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# 1 Introduction

Once valued primarily for high timber yields, temperate rainforests of the Pacific Northwest are now managed with increased emphasis on the conservation of biodiversity (Thomas et al. 2006). Among the drivers of this shift are declining populations of species whose life histories depend on old-growth forests. Some of these species have been placed under federal, provincial, or state protection: the marbled murrelet (*Brachyramphus marmoratus*) is protected under the Species at Risk Act in Canada (COSEWIC 2014), and the coastal population of the pacific marten (*Martes caurina*) is protected under the Endangered Species Act in the United States (US Fish & Wildlife Service 2020). Management under these types of legislation is typically reactive and focuses on conserving each imperiled species on a case-by-case basis (Simberloff 1998). This approach has been widely criticized for failing to provide management for broader ecosystems, including the very ecosystems on which the imperiled species depend (Lambeck 1997). Alternatively, focusing on the larger scales of landscapes or ecosystems should preserve the ecosystem processes and services on which wild species and humans alike depend (Franklin 1993). Yet ecosystem-based management is itself beset by numerous practical, theoretical, and even philosophical challenges which have made it difficult to implement (Lambeck 1997, Simberloff 1998).

Managers have often turned to surrogate species as a solution for the dilemma posed by the single-species and ecosystem-based management debate. At the core of the surrogate species concept is the belief that the requirements or wellbeing of a single species, or a small suite of species, can stand in for the needs and health of numerous co-occurring species or entire ecosystems (Caro 2010). A myriad variations and conflicting definitions are present in the literature, but the original may be the concept of the *indicator species*. The presence and population size of an indicator species is believed to reflect ecosystem processes or the populations of other species (Landres et al. 1988). Perhaps more widespread than indicator species is the *umbrella species* concept. Protections which benefit umbrella species–typically wide-ranging habitat specialists–are assumed to confer protection to co-occurring species with smaller ranges and less restrictive habitat requirements (Roberge & Angelstam 2004, Seddon & Leech 2008). A related concept is the *flagship species*, a species whose protection, like an umbrella species, confers benefit on other species, but which is selected for its charisma and ability to serve as a rallying point for conservation (Andelman & Fagan 2000). These concepts all attempt to extend the relative simplicity of single-species methods to achieve the promise of ecosystem-based management (Lambeck 1997).

No species better embodies the challenges of managing forest species and ecosystems in the Pacific Northwest than the Northern spotted owl (*Strix occidentalis caurina*). The spotted owl is strongly associated with old-growth forest (Forsman et al. 1984) and has at various points been proposed as an indicator (Lee 1985), an umbrella (Tracy & Brussard 1994), and a flagship species () for this ecosystem. In the late 1980s, public outcry and litigation in the United States led to the development of a spotted owl conservation strategy concurrent with the species’ listing as threatened under the Endangered Species Act (Thomas et al. 1990). This single-species plan rapidly expanded to include other species, particularly the marbled murrelet and several salmon stocks, and ultimately evolved into the Northwest Forest Plan. The Northwest Forest Plan remained rooted in spotted owl management, but also included protections for watersheds, monitoring of rare species, and a sustainable annual timber harvest (DeSala & Williams 2006). Not all the Northwest Forest Plan’s goals have been achieved–notably, spotted owl and marbled murrelet populations have continued to decline, although at a slower rate–and some parts of the plan have been eroded under subsequent presidential administrations (DeSalla et al. 2015). Yet the Northwest Forest Plan remains a powerful example of an ecosystem-scale management plan with a single species at its core.

The story of the northern goshawk (*Accipiter gentilis*) in North America parallels that of the spotted owl. Goshawks are present in boreal forests across the continent and in the west range as far south as the high-elevation forests of the American Southwest and northern Mexico. Two subspecies (*A. g. atricapillus* and *A. g. laingi*) are widely recognized and a third (*A. g. apache*) is recognized by some authors (Squires et al. 2020). Goshawks are not associated with old-growth forest to the same degree as the spotted owl, but do show a clear preference for extensive tracts of mature forest with large-diameter trees and closed canopies (Andersen et al. 2005, Squires & Kennedy 2006). Like the spotted owl, goshawks have been proposed as a flagship (Sergio et al. 2006), an indicator (), and an umbrella species (Ozaki et al. 2006). While the Northwest Forest Plan was developing in the Pacific Northwest, alarms were sounded over the impact of timber harvest on northern goshawks in the American Southwest (Crocker-Bedford 1990). Decades of litigation failed to result in listing the southwestern population (proposed subspecies *apache*) under the Endangered Species Act, but a new management plan was developed under the National Forest Management Act in the 1990s (reveiwed in Peck 2000). This single-species management plan disallowed timber harvest near known nests and required a minimum amount of mature forest within the larger home range surrounding known nests (Reynolds et al. 1992). Notably, the plan also specified the inclusion of younger forest, small clearings, snags, and woody debris to provide habitat for eight important goshawk prey species. This recommendation was based on the assumption that goshawks are habitat generalists limited by the abundance, not the availability, of prey–an assumption which has been the subject of heated debate (Greenwald et al. 2005, Reynolds et al. 2007). However, by incorporating multiple species, dynamic ecosystem processes, and human use, the goshawk management plan approaches the principles of ecosystem-based management and shows its potential to scale up to a more cohesive plan in the style of the Northwest Forest Plan (Graham et al. 1994, Peck et al. 2000).

In the Pacific Northwest, naturalists described a small, dark subspecies of goshawk unique to the coastal temperate rainforests of Haida Gwaii and Vancouver Island (Taverner 1940). The size and plumage characteristics of *A. g. laingi* may be an adaptation the dark, dense forests the subspecies inhabits (Ethier 1999) and the agile avian prey believed to dominate its diet (Penteriani et al. 2013, McClaren et al. 2015). The precise range of *laingi* is unclear; based on morphometrics, genetics, and ecosystem mapping, it is believed to extend along the west coast and islands of British Columbia, from Southeast Alaska south to Washington’s Olympic Peninsula (NGRT 2008, Sonsthagen 2012). In the portion of its range within the United States the *laingi* subspecies has no additional protections, but in Canada it is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The *laingi* subspecies is further Red-listed by the British Columbia Conservation Data Centre and is an Identified Wildlife Species under the Forest Practices Code (COSEWIC 2013). Existing management plans call for the creation of buffers around known goshawk nests and the maintenance of a minimum amount of mature forest within the larger home range (McClaren et al. 2015, Parks Canada Agency 2018), similar to the plan from the American Southwest, but do not include recommendations for goshawk prey species. To some extent this is due to the single-species focus of this plan, but it is also a result of several knowledge gaps. Goshawk managers have acknowledged that a landscape-scale plan would be superior to the current fine-scale plan, and ecosystem-based management has been implemented elsewhere in British Columbia, most notably the Great Bear Rainforest (Price et al 2009). Together these suggest an ecosystem-based approach incorporating the goshawk as a focal species may be possible for coastal rainforests elsewhere in British Colubmia. Yet while *laingi* nesting habitat is relatively well documented, foraging behavior and habitat of goshawks remains poorly understood across North America in general and coastal British Columbia in particular. These knowledge gaps hinder current single-species and potential ecosystem-based management alike.

My thesis attempts to fill one small knowledge gap by providing basic ecological information regarding the breeding season diet of goshawks in coastal British Columbia. This first chapter provides background on endangered species conservation in relation to forest management and establishes a rationale for my research. The second chapter describes my research quantifying goshawk diet in coastal British Columbia and investigating potential links between dietary variation and goshawk reproductive success. The final chapter summarizes my results in the context of Pacific Northwest forest management and suggests both implications for management and direction for further research.