Forest Restoration on Haida Gwaii: Implications for Goshawk Habitat

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Abstract

Haida Gwaii, a remote group of islands off the northwest coast of British Columbia, is home to an endemic species of Northern Goshawks (*Accipiter gentilis laingi*), at imminent risk of extirpation. The loss of old growth habitat due to industrial logging is the principal reason for the decline of goshawk populations on Haida Gwaii. The survival of the raptor is dependent on the abundance and accessibility of prey (such as red squirrels *(Sciurus vulgaris)* and red-breasted sapsuckers *(Sphyrapicus ruber)*) which are closely tied to the composition of the forest. Structurally complex forests with widely spaced trees and variable canopy heights, critical attributes for goshawk foraging, have been replaced by monocrop, over-dense conifer plantations that are not accessible to goshawks. In the spring of 2020, a silvicultural thinning treatment was completed to improve the accessibility of second growth stands along the Yakoun River for goshawk foraging. The treatment, part of a multi-year project, reduced the stand density of a 70.6-hectare area from 905 to 531 stems per hectare, while retaining standing dead trees for wildlife habitat. Plot data was collected to quantify the effectiveness of silvicultural treatments in mimicking the conditions of the forest structure and prey resource availability that support existing goshawk forage territory. Results from the 2020 treatment showed that the stand density was successfully reduced to the specifications outlined in the project prescription and that red squirrels were preferentially feeding around large diameter Sitka spruce trees. Results from the old growth control sites showed a lower stem density than the 2020 and 2019 treatment sites and a relatively higher abundance of red squirrels than red-breasted sapsuckers. Plot data from the 2019 treatment site showed a relatively higher abundance of red-breasted-sapsucker compared to red-squirrels. Goshawk prey are present in the 2019 and 2020 treatment areas, and by improving the accessibility of the stand through thinning treatments, these forests may develop the necessary conditions for goshawk foraging. This initial field study has highlighted the need for rigorous scientific monitoring before and after thinning treatments to inform the location and implementation of future restoration projects, and to evaluate whether silvicultural treatments are effective in recruiting new goshawk foraging territory.

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Introduction

The Haida Gwaii Northern Goshawk (*Accipiter gentilis laingi*) is a genetically distinct subspecies of forest raptor endemic to Haida Gwaii, and at extreme risk of extirpation (Geraldes et al. 2018). Goshawks rely on mature, spaced forest stands for nesting and foraging, and much of their habitat has been lost to industrial logging (B.C. MOFML, 2010). Silvicultural thinning treatments in over-dense second growth stands offer a substantial opportunity to recruit new foraging habitat for Haida Gwaii goshawks (Doyle, 2004; McClaren et al. 2015). Quillicum Environmental Services, who have demonstrated expertise in riparian forest management, have partnered with Taan Forest Products, the Council of the Haida Nation and Old Massett Village Council to complete a multi-year forest restoration project in the Yakoun watershed. This report will combine a technical description of the 2020 project with a data analysis comparing prey abundance and forest structure in the 2019 and 2020 treatment sites with old growth control sites that currently support goshawk foraging on Haida Gwaii.

1.0 Background

1.1 Weather and climate

Haida Gwaii is an archipelago located between 50-130km off the mainland coast of British Columbia, north of Vancouver Island and south of the Alaskan panhandle. Comprising two large Islands, Graham and Moresby, and over 200 smaller islets, the archipelago remained ice free during the last ice age. As a result, endemic species of flora and fauna survived in a glacial refuge made possible by the relatively temperate maritime influence of the Pacific Ocean (Banner et al., 2014).

Located within the coastal western hemlock (CWH) biogeoclimatic zone, the climate of Haida Gwaii is characterized by cool summers and mild winters with an annual average precipitation ranging from over 3000mm along the windward west coast to less than 1500mm along the leeward side of Graham Island (Banner et al., 2014). The disturbance regime on Haida Gwaii is dominated by frequent, intense windstorms which result in small canopy gaps where individual or a few large trees fall to the forest floor (Banner et al., 2014). The Islands experience the highest winds in the winter and fall where damaging winds primarily come from the south east. Windthrow in riparian reserves is a common occurrence where trees retained in narrow buffer zones are unable to withstand the wind forces funneling through watershed corridors (Holt, 2005).

1.2 History

The Yakoun River, known to the Haida as the Yaaguun, is an important fishing river for the Haida Nation (pers comm., Humphries, 2020). However, intensive logging has severely degraded freshwater habitat and has resulted in a steep decline of salmon populations (Pacific Salmon Commission, 2019). In the heart of the Skidegate plateau, which includes the Yakoun watershed, what was once 90% old growth forest (trees over 250 years old), has been converted to 90% young forest (less than 50 years old) (Pojar, 2008). Young second growth stands are missing the old growth forest characteristics that provide functional habitat for all organisms, such as varied age classes, layered vertical structures and flora species diversity (Pojar, 2008). Young stands have been further simplified from the intensive browsing by invasive black tailed deer, which is depleting the forest understory and inhibiting the regeneration of western redcedar (*Thuja plicata*) and yellow cedar (*Cupressus nootkatensis*) in particular (Pojar, 2008).

Historically, the impact of clearcutting was exacerbated in riparian areas, where the largest, most easily accessed trees could be harvested and transported downriver. The majority of the mainstem and tributary systems on Haida Gwaii not logged before the Second World War were harvested right up to the edge of both banks between 1960 to the late 1980's (Holt, 2005). Before the enactment of the BC Forest Practices Code in 1995, there were no regulations in place to protect riparian forests along fish bearing streams from being logged (Holt, 2005). The practice of logging to the edge of watercourses prior to 1995 resulted in a significant decline in riparian ecosystem function. Riverbanks stripped of the ancient root systems of old forests became destabilized, leading to increased levels of erosion and turbidity and decreasing channel complexity (Holt, 2005).

1.3 Haida Gwaii Goshawks

A recent study by Geraldes et al. (2018) has confirmed the long-suspected fact that the Haida Gwaii Goshawk is a genetically distinct subspecies. The research team, from the University of British Columbia, has called on the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to upgrade the raptor's official listing from threatened, to endangered, given that their population is estimated to be a mere 48-57 individuals (COSEWIC, 2013).

Loss of mature forest habitat due to logging is primarily responsible for the precipitous decline of goshawk populations in coastal British Columbia (B.C. MOFML., 2010). Goshawk nest density is directly linked to the abundance and availability of prey on the landscape and clear-cut harvesting of mature forests is removing high quality foraging habitat (Mahon and Doyle, 2003). Goshawks, who favor mature, structured forests with closed canopy cover, large diameter trees and open understory (McClaren et al. 2015), require a stand density between 400-500 stems per hectare (sph) to locate their prey and fly freely through the understory to hunt (Mahon and

Doyle, 2003). In particular, Goshawks favor forest habitats with complex vertical structures where different age classes and tree species make up multiple layers of tree height (McClaren et al. 2015; Reynolds, pers comm, 2020). In this environment, the birds have a multitude of perches from which to ambush their prey on the forest floor, in trees or in flight (Mahon and Doyle, 2003). The homogenous second growth forests (less than 50 years), which now dominate Graham Island, do not contribute to the foraging territory of Goshawks on Haida Gwaii (CFCI, 2012; Mahon and Doyle, 2003).

Meanwhile, the conservation of the species remains a high priority for the Haida Nation. Effective as of 2010, the Haida Gwaii Land Use Objectives Order (HGLUOO), works to protect Haida cultural values and maintain the ecological integrity of important wildlife habitats (CHN. and B.C., 2014). The order created twelve goshawk reserve zones across Graham Island to protect nest sites and foraging habitat from human disturbance (CHN and BC, 2014). Further, the order explicitly calls for the recruitment of mature forest through voluntary management intervention in Goshawk nesting areas that have been previously altered or harvested (CHN. and BC, 2014).

Frank Doyle conducted 183 habitat suitability transects on Haida Gwaii in 2003-2004 to assess the abundance and availability of Goshawk prey. His results (Doyle, 2004) indicate that the introduced red squirrel is the leading prey species for Goshawks (43%), followed by red-breasted sapsucker (11.3%) and hairy woodpecker (4.5%). Other studies found that preferred goshawk prey species in coastal BC include red squirrel, passerines (thrushes and jays), woodpeckers and grouse (CFCI, 2012; McClaren et al. 2015; B.C. MOFML, 2010)

Doyle's transects (2004) spanned varying age classes and site series in second growth stands and his results indicated that goshawk forage potential was highest in 30-39-year spruce leading floodplain sites and stands with a combination of hemlock and spruce. Spacing projects within this age class may accelerate the suitability of second growth stands for Goshawk forage up to a decade earlier (Doyle, 2004) than if the stand were left to succeed naturally. Other studies have also identified silvicultural treatments such as pruning or thinning of younger second growth stands (45-60 years) as a way to improve breeding habitat (including foraging) characteristics for Goshawks (McClaren et al. 2015).

Science based guidelines can inform silvicultural treatments and help forest managers make decisions that balance ecological objectives with forest harvesting. The HGLUOO has established conservation reserves along with baseline practices that address the need for conservation and restoration initiatives on Haida Gwaii. In response, Taan Forest Products, the Haida-owned forestry company who hold the largest single land tenure on the Islands, has begun to take an active role in funding and supporting forest restoration projects on Graham Island. Since 2018, Taan Forest Products, Quillicum Environmental services, the council of the Haida Nation and Old Massett Village council have come together to support annual forest restoration treatments along the Yakoun River. The success of the 2019 pilot project, led by Quillicum Environmental Services, led to the expansion of the treatment area and project scope in 2020.

2.0 Site description of 2020 treatment area

The 2020 project site is located in the riparian areas along the north and south bank of the Yakoun River, at longitude 132°17'52"W and latitude 53°26'51"N (Taan, 2019). Our treatment area is an over dense conifer stand totaling 70.6 hectares (Taan, 2019) with a species composition of 80% Sitka spruce (*Picea sitchensis*), 10% western hemlock (*Tsuga heterophylla)* and 10% red Alder (*Alnus rubra*). The average age of the stand is approximately 30 years old and has a stand density of 905 stems per hectare (sph). The site is within the CWHwh1 biogeoclimatic zone has a medium to rich soil nutrient regime and a mesic-sub mesic soil moisture regime (Taan, 2019), which results in a principal site series classification of western hemlock-Sitka spruce (HwSs) – Lanky moss (101) and a lesser component of western redcedar/Sitka spruce (CwSs) – Sword fern (105) (Banner et al., 2014). At 35m above sea level, the site is situated in the lower elevations of the Yakoun watershed (Esri, 2019), which experience mean annual temperatures of 7.5 degrees Celsius and mean annual precipitation levels of 1878mm per year (UBC, 2020), primarily falling as rainfall.

13.3 hectares of our treatment area overlap with the lower HUGLOO designated lower Yakoun Goshawk reserve zone, and the entirety of our treatment area (70.6 ha) is within the foraging territory (5.2km radius) of three confirmed and documented Goshawk nests (Figure 1) (Taan, 2019). The treatment area also lies within the HUGLOO protected area for fish habitat and 100-year floodplain (Taan, 2019). The proximity to HUGLOO Goshawk reserves was one of the principal reasons that this site was chosen for treatment (Taan, 2019). It is also one of the largest riparian areas along the lower Yakoun impacted by past logging activity and as a result has good road access for the safety of the crew (Taan, 2019).

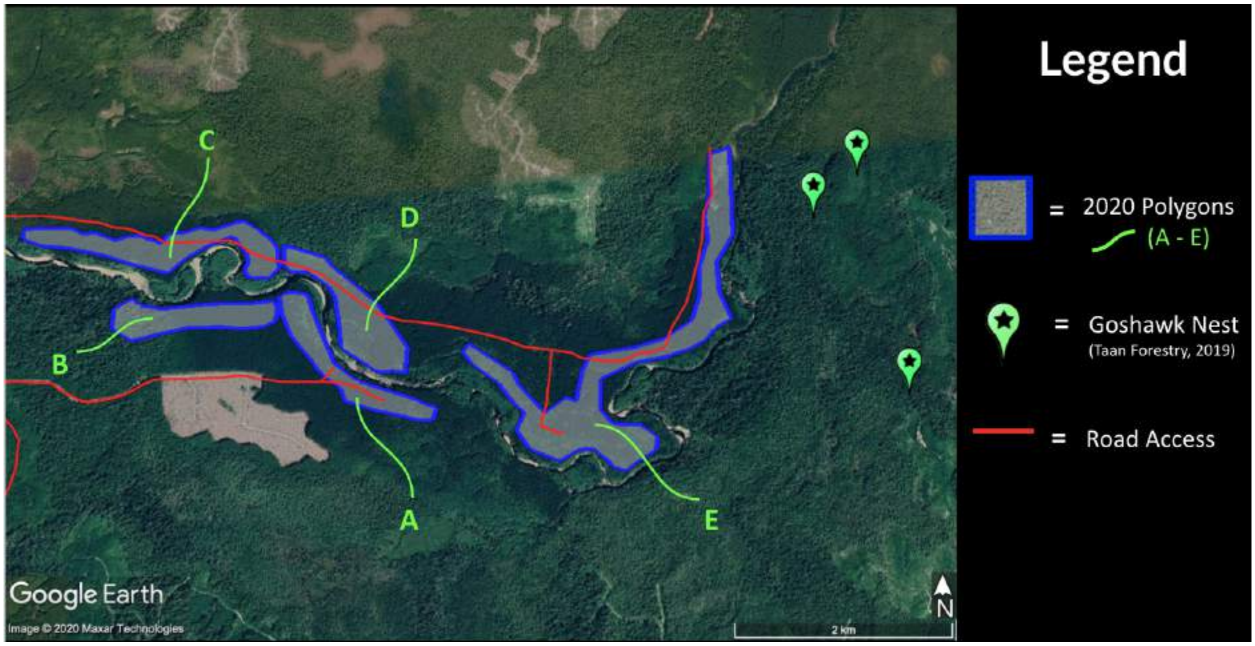

Figure 1 - 2020 treatment polygons and road access (within 5.2km foraging radius of goshawk nests) (Taan, 2019). Plot centre: 53°30'32"N, 132° 9'55"W. (WGS84)

3.0 Objectives

3.1 Work completed by Quillicum Environmental Services:

1. To decrease the density of second growth stands, in order to accelerate forest succession and the development of riparian old growth characteristics.

    i) To recruit additional foraging habitat for the Haida Gwaii Goshawk within 5-10 years
    ii) To increase root development to improve bank stability and reduce erosion (20-30 years)
    iii) To increase stand tree size for the recruitment of large woody debris for terrestrial and aquatic inputs over the long term (60-80 years)

2. To use silvicultural techniques to enhance the wildlife value of standing dead and live trees

    i) To increase insect colonization potential in standing dead trees
    ii) To increase cone production in standing live trees

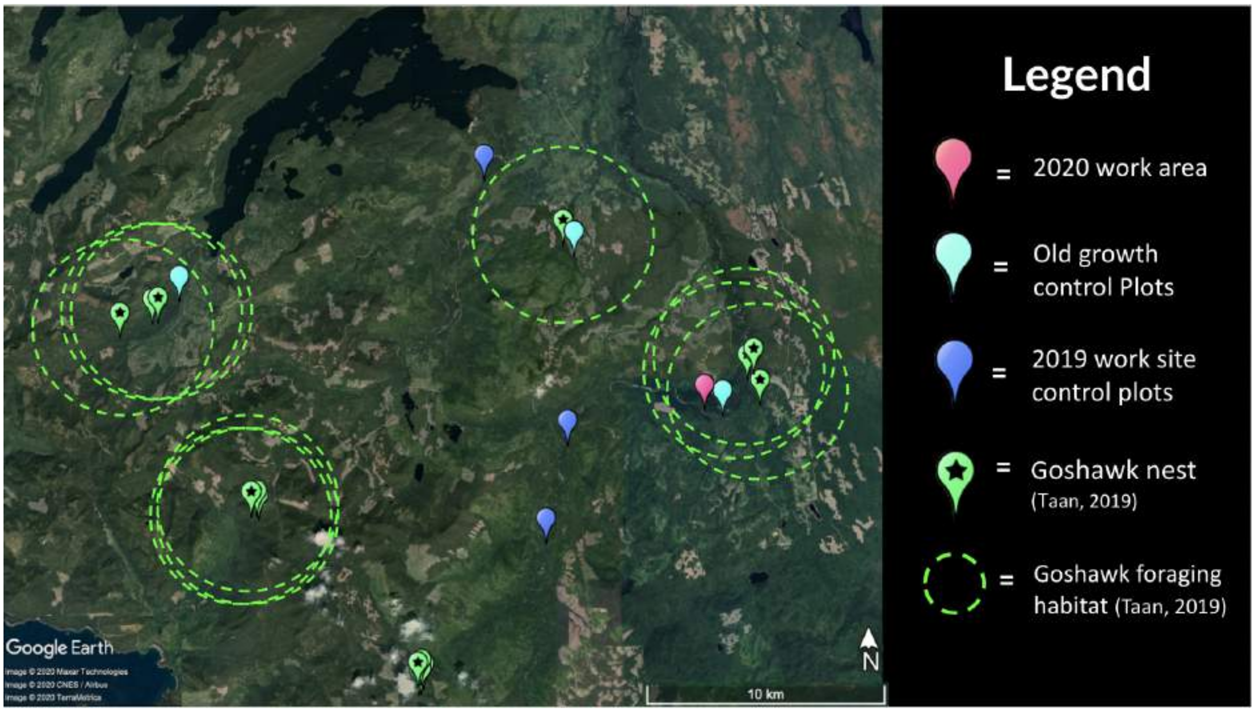

Figure 2 - South Graham Island, Haida Gwaii. Map centre: 53°31'8.00" N, 132°20'21.00"W (WGS84)

3.2 Work completed for UVic ER390 final project:

1. To measure the efficacy of silvicultural treatments in mimicking the conditions of the forest structure and prey resource availability that support existing goshawk forage territory

   i) To quantify the reference (control) conditions of stand density and prey availability in mature forest stands within goshawk foraging habitat

   ii) To quantify the conditions of stand density and prey availability in the 2020 and the 2019 treatment sites (Figure 2)

4.0 Methodology

4.1 Stand Management Prescription

The stand management prescription for the 2020 treatment area was finalized in December 2019. The work was approved by the council of the Haida Nation in January 2020 and work began in February 2020.

Table 1 - Current and Post Treatment Stand Conditions. Hw = western hemlock, Ss = Sitka spruce, Dr = red alder, Snag = dead standing tree. From 2020 SMP (Taan Forest).

CURRENT / POST TREATMENT STAND CONDITIONS											
Polygon	DBH Class	Hw		Ss		Dr		Total		Snag	
		Current Density (sph)	Target Density (sph)	Current Density (sph)	Target Density (sph)	Current Density (sph)	Target Density (sph)	Current Density (sph)	Target Density (sph)	Current Density (sph)	Target Density (sph)
YAKR01 – unit 1	**0 -10**	20	0	0	0	0	0	20	0	N/A	0
	10.1 – 20	28	0	28	0	75	0	130	0	N/A	65
	20.1 – 40	45	20	308	200	10	10	363	230	N/A	133
	40.1 - 60	0	0	328	250	5	5	333	255	N/A	78
	60>	0	0	60	60	0	0	60	60	0	0
	Total	**93**	**20**	**723**	**510**	**90**	**15**	**905**	**545**	**N/A**	**275**

Polygons A-E, represented by YAKR01 in Figure 1, total 70.6 hectares, and were surveyed by employees of Taan Forest in the fall of 2019 to determine stand density (current density in Table 1) prior to treatment. The target density of the treatment area was 545 stems per hectare (sph), and the target species composition was 94% Sitka spruce, 4% western hemlock and 2% red alder. Post treatment stand density (target density in Table 1) was surveyed by employees of Quillicum environmental in the spring of 2020 (see results).

The treatment prioritizes the retention of the largest diameter trees. No trees above 60cm in diameter, measured at breast height (dbh) were targeted for treatment regardless of species. Trees were retained in smaller diameter classes (0-10cm and 10.1- 20cm) if they were necessary to make up the target density of 545 sph. If larger trees were present, then only trees above 20cm dbh were retained, and trees below 20cm were either girdled (>15cm) or felled (<15cm), regardless of species type.

Girdling and cat-facing are chainsaw techniques to kill a tree without having to cut it down (more details in section 5.3). The prescription calls for cat-facing 20 sph of the approximate 340 sph of trees targeted for girdling (Taan, 2019). Girdled trees were only chosen within the 40.1 - 60cm dbh class. The prescription targets the retention of snags (dead standing trees) at a density of 275 sph. Snags include girdled trees, cat-faced trees or existing dead trees present on site not deemed safe by the falling crew.

Figure 3 - Polygon B, pre-treatment stand with a density of 905 sph (majority spruce and hemlock) Deteriorating western redcedar stump (foreground) shows size of previous old growth stand.

4.2 Project stages and timeline

This following section explains the methodology for the six stages of the project in sequential order: Layout, snag falling, operations, 2020 treatment area quality plots, old growth control plots and 2019 treatment area quality plots.

Table 2 - Restoration project timeline

Stage/Task	February	March	April	May
Stage 1/ Layout				
Stage 2/ Falling				
Stage 3 / Operations				
Stage 4/ Quality Plots				
Stage 5,6/ Control Plots				

4.3 Layout – Stage 1

Three employees from Quillicum Environmental completed the site preparation for the 2020 treatment area (70.6 hectares). The layout crew split up according to falling corners as outlined in the maps provided by Taan forestry and loaded into Avenza maps (example on Figure 4). The team flagged all treatment trees (Girdles, Cat-faces, wildlife trees, danger trees) and delineated work boundaries for tree falling (stage 2) and operations (stage 3). The layout team conducted regular plots of 5.64m radius (1/100th of a hectare) to double check their own work and their colleagues' work for quality assurance.

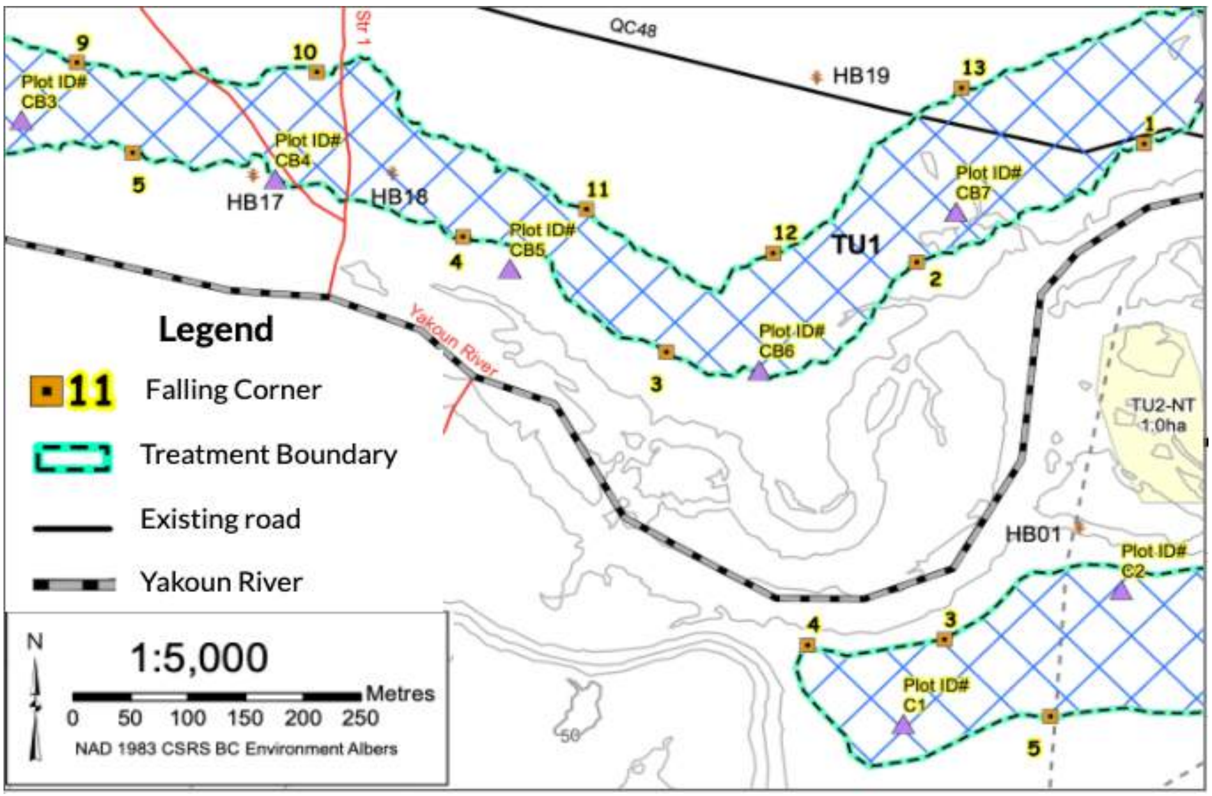

Figure 4 - Operational planning map, Taan Forestry Stand Management Prescription (2020). Sub-section view of polygon C (north side of Yakoun) and polygon B (south side of Yakoun River) treatment area.

4.4 Falling – Stage 2

Once the layout was underway, a crew of four professional fallers began cutting down dangerous trees that could potentially pose a risk to the crew in the operations stage. Danger trees included rotten trees susceptible to blow-down, leaning trees with unstable root systems and fallen trees that were suspended horizontally above the forest floor. Any dead trees flagged by the layout crew that were deemed safe and stable by the fallers were left standing as potential wildlife habitat.

4.5 Operations – Stage 3

Full crew operations began on March 9th, 2020 and included seven Haida from Old Masset and three supervisors from Quillicum Environmental services. Using chainsaws, the crew cut down any live trees less than 15cm dbh. Professional certification is needed to cut down any tree above 15cm dbh, and as a result, any species above 15cm dbh was either girdled or cat-faced.

To girdle trees, the crew used chainsaws to remove the bark and cambium layers around the entire circumference of selected trees at approximately waist height (Figure 5). Girdling removes the phloem, cambial and xylem tissue, which rapidly kills the tree and is a cost-effective technique for selectively thinning forests and plantations (Moore, 2013). Girdled trees remain as standing snags that may provide wildlife value for insects and birds, which in turn may provide prey for Goshawks (Taan, 2019).

Cat-facing is a technique in which a strip of bark and cambium is cut away from the tree in a 1m by 20cm vertical strip (Figure 5). This technique is designed to mimic a natural wind disturbance in which a falling tree strikes another tree and injures it by removing the bark and cambium and exposing the heart wood to disease. Cat-facing will trigger a stress response by the tree by which it will produce more cones, which may provide feed for migratory birds and squirrels and in turn provide feed for Goshawks within 1-3 years (Taan, 2019). Eventually, cat-facing will likely kill the tree, but it will persist much longer than a girdled tree, and after producing the desired cone stock, will remain as standing snag that may provide wildlife value (pers comm, Simmons, 2019).

Figure 5 - Cat-face (left) and Girdle (right) on Sitka spruce (Ss) trees identified for treatment

4.6 2020 Treatment area quality plots – Stage 4

A total of 83 quality plots were conducted in polygons A to E of the 2020 treatment area by myself and one of my co-workers. Quality plots were taken to quantify the post-treatment density of live trees and standing snags. The data was relayed to Taan Forest Products, the tenure license holder, to ensure the project was following the objectives of the stand management prescription.

The team followed the standard methods for the collection of forest inventory data as outlined in the BC field manual for describing terrestrial ecosystems (B.C. M.F.R., 2010). Quality plots were randomly identified on the smartphone application 'Avenza Maps' prior to entering the polygon. The assessor used a 5.64m length plot cord to measure plot circles that represented 1/100th of a hectare. The species composition and diameter at breast height was recorded for each tree in the plot. A tally of live and dead trees (girdled, cat-face, natural snag) was taken to determine post-treatment stand density (sph) as well as snag density (sph). In addition, I collected data on the presence or absence of squirrel feeding in 11 of the 83 plots, all of which were located in polygon E (Figure 1). The GPS location of each plot was recorded using the smartphone application 'maps.me'.

4.7 Old growth control plots – stage 5

With the help of Nick Reynolds of Sangan Environmental Services (pers comm, 2020), Ben Levesque of Taan Forest Products (pers comm, 2020) and Bart Simmons of Quillicum Environmental Services (pers comm, 2020), I was able to identify three different mature forest stands on Graham Island that would act as control sites for this study.

Each control site is located in old growth forest stands that are within the 5.2km foraging habitat radius (Taan, 2019) of documented goshawk nests (Figure 2). The sites were chosen to represent a reference control to evaluate the differences in forest structure and prey availability between the 2020 post-treatment work area and the mature forest stands within goshawk foraging territory.

I recruited one of my co-workers to help me collect data in 15 control plots (Datleman= 5, Yakoun= 6, Florence= 4) at three different locations in the spring of 2020. The GPS locations of each plot were recorded using the smartphone application ‘maps.me’. Table 3 shows the coordinates of the first plot taken at each location.

Table 3 – Location of control sites

Date of field visit	**Location**	**GPS coordinates** (WGS84)
05/10/2020	Yakoun River	53°30'9.04"N, 132° 08'54"W
05/27/2020	Datleman Creek	53°32'47.53"N, 132° 30'11"W
06/26/2020	Florence Creek	53°33'51.36"N, 132°14'43"W

At each control site, I used a 11.3m length plot cord to measure plot circles that represented 1/25th of a hectare. I used a longer plot cord in order to get a more accurate average density given the age structure and large diameter class of trees in old growth stands (pers comm, Simmons, 2020). Although the treatment area quality plots (stage 4) used a 5.64m plot cord, I am confident that given the relatively high number of quality plots (n=83) that we can safely make tree density comparisons across sites.

For each plot, I recorded the species and diameter at breast height of all living and dead standing trees. Next, I recorded the presence or absence of red-breasted sapsucker signs by examining all the trees in the plot for evidence of vertical grid-like bore holes (Figure 6) that are characteristic of sapsuckers (Davidson et al. 2015; BC, 1999). I also recorded the presence or absence of red-squirrel activity including cone shavings from feeding or potential dens around the trunks of trees (Figure 6). For both species, I recorded live sightings and audible animal calls in each plot.

Figure 6 – Sapsucker bore holes (left) and Sitka spruce cone shavings (right) from red squirrel feed site

4.8 2019 Treatment area quality plots – stage 6

As part of my project, I also collected data of the stand density and species composition in the 2019 work areas that were completed by Quillicum environmental services and the crew from Old Masset Village. I worked for Quillicum Environmental in the spring of 2019 and was well acquainted with the layout and location of each polygon (poly).

The 2019 work areas consisted of three different polygons (54, 38 and 42), totaling 27 hectares. The stand management prescription for 2019 targeted the retention of 500 stems per hectare (instead of 545 sph in 2020) but had the same principal objectives as the 2020 project (Quillicum, 2019). The thinning process was designed to reduce the stand density to create additional foraging territory for the Haida Gwaii Goshawk (Quillicum, 2019).

In the spring of 2020, I recruited the help of one of my co-workers to aid in recording data for a total of 16 plots (Poly 54 = 7 plots, Poly 42 = 3 plots, Poly 38 = 6 plots) across three different sites on Graham Island. Table 4 shows the coordinates of the first plot taken at each location.

Table 4 – Location of 2019 Treatment areas

Date of field visit	**Location**	**GPS coordinates** (WGS84)
05/10/2020	Polygon 54	53°35'38"N, 132°18'15"W
05/27/2020	Polygon 42	53°29'27 "N, 132°14'58"W
06/26/2020	Polygon 38	53°27'10.61"N, 132°15'48.72"W

In each polygon I used an 11.3m plot cord to measure plot circles that represented 1/25th of a hectare. As in my quality plots and old growth control plots, I recorded the species and diameter at breast height of all living and dead standing trees in each plot. Again, I used the same methods from stage 4 and 5 to detect the presence or absence of red-breasted sapsucker sign and red-squirrel sign, both of which are goshawk prey.

5.0 Results

5.1 2020 Treatment area

The operational stage of the project, with the crew from Old Masset village, was completed on May 29th, 2020. Our quality plots within the treatment area (n=83) indicated that after the completion of the project, we achieved a stem density of 531 stems per hectare, and a standing dead trees (snag) density of 255 stems per hectare. Five out of 11 (45%) plots in polygon E had evidence of red-squirrel sign in the form of cone shavings or dens, and all of the evidence was concentrated around larger diameter Sitka spruce trees. The standing snags recorded within the quality plots included girdled, cat-faced and wildlife trees left standing by the falling crew.

Table 5 – 2020 treatment results: stems per hectare

	Live trees (sph)	Standing snags (sph)	Tree species composition
Pre-treatment	905	N/A	80% spruce, 10% hemlock, 10% red alder
Target	545	275	94% spruce, 4% hemlock and 2% alder
Post-treatment result	**531**	**255**	97% spruce, 2% hemlock and 1% alder

The post-treatment species composition and the average diameter class (dbh) across 83 quality plots are indicated in Figure 7. The forest stand is approximately 30 years old and is dominated by Sitka spruce. There was no red cedar detected in the treatment area, and there was a minimal component of western hemlock and red alder.

Figure 7 – 2020 post-treatment diameter class and species composition

5.2 Old growth control plots

The old growth control plots are located on the south side of Graham Island (Table 3) and represent a reference condition for existing goshawk foraging territory. Live and dead tree densities are shown in Table 6, as well as the species composition at each site. The Datleman Creek is a low floodplain zone dominated by Sitka spruce, and most closely resembles the species composition of our 2020 treatment area. Out of a total of 15 control plots taken across three sites, 13 plots (87%) had evidence of red squirrel feeding activity and 9 plots (60%) showed evidence of sapsucker feeding. A total of 12 standing snags were detected across 15 plots. Three out of 15 snags were over 100cm dbh and one snag along the Datleman had a dbh of 254cm.

Table 6 – 2020 old growth control sites: stems per hectare

	Live trees (sph)	Standing snags (sph)	Tree species composition
Yakoun River	237.5	12.5	21% spruce, 41% hemlock, 34% alder, 4% cedar
Datleman Creek	205	25	78% spruce, 20% hemlock and

			2% alder
Florence Creek	319	25	15% spruce, 77% hemlock and 8% cedar
Average across sites	**254**	**21**	34% spruce, 48% hemlock, 13% alder, 5% cedar

The species composition and diameter class (dbh) across 15 plots is shown in Figure 8. The y-axis shows the relative percentage of species detected in the plots across three control sites. Western hemlock makes up the largest proportion of tree species followed by Sitka spruce. The majority of the red alder detected was below 50cm dbh and was concentrated in plots dominated by recent disturbance. Western redcedar, though only consisting of 5% of the trees detected in the control plots, made up a relatively significant proportion of the oldest and largest biomass trees (>70cm dbh).

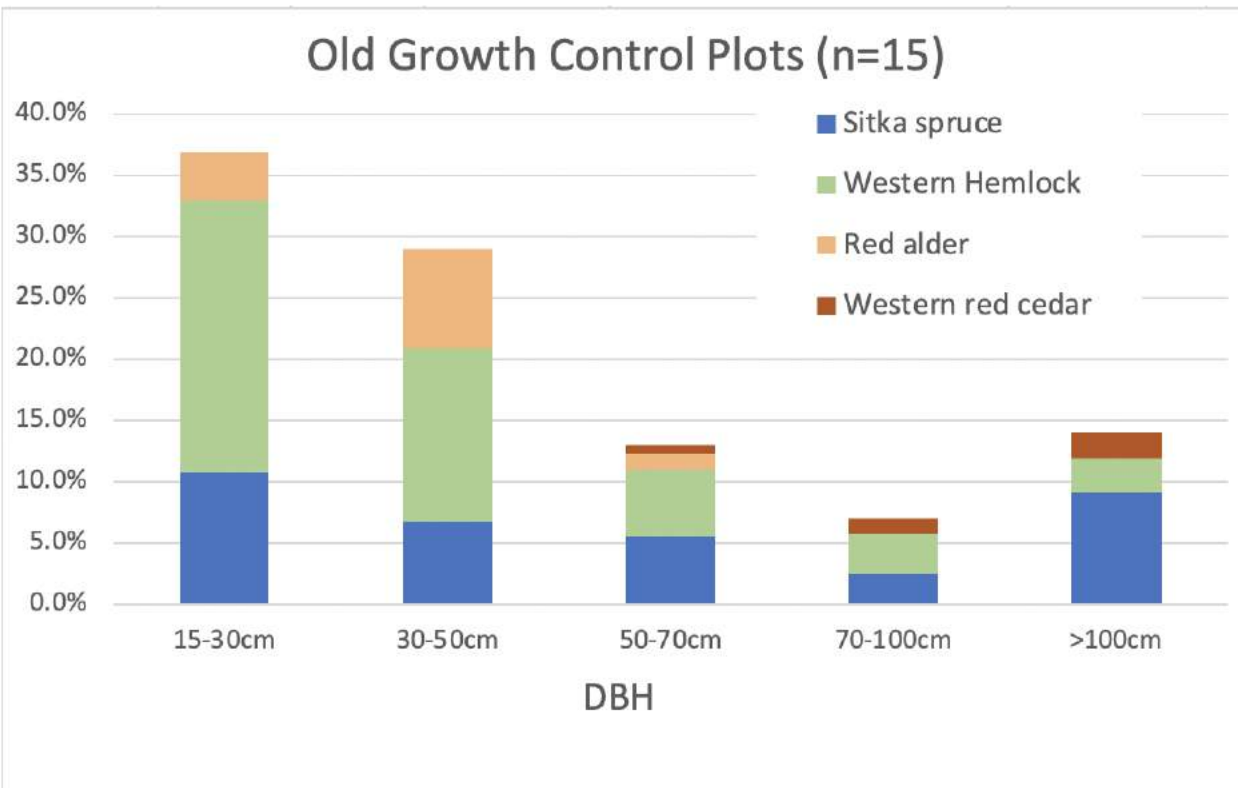

Figure 8 – Old growth control site: diameter class and species composition

5.3 2019 treatment area

Table 7 – 2019 treatment area quality plots: stems per hectare

	Live trees (sph)	Standing snags (sph)	Tree species composition
Polygon 38	458	333	56% spruce, 24% hemlock, 20% alder
Polygon 42	546	225	40% spruce, 59% hemlock, 1% alder
Polygon 54	496	114	25% spruce, 47% hemlock, 1 % alder, 28% cedar
Average across sites	**500**	**224**	40% spruce, 43% hemlock, 7% alder, 10% cedar

Results combining data across 16 plots within the 2019 treatment area (Table 7) indicate a live tree density of 500 sph and a standing snag density of 224 sph. The 2019 polygons had a higher proportion of smaller diameter trees (<15cm) than the 2020 polygons, and as a result, there were more trees cut down by the operations crew and less trees retained as standing snags in the form of girdles or cat-faces. This is particularly evident in polygon 54, with a standing snag density of 114 sph. Across the three polygons, 14 out of 16 plots (88%) had evidence of red-breasted sapsucker bore holes and 9 out of 16 plots (56%) had spruce cone shavings from red squirrel activity.

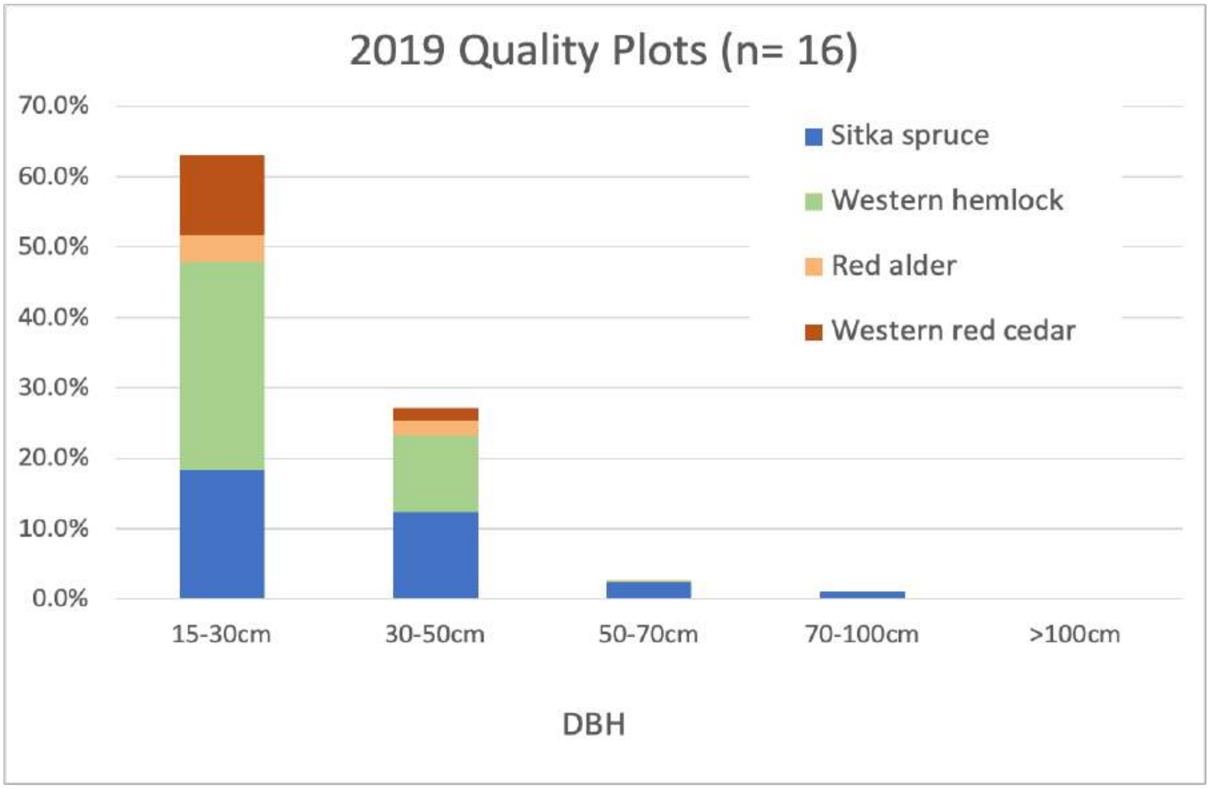

Figure 9 – 2019 treatment area quality plots: diameter class and species composition

As seen in Figure 9, the majority of trees in the 2019 polygons were below 50cm dbh even though the forest stands in polygon 42 and 38 are approximately 55 years old (Quillicum, 2019). Western hemlock is the dominant species across the three sites, followed by Sitka spruce. The majority of the redcedar was found in polygon 54, which had a pre-treatment density of approximately 4000 sph (Quillicum, 2019).

6.0 Discussion

The presence and availability of prey are key drivers in the viability of goshawk populations in coastal British Columbia (CFCI, 2012; Doyle, 2004; McClaren et al. 2015). In an effort to increase the availability of goshawk prey, the 2020 riparian restoration project led by Quillicum Environmental Services reduced the density of live trees in the treatment area from 905 sph to 531 sph. The majority of the trees were either girdled or cat-faced, which contributed to a post treatment snag density of 255 sph.

Though the density of live trees was reduced, the majority of treatment trees (girdles, cat-faces) still remained standing as dead trees. The result will be a delayed and incremental decrease in stand density as the standing snags fall to the forest floor over the next 5-10 years (Taan, 2019), or longer. The majority of the treatment area will not immediately become suitable goshawk foraging territory, as the raptors will likely still have difficulty flying freely through the stand where the majority of treated trees remain as obstacles for attacking and detecting prey. However, the treatment will serve to accelerate the natural thinning process, and, as the remaining live trees express their dominance, the forest will continue to develop characteristics typical of old growth forests, such as multilayered canopies and a stand density closer to 400-500 sph, the ideal forest structure for goshawk nesting and foraging (Doyle, 2004).

In the 2020 treatment area, snag falling and microsite specific treatment selections by the layout crew have created variability in the forest stand, which may accelerate the development of sub-canopy gaps and flyways suitable for goshawk foraging (McClaren et al. 2015). Dense concentrations of dangerous trees were cut down by the falling crew before the operations stage, which resulted in clearings in the canopy and areas with very low density throughout the treatment area. It is not possible to quantify the total change in density of live and dead trees before and after treatment as we do not have data on the density of pre-treatment snags. However, we do know there has been a net decrease in the number of standing stems within the treatment area. The quality plots indicate a live tree density of 531 sph and a snag density of 255 sph, though there is a considerable degree of variability in stand density throughout the treatment site depending on microsites and topography. The prescription took into account this variability by specifying that the target stem density could fluctuate from 500-650 sph depending on specific conditions. This gave the operations crew considerable discretion to retain high value trees (larger dbh or crown) in denser clusters immediately adjacent to forest clearings. Resulting pockets of open forest have created a mosaic of tree densities that more closely resemble the natural windfall disturbance regime on Haida Gwaii. Variable spacing treatments will help develop the stand from a homogenous plantation into a structurally complex forest that is more similar to goshawk foraging habitat in the naturally regenerating old growth control sites.

Goshawks also rely on variations in the vertical structure of the canopy for foraging (McClaren et al. 2015). The old growth control plots, taken within existing goshawk foraging territory, had a density of 254 stems per hectare consisting of trees in each diameter class. In contrast, the 2020 treatment areas had over 80% of trees concentrated in the 30-70cm dbh range, and the 2019 polygons had over 90% of the stand in the 15-50cm dbh range. The mix of tree height and age classes in the old growth control sites enables goshawks to utilize perches at different levels of the canopy depending on whether they are hunting for prey on the forest floor (eg. Grouse, red squirrel) or half-way up a tree (e.g., Songbirds, sapsuckers). In an effort to mimic the complex canopy structures of mature forests, the 2020 project prioritized the retention of trees across a range of diameter classes and species to allow for variability in the height and structure of the stand. In certain cases, for example, a western hemlock measuring 25cm dbh would be retained while a 50cm dbh Sitka spruce is girdled, or a Sitka spruce measuring 55 cm dbh may be selected for a cat-face while an adjacent spruce tree, though much smaller at only 24cm dbh, is retained.

While selectively thinning the forest stand had the objective of improving the accessibility of goshawk prey, the silvicultural methods used on the trees were intended to increase the abundance of prey. Cat-facing was introduced in 2020 as a method to increase cone development, providing more food for red squirrels, the principal prey of goshawks on Haida Gwaii. All of the cone shavings from squirrel feeding detected across the 2020 treatment area quality plots (n=83), old growth control plots (n=15) and 2019 quality plots (n=16) were from Sitka spruce cones. The majority of shavings were detected around larger diameter (>50cm dbh) Sitka spruce trees. Within the 2019 and 2020 quality plots, 56% and 45%, respectively, had evidence of squirrel activity. In contrast, 87% of the old growth plots had evidence of squirrel feeding. Red squirrels favored larger diameter spruce trees for feeding and denning and did not appear to utilize western red cedar or western hemlock as habitat. The 2020 prescription retained all of the largest diameter spruce trees (>70cm) to the benefit of red squirrel populations while simultaneously recruiting additional cone stocks through the selective cat-facing of mature spruce (50-70cm dbh). Red squirrels will continue to provide the majority of goshawk sustenance, as the depletion of the forest understory due to heavy deer browsing has led to the decline of blue grouse, the historically dominant goshawk prey (Doyle, 2003).

Trees were girdled to create high value snag habitat for cavity nesting birds (Quillicum, 2019) such as woodpeckers, passerines and red-breasted sapsuckers, which in turn could provide forage for goshawks. Whereas red-squirrel activity was more prevalent in the old growth sites, the 2019 treatment area quality plots had more evidence of red-breasted sapsucker activity than the old growth plots. For every 2019 plot where evidence of red-breasted sapsucker (88%) was recorded, at least 2 trees within each plot had sapsucker bore holes. Further, I recorded live sightings and audible sapsucker drumming in each of the 2019 work sites. Throughout the control plots and 2019 quality plots, western hemlock was the only species with small vertical boreholes indicative of sapsucker feeding. It is important to acknowledge that I did not take pre-treatment data for sapsucker or squirrel activity within the 2019 treatment area and I do not claim that the treatment created additional sapsucker habitat one year later. However, the consistent presence of sapsuckers in the 2019 work areas indicates that smaller diameter western hemlock trees (<50cm dbh) are providing foraging habitat for red-breasted sapsuckers. Increased sapsucker activity, combined with a more open and complex forest structure, may provide for the recruitment of additional goshawk foraging habitat.

However, as red-breasted sapsuckers are annual migrants to the Islands, they only provide food for goshawks in the summer months, and it is the availability of prey in the winter that remains the main bottleneck for goshawk survival on Haida Gwaii (Doyle, 2003). Red squirrels are the primary prey throughout the year (Doyle, 2003), and their presence in the 2020 and 2019 treatment area is a more important indicator for goshawk forage potential than sapsucker activity, as long as the forest structure allows goshawks to access their prey. The scarcity of prey in the winter and early spring may be leading to an increase in the mortality of adult and recently fledged goshawks due to chicken coop conflicts (Doyle, 2016). In the community of Tlell, on the east side of Graham Island, goshawks often become tangled in wire or fatally injured by chickens, and in some cases have been shot dead by local landowners (pers comm., Wotten, 2020).

For the birds to survive a multitude of threats, forest restoration treatments must be urgently prioritized to recruit new foraging territory for the Haida Gwaii goshawks (Doyle, 2016). Though it will not be immediately evident how effective our project will be in creating new foraging habitat, there is evidence that goshawks will preferentially forage in stands that are more accessible than forests where prey is abundant but less accessible (Beier & Drennan 1997; McClaren et al. 2015). It is clear that prey is present and active in the treatment areas, but the question remains whether or not the forest is accessible to goshawks. The 2020 project, located within a 30-year-old spruce leading floodplain site, has the highest potential to recruit new foraging habitat out of any forest type on Haida Gwaii (Doyle, 2004). The site is located within the foraging range of three goshawk nests, and the treatment prescription is well positioned to successfully improve the accessibility of the stand to goshawk foraging.

7.0 Recommendations and conclusion

The 2020 treatment prescription had the objective of improving the accessibility and abundance of goshawk prey. Given the prevalence of red-breasted sapsucker feeding on western hemlock trees in the 2019 treatment area, I recommend that future treatments retain western hemlock at a greater percentage than that of the 2020 prescription. As I only observed evidence of red squirrel feeding on Sitka spruce cones, I recommend that only spruce trees be cat-faced, and not western hemlock, in order to maximize the potential for additional cone production.

This study did not record data for the presence or absence of red-breasted sapsuckers in the 2020 treatment area, nor was data recorded for the presence of absence of red-squirrels or sapsuckers before the 2019 treatment. In the future, consistent and rigorous scientific monitoring can build on my initial field study to quantify long term changes in ecosystem function for goshawks in thinned second growth stands. I recommend that future restoration prescriptions monitor the relative change in prey abundance before and after thinning treatments. Field work monitoring should include wildlife tree/sign transects (BC, 1999) to determine the relative abundance of sapsuckers and woodpeckers as well as animal sign transect sampling to quantify the relative abundance of red squirrels (BC, 1998). The expectation of recruiting new goshawk foraging habitat within 5-10 years (Taan, 2019) must not be taken on faith alone. The urgency of goshawk conservation demands increased funding and operational capacity for scientifically informed restoration treatments.

Science-based results will help forest managers improve treatment prescriptions and inform decisions on which sites to select for future projects. Transparent and objective reporting of the project results should be communicated to stakeholders, funders and the general public, which may improve public understanding and long-term support for the project on Haida Gwaii. This project, which will continue in 2021, provides local employment for the Haida, and marks an important step in beginning to recover goshawk foraging habitat in the Yakoun watershed.

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