# A COMPARISON OF AERIAL AND BOAT SURVEYS FOR MARBLED MURRELETS IN SOUTHEAST ALASKA, JULY 23-28, 1991

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**PURPOSE AND SUMMARY OF RESULTS:**

Aerial and boat-based surveys for Marbled Murrelets (Brachyramphus marmoratus) were conducted simultaneously over short transect distances (ca. 2 km) in three different areas of the Alexander Archipelago to assess the accuracy and variability of aerial counts compared to boat-based counts. Additional aerial surveys were conducted over a wider geographic area to assess temporal and spatial variability of murrelet aggregations.

A total of 381 linear km were surveyed quantitatively by airplane, and 3227 murrelets were counted on aerial transects. Over 2000 km of open water were examined qualitatively en route to and from transect areas. On simultaneous aerial-boat surveys, 49 linear km were surveyed on 27 different transects and 1034 murrelets were counted from the air, 902 from the boat. There was no statisically significant difference between aerial and boat counts in terms of the total numbers of birds observed or the variance between transects. Murrelet densities ranged widely from (most) areas where they were widely scattered (<5 birds/km$^2$) to relatively small "hotspots" where densities ranged from about 50-300 birds/km$^2$. Murrelet aggregations were ephemeral-- hundreds or thousands observed in some areas on one day were absent in those areas on the next day.

**METHODS:**

Aerial surveys for Marbled Murrelets were flown on 23-28 July, 1991 in southeast Alaska using a DeHavilland Beaver modified for aerial survey work by the U.S. Fish and Wildlife Service. Observers (B. Conant, J. Piatt, D. Groves, Gus van Vliet) counted all birds within 100 m on either side of the aircraft. We visually calibrated our 100 m transect corridor by making several low-level passes along a runway with 100 m distances marked perpendicularly off the center of the runway. Bird observations (species, number, behavior), and data on time, location, observation conditions, etc., were recorded on tape and transcribed later. All surveys were conducted at a height of 35 m, and at a speed of 140 km/h. Incidental observations of murrelets were made while flying at heights of 40-100 m and a speed of 225 km/h between survey sites.

On 23 July, we surveyed murrelets by airplane in Auke Bay and Berner's Bay, and along the east and west shores of Lynn Canal. Similarly, on 28 July we surveyed murrelets by airplane in lower Glacier Bay and Icy Strait.

On 24 July we flew south to Petersburg and Wrangell to conduct simultaneous air and boat surveys for murrelets. Boat surveys were conducted around Rynda Island near the mouth of the Stikine River, at the entrance to Wrangell Narrows off Petersburg, and in Thomas Bay. Boat observers (C. Iverson, P. Walsh, R. Claire) counted all birds within 100 m on either side of their 6-8 m boats. Bird observations and other transect data were recorded on tape and transcribed later. Transects of 2 km distances were marked prior to surveying by placing large red buoys at each end of the transect. Simultaneous surveys were coordinated by radio. On each transect, the boat would travel about half the length of the transect before the airplane would begin to survey the transect. Total time required for completion of the 2 km transects was about 6-10 minutes by boat, and less than one minute by airplane. Transects were re-surveyed by the airplane after the boat finished one transect and moved on to the next one. In Thomas Bay, 3 transects were surveyed 3 times by the boat, another 2 transects were surveyed twice.

On 24 July, we flew south again to locate and conduct surveys in an area with high densities of murrelets. In Endicott Arm we found a large concentration (ca. 2000) of murrelets near Sumdum Island. We offloaded a 5 m aluminum boat and two observers (E. Grossman, C. Hale), and they conducted boat surveys while we counted from the air. Surveys were coordinated from the air by use of radio. Transects were opportunistically established by using natural markers (headlands, floating icebergs, etc.), and transects ranged between 0.5 and 2.5 km (mean = 1.6 km) in length as determined by flight times at known speed. Because it became apparent that the boat was flushing birds out of the transect zone, and after the third transect, we flew all remaining surveys immediately prior to surveys by the boat, and again after the boat completed its survey.

## RESULTS:

### Aerial Surveys

Aerial surveys conducted on 23 July in Auke Bay, Berner's Bay, and on both sides of Lynn Canal north of Auke Bay revealed that murrelets were relatively scarce in this area (Table 1). At-sea densities ranged from about 1.5 to 4 murrelets/$km^2$. Observation conditions were excellent: overcast, no glare, S winds at 10 knots, light rippling on the water except in protected bays where the water was glassy.

En route to Petersburg on 24 July, we flew through Seymour Canal on the east side of Admiralty Island (Figure 1). On the north end of Tiedeman Island, we encountered a large aggregation of murrelets (ca. 800-1000) foraging in glassy-calm waters. We slowed down, dropped to survey elevation and flew several passes over these birds to get an estimate of bird densities (Table 1). No significant numbers of murrelets were observed on the rest of the flight to Petersburg (through southern Stephens Passage and eastern Frederick Sound). On the return route from Thompson Bay, we found and briefly surveyed another large aggregation (ca. 1000-1500 murrelets) in Port Houghton (Table 1). No other significant aggregations of murrelets were observed on the return route through Frederick Sound and Stephens Passage, or in LeConte and Farragut bays.

On 28 July, we surveyed Icy Strait and lower Glacier Bay. Observation conditions were good: calm seas, glassy to light rippling on sea surface, winds < 10 knots, no glare. Murrelet densities were very low in the eastern entrance to Icy Strait and along the northeast shore of Chichagof Island (Table 1). Immediately north of Pt. Adolphus we encountered high numbers of murrelets that were concentrated alongside of, but largely to the west of, an obvious front between milky, green-colored glacial water (presumably the outflow from Glacier Bay) and clearer ocean water. Murrelet densities were twice as great in glacial water on the west side of the front (Pt. Adolphus to Pt. Carolus) than on the east side (Pt. Gustavus to Pt. Adolphus). The front extended all the way from Pt. Adolphus to Glacier Bay. This frontal area was generally "hot" and we saw several humpback whales, thousands of Northern Phalaropes, and hundreds of gulls, kittiwakes and Fork-tailed Storm-petrels. We also saw several Kittlitz's Murrelets.

In lower Glacier Bay we surveyed the Sitakaday Narrows, Beardslee Entrance and Channel (outer Beardslees) and inside the Beardslee Island complex (inner Beardslees). We found moderate densities of murrelets outside, and high densities inside, of the Beardslee Islands (Table 1). We identifed several Kittlitz's

Murrelets. Thousands of Northern Phalaropes were observed in tide rips at Beardslee Entrance.

**Aerial-Boat Surveys**

Aerial surveys were conducted in synchrony with boat surveys around Rynda Island (Table 2) and off Petersburg and in Thomas Bay (Table 3). At Rynda Island, very few murrelets were seen by aerial or boat observers. Many more species and numbers of birds, but less than half as many murrelets, were recorded by aerial observers. Observation conditions were not optimal: some glare, 10-15 knot NE winds, wavelets of ≤15 cm, few whitecaps. Variability in counts between transects was higher in aerial surveys (Table 2, see CV= coefficient of variation).

On 3 transects off Petersburg, only 3 and 1 murrelets were seen by boat and aerial observers, respectively. Numbers of other species (or taxa) observed were similar. Observation conditions were good and seas were calm with a light ripple. At Thomas Bay, boat observers saw over 9 times as many murrelets as aerial observers, and variability in counts of murrelets and other species was half or less than the variability of aerial counts. Observation conditions were not optimal: glare, wavelets of <10 cm, and light chop. On the first 3 transects (T1-T3) in Thomas Bay, the boat surveyed each transect completely before the airplane. In addition, boat surveys were conducted 3 times for each of these transects, showing a marked reduction between the first survey (125 murrelets) and the second (27 murrelets) or third (43 murrelets) surveys. Aerial counts were conducted immediately after the second boat count, and 0 murrelets were seen by aerial observers. On the last 2 transects (T6-T7) in Thomas Bay, aerial surveys were conducted before boat surveys. Aerial observers saw 8 murrelets on the water, while boat observers counted 39 murrelets-- about half of which were flying. On repeating those 2 transects by boat, observers saw 46 murrelets, about a third of which were flying. On all boat transects (including repeats), 47% of 305 murrelets observed were flying across the transect zone when counted.

On 25 July we searched for large concentrations of murrelets in which to conduct aerial-boat survey comparisons. We returned to Tiedeman Island and Port Houghton, but found very few murrelets at either location despite extensive searching. On return to Juneau, we entered Endicott Arm from the head of the bay and encountered large numbers (ca. 2000+) of murrelets near Sumdum Island. Observation conditions were optimal: no glare (90% overcast), glassy-calm water, no wind. Other than 400 Mew Gulls counted on a beach by the boat observers on a coastal transect, there was little difference between numbers and species of birds observed by aerial and boat observers. About 200 more murrelets were counted by aerial observers. Variability in murrelet counts made by boat and aerial observers was virtually identical (Table 4).

The effects of disturbance by the boat were apparent on the first 3 transects when we flew over the boat as it passed the midpoint of a transect. Murrelets (and other birds) ahead of the boat scrambled (diving and flying) to get out of the way of the boat, leaving a vacant zone about 30-50 m wide behind the boat. Therefore on the remaining 9 transects we flew the transect immediately before and after initiation and completion, respectively, of transects by the boat. Aerial counts conducted before the boat passed through the transect were generally 2-5 times higher than aerial counts conducted after the boat surveys (Figure 2).

Effects of the plane on boat counts were apparently minimal. Many murrelets ahead of the plane dove quickly as the plane approached them. This rapid and widespread dive response was seen by both aerial and boat observers. In contrast to their response to the boat, however, birds generally did not fly away or disperse after plane overflights-- they simply re-surfaced after diving and remained in the transect zone. Boat counts that were conducted after aerial overflights were similar to the first pass aerial counts (below).

**Comparison of Aerial and Boat Surveys**

Combining all surveys, there was little difference in either total numbers or species seen by aerial and boat observers (Table 5). Some species were seen by aerial but not boat observers (e.g., loons, cormorants) and vice-versa (e.g., guillemots). The coefficient of variation was slightly higher for aerial counts of murrelets, but lower for total birds observed. A 2-way Chi-square test of frequencies revealed significant variation ($x^2$=65.1, df=2, P<0.0001) in counts due to observation platform (plane, boat) and transect area (Rynda, Thomas, Endicott). Analysis of variance also revealed count variation due to platform and area (F=4.19, df=5,48, P<0.003), but effects of observer platform alone were not significant (F=0.03, P<0.87). Most of the variation was due to area alone (F=10.2, P<0.0002). There was no interaction between platform and area (F=0.23, P<0.80).

Counts obtained on boat and first pass aerial transects were well correlated (Pearson product r=0.87, P<0.0001, n=27; Figure 3). Boat counts were less well correlated with second pass aerial counts (r=0.72, P<0.0001, n=26), or the average of first and second aerial counts (r=0.86, P<0.0001, n=26). First and second pass aerial counts were well correlated with each other (r=0.89, P<0.0001, n=26), although second pass counts were consistently lower than first pass counts (Figure 2). Repeated boat counts were not significantly correlated with each other (r=0.82, P=0.09, n=5).

Regression of boat and aerial counts suggested a strong linear relationship ($r^2$=0.76, P<0.0001, n=27), with:

boat counts = 0.693(aerial counts) + 7.21.

## DISCUSSION AND CONCLUSIONS:

There were several sources of error in our study. Murrelets were flushed from the transect zone by the boat prior to aerial surveys, and this probably reduced aerial counts at Rynda Island and Thomas Bay. All the aerial counts used for this analysis (Table 1) were conducted by the same observers, but boat counts were conducted by different observers in each area and this may have been a large source of variability. Finally, boat counts took 6-10 times longer to complete than aerial counts, and a higher proportion of flying murrelets were recorded on boat counts. This was a relatively smaller source of error where large numbers of birds on the water were encountered.

Despite the above sources of error, this pilot study suggests that aerial surveys can be as effective as boat-based surveys for censusing Marbled Murrelets and other seabird species. With respect to total numbers observed and variance between transects, there was no statistical difference between survey platforms (plane or boat). Most of the variance between transects was due to the patchiness of large murrelet aggregations. The relatively large coefficients of variation for both boat and aerial counts (ca. 180-200% for all 27 synchronized transects) reflects our relatively small sample of transects that, by design, included extremely low and high density aggregations of murrelets.

Aerial counts were lower than boat counts when murrelet densities were very low, but similar or higher in areas of high murrelet densities. Single or dispersed murrelets are more difficult to detect from the plane. Once in an area of high murrelet densities, however, it is easier to count large flocks when looking down on them from the air than it is to count them at eye-level as they disperse ahead or to the side of the boat. In any case, it appears that aerial surveys adequately detect murrelets at both low and high densities, and more simultaneous aerial-boat comparisons could yield a more accurate "correction factor". Although this may prove to be a non-linear relationship, this pilot study suggests a linear, nearly one-to-one relationship-- in which case a correction factor may not be required.

Aerial and boat surveys each have their own strengths and weaknesses. It is easier to identify species on boat surveys, and one can always stop to count large numbers or identify unusual species. We failed to identify many Kittlitz's Murrelets in Glacier Bay-- despite the fact that at least one-third of murrelets in the Beardslee Islands were probably Kittlitz's (as they were in late June; Piatt, Climo, and Springer, unpubl. data). The main advantage of aerial surveys is that large geographic areas may be surveyed rapidly. This may be important given the ephemeral nature of murrelet aggregations. For example, we saw few murrelets in Auke Bay and Berner's Bay where hundreds or thousands were observed in these bays in June (G. van Vliet, J. King, unpubl. data). Even more dramatic was the total disappearance of thousands of murrelets from Seymour Canal and Port Houghton between 23 and 24 July. It is possible that the large numbers of murrelets seen in Endicott Arm on 24 July were comprised of birds seen in the former sites on 23 July. If so, boat surveys would be more prone to errors in assessing populations because of the time required to conduct surveys over large geographic areas. Aerial surveys should provide a more synoptic, and possibly more accurate, view of regional populations. This could be tested with more comparative aerial-boat surveys.

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TABLE 1. Numbers and densities of murrelets observed on aerial and boat surveys in southeast Alaska, July 22-28, 1991 (surveys by air unless otherwise indicated).

| Location | No. of murrelets | Linear distance surveyed (km) | Murrelet density (No./$km^2$) |
|---|---|---|---|
| Auke Bay | 18 | 31.2 | 2.88 |
| E. Lynn Canal | 11 | 36.0 | 1.53 |
| Berner's Bay | 52 | 66.8 | 3.88 |
| W. Lynn Canal | 20 | 48.0 | 2.08 |
| E. Icy Strait | 11 | 18.0 | 3.06 |
| N. Chichagoff I. | 20 | 40.8 | 2.45 |
| Pt. Adolphus (1) | 429 | 18.6 | 115.3 |
| Pt. Adolphus (2) | 130 | 12.5 | 51.9 |
| Outer Beardslees | 335 | 18.7 | 89.6 |
| Inner Beardslees | 734 | 14.4 | 254.9 |
| Tiedeman Is. | 195 | 5.8 | 168.1 |
| Port Houghton | 238 | 8.3 | 143.4 |
| Rynda Is. | 5 | 14.0 | 1.79 |
| Rynda Is. (boat) | 13 | 14.0 | 4.64 |
| Thomas Bay | 8 | 16.0 | 2.50 |
| Thomas Bay (boat) | 69 | 16.0 | 21.6 |
| Endicott Arm | 1021 | 19.2 | 315.1 |
| Endicott Arm (boat) | 820 | 19.2 | 253.1 |
| Aerial Total | 3227 | 380.9 | |

(1) Pt. Adolphus to Pt. Carolus (S to N)
(2) Gustavus Pt. to Pt. Adolphus (N to S)

Table 2. Birds observed on aerial and boat survey transects (n=7) around Rynda Island

| SURVEY TYPE | SPECIES | N | Sum | Mean | CV |
|---|---|---|---|---|---|
| AERIAL | UNML | 7 | 5.0 | 0.7 | 175.5 |
| | BOGU | 7 | 17.0 | 2.4 | 229.1 |
| | MEGU | 7 | 3.0 | 0.4 | 264.6 |
| | GWGU | 7 | 0.0 | 0.0 | . |
| | PIGU | 7 | 0.0 | 0.0 | . |
| | UNGU | 7 | 86.0 | 12.3 | 264.6 |
| | OTHR | 7 | 0.0 | 0.0 | . |
| | TOTAL | 7 | 108.0 | 15.4 | 253.2 |
| BOAT | UNML | 7 | 13.0 | 1.9 | 118.1 |
| | BOGU | 7 | 0.0 | 0.0 | . |
| | MEGU | 7 | 0.0 | 0.0 | . |
| | GWGU | 7 | 0.0 | 0.0 | . |
| | PIGU | 7 | 0.0 | 0.0 | . |
| | UNGU | 7 | 0.0 | 0.0 | . |
| | OTHR | 7 | 0.0 | 0.0 | . |
| | TOTAL | 7 | 13.0 | 1.9 | 118.1 |

Table 3. Birds observed on aerial and boat survey transects (n=7) off Petersburg (n=3) and in Thomas Bay (n=5)

| SURVEY TYPE | SPECIES | N | Sum | Mean | CV |
|---|---|---|---|---|---|
| AERIAL | UNML | 8 | 8.0 | 1.0 | 185.2 |
| | BOGU | 8 | 2.0 | 0.2 | 282.8 |
| | MEGU | 8 | 30.0 | 3.7 | 282.8 |
| | GWGU | 8 | 2.0 | 0.2 | 282.8 |
| | PIGU | 8 | 0.0 | 0.0 | . |
| | UNGU | 8 | 34.0 | 4.2 | 282.8 |
| | OTHR | 8 | 0.0 | 0.0 | . |
| | TOTAL | 8 | 46.0 | 5.7 | 228.8 |
| BOAT | UNML | 8 | 69.0 | 8.6 | 97.6 |
| | BOGU | 8 | 27.0 | 3.4 | 259.7 |
| | MEGU | 8 | 37.0 | 4.6 | 265.8 |
| | GWGU | 8 | 1.0 | 0.1 | 282.8 |
| | PIGU | 8 | 2.0 | 0.2 | 185.2 |
| | UNGU | 8 | 0.0 | 0.0 | . |
| | OTHR | 8 | 0.0 | 0.0 | . |
| | TOTAL | 8 | 99.0 | 12.4 | 85.4 |

Table 4. Birds observed on aerial and boat survey transects (n=12) in Endicott Arm

| SURVEY TYPE | SPECIES | N | Sum | Mean | CV |
|---|---|---|---|---|---|
| AERIAL | UNML | 12 | 1021.0 | 85.1 | 113.5 |
| | BOGU | 12 | 21.0 | 1.8 | 248.6 |
| | MEGU | 12 | 1.0 | 0.1 | 346.4 |
| | GWGU | 12 | 41.0 | 3.4 | 252.8 |
| | PIGU | 12 | 0.0 | 0.0 | . |
| | UNGU | 12 | 2.0 | 0.2 | 233.5 |
| | OTHR | 12 | 3.0 | 0.2 | 248.6 |
| | TOTAL | 12 | 1088.0 | 90.7 | 110.7 |
| BOAT | UNML | 12 | 820.0 | 68.3 | 114.1 |
| | BOGU | 12 | 19.0 | 1.6 | 216.2 |
| | MEGU | 12 | 422.0 | 35.2 | 327.9 |
| | GWGU | 12 | 0.0 | 0.0 | . |
| | PIGU | 12 | 7.0 | 0.6 | 135.9 |
| | UNGU | 12 | 89.0 | 7.4 | 317.5 |
| | OTHR | 12 | 2.0 | 0.2 | 233.5 |
| | TOTAL | 12 | 937.0 | 78.1 | 126.8 |

Table 5. Birds observed on all (n=27) aerial and boat survey transects (all aerial transects surveyed twice, only first pass data used in this analysis)

| SURVEY TYPE | SPECIES | N | Sum | Mean | CV |
|---|---|---|---|---|---|
| AERIAL | UNML | 27 | 1034.0 | 38.3 | 198.3 |
| | BOGU | 27 | 40.0 | 1.5 | 270.2 |
| | MEGU | 27 | 34.0 | 1.3 | 458.6 |
| | GWGU | 27 | 43.0 | 1.6 | 368.7 |
| | PIGU | 27 | 0.0 | 0.0 | . |
| | UNGU | 27 | 122.0 | 4.5 | 388.3 |
| | OTHR | 27 | 3.0 | 0.1 | 381.3 |
| | TOTAL | 27 | 1242.0 | 46.0 | 173.0 |
| BOAT | UNML | 27 | 902.0 | 33.4 | 179.9 |
| | BOGU | 27 | 46.0 | 1.7 | 306.6 |
| | MEGU | 27 | 459.0 | 17.0 | 453.4 |
| | GWGU | 27 | 1.0 | 0.0 | 519.6 |
| | PIGU | 27 | 9.0 | 0.3 | 186.1 |
| | UNGU | 27 | 89.0 | 3.3 | 478.5 |
| | OTHR | 27 | 2.0 | 0.1 | 360.3 |
| | TOTAL | 27 | 1049.0 | 38.9 | 190.4 |

Figure 2.  Aerial counts of murrelets conducted in Endicott Arm before (1) and after (2) the boat surveyed the transect (note that on transects 1-3, the plane flew the transect after the boat had covered half the transect- on all others, the plane surveyed immediately before and after the boat started and ended surveying, respectively).

```
 Bird #'s

   300 +
       |
       |                    1
       |                       1     1
   200 +
       |
       |
       |
   100 +     1
       |                       2  1
       |              1     2
       |     2  1  1  2              2  1
     0 +  1        2     1        2     2  1
       ---+--+--+--+--+--+--+--+--+--+--+--+--
          1  2  3  4  6  7  9 10 11 12 14 15

                    Transect number
```

Figure 3. Numbers of murrelets observed on boat
surveys vs aerial surveys

```
Boat
 #  |
300 +
    |
    |                                                A
    |             r=0.87
200 +            P<0.0001
    |              n=27                          A
    |
    |
100 +        A
    |                                           A
    |    A              A
    |  BBAA   A     A
  0 +  KA  A
    ---+--------+--------+--------+--------+--------+--------+--
      0       50      100      150      200      250      300

                             Aerial #
```

(Legend: A = 1 obs, B = 2 obs, etc.)

Figure 4. Regression (± 95% confidence limits) of numbers of murrelets on aerial vs boat surveys

```
Boat         Boat count= 0.693(Aerial count) +7.21
 #  |
400 +                r^2=0.761, P<0.0001
    |                      n=27
    |                                            -   +
200 +                                           -+
    |        +      -   -                            -
    |  --+-- --         +                       +-
  0 +  +++++  +     +   -
    |  ----- -
    |
    +
    |
    ---+--------+--------+--------+--------+--------+--------+--
       0      50       100      150      200      250      300

                                 Aerial #

        (NOTE: 14 obs hidden.)
```