Determining Critical Marine Foraging Habitats of the Threatened Marbled Murrelet (*Brachyramphus marmoratus*) in Pacific Rim National Park Reserve of Canada

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Introduction

The potential vulnerability of the marbled murrelet (*Brachyramphus marmoratus*) to habitat loss and subsequent population decline has recently raised concerns about the species' status. The marbled murrelet is particularly vulnerable to the loss of old-growth forest habitat which it uses for nesting. While many studies have examined the issues surrounding the potential impacts of old-growth reduction on murrelet nesting habitat, relatively little effort has been put into examining the species' use of marine habitats.

The marbled murrelet spends most of its life at sea and faces a growing number of marine-related impacts due to oil pollution, fisheries by-catch, and aquaculture. Also, the murrelet's breeding success depends heavily on its ability to provide its nestlings with high quality prey from the nearshore marine environment (Burkett 1995).

Although some research has documented the at-sea distribution of marbled murrelets in British Columbia (e.g., Carter 1984), our study will take the next important step by examining what constitutes critical marine foraging habitat for the species. To achieve this objective, we aim to (1) describe and map the temporal and spatial variability in the marine distribution of marbled murrelets in the Broken Group Island region of Pacific Rim National Park Reserve of Canada on the west coast of Vancouver Island, British Columbia, and (2) investigate the underlying relationship between marbled murrelet distribution and marine habitat features by collecting and analyzing data on at-sea distribution/abundance of marbled murrelets, oceanographic and nearshore habitat characteristics, and distribution/abundance of two critical forage fishes: the Pacific sand lance (*Ammodytes hexapterus*) and the Pacific herring (*Clupea pallasi*).

Data on prey distribution, abundance, and quality were collected during the summers of 2002 and 2003; data on the marine distribution of marbled murrelets was collected in 2003. During the

2004 field season, all prey sites sampled in 2003 will be revisited and resampled, and marbled murrelet transects established in 2003 will be resurveyed approximately three times monthly starting in mid-May. Additionally, oceanographic and environmental data were assembled from various sources. After the 2004 summer field season, analysis of all data collected for the project will begin.

Methods

Marbled Murrelet At-sea Distribution/Abundance Data

During the summer of 2003, we collected data on the marine distribution of marbled murrelets by sampling random transects in the nearshore region. The transects were approximately 9 km long and 300-m wide (150 m on each side of the boat), and sampling was conducted by two observers—the boat operator and the data recorder. Three separate transects were surveyed every two weeks from June until mid-August. Each transect was surveyed once in the morning and once in the evening. Morning surveys began at 0700 hours and were completed by 1200 hours; evening surveys began at 1700 hours and were completed before sundown. The following information was recorded for each marbled murrelet detected within the transects:

- distance from the boat based on one of three categories: 0–50 m, 50–100 m, 100–150 m
- compass bearing of the murrelet's location relative to the boat's position
- GPS coordinates of the boat

This information allowed us to plot the approximate spatial location of each marbled murrelet sighting in a Geographic Information System (GIS). This provides better resolution of the data and creates a format that is more suitable for conducting analyses with other spatial data (e.g., Fig. 1).

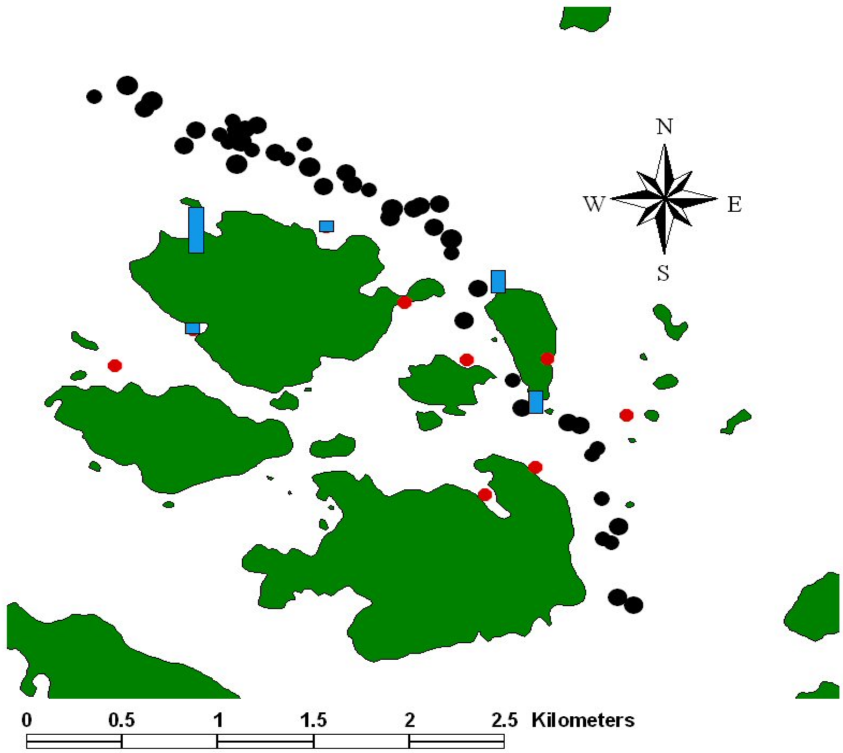

Figure 1. Example of marbled murrelet transect data plotted in conjunction with sand lance site data. Marbled murrelet sightings are represented by black circles. Sites where sand lance were detected are represented by blue bars indicating relative abundance. Sites where sand lance were not detected are represented by red circles.

In addition to the data collected in 2003, Parks Canada has conducted marbled murrelet surveys throughout the summer for the past 10 years. These surveys followed similar methods as those described above except that sightings were grouped into transect leg segments rather than being retained as single data points for each marbled murrelet sighting. Although this provided a different resolution than the 2003 data, the Parks Canada data will allow us to conduct a temporal analysis of marbled murrelet distribution in the study area.

Oceanographic and Environmental Data

Oceanographic and environmental data collected included sea surface temperature and salinity, substrate type, seabed rugosity, tidal velocity, bathymetry, stratification, and coastline exposure. Sea surface temperature and salinity data were collected at the beginning and end of each marbled murrelet survey transect. Sidescan sonar data were collected to examine subtidal benthic habitat properties. Single sidescan sonar survey lines were run using a 100 kHz, fully scale- and slant-range-corrected EdgeTech 260, and then were groundtruthed using an underwater drop video camera. A 100-m range (swath width = 200 m) was used for all surveys. A

Differential Global Positioning System (DGPS, model Garmin 53) interfaced with Fugawi software on a laptop computer was used for navigation.

Tidal velocity, bathymetry, stratification, and exposure were all modeled using GIS. Tidal velocity point data were generated using a finite element model as described in Foreman and Thomson (1997). These data represented a depth integrated average tidal velocity. Points were interpolated into a continuous surface using a Triangulated Irregular Network (TIN) interpolation technique in a GIS environment.

The Simpson and Hunter stratification parameter (Simpson and Hunter 1974) has commonly been used to calculate stratification parameters (e.g., Yuasa and Ueshima 1992; Glorioso and Simpson 1994). It is calculated using the formula

$$\text{Equation (1) } S = \text{Log } (H/U^3)$$

where H is the water depth and U is the amplitude of the tidal current. Stratification (Fig. 2) in the study area was derived from a tidal velocity and bathymetry (water depth) model for the region.

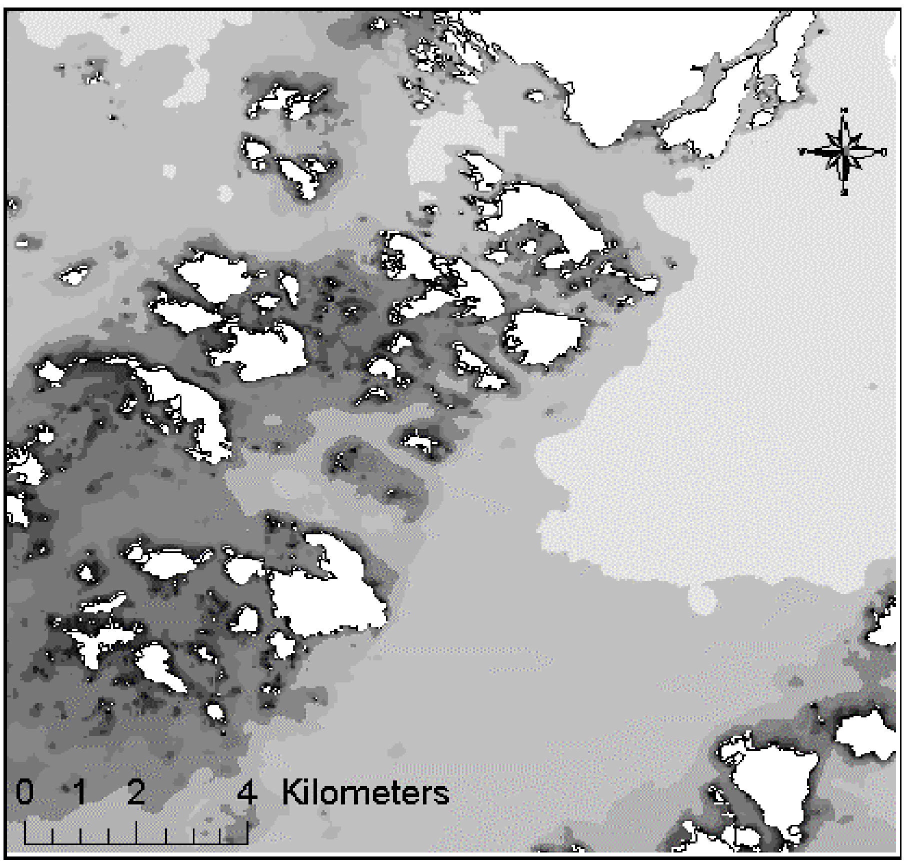

Figure 2. Example of a stratification layer produced using GIS. Dark grey shading denotes well mixed areas; increasingly lighter shading denotes more stratified areas. White areas indicate land masses.

Exposure to wind and wave action plays a major role in determining a coastline's physical characteristics (Ekebom et al. 2002), which in turn determine the characteristics of the ecological community associated with the coastline. Specifically, it has been demonstrated that temperate fishes can be influenced by wave exposure (Thorman 1986). Exposure can also influence habitat characteristics such as substrate type and macrovegetation communities (Keddy 1982, 1983). For this analysis, exposure was determined by first calculating direct fetch (F), then effective fetch (EF), and then a relative exposure index as described by Keddy (1982). Fetch can be defined in various ways. In this study, direct fetch was defined as the distance across water in one direction to the next shoreline, or as the cut off value. Adey (1978) estimated that waves were saturated at 50–100 km; therefore, a cut off value of 100 km was used for this study. Coastal shoreline features were converted into line segments within the GIS. For each coastal line segment, a point was generated in the centre (a centroid) for which fetch was to be calculated. Lines were radiated from each centroid point at every 11.5º starting at 0º. This produced 32 radiating lines, each 100 km long, for each point. These lines were then clipped by the landforms, which produced segments of various lengths that radiated from the original point (i.e., direct fetch values). Effective fetch was calculated by the vector addition of the direct fetch values within a bearing range (as described in Keddy 1982; Duarte and Kalff 1986):

$$F = \sum_{i=1}^{5} D_i \cos_i / 5$$

$$EF = \sum_{i=1}^{5} D_i \cos_i / 5$$

Prey Data

During the summers of 2002 and 2003, we collected data on prey distribution, abundance, and quality. In 2002, the main sampling technique used was beach seining at low tide. The goal of the 2002 sampling season was to investigate the general distribution of sand lance within Barkley Sound in order to gather baseline information that would be used to focus sampling efforts the following year. In 2003, we undertook a more intensive sampling program in order to determine if sand lance were absent from the sites sampled (since absence is more difficult to prove than presence). Various sampling techniques were used during the 2003 field season, including beach seining at various tide heights, intertidal digging, and visual surveys (Table 1). A total of 60 sites were sampled.

Table 1. Number and type of prey surveys conducted in 2003.

Survey type		*No. of surveys*
Beach seining	Low tide set	60
	Mid tide set	46
	High tide set	28
Intertidal digging		59
Visual	Boat surveys—parallel transects	52
	Boat surveys—perpendicular transects	53
	Walking surveys	52
	Snorkeling surveys	36

Beach Seining

To determine the general distribution of sand lance in the Broken Group Island region, beach seining was conducted at low, mid, and high tide. Two replicates were made at each tide height.

Intertidal Digging

Sand lance alternate between swimming pelagically and burying themselves in sediment (Robards et al. 1999). They also have the ability to stay buried in the intertidal sediment after the waterline recedes. To sample for buried sand lance, we conducted intertidal digging at approximately low tide. Using a 24.5 x 28.8 cm square-faced shovel, we dug five 1m x 1m holes just above the waterline. The holes were dug to a depth of > 8 cm, and were generally staggered about 5 m apart along the length of the shoreline. All sand lance excavated during digging were measured for mass and fork length as a means of calculating their condition, which may reflect prey quality.

Visual Surveys

Visual surveys of forage fish were conducted using boat, walking, and snorkeling surveys. All sand lance observed were recorded and school size was estimated when possible.

Boat surveys were conducted from a 5.5 m aluminum boat running at idle speed. An assistant steered the boat along the transects while an observer searched for prey fish using an underwater viewer that consisted of a plastic cone with handles and a glass bottom that was submerged in the water. Two transects per site were surveyed at low tide. One transect ran parallel to the shoreline along its entire length or until a navigation hazard was encountered. This transect was run at a depth of 3 m. The second transect ran perpendicular to the shoreline from the shallow subtidal area out to approximately 30 m or until a navigation hazard was encountered.

Walking surveys were conducted just before mid-tide (six hours after low tide). Wearing chest waders and using polarized glasses to reduce the glare on the water, the surveyor waded parallel to the shoreline in approximately 1 m of water, and scanned the water for sand lance. Transect length was governed by the length of the shoreline being sampled.

Snorkeling surveys were conducted around high tide when water clarity was generally best. The surveyor followed a transect that ran perpendicular from the shoreline for 20 m, then parallel to the shoreline for 20 m , and then perpendicular back to the shore for 20 m. Adjustments were made for navigation hazards, but an effort was made to achieve the standard snorkeling distance of 60 m (three 20-m legs). Because of safety issues, snorkeling could not be conducted at every sample site.

In addition, we compiled existing information on habitat use by other prey species (e.g., Pacific herring) in the region. Herring data for the Barkley Sound region were compiled from field sampling (using the same sampling techniques as for sand lance), from the Department of Fisheries and Oceans' historical data, and from Hourston (1956). All data sets were digitized and entered into a GIS for analysis.

Data Analysis

Examination of marbled murrelet distribution in relation to habitat variables (i.e., prey, oceanographic, and nearshore habitat data) will involve multivariate analysis of empirical data, and GIS-based habitat suitability modeling. The multivariate analyses will quantitatively examine marbled murrelet foraging habitats, and will provide insight into relationships between habitat and prey variables and marbled murrelet distribution. Resource selection function (RSF) and classification and regression tree (CART) analyses may be used for the data analysis. The GIS modeling will provide a spatially explicit method for identifying potential critical foraging areas. With this approach, continuous environmental features will be used to determine spatial patterns in marbled murrelet distribution.

Application

In order for the recovery of the marbled murrelet to be successful, the marine foraging component of the murrelet's habitat must be understood. This work will begin the process of defining features that constitute critical marine foraging habitat for the species. Ultimately, our study will help identify foraging areas that need to be protected, and will assist in the development of monitoring programs for the marbled murrelet and its prey base.

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