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An analysis of northern goshawk prey preferences by biogeoclimatic subzone across coastal British Columbia

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AN ANALYSIS OF NORTHERN GOSHAWK PREY PREFERENCES BY BIOGEOCLIMATIC SUBZONE ACROSS COASTAL BRITISH COLUMBIA

by

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ABSTRACT

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Keywords: dietary preferences, northern goshawk, prey abundance, pellets, prey remains, biogeoclimatic ecosystem classification, forest structure

This thesis investigates the dietary preferences of northern goshawk populations in second growth stands on Vancouver Island and the islands of the Johnstone Strait region on the BC Mainland Coast. Prey abundance was inferred through the analysis of pellets composed of regurgitated non-digested prey remains that were collected during the annual survey monitoring program carried out by Mosaic Forest Management and predecessor companies since 2012. The relative abundance of prey species was compared across three Coastal Western Hemlock subzones (CWHvm1, CWHmm1, CWHxm2) under the Biogeoclimatic Ecosystem Classification (BEC) system using the Chi-square test. No significant correlations were found between prey species abundance and BEC subzone ($\chi^2 = 2.3$, $P = 0.32$) in 2013 and ($\chi^2 = 0.84$, $P = 0.66$) in 2014. Trends within the dataset indicate coastal northern goshawks on Vancouver Island and the BC Mainland Coast show a general dietary propensity towards avian prey, which is consistent with findings from other studies. The variation in prey abundance and species diversity reported in this study is more likely a function of topography and forest structure, season and region than it is to BEC subzones. Findings from this study highlights how younger stands could be providing more suitable habitat than was traditionally thought.

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1.0 INTRODUCTION

The Northern Goshawk (*Accipiter gentilis*; hereafter "goshawk") is a circumboreal forest-dwelling raptor that has been a management concern for over twenty years in western North America. There are two subspecies of Northern Goshawks in British Columbia, *A. g. atricapillus*, and the coastal variant *A. g. laingi*. Goshawks require large areas of forest habitat in order to forage enough prey to survive and reproduce. A significant threat to populations of Northern Goshawks is fragmentation and loss of structurally suitable forest habitat. Due to habitat loss, small population size, and limited geographic range, the coastal *laingi* subspecies is listed as a *Threatened* species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2013), a *Schedule 1* species under the federal *Species at Risk Act* (Government of Canada 2013), a *Red-listed* species by the BC Conservation Data Centre (2013) and has an Identified Wildlife Management Strategy under the *Forest and Range Practice Act* (2004) and Schedule C under Private Foresters Land Management Regulation (2015).

This thesis will investigate the relationship between northern goshawks and the abundance of their prey based on biogeoclimatic ecosystem subzone classification. A better understanding of goshawk diet during the nesting season on Vancouver Island can provide insight on the importance of habitats used by goshawks (Lewis et al. 2006). Based on the literature review, below, I hypothesize that results from statistical analysis of goshawk pellets from Vancouver Island and the mainland coast will show a dietary propensity towards avian prey.

2.0 LITERATURE REVIEW

2.1 SPECIES DESCRIPTION

The Northern Goshawk is a raven-sized forest dwelling raptor found throughout temperate parts of North America and Eurasia. Due to human expansion and industrial resource extraction, goshawk nesting and foraging habitat has become increasingly fragmented. For this reason, policy regarding the management of northern goshawks has increased over the past two decades. Goshawks are a sexually dimorphic species: females are larger than the males (Karedes 2012).

2.11 Morphology

Goshawks are identifiable by their blueish tinted back, light gray breast, long barred tails, and a distinctive light grey stripe above their eyes (Mahon 2009). However, there are several morphologically differences between goshawk sub-species across North America. Coastal populations of goshawk are smaller in size and tend to display darker plumage compared to their interior counterpart, *A. g. atricapillus* McClaren et al. 2015). In addition to having short- rounded wings and long tail, the smaller size of the coastal *A. g. laingi* is thought to improve agility and aid with prey capture in dense coastal forests (Sonsthagen et al. 2012, McClaren et al. 2015). Goshawks employ a stop-and-go, short-stay, perched-hunting strategy and swiftly maneuver between trees under the forest canopy, as seen in Figure 1 (Kennedy 2003, Kenward 2006, McClaren et al. 2015). Juveniles can be identified by size and colouration within two years of hatching, and beyond three years old plumage characteristics cannot reliably be used to infer age (Bond and Stabler 1941, Flatten and McClaren 2003).

Figure 1: Soaring adult goshawk in second growth Douglas fir stand.
(Source: Hallworth 2020).

2.12 Sub-species Delineation

A. g. atricapillus is generally considered to be found east of the Coastal Mountain range (Mahon 2009). Relations between the continental *A. g. atricapillus* and the coastal *A. g. laingi* sub-species are described as panmictic as some gene flow has occurred between goshawk populations for millennia (Talbot et al. 2011, Sonsthagen et al. 2012, McClaren et al. 2015). However, distinguishing genetic characteristics are shared between goshawks in British Columbia and southeastern Alaska, leading to subtle differentiation from populations elsewhere in North America (Talbot et al. 2011, Sonsthagen et al. 2012, McClaren et al. 2015, Geraldes et al. 2018).

In Haida Gwaii, where the *laingi* subspecies was originally described, goshawks have genetic signatures that are unique to the island archipelago (Geraldes et al. 2018).

After many decades of speculation and morphological uncertainty, an intensive genomic sequencing study by Geraldes et al. (2018) confirmed that a distinct genetic cluster exists and is restricted to Haida Gwaii (Geraldes et al. 2018). Moreover, some individual goshawks on Vancouver Island share some genetic signatures of *A. g. laingi* and *A. g. atricapillus* (McClaren et al. 2015). However, there is a lack of analyzed samples from adjacent populations on British Columbia's Mainland Coast rendering the delineation unclear, and legislation has yet to change (Talbot et al. 2011, Sonsthagen et al. 2012, McClaren et al. 2015).

2.2 DISTRIBUTION

Goshawks are circumpolar raptors found in forested landscapes across Europe, Russia, and North America (Brown and Amadon 1989, Squires and Reynolds 1997, McClaren et al. 2015). They are a component of forests throughout Canada, with a range that spans from the Pacific North West to south-central Mexico, east to the Great Lake states and along the Appalachian Mountains. (Squires and Reynolds 1997).

2.21 Regional Distribution

The regional distribution of goshawk pairs is largely driven by prey availability (Doyle and Smith 1994, McClaren et al. 2015). On Vancouver Island, coastal goshawks build nests in forests that are dominated by western hemlock (*Tsuga* heterophylla) or Douglas-fir (*Pseudotsuga menziesii*), with components of western redcedar (*Thuja plicata*), amabilis fir (*Abies amabilis*) and red alder (*Aldus rubra*) (McClaren et al. 2015). The topography in this region is characterized by rugged mountains dissected by

many steep drainages (McClaren et al. 2015). On Vancouver Island, goshawk nests have been found between 150 and 850 m elevation (McClaren et al. 2015).

With regards to British Columbia's Biogeoclimatic Ecosystem Classification (BEC), the range of *A. g. laingi* exists within the Coastal Western Hemlock (CWH) zone and the Coastal Douglas-fir (CDF) zone, which is largely confined to the south eastern coast of Vancouver Island (COSEWIC 2013, McClaren et al. 2015). Several variants of the CWH biogeoclimatic zone (CWHds1, CWHds2, CWHms1, CWHms2, CWHws1, CWHws2) were identified by the Northern Goshawk Recovery Team (2008) to constitute a transitional zone with intermediate conditions between coast and interior (McClaren et al. 2015).

2.22 Landscape Level Distribution

Goshawks are notoriously aggressive towards intruders on their territory during the breeding season, and aerial displays are a common practice amongst male goshawks that wish to attract a female mate or ward off other males (McClaren et al. 2015). At the landscape level, territorial behaviour and breeding area defence results in a relatively even distribution of goshawk pairs in areas with sufficient foraging and breeding habitat (McClaren et al. 2015).

2.3 PREY TYPES

Goshawks have evolved a flexible hunting regime to overcome fluctuations in prey availability throughout the year (Lewis et al. 2006, Beier and Drennan 1997). Being opportunistic generalist, feeding patterns tend to diverge across their geographic range, leading some populations to exhibit local dietary specializations (Mahon 2009, Squires and Reynolds 1997). Many studies have investigated the goshawk diet along the west coast of North America from Southeast Alaska, British Columbia, western Washington and Europe. Throughout their range, goshawks generally feed on mid-sized prey, from small mammals and tree squirrels to passerines (thrushes and jays), woodpeckers, and grouse, as seen in Figure 2 (Watson et al. 1998, Ethier 1999, Bloxton 2002, Lewis et al. 2006, McClaren et al. 2015).

Figure 2: A Red-breasted sapsucker.
(Source: Hallworth 2020).

A study by Lewis et al. (2006) aimed to gain a better understanding of the goshawks' diet in Southeastern Alaska as a means of improving species management. To find discrepancies in the amount of birds and mammals being preyed upon, the researchers conducted their test based on three factors: years, habitat type and region (prey rich or prey poor). Lewis et al. (2006) collected regurgitated pellets from below and within the nest, plucking posts and other surrounding perches. Lab analysis of the egested pellets revealed undigested prey remains including, feathers, bills, feet and skeletal parts of birds, tails, fur, skin, and skeletal parts of mammals, that were divided into 31 distinct prey categories. Lab analysis of 753 whole or partial pellets, from northern and southern sample units, were all taxonomically identified by class, and 77% were assigned to a genus (Lewis et al. 2006). Dietary patterns in the prey-rich area showed a propensity towards hunting birds (75.1%) over small mammals (24.9%). Interestingly in the prey-poor areas birds accounted for 92.2% of the prey remains, with only 7.8% coming from mammals (Lewis et al. 2006).

Studies based on pellet data have suggested that a larger base of prey species may be available in British Columbia compared to Alaska (Lewis et al. 2006). Moreover, a contrast exists between the prey base of the two goshawks subspecies with the diets of coastal birds being far less dependent on small mammals (Watson et al. 1998, Ethier 1999, Andersen et al. 2003, Lewis et al. 2006, McClaren et al. 2015). Goshawks in coastal areas of Europe also preyed on birds as their primary source of food (Bloxton 2002, Lewis et al. 2006). Moreover, the Pacific Northwest is home to the

largest array of small mammals on the coast, yet goshawks in this region showed a greater propensity towards avian prey over mammals (Lewis et al. 2006).

In British Columbia's Interior Sub-Boreal Spruce zone, the snowshoe hares represent the bulk of the goshawk diet (Mahon 2009). This trend was observed in populations of boreal goshawks in southwestern Yukon and interior Alaska, which primarily relied on snowshoe hare (Doyle and Smith 1994, Lewis et al. 2006). In boreal regions of Europe, however, grouse are the main prey species (Lewis et al. 2006). It is believed that prey species which are resident throughout the year become especially important sources of food to overwintering goshawks in boreal Europe (Lewis et al. 2006).

Some prey species were consistent staples in the goshawk's diet, but the relative number of prey species showed significant variation between nests (Lewis et al. 2006). Red squirrels tend to be a focal prey item in areas where they occur but elsewhere goshawks will shift to alternate species (Lewis et al. 2006). Since there are no red squirrels or grouse, in Norway, goshawks primary feed on ptarmigan (Myrbergt 1989, Lewis et al. 2006). In northern Arizona, Beier and Drennan (1997) found only one goshawk home range where red squirrels are present. The opposite was reported in Alaska where red squirrels accounted for 73% of prey deliveries to one nest on a large alluvial spruce stand (Lewis et al. 2006). Further, it has been noted that red squirrels preferentially feed on spruce seeds and, thus, tend to be more abundant in Sitka spruce forests (Lewis et al. 2006).

Prey abundance highly correlated with breeding density of many raptors and is an important factor to goshawks searching for a home range within a larger landscape. Relative prey abundance is especially critical when selecting foraging sites within the home range (Newton 1991, Johnson 1980, Beier and Drennan 1997). However, it has been argued prey abundance is a less important factor than prey availability, which is a function of forest structure (Beier and Drennan 1997).

2.4 HABITAT PREFERENCES

The forest habitat characteristics surrounding the nest tree influences prey-availability, predation levels, competition rates, nest-area climate and reflects the quality of habitat (McClaren et al. 2002). The ideal stand structure for coastal goshawks consists of a closed canopy with an open understorey with lots of flyways and suitable nesting platforms (Iverson et al. 1996, Ethier 1999, McClaren 2005, Mahon 2009, McClaren et al. 2015). On high productivity sites, suitable forest structure may begin to occur in thinned stands after 45 to 60 years; however, these characteristics are best developed in mature stands later in succession (McClaren 2005, Mahon 2009, Toews and Wall 2012). Some believe that individuals in young fragmented forests will have a lower reproductive productivity compared to those breeding in contiguous older forests (McClaren et al. 2002).

2.41 Biogeoclimatic Subzone Ecosystem Classification

In coastal British Columbia, nearly 99% of known goshawk territories are found within the CWH biogeoclimatic zone and are well distributed in each subzone, except for the hyper-maritime zone which is composed of bog forests that offer little potential nesting habitat (Green and Klinka 1994, Mahon 2009, McClaren et al. 2015). Despite there being no known goshawk nests, the CFD zone is expected to offer comparable habitat to the CWH zone; however, few patches of forest exceed 50 hectares due to urban expansion and fragmentation (McClaren et al. 2015). One goshawk nest was located within the Mountain Hemlock (MH) zone (McClaren et al. 2015).

2.42 Breeding Areas

The breeding area is the primary ecological unit for all goshawk breeding activates and encompasses nest trees, nest sites, plucking posts, roosts, and post-fledging areas (McClaren et al. 2015). These areas are generally selected based on the structure of a forest stand, rather than species composition or stand age (McClaren et al. 2015). Once established, goshawks exhibit strong fidelity and will occupy the same breeding area for decades as long as conditions remain suitable (Bloxton 2002, McClaren 2005, Squires and Kennedy 2006, Titus et al. 2006, Doyle 2013, McClaren et al. 2015). The overwinter body condition of the female is a critical factor to breeding success, which is highly dependent upon the foraging quality of the breeding area habitat since the northern goshawk is resident year-round across most of its range (Squires and Reynolds 1997, Mahon 2009). The density of breeding areas varies regionally as a function of prey availability and forest productivity (McClaren et al. 2015). The average spacing

between breeding areas is 10.4 km on Haida Gwaii, and 6.9 km on Vancouver Island (Mitchell et al. 2008, McClaren et al. 2015).

Long-term occupancy of breeding areas not only depends on the persistence of favourable habitat characteristics but also on the availability of prey on large spatial scales (McClaren et al. 2015). In coastal forests, individual breeding areas are generally occupied by a goshawk pair once every two or three years (Bloxton 2002, McClaren 2005). Some long-term studies have reported annual occupancy for over 12 years; although the individual birds may have changed between some years (Titus et al. 2006, Doyle 2013, McClaren et al. 2015). Other long-term studies in Europe have shown several decades of re-occupancy of the same nest (Kenward 2006). As many as six years had passed between occupancy of breeding areas over 17 years of annual surveying on Vancouver Island (McClaren et al. 2015). The goshawk's home range is defined relative to the breeding season and spatially occurs beyond the breeding area. Within a home range, the area used to pursue and capture prey is called the foraging area (McClaren et al. 2015).

Post-fledging areas surround each nest tree, and are used by juveniles prior to dispersal (McClaren et al. 2015). This area provides a safe place for young goshawks to practice flying. The location of the post-fledging area may change each year depending on the active nest, surrounding topography and vegetation, direction of food deliveries and, the number of fledglings (McClaren et al. 2015). The entire breeding area is

defined as the combined space of multiple post-fledging areas that surround the nest trees of a given territory (McClaren et al. 2015).

2.43 Nesting

The nest area describes the unique microclimate habitat characteristics which surrounds the nest tree. This area varies in size depending on availability of suitable trees as well as the topography of the site (McClaren et al. 2015). Significant variation in forest type occurs across the geographic range of goshawks, yet certain structural features, such as large branch sizes, and forks and crooks capable of supporting large nests, are consistently used for nesting (McClaren et al. 2015). Goshawks have a strong propensity towards stands that have relatively closed canopies with sufficient flyway corridors (Penteriani 2002, Kenward 2006, Squires and Kennedy 2006, McClaren et al. 2015). These attributes occur in forests of various ages depending on site history, stand composition, silvicultural interventions and site productivity (Penteriani 2002, Kenward 2006, and Squires and Kennedy 2006, McClaren et al. 2015). As displayed in Figure 3, former logging roads and skid trails regrown with alder or conifers provide flyways and are often found adjacent to nests.

Figure 3: Goshawk nest in a red alder tree on road grade.
(Source: Hallworth 2020).

Large stick nests are built within the first half of the tree, just below the live whorls of the tree's canopy (McClaren et al. 2002). Within the stand, nests are typically situated in trees with larger diameters; although they do sometimes occur in smaller trees with deformities such as hemlock dwarf mistletoe or multiple leaders which act as sufficient nesting platforms (McClaren et al. 2015). On Vancouver Island, nests were an average of 92 cm across and 8 cm in cup depth (Doyle 2013). The active nest is fortified with sticks and greenery from softwood trees (Figure 4).

Figure 4: Active coastal goshawk nest on Vancouver Island.
(Source: Hallworth 2020).

Most goshawk territories contain multiple alternate nests in relatively close proximity, which are used in different years (McClaren et al. 2015). Alternating between nests year by year is important for minimizing exposure to disease and parasites in old nests, and strengthening the pair bond between adults by participating in nest building activities together (Squires and Reynolds 1997, McClaren et al. 2002). Goshawks are central-place foragers during the breeding season; this limits how far they can travel because they are responsible for returning to the nest to feed their young or mate (McClaren et al. 2015). On Vancouver Island, half of all alternate nests are within 200 m of another nest, and 90% are within 500 m; on average, goshawk nest trees are typically within 300 m of each other. (McClaren et al. 2002). Seldomly, a satellite nest will occur beyond one kilometer from other nests (McClaren et al. 2002.

2.5 AUTECOLOGY

Goshawks are described as socially monogamous, territorial, non-colonial, synchronously breeding raptors (Kennedy 2003, Kenward 2006). Coastal populations are classified as non-migratory; however, some years adults elect to relocate from breeding home ranges to non-breeding home ranges (Iverson et al. 1996, Bloxton 2002, McClaren 2005, McClaren et al. 2015). Additionally, individual male and female goshawks select their own unique home range, with varying degrees of overlap (Iverson et al. 1996, McClaren 2005).

Although one-year old females are capable of breeding, and occasionally do breed, most individual goshawks do not initiate breeding until at least two years of age (Squires and Reynolds 1997, Kenward 2006, McClaren et al. 2015). Breeding does take place on an annual basis along the coast, the average number of fledged goshawks from active nests was 1.6 ± 0.1 between 1994 and 2002 on Vancouver Island (n = 141; McClaren 2005); 1.6 ± 0.2 between 1995 and 2012 for Haida Gwaii (n = 49; Doyle 2013); and 2.1 between 1991 and 1998 in southeast Alaska (n = 87; Titus et al. 2006, McClaren et al. 2015). A study by McClaren et al. (2002) found that nest area had little impact on reproductive output of juveniles; rather, temporal changes in weather patterns and fluctuating populations of prey species was suggested to more drastically impact reproductive output (McClaren 2002). Figure 5 displays images of developing juvenile goshawks.

Figure 5: Development of juvenile goshawks.
(Source: Hallworth 2020).

2.51 Breeding Chronology

Sufficient levels of prey availability are required during the winter and early spring for the onset of goshawk breeding because female goshawks must accumulate a critical body mass prior to courtship and laying eggs (Newton 1991, McClaren et al. 2015). During the pre-egg-laying, incubation and early nesting periods, the females receive nearly all food from their mates (Iverson et al. 1996, McClaren et al. 2015). Eggs are laid during mid-to late April, which is followed by a 30 to 32-day incubation period (Iverson et al. 1996, McClaren 2005, McClaren et al. 2005, McClaren et al. 2015). The female lays a single clutch of 1-4 eggs per breeding season (Iverson et al. 1996, Squires and Reynolds 1997, McClaren et al. 2005, Doyle 2012, McClaren et al. 2015). The eggs hatch between mid-May and early June, and nestlings fledge after 38 to 42 days (McClaren et al. 2005, McClaren et al. 2015). The parent birds feed the fledglings for 35-55 days while the young begin to explore the adjacent post-fledging areas (Reynolds et al. 1992, McClaren et al. 2005, McClaren et al. 2015). The total elapsed time between laying eggs and dispersal of the young birds takes between 100 and 127 days (Kennedy and Ward 2003, Titus et al. 2006, McClaren et al. 2015).

2.52 Ecological Role

Goshawks are often considered to be umbrella species due to their large habitat requirements which accommodates the habitat of many species without explicit regulatory management guidelines. Ecologically, goshawks regulate prey populations and influence the spatial distribution of other forest raptors due to their territorial nature (Doyle and Smith 1994, Tornberg and Colpaert 2001, Kennedy 2003, McClaren et al. 2015). Furthermore, several other species use their stick nests, such as spotted owls (*Strix occidentalis*), common ravens (*Corvus corax*) and great blue herons (*Ardea herodias*) (Krüger 2002, McClaren et al. 2015).

2.6 STATUS

The northern goshawk was listed as a sensitive species by the U.S. Forest Service in 1982, which subsequently mandated eight hectare harvesting buffers around all nest stands in the southwestern United States (McClaren et al. 2015). To date, the continental subspecies (*A. g. atricapillus)* is not listed under any provincial or federal species-at-risk designations because populations are considered to be secure (McClaren et al. 2015).

In 1995, the coastal subspecies (*A. g. laingi*) was federally listed as a species of Special Concern and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2013) recognized this subspecies as a “designatable unit” (McClaren et al. 2015). Perceived threats from habitat loss, a small population of breeding adults, and a limited range coupled with ongoing timber extraction and decreasing rotation ages were

eventually realized, and the status of the coastal subspecies was upgraded to Threatened, red-listed federally, and provincially listed by the B.C. Conservation Data Centre (McClaren et al. 2015).

The recent genomic study by Geraldes et al. (2018) found a distinct genetic cluster that is unique to goshawks on Haida Gwaii, which raises concerns of extinction due to a declining population size. The goshawk populations on Haida Gwaii are also impacted by deer that were introduced to the island that have been over-browsing understory vegetation (Doyle 2003, McClaren et al. 2015). Despite this evidence, no policy delineations have been established for coastal British Columbia.

2.7 REGULATORY LEGISLATION

Goshawks are considered to be a focal species for sustainable forest management and were first designated as an Identified Wildlife Species in 1999, under the *Forest Practices Code of British Columbia Act*, and a set of management guidelines were developed to ensure the protection of the coastal and interior species (B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests 1999). This identification led to a heightened awareness, detection, and reporting of goshawk nests by forestry workers and researchers started conducting inventory studies (McClaren et al. 2015). Under the federal *Species at Risk Act*, the coastal subspecies is listed as a Schedule 1 (Government of Canada 2013). Provincially, the *Forest and Range Practices Act* (2004) enabled breeding areas to be protected as Wildlife Habitat Areas (McClaren et al. 2015).

Legal protection is enacted in provincial parks under the *Park Act* (McClaren et al. 2015).

The direct harm and harassment of individual goshawks is illegal under the *Wildlife Act*, which also protects their eggs from possession, molestation, or destruction when birds or eggs are in nests (McClaren et al. 2015). The *Wildlife Act* also declares it illegal to harvest coastal goshawks and their eggs or young form falconry possession (McClaren et al. 2015). Despite the legal framework, goshawk habitat is not explicitly protected under the *Wildlife Act* nor the *Park Act* (McClaren et al. 2015). The *Land Act* also offers protection through the establishment of spatial reserves (McClaren et al. 2015). Through interpretations of the *Wildlife Act,* the *Private Managed Forest Land Act* (2003) fosters engagement between landowners and government to facilitate the long-term protection of any identified critical wildlife habitat.

2.8 MANAGEMENT CONSIDERATIONS

Goshawk management was initially focused on nesting habitat, but has recently shifted to accommodate an abundance of prey species (Reynolds et al. 1992, Reynolds 1993, Lewis et al. 2006). Unfortunately, ideal foraging habitat often overlaps with high-volume and highly valuable forest stands (Beier and Drennan 1997). For this reason, concerns about the effects of forest management on goshawk populations has increased in the past two decades.

Due to the considerable time and effort involved, it can be financially prohibitive to conduct annual monitoring studies of goshawk populations. Furthermore, some breeding areas may go for several years without being occupied, even though these areas constitute an important landscape feature to regional populations (Titus et al. 2006, Manning et al. 2012, Doyle 2013, McClaren et al. 2015). Management strategies of goshawk breeding area must ensure that sufficient habitat is provided for the male and female birds during the breeding season (McClaren et al. 2015). The US Forest Service believes that the key elements for conserving goshawks and their biotic community are the links between prey species, prey habitats, and habitat management practices (Lewis et al. 2006).

The results of Lewis et al. (2006) indicate that northern goshawks in southeastern Alaska rely on few important prey species. Several of those species, including grouse and red squirrels, occur at reduced abundance in association with even-aged silvicultural practices which is common practice by the logging industry in this region (Lewis et al. 2006). Management for goshawks should focus on habitat conservation and accompanying prey base to ensure long term viability and sustainability in this region (Lewis et al. 2006). The impact of establishing breeding area reserves on the timber supply can be reduced by overlapping other legislated harvesting constrains such as, old growth management areas, ungulate winter ranges, wildlife habitat areas for other species at risk, land use planning objectives, parks and protected areas, wildlife tree patches, riparian reserves, inoperable forests, unstable terrain, and areas used to meet visual quality objectives (McClaren et al. 2015).

2.9 CULTURAL SIGNIFICANCE

Outside the breeding season, goshawks are quite cryptic, and are prized by bird watchers and wildlife photographers alike (McClaren et al 2015). Northern Goshawks hold cultural significance in the First Nations on Haida Gwaii, who use the term 'blue hawk' as part the name of the ruling family, or 'St'aawaas Xaaydagaay,' (McClaren et al. 2015). Furthermore, goshawks are revered by falconers for their impressive flight, hunting skills and aggressive nature (Squires and Reynolds 1997, McClaren et al. 2015).

3.0 MATERIALS AND METHODS

3.1 PELLET COLLECTION

Between May 5 and August 3, annual goshawk surveys were conducted on both newly discovered and previously known territories on Mosaic Forest Management's private land and Crown land timber licenses on Vancouver Island and the mainland coast of British Columbia. During the incubation and nestling phases of the breeding cycle, regurgitated castings (pellets) and prey remains (non-digested material) were collected from Northern Goshawk (*A.r g.s laingi*) nest territories. Territories were predominantly located in Douglas-fir (*P. menziesii*) dominated second growth forest stands. Goshawk pellets and prey remains found below the nest trees and plucking posts were collected at each nest-site, placed in uniquely labeled paper bags, and dried until analyses (Figure 6).

Figure 6: Goshawk pellet from below active nest.
(Source: Hallworth 2020).

3.2 LAB ANALYSIS

Pellets were examined under a dissection microscope using 20x and 40x power magnification, according to methods described by Marti (1987). Feathers and hair with distinct coloration and patterning were identified to the lowest possible taxon. Remains which lacked these distinct qualities could not reliably be identified and were recorded as an unknown prey species. For analysis, prey remains were sorted and grouped according to gross similarities. When possible, feather samples were identified using field guides and images from natural museum specimens on the internet, or from a feather and skeletal reference collection. Remains that could not be readily identified were compared to a reference collection developed from a previous visit to archived specimens at the Royal British Columbia Museum in Victoria.

3.3 SCOPE OF THESIS INVESTIGATION

Lab reports from 2012 to 2015, which detail the number of a particular prey species found at a particular goshawk territory were analysed statistically in conjunction with biogeoclimatic ecosystem classification subzone previously assigned to the territory. Out of 24 territories in which pellets were collected, only 13 had yields in successive years. Five of these territories are located in TFL 47 on the mainland coast, and the remaining eight are from private land on Vancouver Island. All territories occurred within the Coastal Western Hemlock BEC zone and between three subzones; CWHmm1, CWHxm2, CWHvm, as seen below in Table 1.

Table 1: Goshawk territory pellet yield inventory summary.

Goshawk Territory	Pellet Data Years	Region	BEC Subzone
Fleece Creek	2012-2013	Van. Isle.	CWHmm1
South Fork	2013-2014-2015	Van. Isle.	CWHxm2
Fourth Lake	2014-2015	Van. Isle.	CWHxm2
Upper Quinsam	2013-2014	Van. Isle.	CWHxm2
Woods Bay	2013-2014	Mainland	CWHxm2
Beaver Inlet	2013-2014	Mainland	CWHvm1
Hardwicke	2013-2014	Mainland	CWHvm1
Heydon Lake	2013-2014	Mainland	CWHvm1
Forward Harbour	2013-2014	Mainland	CWHvm1
Upper Harris	2013-2014	Van. Isle.	CWHmm1
Upper 19 Creek	2013-2014	Van. Isle.	CWHmm1
McKay Creek	2013-2014	Van. Isle.	CWHxm2
Woodhus	2013-2014	Van. Isle.	CWHxm2

3.4 STATISTICAL ANAYSIS OF PELLET REPORTS

3.41 Two-Tailed T-test

I used a T-test (Microsoft Excel) to compare what fraction of different prey species comprise goshawk diets on Vancouver Island and the Mainland Coast. Test results with a t-value ≥ 2 and a p-value ≤ 0.05 are considered statistically significant.

3.42 Chi-Square Test of Independence

I performed a chi-square using SPSS software to examine the hypothesis that goshawks on Vancouver Island have a preference to avian prey over small mammals. This test of independence requires a null hypothesis (H_O) and an alternative hypothesis (H_a) to be mutually exclusive so that if one is true, the other must be false. We reject the null hypothesis if the p-value is equal or less than 0.05, the chosen significant level value. The respective null and alternative hypotheses are as follows:

- Null Hypothesis (H_O): Goshawk prey selection is dependent on BEC subzone.
- Alternative Hypothesis (H_a): Goshawk prey selection is independent of BEC subzones.

To test this hypothesis, occurrences were tallied for 12 prey categories found within 258 pellets from 12 territories in 2013 and 2014. The chi-square test took into account the yields from four territories on British Columbia's mainland coast within the CHWvm1 subzone and one nest at Woods Bay, which occurs on the mainland within the CWHxm2 subzone. On Vancouver Island, there were four territories in the CWHxm2 subzone, and three territories in the CWHmm1 subzone.

The prey categories used in this test are derived from the annual pellet analysis lab reports. Mammalian prey include red squirrel (*Tamiasciurus hudsonicus*), Townsend vole[1] (*Microtus townsendii*), shrew spp.[1] (*Sorex spp.*), rodent spp[1]., and unidentified mammals[2]. Avian prey include Steller's Jay (*Cyanocitta stelleri*), Northern Flicker (*Colaptes auratus*), Varied Thrush (*Ixoreus naevius*), Band-tailed Pigeon (*Columba*

fasciata), Red-breasted Sapsucker (*Sphyrapicus ruber*), woodpecker spp. (*Picoides spp*.), grouse spp., duck spp., and unidentified birds[3]. A third category were; plant debris and seeds[4], insect remains[5], and snake spp.

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[1]: Non-squirrel mammals were identified based on size of skull and dentition.

[2]: Fur with non-distinct colouration or patterning not reliably identified.

[3]: Avian bones or feathers with non-distinct colouration or patterning not reliably identified.

[4]: Seeds present in castings are thought to have been food material ingested by prey species.

[5]: Insects likely represent secondary ingestion of gut contents from insectivorous avian prey.

4.0 RESULTS

A combined 621 identified prey remains from 12 territories, spanning three BEC subzones and two breeding seasons (365 in 2013 and 256 in 2014), were analyzed statistically on SPSS according to species abundance within the pellet castings using the Chi-square test. Comparing mammals and birds in the prey remains produced no significant differences by BEC subzone in 2013 ($\chi^2 = 2.3$, $P = 0.32$) and 2014 ($\chi^2 = 0.84$, $P = 0.66$). This study failed to reject the null hypothesis because no differences were found and, therefore, supports the alternative hypothesis. Both mammal and avian prey were most prevalent in the CWHxm2 subzone (Table 2).

Table 2: Comparison of mammalian and avian occurrences by subzone.

Year	2013			2014		
BEC Subzone	CWHvm1	CWHmm1	CWHxm2	CWHvm1	CWHmm1	CWHmm2
Mammal	7	31	39	25	22	30
Avian	43	119	124	59	42	78

Compilation and analysis of the data set revealed the most common prey species category as unidentified birds (192), followed by; insect remains (160), Northern Flicker (152), red squirrel (136), plant debris and seeds (109), Varied Thrush (72), Steller's jay (59), Band-tailed Pigeon (56), unidentified mammal (41), woodpecker spp. (16), Red-breasted Sapsucker (14), Townsend Vole (3), rodent spp. (1), and Grouse spp. (Figure 7).

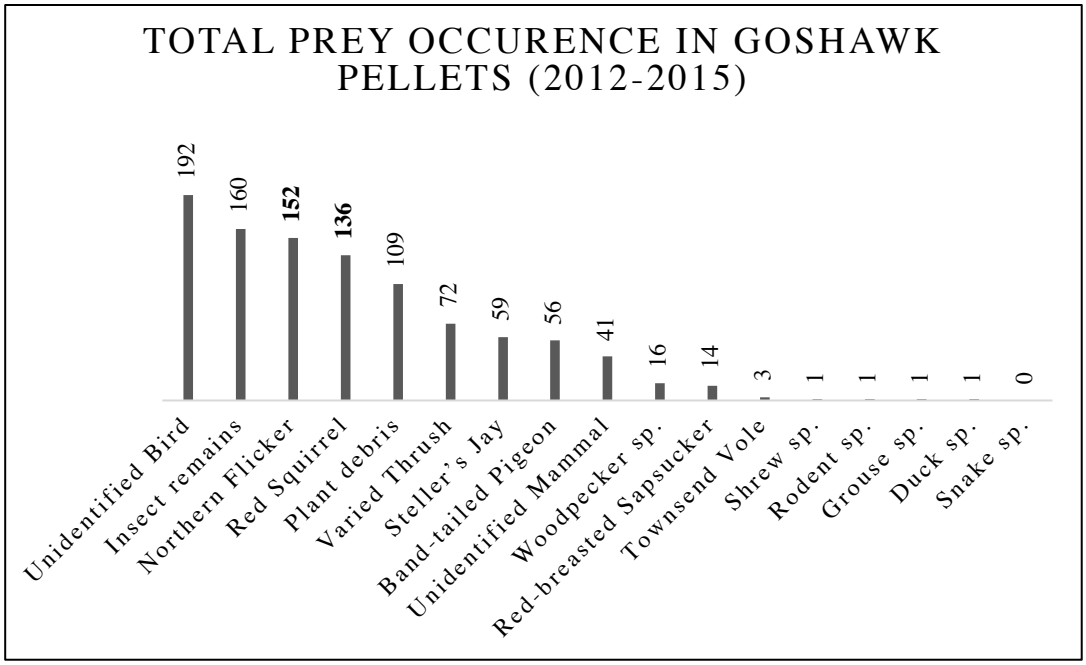

Figure 7: Tally of prey species occurrences between 2012 and 2015.

Within the pellet records, the northern flicker was the most prominent identified avian prey species and the red squirrel was the most abundantly identified mammal prey species. When averages were calculated for all years (2012-2015) regardless of BEC classification, the 708 prey species identified in pellets from territories on Vancouver Island demonstrated that avian prey represented 58% of occurrences and mammals represented 29%. Of 266 samples taken from the BC Mainland Coast, 50% of prey were avian and 21% were mammalian (Table 3).

Table 3: Relative abundance of mammalian and avian goshawk prey species.

Prey Type	Vancouver Island	BC Mainland Coast
Mammalian	58%	50%
Avian	29%	21%

T-tests investigating the respective fraction of the goshawk diet occupied by red squirrels and northern flickers proved to be statistically insignificant as the t-value was <2 and the p-value was >0.05 (Tables 4 and 5).

Table 4: Red squirrel fraction of goshawk diet T-test.

Region	Vancouver Island		BC Mainland Coast	
Year	2013		2014	
μ	0.09	0.27	0.06	0.09
t	0.58		0.31	
p	0.71		0.62	

Table 5: Northern flicker fraction of goshawk diet T-test.

Region	Vancouver Island		BC Mainland Coast	
Year	2013		2014	
μ	0.42	0.25	0.09	0.12
t	0.15		0.46	
p	0.56		0.67	

5.0 DISCUSSION

This assessment of northern goshawk dietary preferences may involve some inherent biases because the analysis in this study is based on identified prey from regurgitated pellets and may not be representative of smaller species which are not as readily identifiable. In the statistical model, the most populous prey category was unidentified birds, which may represent several species of songbirds unaccounted for in this study. Relying only on data derived from pellet castings is a slight limitation to this study; however, Kennedy (1991) concluded that "periodic samples of prey remains at nests adequately characterized diet composition of nesting goshawks," after comparing results between remains analysis, pellet analysis, and direct observation, to study dietary preferences of Cooper's Hawk and goshawks (USDI 1998). When compared to remains analysis, and direct observation techniques, pellet analysis proved successful in accurately ranking the prey taxa remains of golden eagles (USDI 1998). Due to the limited number of pellet samples and territories with consistent annual yields, statistically definitive preferences cannot be inferred from this study; however, the results do help to illustrate the importance of avian prey fraction of the goshawk diet on Coastal British Columbia. The findings that avian prey represent more than 50% of the diet of coastal goshawks on Vancouver Island and the BC Mainland Coast are consistent with the results from a study in Washington State in which Watson et al. (1998) found the faction of avian prey in the diet of coastal goshawks to be 53%.

There were no clear differences in Northern Goshawk prey selection preferences based on biogeoclimatic subzone classification (Figure 8); however, trends in this study

which indicate a dietary propensity towards avian prey is consistent with findings of several other studies (Watson et al. 1998, Ethier 1999, Lewis et al. 2006, McClaren et al. 2015, Bloxton 2002, Andersen et al. 2003). Furthermore, no statistically significant dietary discrepancies were observed between samples from Vancouver Island and the Mainland Coast, indicating relatively consistent prey patterns across the southern portion of the historic coastal goshawk range.

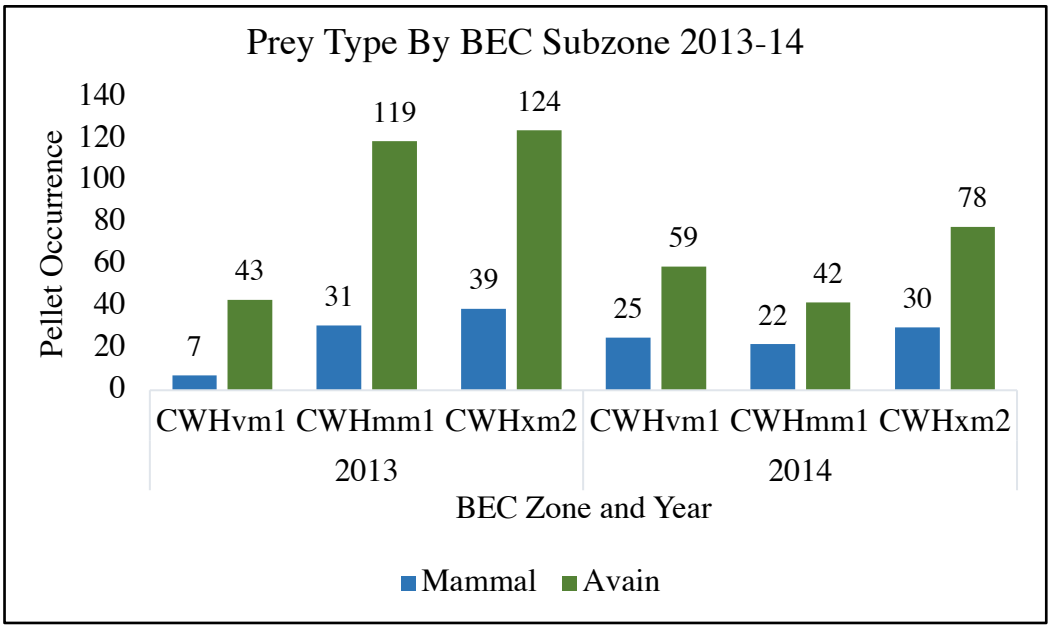

Figure 8: Comparison of mammalian and avian occurrences by subzone.

Although results from this study do not provide a definitive representation of the dietary preferences exhibited by coastal goshawks, it does highlight some discrepancies when compared to other studies. For instance, the northern flicker was the most abundant prey species in this study, with remains identified from each territory except Fleece Creek in 2012. The importance of the northern flicker as a goshawk prey item is

generally understated within scientific literature. For example, Beebe (1974) stated that goshawks on Vancouver Island predominately feed on the Steller's Jay and Varied Thrushes; however, these species were common constituents of most territories but were not the primary prey species across the region.

Moreover, Johnsgard (1990) suggested that grouse are generally the most important avian component of diets: accounts from falconers on Vancouver Island reported that grouse accounted for 95% of observed goshawk prey remains (SCBD 1994). Surprisingly, only one grouse was recorded in the dataset used in this study. This apparent lack of grouse may be a function of the cyclical nature of grouse populations or misdiagnosis as an unidentified bird during lab analysis. Insects and plant debris or seeds were present in pellet samples for every territory and would seem to constitute a staple of the goshawks diet. However, it is believed that these remains were a result of secondary ingestion of the gut contents of primary prey species.

Other studies using goshawk pellets found red squirrels to be the most important prey species, especially early in the breeding season (Cooper and Stevens 2006). In this study, red squirrel was determined to be the principle mammalian prey species, as only a minor component of rodents (shrews and voles) was observed in the pellets. The only two territories without red squirrel occurrences were Forward Harbor and Woods Bay, which are both on the Mainland Coast and classified under different biogeoclimatic subzones. Forward Harbor is classified as CWHvm1, and Woods Bay is the only territory found on the mainland coast within the CWHxm2. Both territories produced

samples containing red squirrel samples in subsequent years. Full descriptions of each BEC subzone variant can be found in Appendix VII.

6.0 CONCLUSION

In conclusion, coastal northern goshawks on Vancouver Island and the BC Mainland Coast show a general dietary propensity towards avian prey. The variation in prey abundance and species diversity reported in this study is more likely a function of topography and forest structure, season and region than it is statistically correlated to BEC subzones. This study also highlights that management using Goshawk Management Areas (GMAs), as employed by Mosaic Forest Management, is effective in providing the habitat required for goshawk breeding, nesting and foraging in second growth forests on landscapes primarily used for timber harvesting. Considering every territory sampled in this study was in a second growth stand, and increased populations across Vancouver Island were observed, it seems entirely possible that younger stands could be providing more suitable habitat than was traditionally thought. Small discoveries at the frontier of science help build the framework on which informed pragmatic and sustainable solutions can be implemented in society. In a world filled with malice and doubt, our best hope might just be another anecdote.

7.0 LITERATURE CITED

Andersen, D. E., S. Destefano, M. I. Goldstein, K. Titus, C. Crocker-Bedford, J. J. Keane, R. G. Anthony, and R. N. Rosenfield. 2003. The status of northern goshawks in the western United States. Wildlife Society Technical Review 04-1, Bethesda, Maryland, USA.

Beier. P., and J.E. Drennan. 1997. Forest Structure and Prey Abundance in Foraging Areas of Northern Goshawk. Ecological Applications 7(2): 564-571.

Bloxton, T.D., Jr. 2002. Prey abundance, space use, demography, and foraging habitat of Northern Goshawks in western Washington. MSc thesis. University of Washington, Seattle, Wash.

Bond, R.M., and R.M. Stabler. 1941. Second-year plumage of the goshawk. Auk 58:346 349.

Brown, L., and D. Amadon. 1989. Eagles, hawks and falcons of the world. Volume 2. McGraw Hill Book Company, New York, NY.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2013. COSEWIC assessment and status report on the Northern Goshawk *Accipiter gentilis laingi* in Canada. Ottawa, ON.www.sararegistry.gc.ca/virtual_sara/ files/cosewic/sr_autour_palombes_northern_goshawk_1213_e.pdf. Nov. 3, 2019.

Cooper, J.M., and V. Stevens. 2006. A Review of the Ecology, Management and Conservation of the Northern Goshawk in British Columbia. B.C. Minist. Environ., Lands and Parks, Wildl. Branch, Victoria, BC. Wild. Bull. No. B-1010. 33pp.

Doyle, F.I. 2013. Haida Gwaii Goshawks (*A. g. laingi*) 2013. [Unpublished report]. BC TimberSupply (BCTS), Husby Forest Products Ltd., Parks Canada, TAAN Forest LP.

Doyle, F.I., and J.M.N. Smith. 1994. Population responses of Northern Goshawks to the 10-year cycle in numbers of snowshoe hares. Studies in Avian Biology 16:122 129.

Ethier, T.J. 1999. Breeding ecology and habitat of Northern Goshawks (*Accipiter gentilis laingi*) on Vancouver Island: a hierarchical approach. MSc thesis, University of Victoria, B.C.

Flatten, C.J., and E.L. McClaren. 2003. Size and color variation of Northern Goshawks from southeast Alaska and Vancouver Island [Abstract]. In: Raptor Research Foundation, 2003 Annual Meeting - Northern Goshawk Symposium, Anchorage, AK.

Geraldes, A., K. K. Askelson, E. Nikelski, F. I. Doyle, W. L. Harrower, K. Winker, and D. E. Irwin. 2018. Population genomic analyses reveal a highly differentiated and endangered genetic cluster of northern goshawks (Accipiter gentilis laingi) in Haida Gwaii. Evolutionary Applications 1-16.

Green, R.N., and K. Klinka. 1994. A field guide to site identification and interpretation for the Vancouver Forest Region. B.C. Ministry of Forests, Victoria, B.C. Land Management Handbook No. 28. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/htm. Nov. 3, 2019.

Iverson, G. C., G. D. Hayward, K. Titus, E. DeGayner, R. E. Lowell, D. C. Crocker Bedford, P. F. Schempf, and J. Lindell. 1996. Conservation assessment for the northern goshawk in southeast Alaska. U.S. Forest Service, General Technical Report PNW-387, Portland, Oregon, USA.

Johnson, D. H. 1980. The comparison of usage and avail- ability measurements for evaluating resource preference. Ecology 61:65–71.

Karedes, A. 2012. Multi-scale analysis of northern goshawk (Acciptiter gentilis) breeding habitat in New Hampshire. Master's Theses and Capstone. scholars.unh.edu/thesis/756.

Kennedy, P.L., and J.M. Ward. 2003. Effects of experimental food supplementation on movements of juvenile Northern Goshawk (*Accipiter gentilis atricapillus*). Oecologia 134(2):284 291. http://link.springer.com/article/10.1007%2Fs00442 002-1108-0. Nov. 3, 2019.

Kenward, R.E. 2006. Death and demography. In: The goshawk. T. and A.D. Poyser Ltd., London, UK. pp. 217–251.

Krüger, O. 2002. Interactions between Common Buzzard *Buteo buteo* and goshawk *Accipiter gentilis*: trade-offs revealed by a field experiment. Oikos 96(3):441 452. doi.org/10.1034/j.1600-0706.2002.960306. Nov. 3, 2019.

Lewis, S. B., K. Titus, and M. R. Fuller. 2006. Northern Goshawk Diet During the Nesting Season in Southeast Alaska. The Journal of Wildlife Management, Vol. 70, pp. 1151 1160. https://www.jstor.org/stable/3803484. Nov. 2, 2019.

Mahon, T. 2009. Northern Goshawks in West-Central British Columbia. Bulkley Valley Centre for Natural Resources Research.

Marti, C. 1987. Raptor food habits studies. Raptor Management Techniques Manual. National Wildlife Federation, Washington, D.C.

McClaren, E., T. Mahon, F.I. Doyle and W.L. Harrower. 2015. Science-Based Guidelines for Managing Northern Goshawk Breeding Areas in Coastal British Columbia. Journal of Ecosystem Management 15(2):1-91.

McClaren, E., Kennedy, P. L., and Doyle, D. D. (2005). Northern Goshawk (Accipiter gentilis laingi) post-fledging areas on Vancouver Island, British Columbia. Journal of Raptor Research, 39(3): 253-263.

McClaren, E. (2011). Suggested protocol for conducting Northern Goshawk surveys within established and unknown goshawk nest areas. BC Ministry of Environment.

McClaren, E., P.L. Kennedy, and S.R. Dewey. 2002. Do Some Northern Goshawk Nests Areas Consistently Fledge More Young Than Others? The Condor 104(2): 343 352. www.jstor.org/stable/1370036.

Mitchell, A., V. Michelfelder, and R. van der Marel. 2008. Proposed wildlife habitat areas for the Northern Goshawk (*Accipiter gentilis laingi*) on the Central Coast of British Columbia. [Unpublished report]. B.C. Ministry of Environment, B.C.www.for.gov.bc.ca/tasb/slrp/lrmp/nanaimo/cencoast/ebmwg_ docs/e102a_NOGO_gener_release_report_CC.pdf. Nov. 2, 2019.

Newton, I. 1991. Population limitation in birds of prey: a comparative approach. Pages 3–21 *in* C. M. Perrins, J. D. Lebreton, and G. J. M. Hirons, editors. Bird population studies. Oxford University Press, Oxford, UK.

Newton, I. 1994. Experiments on the limitation of bird breeding densities: a review. Ibis 136:397–411.

Northern Goshawk *Accipiter gentilis laingi* Recovery Team. 2008. Recovery strategy for the Northern Goshawk, laingi subspecies (*Accipiter gentilis laingi*) in British Columbia. B.C. Ministry of Environment, Victoria, B.C.www.env.gov.bc.ca /wld/documents/recovery/rcvrystrat/northern_goshawk_rcvry_strat_200508.pdf. Nov. 3, 2019.

Penteriani, V. 2002. Long-term study of a goshawk breeding population on a Mediterranean mountain (Abruzzi Apennines, Central Italy): density, breeding performance and diet. Journal of Raptor Research 31:308–312.

Reynolds, R. T. 1993. Management of western coniferous forest habitat for nesting accipiter hawks. USDA Forest Service General Technical Report RM-102.

Reynolds, R. T., R. T. Graham, M. H. Reiser, R.L. Bassett, P. L. Kennedy, D. A. Boyce, G. Goodwin, R. Smith, and E. L. Fisher. 1992. Management recommendations for the Northern Goshawk in the southwestern United States. USDA Forest Service General Technical Report RM-217.

Sonsthagen, S.A., E.L. McClaren, F.I. Doyle, K. Titus, G.K. Sage, R.E. Wilson, J. Gust, and S.L. Talbot. 2012. Identification of metapopulation dynamics among Northern Goshawks ofthe Alexander Archipelago, Alaska, and coastal British Columbia. Conservation Genetics 13:1045 1057.link.springer.com/article/10.1007%2Fs10592012-0352-z. Nov. 3, 2019.

Squires, J.R., and P.L. Kennedy. 2006. Northern Goshawk ecology: an assessment of current knowledge and information needs for conservation and management. In: The Northern Goshawk: a technical assessment of its status, ecology and management. M.L. Morrison (ed.), Cooper Ornithological Society. Studies in Avian Biology 31:8–62.

Squires, J.R., and R.T. Reynolds. 1997. Northern Goshawk (*Accipiter gentilis*). In: Birds of North America, No. 298. A. Poole and F. Gill (editors).The Academy of Natural Sciences, Philadelphia, Penn. and Am. Ornithologists' Union, Washington, DC.

Talbot, S.L., S.A. Sonsthagen, and G.K. Sage. 2011. Genetic relationship among goshawks of British Columbia and Alaska. [Unpublished report]. U.S. Geological Survey, Alaska Science Center, Anchorage, AK.

Taverner, P.A. 1940. Variation in the American Goshawk. Condor 42:157–160.

The Southwest Center for Biological Diversity (SCBD), The Greater Gila Biodiversity Project, The Biodiversity Legal Foundation, The Greater Ecosystem Alliance. 1994. Petition to list the Queen Charlotte Goshawk *Accipiter Gentilis laingi* as a Federally Endangered Species. www.biologicaldiversity.org/species/birds/ Queen_Charlotte_goshawk/pdfs/qs_petition.pdf. Mar. 1, 2020.

Titus, K., S. Lewis, W. Smith, R. Fairbanks, R. Lowell, M. Goldstein, G. Pendleton, G. Fisher, and M. Cady. 2006. Conservation strategy review: an assessment of new information since 1997. Northern Goshawks on the Tongass National Forest: summary of study findings related to forest management. Interagency review of Tongass National Forest conservation strategy.

Tornberg, R., and A. Colpaert. 2001. Survival, ranging, habitat choice and diet of the Northern Goshawk *Accipiter gentilis* during winter in Northern Finland. Ibis 143(1):41–50. onlinelibrary.wiley.com /doi/10.1111/j.1474 919X.2001.tb04168.x/abstract. Nov. 3, 2019.

Toews, M., and W. Wall. 2012. Summary of Northern Goshawk territory monitoring 2012. [Unpublished report]. Prepared for TimberWest Ltd., Duncan, B.C.

[USDI] United States Department of the Interior. 1998. Endangered and threatened wildlife and plants: notice of 12-month finding on a petition to list the Northern Goshawk in the contiguous United States west of the 100th meridian. Federal Register 63. 35183-35184.

Watson, J.W., D.W. Hays, and S.P. Finn. 1998. Prey of breeding Northern Goshawks in Washington. Journal of Raptor Research 32:297–305.

Webster, J.D. 1988. Some bird specimens from Sitka, Alaska. Murrelet 69(2):46–48. http://www.jstor .org/stable/3535845. Nov. 3, 2019.

APPENDICES

APPENDIX I: VANCOUVER ISLAND PELLET DATA 2012

Region		Vancouver Island
BEC Subzone		CWHmm1
Territory		Fleece Creek
Nest		FLEECE1
Pellets		n=1
Class	Species	Count
Mammalian	Red Squirrel	
	Townsend Vole	
	Shrew sp.	
	Rodent sp.	
	Unidentified Mammal	1
Avian	Steller's Jay	1
	Northern Flicker	
	Varied Thrush	1
	Band-tailed Pigeon	1
	Red-breasted Sapsucker	
	Woodpecker sp.	
	Grouse sp.	
	Duck sp.	
	Unidentified Bird	1
Reptilian	Snake sp.	
Secondary Ingestion	Plant debris	
	Insect remains	1

APPENDIX II: VANCOUVER ISLAND PELLET DATA 2013

BEC Subzone		CWHxm2				CWHmm1		
Territory		South Fork	Quinsam	Woodhus	McKay Creek	Fleece Creek	Harris	Upper 19 Creek
Nest(s)		STH300-2	QU3	Woodhus7	MK1	FLEECE1	UPHAR1	UP19CRK
Pellets		n=9	n=9	n=9	n=11	n=33	n=18	n=5
Class	Species	Count						
Mammalian	Red Squirrel	6	6	6	2	23	2	3
	Townsend Vole					1		
	Shrew sp.							1
	Rodent sp.							1
	Unidentified Mammal							
Avian	Steller's Jay	1	1	2		6		2
	Northern Flicker	5	7	6	9	22	15	3
	Varied Thrush	4	7	6	2	19	6	3
	Band-tailed Pigeon			2	7	13	4	1
	Red-breasted Sapsucker	3			5			
	Woodpecker sp.				1	5	1	
	Grouse sp.							
	Duck sp.	1						
	Unidentified Bird	9	5	4	5	25	15	3
Reptilian	Snake sp.							
Secondary Ingestion	Plant debris							
	Insect remains	5	7	6	6	19	7	4

APPENDIX III: BC MAINLAND COAST PELLET DATA 2013

Region		BC Mainland Coast				
BEC Subzone		CWHvm1				CWHxm2
Territory		Beaver Inlet	Hardwicke Island	Heydon Lake	Forward Harbour	Woods Bay
Nest(s)		BL1	HARD4	HEYDLK1	FWDHARB1	WOOD2 and WOOD4
Pellets		n=3	n=4	n=3	n=2	n=21
Class	Species	Count				
Mammalian	Red Squirrel	3	2	2		19
	Townsend Vole					
	Shrew sp.					
	Rodent sp.					
	Unidentified Mammal					
Avian	Steller's Jay		1		1	2
	Northern Flicker	2	3	2	2	16
	Varied Thrush		2		1	3
	Band-tailed Pigeon			1		1
	Red-breasted Sapsucker	3	1			
	Woodpecker sp.					1
	Grouse sp.					
	Duck sp.					
	Unidentified Bird	2	3	2	1	15
Reptilian	Snake sp.					
Secondary Ingestion	Plant debris					
	Insect remains	1	3	2	1	11

APPENDIX IV: VANCOUVER ISLAND PELLET DATA 2014

BEC Subzone		CWHxm2					CWHmm1	
Territory		South Fork	Fourth Lake	Quinsam	Woodhus	McKay Creek	Harris	Upper 19 Creek
Nest(s)		STH300-3	4LK1	UPQUIN2	Woodhus8	MK2	UPHAR3	UP19CRK2
Pellets		n=8	n=10	n=5	n=5	n=10	n=10	n=5
Class	Species	Count						
Mammalian	Red Squirrel	7	8	3	3	5	4	2
	Townsend Vole				2			
	Shrew sp.							
	Rodent sp.							
	Unidentified Mammal	4		1		1	3	2
Avian	Steller's Jay	3	2	1	1	6	7	1
	Northern Flicker	3	4	1	4	4	3	1
	Varied Thrush	1	3	2	3	1		
	Band-tailed Pigeon	1	5			1	2	1
	Red-breasted Sapsucker							
	Woodpecker sp.		1			1		
	Grouse sp.							
	Duck sp.							
	Unidentified Bird	7	10	5	5	8	9	3
Reptilian	Snake sp.							
Secondary Ingestion	Plant debris	7	8	4	4	8	6	5
	Insect remains	4	7	3	5	6	6	3

APPENDIX V: BC MAINLAND COAST PELLET DATA 2014

BEC Subzone		CWHvm1				CWHxm2
Territory		Beaver Inlet	Hardwicke Island	Heydon Lake	Forward Harbour	Woods Bay
Nest(s)		BL1	HARD4	HEYDLK4	FWDHARB1 and FWDHARB2	WOODS4
Pellets		n=9	n=4	n=9	n=7	n=7
Class	Species	Count				
Mammalian	Red Squirrel	8	2	4	3	
	Townsend Vole					
	Shrew sp.					
	Rodent sp.					
	Unidentified Mammal	1	1	3	3	7
Avian	Steller's Jay		4	4	2	1
	Northern Flicker	4	1	3	3	5
	Varied Thrush	1	1		3	
	Band-tailed Pigeon	3			1	
	Red-breasted Sapsucker					
	Woodpecker sp.	3		2		
	Grouse sp.					
	Duck sp.					
	Unidentified Bird	8	3	7	6	4
Reptilian	Snake sp.					
Secondary Ingestion	Plant debris	8	4	8	6	5
	Insect remains	8	3	6	3	5

APPENDIX VI: VANCOUVER ISLAND PELLET DATA 2015

BEC Subzone		CWHmm1	CWHxm2			
Territory		Harris	South Fork	Fourth Lake	Quinsam	Woodhus
Nest(s)		HARRIS4	STH300-1	4LK1	QUINLK3	Woodhus8
Pellets		n=11	n=5	n=10	n=10	n=5
Class	Species	Count				
Mammalian	Red Squirrel	10		1	1	1
	Townsend Vole					
	Shrew sp.					
	Rodent sp.					
	Unidentified Mammal	4	1	2	5	2
Avian	Steller's Jay	3	3	3	1	
	Northern Flicker	7	1	8	4	4
	Varied Thrush			1		2
	Band-tailed Pigeon	2	3	2	5	
	Red-breasted Sapsucker				2	
	Woodpecker sp.		1			
	Grouse sp.				1	
	Duck sp.					
	Unidentified Bird	9	4	6	5	3
Reptilian	Snake sp.					
Secondary Ingestion	Plant debris	10	5	7	10	4
	Insect remains	6	3	8	7	4

APPENDIX VII: COASTAL WESTERN HEMLOCK SUBZONE DELINEATION

The Following information is derived from 'A Field Guide to Site Identification and Interpretation for the Vancouver Forest Region' by Green and Klinka (1994).

CWHvm1:

- Represents Sub-montane Very Wet Maritime Coastal Western Hemlock BEC subzone variant.
- Most extensive biogeoclimatic unit in the Vancouver Forest Region.
- Occurs on windward slopes between sea level (above CWHxm if present) and up to 600m elevation.
- Has a wet, humid climate with cool summers.
- Mild winters receiving relatively little snow.
- Growing seasons are long.
- Forest stands are dominated by Western hemlock Amabilis fir, which lesser component of Cedar.
- Well- developed shrub layer dominated by red huckleberry and Alaskan blueberry.
- Herbs are sparse, includes deer fern, five-leaved bramble, bunchberry, and queen's cup.
- Well-developed moss layer.

CWHmm1:

- Represents the Sub-montane Moist Maritime Coastal Western Hemlock BEC subzone variant**.**
- Mainly restricted to Vancouver Island.
- Occurs on leeward side of mountains, above the CWHxm subzone, between 450 and 700m elevation.
- Has a discontinuous distribution, often in the upper portions of valleys with eastern slopes.
- Climatic conditions intermediate between the CWHxm and the CWHvm subzones.
- Has moist, mild winters and cool but relatively dry summers.
- Zonal sites dominated by Western Hemlock, Amabilis fir and Douglas fir.
- Shrub layers include red huckleberry, Alaskan blueberry, with some salal and dull Oregon-grape.
- Historically, dry summers have occasionally resulted in stand-replacing wildfires, which have contributed to the abundance of Douglas fir in this variant.

CWHxm2:

- Represents the Very Dry Maritime Coastal Western Hemlock BEC variant.
- Occurs from sea level (or above the CDFmm where present) to approximately 700 m.
- On eastern Vancouver Island, along major inland valleys and on islands in the southern Johnstone Strait.
- Has warm, dry summers and moist, mild winters with relatively little snowfall.
- Growing seasons are long, and feature water deficits on zonal sites.
- Forests are dominated by Douglas fir and Western hemlock and minor amounts of Western Redcedar.
- Major understorey species include salal, dull Oregon-grape, red huckleberry.
- Less common species include vanilla-leaf, sword fern, twinflower, and bracken fern.
- Amabilis fir and Alaskan blueberry are rare in this zone.