Northern Goshawk and Marbled Murrelet Habitat Models and carrying out Field Surveys Gwaii Haanas National Park Reserve and Haida Heritage Site

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Executive Summary

The Queen Charlotte Goshawk (*Accipiter gentilis laingi*) and Marbled Murrelet (*Brachyramphus marmoratus*) have been identified as a threatened species on Haida Gwaii/Queen Charlotte Islands. Gwaii Haanas National Park, is trying to establish its role in the protection of this species on the islands, and this project is designed to establish the habitat suitability and distribution, for these two species within the Park. Specifically, this project ground truthed a habitat suitability algorithm for goshawks, and Marbled Murrelets, that was developed using the Ecosystem mapping and Forest Cover information available within the Park.

Ground truthing of the habitat suitability algorithm was completed along 26 transects located within habitat areas that were predicted to have the highest possibility of supporting breeding goshawks. This ground truthing involved 26 goshawk playback and habitat suitability assessment transects, 18 detailed structural habitat and prey transects and four Marbled Murrelet dawn surveys. Ground truthing of the habitat mapping themed using the suitability algorithm, showed >80% accuracy in assigning the correct ranking, and ≥88%, were out by just one rank. Habitat suitability mapping identified five areas that had sufficient high ranked foraging habitat to support a pair of breeding goshawks. During goshawk playback surveys within these areas, 96 playback stations were completed, and one goshawk nest with two fledged young was located on Lyell Island. This area was ranked as the most likely to support a pair of goshawks, as it had the closest match to the predicted foraging area requirements. The four remaining sites had smaller areas of suitable habitat, and no go goshawks were detected, however, far more systematic surveys over multiple years will be required to establish if other pairs are present in these other areas. Four Marbled Murrelet dawn survey confirmed the presence of birds in areas ranked as having high ranked suitability. Detailed habitat mapping confirmed the association of suitability ratings with tree species, tree height and tree age, and these are consistent with other ongoing habitat suitability mapping in other areas of the islands.

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Acknowledgements

This work is indebted to the hard work and expertise of Gerry Morigeau, Jacques Morin, Kiku Dhanwant and Todd Mahon. Donald McLennan and Todd Golumbia were instrumental in initiating this project, and more recently Scott Parker and Doug Burles from Gwaii Haanas National Park, have both been pivotal in ensuring the smooth running of the project, by both identifying suitable survey habitats, and providing logistic support to access these sites. Pat Bartier the Parks GIS technician at Gwaii Haanas, helped to develop the habitat suitability algorithm and produced the maps, and his depth of historic knowledge, steered the project around the many pitfalls that can undermine this type of project. Finally this project would not have been possible without support from the SAR Recovery Fund.

Background:

This project will test the accuracy of predicted availability of nesting habitat for the Marbled Murrelet (*Brachyramphus marmoratus*) and the predicted availability of nesting and foraging habitat for the Northern Goshawk (*Accipiter gentilis laingi*), and its prey. This information will be combined with linked projects outside of the protected area and used to help in the management of critical habitat through regional land use planning initiatives. The goshawk is a top avian forest predator on the islands for which only 6 nest areas have been located despite several years of inventory. The murrelet is equally cryptic and both are listed as Threatened by COSEWIC. A new recovery plan has been drafted for the Marbled Murrelet and the Northern Goshawk Recovery Team has not yet been established. This inventory work contributes to achieving objectives described in the Marbled Murrelet (Burger 2002) and Goshawk (Zeeman 1997) conservation assessments and will likely be key to either recovery strategy. Impacts on the density and species composition of prey populations are known to impact the density and breeding success of goshawks (Doyle and Smith 1994). Therefore habitat verification for the Northern Goshawk will include a test of the predicted distribution of nest areas as well as an indication of prey availability. The outcomes of this work will address conservation objectives for both species with respect to habitat supply and population monitoring.

Rationale:

1. To verify habitat mapping and species habitat models for the protected area of Gwaii Haanas to compliment similar efforts completed by provincial government agencies, timber companies and other organisations on Haida Gwaii.

2. Develop a clear understanding of the role that Gwaii Haanas plays in protecting habitat and individuals (direct observations) of target species at risk on Haida Gwaii.

Project objectives:

This project will confirm predicted quality and extent of suitable nesting/foraging habitat for target species as well as opportunistic identification of other species or communities of concern. With linkages to completed work and proposed future work on the archipelago, the intent is to provide a comprehensive ecologically based habitat supply

analysis for the goshawk and marbled murrelet on Haida Gwaii in support of proposed comprehensive land use planning. In summary, this project will:

1. Ground truth forest cover and ecosystem classification maps to determine their accuracy and usefulness in predictive habitat supply analyses.

2. Use the current NOGO and MAMU habitat supply models to predict locations with medium or high potential to support nesting habitat. Ground truth these locations for use by NOGOs and MAMUs.

3. Determine the presence and abundance of key prey species for NOGO at all locations investigated.

4. Identify and record the locations of other relevant species or plant communities of concern (COSEWIC and CDC listings).

5. Combine this information into a report summarising model suitability and habitat supply analysis in relation to the regional landscape.

Objective 1:

a) Ground truthing will be conducted to verify the accuracy of ecosystem and forest cover data (site series and stand structural stage) particularly as they relate to interpretations of nesting and foraging suitability for goshawk and nesting suitability for murrelet. This will include assessing the accuracy of ranking and habitat boundaries identified through NOGO and MAMU habitat suitability index mapping.

b) Ground truthing will include a full spectrum of suitability classes for both target species.

c) Where possible, field crews will identify any map line work or polygon attribute changes needed for capability and suitability maps.

Objective 2:

a) Survey transects will be established across a full range of habitat suitability indices for both target species. The majority of transect stations will be focussed on high suitability sites.

b) At each selected location, NOGO call playback transects will be conducted as per RIC standards. If a nest is located, information is collected on nest location (GPS), as well as canopy closure and forest cover data. If the bird is detected and disturbed, crews will not spend any time looking for the nest or doing habitat descriptions.

c) In all areas where ground truthing takes place, the accuracy of the marbled murrelet habitat suitability ranking will also be verified based on RIC standards. Field crews will undertake dawn counts for marbled murrelets at a select subset of transect sites to assess habitat use in preparation for follow up radar surveys. If a nest is located, information is to be collected on nest location (GPS), as well as canopy closure and forest cover data. If the bird is detected and disturbed, crews will not spend any time looking for the nest or doing habitat descriptions.

Objective 3:

At each selected location, breeding bird survey point counts will be undertaken to determine the presence/absence and abundance of forest bird species (particularly potential NOGO prey).

Objective 4:

If field crews identify any red or blue listed species or ecosystems, they will record their locations. If any rare ecosystem is encountered field crews will delineate the location of the ecosystem boundaries on 1:5000 or 1:20,000 maps (as available) and complete an Ecosystem Field Form.

Objective 5:

The final report will include a discussion of the above objectives. Report will be delivered in hard copy and digital format (WORD). Data must be submitted in a form that is compatible with Microsoft Access.

Measurable outcomes and deliverables:

Objective 1:

A ground-truthed forest cover and ecosite habitat suitability map with estimates of accuracy.

Objectives 2 & 3:

Maps and summary tables delineating percentage of habitat polygons rated correctly for NOGO and MAMU habitat.
Maps and/or summary tables showing percentage of transect sample points that support either nesting or foraging habitat for NOGO.
Map showing number of active or potential NOGO territories as well as any survey points showing NOGO presence.
Map showing number of potential MAMU nesting areas as well as any survey points showing MAMU presence.

Objective 4:

Map delineating locations of any listed species or ecosystems at risk.

Objective 5:

The report will summarize findings including accuracy assessments of model attributes (forest cover and ecosite descriptions), hectares of characterized potential habitat in relation to other archipelago sites and number of individual birds observed. Recommendations will be made for activities to monitor species at risk and promote their recovery including a strategy and budget.

Ground Truthing of the Habitat Suitability Algorithm

Location:

Gwaii Haanas National Park is located in the southern portion of Haida Gwaii/Queen Charlotte Islands which is an island archipelago situated 75 miles off the coast of British Columbia, Canada and consists of two large islands and some 160 smaller islands, covering in all some 250 X 90 kilometers (9,500 sq km). During the last ice age it was a glacial refugia to many species of birds, animals, plants, etc, and due to this isolation some are found here and nowhere else in the world.

This archipelago is part of the temperate old-growth rain forest with a very wet maritime climate, and is largely snow free, and all but the poorest drained sites are heavily forested. With the exception of the wettest and most exposed sites, trees typically grow to 30-40 meters, with trees >50 m in some sites, with the larger branches becoming covered in a dense blanket of moss and epiphytes. This is within the Coastal Western Hemlock biogeoclimatic zone and tree species are dominated by Western Red Cedar (*Thuja plicata)* and Yellow Cedar (*Chamaecyparis nootkatensis*), Western Hemlock (*Tsuga heterophylla*) with Sitka Spruce (*Picea sitchensis*) in the richer sites, with Red Alder (*Alnus oregona*) found along the riparian zone. The islands are separated into three ecosections, with the very wet hypermaritime Windward Queen Charlotte Mountains (WQC) on the west coast, the drier wet montane hypermaritime Skidegate Plateau (SP) area lying down the middle of the islands, and this then drops in elevation to the submontane wet hypermaritime Queen Charlotte Lowlands (QCL) in the east and north eastern section of the islands. The disturbance regime is characterized as dynamic with frequent small scale disturbances, with individual or small groups of trees dying or being blown down (Alaback and Tappeiner 1991), interspersed with the occasional large windstorm that causes extensive damage (Harris 1989).

Methods

Habitat suitability ranking for goshawks and Marbled Murrelets was conducted using Forest Cover, topography and Ecosystem Classification mapping information (McLennan et al. 2002). Maps of the entire Park depicting this themed ranking (Appendix 2 and Appendix 3) were then produced by the Parks staff. Based on the distribution of these themed habitats and the need to focus work in areas accessible by boat, and with the highest probability of detecting goshawk nesting, areas were then prior selected in which to ground truth the accuracy of the habitat suitability mapping.

Each area that was visited (Table 1.) was then ranked for the key attributes for goshawk nesting and foraging, and for Marbled Murrelet nesting (Appendix 1), and this was cross referenced with the forest cover polygon, topography and Ecosystem Classification to determine the accuracy of the suitability ranking. In addition detailed habitat/prey transects were also conducted within Forest Cover polygons following the established protocol (McLennan 2000, Doyle 2003a), in which Site Series (MELP 1998) of the polygon is identified. Site series, has been shown to be linked to the suitability of the site for goshawks

and Marbled Murrelets, and as such is an effective suitability ranking mapping tool. In addition, it has been used to create habitat suitability maps for the rest of Haida Gwaii (where this information is available), and therefore this will allow continuity of habitat theming both inside and outside of the Park.

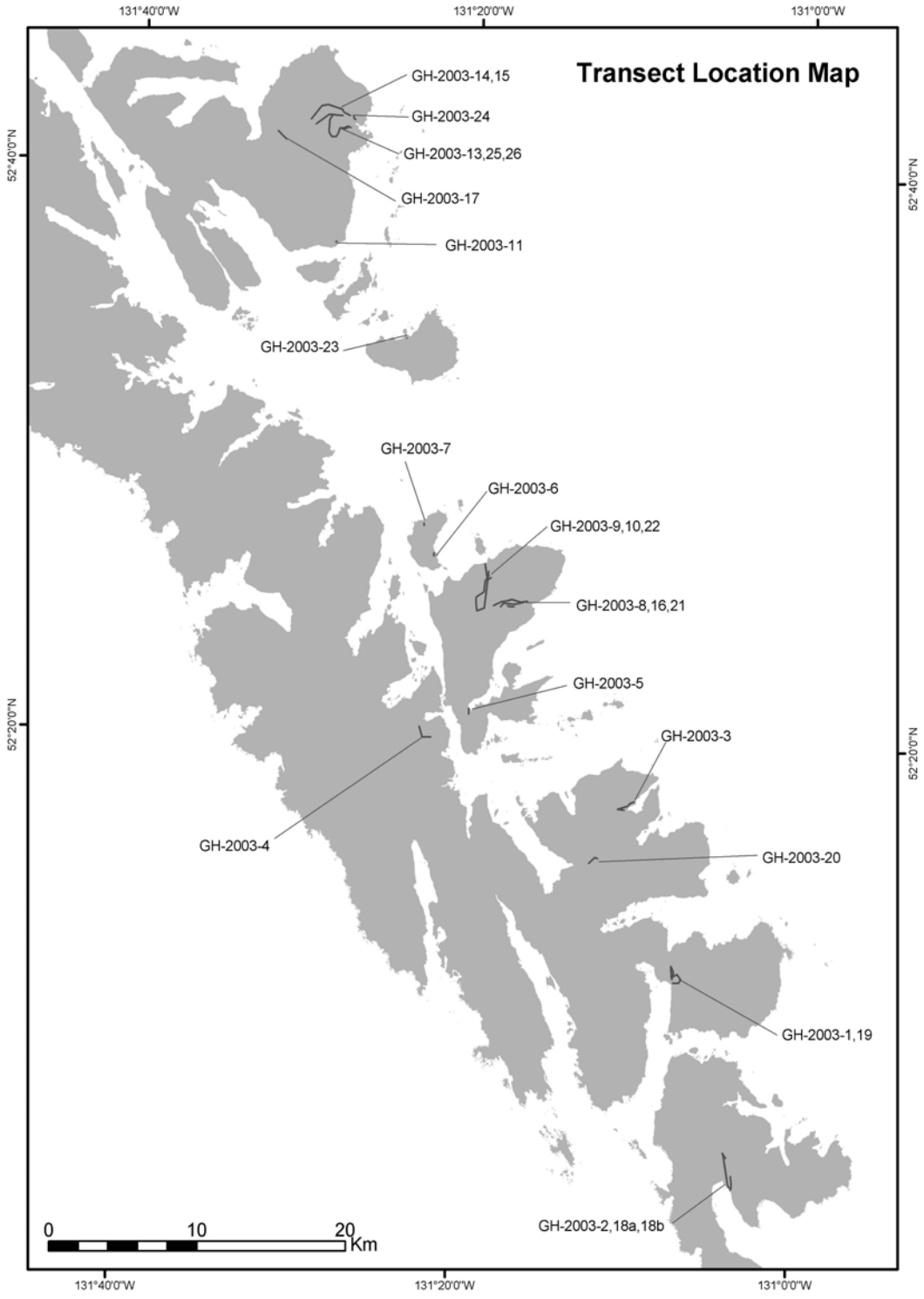
Table 1. Location, Date and Survey type conducted in 2003. Red Square = Survey Conducted

ID LABEL	LOCATION	DATE	Habitat Suitability Assessments	Goshawk Playback	Goshawk Prey Inventory	Marbled Murrelet Dawn Surveys
GH-2003-1	Rose Inlet	6/18/2003	■	■		
GH-2003-2	Luxana Bay	6/19/2003	■	■		
GH-2003-3	Ikeda Cove	6/21/2003	■	■		
GH-2003-4	Bag Harbour	6/21/2003	■	■		
GH-2003-5	Pool Inlet	6/22/2003	■	■		
GH-2003-6	Huxley East	6/23/2003	■	■	■	
GH-2003-7	Huxley North	6/23/2003	■	■	■	
GH-2003-8	Burnaby East	6/24/2003	■	■	■	
GH-2003-9-10	Burnaby North	6/25/2003	■	■	■	
GH-2003-11	Lyell South	6/26/2003	■	■	■	
GH-2003-13	Lyell East	6/26/2003	■	■	■	
GH-2003-14-15	Lyell East	6/27/2003	■	■	■	
GH-2003-16	Burnaby East	6/28/2003	■	■	■	
GH-2003-17	Lyell West	6/29/2003	■	■	■	
GH-2003-18a-b	Luxana Bay	7/17/2003	■	■	■	
GH-2003-19	Rose Inlet	7/18/2003	■	■	■	
GH-2003-20	Huston Inlet	7/20/2003	■	■	■	
GH-2003-21	Burnaby East	7/21/2003	■	■	■	
GH-2003-22	Burnaby North	7/22/2003	■	■	■	
GH-2003-23	Ramsay Island	7/24/2003	■		■	
GH-2003-24	Windy Bay	7/25/2003	■	■	■	
GH-2003-25	Windy Bay	7/26/2003	■	■	■	
GH-2003-26	Windy Bay	7/27/2003	■	■	■	
GH-1-MAMU	Rose Inlet	7/8/2003				■
GH-2-MAMU	North Burnaby	7/23/2003				■
GH-3-MAMU	East Burnaby	7/24/2003				■
GH-4-MAMU	Windy Bay	7/28/2003				■

Results

A total of 11 distinct geographic areas (Figure 1.) were visited within the Park. Within these areas a total of 19 detailed habitat suitability assessments (Table 2, Figure 2) with Site Series identification, were conducted in the latter half of June and July 2003. As suitable goshawk and Marbled Murrelet habitat is predominantly distributed in the east of the Park, most (17 of 19) transects were found to be in the drier CWH wh1 Biogeclimatic Unit, with only 2 sites (GH 18a-b) were in the wetter CWH vh2, found in the west and extreme south of the Park.

Figure 1. Location of ground truthing transects within Gwaii Haanas National Park.



Ground Truthing

Mapped habitat suitability was compared to rating and ranking of 25 ground truthing transects (Table 2). The comparison tested if the rankings matched, or shared a ranking if more than one was assigned, or if the ranking was completely wrong.

In all accuracy for goshawk mapping was 84% for an exact match for goshawk foraging and for 88% for goshawk nesting. If we look to see if the ranking between mapped and the actual shared a ranking, then accuracy for foraging goes up to 100% and for nesting to 96%. Altogether, those sites that were incorrect were one ranking out (Scale: High, Medium, Low, Nil) in 6 cases (86%) the actual ranking was lower and in one case (14%) it was higher. For Marbled Murrelets an exact match between mapped and actual ranking was 80%, when comparing transects that have single rankings, and this increase to 88% when multiple mapped rankings are compared to the range of designated actual rankings. For those three sites that were incorrectly ranked, one (33%) was too high, one (33%) was too low, and the other was ranked as Medium on the map and was designated High/Low in the field.

Table 2. Mapped habitat suitability ranking versus ground truthed (actual) ranking of transects.

	Habitat Suitability Ranking					
	Goshawk		Goshawk		Marbled Murrelet	
	Foraging		Nesting		Nesting	
Transect ID	Predicted	Actual	Predicted	Actual	Predicted	Actual
GH-01	H	H	H/M	H	H	H
GH-02	H	H/L	H	H/L	H	H
GH-03	H/M	H/M	H/L	H/L	M	M
GH-04	M	M	N	N	M	M/L
GH-05	M/H	M/H	M	M	H	H
GH-06	M	M	M	M	NIL	NIL
GH-07	M	M	M	M	NIL	NIL
GH-08	H	H	H	H	H/M	H/M
GH-09	H	H	H	H	H	H/M
GH-10	H	H	H	H	H	H/M
GH-11	M	M	M	M	NIL	NIL
GH-13	H	H	H	H	H	H
GH-14	H	H	H	H	H/M	H
GH-15	H	H	H	H	H/M	H
GH-16	H	H	H	H	M	M
GH-17	H	H	H	H	M	H
GH-18a-b	H	H	H	H	H	H
GH-19	H	H/M	H/M/L	H/M/L	H/M/L	H/M/L
GH-20	H/M	H/M	H	H	H/M	H/M
GH-21	H	H	H	H	H/M	M
GH-22	H/M	H/M	H/M	H/M	H/M	H/M
GH-23	H/M	H/M	H/M	H/M	H/M	H/M
GH-24	H/M	M	H	M	M	L
GH-25	H/M	H/M	H/M/L	H/M/L	M	M
GH-26	H/M	M	H	H	H/M	H

Habitat Suitability of Transects

Habitat suitability of these transects (Figure 2.) indicated a great range in the habitat suitability ranking for all three variables tested (goshawk foraging, nesting and Marbled Murrelet nesting). As is the pattern elsewhere on Haida Gwaii, in general habitats that were

the most suitable for goshawks were also the highest ranked for Marbled Murrelet nesting. The main exception to this was the younger stands, transects 6 and 7 (Table 2, Figure 3), where murrelet suitability was much lower than goshawk foraging and nesting. These transects were on Huxley Island (2), Burnaby Island (1) and Lyell Island (1) in stands that were harvested 50 year. Although they were at the low – medium suitability for goshawk foraging and nesting, they were not suitable for Marbled Murrelets as potential nesting platforms had yet to develop.

Habitat suitability ranking for all three variables tested (goshawk foraging and nesting and Marbled Murrelet nesting) showed an increase in suitability linked to growing conditions (Table 3). With drier well drained sites with a correspondingly higher percentage of Sitka Spuce in the species composition, on a per forest type (polygon) basis, showing the highest overall ranking (Figure 2). High suitability for Marbled Murrelets occurring once spruce became the dominant forest type.

Table 3. Relationship between Site Type, forest cover type, structural stage and site series, and with habitat suitability rating for goshawks and Marbled Murrelets.

Growing**** Condition

Poor/ Wet

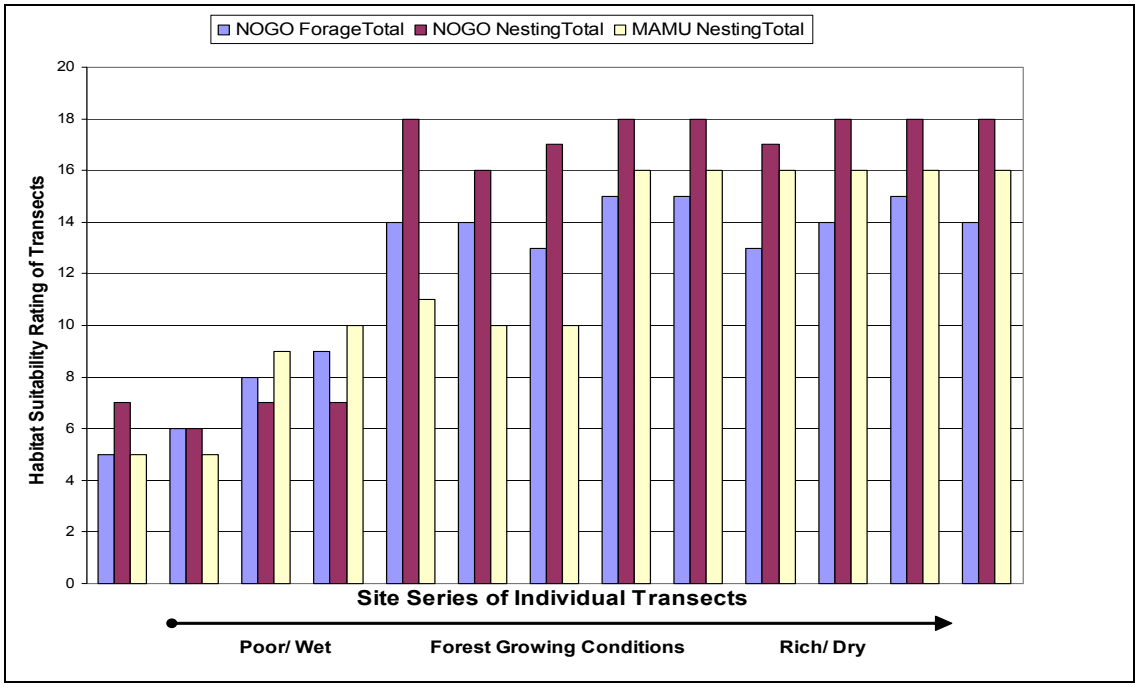
Dry/ Rich

Young Forest****

						SUITABILITY RATING		
Transect ID	Forest Cover**	Biogeoclimatic Units	Structural Stage	Site Series	TEM*** Site Series	NOGO Forage Total	NOGO Nesting Total	MAMU Nesting Total
GH-19	CYCHPL 94	CWHwh1	7	10	YG	5	7	5
GH-24	CHS 83	CWHwh1	7	10	YG	6	6	5
GH-21	CYC 83	CWHwh1	7	4	HS	8	7	9
GH-22	CHS 83	CWHwh1	7	4	HS	9	7	10
GH-09	SH 86	CWHwh1	7	1	SM	14	18	11
GH-16	HS 85	CWHwh1	7	1	SM	14	16	10
GH-23	HS 85	CWHwh1	7	1	SM	13	17	10
GH-20	SH 97	CWHwh1	7	3	SF	15	18	16
GH-17	SH 87	CWHwh1	7	6	SC	15	18	16
GH-08	SHC 86	CWHwh1	7	5	RF	13	17	16
GH-13	SH 93	CWHwh1	7	5	RF	14	18	16
GH-14	SCH 87	CWHwh1	7	5	RF	15	18	16
GH-15	H 84	CWHwh1	7	5	RF	14	18	16
GH-18b*	SH 96	CWHvh2	7	7	SD	10	13	10
GH-18a*	HSC 95	CWHvh2	7	6	SF	8	10	10
GH-10	SH 93	CWHwh1	4	1	SM	3	7	2
GH-11	HCS 93	CWHwh1	4	2	RS	8	8	2
GH-06	50 yr old SH	CWHwh1	5	3	SF	13	14	5
GH-07	50 yr old SH	CWHwh1	5	3	SF	12	11	2

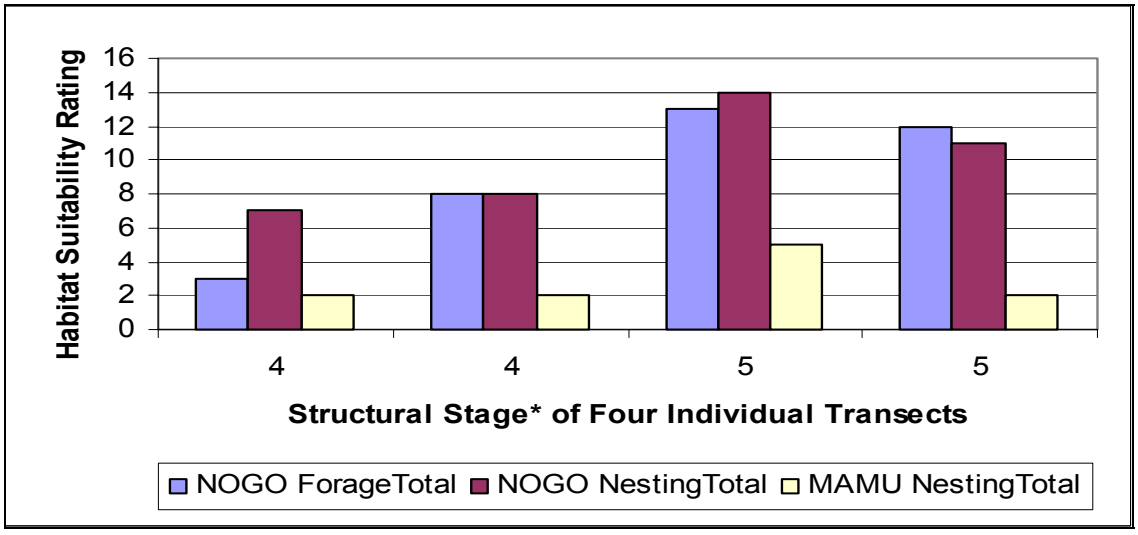
*Biogeoclimatic Unit CWH vh2, **Tree Species in order of abundance, Age Class and Height Class, ***Terrain Ecosystem Site Series Classification, **** Growing conditions improve with site drainage, typically with an increase in the Spruce component, ***** Forest harvested in the 1950 -1960's.

Figure 2. Habitat Suitability Rating of mature-old growth on the detailed Habitat Sample Transects.



Within the present Park boundary several areas saw intensive harvesting prior to its establishment, and these areas show that in the 50 years since harvest that some stands are starting to self thin and are providing some goshawk foraging and nesting potential (Figure 3). However, the most suitable transect (GH-06) is still only ranked as providing low goshawk foraging and nesting potential when compared to mature-old growth forest transects (Figure 2.).

Figure 3. Habitat suitability rating of Young Forest (50-60 years post harvest).



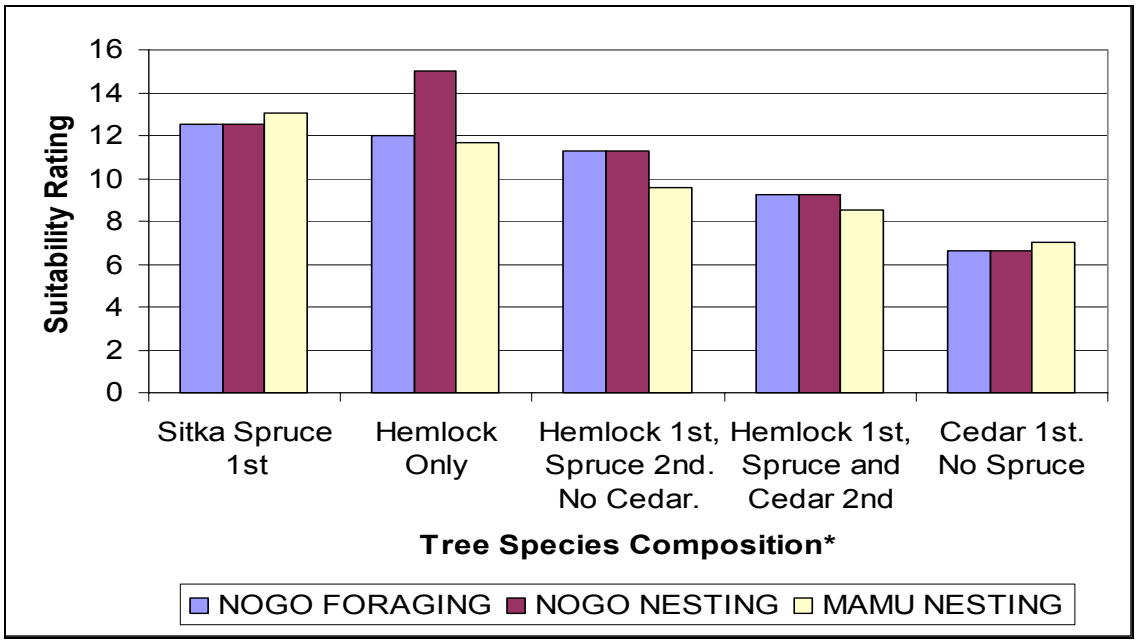
* 4 = Pole Sapling > 10m tall, 5 = Young Forest Self thinning occurring.

In addition to the detailed habitat suitability assessments, a further 69 habitat suitability assessments were conducted at goshawk call playback stations. When combined with the information from the detailed habitat surveys (Table 4, Figure 4) they show a similar trend to the detailed transects, with stands containing spruce having the highest suitability ranking for both goshawks and Marbled Murrelets. Stands with Cedar and other species (excluding Spruce), had the lowest ranking in suitability for all three variables.

Table 4. Habitat Suitability Rating versus tree species composition of mature-old growth forest.

		SUITABILITY RATING					
		Goshawk Foraging		Goshawk Nesting		Marbled Murrelet Nesting	
Forest Cover Tree Species Ranking	Sample Size	**Mean**	SD (Range)	**Mean**	SD (Range)	**Mean**	SD (Range)
Sitka Spruce 1st	26	12.54	2.18 (8-15)	12.54	2.29 (10-18)	13.08	2.92 (10-16)
Hemlock Only	3	12.00	1.00 (11-13)	15.00	2.00 (13-17)	11.67	3.79 (9-16)
Hemlock 1st, Spruce 2nd. No Cedar.	11	11.27	1.9 (9 -14)	11.27	2.53 (10-18)	9.55	1.29 (7-10)
Hemlock 1st, Spruce and Cedar 2nd	17	9.22	2.32 (6 -14)	9.22	3.37 (6-16)	8.50	2.00 (6-10)
Cedar 1st. No Spruce	5	6.6	2.3 (5 -10)	6.6	1.64 (6-10)	7.00	2.00 (5-9)

Figure 4. Habitat Suitability Rating versus tree species composition of mature-old growth forest.



* Information from Forest Cover Polygon Label

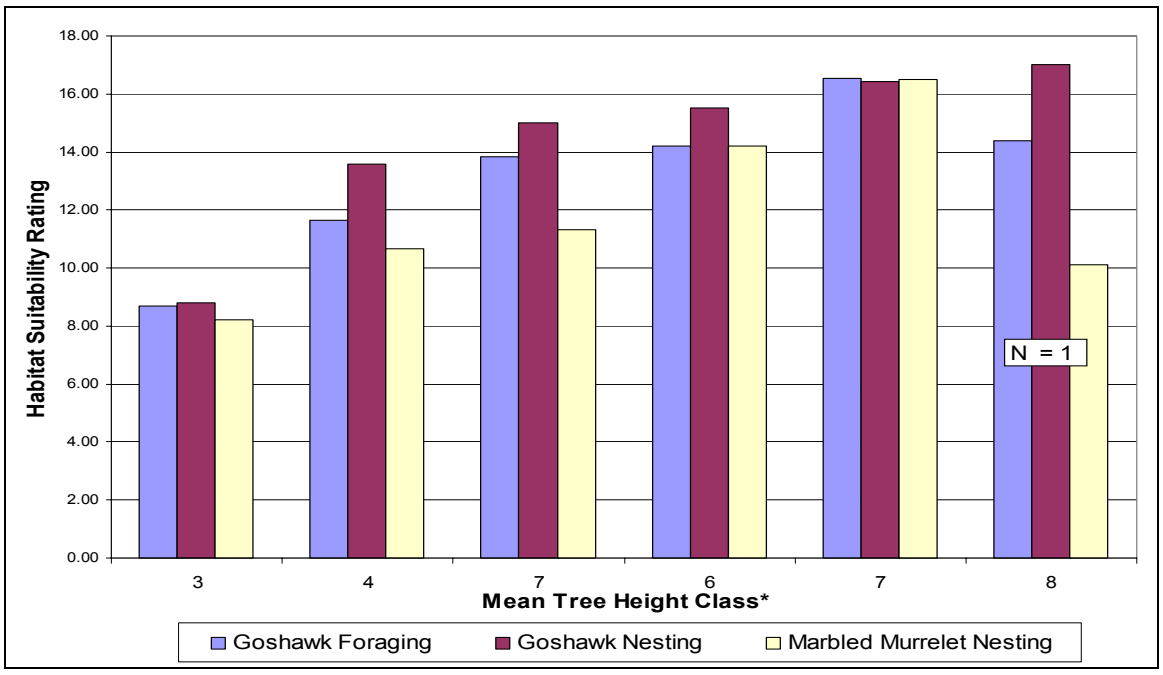
In addition to tree species composition, tree height in mature-old growth forest is used in the algorithm as height is linked to habitat suitability for use by both goshawks and Marbled Murrelets. Stands that were above 46.5m height were ranked as having high suitability (Table 5, Figure 5) for all three variables. In the tallest height class only one stand was sampled, and this showed a drop in suitability, however this may be an artefact of the small sample size.

Table 5. Habitat suitability rating versus Tree Height of mature-old growth forest.

		SUITABILITY RATING					
		Goshawk Foraging		Goshawk Nesting		Marbled Murrelet Nesting	
Tree Height Class Code*	Sample Size	**Mean**	SD (Range)	**Mean**	SD (Range)	**Mean**	SD (Range)
3	12	8.70	2.80 (3-14)	8.80	3.88 (6-18)	8.21	4.00 (5-16)
4	16	11.64	2.28 (5-14)	13.58	2.50 (9-16)	10.65	2.21 (6-10)
5	17	13.84	2.18 (9-14)	15.00	2.43(10-18)	11.32	1.86 (7-11)
6	13	14.22	2.41 (6-15)	15.50	2.59 (9-18)	14.20	3.47 (6-16)
7	9	16.54	1.92 (9-15)	16.44	1.64 (13-18)	16.50	2.40 (11-16)
8	1	14.40		17.00		10.13	

* 3 = 19.5 – 28.4 m, 4 = 28.5 – 37.4m, 5 = 37.5 – 46.4m, 6 = 46.5 – 55.4, 7 = 55.5 – 64.4, 8 = 64.5+

Figure 5. Habitat suitability rating versus Tree Height of mature-old growth forest



* 3 = 19.5 – 28.4 m, 4 = 28.5 – 37.4m, 5 = 37.5 – 46.4m, 6 = 46.5 – 55.4, 7 = 55.5 – 64.4, 8 = 64.5+

Goshawk Call Playback

Survey Methods

Standardized inventory methods, adapted from Kennedy and Stahleker (1993) for the Resource Inventory Committee (RIC 1997), were used for all goshawk surveys. Crews broadcast calls from stations at 400-m intervals along transects. No roads are present in the Park, so all transects were conducted on foot. At each station surveyors first listened for 2 minutes for spontaneously calling goshawks. After the brief listening period, surveyors broadcast calls for three bouts of 15 seconds with 60 second intervals between bouts in which to detect responses. Each of the three broadcasts was played in a different direction, with the megaphone rotated 120^{o} between calls. At the end of the three broadcasts, an additional 5 minutes were spent listening and visually searching for birds at each station. Broadcast calls were played at a volume that was audible to observers at a minimum of 200 m. Call surveys were discontinued during rain or winds exceeding 20 km/h because these conditions may diminish broadcast distance or minimize response detections. The location of playback stations was recorded from hand held GPS units and plotted as accurately as possible on 1:20,000 scale maps while in the field. Each call station was only visited once (i.e. surveys were not replicated over the summer).

Following Kennedy and Stahlecker (1993), surveys were conducted during the nestling and fledgling portions of the breeding period (May to late August) when response rates are highest. Different calls were utilized depending on the development phase of the young. During the nestling period in the spring, alarm calls, characteristic of territorial defense by goshawks, were broadcast. During July and August, juvenile food begging calls, which have been found to be more effective at the fledgling stage of development, were used (Joy *et al*. 1994). However, a negative response cannot be used with any confidence to infer that a goshawk nest area does not occur within the effective sample area on a station by station basis. To increase the probability of detection therefore, multiple surveys of the same area should be conducted during the breeding season (Mahon and Doyle 2000).

All survey crews were trained to distinguish goshawks from other raptors (Sharp-shinned Hawk, Red-tailed Hawk, and Merlin) and from goshawk mimics (jays and sapsuckers). Crews recorded any responses to a broadcast including those from other hawks and mimics, in addition to the time, species, sex, age and type of response (visual/aural). Crews also estimated the initial distance and compass bearing to any hawk, as well as the direction of departure (where appropriate), as these provide clues to the proximity and direction of a nest. When a call playback elicited a response from a goshawk, crews mapped the location and conducted an intense search for active nests within a 600 m radius of the detection.

Criteria for Survey Area Selection

Goshawk breeding density (landscape carrying capacity) is known to be tied to food supply (Doyle and Smith 1994), with nest areas distributed evenly throughout landscapes within relatively homogenous suitable foraging habitat (Joy and Reynolds 1998, Doyle 2000). On Haida Gwaii (outside of the Park) work on goshawks since 1995, has resulted in an understanding of the spatial arrangement and habitat selection of goshawks on the islands

(Doyle 2003). In this landscape, within areas (now or until recent harvesting) of relatively homogenous suitable foraging habitat, nest areas are evenly distributed around every 11.5 km (N = 6, SD = 2.2, Range 9.5 -15 km) (Doyle 2003).

This information was then used as the basis for the habitat selection for the goshawk nest area search criteria within the Park. Areas that did not have enough suitable foraging habitat (approaching 9,000 ha) focused around a central core area of suitable foraging habitat were not surveyed. In addition as few goshawk nests are know within 500m of the ocean (Iverson et al. 1996, Doyle 2003, McClaren 2003), these areas were also exclude from this initial set of goshawk nest surveys. Finally one area (Bag Harbour) was included in the surveys as birds "possible goshawks" had been reported calling in the area in previous years.

Results

Based on the size of the foraging area required to support an active nest, five areas with the highest likelihood of supporting a nest area were selected for goshawk surveys. These sites were located in the interior portion of Kunghit Island, north and east of Rose Inlet, west of Ikeda Cove, Burnaby Island and Lyell Island.

A total of 96 call play backs were conducted on 24 transects (Table 1), resulting in the detection of young and adults at the one site in Windy Bay, Lyell Island, equivalent to 1 detection per 22 km of area traversed.

At Windy Bay a defensive adult bird was first detected on 26th June, and follow up intensive search in late July resulted in the location of 2 fledged young and an old goshawk nest in a western Hemlock, dbh = 75cm, height = 35m. Site series of nest site = 05. Forest cover label = HSC (Cy) 952, aspect = 330, slope = 40%, elevation =100m, nest height 17m, Canopy Closure around nest = 60%, nest aspect = 180 degrees. Nest on second branch up on mistletoe growth, approximately 80cm across by 60 cm thick. A few bones and an almost completely decomposed feather indicate this nest may have been active in the past three years.

Marbled Murrelet Dawn Surveys

Methods

Marbled Murrelet dawn surveys were conducted semi-opportunistically at four locations within the Park. These sites were not chosen at random, but were selected primarily because during assessment of these areas for goshawk foraging and nesting potential, these areas were also confirmed as having high ranked murrelet potential nesting, in addition to geographic characteristics that made these sites suitable locations for Marbled Murrelet Dawn surveys. At these sites the RIC Marbled Murrelet dawn survey protocol (RISC 2001) was used by trained personnel to count and evaluate the activity of Murrelets entering the watershed at the survey point.

Results

Marbled Murrelets were detected in all locations (Table 6.) with the highest number of occupied detections occurring in North Burnaby. As no further surveys were conducted these surveys do not quantify the relative abundance of birds, but do confirm the presence of birds in all locations.

Table 6. Marbled Murrelet dawn survey detections in Gwaii Haanas 2003.

					Detections				
Location	zone	easting	northing	Date	Audio	Visual	Audio/Visual	Total	Occupied
Rose Inlet	9	355217	5785751	7/18/2003	35	0	12	**47**	5
Windy Bay	9	342639	5812190	7/28/2003	22	2	1	**25**	0
East Burnaby	9	345804	5809384	7/24/2003	65	3	0	**68**	0
North Burnaby	9	333099	5841806	7/23/2003	41	23	14	**78**	26

Goshawk Prey and Avian Species Abundance

Methods

While conducting goshawk playback transects, the surveyor used stops every 200 meters and conducts a standard (RIC 1999) playback protocol, which includes a set amount of time listening for goshawks at each playback station. During this time any species of bird or mammal seen or heard was recorded. The surveyor also recorded the Forest Cover Polygon in which the survey was conducted. This information was then used as a coarse assessment of the relative abundance of each species in each forest type.

In addition, surveys to determine the relative abundance of goshawk prey species were also conducted along a detailed 200m X 30m habitat/prey transect survey transects. This wildlife survey, included the number of individuals detected, cavity trees observed [Red-breasted Sapsuckers (*Sphyriapicus ruber*), Hairy Woodpeckers (*Picoides villosus picoideus*)] and feed sites (sapsucker/woodpecker feed trees, Red Squirrel (*Tamiascurius hudsonicus)* feed sites and middens). Personnel on all survey crews were from the islands and have a detailed knowledge of the species present and are experienced in conducting Breeding Bird surveys.

Results

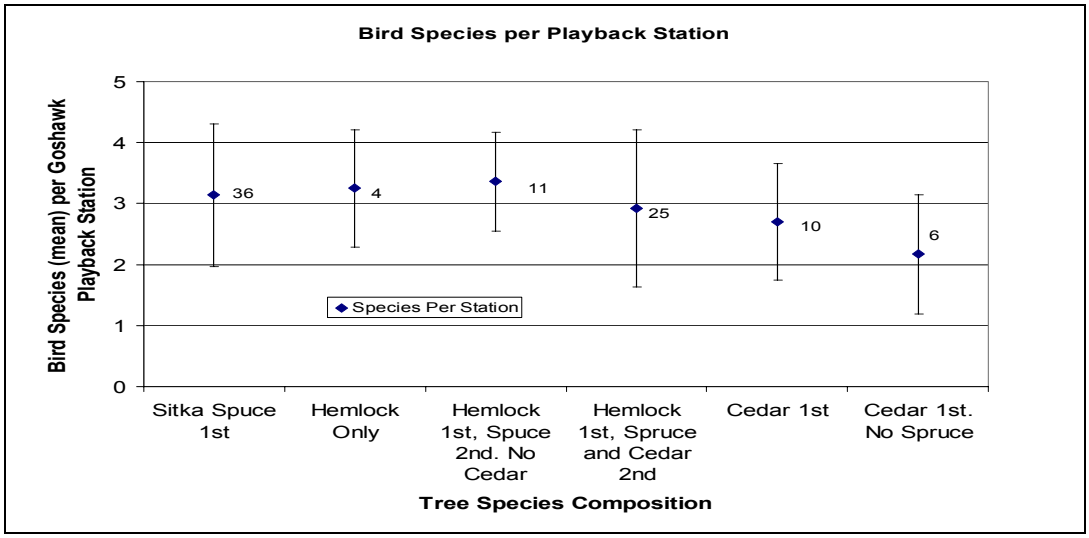
Overall 17 species of bird were detected, and of these the Pacific Slope Flycatcher was the most common, detected at 55% of stations (Table 7), after that six of the remaining species occurred at >25% of the stations (Hermit Thrush, Varied Thrush, Golden Crowned Kinglet, Winter Wren, Townsend's Warbler and Red Crossbill). After that the remaining 59% of species were detected at <13% of the stations, with a main goshawk prey the red squirrel only detected at 8% of stations.

Table 7. Bird and squirrel species occurrence per goshawk playback station.

	Total Species Occurrence	% Occurrence per Survey Station
Pacific Slope Flycatcher	47	55.29
Hermit Thrush	39	45.88
Varied Thrush	38	44.71
Golden-crowned Kinglet	35	41.18
Winter Wren	34	40.00
Townsend's Warbler	26	30.59
Red Crossbill	22	25.88
Hairy Woodpecker	11	12.94
Chestnut-backed Chickadee	9	10.59
Red-breasted Sapsucker	9	10.59
RED SQUIRREL	7	8.24
Common Raven	6	7.06
Pine Siskin	4	4.71
Blue Grouse	3	3.53
Bald Eagle	2	2.35
Red-breasted Nuthatch	2	2.35
Brown Creeper	1	1.18
Red-tailed Hawk	1	1.18

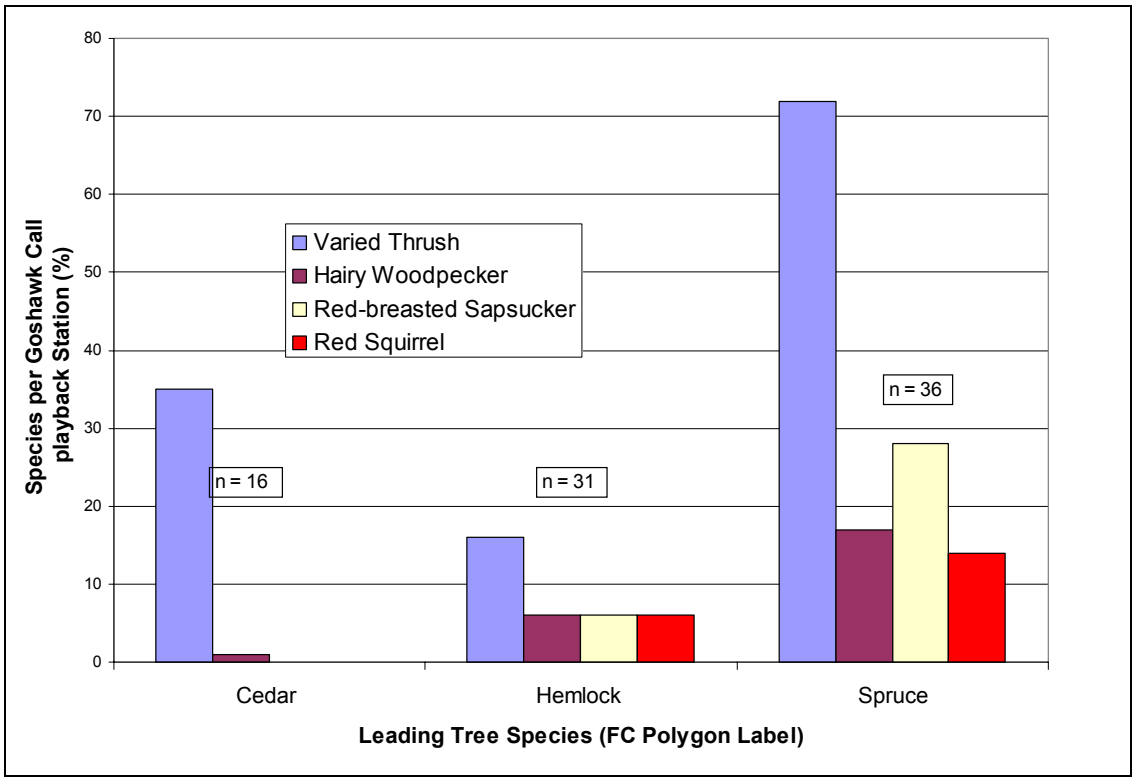
When we look at species abundance (Figure 6) on the goshawk playback transects compared the main forest type groupings from Forest Cover information, bird species abundance was highest in the spruce leading, hemlock and hemlock and spruce stands and was lowest in the cedar dominated stands.

Figure 6. Number (mean) of bird species encountered per goshawk playback station.



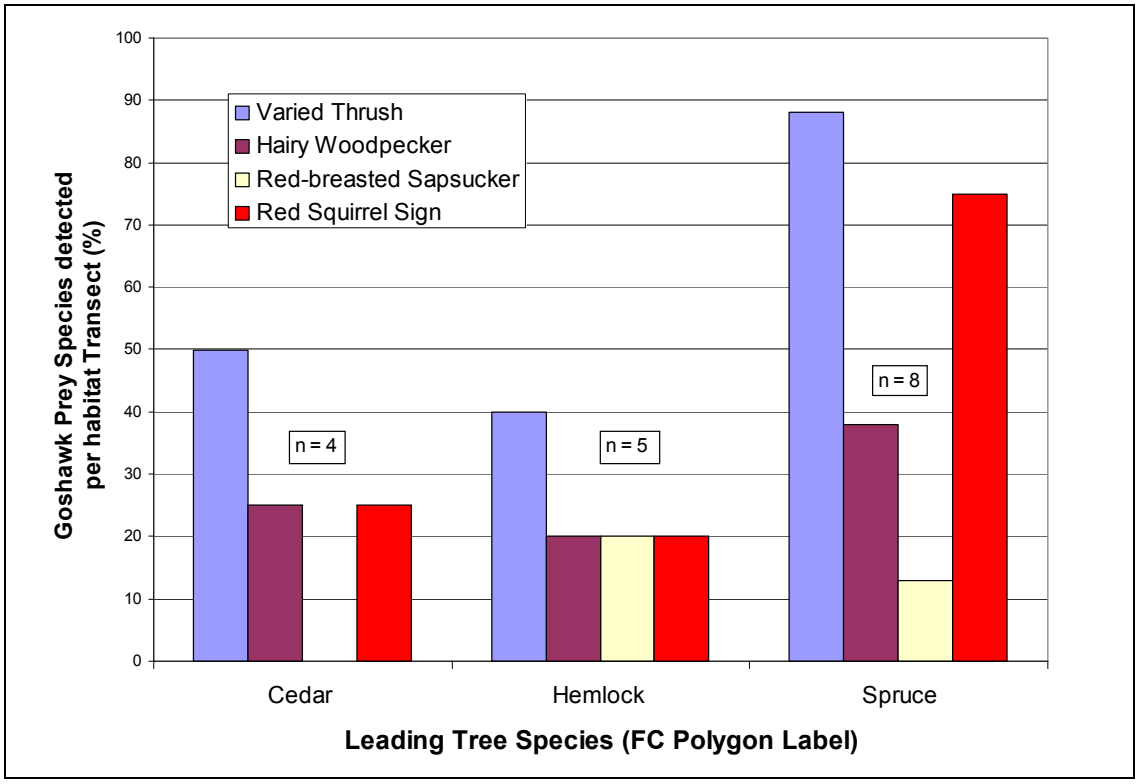
If we focus on the known goshawk prey (Figure 7) and the relationship between them and the leading tree species in a stand, Varied Thrush (*Ixoreus naevius*) were the most commonly detected species in stands of all three leading species (cedar, hemlock and spruce). Varied Thrush's were detected at over 70% of call playback stations in spruce leading sites, while they were only detected at 35% of cedar and 17% of hemlock leading sites. Of the other three prey, all were detected more frequently in spruce leading sites, followed by hemlock and finally cedar in which no squirrels or sapsuckers were detected.

Figure 7. Detection rates of prey species at goshawk call playback stations compared to leading tree species.



A similar pattern was also seen independent of goshawk call playback stations with Varied Thrushes again the most commonly detected prey species on habitat/prey transects (Figure 8) in stands of all three leading tree species. Similarly squirrels and Hairy Woodpeckers were most commonly detected in spruce leading stands, but both were detected slightly more in cedar leading than in hemlock stands. Finally Red-breasted Sapsuckers were again detected in spruce and hemlock leading stands, although the reverse of the earlier pattern was seen, with slightly more were now detected in the hemlock than in the spruce. However, sample sizes are small and these small variations may not be significant. Finally, sapsuckers were again absent from cedar leading stands.

Figure 8. Detection rates of prey species on habitat/prey transects compared to leading tree species.



Discussion

The ground truthing portion of this work, showed clearly that for goshawk foraging and nesting that the suitability algorithm broadly meets its objectives, identifying correctly the habitat suitability of ≥84% of transects. The exact habitat suitability ranking of Marbled Murrelet transects was also high at 80%, for those transects assigned single rankings. For all three suitability rankings, the accuracy rate is even higher, if one takes into account those which share a rank on transects with multiple rakings. We therefore appear to a have a robust algorithm that allows us to predict suitability at this stage. In the field, the lack of Canopy Closure information and its known close association with nesting (Squires and Reynolds 1997, McGrath et al. 2003) and to a lesser extend with foraging in goshawks (Bloxton 2002), was identified as an area that can increase our ability to correctly assign habitat suitability rankings. This was particularly noticeable on steeper slopes, where an open forest with thick understory, was impeding under canopy access and therefore the suitability of the stands for goshawk nesting.

In addition to this work, another project on the islands this year, funded by HCTF on a focal goshawk prey species the Blue Grouse (*Dendragapus obscurus*) (the only species

found on the islands), indicates that alpine areas in combination with the area of mature-old growth provides suitable habitat for this species (Doyle 2004b). This has led to the need to slightly change our algorithm for foraging such in the future the alpine forest areas will be weighted slightly higher for goshawk forage rating.

As with similar work being carried out further north on Haida Gwaii in TFL 39, (Doyle 2004), Sites Series and Forest Cover were also seen to be predictably linked to suitability for all three species. Typically, drier sites had better growing condition and overall higher suitability. TEM within the Park may therefore increase the predictive accuracy of habitat suitability within the Park. However, within the Park, a detailed Ecological Land Classification (Westland Resource Group 1994) is already available, and suitability verification transects placed within distinct polygon boundaries of a cross-section of these classes, may also strengthen the predictive accuracy of this algorithm.

Tree species composition as identified in Forest Cover polygons showed that for all three ratings suitability was highest for the stands which were dominated by Sitka Spruce and Western Hemlock individually or in combination, and ratings were lowest for cedar (Yellow and Western Red) dominated stands. This pattern supports the Site Series pattern identified in the field, as the cedar if often associated with more poorly drained sites. Tree height, is also linked to growing condition, and again we saw an increase in suitability of stands for all three ratings as the height of those stands increased. Typically for goshawks with increasing height we saw an increase in the sub-canopy openness and therefore access to prey, and an increase in prey. However, the increase in prey was also linked to the tree species composition with spruce and spruce hemlock dominated sites linked to the presence of more prey species, including squirrels and the other three main prey species (Red-breasted Sapsucker, Varied Thrush and Hairy Woodpecker) as identified by diet analysis on Haida Gwaii (Doyle 2003b). In contrast, cedar dominated sites, had a lower overall abundance of bird species associated with them, and of those species identified as typical goshawk prey only the Varied Thrush was found more frequently at these sites when compared to hemlock sites, however encounter rates were still lower than seen in those spruce dominated stands.

The diversity of bird species and the species encounter rates was broadly consistent with the earlier detailed Land Classification conducted 12 years ago (Westland Resource Group 1994). However, it is difficult to make comparisons as the studies were conducted on different time scales, and we did not conduct a standardised Breeding Bird Survey. On this broad comparative basis, no previously recorded closed forest species were now absent; however, the relative ranking in occurrence of many of these species had changed. With Winter Wrens less frequently detected and Varied Thrushes more frequently detected in our study.

For Marbled Murrelets the increase in height, may increase access, but primarily it was associated (as with goshawks) with tree species composition, with the tallest sites, dominated by spruce and hemlock, which structurally support more potential nest platforms, and have greater access to those sites, when compared to cedar dominated mature-old growth forest (Burger 2002). The only exception was seen in the tallest stand (>64m) which may be due to the sub-canopy preventing access to potential nest sites (goshawk an murrelets) and prey (goshawk), but may simply be an artefact of having a sample size of one. At the same time as this study, work using the same methodology in Weyerhaeuser's Ltd. TFL 39 (Doyle 2004), has shown that habitat suitability ranking for Marbled Murrelets in mature-old growth forest was driven primarily by potential nest platform density in this

algorithm, and as we saw this resulted in the highest ranking occurring in floodplain sites. However, although the highest density of potential platforms are located in such sites, it is still unclear how the density of platforms relates to the density of birds using the stand, as the birds are believed to non-randomly space themselves within a landscape (Burger 2002). As more is learned about the density of birds, in relation to platform density, or indeed in relation to topographic or habitat characteristics then this algorithm will likely need refining.

Gwaii Haanas Park has some of the oldest logged areas on Haida Gwaii, and we therefore took the opportunity to assign habitat suitability ratings to these stands, to allow us to see when such stands contribute significantly the foraging (goshawks only) and nesting requirements of these two species. This information is valuable as we develop recovery strategies for these species. Keeping in mind that the sample sizes are very small, this case looked at two sites logged in the early 1940's and two in the mid 1970's. The suitability ranking of these habitats indicated that the 30 years difference in growth "may" dramatically change the suitability for goshawk from low, with limited access to prey, and few if any nest sites, to medium suitability with moderate prey abundance and with some potential nest sites in the older sites, an overall ratings increasing of nearly 80%. In contrast, for Marbled Murrelets the habitat suitability was still Low (1 transect) to Nil (1 transect) even in the oldest blocks, with only a few potential nest platforms that provided little or no access to this ungainly flying alcid.

This project also took the opportunity to begin testing the predictive spacing and foraging area requirements of goshawks on Haida Gwaii (Doyle 2003, Doyle and McLennan, 2003). In all, only five areas were identified as potentially providing a large enough foraging area to support a breeding pair, and although time was limited, we visited all areas to confirm habitat suitability but also to opportunistically see if we could locate the birds in the areas we were sampling. This opportunistic approach was rewarded when in the largest identified area of suitable habitat (Lyell Island) an active territory with two fledged young was found. Further, the one identified nest site (not this years), also conformed to the other known nests site locations on the islands, as the nest was located in a hemlock in a tall (>37m) hemlock, spruce stand, a site type that is ranked high in the habitat suitability algorithm. Other, active nest areas may have been missed in the other locations, but more dedicated time will be necessary to establish this, particularly as the annual number of pairs breeding appears to be so low on the islands (Doyle 2003).

In addition to the opportunistic goshawk breeding survey, we also conducted four Marbled Murrelet dawn surveys in areas that were identified by the algorithm, and in the field, as having high suitability ranking for potential murrelet nesting. These areas were also selected as they had relatively easy access, suitable vantage point and topographic characteristics that provided the potential that birds would be funnelled into the area as they came in from the ocean. In all areas birds were detected, but were seen entering the forest at only at the site, North Burnaby. However, the differences in the numbers of birds and their activity between sites, needs far more work to establish if any real differences in populations are present (Harfinest pers comm.).

Future Research

To further enhance the accuracy of the predictive habitat suitability mapping the algorithm would be strengthened by the addition of Canopy Closure information to the forest database for the Park. Nesting and to a lesser extent foraging in goshawks has been

consistently linked to particular percentage thresholds in canopy closure, and the ability to use this criteria in the map theming algorithm, will increase our ability to determine the area of suitable habitat and therefore the probable number of territories in the Park.

The benefit of this mapping technique to our understanding of the distribution of critical habitats within the Park could be further enhanced, by adding other at risk species and their habitat requirements to the algorithm, such that areas can be ranked on their value for both single and multiple species. In particular, based on the work on goshawks and Marbled Murrelets rating of Site Series, Landscape Classification, and Forest Cover polygon information, this approach needs to be applied to other species. In this role the Park can take a lead, by identifying species associations, information that can be applied inside the Park, but also will contribute greatly to our understanding and management of species outside of Gwaii Haanas.

The goshawk algorithms could further be strengthened by locating the goshawk nest on Lyell Island and any nests in other areas, to ensure:

- That in the Nesting algorithm the individual structural and Forest attributes are weighted correctly, and thus ranking of habitat suitability is accurate.
- The accuracy of the Foraging algorithm through the collection of diet information, through pellets and prey remains collected at the nests, such that the relative contribution of the individual prey in the diet, is used to rank the subsequent suitability of habitat types dependent on the prey densities in those habitats.

Monitoring of the one known goshawk nest and any subsequent nest areas located will greatly enhance our understanding of the reproductive success of goshawks on the islands. At present the population on Haida Gwaii has been identified as threatened and possibly declining with only one (14%) of the seven previously known nest areas, active last year. Any knowledge, on the number and success of pairs within the protected area of the park, will greatly increase our understanding of the possible impacts of harvesting outside of this protected area.

- Using the Park as a control population, is harvesting impacting the breeding success of birds outside of the park?
- What contribution are goshawks in the Park contributing to the island population as a whole?
- If we known the diet of the birds inside the Park and the habitat in which this prey is found, we can possibly determine if, 1. harvesting or 2. introduced species are driving the identified population decline?

Finally, the relatively large area of alpine habitat within the Park also provides the opportunity to establish if and when a threshold in the observed link, between an increase in the percentage of alpine forest, with an increasing Blue Grouse populations occurs. This information can the be used not only to refine the foraging algorithm used in the Park, but will also be applicable across the islands.

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Appendices

Appendix 1.

Algorithms Used for Ground Truthing Habitat Suitability Ranking

Doyle and McLennan 2002.

Northern Goshawk Nesting Habitat Suitability

In the field the structural characteristics of forest cover polygons were assessed as to the suitability of that polygon as a goshawk nest stand based on the criteria below. These attributes are based on the known habitat characteristics of the nest areas located on the Islands (Chapter 2, Table 1), and the range of know parameters personally observed within the same CWH Biogeclimatic zones on the adjacent mainland (Table 2). Similar work has taken place on Vancouver Island (McClaren 2001) and S. E. Alaska (Iverson et al. 1996), however, where the same ranges in nest habitat attributes have been observed. The individual rankings were then ground truthed to ensure that when a critical attribute for nesting was absent, that the cumulative ranking would result in a low-nil ranking of that forest cover polygon.

	Crown Closure	Nest Access	Structural Stage	Height Class	Score	Rating
NoGo Nesting Suitability						

Total Score: 18 High: >12 Moderate: 10-12 Low: 7-10 Nil:0-6

High ranked habitat is considered to have a combination of attributes that would typically be seen within known goshawk nest areas. Moderate sites were considered to be sites in which nest areas were less likely to be seen, based on observed nest area attributes, however, nests are occasionally found in such stands. Low suitability sites, contains forest attributes where nest areas have not been located, however, they may contain occasional attributes that would by themselves support nesting goshawks, and therefore it could be argued that they would use these sites if no other habitat was available. Areas ranked as NIL contained no forest attributes that would support a goshawk nest area.

Crown closure

After the fundamental requirement of a 'mature' forest stage, canopy closure is probably the single most important structural variable relating to nest area suitability. Virtually every study examining goshawk nest areas identifies canopy closure as a key attribute, with few examples of goshawks nesting in stands with <40% canopy closure (apart from those in SW Arizona, where stands are more open, however understory in this dry climate is also less dense). Optimal values, as represented from our observed sample of nest areas, are >60%. Corresponding suitability ratings for the canopy closure classes available in the forest cover database are provided below.

Crown closure: measured as per DEIF. Use drip line of canopies for estimates. Estimate should be based on a number of locations within the stand.

Crown Closure	
Closure %	**Score**
60 – 100	5
40 - <60	2
<40	1

Nest access

Known goshawk nest stands all exhibit an open under story beneath the mature canopy. This pre-requisite is required as it allows goshawks to access their nests, which are typically placed at the base of the canopy, and also allows access to plucking sites, which are typically located on the forest floor. Excellent access: allows this raven sized raptor to fly readily under the canopy in any direction. Fair access: flyways are somewhat impeded. Poor access: Flyways uncommon, but at occasional points in the stand there is possibly room for birds to access nest trees. Very Poor Access: Access impeded in all directions.

Nest Access: an evaluation of the ease with which nests can be accessed, especially understory accessibility.

	Nest Access
Description	**Score**
• Very poor access	0
• Poor access	1
• Fair access	4
• Excellent access	5

Structural Stage

The structural maturity of a stand, and trees within a stand, form the fundamental basis for nesting suitability for goshawks. Individual trees must have developed large enough branches to support the nest structure. “Structural Stage” (as classified in: BC Ministry of Environment, Lands and Parks and BC Ministry of Forests 1998). Mature (MF,6) and Old growth Forest (OF,7), possesses many feature that would support a nest structure. Young Forest (YF,5) has fewer sites that would support a nest. Pole Sapling (PS,4) nest sites typically absent.

Structural Stage:

Description	**Score**
PS(4)	1
YF(5)	2
MF(6), OF(7)	3

Height Class

In addition to "Openness" and "Structural stage" height class was also used as it helps to tease out the habitat characteristics of the stand needed to support a goshawk nest area, particularly as it pertains to the ability of goshawk to maneuver freely beneath the canopy. "Height Class" (as classified in: BC Ministry of Environment, Lands and Parks and BC Ministry of Forests 1998).

Height Class:

Description	Score
<3	0
3	1
4 – 5	4
>5	5

Northern Goshawk Foraging Habitat Suitability

Information on Suitable foraging habitat is based on radio telemetry locations of foraging goshawks (Bright-Smith and Mannan 1994, Iverson et al. 1996), where their prey are found (Godfrey 1986, Banfield 1974), and in particular, sites in which they successfully killed prey. Kill sites are located within mature/old growth forests, with high canopy closure, clear under story, and were frequently near small openings, which were associate with higher densities of prey (Good 1998, Stephens 2001). Prey has not only to be present, but also available if the habitat can be considered as a suitable foraging habitat for goshawks (Beier and Drennan 1997). Goshawks are a perch and wait hunter of forests, flying beneath the canopy, or hunting from edges to ambushing unwary prey (Kenward 1982).

	Crown Closure	Sub-Canopy Openness	Prey Availability	Prey Access	Score	Rating
NoGo Foraging Suitability						

Total Score: 15 High: >10; Moderate: 7-10 Low:4-7; Nil:<4

High ranked stands, are habitats in which prey is both abundant and "available". Moderate sites may possess habitat characteristics in which the birds can hunt, but prey

may be less abundant. Low suitability sites typically exhibited limited ability for goshawks to hunt and access prey even if prey is abundant. In Nil suitability sites, if prey is present it is inaccessible, eg 25-50 year old stands, whose habitat structure inhibits the ability of goshawks to access prey.

Crown Closure: See Nesting habitat rankings

Crown closure: measured as per DEIF. Use drip line of canopies for estimates. Estimate should be based on a number of locations within the stand. Record range of cover (= gapiness).

Crown Closure	
Closure %	**Score**
0 – <30	1
30 - <40	2
>40	3

Sub-Canopy Openness and Prey Accessibility

Goshawks have to be able to access their prey, and that prey also has to be somewhat vulnerable with limited refuge from this predator. As goshawks hunt from perches beneath the canopy they therefore have to be able to see and access prey from these hunting locations. In addition the more perches that are available, there is a proportional increase in the possibility of a suitable hunting perch being available from which to access prey. These subjective categories are therefore a standardized assessment of the ability of the goshawks to hunt within a habitat and to see and access their prey.

2. Subcanopy openness: estimate of ease with which goshawks can fly beneath the canopy and select a suitable perch from which to hunt, and should be proportional to percent cover estimates for tree layers, e.g. A3 and B1 in OF stands.

Description	**Score**
• Subcanopy highly obstructed	0
• Subcanopy with major obstructions but some flight possible	1
• Subcanopy with minor obstructions to subcanopy flight	2
• Very open; in mature stands this means low B2 and A3 layer coverages	3

3. Prey Accessibility: an estimate of the ease with which prey can be hunted under the canopy; from a hunting perch. A dense ground cover of shrubs, CWD, and regen may impede prey accessibility, and the potential for an attached prey to escape; should agree with cover estimates of B layer.

Description	Score
• Prey almost completely unavailable	0
• Prey access heavily impeded	1
• Prey access somewhat impeded	3
• Prey completely available	6

Prey Abundance

Prey abundance is based on the typically suite of forest prey taken by goshawks based on diet analysis both on the Queen Charlotte Islands (Roberts 1997) and from adjacent areas with similar forest type (Iverson et al. 1996. Ethier 1999). These typically taken prey include red squirrel, varied thrush, jays, woodpeckers, forest grouse and a range of smaller forest passerines. In most of the studies red squirrels and grouse are identified as key prey and their presence or habitat that support their presence is more heavily weighted.

4. **Prey abundance**: Estimates the relative amount of prey occurring in the stand; consider squirrel middens, songbird observations, and other factors such as feed sites, snags, cavities, berries, etc. This is a coarse grained approach but is intended to tease out sites with little prey versus sites where common prey area abundant.

Description	Score
• Almost no productivity	0
• Low productivity	1
• Moderately productive	2
• Very productive	3

Marbled Murrelet Nesting Habitat Suitability

This was based on the RIC Standard methodology (1997), except for plot size which was based on the an estimated average for the forest polygon traversed while conducting the Northern Goshawk nest and foraging habitat suitability transect.

MaMu Nesting Suitability

	Platform Density	Crown Closure	Height Class	Score	Rating
NoGo Nesting Suitability					

Total Score =16 High >11 Med 6-10 Low0-5

Nest Platform Density: Visual estimate of density of potential nesting platforms.

Nest Platform Density	
Density Class	**Score**

High (>250/ha)	10
Medium (150-250/ha)	5
Low (<150ha)	2
None	0

Nesting platforms (branches) were those platforms estimated to be ≥18 cm diameter. As per appropriate RIC, Marbled Murrelet Methodology Version 2.

Crown closure: measured as per DEIF. Use drip line of canopies for estimates.

In a departure from the RIC habitat suitability methodology, Crown Closure was used as earlier work on Marbled Murrelet Platform density on the Queen Charlotte Islands (McLennan 2000), showed that canopy closure was significantly linked to the density of platforms/ha. The scoring below reflects the relative abundance of platforms to the percentage of canopy closure. In addition, it also supports the observation that as murrelets are poor fliers, they need spaces in the canopy to access nest platforms and these openings were seen as limiting with canopy closure ratings ≥75%.

Crown Closure	
Closure %	**Score**
90-100	0
75 - <90	1
45 - <75	3
20 - <45	2
<20	0

Height Class:

Description	Score
<3	0
3	1
4 - ≤5	2
>5	3

Increased suitability ranking with increasing height was linked the observed increase in structural features that support nest platforms. Taller trees were typical of old growth stands on rich sites, whereby these stands were not only old thereby creating gaps in the canopy allowing greater access to nest platforms, but also had more suitable nesting branches ≥18 cm diameter.

Appendix 2.

Habitat Suitability Mapping for Marbled Murrelet (Brachyramphus marmoratus) and Northern Goshawk (Accipter gentilis laingi) in Gwaii Haanas National Park Reserve.

McLennan et al. 2002

4.0 Model Variables and Weightings

The following section describes the variables used in the model and the rationale for their weightings in the models. Classes and weights for each of the models are shown in the algorithm summaries in Table 2-4.

4.1 Biophysical Unit Score

Biophysical Units (BUs) were correlated with biogeoclimatic site series and ranked for their relative suitability for NoGo foraging and nesting and MaMu nesting (Table 1). Information for making the ranking was based on suitability-site series relationships described in Oikos (2000) for Graham Island, and on the authors' experience with forest structural attributes such as canopy closure, stocking and density of understory vegetation in old forest stands within each site series. The BU rankings helped fine tune the forest cover data by accounting for stand structural characteristics typical of the various site series.

4.2 Age Class

Age classes 8 and 9 are weighted the highest in both NoGo models based on information from Graham Island, where all nest sites have been found in age class 8 and 9 stands. Stands surrounding nest stands used for foraging are also age classes 8 and 9 on Graham Island. MaMu nest platform densities are significantly higher in age class 9 stands in Graham Island (Oikos 2000), as these old forest stands are sufficiently old to develop the requisite large lateral, moss-covered branches.

4.3 Height Class

Height classes greater than 4 have the highest weights in all models. As for age class all NoGo nest sites on Graham Island are in stands with height class 4 or greater. NoGo foraging is assumed to be highest in stands with height class greter than 4 because of desirable stand structural characteristcs in these stands such as relatively clear subcanopy areas for hunting and desirable canopy closure characteristics. MaMu nest platform density was found to be much higher in height class 4 or higher.

4.4 Species

Western/mountain hemlock (H) and Sitka spruce (S) have the highest weights in the NoGo nesting model because all nest sites located to date on Graham Island have been in these two species. Sitka spruce weights are also high for NoGo foraging, because red squirrels feed primarily on Sitka spruce cones and are the main prey species of NoGo on Haida Gwaii (Doyle 2003b).

4.5 Elevation

Elevation weights favour elevations below 350m for all models. For NoGo nest sites discovered on Graham Island are all at or below 350 m, and it is assumed that the productivity of NoGo prey is also inversely related to elevation. MaMu weights are higher at lower elevations because larger stands with more nest platforms. In all cases the weights assigned to elevation are low, reflecting the generally low emphasis placed on this variable.

3.2 6 Slope

Slope weights are the lowest of all variables for all models and reflect the lower predictive capacity of slope class. Generally lower slopes have higher rankings based on known NoGo nest sites, NoGo foraging requirements, and background information on MaMu nesting (Doyle and McLennan 1999).

Table 1: NoGo foraging and nesting indices and MaMu nesting index for biophysical unit (BU) classes.

BU	Subzone	Site Series	Index value NoGo Forage	Index value MaMu Nest	Index value NoGo Nest	Spruce % Class
DT	AT	n/a	0	0	0	1
LA	AT	n/a	0	0	0	1
MI	MHwh	2	0	0	0	0
SU	MHwh	n/a	0	0	0	0
TH	MHwh	n/a	0	0	0	0
DB	CWHvh	n/a	0	0	0	1
DS	CWHvh	n/a	0	0	0	0
EH	CWHvh	n/a	8	0	0	1
HU	CWHwh	n/a	8	0	0	0
IC	CWHwh	n/a	0	0	0	0
PO	CWHwh	n/a	5	0	0	0
AN	CWHvh	2	1	1	1	0
KU	CWHvh	12	1	1	1	0
UV	CWHvh	2	1	1	1	0
BF	CWHwh	01(b)	5	2	3	2
BA	CWHvh	3	2	2	2	1
PC	CWHvh	11	3	3	3	0
PF	CWHvh	14	2	3	1	2
BY	CWHwh	12	6	3	3	3
SG	CWHwh	2	3	3	3	2
WB	CWHwh	12	6	3	3	3
FL	CWHvh	1	4	4	4	1
RI	CWHwh	4	5	4	4	1
YZ	CWHwh	1,3,4	5	5	5	3
WF	CWHvh	16,17,18	5	5	5	2
MU	CWHwh	13	4	5	5	1
SP	CWHwh	13	4	5	5	1

MA	CWHvh	4	7	7	7	2
HI	CWHwh	14	7	7	7	2
SB	CWHwh	1	7	7	7	2
GG	CWHvh	6	8	8	8	2
HY	CWHvh	7	8	8	8	2
SL	CWHvh	8	9	9	9	2
GO	CWHwh	07,05	10	10	10	2
RA	CWHwh	8	5	10	10	2

Table 2: NoGo foraging habitat suitability algorithm.

Variable	Class/Score	Rating
Height of Canopy	Height Class	
	<2	1
	2 and 3	10
	>3	20
Stand Age	Age Class	
	8 and 9	20
	6 and 7	15
	4 and 5	10
	<4	5
Leading Tree Species	Species	
	western/mountain hemlock	5
	western redcedar	5
	Sitka spruce	10
	Yellow Cypress	2
	Red Alder	5
	lodgepole pine	2
Ecosystem Type	BU Score (see Table ?)	
	> 7.9	10
	6.0-7.9	7
	4.0-5.9	3
	< 4.0	0
Elevation	Elevation (m)	
	0-350 m	10
	350 – 800 m	5
	>800 m	0
Slope Angle	DEM Slope Angle	
	< 35%	5
	35-70%	3
	> 70%	1

Table 3: NoGo nesting habitat suitability algorithm.

Variable	Class/Score	Rating
Height of Canopy	Height Class	
	1	0.1
	2	0.4
	3	0.6
	>3	1.0
Stand Age	Age Class	
	8 and 9	1.0
	7	0.4
	6	0.3
	<6	0.1
Leading Tree Species	Species	
	western/mountain hemlock	1.0
	western redcedar	0.5
	Sitka spruce	1.0
	Yellow Cypress	0.2
	Red Alder	0.8
	lodgepole pine	0.1
Ecosystem Type	BU Score (see Table ?)	
	> 7.9	1.0
	6.0-7.9	0.8
	4.0-5.9	0.6
	< 4.0	0.1
Elevation	Elevation (m)	
	0-350 m	1.0
	350 – 800 m	0.75
	>800 m	0.1
Slope Angle	DEM Slope Angle	
	< 35%	1.0
	35-70%	0.75
	> 70%	0.1

Table 4: MaMu nesting habitat suitability algorithm.

Variable	***TFL24***		***TSA***	
Height Class	1	0.10	1,2	0.10
	2,3	0.30	3	0.30
	4,5	0.80	4,5,6	0.80

	>5	1.00	>6	1.00
Age Class	8,9	1.00	9	1.00
	<8	0.05	8	0.50
			<8	0.05
Species	H	1.00	H	1.00
	C	1.00	C	1.00
	S	1.00	S	1.00
	Cy	0.20	Cy	0.20
	D	0.01	D	0.01
	Pl	0.01	Pl	0.01
BU Score	>7.9	1.00	>7.9	1.00
	6-7.9	0.80	6-7.9	0.80
	4-5.9	0.60	4-5.9	0.60
	<4	0.10	<4	0.10
Elevation	0-350	1.0	0-350	1.0
	350-800	0.75	350-800	0.75
	>800	0.10	>800	0.10

Appendix 3.

Northern Goshawk (Accipiter gentilis ??) Habitat in the North Coast Forest District.

:Foraging and Nesting Habitat Suitability Models: February 2002. *:*

Todd Mahon and Doyle 2002.

Stand Height

The structural maturity of a stand, and trees within a stand, form the fundamental basis for nesting suitability for goshawks. Individual trees must have developed large enough branches to support the nest structure. Suitable stands will have progressed through the self-thinning process and be tall enough to provide open fly ways below the main canopy layer. "Structural Stage" (as classified in: BC Ministry of Environment, Lands and Parks and BC Ministry of Forests 1998) would probably provide the best scheme for categorizing this habitat variable, however it is not directly available in the existing inventory information. As a surrogate to structural stage we use stand height, or more specifically, projected stand height class. Initially we planned to use project stand height as the variable, however, limited ground truthing indicated that due to poor accuracy and precision the model would be improved over using the height classes. Nesting suitability for the different projected height classes are provided below.

Height Class	Height (m)	Rating
1	0-10.4	0.1
2	10.5-19.4	0.4

3	19.5-28.4	.75
=>4	>28.4	1

In other Forest Districts we preferentially use projected age class to identify suitable mature forest structure. In the NCFD age class appeared to have frequent errors in the database and had poorer correlation to mature forest structure than height.

Canopy closure

After the fundamental requirement of a 'mature' forest stage, canopy closure is probably the single most important structural variable relating to nest area suitability. Virtually every study examining goshawk nest areas identifies canopy closure as a key attribute. Stands <30% canopy closure are generally too open for nesting. Optimal values, as represented from our observed sample of nest areas, are 45-70%. Corresponding suitability ratings for the canopy closure classes available in the forest cover database are provided below.

Canopy Closure Class	Canopy Closure %	Rating
0-1	0-15	0
2	16-25	0.2
3	26-35	0.4
4	36-45	0.8
5-7	46-75	1
8-9	>75	0.8

Tree Species

All known nest areas in the CWH in the Skeena Region are in hemlock leading stands. Suitability ratings in the following table are based on the associations of secondary species observed at nest areas. Suitability depends on the form and structure of the trees and the stands they make up, and can therefore vary with site and age. Hemlock seem to be preferred because they often form even-aged stands with closed canopies and open understories, and the branching pattern creates good nest platforms. Other species such as spruce and fir tend to have more broken canopies, greater vertical stand structure (with less open understories) and poorer branch structures for nests.

Species	Rating
Yc	0.3
Cw	0.7
Pl	0.7
Ac, At, Ep	0.5
Ss, Sx, S	0.8
Ba, B	0.8

Dr	0.8
Hw,Hm, H	1

Overall stand forest type suitability ratings are calculated by multiplying the species rating by its percentage composition and summing all for all types in the stand.

E.g. $H_{70}B_{20}S_{10}$=.7(1)+.2(.8)+.1(.8)=0.93

Nest Area Habitat Suitability Model Equation

This nest area model follows a limiting factor, non-compensatory approach. From an ecological perspective this means that when the suitability rating of one variable decreases below its optimal range it decreases the overall suitability by that amount. Further, suboptimal ratings in two or more variables are combined, through a multiplicative function, to decrease the overall value. The function is non-compensatory in that the value of one variable cannot compensate for a deficiency in another.

Nest Area Suitability = Ht Cl Rating **x Can. Cl.** Rating **x Tree Sp.**

Ratings resulting from this model are relative in nature. Due to over-riding demographic factors (population density and territory spacing) these ratings cannot be used to predict numbers of goshawks across the landscape.

Ratings can be categorized within a 4-class system for map theming:

Ratings	Class
0-.249	Nil
.25-.499	Low
.5-.749	Moderate
>=.75	High

Based on our experience with a similar model and observed nest area habitat variation in the CWH in the Kispiox District we estimate that approximately 75-85% of observed nest areas would have a rating ≥0.75, 15-20% would have a rating of 0.50-0.75, and 0-5% would have a rating <0.50.