# APPENDIX E

## Radar Survey Techniques Employed at Channel Islands National Park for Seabirds Nesting in Remote and Challenging Habitats

Ornithological surveillance radar techniques have been recently applied to successfully monitor and study aspects of the biology of other seabirds nesting in inaccessible habitats in old-growth forests (e.g., Marbled Murrelets *Brachyramphus marmoratus*), at offshore islands (e.g. Cassin's Auklets *Ptychoramphus aleuticus*; Xantus's Murrelets at Anacapa Island), and in high mountains (e.g., Newell's Shearwaters *Puffinus puffinus newelli*). In these studies, the radar was either mounted on boats for offshore work or mounted on a camper unit and 4-wheel drive truck for terrestrial work. Radar monitoring techniques have provided a new opportunity to measure changes in abundance and distribution of Several types of radar have been effective tools in ornithological research for more than four decades (Eastwood 1967). Marine radar is probably the easiest and least expensive to operate, and has additional benefits of high resolution, small minimal sampling range, high availability, and high portability (Cooper et al. 1991, Hamer et al. 1995). Radar surveys have a distinct advantage over many types of surveys because they are able to detect flying birds: regardless of light levels and in complete darkness and fog; regardless of whether or not they are vocalizing; and small birds can be tracked out to a 1.2 km radius, much farther than by eye during daylight (Hamer et al. 1995). Radar also provides valuable information on bird flight speed, flight direction, behavior, and use areas (Hamer and Schuster. 2003).

### Equipment

Radar surveys were conducted using a Furuno model FCR-1411, 10-kW, X-band radar unit, with a flexible 2-m long slotted wave-guide array antenna. Pulse length could be set at .08, 0.6, or 1.0 u sec, depending on range setting. The radar beam had a vertical span of 25 degrees and a horizontal beam width of 2 degrees. We mounted the radar equipment on and conducted radar surveys from the CINMS vessel Balleña in 2000 and the CINP vessel Pacific Ranger in 2001-02. In 2000 we mounted the radar apparatus on the roof of the main wheelhouse of the Balleña, while in 2001-02 the radar was mounted on a specially fabricated steel tripod 2 m above the wheelhouse of the Pacific Ranger. In 2001-02, we installed a Furuno model PG-1000 flux-gate compass to the radar which fixed the shoreline image on the radar monitor regardless of the shifting position of the vessel. In 2002, CINP skippers also developed a functioning stern anchoring system which greatly reduced boat movement due to anchor swing and anchor drag. The stern anchoring system kept the boat with the bow pointed toward the island such that the clarity of murrelet echoes near island-cliff nesting habitats were not affected by radar backscatter.

In 2002, we also refined our radar-tilting protocol to minimize the variation in murrelet detection rates during periods of poor weather. The angle of the radar antenna could be raised (in 5° increments) off the water to minimize wave clutter. However, echo sizes of targets near the surface of the ocean became smaller with each increment. Through several 2002 trials under different weather conditions, a tilt of $< 10°$ was found to reduce wave clutter without reducing the overall detection rate or increasing the difficulty of identifying murrelets. In addition, working under high SW winds in particular tended to clutter-out portions of the water within 100 m of the shoreline in the “cliff zone” (see later). Radar counts typically show a reduction with higher winds (producing wave clutter on the radar screen) and radar tilt positions $>10°$. In 2002, we determined that $\geq 50\%$ of the shoreline must be free of clutter to complete an adequate survey.

All data in 2000-02 were collected under relatively calm sea conditions with a radar tilt of 0-10° and, if increasing wave clutter prevented a complete four-hour survey of the cliff zone from 23:00-03:00, the survey was cancelled and the data was not used in the analyses. These various improvements served to increase the numbers of nights of data collection per year (by allowing data collection during marginal conditions) and improved data quality (by facilitating interpretation of echo trails) but we believe that data were still comparable between years. Due to the difficulty of detecting a small murrelet-type target at great distances with the radar, we found the 0.5 nm setting (1.1 km radius) was the most appropriate scale for monitoring. The radar completed one scan every 2.5 sec with a plotting function set to 30 sec. Therefore, each radar target would leave an echo trail with each echo retained for 30 sec. The echo trail could be subsequently plotted and measured, allowing us to estimate flight speeds by using a hand-held scale and measuring the distance between three or more echoes.

Data Collection

A biologist experienced in interpretation of radar echoes monitored the screen and recorded murrelet detections on a data sheet. Echoes on the radar screen were also recorded for the duration of each survey using a Sony 8mm video camera to enable biologists to review survey sessions at a later date. In 2000-2002, sites were monitored during the main incubation period in April and May, based on average timing at the SBI colony (Murray et al. 1983, Drost and Lewis 1995). In 2000, radar surveys were conducted throughout the night from 20:00 to 05:00 (PDT) (Hamer and Meekins 2000). This monitoring schedule allowed us to document activity patterns of murrelets throughout each night. In 2001-02, radar surveys were conducted at night during a four hour period from 23:00 to 03:00 (PDT). In 2000, these sampling hours had the smallest coefficient of variation in radar counts (Hamer and Meekins 2000).

For each radar detection we recorded: identification number, time, flight zone, flight behavior, distance between echoes on the radar screen (mm), flight speed (mph), and the number of radar echoes. In 2000, we segregated all murrelet detections into three zones of activity: a) cliff zone -murrelet targets detected within 100 m of the coastline; b) middle zone - murrelet targets detected seaward but within 101-400 m of the coastline; and c) sea zone - murrelet targets detected seaward > 400 m from the coastline. In 2001-02, we just recorded detections in the cliff zone since these counts had the lowest coefficient of variation in 2000 and murrelets detected flying into or out of steep slopes and cliffs at a distance of < 100 m from shoreline were more likely to be directly arriving at or departing from the monitoring area, reducing possible doublecounting (Hamer and Meekins 2000). In 2000-2001, large samples of flight paths in the cliff zone were plotted on U.S. Geological Survey 7.5' topographic maps, when time allowed. In 2002, we standardized this procedure and mapped the first detection observed at the beginning of every five minute interval. Within the cliff zone, we recorded four categories of flight behaviors: a) inbound - targets flying towards the island within + 45 degrees of the coastline axis; b) outbound - targets flying away from the island within + 45 degrees of the coastline axis; c) circling - targets detected circling with a minimum of a 1/4 arc and; d) unknown - targets flying parallel to coastline or at angles >45 degrees of the coastline axis or targets that had no initial or final bearing from the shoreline.

In 2000-01, we recorded weather conditions at the beginning and end of each survey period. In 2002, we increased the frequency of weather data collection with weather and sea state information recorded at the beginning of each survey hour, including: percent cloud cover, horizontal visibility (good, fair, poor), wind speed (mph), wind direction, precipitation, air temperature (C°), sea surface temperature (C°), cloud ceiling height (m), and moon phase (quarterly). In 2002, we also collected data on light intensity (lumens/sqf) using a stow-a-way ® data logger attached to the roof of the main wheelhouse. To minimize the effect of the anchor light (which is required on each vessel by law) on the data logger, the light was turned off at the beginning of each hour for 15 minutes while the logger retrieved information."