Long-term Radar Monitoring of Marbled Murrelets in the Nimpkish Valley, Vancouver Island: 2005 Progress Report

By

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1. EXECUTIVE SUMMARY

Radar surveys are becoming a standard method for estimating Marbled Murrelet (Brachyramphus marmoratus) populations and determining the importance of watersheds for murrelets along coastal British Columbia and the Pacific Northwest. Abundance indices derived from radar, due to their low among-day variability, can provide useful data for long-term population monitoring. Marine surveillance radar was used to inventory murrelet populations at both coastal and inland sites on northern Vancouver Island, British Columbia between June 7 and July 25, 2005. This project is part of a multi-level management program for Marbled Murrelets in Tree Farm Licence (TFL) 37 that includes reconnaissance and site-specific habitat assessments, dawn audio-visual surveys and long-term habitat conservation for marbled murrelets. The radar component of the project is designed to monitor long-term population trends at the landscape level as part of a program to evaluate the effectiveness of the nesting habitat conservation plan.

Two tilted-scanner marine surveillance radar units were used to collect data for murrelet population monitoring, a 10-kW Furuno FR-7111 and a 7-kW Furuno FR-805D. In 2005 we had a total of 628 radar detections of 687 targets (birds) from 22 morning surveys at 10 radar stations. Surveys were conducted at 9 of 10 radar stations twice, and most were surveyed on consecutive days to reduce seasonal variation in radar counts. The largest numbers of daily maximum counts were observed at coastal radar stations; RS09 – 70 birds and RS13 – 63 birds, but many inland sites also had relatively large daily maximum counts including, RS02 – 30 birds, RS03 – 59 birds, RS08 – 25 birds, and RS04 – 33 birds. On average, 9% of the detections were of "flocks" (i.e. single detections consisting of 2 and occasionally 3 separate targets or birds).

At RS09 a lower power 7-kW Furuno FR-805D with a tilted scanner was operated simultaneously with the higher power 10-kW tilted unit in order to examine differences in detection rates between scanners of different power. Over 2 survey mornings (363 min.) the lower power unit had 70 total detections compared to 112 for the higher power unit (60% more). The 7-kW unit was able to detect about the same number of multiple target “flocks” as the 10-kW unit, 19% versus 17%, respectively.

Consecutive-day variation in detections as measured by coefficient of variation (CVs) is important to calculate because it determines the power of any statistical tests to detect significant changes in the murrelet population. The addition of 5 pairs of consecutive-day data collected in 2005 had little effect on estimates of consecutive-day CVs. Coastal stations remained at 18% and inland stations increased from 31% to 27%. When only incoming detections were analysed, coastal station CVs averaged 28% and inland station CVs averaged 41%. There appears to be a substantial reduction in sampling variance by sampling individual radar stations on consecutive days rather than intervals longer than consecutive
days. As well, sampling at approximately same time each year should also help to control seasonal variance within sites.

Although equivalent boat survey data going back to 1999 is available for 3 coastal radar stations (RS09, RS21, and RS28), additional data are required to detect any statistically significant trend in detections. However, radar detections were much lower in 2005 compared to 2004, particularly at the coastal radar stations. Overall, maximum daily detections at the 10 radar stations were 68% lower in 2005 compared to 2004. No inference concerning population trends should be made from the first three years of data. This large decrease in Marbled Murrelets detections is similar to other south coast radar surveys in 2005 (D. Bertram, Marbled Murrelet Recovery Team Chair, pers. comm.), a phenomenon which did not occur among north coast radar surveys and that may be related to higher than normal sea temperatures. Subject to funding, long-term radar monitoring of Marbled Murrelet populations will be conducted at a minimum of 10 sites, at least every second year, on or adjacent to TFL 37 to determine the effectiveness of the Marbled Murrelet Nesting Habitat Conservation Plan.
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2. INTRODUCTION

2.1 Goals and Objectives
The goals for Marbled Murrelet conservation within TFL 37 are to:

1. Conserve important nesting habitats through establishment of Wildlife Habitat Areas under the Identified Wildlife Management Strategy of the Forest and Range Practices Act;
2. Monitor distribution and abundance Marbled Murrelet nesting habitat in the TFL; and
3. Monitor the long-term distribution and abundance Marbled Murrelets at the landscape level.

This project is designed to address overall goal number 3, through the use of marine surveillance radar to inventory populations of Marbled Murrelets that are moving within or towards TFL 37. The two objectives under goal number 3 are to:

1. Establish radar stations to monitor long-term population trends of Marbled Murrelets nesting in TFL 37; and
2. Provide data suitable for inclusion in larger scale monitoring of provincial populations.

These objectives are consistent with the Canadian Marbled Murrelet Conservation Assessment that recommends a multi-pronged approach that includes identifying and tracking nesting habitat and monitoring population numbers (Canadian Marbled Murrelet Recovery Team 2003). They are also consistent with monitoring plans to detect long-term declines in the number of Marbled Murrelets at regional and coast-wide scales in British Columbia (Arcese et al. in press).

2.2 Background
Marbled Murrelets (Brachyramphus marmoratus) in British Columbia nest almost exclusively in the trees of old forests along the coast. Populations are believed to be declining in some areas, and are apparently stable in others. The main threats to murrelet populations are loss of old forest nesting habitat due to timber harvesting, as well as impacts associated with oil spills and gill nets (McShane et al. 2004, Burger 2002a, Hull 1999, Nelson 1997, Beissinger 1995, Kaiser et al. 1994). Marbled Murrelets are considered at risk in the United States outside of Alaska (U.S. Endangered Species Act - Threatened), nationally (Committee on the Status of Endangered Wildlife in Canada: COSEWIC – Threatened, Hull 1999), and provincially (Ministry of Water, Land and Air Protection: MWLAP - Red-listed, Fraser et al. 1999).
Marbled Murrelets are a Threatened Schedule 1 species under the federal Species at Risk Act (SARA) (Environment Canada 2004) and also a Species At Risk Schedule 1 species under the Identified Wildlife Management Strategy and the provincial Forest and Range Practices Act (Province of British Columbia 2004).

Breeding habitat in British Columbia is generally in old-growth Sitka spruce (Picea sitchensis) and western hemlock (Tsuga heterophylla) forests, particularly moist stands with a well-developed epiphytic moss component (Burger 1995). Because adults do not build nests, they depend on large diameter tree limbs and natural platforms created by damage or disease, with a thick substrate of moss, needles or lichen, on which to lay their egg (Naslund et al. 1995, Nelson 1997).

Management of Marbled Murrelets is a high priority in TFL 37 and Canadian Forest Products Ltd (Canfor) has been implementing conservation initiatives for many years, initially through a sustainable forest management plan (SFMP) (Deal and Manning 2002), and more recently through a comprehensive conservation plan involving 23,789 ha of nesting habitat (Deal and Harper 2005). However, it is unclear what impact these conservation actions will have on the distribution and abundance of Marbled Murrelets within the TFL. A long-term population monitoring program is important to determine the effectiveness of management actions, and provide feedback to forest managers in order to support sound decision-making and make necessary adaptive management adjustments to the SFMP.

2.3 Summary of Existing Information

2.3.1 Habitat Inventory
Between 1999 and 2003 a total of 96 transects (1.0 ha) and 32 plots (0.2 ha) were established according to RISC (2001) standards in TFL 37 to estimate potential nesting platform densities. Thirty-three transects (1.0 ha) were established in 1999 and 2000 in the Lower Nimpkish Landscape Unit (Harper et al. 2001a) and 44 transects were established 2000 and 2001 in the Upper Nimpkish Landscape Unit (Harper et al. 2002). In 2002, habitat inventory
concentrated on areas in the vicinity of dawn audio-visual surveys (32 circular plots, 0.2 ha in size, Harper et al. 2003). In 2003, 19 transects (1.0 ha) were established primarily in the Upper Tsitika Landscape Unit. Most (67) of these transects and plots were in the CWHvm1 biogeoclimatic subzone variant, followed by CWHvm2 (22), MHmm1 (17), CWHmm1 (14) and CWHxm (8).

There was no difference in Marbled Murrelet nesting potential among different land use classifications in the Nimpkish Valley. For example, within the CWHvm1 variant of the Lower Nimpkish Landscape Unit, the timber harvesting landbase, ungulate winter range (as defined in 2000), and steep inoperable sites had platform densities that averaged 234, 234, and 178 large tree (>80 cm dbh) platforms per ha, respectively (Harper et al. 2001a). There were no statistically significant differences among these land use designations in terms of the density of large trees per ha, or potential platform densities in the Upper Nimpkish Landscape Unit (Harper et al. 2002). Generally, the better Marbled Murrelet nesting habitat was located at low to mid elevations in the CWHxm, CWHmm1 and CWHvm1 biogeoclimatic subzone variants. The tree species with the best nesting characteristics was amabilis fir. Amabilis fir had the highest number of potential platforms per tree and the highest epiphyte cover score (Harper et al. 2001a, Harper et al. 2001b, and Harper et al. 2000).

2.3.2 Habitat Mapping

2.3.2.1 Helicopter Reconnaissance

Helicopter reconnaissance mapping was conducted in the Englewood DFA in 2002 and 2003 (Deal and Smart 2004). Helicopter-based habitat assessments have also been compared to detailed ground measurement data collected in the study area (Harper et al. 2004b). Correlations between helicopter-rated nesting suitability and ground measurements in the TFL 37 study were higher than correlation values compared between ground measurements and a predictive habitat model developed for the same area (Table 1).

<table>
<thead>
<tr>
<th>Variables compared</th>
<th>Platform Density</th>
<th>Large tree (&gt;80 cm dbh) platform density</th>
<th>On the ground habitat suitability rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helicopter-assessment &amp; Ground measurements</td>
<td>( R^2 = 0.46^* )</td>
<td>( R^2 = 0.51^* )</td>
<td>( R^2 = 0.44^* )</td>
</tr>
<tr>
<td>Predictive habitat model &amp; Ground measurements</td>
<td>( R^2 = 0.29^* )</td>
<td>( R^2 = 0.28^* )</td>
<td>( R^2 = 0.30^* )</td>
</tr>
</tbody>
</table>

*An \( R^2 \) value of 1.0 indicates a perfect correlation between two variables, and 0.0 indicates no correlation.
2.3.2.2 Forest Cover Based Habitat Modeling
With the objective to develop a predictive model of potential Marbled Murrelet nesting habitats in TFL 37, maps were generated in 2001 to serve as a decision-support tool for timber management and Marbled Murrelet conservation. A 5-class system of very high, high, moderate, low and nil habitat potential was used to predict which forest polygons contained the structural elements required by Marbled Murrelets for successful nesting. The model is driven primarily by forest age and tree height, but is also modified by forest productivity and BEC subzone variant (Harper et al. 2001c). Correlations between modeled polygon ratings and ground measurements (Harper et al. 2004b, 2002, 2001) were $R^2 = 0.29$ for platform density, $R^2 = 0.28$ for large tree (>80 cm dbh) platform density, and $R^2 = 0.30$ for on the ground habitat ratings (Spearman Rank correlation coefficients; Harper et al. 2004b). Sources of error in the forest cover based habitat model include inaccuracy in tree heights estimated through airphoto interpretation and questions of scale (large polygons compared to small transects).

2.3.3 Dawn Audio-Visual Surveys
In May, June and July of 2001, a total of 46 dawn audio-visual surveys were conducted at 22 different stations in the vicinity of potential WHAs, mainly within the draft Lower Nimpkish Landscape Unit. Of the 373 total detections of Marbled Murrelets, 52 were occupied detections. In total, 10 of the 22 stations were considered “occupied” by breeding murrelets (Cooper et al. 2002).

Between June 2 and August 2, 2002, a total of 88 dawn audio-visual surveys were conducted at 22 different study sites associated with potential WHAs within the draft Upper Nimpkish and Tsitika Landscape Units. There were 803 total detections of Marbled Murrelets and of those, 91 were occupied detections. Twelve of the 19 study sites that were fully sampled were considered “occupied” by breeding murrelets according to RISC (2001) standards (Harper et al. 2003).

Fifty dawn audio-visual surveys were conducted throughout TFL 37 in 2003. There were 617 total detections of Marbled Murrelets and of those, 83 were occupied detections. Twelve of the 13 study sites that were fully sampled were considered “occupied” by breeding murrelets according to RISC (2001) standards (Harper et al. 2004a).

2.3.4 Radar Monitoring Surveys
Burger (2001) investigated the factors affecting the acquisition of radar data to estimate local populations, compare different geographic areas, and monitoring population changes over time. Among the goals of his study of was to determine the most appropriate protocol for using high-frequency marine surveillance radar to count Marbled Murrelets. Using a mobile 9410 MHz radar unit with a 2 m scanner, Burger (2001) found dawn counts gave higher and less-variable counts than dusk counts, and recommended a core sampling period of 15 May to 16
July. Weather had a significant effect on radar counts, with higher numbers counted on cloudy or drizzly/foggy days compared to clear days. The radar units were ineffective during heavy drizzle or rain.

For population monitoring using radar to be effective, radar stations should be located where:

a. Relatively large numbers of Marbled Murrelets are expected to fly by,

b. The birds present are relatively concentrated (e.g. narrow inlets, fjords, and valleys), and

c. A clear view across the expected flight path is available.

In November 2001, a total of 35 potential radar sites were assessed in and around TFL 37. Information regarding their potential as long-term population monitoring stations were collected on standardized data forms (Harper and Chytyk 2002). These sites were rated using a 6-level system (Nil, Low, Moderately Low, Moderate, Moderately High, or High) based on site characteristics including height of the potential station above valley bottom, distance to the other side of the valley, field-of-view, and position of vertical obstacles to radar signals. With the goal of establishing a long-term, watershed-level population-monitoring program for Marbled Murrelets, 10 preliminary radar sites were identified based on the non-radar data (visual inspection) and an analysis of topographic maps to predict likely flight paths and areas of bird concentration (Harper and Chytyk 2002).

In 2002, a total of 25 morning surveys and 23 evening surveys were conducted using a 5-kW untilted radar unit at 19 different radar stations (RSs) from late May to late July 2002 (Harper and Chytyk 2003). Sixteen of the 19 radar stations were located within TFL 37 and three were located outside the TFL. The average detection rate of morning surveys was 0.26 per minute, about 6 times higher than the 0.04 detections per minute that was averaged in evening surveys. Overall there were 1148 detections during morning surveys and 92 detections during evening surveys. Only 10 of 19 sites surveyed had ≥10 in 2002. Concurrent audio-visual surveys at radar sites detected 7% of the number of radar observations, but this varied greatly among sites.

In 2003, long-term population monitoring data were collected from 32 effective morning surveys at 19 radar stations using a tilted radar scanner from May 11 to July 19, 2003 (Harper and Schroeder 2004, Harper et al. 2004c, 2004d). Effective surveys are those in which any precipitation that may have occurred did not result in a significantly reduced ability to detect murrelets due to clutter on the radar monitor. The largest numbers of detections were observed on Tahsish Inlet at the Artlsh River Mouth (RS09 – 894 birds) and Tahsish-Kwois Park (RS23 – 448 birds). Other coastal sites also had large daily maximum target counts of
murrelets including, RS28 Tahsish Gov’t Dock with 280 birds, RS21 Zeballos Inlet with 111 birds, and RS13 Nimpkish River Mouth with 82 murrelet birds (Harper and Schroeder 2004).

In 2004, long-term population monitoring data were collected from 30 morning surveys at 15 radar stations (Harper et al. 2005). The largest numbers of daily maximum counts were observed at coastal radar stations; RS09 – 1201 birds, RS30 – 570 birds, RS28 – 454 birds, RS13 – 390 birds, RS21 – 344 birds, RS29 – 204 birds, and RS19 – 159 birds. For the most part, inland radar stations had fewer radar detections than coastal stations, but many inland sites also had large daily maximum counts including, RS02 – 85 birds, RS03 – 93 birds, RS25 – 147 birds, RS24 – 88 birds, RS08 – 85 birds, and RS04 – 81 birds. At coastal radar stations, detections were generally higher in 2004 compared to 2003, while at interior radar stations detections were generally lower in 2004.

3. STUDY AREA

The study area is centred in Canadian Forest Products Ltd. (Canfor) Tree Farm Licence (TFL) 37, which includes entire draft Lower Nimpkish and Upper Nimpkish Landscape Units, as well as a portion of the draft Tsitika Landscape Unit. TFL 37 is located immediately south of Port McNeill on Vancouver Island, and encompasses Nimpkish Lake, the Nimpkish River, Woss Lake, Vernon Lake, and the upper reaches of the Tsitika River (Figures 1 & 2).

Figure 1. Location of TFL 37 on Vancouver Island, British Columbia.

The study area is located within the West and North Vancouver Island Marbled Murrelet Conservation Region (Canadian Marbled Murrelet Recovery Team 2003). Administratively, TFL 37 is located within the Port McNeill Forest District (BC Ministry of Forests) and the Vancouver Island Region of the BC Ministry of Water, Land and Air Protection.

Administratively, the study area is located within the Port McNeill Forest District (BC Ministry of Forests), the Vancouver Island Region (BC Ministry of Water, Land and Air Protection), and the Pacific and Yukon Region (Environment Canada).
Ecoregion Classification
TFL 37 is located in the Northern Island Mountains (NIM) ecosection (Demarchi 1995) as follows:

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecoprovince</td>
<td>Coast and Mountains</td>
<td>CAM</td>
</tr>
<tr>
<td>Ecoregion</td>
<td>Western Vancouver Island</td>
<td>WVI</td>
</tr>
<tr>
<td>Ecosection</td>
<td>Northern Island Mountains</td>
<td>NIM</td>
</tr>
</tbody>
</table>

Biogeoclimatic Ecosystem Classification (BEC)
TFL 37 contains three biogeoclimatic zones, Coastal Western Hemlock, Mountain Hemlock, and Alpine Tundra (Green and Klinka 1994) as follows:

**Biogeoclimatic Zone:**
Coastal Western Hemlock - CWH
Subzone: Very Dry Maritime - CWHxm
Subzone: *Submontane* Moist Maritime - CWHmm1
Subzone: *Submontane* Very Wet Maritime - CWHvm1
Subzone: *Montane* Very Wet Maritime - CWHvm2

**Biogeoclimatic Zone:**
Mountain Hemlock - MH
Subzone: *Windward* Moist Maritime - MHmm1
Subzone: Moist Maritime Parkland - MHmmp

**Biogeoclimatic Zone:**
Alpine Tundra - AT

Figure 2. Boundary of TFL 37 and location of communities.
4. METHODS

4.1 Radar Surveys

Methods for conducting radar surveys in the Nimpkish Valley followed protocols described in the Resources Inventory Committee Standards (RISC) manual *Inventory Methods for Marbled Murrelets in Marine and Terrestrial Habitats*, version 2.0 (RISC 2001) and the more recent *Guidelines and Data Forms for Collecting Data during Marbled Murrelet Radar Surveys* (Manley et al. 2005). These survey protocols were developed from work that has occurred along coastal British Columbia and the Pacific Northwest (Burger 1997, 2001; Cooper and Hamer 2000). As well, information and methods from the Pacific Seabird Group protocol *Use of Radar for Marbled Murrelet Surveys* (Cooper and Hamer 2003) was consulted during the planning and implementation stages of the project.

Radar surveyors participated in training sessions organized by Alan Burger on 21-23 May 2002 and Irene Manley on 11-13 May 2003 with result that the methods used in the Nimpkish Valley closely resembled those used in Clayoquot Sound, southwest Vancouver Island (Burger 1997, 2001) and the coastal BC mainland (Schroeder et al. 1999; Cullen 2002; Steventon and Holmes 2002).

A 10-kW Furuno FR-7111 mobile marine surveillance radar unit with a tilted scanner was at all radar stations to collect data for murrelet population monitoring. At RS09 (Artlish River Mouth) a lower power 7-kW Furuno FR-805D with a tilted scanner was used at the same time for comparison purposes. Both radar units transmitted X-band at 9410 MHz through a 2 m scanner, and both units had their waveguide manually adjusted to scan a vertical arc of approximately 25°. The magnetron and scanner of both these radar units had been recently serviced (D. Bertram and T. Chatwin pers. comm.).

The scanner was generally mounted on the roof of a truck, approximately 2.0 m above the ground (Figure 3), or when helicopter access was used, on a wooden platform 2.5 m above the ground. When two radar scanners were operated simultaneously the scanners were placed at different heights to minimize interference (Figure 3). The radar scanner was positioned in a location that maximized an unobstructed view of potential murrelet flight paths and minimized the amount of foreground objects such as trees and shrubs that would result in ground clutter on the radar monitor. The sea and rain scatter suppressors were turned off and the gain was set to near maximum to increase the radar's sensitivity for detecting small objects such as murrelets (Burger 2001). As reported in Burger (1997, 2001) we found it relatively easy to distinguish murrelets from other species on the radar screen due to their speed, linear flight path and the size and shape of their radar image.
Radar surveys were conducted at 10 locations throughout northern Vancouver Island between June 7 and July 25, 2005. At most survey locations, brief radar surveys were conducted during the evening prior to main survey following morning. Evening surveys were conducted only for relatively short periods after sunset to identify potential murrelet flight corridors, to establish the best radar placement for detecting murrelets, and to identify what other species were present in the area that may be confused with murrelet radar echoes.

Dawn radar surveys began 2 hr before official sunrise and ended 1 hr after sunrise or 15 minutes after the last murrelet detection (Burger 2001). The time of official sunrise was established each survey day by determining sunrise at Woss, British Columbia (centre of study area) using data from Herzberg Institute of Astrophysics website (Herzberg Institute of Astrophysics 2005).

Concurrent audio-visual surveys were conducted within 50 m of the radar site. Surveyors were in radio contact with one another allowing the audio-visual surveyor to confirm species identification made by radar. Audio-visual surveys followed RISC standards (RISC 2001) and are described in (Harper et al. 2003). Tandem audio-visual surveys began 1 hr before official sunrise and ended 1 hr after sunrise or 15 minutes after the last murrelet detection (RISC 2001).
To ensure consistent data collection over time, data was collected at each survey location to document the precise location and placement of the radar scanner for subsequent surveys.

A transparency was placed over the radar screen and the shaded echoes of ground clutter were traced onto the transparency (Appendix 9.2). The north compass bearing and any large topographical features (i.e., roads or rivers) were drawn on the transparency to aid re-orientating subsequent scanner placements. Main murrelet flight corridors were identified on the transparency by drawing arrows in the direction and along the length of movement areas. Each transparency was labeled with the location name, the date of the survey, and the range of the radar in nautical miles. A photo was also taken of the visual display of the radar screen at each survey site (Appendix 9.3). Most radar surveys were conducted with the radar range set at 0.75 nautical miles, giving a maximum detection limit of 1.4 km on the short axis and 1.9 km on the long axis of the radar monitor screen.

To gauge the speed of different bird species, the distance between radar echoes was measured to the nearest 0.1 mm with dial and/or digital calipers and calibrated with the measured rotation rate of the radar scanner. This ratio was then converted to km/hr to estimate the speed of the bird.

Figure 4. Simultaneous direct comparison of two different radar scanners.

The following data were collected at each survey site on a tape recorder: date, name of survey location, elevation, slope position of survey site, the radar range distance, and a list of other species in the area that radar or audio-visual surveys detected (Manley et al. 2005, RISC 2001, Burger 2001). The survey start/end times and official sunrise time were recorded, as well as weather conditions at the start and end of the survey period. Any weather conditions that occurred during the survey period that might affect murrelet detections (i.e., periods of rain) were noted, along with the times that they occurred. Periods of rain that
obscured murrelet detections and lasted >10 minutes were recorded because survey protocols regard such datasets as incomplete (RISC 2001, Burger 2001). Caution was used to identify murrelets during periods of wind >20 km/hr (Beaufort scale 4 and higher), because strong tailwinds may cause slower-flying species to be misidentified as murrelets, and murrelets flying against strong headwinds to be misidentified as a slower-flying species (Burger 1997, 2001; RISC 2001; Cooper and Hamer 2003).

For each murrelet detection, the following data were recorded into a tape recorder:
1. Time of the detection,
2. Number of birds,
3. Bearing the bird(s) were flying,
4. Flight behaviour (circling or direct flight),
5. Whether the bird(s) were flying in towards the forest or out towards sea,
6. Closest distance to the detection from the radar unit in nautical miles,
7. Direction of where the detection was closest to the radar unit, and
8. Number of radar echoes associated with each detection.

All data were transcribed onto field forms (Appendix 9.1), based on templates found in RISC (2001) and used by Burger (pers. comm.). Field data were entered into an Excel 2000 spreadsheet for sorting, statistical analysis, and graphical display of results. Microsoft Excel 2000 was used to calculate means and standard deviations.
5. RESULTS

5.1 Population Monitoring

A total of 22 morning surveys were conducted at 10 different radar stations (RS) from early June to late July 2005. Seven of the 10 radar stations were located within TFL 37, 2 were located outside the TFL at coastal locations where murrelets were potentially flying into TFL 37 to nest, and 1 was located in a provincial park adjacent to TFL 37 (Figures 5 and 6). Five of the radar stations were located on large inland lakes, 1 on a small inland lake, 2 on coastal inlets, 1 on an inland cutblocks, and 1 near the end of a small gravel airstrip (Table 2).

Weather conditions were favourable for radar operations for 18 of 22 surveys, but significant amounts and duration of precipitation causing “rain clutter” on the monitor screen occurred on 10 June 2005 at RS02, 4 July 2005 at RS08 and on 8 July 2005 at RS09 (Table 3). These three surveys were considered “rainouts”, and their data were discarded for the purpose of monitoring populations.

Data were collected from 6 effective morning surveys at 3 radar stations using the 7-kW Furuno FR-805D tilted radar scanner, and from 11 effective morning surveys at 7 radar stations using the 10-kW Furuno FR-7111 tilted radar scanner. Two radar stations were surveyed early in the nesting season (7 Jun – 10 Jun), 4 stations were surveyed midway through the nesting season (16 Jun – 9 Jul), and 3 stations were surveyed late in the nesting season (10 Jul – 25 Jul, Table 2). Surveys were conducted at all radar stations twice, and most were surveyed on consecutive days to reduce seasonal variation in radar counts. Due to “rainouts” and time constraints, surveys at RS09 were not conducted on consecutive days, and only one effective morning survey was conducted at RS02, RS08, and RS16.

Overall there were 628 detections of 687 murrelet targets (birds) during 22 morning surveys to collect data for population monitoring (Table 4). Of the 351 detections observed flying inland, 238 (68%) occurred prior to official sunrise (Table 4). The largest numbers of murrelets were observed at the two coastal stations Tahshish Inlet at the Artlish River Mouth (RS09 – maximum count of 70 targets), RS13 Nimpkish River Mouth with 63 targets (Table 4). Of the hundreds of murrelet detections none were observed to exhibit a circling flight pattern.
Table 2. Location, position and time of morning radar surveys for marbled murrelets in 2005 in and near TFL 37.

<table>
<thead>
<tr>
<th>Date of 1&lt;sup&gt;st&lt;/sup&gt; Survey</th>
<th>Radar Station&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Location</th>
<th>Position</th>
<th>Seasonal Timing&lt;sup&gt;2&lt;/sup&gt;</th>
<th>No. of Effective&lt;sup&gt;3&lt;/sup&gt; Morning Surveys</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-Jul-05</td>
<td>RS01</td>
<td>Vernon Lake North</td>
<td>Large inland lake</td>
<td>Mid</td>
<td>2</td>
</tr>
<tr>
<td>9-Jun-05</td>
<td>RS02</td>
<td>Atluck Lake West</td>
<td>Large inland lake</td>
<td>Early</td>
<td>1</td>
</tr>
<tr>
<td>7-Jun-05</td>
<td>RS03</td>
<td>Claude Elliott Landing</td>
<td>Inland cutblock</td>
<td>Early</td>
<td>2</td>
</tr>
<tr>
<td>2-Jul-05</td>
<td>RS04</td>
<td>Woss Lake North</td>
<td>Large inland lake</td>
<td>Mid</td>
<td>2</td>
</tr>
<tr>
<td>4-Jul-05</td>
<td>RS08</td>
<td>Woss Airstrip</td>
<td>Inland airstrip</td>
<td>Mid</td>
<td>1</td>
</tr>
<tr>
<td>8-Jul-05</td>
<td>RS09</td>
<td>Artlish River (Tahsish)</td>
<td>Coastal Inlet</td>
<td>Mid &amp; Late</td>
<td>2</td>
</tr>
<tr>
<td>16-Jun-05</td>
<td>RS13</td>
<td>Nimpkish River Mouth</td>
<td>Coastal Inlet</td>
<td>Mid</td>
<td>2</td>
</tr>
<tr>
<td>22-Jul-05</td>
<td>RS16</td>
<td>Nimpkish Lake South</td>
<td>Large inland lake</td>
<td>Late</td>
<td>1</td>
</tr>
<tr>
<td>26-Jul-05</td>
<td>RS25&lt;sup&gt;H&lt;/sup&gt;</td>
<td>Nimpkish Lk-Kilpala R.</td>
<td>Large inland lake</td>
<td>Late</td>
<td>2</td>
</tr>
<tr>
<td>24-Jul-05</td>
<td>RS31&lt;sup&gt;H&lt;/sup&gt;</td>
<td>Schoen Lake Southeast</td>
<td>Small inland lake</td>
<td>Late</td>
<td>2</td>
</tr>
</tbody>
</table>

Total 17

1 – H = site accessed by helicopter, all others accessed by vehicle.
2 – Timing is divided into three categories relative to the breeding season: Early (May 11 - Jun 12), Mid (Jun 13 - Jul 9), and Late (Jul 10 - Jul 27).
2 – Effective surveys are those in which any precipitation that may have occurred did not result in a significantly reduced ability to detect murrelets due to rain clutter on the radar monitor.
Figure 5. Location of 8 inland and 2 coastal radar stations monitored on northern Vancouver Island in 2005.
Figure 6. Location of tilted scanner radar stations (RS) monitored in 2005.
### Table 3. Weather conditions during radar surveys.

<table>
<thead>
<tr>
<th>Date</th>
<th>Radar Station</th>
<th>Location</th>
<th>Cloud Cover</th>
<th>Ceiling</th>
<th>Cloud Type</th>
<th>Precip</th>
<th>Wind</th>
<th>Temp °C</th>
<th>Weather comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>06 Jul 2005</td>
<td>RS01</td>
<td>Vernon Lake North</td>
<td>3-4</td>
<td>BR</td>
<td>CU-ST</td>
<td>M-N</td>
<td>3-1</td>
<td>12</td>
<td>Wind from SSW. Up to 80% of screen obscured for 24 minutes beginning at 0357.</td>
</tr>
<tr>
<td>07 Jul 2005</td>
<td>RS01</td>
<td>Vernon Lake North</td>
<td>4</td>
<td>AR-BR</td>
<td>NS</td>
<td>N-M</td>
<td>1-4</td>
<td>11</td>
<td>Light mist in air for a short time at beginning of survey that obscured less than 10% for a short time. Strong gusting wind from SSW near end of survey (began at 0618).</td>
</tr>
<tr>
<td>09 Jun 2005</td>
<td>RS02</td>
<td>Atluck Lake West</td>
<td>4</td>
<td>AR</td>
<td>AS</td>
<td>N</td>
<td>1</td>
<td>11</td>
<td>Radar screen obscured 50% for a total of 33 minutes, mostly between 0339 and 0409 hrs. RAINOUT.</td>
</tr>
<tr>
<td>10 Jun 2005</td>
<td>RS02</td>
<td>Atluck Lake West</td>
<td>4</td>
<td>BR</td>
<td>NS</td>
<td>LR-M</td>
<td>1</td>
<td>10</td>
<td>Overcast and calm.</td>
</tr>
<tr>
<td>07 Jun 2005</td>
<td>RS03</td>
<td>Claude Elliott Landing</td>
<td>2</td>
<td>VH</td>
<td>CI</td>
<td>N</td>
<td>0</td>
<td>5</td>
<td>Clear and calm.</td>
</tr>
<tr>
<td>08 Jun 2005</td>
<td>RS03</td>
<td>Claude Elliott Landing</td>
<td>4</td>
<td>BR</td>
<td>ST</td>
<td>N</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>03 Jul 2005</td>
<td>RS04</td>
<td>Woss Lake North</td>
<td>3</td>
<td>AR</td>
<td>AS</td>
<td>N</td>
<td>0-1</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>03 Jul 2005</td>
<td>RS04</td>
<td>Woss Lake North</td>
<td>4</td>
<td>VH-AR</td>
<td>CI-CU</td>
<td>N-D</td>
<td>1-3</td>
<td>12</td>
<td>Small pockets of light rain obscured up to 40% of radar screen for less than 5 minutes total beginning at 0615 hrs.</td>
</tr>
<tr>
<td>04 Jul 2005</td>
<td>RS08</td>
<td>Woss Airstrip</td>
<td>4</td>
<td>AR</td>
<td>NS</td>
<td>LR-HR</td>
<td>2</td>
<td>12</td>
<td>A total of 31 minutes of 70-80% screen obscured from 0402 to 0454. RAINOUT.</td>
</tr>
<tr>
<td>05 Jul 2005</td>
<td>RS08</td>
<td>Woss Airstrip</td>
<td>4</td>
<td>AR</td>
<td>NS</td>
<td>M-LR</td>
<td>2-3</td>
<td>15</td>
<td>Wind from SE with gusts to 3. A total of 16 minutes of 50-70% screen obscured including 8 min beginning at 0442 hrs.</td>
</tr>
<tr>
<td>08 Jul 2005</td>
<td>RS09</td>
<td>Artlish River (Tahsish)</td>
<td>4</td>
<td>BR</td>
<td>NS</td>
<td>LR-HR</td>
<td>4-2</td>
<td>11</td>
<td>Wind from SW. 80%-100% of radar screen obscured by rainsqualls for over 2 hours. RAINOUT.</td>
</tr>
<tr>
<td>09 Jul 2005</td>
<td>RS09</td>
<td>Artlish River (Tahsish)</td>
<td>3</td>
<td>BR</td>
<td>NS</td>
<td>N-LR</td>
<td>1</td>
<td>12</td>
<td>Up to 75%-100% of screen obscured by rainsqualls twice for 10 minutes (0508 to 0518 hrs and again beginning at 0547 hrs).</td>
</tr>
<tr>
<td>23 Jul 2005</td>
<td>RS09</td>
<td>Artlish River (Tahsish)</td>
<td>2</td>
<td>AR</td>
<td>CU</td>
<td>N</td>
<td>0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>16 Jun 2005</td>
<td>RS13</td>
<td>Nimpkish River Mouth</td>
<td>4</td>
<td>H</td>
<td>AS</td>
<td>N</td>
<td>0-1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>17 Jun 2005</td>
<td>RS13</td>
<td>Nimpkish River Mouth</td>
<td>3</td>
<td>H</td>
<td>AS</td>
<td>N</td>
<td>0</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

-continued
Table 3 continued.

<table>
<thead>
<tr>
<th>Date</th>
<th>Radar Station</th>
<th>Location</th>
<th>Cloud Cover</th>
<th>Ceiling</th>
<th>Cloud Type</th>
<th>Precip</th>
<th>Wind</th>
<th>Temp.</th>
<th>Weather comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 Jul 2005</td>
<td>RS16</td>
<td>Nimpkish Lake South</td>
<td>2</td>
<td>AR</td>
<td>AC</td>
<td>N</td>
<td>0</td>
<td>-</td>
<td>Clear and calm and bright with large moon.</td>
</tr>
<tr>
<td>26 Jul 2005</td>
<td>RS25</td>
<td>Nimpkish Lk-Kilpala</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>N</td>
<td>1</td>
<td>-</td>
<td>Clear and calm and bright with a 2/3 waning moon.</td>
</tr>
<tr>
<td>27 Jul 2005</td>
<td>RS25</td>
<td>Nimpkish Lk-Kilpala</td>
<td>4</td>
<td>BR</td>
<td>-</td>
<td>F</td>
<td>3</td>
<td>-</td>
<td>Clear above fog layer. Wind from the NW.</td>
</tr>
<tr>
<td>24 Jul 2005</td>
<td>RS31</td>
<td>Schoen Lake SE</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>N</td>
<td>1</td>
<td>-</td>
<td>Clear and calm. Wind from the W.</td>
</tr>
<tr>
<td>25 Jul 2005</td>
<td>RS31</td>
<td>Schoen Lake SE</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>N</td>
<td>1-2</td>
<td>-</td>
<td>Clear and calm. Wind from the W.</td>
</tr>
</tbody>
</table>

1 – Cloud Cover: 1 = clear; 2 = scattered clouds (<50%); 3 = scattered clouds (>50%); 4 = unbroken clouds.
2 – Cloud Type: AC=altocumulus, AS=altostratus, CI=cirrus, CC=cirrocumulus, CU=cumulus, NS=nimbostratus, SC=stratocumulus, ST=stratus.
3 – Ceiling (height of cloud cover): BR=below ridges, AT=above trees, AR=above ridges, H=high, VH=very high.
4 – Wind (Beaufort scale): 0 = calm (< 2 km/h); 1 = light air (2-5 km/h); 2 = light breeze, leaves rustle (6-12 km/h); 3 = gentle breeze, leaves and twigs constantly move 13-19 km/h); 4 = moderate breeze, small branches move, dust rises (20-29 km/h); 5 = fresh breeze, small trees sway (30-39 km/h); 6 = strong breeze, large branches moving, wind whistling (40-50 km/h).
5 – Temperature in degrees Celsius taken at the beginning of the survey.
Table 4. Number of detections and targets (birds) observed with tilted radar during 22 early morning surveys in 2005.

<table>
<thead>
<tr>
<th>Date</th>
<th>Tilted Radar Station-Yr-Visit</th>
<th>Seasonal Timing¹</th>
<th>Location</th>
<th>Radar Unit²</th>
<th>Predawn Detect In³</th>
<th>Detect In</th>
<th>Detect Circle</th>
<th>Detect Out</th>
<th>Detect Total</th>
<th>Predawn Birds In</th>
<th>Birds In</th>
<th>Birds Circle</th>
<th>Birds Out</th>
<th>Birds Total</th>
<th>% “Flocks”⁴</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-Jul-05</td>
<td>RS01-05-01</td>
<td>Mid</td>
<td>Vernon Lake</td>
<td>North</td>
<td>T-Tilted</td>
<td>9</td>
<td>14</td>
<td>0</td>
<td>14</td>
<td>28</td>
<td>9</td>
<td>15</td>
<td>0</td>
<td>15</td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>7-Jul-05</td>
<td>RS01-05-02</td>
<td>Mid</td>
<td>Vernon Lake</td>
<td>North</td>
<td>T-Tilted</td>
<td>15</td>
<td>25</td>
<td>0</td>
<td>11</td>
<td>36</td>
<td>16</td>
<td>27</td>
<td>0</td>
<td>12</td>
<td>39</td>
<td>8</td>
</tr>
<tr>
<td>9-Jun-05</td>
<td>RS02-05-01</td>
<td>Early</td>
<td>Atluck Lake</td>
<td>West</td>
<td>D-Tilted</td>
<td>5</td>
<td>8</td>
<td>0</td>
<td>22</td>
<td>30</td>
<td>5</td>
<td>8</td>
<td>0</td>
<td>25</td>
<td>33</td>
<td>10</td>
</tr>
<tr>
<td>10-Jun-05</td>
<td>RS02-05-02</td>
<td>Early</td>
<td>Atluck Lake</td>
<td>West</td>
<td>D-Tilted</td>
<td>4</td>
<td>0</td>
<td>7</td>
<td>11</td>
<td>11</td>
<td>14</td>
<td>0</td>
<td>7</td>
<td>11</td>
<td>0%</td>
<td>Rainout</td>
</tr>
<tr>
<td>7-Jun-05</td>
<td>RS03-05-01</td>
<td>Early</td>
<td>Claude Elliott Landing</td>
<td>D-Tilted</td>
<td>15</td>
<td>15</td>
<td>0</td>
<td>22</td>
<td>37</td>
<td>17</td>
<td>17</td>
<td>0</td>
<td>25</td>
<td>42</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>8-Jun-05</td>
<td>RS03-05-02</td>
<td>Early</td>
<td>Claude Elliott Landing</td>
<td>D-Tilted</td>
<td>32</td>
<td>36</td>
<td>0</td>
<td>23</td>
<td>59</td>
<td>32</td>
<td>36</td>
<td>0</td>
<td>23</td>
<td>59</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2-Jul-05</td>
<td>RS04-05-01</td>
<td>Mid</td>
<td>Woss Lake</td>
<td>North</td>
<td>T-Tilted</td>
<td>8</td>
<td>12</td>
<td>0</td>
<td>19</td>
<td>31</td>
<td>9</td>
<td>13</td>
<td>0</td>
<td>21</td>
<td>34</td>
<td>10</td>
</tr>
<tr>
<td>3-Jul-05</td>
<td>RS04-05-02</td>
<td>Mid</td>
<td>Woss Lake</td>
<td>North</td>
<td>T-Tilted</td>
<td>10</td>
<td>13</td>
<td>0</td>
<td>20</td>
<td>33</td>
<td>10</td>
<td>14</td>
<td>0</td>
<td>22</td>
<td>36</td>
<td>9</td>
</tr>
<tr>
<td>4-Jul-05</td>
<td>RS08-05-01</td>
<td>Mid</td>
<td>Woss Airstrip</td>
<td>T-Tilted</td>
<td>8</td>
<td>0</td>
<td>3</td>
<td>44</td>
<td>48</td>
<td>8</td>
<td>0</td>
<td>3</td>
<td>44</td>
<td>0%</td>
<td>Rainout</td>
<td></td>
</tr>
<tr>
<td>5-Jul-05</td>
<td>RS08-05-02</td>
<td>Mid</td>
<td>Woss Airstrip</td>
<td>T-Tilted</td>
<td>8</td>
<td>14</td>
<td>0</td>
<td>11</td>
<td>25</td>
<td>8</td>
<td>14</td>
<td>0</td>
<td>11</td>
<td>25</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>8-Jul-05</td>
<td>RS09-05-01</td>
<td>Mid</td>
<td>Artlish River</td>
<td>(Tahsish)</td>
<td>T-Tilted</td>
<td>37</td>
<td>0</td>
<td>5</td>
<td>42</td>
<td>46</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>51</td>
<td>21% Rainout</td>
<td></td>
</tr>
<tr>
<td>8-Jul-05</td>
<td>RS09-05-01</td>
<td>Mid</td>
<td>Artlish River</td>
<td>(Tahsish)</td>
<td>D-Tilted</td>
<td>46</td>
<td>0</td>
<td>4</td>
<td>47</td>
<td>24</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>22</td>
<td>29% Rainout</td>
<td></td>
</tr>
<tr>
<td>9-Jul-05</td>
<td>RS09-05-02</td>
<td>Mid</td>
<td>Artlish River</td>
<td>(Tahsish)</td>
<td>T-Tilted</td>
<td>48</td>
<td>52</td>
<td>0</td>
<td>18</td>
<td>70</td>
<td>53</td>
<td>57</td>
<td>0</td>
<td>23</td>
<td>80</td>
<td>14%</td>
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<tr>
<td>9-Jul-05</td>
<td>RS09-05-02</td>
<td>Mid</td>
<td>Artlish River</td>
<td>(Tahsish)</td>
<td>D-Tilted</td>
<td>40</td>
<td>43</td>
<td>0</td>
<td>10</td>
<td>53</td>
<td>46</td>
<td>50</td>
<td>0</td>
<td>11</td>
<td>61</td>
<td>15%</td>
</tr>
<tr>
<td>23-Jul-05</td>
<td>RS09-05-03</td>
<td>Late</td>
<td>Artlish River</td>
<td>(Tahsish)</td>
<td>T-Tilted</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>8</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>10</td>
<td>11%</td>
</tr>
</tbody>
</table>

-continued
Table 4 continued.

<table>
<thead>
<tr>
<th>Date</th>
<th>Tilted Radar Station-Yr-Visit</th>
<th>Seasonal Timing¹</th>
<th>Location</th>
<th>Radar Unit²</th>
<th>Predawn Detect</th>
<th>Detect In</th>
<th>Detect Circle</th>
<th>Detect Out</th>
<th>Detect Total</th>
<th>Predawn Birds In</th>
<th>Birds In</th>
<th>Birds Circle</th>
<th>Birds Out</th>
<th>Birds Total</th>
<th>% “Flocks”³</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-Jun-05</td>
<td>RS13-05-01</td>
<td>Mid</td>
<td>Nimpkish River Mouth</td>
<td>D-Tilted</td>
<td>21</td>
<td>21</td>
<td>0</td>
<td>29</td>
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<td>21</td>
<td>21</td>
<td>0</td>
<td>30</td>
<td>51</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>17-Jun-05</td>
<td>RS13-05-02</td>
<td>Mid</td>
<td>Nimpkish River Mouth</td>
<td>D-Tilted</td>
<td>14</td>
<td>14</td>
<td>0</td>
<td>49</td>
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<td>14</td>
<td>14</td>
<td>0</td>
<td>50</td>
<td>64</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>22-Jul-05</td>
<td>RS16-05-01</td>
<td>Late</td>
<td>Nimpkish Lake South</td>
<td>T-Tilted</td>
<td>26</td>
<td>70</td>
<td>3</td>
<td>9</td>
<td>13</td>
<td>5</td>
<td>8</td>
<td>0</td>
<td>4</td>
<td>12</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>26-Jul-05</td>
<td>RS25-05-01</td>
<td>Late</td>
<td>Nimpkish Lake Kilpala R.</td>
<td>T-Tilted</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27-Jul-05</td>
<td>RS25-05-02</td>
<td>Late</td>
<td>Nimpkish Lake Kilpala R.</td>
<td>T-Tilted</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>8</td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td>24-Jul-05</td>
<td>RS31-05-01</td>
<td>Late</td>
<td>Schoen Lake Southeast</td>
<td>T-Tilted</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>25-Jul-05</td>
<td>RS31-05-02</td>
<td>Late</td>
<td>Schoen Lake Southeast</td>
<td>T-Tilted</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

Totals 238 351 0 277 628 258 388 0 299 687 9%

Proportion before dawn 68% 66%

1 – Timing is divided into three categories relative to the breeding season: Early (May 11 - Jun 12), Mid (Jun 13 - Jul 9), and Late (Jul 10 - Jul 27).
2 – T-Tilted is BC Ministry of Environment’s (Nanaimo Regional Office) 10-kW Furuno FR-7111, D-Tilted is Canadian Wildlife Service’s (Pacific and Yukon Regional Office) 7 kW Furuno FR-805D (CWS Unit #2). Both waveguides were tilted to scan a vertical arc of approximately 25°.
3 – Predawn detections are those that occurred prior to official sunrise.
4 – Single detections consisting of 2 and occasionally 3 separate targets or birds.
For the most part, inland radar stations had fewer radar detections than coastal stations, but many inland sites also had relatively large daily maximum counts including, RS03 Claude-Elliott Landing with 59 targets, RS01 Vernon Lake North with 39 targets, and Woss Lake North with 36 targets (Table 4). The fewest radar detections occurred at Schoen Lake Southeast with 0 targets counted on each of two successive morning surveys (Table 4).

On average, 9% of the detections were of “flocks” (i.e. single detections consisting of 2 and occasionally 3 separate targets or birds). The proportion of detections that consisted of flocks” ranged from 0% to 33% for individual survey mornings (Table 4). The number of targets within a single detection should be considered a minimum estimate of the actual number of birds in a flock.

5.2 Comparing Radar Units of Different Power Output

On the 8 and 9 July 2005 a lower power 7-kW tilted radar unit was operated simultaneously with a higher power 10-kW tilted radar unit at RS09 (Artlish River Mouth). Over 2 mornings (363 min. total) the lower power unit had 70 total detections of Marbled Murrelets compared to 112 for the higher power unit (Table 5). There was a mean average of 60% more detections with the higher power radar unit. When targets (birds) were analysed the difference between radar units was similar; 83 targets with the 7-kW unit versus 131 targets with the 10-kW unit, for an average increase of 58% (Table 5). The 7-kW unit was able to detect about the same number of multiple target “flocks” as the 10-kW unit, 19% versus 17%, respectively (Table 5).

The difference between the two radar units was particularly evident during the morning of 8 July 2005 when rainstorms obscured the radar screen during most of the survey. The 10-kW unit had 147% more detections than the 7-kW unit (42 versus 17 – Table 5). This is significantly greater than the 32% more detections the higher power unit had during better survey weather the following day (Table 5).
Table 5. Direct comparison of tilted radar units of different power outputs at the Artlish River Mouth (RS09) in Tahsish Inlet in 2005.

<table>
<thead>
<tr>
<th>Radar Unit and Direction of Movement</th>
<th>8 Jul 2005: Morning - Rainout²</th>
<th>9 Jul 2005: Morning¹</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Detections</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 kW - inland</td>
<td>16</td>
<td>43</td>
<td>59</td>
</tr>
<tr>
<td>10 kW - inland</td>
<td>37</td>
<td>52</td>
<td>89</td>
</tr>
<tr>
<td>7 kW - circling</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10 kW - circling</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7 kW - seaward</td>
<td>1</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>10 kW - seaward</td>
<td>5</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td><strong>Total - 7 kW</strong></td>
<td>17</td>
<td>53</td>
<td>70</td>
</tr>
<tr>
<td><strong>Total - 10 kW</strong></td>
<td>42</td>
<td>70</td>
<td>112</td>
</tr>
</tbody>
</table>

| **Targets (birds)**                 |                                |                     |       |
| 7 kW - inland                       | 21                             | 50                  | 71    |
| 10 kW - inland                      | 46                             | 57                  | 103   |
| 7 kW - circling                     | 0                              | 0                   | 0     |
| 10 kW - circling                    | 0                              | 0                   | 0     |
| 7 kW - seaward                      | 1                              | 11                  | 12    |
| 10 kW - seaward                     | 5                              | 23                  | 28    |
| **Total - 7 kW**                    | 22                             | 61                  | 83    |
| **Total - 10 kW**                   | 51                             | 80                  | 131   |

| **% “flocks”**                      |                                |                     |       |
| 7 kW - inland                       | 31%                            | 16%                 | 20%   |
| 10 kW - inland                      | 24%                            | 10%                 | 16%   |
| 7 kW - circling                     | -                              | -                   | -     |
| 10 kW - circling                    | -                              | -                   | -     |
| 7 kW - seaward                      | 0%                             | 10%                 | 9%    |
| 10 kW - seaward                     | 0%                             | 28%                 | 22%   |
| **Total - 7 kW**                    | 29%                            | 15%                 | 19%   |
| **Total - 10 kW**                   | 21%                            | 14%                 | 17%   |

¹ – Direct comparison of radar units between 0327 and 0728 hrs with no rain.
² – Direct comparison of radar units between 0324 and 0726 hrs with light and heavy rain (RAINOUT).
4 – Single detections consisting of 2 and occasionally 3 separate targets or birds.
5 – 10-kW unit is a Furuno FR-7111 (property of provincial MOE) with a tilted waveguide.
6 – 7-kW unit is a Furuno FR-805D (property of federal CWS) with a tilted waveguide.
6. DISCUSSION

Maintaining an effective breeding population of threatened Marbled Murrelets in British Columbia is high priority consistent with regional, provincial and national goals for the conservation of biodiversity. Western Forest Products’s TFL 37 is within the range of nesting Marbled Murrelets from both sides of Vancouver Island. A Marbled Murrelet Conservation Plan for the Nimpkish Defined Forest Area (TFL 37 plus adjacent protected areas) has been developed that includes over 20,000 ha of potential Marbled Murrelet nesting habitat (Deal and Harper 2005). This plan is designed around five major programs or initiatives: Protected Areas, Old Growth Management Areas (OGMAs), the provincial Identified Wildlife Management Strategy (IWMS), the federal Species at Risk Act (SARA) and the national Sustainable Forest Management System. The plan includes conservation areas that have been identified as potential Wildlife Habitat Areas (WHAs) under the Forest and Range Practices Act. The Plan’s objective is to ensure that sufficient habitat is maintained (based on population) to ensure the long-term persistence of the breeding population in the Nimpkish DFA (Deal and Harper 2005).

The objective of the radar-monitoring program is to provide specific information on the effectiveness of the Marbled Murrelet Conservation Plan for the Nimpkish DFA in maintaining populations. Marine surveillance radar monitoring is a proven technique that allows population indices to be generated for murrelets entering large landscape units (Raphael et al. 1995; Burger 1997, 2001; Schroeder et al 1999; Manley 2000; RISC 2001; Cooper et al. 2001; Cooper and Hamer 2003). Analysis of sampling variation from 126 radar stations in British Columbia indicated radar surveys offer a reliable method of detecting population trends within a timeframe relevant to management planning (Arcese et al. in press). Subject to funding, long-term radar monitoring of Marbled Murrelet populations will be conducted at a minimum of 10 sites, at least every second year, on or adjacent to TFL 37 to determine the effectiveness of the nesting habitat conservation plan (Deal and Harper 2005).

6.1 Population Monitoring

6.1.1 Coefficients of Variation

Measures of variance are important to determine because it is one of the more important factors that determines the power of a test to detect a trend. Harper and Schroeder (2004) reported consecutive-day coefficients of variation (CVs) for detections of 19% at coastal stations and 29% at inland stations. The addition of 13 pairs of consecutive-day data collected in 2004, and 5 pairs of consecutive-day data collected in 2005 had little effect on estimates of consecutive-day CVs. With the addition of new data, CVs from both coastal stations and inland stations decreased slightly to 18% and 27%, respectively. When only incoming detections
were analysed, coastal station CVs averaged 28% and inland station CVs averaged 41%.

The larger CVs associated with inland stations and incoming detections indicate it would take longer to detect significant population changes if only these data sources were used, because the population indices associated with these data is less precise. There may be a tendency toward smaller CVs with an increase in total detections (Figure 7), but this could also be more related to characteristics of coastal stations, that appear to have less variable day-to-day detections.

![Figure 7](image.png)

**Figure 7.** Consecutive-day coefficients of variation (CV) for coastal and interior radar stations plotted against mean total radar detections.

In order to reduce variation in radar counts of murrelets it will be important to use the same, or at least very similar, radar units each year. The position of the waveguide has a significant effect on the number of detections, but more subtle difference in horizontal beam width, pulse length and power can affect the ability of radar to differentiate between birds flying close together. There appears to be a substantial reduction in daily sampling variance by sampling individual radar stations on consecutive days, instead of throughout the season. Sampling at approximately same time each year should also help control seasonal variance within sites.
6.1.2 Time-Series Data

Differences in detection rates among years reflect sampling error, environmental fluctuations, and most importantly real changes in the size of population of Marbled Murrelets. Boat surveys were conducted in 1999 and 2001 at a number of inlets on the west coast of Vancouver Island near TFL 37 (Manley 2000, Manley pers. comm.), including one of our long-term monitoring stations. Although this early boat survey data can be compared to data collected in the past 4 years, the variance in the data is too high to detect statistically significant trends based at this time (Figure 8). Of interest, however, is dramatic decline in radar detections in 2005 compared to previous years data (Figure 8).

![Figure 8. Time-series of maximum mid-season radar detections at RS-09 Artlish River Mouth from 1999 to 2005.](image)

![Figure 9. Time-series of maximum mid-season radar detections at RS-03 Claude Elliott from 2002 to 2005.](image)
The decline in radar detections in 2005 at the interior radar station RS-04 Claude-Elliott was not as great as at the coast stations surveyed in 2005 (Figure 9). When time-series data are compared for 4 coastal radar stations the highest number of radar detections occurred in 2004 (Figure 10). Interestingly, the highest number of radar detections occurred one year earlier in 2003 among four of the inland radar stations (Figure 11).

Figure 10. Time-series of maximum radar detections at 5 coastal radar stations 1999 to 2005.

Figure 11. Time-series of maximum radar detections at 5 inland radar stations 2002 to 2005.
When maximum daily detections in 2004 at 12 radar stations were compared with 2003, there were 28% more detections in 2004. However, within that total interior stations were down 25% from 2003 (632 in 2004 versus 845 in 2004). A more consistent and dramatic decrease occurred in 2005 when comparing murrelet detections to 2004 data. Overall, maximum daily detections at the 10 radar stations were 68% lower in 2005 compared to 2004, and all radar stations were lower in 2005 than 2004.

No inference concerning population trends should be made from these data comparing just three or four years of radar surveys. This large decrease in Marbled Murrelets detections is similar to other south coast radar surveys in 2005 (D. Bertram, Marbled Murrelet Recovery Team Chair, pers. comm.), a phenomenon that did not occur among north coast radar surveys. The likely explanation is high sea temperatures led to poor fish forage availability and breeding failures in south coast waters in 2005. Given more normal sea temperatures in 2006 we can expect murrelet radar detections to return to levels observed in 2003 and 2004.

7. ACKNOWLEDGEMENTS

The Forest Inventory Account (FIA), Canadian Forest Products Ltd., and the Canadian Wildlife Service provided funding through the efforts of John Deal and Patrick Bryant. John also provided overall direction for the project, as well as logistical and GIS support. Trudy Chatwin of the Ministry of Water, Land and Air Protection provided the 10-kW radar unit, and Doug Bertram of the Canadian Wildlife Service provided the 7-kW radar unit used in this project.
8. LITERATURE CITED


Hull, C. L. 1999. COSEWIC Status Report Update on Marbled Murrelet Brachyramphus marmoratus (Gmelin). Report to Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Centre for Wildlife Ecology, Department Biological Sciences, Simon Fraser University, Burnaby, BC.


Manley, I.A. 1999. Marbled Murrelet (Brachyramphus marmoratus) activity and behaviour patterns at forest nesting sites in the Carmanah and Walbran valleys, BC. BSc. honors thesis. University of Victoria, Victoria, BC. 46pp


Resource Inventory Standards Committee (RISC). 2001. Inventory methods for Marbled Murrelets in marine and terrestrial habitats, v. 2.0, Standards for components of British Columbia’s biodiversity. No. 10. BC Ministry of Environment, Lands and Parks, Resources Inventory Branch, Victoria, BC.


9. APPENDICES

9.1 Appendix 1. Example of datasheet used to record radar observations.

![Example of datasheet used to record radar observations](image-url)

**OSIRIS WILDLIFE CONSULTING**

**RADAR SURVEY FORM 2005**

**STATION:** 8501

**Visit No.:** 65

**Timing (E of M):**

**Using radius:** (NM) 0.75

**Scanning radius:** (KM)

**Detections in:** 14

**Detections Circle:** 0

**Detections Out:** 11

**Total Detections:** 25

**Area Name:** NIMPISH

**Site Name:** MORNING

**E (x) coordinate:**

**N (y) coordinate:**

**Source:**

**Date:**

**Observer (x) Name:**

**Initials:**

**AV Observer:**

**Obs Sta Label of paired AV:**

**Station Elevation:**

**Rain or Sea Clutter Time On 1:**

**Time Off 1:**

**Time On 2:**

**Time Off 2:**

**Descrip. of Station Placement (DRAW MAP of other side):**

**Time On 3:**

**Time Off 3:**

**Time On 4:**

**Time Off 4:**

**Other species in area:**

**% screen obscured 1:**

**% screen obscured 2:**

**1st of radar screen photo:**

**Rain or Sea Clutter total time on 16:**

**Rain Out:**

**ENVIR. CONDITIONS:**

**Official Sunrise:**

**Source:**

**DOA or:**

**Begin Survey Time:**

**End Survey Time:**

**Temp (C) at Sunrise:**

**Temp (C) at End of Survey:**

**Windspeed:**

**Wind Direction:**

**Ceiling:**

**Cloud Cover (CC):**

**Cloud Type:**

**Precip:**

**Weather Comments:**

<table>
<thead>
<tr>
<th>TIME (MM)</th>
<th>IN (enter forest)</th>
<th>CIRCLE (in forest)</th>
<th>OUT (leave forest)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Su</td>
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</tr>
</tbody>
</table>

**May 2004**

**Osiris Wildlife Consulting**

---

**Number:** No. of Marbled Murrelets. **Bearing:** Bearing (e.g., NNW, ESE) of flight path heading. **Distance:** Closest distance in metres of flight path to radar. **Direction:** Direction (e.g., NW, SE) of the closest point of flight path to radar unit. **Number of Hits:** Number of signals received from target. **Severity:** Type of signal received (e.g., nongenuine, genuine, etc.). **Impact:** Impact of signal received (e.g., nongenuine, genuine, etc.). **Notes:** Any additional notes or observations (e.g., nongenuine, genuine, etc.).
## Appendix 1 continued

### Radar Survey Description: Marbled Murrelet Radar Survey

(Complete this form to summarize each radar survey)

<table>
<thead>
<tr>
<th>Radar Station ID</th>
<th>Vernon Lake</th>
<th>Radar Survey ID: RS01-01</th>
<th>Date of Survey</th>
<th>Y2005 M07 D 06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey Type:</td>
<td>Dawn/Dusk</td>
<td>Sonar/Sunrise/Sunset time</td>
<td>05:24</td>
<td>Source: DA0</td>
</tr>
<tr>
<td>Radar Screen:</td>
<td>Offset distance</td>
<td>Scanning radius (NM)</td>
<td>0.5</td>
<td>0.75</td>
</tr>
</tbody>
</table>

**Weather Conditions:**
- Wind: N, 10 knots
- Visibility: 10 miles
- Barometric Pressure: 30.0 inches
- Temperature: 72°F
- Humidity: 24%

**Survey Start Time:** 04:32 | **Survey End Time:**

### Flightpath: Vernon Lake

**Total Minutes of Screen Obstruction:** 31

<table>
<thead>
<tr>
<th>Flight</th>
<th>Radar Screen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vernon Lake</td>
<td>Vernon Lake</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1 Bird</th>
<th>2 Birds</th>
<th>Total Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>1</td>
<td>14</td>
</tr>
</tbody>
</table>

**Flight Speed Cut-off:** No X Yes ☑ **Minimum Maneuver Speed:** _mm_ _km/h_

---

### Radar Station Description: Marbled Murrelet Radar Survey

(Complete this form at the start of each survey and if the station is known during a survey)

<table>
<thead>
<tr>
<th>Radar Station ID</th>
<th>Vernon Lake North</th>
<th>Radar Station Name: RS01-01</th>
<th>Radar Station ID: RS01</th>
<th>Date of Station Description</th>
<th>2005 M07 D 06</th>
<th>Year Station Established</th>
<th>2002</th>
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<tbody>
<tr>
<td>Description:</td>
<td>Boat launch at Vernon Lake Campfire north end of lake.</td>
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<td></td>
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<tr>
<td>Description of Radar Station:</td>
<td>Boat launch at Vernon Lake Campfire north end of lake.</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Directions:</td>
<td>South of Woss, BC En 40 Run Time Highway 19 off Logging Road</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UTM 1/1</td>
<td>Elevation (m):</td>
<td>Mapsheet #:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radar Station Type: Coastal/Island/Inland Lake/Other</td>
<td>Radar Unit Base: Boat</td>
<td>Land</td>
<td>Vehicle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radar Type:</td>
<td>2.5</td>
<td>Orientation of Antenna (degrees): 180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photo of Radar Station: Date Y2005 M07 D 06</td>
<td>Filename: RS01_VERNON_SITE.JPG</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Photo of Radar Screen: Date Y2005 M07 D 06</td>
<td>Filename: RS01_VERNON.Screen.jpg</td>
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</tr>
<tr>
<td>Antenna Overlay of Radar Screen: Date Y2005 M07 D 06</td>
<td>Filename: RS01_VERNON_AUATE.jpg</td>
<td></td>
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</tr>
</tbody>
</table>

**Radar Unit Information:**
- **Unit Name/ID:** TRU045
- **Radar Model:** FR
- **Radar Serial #:**
- **Radar Unit Power:** 10 KW
- **Antenna Length (cm):** 200
- **Antenna Tilt (degrees):** 12

**Notes:**
9.2 Appendix 2. Example of acetate sheet used to record flight paths.