Blue Grouse Habitat on

Haida Gwaii/Queen Charlotte Islands

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Executive Summary

For many years on Haida Gwaii/Queen Charlotte Islands (Haida Gwaii), there has been local concern that the population of Blue Grouse (*Dendragapus obscurus*) was declining. In addition, scientists working with the threatened Queen Charlotte Goshawk (*Accipiter gentilis laingi)* are concerned that the reduction in grouse, one of the goshawks main prey items, was threatening the ability of the islands to maintain a viable goshawk population. Other research on Blue Grouse has linked population trends to the age of the forest (recent harvested – old growth), and within the central part of the islands only 14% of the original mature-old growth forest remains. This study therefore set out to determine if grouse were being impacted by harvesting, and to do this grouse survey transects were set up across the spectrum of available harvested landscape types, to establish if and when harvesting was impacting densities of birds.

In all three transect were established within each landscape type, resulting in a total of 27 transects which were surveyed at least three times, culminating in a total of 866 grouse survey points. The number of birds singing was recorded at each station, and both an in-field, and GIS landscape analysis of the available habitat was then conducted.

Independent from harvesting impacts, the survey results indicate that the density of grouse on Haida Gwaii is at least seven times lower than observed in similar habitats (old growth with recent harvesting) on the adjacent islands to the north in SE Alaska, and on Vancouver Island and the Gulf Islands to the south. However, historical accounts suggest grouse densities on Haida Gwaii were likely far higher in the past, and the introduced deer has been identified as a probable factor in the reduction in the numbers of grouse, as it directly competes with the grouse for forage plants. In addition, introduced nest predators, such as the raccoon are also likely to be impacting the success of breeding birds.

Grouse densities were highest in the central, most productive portion of the island, the Skidegate Plateau Ecosection, and this is also the area with the highest area of harvesting. However, at a landscape scale (2 km radius of a survey station) the larger the area of mature-old growth in the landscape the more birds that were heard. At a finer scale (<300m radius of a survey station), the highest number of birds were heard in the recently (<15 years) harvested areas, but this density then declined sharply as the stands aged.

The area of alpine and alpine forest present within 2 km of a survey transect, was also positively linked, such that the larger the area of alpine the more grouse that were heard. No other habitat type was significantly linked to the number of grouse singing. In addition, tree species composition in the landscape, as represented by the leading species within Forest Cover polygons, was also not correlated to the number of birds heard singing. Grouse may also be impacted by introduced species on Haida Gwaii, but the pattern in the density of birds with habitat type was consistent with other studies, suggesting that this rather than the impact of these species was the main factor behind the observed population decline.

Based on the size and spatial arrangement of the area harvested, grouse populations have probably declined in the 50 years since intensive harvesting was initiated, even though populations may benefit from some recent harvesting, as new openings (<15 years) are used by breeding birds. This decrease in grouse may have substantially impacted the viability of the threatened goshawk population, with near to 50% of known and predicted goshawk territories impacted by an area of harvest that is likely reducing the densities and availability of grouse. However, it is also probable that island wide impacts from introduced species on the numbers of grouse, is severely impacting the ability of the landscape to support a healthy goshawk population. This impact may be such that independent of forest management practices goshawk

healthy goshawk populations can only be maintained by managing for a reduction in the impact by the introduced species.

To provide for the best opportunity to successfully manage for a healthy grouse and goshawk population will therefore probably require a combined approach. This would see the implementation of forest management practices that support high grouse populations, and access to the grouse for goshawks, taking place while at the same time reducing the direct and indirect impacts of introduced species on grouse populations, in particular by the deer.

The results from this work have been submitted to all provincial and Haida Gwaii land management groups, including local conservation and hunting associations. In addition the information has been presented to the Goshawk Recovery Planning Team and to the provincial Land Use Planning forum, so that the information can be incorporated within the long term landscape management objectives for Haida Gwaii/Queen Charlotte Islands, which include the maintenance of a healthy ecosystem.

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Acknowledgements

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Introduction

Wildlife biologists for Parks Canada, the Haida and the Provincial Government on Haida Gwaii/Queen Charlotte Islands (Haida Gwaii) have all expressed concern about the population status of Blue Grouse (*Dendragapus obscurus*) population. It is the only grouse found on Haida Gwaii. Rapid loss of large areas of mature/old growth forest has occurred on Haida Gwaii in the past 40 years with only 14% of this habitat remaining in large areas of the productive Skidegate Plateau Ecosection, which covers the central 1/3rd of this island archipelago.

On Haida Gwaii, Bendell and Zwickel (1984) reported that the Blue Grouse did not breed in open clear-cut areas. If this bird does indeed not breed in this habitat, and this habitat is increasing in area annually, then its population status, both in its contribution to biodiversity and to hunters may well be under threat. Any decline in grouse populations maybe also be having a devastating impact on the population of the COSEWIC Threatened and provincially red listed Queen Charlotte Goshawk (*Accipiter gentilis laingi*), for which grouse is an important prey (Lewis 2001), particularly when other common prey such as rabbits and other grouse species are absent such as on Haida Gwaii. Recent monitoring of goshawk nests on these islands, indicate a very low breeding rate and low productivity of breeding pairs, indicating a probably declining population (Doyle 2003).

Base line information is therefore required on the habitat requirements and density of this species on Haida Gwaii, particularly in relation to thresholds in harvest patterns and area impacts, such that any negative impacts can be avoided In addition, this study will try to establish if other factors such as introduced competitors or predators may possibly be causing a population decline.

Information from this study will be made available hunters and those developing ongoing Harvest and Ecosystem plans (LURMP, Haida Protected Areas Network, Licensee Forest Development Plans, etc.,) such that the population of grouse, and the goshawk that may rely on it is as prey, can be maintained through stewardship planning that maintains this vital component of the ecosystem.

Location

Haida Gwaii/Queen Charlotte Islands 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).

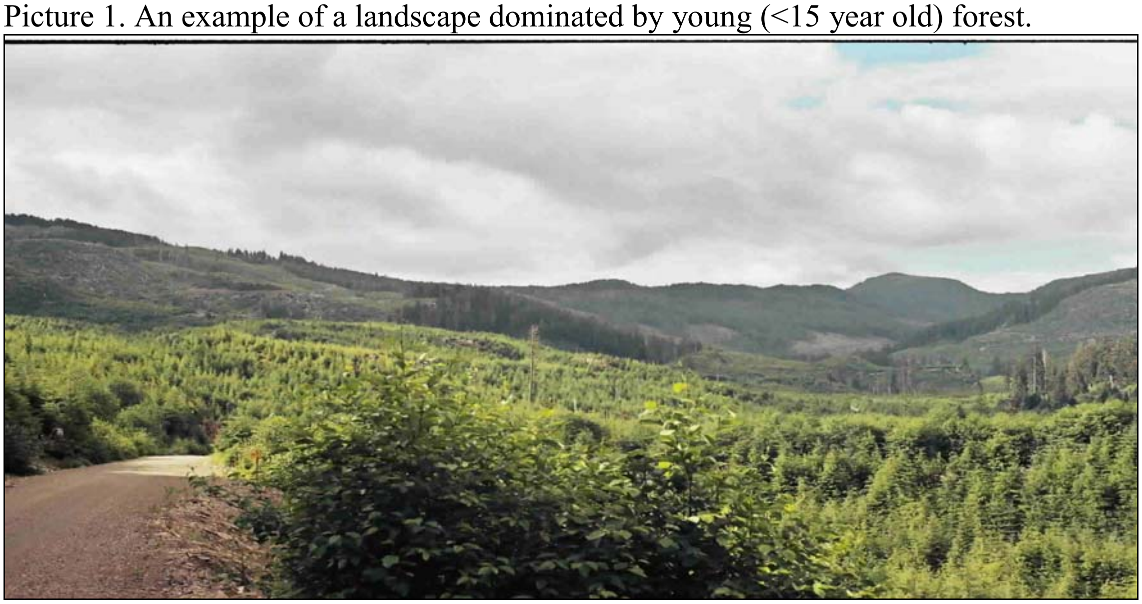
Methods

Habitat was stratified (young seral-old growth and contiguous-fragmented forest) across the islands (e.g. Picture 1) and the relative abundance of singing birds within each landscape was measured using ~10 km long transects, with song stations placed 1km apart (RIC 1997). These survey transects were repeated a minimum of three times, to ensure daily weather patterns or other factors (harvesting operational noise, etc) did not influence the number of birds associated with particular habitat types. All crew members were familiar with grouse song, and together several dry runs were conducted to ensure standardization of methodology. Daily survey information collected included date, time, weather, noise level, number of birds singing, direction, and estimated distance.

Habitat assessments adjacent to song stations were conducted in the field, based on what the observer could see with both the primary, secondary and tertiary habitat types (if present) identified (Table 1). In addition, GIS analysis was conducted of all habitat types (Appendix 1) within a 2 km radius of each song station along the transect. This scale was chosen, as it was outside of the area identified in the “In-field” assessment, but may still be expected to influence the abundance of this relatively mobile bird. In particular, if they were present, it also encompassed adjacent ridge tops, which some studies have identified as being selected for by the birds in winter (Zwickel 1992).

Where sample sizes allow, standard statistical procedures are used. In most cases, P values are presented for their descriptive value rather than as tests of statistical hypothesis (Arcese et al. 1992) and stress is placed on the magnitude of "r" values as supportive evidence to the strength or weakness of observed correlations. I used 'Statistica' (StatSoft Inc. 1995) for all statistical analysis, and all tests for significance were set at $P < 0.05$.

Picture 1. An example of a landscape dominated by young (<15 year old) forest.



Results

Grouse Song Rates in Relation to Field Habitat Evaluation

A total of 27 Blue Grouse survey transects were set out across 9 landscape types (Table 1) on Graham and Moresby Islands on Haida Gwaii in May and June 2002. On average 10 survey stations (7-11), spaced 1 km apart were set out per transect. This resulted in the setting up of 266 survey stations which were surveyed a minimum of three (3-5) times each, culminating in a total of 843 grouse song station visits.

The number of grouse singing per transect and per station were compared to landscape and habitat composition based on the overall landscape setting target "Stratum" of the transect, the dominant habitat type at each survey station, and the number of birds singing at sites where only one habitat was present.

Table 1. Landscape and habitat types selected for Blue Grouse surveys.

Stratum	Biogeclimatic Zone and Dominant Forest Type/Harvest Pattern	# Visits	# Stations
	Skidegate Plateau		
1	2nd growth 0 - 15 yrs	10	97
2	2nd growth 16 - 45 yrs	11	110
3	2nd growth 46 + years old	9	88
7	old growth highly productive*	11	106
8	old growth medium productivity*	9	93
9	old growth low productivity*	9	83
	Queen Charlotte Lowlands		
4	qc lowlands (boggy)	9	92
5	qc lowlands (forested)	9	84
	Windward Queen Charlotte Mtns'		
6	West Coast	9	90

*Based on Site Series and Forest Cover growing condition (Doyle 2004).

Based on the number of visits to each transect no significant change in grouse song rates were detected between the first (12/05/02) and last song transect (22/06/02) (Table 2), even though slightly more birds were detected on the fourth visit to six transects. Climatic variables (rain, cloud cover and temperature) were also measured, and on average the temperature was 8.6 Celsius (SD 3.05) for each of the 86 individual survey transects conducted. Rain and wind both significantly influenced the number of birds heard, with fewer birds singing in days with light rain and/or windy conditions. However, there was no significant difference in the individual transects visited within the different weather patterns. No significant correlation between grouse song rates and temperature was detected.

Table 2. Grouse song rates over the period of the study.

Visit #	# Visits	# of Grouse Heard	Mean Number of Birds calling per Transect	SD	Range
1	27	114	4.22	5.16	0-19
2	27	102	3.78	4.14	0-13
3	27	96	3.69	5.07	0-19
4	6	35	5.83	5.19	0-14

These surveys resulted in the detection of 347 singing male grouse, with the highest number of birds detected in the mature-old growth (Stratum 9) and the lowest song rates detected in the older second growth stands (Stratum 3) (Table 3). Song rates in the least disturbed habitats (<28% harvest) in all three Ecosections, ranged from an average of 0.69 per survey station in the Skidegate Plateau, 0.29 per station in the Queen Charlotte Lowlands down to 0.18 in the Windward Queen Charlotte Mtn's.

Table 3. Number of Blue Grouse heard per survey station per Landscape Forest Type/Harvest Pattern (Stratum).

Landscape Forest Type/Harvest Pattern*	Mean per Survey Station	SD	Range per Transect	# Grouse	# Stations
1	0.57	0.9	0-19	55	97
2	0.25	0.5	0-7	28	110
3	0.05	0.21	0-1	4	88
4	0.37	0.67	0-12	34	92
5	0.21	0.44	0-7	18	84
6	0.18	0.44	0-8	16	90
7	0.69	0.8	1-15.	73	106
8	0.53	0.75	0-13	49	93
9	0.84	1.08	0-19	70	83

* Estimated based on < 2km from transect.

Once in the field, individual transects were also ranked as to the primary habitat type that was found surrounding (<300m) the individual song station (Table 4). This showed a change in the pattern seen in the overall landscape scale, with the highest numbers of grouse now heard from stations adjacent to the most recently harvested areas (<15 years), typically these recently harvested stands were adjacent (94%, N = 32) to mature-old growth stands. Similarly, it was also seen that within the landscapes with the most intact forest (# 4, 5, 6, 7, 8, 9 above), that these areas were primarily impacted by recent (<15 years old) harvesting (79%, N = 61). However, the difference in the number of grouse heard in recent harvested areas was significantly (F Test: p = 0.0005) different from the number of birds in the more intact forest.

In the older harvested areas (# 2 and 3 above) the grouse song rates remained low at the landscape and primary habitat scales, and compared to the recently harvested areas these areas were typically (73%, N = 75) **not** adjacent to mature old growth forest stands, but instead are adjacent to larger areas of the same habitat type.

Table 4. Number of grouse heard per dominant habitat type present at each survey station.

Dominant Habitat Type*	Mean Number of Grouse per Survey Station	SD	Sample Size
1	0.87	1.04	100
2	0.32	0.64	150
3	0.04	0.21	88
4	0.38	0.68	96
5	0.2	0.4	60
6	0.2	0.48	90
7	0.5	0.78	24
8	0.75	0.89	114
9	0.36	0.61	118

* Habitat assessment <300m from a survey station.

Finally, at the landscape scale (<300m from the song station) when we looked at the number of grouse singing at stations where only one habitat type was present (Table 5), the main change from the pattern seen with the Dominant habitat types (Table 4), is the decrease in the number of birds heard in the lower productivity mature-old growth forest (# 9). In addition this is substantially lower than seen at the landscape scale (Table 3). This suggests that the association of other more productive habitat types at the Landscape (Table 3) and Dominant (Table 4) scales, may result in an in increase in the number of birds heard singing.

Table 5. Number of Grouse singing per Station at sites when only one habitat type was present.

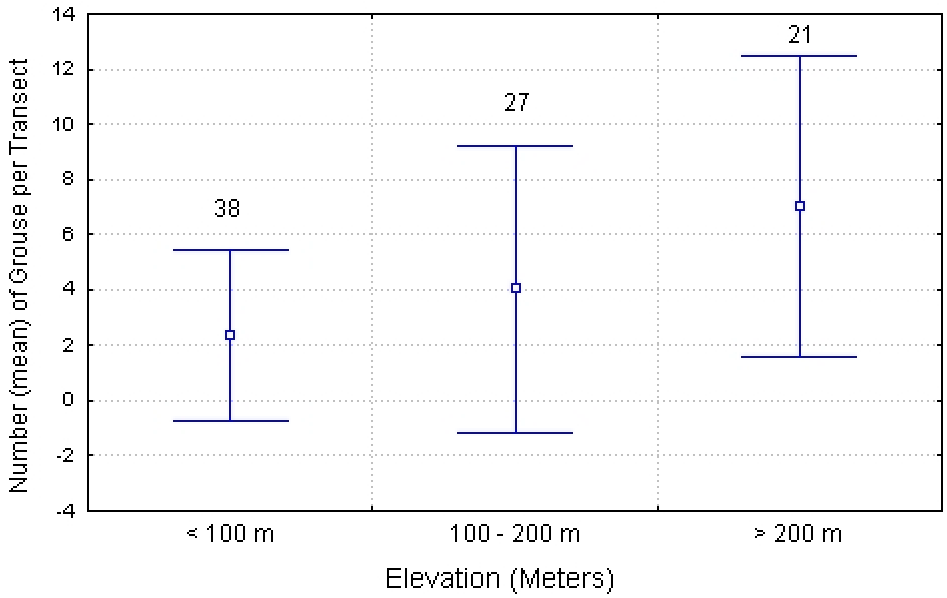
Only Forest Type/Harvest Pattern*	**Mean per Survey Station**	**SD**	**# Stations**
1			0
2	0.29	0.54	71
3	0.05	0.22	80
4	0.29	0.46	21
5			0
6	0.24	0.5	63
7			0
8	1.00	0.82	10
9	0.09	0.29	12

* No Secondary habitats <300m of Station

At all scales, and combinations of habitat types, another consistent pattern that emerged was that the older harvested areas (>15 years) had fewer grouse (Table 3, 4 and 5) detections per survey station. With a 56% decline in grouse singing in <15 yrs stands to 16-45 years old stands and further 80% decline in >46 yr stands based on Stratum Type (Table 3), a corresponding 63% and 90% decline in stands based on the dominant habitat seen at the survey station (Table 4), and where only one habitat exists at a station an 83% decline in birds from the 15 - 45 year old, to the >46 year old stands.

Finally at a topographic scale, the elevation of the transects in relation to the number of grouse singing showed that at higher elevations more birds were heard (Figure 1). This difference was significant for transects conducted at < 100m elevation, compared to those at 100-200m, but was not significant between those conducted at 100 – 200 m compared to those >200m.

Figure 1. Grouse song rates (mean) per transect versus elevation of transect. (Tail = SD)



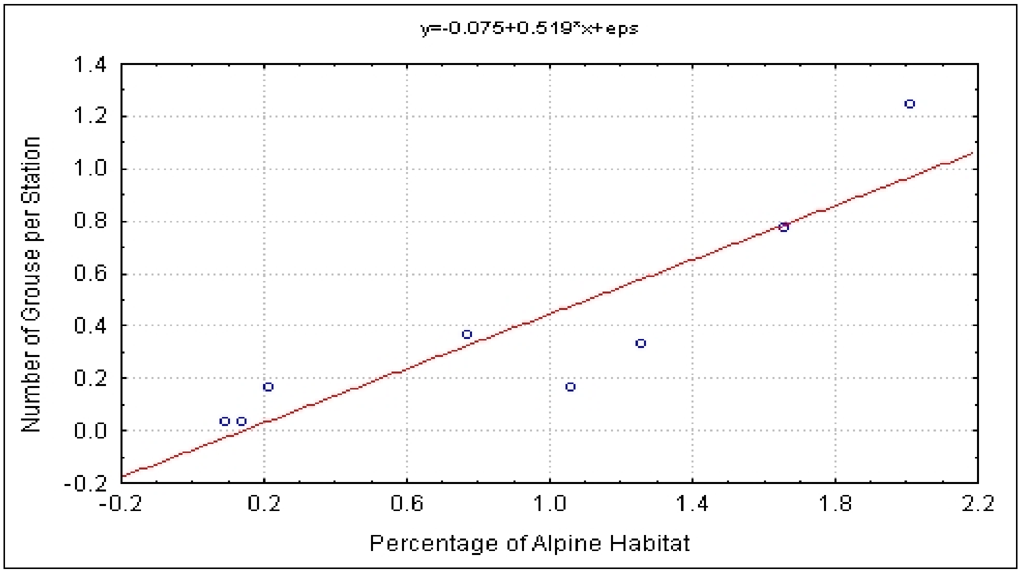
Grouse Song Rates in Relation to GIS Habitat Evaluation

In addition to the in the field habitat evaluation centered on survey stations, we also conducted GIS analysis of the landscape <2 km of the survey transect, to identify any other habitat influences on song rates at the landscape scale. (See Appendix 1 for list of habitat variables evaluated.)

Of all these variables only the area of mature-old growth, area harvested, and area of alpine were significantly correlated to changes in the number of singing birds. In addition, an increasing area of water (Lake, Sea and River) was negatively linked to the number of singing birds.

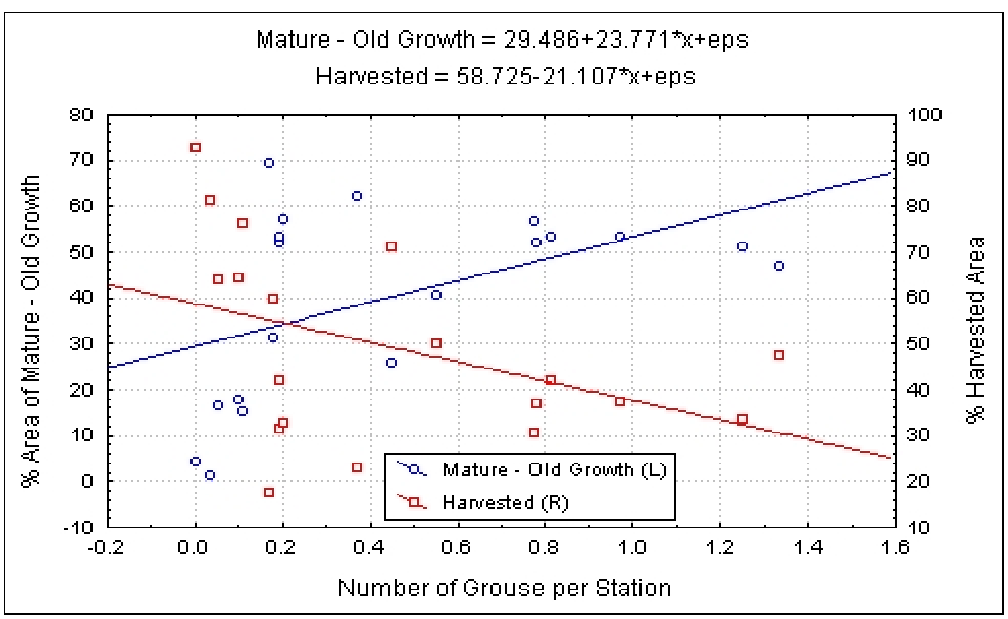
Independent of any possible harvesting impacts, grouse populations were most closely tied to the percentage of the landscape that was Alpine-Alpine Forest, with a significant ($r = 0.90$, $p = 0.002$, $N = 8$) increase in the numbers of grouse in areas with greater amounts of Alpine (Figure 2).

Figure 2. Numbers of grouse heard singing compared to the area of Alpine habitat available.



Most landscapes on Haida Gwaii however, have no alpine, and within the central Skidegate Plateau on transects not adjacent to alpine, the number of grouse increased significantly (r = 0.5, p = 0.03, N = 19) with the area of mature-old growth forest, and decreased significantly (r = 0.5, p = 0.03, N = 19) with the area harvested (Figure 3). The link with the area of mature-old growth forest was also seen when we looked at the islands as a whole and included the eight transects conducted in the Wet Windward and Queen Charlotte Lowland Ecosections. Combined, higher densities of grouse were found in areas with a higher percentage of mature-old growth forest (r = 0.41, p = 0.32, N = 27)

Figure 3. Number of grouse singing compared to the area of mature-old growth and the area harvested.

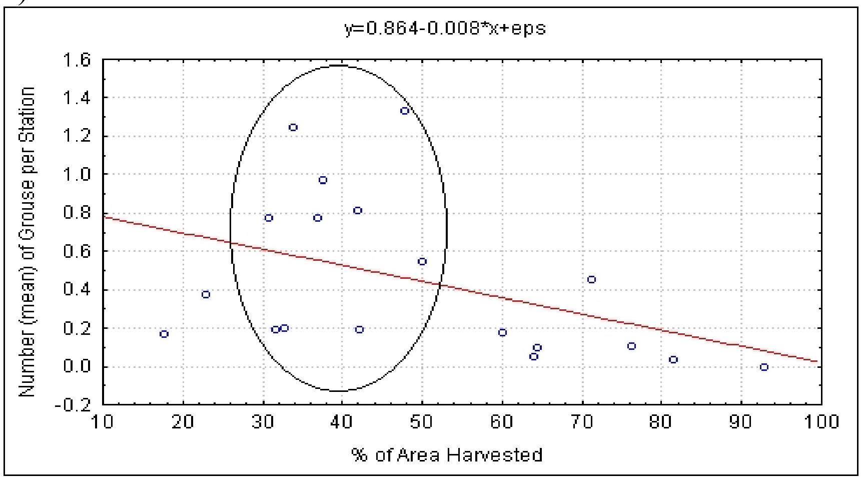


When we look at the pattern of singing in the Skidegate Plateau Ecosection in relation to the amount of mature-old growth, all natural habitats (excluding water), and the area harvested (Figure 4), there appears to be a threshold effect with a cluster (points surrounded by an oval in each figure) delineating the area where no significant habitat area impact is influencing the number of grouse. (Within this cluster, the rate of singing in three sites remained low, however two of these sites are transition habitats between the Queen Charlotte Lowland Ecosection which has a lower song rate). It we just look at the point at which the rate of singing is more closely associated with the size of the area, we find a significant decline in grouse singing if >50% of the mature-old growth is harvested ($r = -0.71$, $p = 0.047$, $N = 8$) (Figure 4a). Looking at the amount of mature-old growth in a landscape, if there is <40%, we also see a significant decline in the number of birds singing ($r = 0.88$, $p = 0.004$, $N = 8$) (Figure 4b). Finally if we combine the area of mature-old growth with the other natural terrestrial habitats (i.e. exclude: water, urban, gravel pit, etc) we see a significant decline if the terrestrial habitat is <50% of the landscape ($r = 0.93$, $p = 0.0008$, $N = 8$) (Figure 4c).

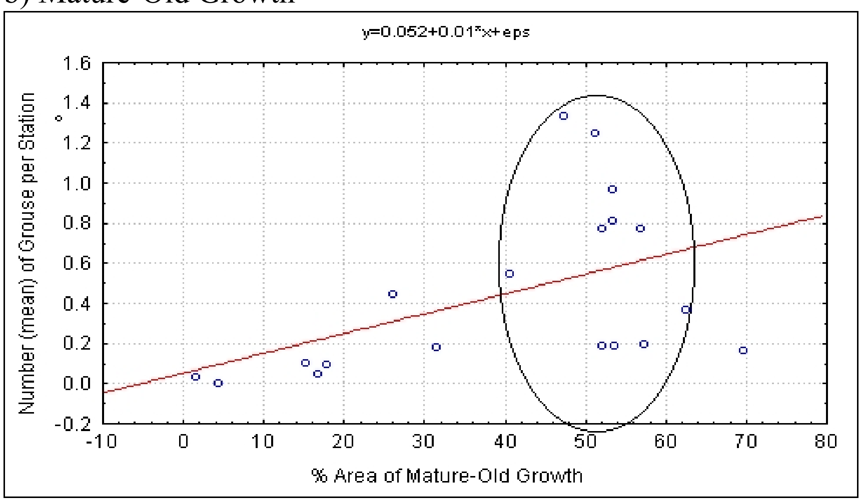
In addition, to the possible threshold in habitat below which grouse populations may be declining, there is also possibly an increase in the number of birds heard with some (~20-30 %) harvesting or with natural fragmentation (Figure 4a-c). However, sample sizes are small.

Figure 4 a-c. Number of Grouse singing per Station in harvested and non-harvested forest landscapes in the Skidegate Plateau Ecosection.

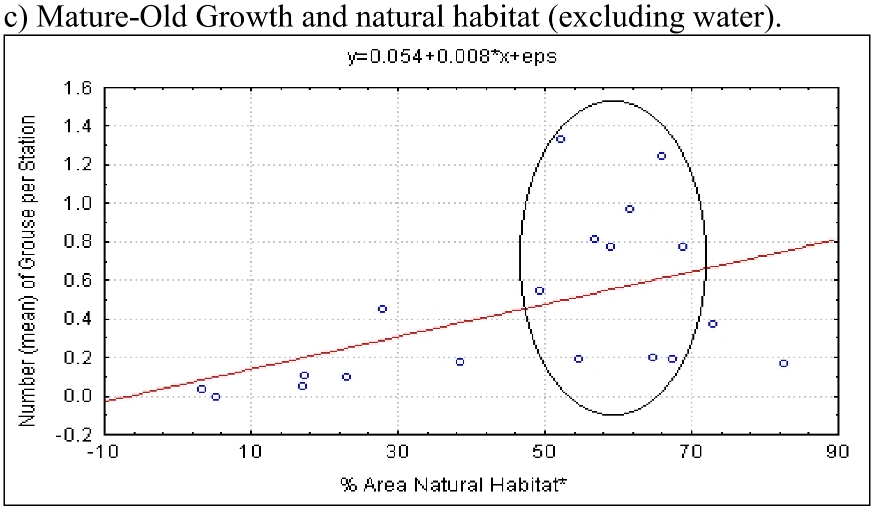
a) Harvested



b) Mature-Old Growth



c) Mature-Old Growth and natural habitat (excluding water).

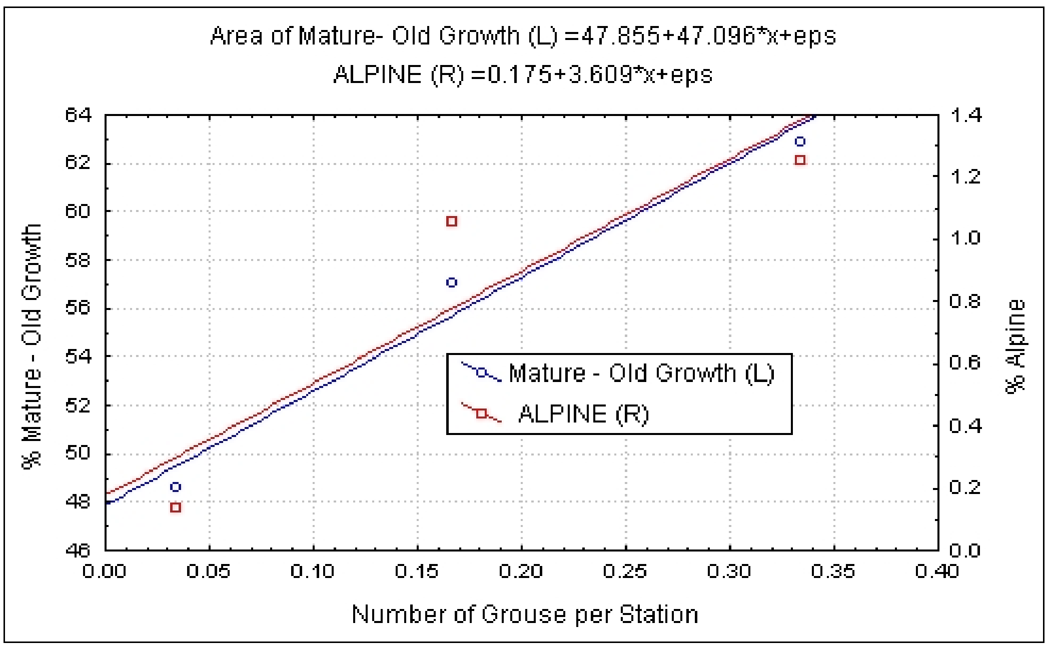


In addition to the patterns seen in the landscape as a whole and within the Skidegate Plateau (above), we also looked at song rates compared to the range of habitat types within the two other ecosections, the wet mountain WQC and the drier QCL Ecosections.

Within the QCL Ecosection the area of harvest is low (<25% of the forest) and song rates were not linked to harvesting of mature-old growth forest, or to the area of mature-old growth forest in the landscape, however the sample size (N = 5) may be too small to detect any change. The QCL does not contain any alpine habitat.

As with the QCL the area harvested in the WQC is comparatively low (<28%), and again no relationship with the amount of area harvested with grouse population was observed. In contrast to the QCL, alpine areas were present on all transects and the there was a linear relationship between this increase and grouse populations (Figure 5). In addition, the same linear pattern was also seen when we compared the amount of mature-old growth in the landscape and with the number of birds singing. Sample sizes were again small.

Figure 5. Number of grouse singing compared to the area of Alpine and area of Mature-old growth forest.



The influence of tree species in a landscape was also compared to grouse population by using the leading tree species as identified through Forest Cover label information. No relationship at all was found between the area of forest polygons in which Spruce, Hemlock or Cedar, Pine or Alder were the leading species, and between the numbers of grouse singing.

Results Summary

The number of grouse was highest within the central SKP Ecosection, and >50% lower in the WQC and QCL Ecosections. More grouse were heard along higher elevation transects, and the higher the percentage of alpine area adjacent (≤2 km) to the transect, the higher the number of grouse heard.

Looking at the "in-field" and GIS analysis together, the number of grouse singing was highest in landscapes with more mature-old growth forest and lowest in harvested landscapes, however, at the stand "in-field" scale more birds were heard singing at stations adjacent to recent (<15 years) clear cuts. Overall, the higher the percentage of harvest at a stand and landscape scale the fewer the number of grouse heard singing.

A possible landscape threshold in the percentage of mature-old growth forest and harvesting of that forest, below which the number of birds heard singing declined was also seen. With a significant decline in singing in landscapes with <40% of mature-old growth forest, and landscapes in which >50% of the available mature-old growth had been harvested.

Discussion

As a backdrop to the possible influence of harvesting on Blue Grouse populations on Haida Gwaii, comparisons with grouse populations elsewhere were also explored, and this revealed that independent of any harvesting impacts that the grouse population was considerably lower than elsewhere. Although it was not possible to directly compare our singing densities with the more detailed long-term studies that have mapped territories and densities of Blue Grouse (Zwickel 1992), I was able to compare with a study in similar habitat on the islands of southeast Alaska (Doerr *et. al.* 1984). Here an average of 0.16 birds per 100 ha, were heard in cleacuts (<25 years old), and 7.2 in mature-old growth forest. This compares to 1.1 (n = 100) birds heard singing in recently (<15 years) harvested areas in this study, 0.28 (n = 150) in the older clearcuts, and 0.95 (n = 114) to 0.45 (n = 118) birds heard in mature-old growth habitats. Taken as a whole, the grouse population in old growth forest on Haida Gwaii is 7 – 16 times lower than in the comparable old growth on the adjacent islands of SE Alaska. This difference in the number of birds also corresponds to Blue Grouse research and inventory in similar habitat (old-growth rainforest interspersed with recent harvest (<100 years)) on Vancouver Island and on the Gulf Islands to the south, where absolute population densities indicate a far higher density than indicated by singing birds on Haida Gwaii. Compared to the landscape with the highest density of grouse on Haida Gwaii, densities ranged from 6 – 103 times higher per 100ha, in four long term studies on Vancouver Island and the Gulf Islands to the south (Zwickel 1992). These other long term studies also indicate that within a landscape there is little annual variation in populations (Zwickel 1992), which contrasts to the wide range seen in cyclic grouse populations (Martin et al. 2001), therefore the differences in grouse densities between Haida Gwaii and elsewhere are believed to represent real differences in overall densities versus variations in inter annual populations between study areas. This differences in population density may not always have been present, as observation by the community as a whole, suggest that grouse densities on Haida Gwaii are considerably lower than in the past when the Haida First Nation used the grouse as a food resource (Ellis 1991), and certainly lower than indicated by the first white man's written report, when "Grouse were very numerous….. and excellent eating, quite fat and tender" (Chittenden 1884).

As harvesting is also taking place within the other comparable study sites, with far higher densities of grouse, then another mechanism for the probable reduction in grouse population on Haida Gwaii may be a play. As possible mechanism for a reduction in populations on Haida Gwaii the impact of introduced species is of the greatest concern. Of these species, the black-tailed deer (*Odocoileus hemionus sitkensis*) introduced in 1878, is possible directly competing for summer forage, and indirectly through the removal of plants, reducing the abundance and diversity of insects (Allombert 2002). This deer has heavily impacted the forest fauna and flora, such that many vascular plants and shrubs, including *Vaccinium sp*. and Salal (*Gaultheria shallon*), known common food plants for the grouse (Schroeder 1984, Zwickel 1992) are heavily browsed and absent from many areas (Pojar et al. 1980, Sharp 2001). This grazing and browsing competition appears to occur equally in old growth and young (<15 years) harvested stands and therefore it is possible that the deer may be influencing the ability of these young stands to support a healthy breeding population of grouse. One study by Pojar et al. (1980), attempted to quantify the impact of deer browse on the vegetation on Haida Gwaii, and they compared the amount (biomass) of ground level low forest plants now present on the islands with sites of similar attributes on the adjacent mainland. On the mainland they found a 5.1 fold increase in *Vaccinium sp*. (huckleberry, blueberry, etc), a 2.7 fold increase in Salal, and a 4.2 fold increase in herbs, all these plants are not only browsed by the deer, but also used as main forage plants by Blue Grouse in summer. In addition, they collected many written and oral reports from the turn of the century that indicated that the forest vegetation was thick and luxuriant, which is in starck contrast to what they reported in their study.

Another introduced (1940's) species, the raccoon (*Procyon lotor*) may not only compete for food but this omnivore is a known nest predator. In other areas studies of Blue Grouse have shown that nest depredation by mammalian predators is very high (Zwickel 1992, Hewitt et al. 2001). As no similar predators were present on the islands prior to its introduction, and as the grouse here have largely evolved without the usual selection pressure associated with natural selection of nest sites, etc, brought about by the presence of such a predator, they may be particularly vulnerable. The raccoon is typically associated with rich feeding sites near water (Banfield 1974), and therefore although they are found throughout the islands, they are likely to be more abundant in the more productive valleys and estuaries, including the rich intertidal zone. If this is true, then there may be a gradient in nest predation pressure, which arguably may be represented by the elevational gradient in the number of grouse singing seen in this study, with more birds higher up the slopes, which presumably are further away from rich feeding sites frequented by the raccoons. As with the deer therefore, it is possible that the raccoons and other introduced species (rats, red squirrels, etc.,) are also attracted to the younger stands by the presence of forage plants and bird nests, etc, and this is influencing the pattern seen in the number of grouse heard singing at a stand and landscape scales. However, as the pattern in the relative density of birds with habitat type was consistent with other studies, it suggests that this, rather than the impact of these species may still be the main factor behind the observed population decline.

Looking specifically at the impacts of harvesting, the number of grouse heard compared to the age of harvesting, was consistent with several other studies from southern coastal populations (Zwickel and Bendell 1972, Zwickel 1992, Hartwig 2003), with higher densities of birds singing in recently (<15 yrs) harvested areas. Further north the study in SE Alaska, by Doerr *et. al.* (1984) reported higher populations in mature-old growth forest and although we did not see this at the stand level, we did see a significant link between the area of mature-old growth and the number of grouse heard, at a landscape scale.

However, the percentage of each habitat type (mature-old growth and <15 years) harvested within a landscape, may result in both of the above patterns in grouse density with recent harvesting being accurate. This study indicates that there is a threshold in habitat requirements, possibly driven by the need for winter foraging on hemlock needles (King 1971, Hines 1987), or elevated perches for territorial male song sites in spring (Doerr *et al.* 1984). Below this threshold populations may increase with fragmentation, presumably as the openings are selected for as they provide suitable conditions (food and nesting) to raise the young (Schroeder 1984, Zwickel and

Bendell 1985). Once this threshold in harvesting is exceeded, or if the percentage of mature-old growth in a landscape is too low, then number of birds appears to decline. This need for a balance in patch size and distribution in harvested landscapes, is seen in many other bird species (Andrén 1994). In the case of the grouse, if for example male singing trees are required (Doerr *et al.* 1984), then the spatial arrangement of the harvested areas to mature-old growth may be crucial to the abundance of female grouse within particular harvested areas.

The pattern of harvesting on Haida Gwaii, as elsewhere, does not allow us to establish which of the suspected drivers (although perhaps secondary to the impacts of introduced species on Haida Gwaii) in population regulation (mature-old growth and harvesting impacts) are limiting populations, as the percentage of older (>15 years) harvested areas in a landscape is correlated to a reduction in size of the area of mature old growth forest. Old harvesting practices resulting in progressively larger clearcuts, while recent clearcuts are placed within mature-old growth landscapes. However, taken together, the more in-depth ecological reviews (Zwickel 1992, Hartwig 2003), suggest that all these factors are likely to be at play, and on Haida Gwaii it appears that the grouse population decline starts to occur once >50% of the timber harvestable landbase has been harvested.

Apart from the impacts of harvesting, and the area of mature-old growth forest, on grouse populations themselves, this has obvious implications on the availability of this resource for hunters. Certainly, this study supports the observation by the members of both the Sandspit and Port Clements Rod and Gun Clubs on the islands, which suggested that the densities of grouse were declining. This pattern will likely be particularly evident around these communities, as they are centered in areas with some of the longest history of large scale harvesting, and therefore the harvested areas are now at an age in which the lowest number of birds are heard.

The area of mature-old growth, and/or the area of harvesting was not the only identified habitat factor influencing grouse populations on the islands, the area of alpine and alpine forest was also positively linked to an increase in the number of singing birds, for those transects placed adjacent to such areas. In the adjacent islands of southeast Alaska a study on grouse habitat selection (Unpub Report: Brown 1966) suggests the density of males was highest within 100 meters of the tree line, and this alpine habitat has also been identified as preferred habitat for the grouse in winter (Wing 1947, King 1971). In addition, prior to large scale harvesting, this habitat may have been one of the few habitats providing the shrubby habitats preferred by females during breeding (Schroeder 1984, Zwickel and Bendell 1985). This link with alpine habitat may also be influencing the densities of grouse on transects that are not adjacent to alpine areas as grouse are known to migrate considerable distances uphill from their summer to their winter ranges (Hartwiig 2003). Therefore the overall contribution of this habitat to the health of the grouse populations across the islands is unknown. However, as the area covered by this habitat has not changed, it is unlikely to be driving the population patterns seen in relation to the area of mature-old growth and harvesting in other areas of the islands.

The probable impacts that the introduced species, and extensive areas of older harvesting are having on grouse populations, may also be having a secondary impact, as the likely reduction in grouse densities, may be severely impacting the density and breeding success of the BC red listed, and threatened COSEWIC listed, Queen Charlotte Goshawk (*Accipiter gentilis laingi*). This bird has been identified as probably declining in numbers, and its breeding success is so low (Doyle 2003a), that the island population is unlikely to have the ability to maintain a healthy viable population. When we look at the diet of the goshawk, it is a generalist forest predator typically taking grouse, medium sized passerine, rabbits and squirrels (Squires and Reynolds 1997). Prior, to the introduction (1947) of red squirrels *(Tamiasciurus hudsonicus),* grouse were probably one of the main prey, as they are on some of the adjacent islands of SE Alaska where squirrels and rabbits are absent (Lewis 2001). In addition, in landscapes where squirrels are common prey, and where densities of squirrels are far higher than observed on Haida Gwaii (Doyle 2000, Mahon and Doyle unpub. data.), population densities of goshawks are still tied to the abundance of the larger hares and grouse within those landscapes. Studies on the grouse themselves have also identified the goshawk as one of the main predators (Zwickel 1992, Hewitt *et. al.* 2001). The probable decline in grouse densities on Haida Gwaii, may therefore have severely impacted the ability of the landscape to support a healthy goshawk population independent of any secondary impacts due to the impacts of harvesting on grouse populations.

Independent of the impact of introduced species, there is also an additional impact of harvesting on grouse, and therefore probably on goshawk populations. A recent analysis of the percentage of harvesting in known and predicted goshawk territories across the islands (Doyle 2003a) has shown that in 30% of territories >50% of the original mature-old growth has been harvested, and that in another 30% between 25-50% has been harvested to date. This would suggest that in probably around 50% of the known and predicted territories, that >50% of the forest has been harvested, and as we saw the number of singing grouse declined proportionately to the area of harvest once >50% of the mature forest in a landscape had been harvested.

From a goshawk management perspective we are left with dilemma, as any forestry management for Blue Grouse may be insufficient to maintain goshawk populations unless a comparable reduction in the probable impacts of introduced species on grouse populations is also attained.

Finally on a positive note, this study has possibly identified thresholds in habitat requirements that can be used by licensees, hunters, the ongoing Land Use Plan, the Haida Protected Area Network and the Goshawk Recovery Team, which can be applied such that grouse densities can be maintained in newly harvested landscapes. In addition, this information was consistent with studies on Blue Grouse in SE Alaska and to the south, and therefore the possible thresholds identified here may be applicable for grouse management elsewhere.

This work, as with the other grouse studies, also provides for the possibility that harvesting that only removes ~20-30% of the landscape, may actually enhance grouse populations such that perhaps the carrying capacity of the landscape can be increased, to support the viability of threatened goshawk population while the large areas of older 2nd growth mature. This can occur as the newly harvested areas initially provide increased foraging opportunities, through increases in herb and shrub abundance (Deal 2001). In addition, the selection for more open canopy with a variety of heights and a patchy shrub layer observed in some studies (Bendell and Elliot 1966, Donaldson and Bergerud 1974), provides for the possibility that there may be a single tree select (Weyerhaeuser 2003, Doyle 2004), or patch retention harvest threshold (Huggard 2002), that will allow harvesting without impacting grouse populations. On Haida Gwaii, single tree select harvesting using helicopters, retains the forage value of the forest for goshawks, based on its suitability for the other main goshawk prey (medium sized forest birds and red squirrels) (Doyle 2003b) and the ability for goshawks to hunt in such habitats (Doyle and Nelligan 2004). Work is now required to see if this technique, or the more widely used variable patch retention, can reduce the harvest impact on grouse or indeed increases the overall habitat suitability for the birds. A cautious approach is required however to the harvest techniques employed, and area of harvest intensity used under partial cutting practices, as the abundance of important shrubs such as *Vaccinium* can be reduced with increased cutting intensity (Deal 2001). In particular, browse intensity from the introduced deer, may severely influence our present predictive ability to determine which harvest strategy is likely to be the most beneficial to grouse populations.

Finally, large areas of the islands are now in older (>15 years) second growth stands and here we know grouse densities are low in spring (this study), and possibly absent in winter (vanderBrink 1992). In addition, any grouse that are present are likely to be inaccessible to foraging goshawks (Beier and Drennan 1997), therefore work needs to be initiated to see how this habitat can, through silvicultural practices, be brought back to suitability for grouse (Hartwig 2003), and as foraging habitat for the threatened goshawks, to provide as many grouse as possible in the shortest possible time. Independent of managing for the probable impacts of introduced species, our ability to maintain healthy grouse and subsequently healthy goshawk populations across the islands may however remain limited.

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Appendices

Appendix 1. Variables used in the GIS habitat analysis

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Habitat Variables
Icefield
Alpine
Rock
Gravel Pit
Sand
Clay Bank
Alpine Forest (with Species etc.)
Non-Productive Brush
Non-Productive
Non-Productive Forest (with species etc.)
Non-Productive Burn
Mature-Old Growth
Harvested
Leading tree species
Lake
Tidal Flat
Gravel Bar
River
Mud Flat
Swamp (muskeg)
Clearing
Roads
Urban
Hayfield
Meadow
Open Range
Non-Applicable (salt water)