged individuals (especially females) to determine their nesting territories and nest trees. Once general nest locations were determined by air, ground telemetry was performed on foot using a 6-element antenna (Lindsay, ON) to locate and/or verify active nest trees. On average, air telemetry occurred twice a month, from September through April, 1996–1999. Goshawk locations (UTM [universal transverse mercator] coordinates) were recorded using a GPS (global positioning system) from the aircraft. Additionally, broad habitat data, such as tree species composition, age class and forest stand type, were recorded from the air. UTM coordinates were entered into a spreadsheet in Microsoft Excel® where the distance between an individual's current location and its nest site and last telemetry location were calculated to examine movement patterns. UTM coordinates were also entered into a GIS (geographic information system) database so that telemetry locations could be viewed on maps in relation to landscape-level habitat features. Aerial locations will be used to determine goshawk winter home ranges, winter habitat associations, and survival when sufficient data are available.

RESULTS

Goshawk Inventory

Between May and August, 1994–1998, approximately 2,912 broadcast stations (37,856 ha) resulted in 51 confirmed goshawk detections and the location of 19 goshawk territories (Table 1). Approximately 45% of these call stations occurred

Table 1. Survey effort, goshawk detections, and nest territories found on Vancouver Island in 3 forest types, May–August, 1994–1998.

Survey areas	Forest type[a]	Call stations			Stand-watches		No. of new nests
		No.	Area (ha)	Detections	Hours	Detections	
Vancouver	Continuous OG	1,285	16,705	30	494	14	12
Island	Continuous SG	962	12,506	6	76	1	3
	Fragmented OG/SG	665	8,645	15	162	5	5
OVERALL TOTAL	All Forest Types	2,912	37,856	51	732	20	20

[a] OG = old growth, SG = second growth.

in continuous old-growth forests, 32% in continuous second-growth forests, and 23% in fragmented forests. Of the 51 goshawk detections, 59% occurred in continuous old growth, 12% occurred in continuous second growth, and 29% occurred in fragmented forests.

Stand-watches appear to be a less effective inventory technique, with approximately 732 stand-watch hours conducted between 1995 and 1998 generating 20 confirmed goshawk detections and 1 new nest territory (Table 1).

Additionally, 12 goshawk territories were reported by forestry workers and members of the public, and 3 were found using radiotelemetry, increasing the total number of goshawk nest territories currently known on Vancouver Island to 35.

Territory Occupancy and Nest Productivity

Between 1995 and 1998, occupancy of known goshawk territories on Vancouver Island was consistently higher at nests located in continuous old-growth forests, although a greater number of nests are known within this forest type (Fig. 1). Furthermore, overall occupancy rates varied annually.

As well as assessing known goshawk territories for occupancy, the number of young in each nest approximately 1 week prior to fledging (approx. 39 days of age) was documented (Table 2). Mean productivity between 1994 and 1998 varied by year and by forest type.

Nesting Habitat

Of the 35 goshawk territories located on Vancouver Island between 1994 and 1998, 18 (51%) are in continuous old-growth forests, 11 (32%) are in a continuous second-growth forests, and 6 (17%) are in fragmented forests (Table 3). These territories are distributed fairly evenly among the 4 cardinal directions for stand aspects (Fig. 2). Thus, goshawk nests are situated in forested stands with various slope aspects. The elevational range of known goshawk nest trees is between 80 m for the West Cracroft Island nest and 810 m for the Oktawanch nest, with a mean nest elevation of 375.1 ± 31.4 m for the 35 territories.

At a smaller scale, goshawk nests were in a wide variety of tree species (Table 3). Twenty-nine (53.7%) were in Douglas-fir (*Pseudotsuga menziesii*), 19 (35.2%) in western hemlock (*Tsuga heterophylla*), 6 (11.1%) in red alder (*Alnus rubra*), 1 in a Sitka spruce (*Picea sitchensis*), and 1 in a western redcedar (*Thuja plicata*). Tree species data are missing for 5 nest trees. In general, nest trees had a large diameter at breast height (DBH; mean = 68.6 ± 5.8 cm) and nests were located one-third to one-half the way up the nest

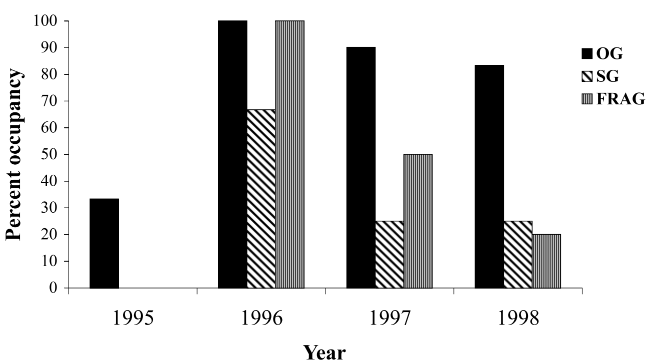

Figure 1. Percent occupancy of known goshawk territories on Vancouver Island, 1994–1998.

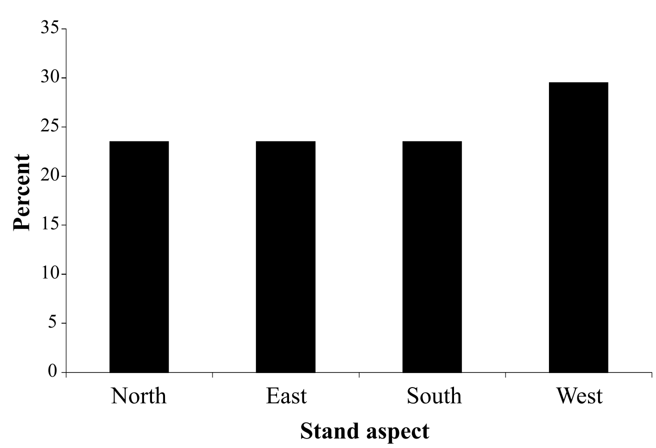

Figure 2. Percent of goshawk nest territories on each stand aspect.

Table 2. Mean nest productivity (number fledglings/active nest), 1994–1998, by year and forest type. Means are followed by standard errors and sample size.

Forest Type[a]	1994 $\bar{\chi}$ ±SE (n)	1995 $\bar{\chi}$ ±SE (n)	1996 $\bar{\chi}$ ±SE (n)	1997 $\bar{\chi}$ ±SE (n)	1998 $\bar{\chi}$ ±SE (n)	Total
COG	2.0±0.4 (4)	2.0±0.0 (4)	2.0±0.2 (10)	1.2±0.4 (9)	1.9±0.2 (12)	1.7±0.1 (35)
CSG	3.0±0.0 (1)	2.0±0.0 (2)	2.0±1.0 (3)	1.7±0.2 (6)	2.0±0.6 (3)	1.9±0.2 (14)
FRAG			0.7±0.5 (4)	2.0±0.0 (2)	2.0±0.0 (1)	1.3±0.4 (7)
Total	2.2±0.4 (5)	2.0±0.0 (6)	1.7±0.2 (17)	1.4±0.2 (17)	1.9±0.2 (16)	1.7±0.1 (56)

[a] COG = continuous old-growth forests; CSG = continuous second-growth forests; FRAG = fragmented old-growth and second-growth forests.

tree. With the exception of 4 nests, most goshawk nests were built in live trees.

DISCUSSION

Goshawk Inventory

Between 1994 and 1998, goshawk inventory occurred in several different areas on Vancouver Island. Inventory work in new areas improves our understanding of the nesting distribution and habitat associations of goshawks on Vancouver Island. Surveys conducted repeatedly within known territories are used to determine territory occupancy status and to locate alternate nest sites. Repeated inventory within the Woss/Sayward research areas enables us monitor goshawk populations in this area over time, to evaluate territory occupancy and nest productivity in relation to forest age class distribution and the degree of fragmentation within breeding home ranges, and to gain more information on nest site and mate fidelity for tagged individuals.

The effectiveness of broadcast surveys for goshawks within the dense, rugged, rain-soaked Pacific Northwest forests has been questioned by several researchers and inventory personnel (western Washington: Bosakowski and Vaughn 1996; southeast Alaska: Iverson et al. 1996; western Oregon: DeStefano and McCloskey 1997). However, in a recent test of the broadcast survey methodology in western Washington, Watson et al. (1999) concluded that the effectiveness of broadcast surveys within Pacific Northwest forests was comparable to the dry, southwestern forests where the methodology was originally described (Kennedy and Stahlecker 1993). Between June and August, 1994–1998, 51 goshawk detections occurred through broadcast surveys on Vancouver Island. Although this appears to be low relative to the number of broadcast stations, it compares well with other studies. For example, a study conducted on a population of goshawks with 1 of the highest known nesting densities in North America, the Kaibab Plateau in Arizona, reported 2.0 detections (nestling phase) and 1.0 detections (fledgling phase)/100 broadcast stations (Joy et al. 1994). Additionally, broadcast survey success has improved annually on Vancouver Island with 0.4, 1.1, 1.6, and 5.2 detections per 100 call stations in 1995, 1996, 1997, and 1998 respectively (Quayle et al. 1995, McClaren 1997). The greater detection rates over recent years probably reflect a combination of increased inventory efforts within known goshawk territories to determine occupancy status and returning employees who have higher skill levels. It is unlikely that increased detection rates reflect greater goshawk numbers over this 4-year period, although it may reflect fluctuations in the percentage of goshawks nesting from year to year. Therefore, broadcast surveys, although time-consuming, labour-intensive, and costly, appear to be the most effective survey technique currently known to detect breeding goshawks. Furthermore, this survey methodology appears to be nearly as effective in the forests on Vancouver Island as it does in the dry forests of the southwestern United States.

Stand-watches, originally described by Reynolds (1983) as an alternate method for conducting goshawk surveys, remain relatively effective for detecting goshawks, but less useful for locating goshawk nest sites. Detection rates were 5.0 (1995), 10.0 (1996), 11.0 (1997), and 6.2 (1998) per 100 stand-watch hours (Quayle et al. 1995; McClaren 1997, 1999). It is difficult to compare detection rates between stand-watches and broadcast surveys since the latter is measured as detections per hour and the former as detections per 100 stations. Regardless, more goshawks are detected per unit of effort with stand-watches than broadcast surveys. However, stand-watches are relatively ineffective for locating goshawk nest sites. For example, stand-watch detections on Vancouver Island led to no new nest sites in 1995, 1997, or 1998, and to only 1 in 1996 (Quayle et al. 1995, McClaren 1997). In comparison, broadcast surveys resulted in 2, 4, 3, and 5 new nest territories from 1995 to 1998, respectively (Quayle et al. 1995, McClaren 1997). Broadcast surveys are more effective for locating nests than stand-watches because, typically, detections are highest within 300 m of an active nest (Kennedy and Stahlecker 1993, Watson et al. 1999). In comparison, goshawk detections during stand-watches may be foraging birds far from their nests, or birds that are not associated with active territories. Additionally, the stand-watch survey technique is more weather-dependent

Table 3. Habitat characteristics of known goshawk nest trees found during the summers of 1994–1998 in continuous old-growth (COG), continuous second-growth (CSG) and fragmented (FRAG) forests on Vancouver Island. (No data [ND] were collected for some parameters due to time constraints and/or equipment limitations).

Nest	Forest type	Tree species[a]	Elevation(m)	DBH[b] (cm)	Nest ht.(m)	Tree ht.(m)	Tree age (yr)	Decay
Artlish	COG	WH	215	47.5	19.0	49.3	>250	Alive
McLaughlin R. #1	COG	WH	700	45.0	20.8	28.6	>250	Alive
McLaughlin R. #2	COG	DF	650	65.0	21.2	36.2	>250	Alive
McLaughlin R. #3	COG	DF	800	75.5	19.0	20.4	>250	Alive
Lower Stella #1	CSG	DF	155	40.2	18.6	34.0	60–80	Alive
Lower Stella #2	CSG	DF	170	51.3	11.9	33.0	60–80	Alive
Loon Lake #1	FRAG	DF	375	41.7	16.3	17.1	>250	Alive
Loon Lake #2	FRAG	DF	300	38.2	ND	ND	>250	Dead
Tlatlos #1	COG	WH	465	66.3	14.7	44.9	>250	Alive
Tlatlos #2	COG	WH	450	74.6	21.9	36.3	>250	Dead
Tlatlos #3	COG	WH	460	84.0	24.3	44.5	>250	Alive
Tsitika	COG	WH	520	79.4	21.9	72.4	>250	Alive
Patterson Lake #1	CSG	DF	280	69.9	18.5	35.4	60–80	Alive
Patterson Lake #2	CSG	WH	300	72.5	10.6	30.2	60–80	Alive
Patterson Lake #3	CSG	WH	285	46.0	16.5	35.6	60–80	Alive
Patterson Lake #4	CSG	DF	370	51.5	17.3	40.7	60–80	Alive
Cervus Creek #1	COG	DF	423	84.5	19.3	64.3	>250	Alive
Cervus Creek #2	COG	DF	440	92.5	41.0	112.0	>250	Alive
Cervus Creek #3	COG	DF	430	82.5	21.5	53.6	>250	Alive
Cervus Creek #4	COG	DF	ND	ND	ND	ND	>250	Alive
Anderson Lake #1	COG	WH	230	68.0	13.8	51.6	>250	Alive
Anderson Lake #2	COG	ND	ND	ND	ND	ND	ND	ND
Cowichan Lake	CSG	DF	260	33.0	6.7	27.0	50–60	Alive
Mt. Edinburgh #1	COG	WH	230	58.7	21.7	35.8	>250	Alive
Mt. Edinburgh #2	COG	ND	ND	ND	ND	ND	ND	ND
Mt. Edinburgh #3	COG	ND	ND	ND	ND	ND	ND	ND
Lupin Falls	COG	DF	475	57.6	26.2	44.5	>250	Alive
Derby #1	COG	WH	420	56.2	19.3	41.3	>250	Alive
Derby #2	COG	WH	430	59.6	17.2	36.5	>250	Alive
Derby #3	COG	WH	490	58.5	11.0	23.0	>250	Alive
Claud Elliot #1	COG	WH	550	52.3	20.3	35.5	>250	Alive
Claud Elliot #2	COG	WH	500	76.0	20.5	27.5	>250	Alive
Lukwa	COG	WH	650	82.6	14.2	42.8	>250	Alive
Klaklakama #1	FRAG	WH	450	89.5	32.7	ND	>250	Alive
Klaklakama #2	FRAG	DF	500	103.0	24.8	56.4	>250	Alive
Klaklakama #3	FRAG	DF	510	104.0	32.0	ND	>250	Alive
Klaklakama #4	FRAG	WC	620	90.1	15.0	31.2	>250	Alive
W. Cracroft Is. #1	CSG	DF	80	31.0	ND	ND	60–80	Dead
W. Cracroft Is. #2	CSG	DF	ND	ND	ND	ND	60–80	Alive
Nimpkish Is. #1	FRAG	DF	200	112.0	46.1	82.4	>250	Alive
Nimpkish Is. #2	FRAG	DF	250	178.0	22.7	63.2	>250	Alive
Hoomak Lake	FRAG	DF	270	93.3	21.7	74.2	>250	Alive
Consort Creek	COG	WH	670	70.7	20.1	37.1	>250	Alive
Pye Lake	CSG	RA	305	25.5	11.9	16.7	60–80	Alive
Upper Stella	CSG	RA	270	37.3	ND	ND	60–80	Alive
Rona Loop	FRAG	DF	170	112.5	20.2	44.8	>250	Alive
Vernon Ridge #1	COG	WH	435	95.3	55.7	79.8	>250	Alive
Vernon Ridge #2	COG	DF	420	100.3	24.8	57.9	>250	Alive
Nahmint #1	COG	DF	450	82.5	25.1	>60	>250	Alive
Nahmint #2	COG	ND	ND	ND	ND	ND	>250	Alive
Museum Ck.	CSG	RA	380	25.0	11.4	20.0	50–60	Alive
Cottonwood #1	CSG	RA	550	ND	ND	ND	50–60	Alive
Cottonwood #2	CSG	RA	550	ND	ND	ND	50–60	Alive

Table 3. Continued.

Nest	Forest type	Tree species[a]	Elevation(m)	DBH[b] (cm)	Nest ht.(m)	Tree ht.(m)	Tree age (yr)	Decay
Cook Creek	CSG	RA	370	22.8	ND	ND	50–60	Alive
Supply Creek	CSG	DF	250	42.2	13.9	30.4	68–70	Alive
Quadra Island	FRAG	SS	220	44.4	12	22.8	74	Dead
China Creek	COG	ND	ND	ND	ND	ND	>250	Alive
Goose Creek	CSG	DF	ND	ND	ND	ND	50–60	Alive
Gold Park	COG	DF	280	99.3	13.8	38.9	>250	Alive
Muchalat Lake	COG	DF	430	42.9	19.4	22.5	>250	Alive
Oktawanch	COG	DF	810	85.9	ND	33.1	>250	Alive
TOTALS, Means±SE	18: COG 11: CSG 6: FRAG	29: DF 19: WH 6: RA 1: SS 1: WC	375±31.4	68.6±5.8	20.5±2.1	42.6±4.4	40: >250 18: 50–80 3: ND	52: Alive 4: Dead 3: ND

[a] DF = Douglas-fir; WH = western hemlock; WC = western redcedar; RA = red alder; SS = Sitka spruce.
[b] DBH = diameter at breast height.

than broadcast surveys and it is limited to areas with good vantage points near forested stands.

Broadcast surveys and stand-watches appear to be more useful during certain times of the summer than others, corresponding to specific periods during goshawk breeding phenology. There seem to be 2 peak times for conducting broadcast surveys: 1 when nestlings are young and adults respond to the alarm call, and another when young are in the late-nestling phase or early-fledgling phase and respond to the juvenile food-begging call. These results are similar to broadcast survey experiments performed by Kennedy and Stahlecker (1993) and Watson et al. (1999). As well, the likelihood of locating a goshawk nest after a detection is greater during the nestling phase because detections are most often within 100 m of nests, whereas during the post-fledgling phase detection rates are frequently greater than 100 m from nests (Kennedy and Stahlecker 1993, Watson et al. 1999). Thus, it is important to determine the dates corresponding to these stages in the breeding phenology of goshawk pairs each year, as they will vary annually and geographically (Squires and Reynolds 1997), so that survey efforts may be concentrated during these time periods.

Stand-watches have been most effective during the late post-fledgling period for detecting the presence of immature goshawks, and therefore, may be useful for supplementing broadcast surveys during this time period. Additionally, stand-watches have proven to be useful during courtship (March and April) to detect the presence of adults within territories (C. Crocker-Bedford, U.S. Forest Service, AK, 1996, pers. comm.; Chytyk et al. 1997).

Two other inventory techniques may have potential for detecting goshawks and locating their nest sites. These include dawn vocalization surveys during the courtship period and broadcasting the "chup" call, a goshawk vocalization given by males when they enter the nest stand with food (Sutton 1925, Schnell 1958, Palmer 1988, Squires and Reynolds 1997) during the courtship, nestling, and post-fledgling periods. Currently, both these techniques are being tested on Vancouver Island. Dawn vocalization surveys are an effective method for locating Cooper's hawk nests in the urban environment of Victoria, B.C. (Stewart et al. 1996) and were 100% effective for detecting goshawks within known nest territories in France (Penteriani 1999). However, it remains unclear how feasible dawn vocalization surveys will be due to the remote and often rugged areas where goshawk nests are situated on Vancouver Island, the limitations of poor weather conditions during the courtship period, and their utility for locating new goshawk territories.

In 1997 and 1998, 2 new goshawk territories were located by tracking a radio-tagged female that moved to nest in a new location from the previous year. Thus, radiotelemetry has proven to be an additional method for locating alternate nests within known territories and for locating new territories. Because field crews can only survey a small portion of Vancouver Island each summer, educational talks to industry and government field workers and to members of the public are also a valuable means of generating reports of new goshawk nest locations.

Territory Occupancy and Nest Productivity

Occupancy rates at known goshawk territories on Vancouver Island have decreased between 1996 and 1998 (years where sufficient data are available). Occupancy averaged 90.0% (n = 11) in 1996, 68.4% (n = 19) in 1997, and 52.0% (n = 25) in 1998 (McClaren 1997, 1999). It is difficult to know whether this decrease in territory occupancy from 1996 to 1998 is merely a function of increased sample sizes or whether there are other influential factors. Occupancy rates are difficult to compare among studies because rates vary according to the methods used and the amount of effort expended to determine occupancy (Kennedy 1997). However, when occupancy rates are averaged for 1996–1998, mean occupancy on Vancouver Island is 70.1%, which is similar to other studies (New Mexico: 74.4%, n = 22; Utah: 74.7%, n = 26, Kennedy 1997; California: 74%, n = 26, Woodbridge and Detrich 1994). It is not unusual for occupancy rates to fluctuate annually for goshawks (Kennedy 1997). Consequently, the low rates observed in 1998 may just reflect a year with low numbers of nesting goshawks rather than indicating a decreasing trend in occupancy rates for goshawk territories on Vancouver Island.

Although territory occupancy was relatively low in 1998, nest productivity was relatively high, with an average of 1.9±0.2 fledglings per active nest (including newly found and previously known territories). This is higher than in 1996 and 1997 when nest productivity averaged 1.7±0.2 (n = 17) and 1.4±0.2 (n = 17), respectively (McClaren 1997). Including newly found nests in nest productivity estimates has been shown to inflate productivity values because nests that fail are less likely to be found and are therefore not included in productivity estimates (Steenhof 1987). However, with this in mind, mean nest productivity for Vancouver Island appears to be similar to other studies where productivity values range from 0.0 to 2.8 (Doyle and Smith 1994). Furthermore, the number of fledglings per nest ranged from 1.0 to 2.1 in Oregon (DeStephano et al. 1994), averaged 1.8 in Washington (Sheets 1993), and averaged 2.3±0.4 in Mediterranean Italy (Penteriani 1997).

Annual fluctuations in territory occupancy and nest productivity are hypothesized to be caused by changes in food supply (Doyle and Smith 1994, Ward and Kennedy 1996), and weather (Penteriani 1997). Newton (1979) documented that raptors will postpone breeding when food resources are limiting. For example, goshawk reproduction in the Yukon has been demonstrated to cycle with the abundance of their primary food source, snowshoe hare (*Lepus americanus*; Doyle and Smith 1994). As there are no snowshoe hare on Vancouver Island, red squirrel (*Tamiasciurus hudsonicus*) rather than snowshoe hare, are considered to be an important prey item for goshawks (T. Ethier, B.C. Ministry of Environment, Lands and Parks, Penticton, 1995, pers. comm.). However, a relationship between red squirrel numbers and goshawk nest success remains to be demonstrated.

In terms of weather conditions, research on goshawks by Penteriani (1997) in the Mediterranean demonstrated goshawk nesting success to be closely correlated to rainfall levels during the spring and, particularly, during the incubation period. During years of cold, wet springs Penteriani (1997) found that goshawks began incubation later and suffered reduced nesting success, possibly due to decreased hunting and food intake. This aspect has to be further examined for goshawks on Vancouver Island, but high snowfall levels and occasional extremely wet months of March, April, and May could be factors contributing to years of lower nesting success and reduced nest productivity. Nest predation can also be a factor that reduces the number of fledglings at nest sites (Ward and Kennedy 1996); however, we have no evidence of higher than average nest predation rates on Vancouver Island.

Some researchers have suggested that certain habitat characteristics influence territory occupancy and nest productivity and that over the long run, habitat fragmentation and removal may have a negative impact on goshawks (Woodbridge and Detrich 1994, Patla 1997, Desimone 1997). Territory occupancy has been demonstrated to be positively correlated with: nest stand and nest stand cluster size (defined as the aggregate of all nest stands within one pair's territory; California: Woodbridge and Detrich 1994); the amount of mid-aged, closed forest (average stand DBH: 23–53 cm, >50% canopy cover) and late, closed forest (>53 cm DBH, >50% canopy cover) at 5 spatial scales (12, 24, 52, 120, and 170 ha; Oregon: Desimone 1997); and significantly more mature forest cover (DBH: 45.7–60.9 cm) within the nest area (81 ha) and post-fledgling family area (162 ha), less seedling (DBH: 2.54–12.7 cm) and young forest (DBH: 12.7–30.5 cm) cover, and with the proportion of sagebrush/shrub within 2,428 ha (eastern Idaho; western Wyoming: Patla 1997). Although nest productivity was not influenced by stand cluster size in California (Woodbridge and Detrich 1994), it was positively related to basal area at the 81-ha scale and to the proportion of sagebrush/shrub at the 2,428-ha scale in eastern Idaho/western Wyoming (Patla 1997). Regression analysis failed to show a significant relationship between forest age class and pooled occupancy rates or nest productivity in Patla's (1997) research, most likely because a large portion (mean of 60%) of territories were located in mature forest, so there were few habitat differences among nest sites.

On Vancouver Island, where there are dramatic habitat differences among nest sites, territory occupancy has been consistently higher in continuous old-growth forests compared to continuous second-growth and fragmented forests. Nest productivity, on the other hand, appears to be similar between continuous old-growth and continuous second-growth forests, although it is slightly lower in fragmented forests. Territory occupancy and nest productivity in relation to forest age class and the amount of fragmentation within goshawk home ranges is being further investigated (McClaren in prog.).

Nesting Habitat

Within the literature there exists a great deal of debate regarding the habitat requirements of goshawks (Clark 1998, Daw et al. 1998). Most habitat information has been collected around nest sites during the breeding season, whereas data on the winter habitat associations of goshawks are scant (Kennedy 1997, Squires and Reynolds 1997). In a status evaluation of goshawks, the United States Fish and Wildlife Service found that goshawks, although typically nesting in mature or old-growth forests, appear to be able to use many ages and types of forests to fulfill their life history requirements (Clark 1998). Conversely, a literature review of the habitat characteristics around goshawk nests in the western United States by Daw et al. (1998) concluded that, regardless of region or forest type, there was a trend for goshawks to nest in stands comprised of large trees (>53 cm DBH) with high canopy closure (>50–60%). To further complicate matters, biased sampling of goshawk breeding habitat in many studies may have misconstrued our understanding of their habitat associations (Kennedy 1997, Daw et al. 1998, Rosenfield et al. 1998).

More in-depth descriptions of habitat associations of goshawks on Vancouver Island at the nest site, stand, and landscape levels are described by Ethier (1999). From general habitat data collected at goshawk nest trees during inventory efforts, goshawks appear to nest in a variety of tree species on Vancouver Island, including Douglas-fir, western hemlock, Sitka spruce, red alder, and western redcedar. Although most nests are in Douglas-fir and western hemlock, many nests in second-growth forests are in red alder trees. Thus, it appears that goshawks select for tree structure rather than species, and if trees have sufficient support structures for goshawk nests and are surrounded by forests that will provide forage opportunities, protection from predators, and suitable habitat to raise young, (i.e., high canopy closure and large DBH; Daw et al. 1998), goshawks will nest in these locations.

More recently, the importance of understanding goshawk habitat relationships at larger scales has been acknowledged (Kenward 1982, Bosakowski and Speiser 1994, Bright-Smith and Mannan 1994, Hargis et al. 1994, Squires and Reynolds 1997, Widen 1997, Daw et al. 1998). However, there is a paucity of information available at this scale. The results of goshawk habitat studies at larger spatial scales are equivocal. Some investigators claim that goshawks require relatively large, undisturbed tracts of older forest to nest successfully (Bosakowski and Speiser 1994, Desimone 1997, Patla 1997). Alternatively, others suggest that goshawks are able to nest in small (0.4–20 ha), widely spaced stands of mature forest (Lindell 1984, Woodbridge and Detrich 1994, Younk and Bechard 1994, Squires and Ruggerio 1996, Widen 1997). Widen (1997) and Beier and Drennan (1997) propose that fragmentation of foraging habitat as it relates to prey availability and abundance may be more limiting to goshawks than suitable nest sites. In fact, Widen (1997) suggests that goshawk populations in Sweden, Finland, and Norway (Fennoscandia) are declining due to the deterioration of goshawk foraging habitat in the boreal forests and that this decline cannot be overcome by creating protected areas, because they need areas that are much too large to be effectively protected in this manner. Thus, whether goshawks are forest generalists at large spatial scales, as some researchers claim (Reynolds et al. 1992, Squires and Reynolds 1997, Daw et al. 1998), and the types and amount of habitat they require to meet their life history requirements, remain unanswered.

At a larger scale, goshawk nests on Vancouver Island are generally located on the bottom to middle portion of forested slopes, at lower elevations, on moderate slopes. After 2 years of goshawk inventory on Vancouver Island, the majority of goshawk nests were found on slopes with southwest aspects (Quayle et al. 1995). Therefore, from these data it was assumed that goshawks on Vancouver Island preferred to nest on forested slopes with southwest aspects. However, there were only 11 nests known at this time. Since 1995, goshawk nests have been found on all aspects and there is no particular trend in nest stand aspect. In the southern United States, goshawk nests are typically found on north- and east-facing slopes (Reynolds et al. 1982, Hayward 1983, Bull and Hohmann 1994, Crocker-Bedford 1994). In southeast Alaska, Titus et al. (1994) reported most nests to be on northeast aspects, whereas McGowan (1975) described the majority of goshawk nests to be on southern slopes. Elevation and aspect may be important habitat selection criteria for goshawks, as these factors influence the microclimate around their nests. However, there has been minimal information collected in this area of goshawk ecology (Squires and Reynolds 1997). If microclimate is important to goshawk nesting success, we would expect nests in southern latitudes to be on cooler, northeast aspects to prevent overheating, whereas nests in northern latitudes should be on the warmer, southwest aspects. Although data from the southern states support this hypothesis, data from Vancouver Island and southeast Alaska suggest that other habitat characteristics (i.e., tree density, DBH, canopy closure) are more influential in determining where goshawks establish nest territories.

Furthermore, data collected from Vancouver Island do not suggest that goshawk nest locations are associated with particular elevations, as this may also influence the heat regime around goshawk nest sites. Goshawks have been found nesting from sea level in southeast Alaska to high-elevation forests in Colorado (Squires and Reynolds 1997). On Vancouver Island, goshawk nests range in elevation from 80 to 810 m, with most nests located between 300 and 500 m. Nests are typically below 900 m on Vancouver Island and in southeast Alaska (Titus et al. 1994), probably because forest stand characteristics change at higher elevations. Above 1,000 m, most forests on the east coast and central parts of Vancouver Island change from being dominated by western hemlock, Douglas-fir, western redcedar, and amabalis fir

(*Abies amabalis*) to domination by mountain hemlock (*Tsuga mertensiana*), yellow-cedar (*Chamaecyparis nootkatensis*), and subalpine fir (*Abies lasiocarpa*), with a dense salal (*Gaultheria shallon*) understory. Additionally, forests at higher elevations have more open canopies and smaller trees. Therefore, it appears goshawks on Vancouver Island, and possibly in southeast Alaska, are restricted to nesting below 1,000 m. However, these data may reflect a biased search effort, with most goshawk surveys occurring in the more easily accessed, lower elevation forests.

CONCLUSIONS

In conclusion, goshawk inventory has occurred for 5 years within the same areas on northern Vancouver Island. Repeated inventory on northern Vancouver Island continues to provide new and interesting information about goshawks that enables us to adapt habitat suitability models and manage more effectively for goshawks in British Columbia. Additionally, expanding goshawk inventory into new areas of Vancouver Island each year allows us to gather more information on their distribution and habitat associations. Although a valuable baseline of information was gathered by Ethier (1999) on goshawk nest site selection, nest stand structure, and prey use, there are still several information gaps for goshawk ecology on Vancouver Island that must be filled. These include: population size estimates; landscape-level habitat requirements; breeding and winter home range size estimates; juvenile and adult survivorship; and juvenile dispersal distances. This information is critical so that we can gain a better understanding of the goshawk's role in the forest ecosystems on Vancouver Island and learn more about how goshawks respond to current logging practices. Management guidelines outlined in the *Managing Identified Wildlife: Procedures and Measures, volume I* (B.C. MOF and B.C. MELP 1999) for goshawks in British Columbia were primarily developed from goshawk studies conducted outside British Columbia, due to the lack of local information on goshawk populations. This emphasizes the importance of continuing goshawk inventory and research on Vancouver Island and throughout the rest of British Columbia. We must guarantee that science-based practices are used to manage goshawk populations appropriately to ensure populations persist into the future.

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