Distribution and Abundance of Marbled Murrelets and Common Murres on the Outer Coast of Washington — Summer 1997 through Winter 1998-1999

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For the summers of 1997 and 1998, and winters of 1997-1998 and 1998-1999, the *Tenyo Maru* Trustee's Council (TMTC), U.S. Fish and Wildlife Service, and Washington Department of Natural Resources Funded Washington Department of Fish and Wildlife (WDFW) to complete a variety of specific tasks related to three general objectives: (1) further document the summer and winter at-sea distribution and abundance of Common Murres and Marbled Murrelets along the outer coast of Washington and Strait of Juan de Fuca, (2) conduct surveys of potential Common Murre breeding colonies along the central coast of Washington, and (3) document post-breeding dispersal of of Common Murres from the breeding colonies in Oregon northward along the outer coast of Washington and eastward along the Strait of Juan de Fuca. The specific tasks associated with each of these objectives were completed; analyses of the data collected for each of these tasks are presented and discussed below.

Objective 1: At-sea distribution and abundance of Common Murres and Marbled Murrelets.

Specific tasks funded:

(1) Empirically quantify sampling efficiencies of zig-zag vs. parallel transects
(2) Continue to document long-term seasonal and annual variation in abundance and distribution
(3) Evaluate line vs. strip transect methodology

<u>Task 1</u>

There are two related components to this task: (a) comparison of accuracy and relative statistical power of zig-zag vs. parallel transects for both Common Murres (hereafter murres) and Marbled Murrelets (hereafter murrelets), and (b) determination of the average number of transects necessary to detect a change in density of murres or murrelets of a specified magnitude over a specified time interval (e.g., between seasons, years).

In previous summers and winters, we conducted replicate transects at various distances parallel to shore along the outer coast of Washington and Strait of Juan de Fuca as well as zig-zag transects that covered the range of distances from shore that were covered by parallel transects. To increase our sample size as well as gain additional data on seasonal and annual variation in murrelet density, we collected additional sets of parallel and zig-zag transects in the summers and winters of 1997 and 1998. Our overall survey effort is summarized in Tables 1- 5 below. The data from our parallel and zig-zag transects is summarized in Figures 1-5 and Tables 6 - 8 below.

Table 1. Date, geographic location, and length (kilometers) of transects conducted in the winter of 1996-1997 and associated densities of Marbled Murrelets along the outer coast of Washington and Strait of Juan de Fuca.

Survey Date	Transect Location, Description, and Time	Transect Length (km)	Number of Marbled Murrelets Observed	Density of Marbled Murrelets per km^2
04 February	Port Angeles to Hoko River, 200 M, AM	83.58	24	1.44
04 February	Slip Point to Observatory Point, 400 M, PM	61.84	5	0.40
05 February	Port Angeles to Slip Point, 400 M, AM	71.77	10	0.70
05 February	Slip Point to Port Angeles, 200 M, PM	68.06	8	0.59
06 February	Port Angeles to Slip Point, 800 M, AM	71.56	11	0.77
06 February	Slip Point to Port Angeles, 1200 M, PM	70.69	34	2.40
07 February	Port Angeles to Slip Point, 1200 M, AM	71.27	12	0.84
07 February	Slip Point to Port Angeles, 400 M, PM	71.66	7	0.49
13 February	Neah Bay to Slip Point, 200 M, AM	31.40	44	7.01
13 February	Slip Point to Neah Bay, 400 M, AM	30.10	9	1.50
13 February	Neah Bay to Slip Point (inc.), 200 M, PM	4.88	5	5.12
20 February	Slip Point to Neah Bay, 800 M, AM	29.69	1	0.17
20 February	Neah Bay to Slip Point, 1200 M, PM	27.36	2	0.37
04 March	Gray's Harbor, AM/PM	80.70	2	0.12
05 March	Gray's Harbor, AM/PM	36.62	8	1.09
06 March	Willapa Bay, AM	26.34	0	0
11 March	Ocean Shores to Point Grenville, 1200 M, AM	16.96	0	0
11 March	Point Grenville to Ocean Shores, 200 M, AM	22.43	7	1.56
12 March	Gray's Harbor to Willapa Bay, 1200 M, AM	22.02	1	0.23
20 March	Willapa Bay, high tide, PM	22.93	0	0
20 March	Willapa Bay, low tide, PM	36.14	2	0.28
21 March	Willapa Bay, AM/PM	104.64	17	0.81
25 March	Gray's Harbor to Willapa Bay, 200 M, PM	16.43	1	0.30
25 March	Willapa Bay to Gray's Harbor, 1200 M, PM	15.96	0	0
26 March	Gray's Harbor to Willapa Bay, 200 M, AM	16.02	2	0.62
26 March	Willapa Bay to Gray's Harbor, 1200 M, AM	20.78	8	1.92

Total Kilometers Surveyed: 1131.83

Table 2. Date, geographic location, and length (kilometers) of transects conducted in the summer of 1997 and associated densities of Common Murres and Marbled Murrelets along the outer coast of Washington and Strait of Juan de Fuca.

Survey Date	General Geographic Location	Transect Location	Distance from shore	Time of Day (AM or PM)	Transect Length (km)	Number of Common Murres Observed	Density of Common Murres per Square Km	Number of Marbled Murrelets Observed	Density of Marbled Murrelets per Square Km
11 June	North Coast	Fuca Pillar to Point of Arches	400 M	AM	10.42	39	18.71	2	0.53
11 June	North Coast	Fuca Pillar to Point of Arches	Zig-Zag	AM	17.28	140	40.51	5	0.62
12 June	North Coast	Fuca Pillar to Point of Arches	1000 M	AM	16.06	81	25.22	6	1.19
12 June	North Coast	Fuca Pillar to Point of Arches	400 M	AM	16.98	53	15.61	8	2.56
12 June	North Coast	Fuca Pillar to Point of Arches	700 M	AM	12.52	107	42.73	3	0.35
12 June	North Coast	Fuca Pillar to Point of Arches	Zig-Zag	AM	15.74	37	11.75	7	2.98
12 June	North Coast	Fuca Pillar to Point of Arches	1000 M	PM	13.91	38	13.66	0	0.00
12 June	North Coast	Fuca Pillar to Point of Arches	400 M	PM	16.73	73	21.82	10	2.29
12 June	North Coast	Fuca Pillar to Point of Arches	700 M	PM	12.27	78	31.78	3	0.47
12 June	North Coast	Fuca Pillar to Point of Arches	Zig-Zag	PM	16.41	119	36.26	0	0.00
19 June	South Coast	Columbia R. to Gray's Harbor	Nearshore	AM	82.9	828	49.94	0	0.00
20 June	South Coast	Columbia R. to Gray's Harbor	Offshore	PM	73.03	569	38.96	2	0.26
20 June	South Coast	Columbia R. to Gray's Harbor	Nearshore	AM	75.82	275	18.14	2	0.55
20 June	Gray's Harbor	Gray's Harbor (mouth)		PM	7.81	115	73.62	0	0.00
24 June	North Coast	Fuca Pillar to Point of Arches	1000 M	AM	14.57	138	47.36	0	0.00
24 June	North Coast	Fuca Pillar to Point of Arches	400 M	AM	16.53	102	30.85	6	0.97
24 June	North Coast	Fuca Pillar to Point of Arches	700 M	AM	12.46	44	17.66	2	0.57
24 June	North Coast	Fuca Pillar to Point of Arches	Zig-Zag	AM	17.41	113	32.45	2	0.31
24 June	North Coast	Fuca Pillar to Point of Arches	1000 M	PM	16.1	109	33.85	0	0.00
24 June	North Coast	Fuca Pillar to Point of Arches	400 M	PM	17.08	72	21.08	17	4.03
24 June	North Coast	Fuca Pillar to Point of Arches	700 M	PM	12.81	129	50.35	3	0.30
24 June	North Coast	Fuca Pillar to Point of Arches	Zig-Zag	PM	19.21	144	37.48	2	0.27
25 June	North Coast	Fuca Pillar to Point of Arches	1000 M	PM	14.74	244	82.77	0	0.00
25 June	North Coast	Fuca Pillar to Point of Arches	400 M	PM	16.31	111	34.03	1	0.15
25 June	North Coast	Fuca Pillar to Point of Arches	700 M	AM	12.64	29	11.47	1	0.44
25 June	North Coast	Fuca Pillar to Point of Arches	Zig-Zag	AM	17.93	99	27.61	2	0.36
02 July	Columbia River	Columbia River (mouth)		PM	67.88	52	3.83	0	0.00
02 July	South Coast	Willapa Bay to Columbia R.	Nearshore	AM	70.4	370	26.28	0	0.00
02 July	South Coast	Willapa Bay to Columbia R.	Offshore	PM	51.81	116	11.19	4	1.79
09 July	North Coast	Fuca Pillar to Point of Arches	1000 M	AM	14.07	144	51.17	12	1.17
09 July	North Coast	Fuca Pillar to Point of Arches	400 M	AM	18.08	240	66.37	6	0.45
09 July	North Coast	Fuca Pillar to Point of Arches	700 M	AM	9.42	65	34.50	11	1.59
09 July	North Coast	Fuca Pillar to Point of Arches	Zig-Zag	AM	16.04	277	86.35	15	0.87
09 July	North Coast	Fuca Pillar to Point of Arches	1000 M	PM	14.22	191	67.16	3	0.22

09 July	North Coast	Fuca Pillar to Point of Arches	400 M	PM	16.26	256	78.72	27	1.71
09 July	North Coast	Fuca Pillar to Point of Arches	700 M	PM	10.59	130	61.38	5	0.41
09 July	North Coast	Fuca Pillar to Point of Arches	Zig-Zag	PM	17	224	65.88	14	1.06
10 July	North Coast	Fuca Pillar to Point of Arches	1000 M	AM	14.04	171	60.90	6	0.49
10 July	North Coast	Fuca Pillar to Point of Arches	400 M	AM	11.44	160	69.93	4	0.29
10 July	North Coast	Fuca Pillar to Point of Arches	700 M	AM	13.03	103	39.52	3	0.38
10 July	North Coast	Fuca Pillar to Point of Arches	Zig-Zag	AM	16.82	160	47.56	17	1.79
10 July	North Coast	Fuca Pillar to Point of Arches	1000 M	PM	13.97	93	33.29	12	1.80
10 July	North Coast	Fuca Pillar to Point of Arches	400 M	PM	15.97	92	28.80	27	4.69
15 July	North Coast	Ocean Shores to Pt. Grenville	Nearshore	AM	43.24	238	27.52	34	6.18
15 July	North Coast	Pt. Grenville Grid		AM	46.58	730	78.36	30	1.91
15 July	North Coast	Ocean Shores to Pt. Grenville	Offshore	PM	42.72	150	17.56	7	1.99
16 July	South Coast	Columbia River to Willapa Bay	Offshore	AM	76.34	919	60.19	12	1.00
16 July	Gray's Harbor	Gray's Harbor (mouth)		PM	6.49	24	18.49	0	0.00
17 July	North Coast	Pt. Grenville Grid		AM	42.86	318	37.10	33	4.45
17 July	South Coast	Columbia River to Willapa Bay	Nearshore	PM	75.48	1333	88.30	8	0.45
22 July	Strait	Seal Rock to Kydaka Point	200 M	AM	14.48	1	0.35	30	434.40
22 July	Strait	Seal Rock to Kydaka Point	500 M	AM	14.14	27	9.55	9	4.71
22 July	Strait	Seal Rock to Kydaka Point	800 M	AM	14.39	31	10.77	3	1.39
22 July	Strait	Seal Rock to Kydaka Point	Zig-Zag	PM	16.72	52	15.55	12	3.86
22 July	Strait	Seal Rock to Kydaka Point	200 M	PM	14.4	11	3.82	8	10.47
22 July	Strait	Seal Rock to Kydaka Point	500 M	PM	14.74	9	3.05	1	1.64
22 July	Strait	Seal Rock to Kydaka Point	800 M	PM	14.28	34	11.90	1	0.42
22 July	Strait	Seal Rock to Kydaka Point	Zig-Zag	PM	17.3	52	15.03	0	0.00
23 July	Strait	Seal Rock to Kydaka Point	200 M (inc)	AM	6.1	30	24.59	9	1.83
23 July	Strait	Seal Rock to Kydaka Point	200 M	PM	14.68	324	110.35	9	0.41
23 July	Strait	Seal Rock to Kydaka Point	500 M (inc)	PM	7.33	8	5.46	0	0.00
23 July	Strait	Seal Rock to Kydaka Point	800 M	AM	14.1	256	90.78	2	0.11
23 July	Strait	Seal Rock to Kydaka Point	Zig-Zag	PM	21.03	131	31.15	2	0.32
23 July	Strait	Seal Rock to Kydaka Point	500 M	PM	14.1	69	24.47	1	0.20
24 July	Strait	Seal Rock to Kydaka Point	200 M	AM	15.04	41	13.63	19	6.97
24 July	Strait	Seal Rock to Kydaka Point	500 M	AM	14.33	51	17.79	4	1.12
24 July	Strait	Seal Rock to Kydaka Point	800 M	AM	13.93	42	15.08	0	0.00
24 July	Strait	Seal Rock to Kydaka Point	Zig-Zag	AM	19.68	208	52.85	16	1.51
24 July	Strait	Seal Rock to Kydaka Point	200 M	PM	15.03	14	4.66	23	24.69
24 July	Strait	Seal Rock to Kydaka Point	500 M	AM	14.28	159	55.67	5	0.45
24 July	Strait	Seal Rock to Kydaka Point	800 M	PM	14	29	10.36	0	0.00
24 July	Strait	Seal Rock to Kydaka Point	Zig-Zag	PM	20.78	183	44.03	8	0.91
25 July	Strait	Seal Rock to Kydaka Point	500 M (inc)	AM	10.32	41	19.86	3	0.76
25 July	Strait	Seal Rock to Kydaka Point	800 M	AM	14.05	115	40.93	2	0.24
30 July	South Coast	Columbia River to Willapa Bay	Nearshore	AM	80.88	1451	89.70	2	0.11
30 July	South Coast	Columbia River to Willapa Bay	Offshore	PM	81.09	1147	70.72	1	0.07

31 July	South Coast	Columbia River to Willapa Bay	Offshore	AM	82.91	757	45.65	0	0.00
31 July	South Coast	Columbia River to Willapa Bay	Nearshore	PM	77.06	437	28.35	1	0.18
05 Aug	Strait	Port Angeles to Neah Bay	Nearshore	AM	102.41	32	1.56	293	937.69
06 Aug	North Coast	Lapush to Neah Bay	offshore	PM	80.25	448	27.91	0	0.00
06 Aug	North Coast	Neah Bay to Lapush	nearshore	AM	80.11	392	24.47	20	4.09
07 Aug	Strait	Neah Bay to Port Angeles	Offshore	AM	97.95	372	18.99	35	9.22
12 Aug	South Coast	Columbia River to Willapa Bay	Offshore	PM	77.03	511	33.17	4	0.60
12 Aug	Gray's Harbor	Grays Harbor (mouth)		PM	4.26	1	1.17	0	0.00
12 Aug	South Coast	Columbia River to Willapa Bay	Nearshore	AM	76.79	563	36.66	0	0.00
13 Aug	North Coast	Umatilla to Lapush	Offshore	PM	133.56	89	3.33	6	9.00
13 Aug	North Coast	Lapush to Willapa Bay	Nearshore	AM	161.06	406	12.60	95	37.69
14 Aug	Gray's Harbor	Gray's Harbor (mouth)		PM	8.15	20	12.27	0	0.00
14 Aug	North Coast	Lapush to Willapa Bay	Offshore	AM	124.66	754	30.24	44	7.27
19 Aug	Strait	Port Angeles to Neah Bay	Offshore	AM	97.08	315	16.22	2	0.62
19 Aug	Strait	Seal Rock to Kydaka Point	200 M	PM	14.63	40	13.67	13	4.75
19 Aug	Strait	Seal Rock to Kydaka Point	500 M	PM	15.52	17	5.48	1	0.91
19 Aug	Strait	Seal Rock to Kydaka Point	800 M	PM	14.67	40	13.63	1	0.37
19 Aug	Strait	Seal Rock to Kydaka Point	Zig-Zag	PM	18.98	58	15.28	2	0.65
20 Aug	Strait	Seal Rock to Kydaka Point	500 M	AM	14.99	31	10.34	1	0.48
20 Aug	Strait	Seal Rock to Kydaka Point	Zig-Zag	AM	20.69	67	16.19	4	1.24
20 Aug	Strait	Neah Bay to Port Angeles	Nearshore	PM	102.9	210	10.20	306	149.94
25 Aug	Strait	Seal Rock to Kydaka Point	200 M	AM	14.99	55	18.35	6	1.64
25 Aug	Strait	Seal Rock to Kydaka Point	800 M	AM	13.73	25	9.10	0	0.00
25 Aug	Strait	Seal Rock to Kydaka Point	200 M	PM	14.87	26	8.74	3	1.72
25 Aug	Strait	Seal Rock to Kydaka Point	500 M	PM	14.17	10	3.53	0	0.00
25 Aug	Strait	Seal Rock to Kydaka Point	800 M	PM	13.89	19	6.84	0	0.00
25 Aug	Strait	Seal Rock to Kydaka Point	Zig-Zag	AM	20.6	25	6.07	3	2.47
28 Aug	North Coast	Line 1[1] (first part)			28.61	15	2.62	0	0.00
29 Aug	North Coast	Line 1 (completion)			50.42	28	2.78	0	0.00
30 Aug	North Coast	Line 7			4.87	0	0.00	0	0.00
30 Aug	North Coast	Line 8			6.12	1	0.82	0	0.00
30 Aug	North Coast	Line 9			8.33	4	2.40	0	0.00
30 Aug	North Coast	Line 10			6.49	10	7.70	0	0.00
30 Aug	North Coast	Line 11			10.16	11	5.41	0	0.00
30 Aug	North Coast	Line 12			7.35	1	0.68	0	0.00
31 Aug	South Coast	Line 13			44.08	194	22.01	0	0.00
1 Sept	South Coast	Line 14			47.61	41	4.31	0	0.00
1 Sept	South Coast	Line 15			11.07	0	0.00	0	0.00
2 Sept	South Coast	Line 16			36.02	12	1.67	0	0.00
2 Sept	South Coast	Line 17			4.89	0	0.00	0	0.00
2 Sept	South Coast	Line 18			23.07	20	4.33	0	0.00
3 Sept	South Coast	Line 19			18.4	18	4.89	0	0.00

3 Sept	South Coast	Line 20	6.51	0	0.00	0	0.00
3 Sept	South Coast	Line 21	17.89	19	5.31	0	0.00
3 Sept	South Coast	Line 22	6.19	11	8.89	0	0.00
3 Sept	South Coast	Line 23	22.51	18	4.00	0	0.00
4 Sept	South Coast	Line 24	26.81	34	6.34	0	0.00
4 Sept	South Coast	Line 25	5.99	1	0.83	0	0.00
4 Sept	South Coast	Line 26	22.54	29	6.43	0	0.00
5 Sept	South Coast	Line 27	31.59	26	4.12	0	0.00
5 Sept	South Coast	Line 28	20.29	66	16.26	0	0.00
6 Sept	South Coast	Line 29	13.73	16	5.83	0	0.00
6 Sept	South Coast	Line 30	42.88	64	7.46	0	0.00
7 Sept	South Coast	Line 31	19.53	80	20.48	0	0.00
7 Sept	South Coast	Line 32	5.6	2	1.79	0	0.00
7 Sept	South Coast	Line 33	20.43	44	10.77	0	0.00
8 Sept	South Coast	Line 34	21	14	3.33	0	0.00
8 Sept	South Coast	Line 35	5.62	0	0.00	0	0.00
8 Sept	South Coast	Line 36	21.96	17	3.87	0	0.00
9 Sept	South Coast	Line 37	23.41	9	1.92	0	0.00
9 Sept	South Coast	Line 38	20.73	6	1.45	0	0.00
10 Sept	South Coast	Line 39	81.36	288	17.70	0	0.00
12 Sept	South Coast	Line 40	5.94	0	0.00	0	0.00
12 Sept	South Coast	Line 41	25.08	20	3.99	0	0.00
12 Sept	South Coast	Line 42	5.71	1	0.88	0	0.00
12 Sept	South Coast	Line 43	24.4	17	3.48	0	0.00
13 Sept	South Coast	Line 44	2.33	5	10.73	0	0.00
13 Sept	South Coast	Line 45	15.97	2	0.63	0	0.00
13 Sept	South Coast	Line 46	21.78	15	3.44	1	1.45
13 Sept	South Coast	Line 47	23.68	22	4.65	0	0.00

Total Kilometers Surveyed: 4178.48

[1] These line numbers refer to transects approximately parallel and perpendicular to shore conducted by the U.S. Geological Survey as part of a study of nearshore bathymetry along the outer coast of northern Oregon and southern Washington.

Table 3. Date, geographic location, and length (kilometers) of transects conducted in the winter of 1997-1998 and associated densities of Common Murres and Marbled Murrelets along the outer coast of Washington and Strait of Juan de Fuca.

Survey Date	Location	Transect Length (km)	Number of Common Murres	Common Murre Density per sq. km	Number of Marbled Murrelets	Marbled Murrelet Density per sq. km
22 January 1998	Seal/Sail Rock to Kydaka Point, 200 M, AM	15.52	1	0.32	10	3.22
"	Seal/Sail Rock to Kydaka Point, 500 M, AM	15.11	10	3.31	10	3.31
27 January 1998	Seal/Sail Rock to Kydaka Point, 200 M, AM	15.98	1	0.31	5	1.56
"	Seal/Sail Rock to Kydaka Point, 500 M, PM	13.98	29	10.37	10	3.58
"	Seal/Sail Rock to Kydaka Point, 800 M, AM	14.07	20	7.11	1	0.36
"	Seal/Sail Rock to Kydaka Point, Zig-Zag, AM	20.62	24	5.82	10	2.42
29 January 1998	Seal/Sail Rock to Kydaka Point, 200 M, AM	15.22	1	0.33	32	10.51
"	Seal/Sail Rock to Kydaka Point, 500 M, AM	14.62	5	1.71	19	6.50
"	Seal/Sail Rock to Kydaka Point, 800 M, AM	14.08	19	6.75	7	2.49
"	Seal/Sail Rock to Kydaka Point, Zig-Zag, AM	21.33	9	2.11	26	6.09
"	Seal/Sail Rock to Kydaka Point, 200 M, PM	15.42	2	0.65	33	10.70
"	Seal/Sail Rock to Kydaka Point, 500 M, PM	14.54	8	2.75	48	16.51
"	Seal/Sail Rock to Kydaka Point 800 M, PM	13.98	24	8.58	1	0.36
"	Seal/Sail Rock to Kydaka Point, Zig-Zag, PM	21.81	58	13.30	28	6.42
4 February 1998	Seal/Sail Rock to Kydaka Point, 200 M, PM	15.65	0	0.00	5	1.60
"	Seal/Sail Rock to Kydaka Point, Zig-Zag, PM	21.13	1	0.24	11	2.60
5 February 1998	Seal/Sail Rock to Kydaka Point, 500 M, AM	15.13	0	0.00	10	3.30
"	Seal/Sail Rock to Kydaka Point, 800 M, AM	13.9	10	3.60	0	0.00
"	Seal/Sail Rock to Kydaka Point, Zig-Zag, AM	35.8	6	0.84	4	0.56
"	Seal/Sail Rock to Kydaka Point, 200 M, PM	15.75	0	0.00	8	2.54
"	Seal/Sail Rock to Kydaka Point, 500 M, PM	15.14	0	0.00	21	6.94
"	Seal/Sail Rock to Kydaka Point, 800 M, PM	14.74	1	0.34	2	0.68
"	Seal/Sail Rock to Kydaka Point, Zig-Zag, PM	24.03	0	0.00	11	2.29
11 February 1998	Seal/Sail Rock to Kydaka Point, 500 M, AM	16.15	1	0.31	20	6.19
"	Seal/Sail Rock to Kydaka Point, 800 M, AM	15.57	6	1.93	17	5.46
"	Seal/Sail Rock to Kydaka Point, Zig-Zag, AM	22.93	14	3.05	26	5.67
"	Seal/Sail Rock to Kydaka Point, 200 M, PM	16.41	3	0.91	3	0.91
"	Seal/Sail Rock to Kydaka Point, 200 M, PM	15.9	1	0.31	0	0.00
"	Seal/Sail Rock to Kydaka Point, 500 M, PM	16.12	4	1.24	25	7.75
"	Seal/Sail Rock to Kydaka Point, 800 M, PM	14.74	1	0.34	2	0.68
"	Seal/Sail Rock to Kydaka Point, Zig-Zag, PM	23.66	28	5.92	25	5.28
17 February 1998	Fuca Pillar to Point of Arches, 1000 M, AM	14.1	76	26.95	12	4.26
"	Fuca Pillar to Point of Arches, 700 M, AM	12.55	32	12.75	7	2.79
"	Fuca Pillar to Point of Arches (Partial), 700 M, AM	9.45	152	80.42	9	4.76
"	Tatoosh Island to Seal/Sail Rock, 1000 M, PM	17.37	1790	515.26	25	7.20
"	Tatoosh Island to Seal/Sail Rock, 500 M, AM	17.09	58	16.97	25	7.31
18 February 1998	Kydaka Point to Waadah Island, 1000 M, PM	4.39	1	1.14	2	2.28
"	Sekui to Port Angeles, 1000 M, PM	80.04	17	1.06	119	7.43
"	Sekui to Port Angeles, 500 M, AM	81.43	2	0.12	60	3.68
19 February 1998	Majestic Beach (nr Lyre R.) to Tatoosh Is., 880 M, PM	76.51	674	44.05	89	5.82
"	Tatoosh Island to Seal/Sail Rock, 400 M, AM	77.72	3009	193.58	220	14.15
24 February 1998	Fuca Pillar to Point of Arches, 1000 M, AM	14.5	0	0.00	13	4.48
"	Fuca Pillar to Point of Arches, 1000 M, AM	13.78	0	0.00	14	5.08

"	Fuca Pillar to Point of Arches, 1000 M, PM	13.65	0	0.00	17	6.23
"	Fuca Pillar to Point of Arches, 1000 M, PM	14	6	2.14	14	5.00
"	Fuca Pillar to Point of Arches, 1000 M, PM	14.04	1	0.36	27	9.62
"	Fuca Pillar to Point of Arches, 200 M, AM	12.72	0	0.00	10	3.93
"	Fuca Pillar to Point of Arches, 700 M, AM	13.9	0	0.00	23	8.27
"	Fuca Pillar to Point of Arches, 700 M, AM	13.07	1	0.38	23	8.80
"	Fuca Pillar to Point of Arches, 700 M, PM	12.32	10	4.06	16	6.49
"	Fuca Pillar to Point of Arches, , 700 M, PM	13.42	2	0.75	11	4.10
25 February 1998	Slip Point to Crescent Bay, 1200 M, AM	42.01	18	2.14	16	1.90
	Fuca Pillar to Point of Arches, 1000 M, PM	14.96	2	0.67	14	4.68
"	Fuca Pillar to Point of Arches, 1000 M, AM	14.36	3	1.04	15	5.22
"	Fuca Pillar to Point of Arches, 1000 M, PM	16.37	10	3.05	6	1.83
"	Fuca Pillar to Point of Arches, 700 M, AM	10.88	4	1.84	15	6.89
"	Fuca Pillar to Point of Arches, 700 M, PM	12.56	0	0.00	19	7.56
"	Fuca Pillar to Point of Arches, 700 M, PM	12.98	2	0.77	17	6.55
"	Skagway Rocks to Neah Bay, 700 M, PM	15.79	72	22.80	94	29.77
3 March 1998	Point of Arches to Quilleute River, nearshore, AM	55.76	69	6.19	59	5.29
"	Point of Arches to Skagway Rocks, offshore, PM	14.09	7	2.48	10	3.55
"	Quilleute River to Point of Arches, offshore, PM	47.11	864	91.70	36	3.82
"	Skagway Rocks to Neah Bay, offshore, PM	18.95	207	54.62	15	3.96
4 March 1998	Neah Bay to Port Angeles, 1700 M, AM	98.42	583	29.62	38	1.93
"	Port Angeles to Neah Bay, 400 M, PM	100.84	20	0.99	139	6.89
5 March 1998	Neah Bay to Skagway Rocks, nearshore, AM	16.22	9	2.77	32	9.86
"	Point of Arches to Skagway Rocks, 400 M, AM	15.94	0	0.00	23	7.21
"	Point of Arches to Skagway Rocks, 400 M, AM	15.94	0	0.00	8	2.51
"	Point of Arches to Skagway Rocks, 400 M, AM	16.21	1	0.31	7	2.16
"	Neah Bay to Skagway Rocks, nearshore, PM	15.91	4	1.26	25	7.86
"	Point of Arches to Skagway Rocks, 400 M, AM	16.49	0	0.00	20	6.06
10 March 1998	Ocean Shores to Point Grenville, nearshore, AM	49.01	263	26.83	32	3.26
	Westport to Willapa Bay, nearshore, AM	38.95	40	5.13	55	7.06
"	Willapa Bay to Columbia River, nearshore, AM	41.84	46	5.50	81	9.68
"	Columbia River to Willapa Bay, offshore, PM	42.91	329	38.34	197	22.96
"	Willapa Bay to Westport, offshore, PM	39.12	63	8.05	73	9.33
13 March 1998	Outside Gray's Harbor seawall	56.15	6	0.53	67	5.97
17 March 1998	Around Destruction Island	8.35	0	0.00	3	1.80
"	Pt. Grenville to Hoh Head, first half, offshore, AM	47.24	5	0.53	4	0.42
"	Pt. Grenville to Hoh Head, second half, offshore, AM	9.66	0	0.00	0	0.00
"	Hoh Head to Point Grenville, nearshore, PM	57.45	10	0.87	0	0.00
18 March 1998	Inside Willapa Bay	82.98	0	0.00	32	1.93
"	Inside Willapa Bay	41	2	0.24	24	2.93
19 March 1998	Hoh Head to Lapush, nearshore, AM	24.87	0	0.00	0	0.00
"	Lapush to Hoh Head, offshore, AM	19.24	82	21.31	3	0.78
"	Pt. Grenville to Gray's Harbor, offshore, PM	46.61	73	7.83	5	0.54
	Total Kilometers surveyed:	2242.25				

Table 4. Date, geographic location, and length (kilometers) of transects conducted in the summer of 1998 and associated densities of Common Murres and Marbled Murrelets along the outer coast of Washington and Strait of Juan de Fuca.

SURVEY DATE	Location	Transect Length (km)	Number of Common Murres	Common Murre Density per sq. km	Number of Common Murre Chicks	Common Murre Chick Density per sq. km	Number of Marbled Murrelets	Marbled Murrelet Density per sq. km
2 June 1998	Kydaka Point to Pillar Point, 400 M AM	20.15	0	0.00	0	0.00	11	2.73
"	Neah Bay to Kydaka Point, 400 M, AM	21.2	9	2.12	0	0.00	26	6.13
2 June 1998	Low Point to Pillar Point, 400 M, PM	21.45	23	5.36	0	0.00	109	25.41
"	Pillar Point to Low Point, 400 M, PM	22.58	0	0.00	0	0.00	30	6.64
3 June 1998	Point of Arches to Skagway Rocks, 700 meters	12.52	97	38.74	0	0.00	2	0.80
"	Skagway Rocks to Neah Bay, nearshore	15.59	43	13.79	0	0.00	2	0.64
"	Point of Arches to Skagway Rocks, 400 meters	16.49	36	10.92	0	0.00	6	1.82
4 June 1998	Kydaka Point to Pillar Point, nearshore	22.06	1	0.23	0	0.00	17	3.85
"	Neah Bay to Kydaka Point, nearshore	19.7	7	1.78	0	0.00	32	8.12
4 June 1998	Kydaka Point to Neah Bay, offshore	19.88	16	4.02	0	0.00	22	5.53
"	Pillar Point to Kydaka Point, offshore	22.63	6	1.33	0	0.00	4	0.88
4 June 1998	Kydaka Point to Pillar Point, offshore	20.46	4	0.98	0	0.00	4	0.98
"	Neah Bay to Kydaka Point, offshore	21.07	16	3.80	0	0.00	17	4.03
4 June 1998	Kydaka Point to Neah Bay, nearshore	19.91	12	3.01	0	0.00	27	6.78
"	Pillar Point to Neah Bay, nearshore	23.05	1	0.22	0	0.00	10	2.17
9 June 1998	Gray's Harbor - Willapa Bay, nearshore	30.31	1185	195.48	0	0.00	4	0.66
"	Klipson Beach - Columbia River, nearshore	20.58	1386	336.73	0	0.00	1	0.24
"	Willapa Bay to Klipson Beach, nearshore	31.44	6078	966.60	0	0.00	0	0.00
9 June 1998	Columbia River - Klipson Beach, offshore	23.19	1671	360.28	0	0.00	0	0.00
"	Klipson Beach - Willapa Bay, offshore	28.47	1215	213.38	0	0.00	0	0.00
"	Willapa Bay - Gray's Harbor, offshore	33.2	1322	199.10	0	0.00	0	0.00
10 June 1998	Gray's Harbor - Willapa Bay, offshore	18.99	1811	476.83	0	0.00	1	0.26
11 June 1998	Gray's Harbor - Willapa Bay, offshore	27.23	892	163.79	0	0.00	0	0.00
"	Klipson Beach - Columbia River, offshore	18.8	2133	567.29	0	0.00	1	0.27
"	Willapa Bay - Klipson Beach, offshore	30.51	412	67.52	0	0.00	1	0.16
11 June 1998	Columbia River - Klipson Beach, nearshore	19.31	6571	1701.45	0	0.00	0	0.00
"	Klipson Beach - Willapa Bay, nearshore	29	1196	206.21	0	0.00	2	0.34
"	Willapa Bay - Gray's Harbor, nearshore	27.01	165	30.54	0	0.00	0	0.00
16 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	15.15	0	0.00	0	0.00	129	42.57
"	Seal/Sail Rock to Kydaka PT., 500 M, AM	14.41	10	3.47	0	0.00	41	14.23
"	Seal/Sail Rock to Kydaka PT., 800 M, AM	13.81	9	3.26	0	0.00	0	0.00

"	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	21.34	16	3.75	0	0.00	74	17.34
16 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, PM	15.72	1	0.32	0	0.00	93	29.58
"	Seal/Sail Rock to Kydaka PT., 500 M, AM	14.43	4	1.39	0	0.00	8	2.77
"	Seal/Sail Rock to Kydaka PT., 800 M, PM	8.75	54	30.86	0	0.00	0	0.00
17 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	15.01	3	1.00	0	0.00	126	41.97
"	Seal/Sail Rock to Kydaka PT., 500 M, AM	14.43	1	0.35	0	0.00	56	19.40
"	Seal/Sail Rock to Kydaka PT., 800 M, AM	13.99	19	6.79	0	0.00	11	3.93
"	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	20.89	20	4.79	0	0.00	70	16.75
17 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, PM	15.06	4	1.33	0	0.00	125	41.50
"	Seal/Sail Rock to Kydaka PT., 500 M, PM	14.5	12	4.14	0	0.00	15	5.17
"	Seal/Sail Rock to Kydaka PT., 800 M, AM	13.98	9	3.22	0	0.00	4	1.43
"	Seal/Sail Rock to Kydaka PT., Zig-Zag, PM	20.36	14	3.44	0	0.00	50	12.28
18 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	15.25	3	0.98	0	0.00	239	78.36
"	Seal/Sail Rock to Kydaka PT., 500 M, AM	14.33	7	2.44	0	0.00	32	11.17
"	Seal/Sail Rock to Kydaka PT., 800 M, AM	14.3	5	1.75	0	0.00	2	0.70
"	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	21.49	17	3.96	0	0.00	40	9.31
18 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, PM	15.11	4	1.32	0	0.00	195	64.53
"	Seal/Sail Rock to Kydaka PT., 500 M, PM	14.64	6	2.05	0	0.00	7	2.39
"	Seal/Sail Rock to Kydaka PT., 200 M, PM	13.77	35	12.71	0	0.00	6	2.18
"	Seal/Sail Rock to Kydaka PT., Zig-Zag, PM	21.28	24	5.64	0	0.00	36	8.46
23 June 1998	Low Point to Pillar Point, nearshore	22.92	16	3.49	0	0.00	302	65.88
"	Observatory Point to Low Point, nearshore	15.67	2	0.64	0	0.00	70	22.34
"	Port Angeles to Observatory Point, nearshore	19.75	25	6.33	0	0.00	111	28.10
"	Pillar Point to Kydaka Point, nearshore	23.38	1	0.21	0	0.00	111	23.74
23 June 1998	Kydaka Point to Pillar Point, offshore	25.8	21	4.07	0	0.00	44	8.53
"	Low Point to Observatory Point, offshore	15.67	1	0.32	0	0.00	15	4.79
"	Observatory Point to Port Angeles, offshore	20.17	15	3.72	0	0.00	45	11.16
"	Pillar Point to Low Point, offshore	19.46	20	5.14	0	0.00	120	30.83
24 June 1998	Low Point to Pillar Point, offshore	22.33	8	1.79	0	0.00	136	30.45
"	Observatory Point to Low Point, offshore	15.73	1	0.32	0	0.00	47	14.94
"	Port Angeles to Observatory Point, offshore	19.48	4	1.03	0	0.00	72	18.48
24 June 1998	Kydaka Point to Pillar Point, nearshore	23.75	5	1.05	0	0.00	130	27.37
"	Low Point to Observatory Point, nearshore	15.89	1	0.31	0	0.00	93	29.26
"	Observatory Point to Port Angeles, nearshore	19.33	0	0.00	0	0.00	271	70.10
"	Pillar Point to Low Point, nearshore	22.68	8	1.76	0	0.00	283	62.39
25 June 1998	Kydaka Point to Pillar Point, nearshore	23.7	2	0.42	0	0.00	167	35.23
"	Low Point to Observatory Point, nearshore	15.99	0	0.00	0	0.00	86	26.89
"	Observatory Point to Port Angeles, nearshore	20.2	6	1.49	0	0.00	183	45.30
"	Pillar Point to Low Point, nearshore	22.77	5	1.10	0	0.00	268	58.85

30 June 1998	Columbia River - Klipson Beach, nearshore	22.62	1955	432.14	0	0.00	2	0.44
"	Gray's Harbor - Willapa Bay, offshore	26.71	229	42.87	0	0.00	4	0.75
"	Klipson Beach - Columbia River, offshore	22.06	5408	1225.75	0	0.00	3	0.68
"	Klipson Beach - Willapa Bay, nearshore	31.41	765	121.78	0	0.00	7	1.11
"	Willapa Bay - Gray's Harbor, nearshore	32.65	28	4.29	0	0.00	0	0.00
"	Willapa Bay - Klipson Beach, offshore	30.15	902	149.59	0	0.00	4	0.66
1 July 1998	Columbia River - Klipson Beach, offshore	22.25	2607	585.84	0	0.00	7	1.57
"	Gray's Harbor - Willapa Bay, nearshore	24.53	368	75.01	0	0.00	0	0.00
"	Klipson Beach - Columbia River, nearshore	21.18	1950	460.34	0	0.00	3	0.71
"	Klipson Beach - Willapa Bay, offshore	29.86	961	160.92	0	0.00	2	0.33
"	Willapa Bay - Gray's Harbor, offshore	25.14	250	49.72	0	0.00	3	0.60
"	Willapa Bay - Klipson Beach, nearshore	32.91	575	87.36	0	0.00	2	0.30
7 July 1998	Outer Coast, Neah Bay south, 1000M, AM	14.35	96	33.45	0	0.00	2	0.70
"	Outer Coast, Neah Bay south, 400M, AM	17.61	310	88.02	0	0.00	20	5.68
"	Outer Coast, Neah Bay south, 700M, AM	12.44	89	35.77	0	0.00	3	1.21
"	Outer Coast, Neah Bay south, Zig-Zag, AM	17.57	75	21.34	0	0.00	0	0.00
"	Outer Coast, Neah Bay south, 1000M, PM	14.22	146	51.34	0	0.00	0	0.00
"	Outer Coast, Neah Bay south, 400M, AM	17.14	126	36.76	0	0.00	11	3.21
"	Outer Coast, Neah Bay south, 700M, PM	12.61	212	84.06	0	0.00	0	0.00
"	Outer Coast, Neah Bay south, Zig-Zag, AM	18.42	111	30.13	0	0.00	0	0.00
"	Kydaka Point to Pillar Point, nearshore	23.18	6	1.29	0	0.00	78	16.82
"	Low Point to Observatory Point, nearshore	17.77	49	13.79	0	0.00	181	50.93
"	Neah Bay to Kydaka Point, nearshore	21.15	149	35.22	0	0.00	192	45.39
"	Observatory Point to Port Angeles, nearshore	19.88	21	5.28	0	0.00	97	24.40
"	Pillar Point to Low Point, nearshore	22.67	21	4.63	0	0.00	420	92.63
9 July 1998	Outer Coast, Neah Bay south, 1000M, PM	13.67	38	13.90	0	0.00	0	0.00
"	Outer Coast, Neah Bay south, 400M, AM	16.61	36	10.84	0	0.00	22	6.62
"	Outer Coast, Neah Bay south, 700M, PM	12.8	42	16.41	0	0.00	5	1.95
"	Outer Coast, Neah Bay south, Zig-Zag, AM	18.43	41	11.12	0	0.00	4	1.09
16 July 1998	Columbia River - Klipson Beach, offshore	22.94	804	175.24	9	1.96	0	0.00
"	Gray's Harbor - Willapa Bay, nearshore	23.15	652	140.82	6	1.30	0	0.00
"	Klipson Beach - Columbia River, nearshore	21.07	981	232.80	14	3.32	1	0.24
"	Klipson Beach - Willapa Bay, offshore	34.69	489	70.48	2	0.29	2	0.29
"	Willapa Bay - Gray's Harbor, offshore	22.86	412	90.11	4	0.87	0	0.00
"	Willapa Bay - Klipson Beach, nearshore	32.47	1695	261.01	14	2.16	2	0.31
21 July 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	14.63	26	8.89	0	0.00	54	18.46
"	Seal/Sail Rock to Kydaka PT., 500 M, AM	13.89	91	32.76	0	0.00	13	4.68
"	Seal/Sail Rock to Kydaka PT., 800 M, PM	14.18	112	39.49	0	0.00	2	0.71
"	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	21.95	194	44.19	0	0.00	31	7.06

21 July 1998	Seal/Sail Rock to Kydaka PT., 200 M, PM	15.56	112	35.99	0	0.00	32	10.28
"	Seal/Sail Rock to Kydaka PT., 500 M, PM	14.48	31	10.70	0	0.00	19	6.56
"	Seal/Sail Rock to Kydaka PT., 800 M, PM	14.57	57	19.56	0	0.00	3	1.03
"	Seal/Sail Rock to Kydaka PT., Zig-Zag, PM	22.57	186	41.21	0	0.00	27	5.98
22 July 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	15.57	22	7.06	0	0.00	43	13.81
"	Seal/Sail Rock to Kydaka PT., 500 M, AM	14.23	94	33.03	0	0.00	5	1.76
"	Seal/Sail Rock to Kydaka PT., 800 M, AM	13.27	181	68.20	0	0.00	4	1.51
"	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	21.5	395	91.86	0	0.00	24	5.58
23 July 1998	Outer Coast, Neah Bay south, 400M, AM	16.4	49	14.94	0	0.00	6	1.83
"	Outer Coast, Neah Bay south, 700M, AM	12.57	31	12.33	0	0.00	3	1.19
"	Outer Coast, Neah Bay south, 1000M, AM	14.19	42	14.80	0	0.00	1	0.35
"	Outer Coast, Neah Bay south, Zig-Zag, AM	16.59	177	53.35	0	0.00	5	1.51
28 July 1998	Columbia River - Klipson Beach, offshore	21.77	1371	314.88	7	1.61	0	0.00
"	Gray's Harbor - Willapa Bay, nearshore	24.98	1222	244.60	13	2.60	0	0.00
"	Klipson Beach - Columbia River, nearshore	21.8	1569	359.86	74	16.97	2	0.46
"	Klipson Beach - Willapa Bay, offshore	26.01	401	77.09	18	3.46	2	0.38
"	Willapa Bay - Gray's Harbor, offshore	41.37	375	45.32	6	0.73	0	0.00
"	Willapa Bay - Klipson Beach, nearshore	30.91	1776	287.29	50	8.09	2	0.32
30 July 1998	Cape Alava to Point of Arches, nearshore	19.15	139	36.29	3	0.78	11	2.87
"	Cape Alava to Quilleute River, offshore	35.12	531	75.60	15	2.14	1	0.14
"	Point of Arches to Cape Alava, offshore	16.16	142	43.94	1	0.31	0	0.00
"	Quilleute River to Cape Alava, nearshore	32.97	215	32.61	4	0.61	1	0.15
11 Aug 1998	Neah Bay to Kydaka Point, nearshore	19.63	4	1.02	0	0.00	10	2.55
11 Aug 1998	Kydaka Point to Pillar Point, nearshore	22.93	1	0.22	0	0.00	7	1.53
12 Aug 1998	Low Point to Observation Point, nearshore	15.95	2	0.63	0	0.00	33	10.34
"	Low Point to Pillar Point, offshore	18.57	8	2.15	0	0.00	5	1.35
"	Observatory Point to Low Point, offshore	7.97	1	0.63	0	0.00	0	0.00
"	Observatory Point to Port Angeles, nearshore	18.15	9	2.48	1	0.28	18	4.96
"	Port Angeles to Observatory Point, offshore	16.22	101	31.13	2	0.62	1	0.31
"	Pillar Point to Low Point, nearshore	22.55	3	0.67	0	0.00	111	24.61
13 Aug 1998	Kydaka Point to Pillar Point, nearshore	20.52	0	0.00	0	0.00	9	2.19
"	Neah Bay to Kydaka Point, nearshore	20.86	12	2.88	0	0.00	11	2.64
"	Pillar Point to Low Point, nearshore	24.46	0	0.00	0	0.00	182	37.20
13 Aug 1998	Low Point to Pillar Point, offshore	22.21	3	0.68	0	0.00	85	19.14
"	Slip Point to Neah Bay, nearshore	30.15	8	1.33	0	0.00	16	2.65
26 Aug 1998	Kydaka Point to Neah Bay, Zig-Zag	25.47	25	4.91	2	0.39	0	0.00
"	Low Point to Pillar Point, Zig-Zag	25.19	41	8.14	2	0.40	17	3.37

"	Observatory Point to Low Point, Zig-Zag	20.29	41	10.10	3	0.74	3	0.74
"	Port Angeles to Observatory Point, Zig-Zag	25.07	41	8.18	3	0.60	4	0.80
"	Pillar Point to Kydaka Point, Zig-Zag	26.71	24	4.49	4	0.75	1	0.19
27 Aug 1998	Cape Alava to Jagged Island, nearshore	31.34	14	2.23	2	0.32	6	0.96
"	Cape Alava to Point of Arches, offshore	11.85	101	42.62	8	3.38	1	0.42
"	Fuca Pillar to Neah Bay, offshore	17.86	117	32.75	3	0.84	0	0.00
"	Fuca Pillar to Point of Arches, nearshore	18.84	22	5.84	1	0.27	3	0.80
"	Jagged Island to Cape Alava, offshore	24.51	43	8.77	9	1.84	0	0.00
"	Neah Bay to Fuca Pillar, nearshore	14.69	39	13.27	4	1.36	3	1.02
"	Point of Arches to Cape Alava, nearshore	13.08	8	3.06	0	0.00	6	2.29
"	Point of Arches to Fuca Pillar, offshore	17.46	33	9.45	4	1.15	4	1.15
28 Aug 1998	Kydaka Point to Pillar Point, Zig-Zag	29.31	17	2.90	1	0.17	0	0.00
"	Low Point to Observatory Point, Zig-Zag	20.28	70	17.26	3	0.74	2	0.49
"	Neah Bay to Kydaka Point, Zig-Zag	25.41	31	6.10	2	0.39	3	0.59
"	Observatory Point to Port Angeles, Zig-Zag	25.49	56	10.98	7	1.37	4	0.78
"	Pillar Point to Low Point, Zig-Zag	38.62	95	12.30	5	0.65	45	5.83
1 Sept 1998	Kydaka Point to Pillar Point, Zig-Zag	19.5	2	0.51	0	0.00	0	0.00
"	Neah Bay to Kydaka Point, Zig-Zag	22.98	9	1.96	1	0.22	6	1.31
1 Sept 1998	Fuca Pillar to Point of Arches, 400 M, PM	46.21	49	5.30	0	0.00	0	0.00
"	Neah Bay to Fuca Pillar, Zig-Zag	10.36	13	6.27	0	0.00	0	0.00
2 Sept 1998	Kydaka Point to Pillar Point, Zig-Zag	1.43	16	55.94	2	6.99	1	3.50
"	Low Point to Observatory Point, Zig-Zag	7.21	4	2.77	0	0.00	0	0.00
"	Pillar Point to Low Point, Zig-Zag	15.41	16	5.19	0	0.00	0	0.00
2 Sept 1998	Low Point to Observatory Point, Zig-Zag	7.46	3	2.01	0	0.00	2	1.34
"	Observatory Point to Port Angeles, Zig-Zag	20.75	3	0.72	0	0.00	2	0.48
	Total Kilometers Surveyed:	3501.96						

Table 5. Date, geographic location, and length (kilometers) of transects conducted in the winter of 1998-1999 and associated densities of Common Murres and Marbled Murrelets along the Strait of Juan de Fuca.

Survey Date	Transect Location	Distance from shore (m)	Time of Day (AM or PM)	Transect Length (Km)	Number of Common Murres Observed	Density of Common Murres per Km^2	Number of Marbled Murrelets Observed	Density of Marbled Murrelets per Km^2
17 February 1999	Seal/Sail Rock to Pillar Point	200	AM	15.68	0	0.00	1	0.32
17 February 1999	Seal/Sail Rock to Pillar Point	200	PM	16.81	4	1.19	0	0.00
17 February 1999	Seal/Sail Rock to Pillar Point	500	AM	14.46	0	0.00	0	0.00
17 February 1999	Seal/Sail Rock to Pillar Point	800	PM	13.97	8	2.86	0	0.00
17 February 1999	Seal/Sail Rock to Pillar Point	Zig-Zag	PM	24.86	15	3.02	4	0.80
19 February 1999	Seal/Sail Rock to Pillar Point	200	PM	18.28	0	0.00	3	0.82
19 February 1999	Seal/Sail Rock to Pillar Point	500	AM	14.59	1	0.34	3	1.03
19 February 1999	Seal/Sail Rock to Pillar Point	800	AM	13.82	43	15.56	1	0.36
19 February 1999	Seal/Sail Rock to Pillar Point	1200	AM	13.53	14	5.17	1	0.37
19 February 1999	Seal/Sail Rock to Pillar Point	Zig-Zag	AM	24.11	24	4.98	8	1.66
19 February 1999	Seal/Sail Rock to Pillar Point	800	PM	13.90	11	3.96	0	0.00
19 February 1999	Seal/Sail Rock to Pillar Point	1200	PM	13.27	43	16.20	1	0.38
19 February 1999	Seal/Sail Rock to Pillar Point	Zig-Zag	PM	24.62	33	6.70	1	0.20
04 March 1999	Seal/Sail Rock to Pillar Point	200	AM	15.42	0	0.00	4	1.30
04 March 1999	Seal/Sail Rock to Pillar Point	500	AM	14.47	56	19.35	1	0.35
04 March 1999	Seal/Sail Rock to Pillar Point	Zig-Zag	AM	26.19	28	5.35	6	1.15
04 March 1999	Seal/Sail Rock to Pillar Point	200	PM	16.78	0	0.00	5	1.49
04 March 1999	Seal/Sail Rock to Pillar Point	1200	AM	16.74	12	3.58	0	0.00
04 March 1999	Seal/Sail Rock to Pillar Point	500	PM	7.21	0	0.00	1	0.69
05 March 1999	Seal/Sail Rock to Pillar Point	1200	AM	13.26	20	7.54	0	0.00
05 March 1999	Seal/Sail Rock to Pillar Point	200	PM	21.24	0	0.00	12	2.82
05 March 1999	Seal/Sail Rock to Pillar Point	200	AM	15.25	1	0.33	14	4.59
05 March 1999	Seal/Sail Rock to Pillar Point	500	PM	23.97	49	10.22	2	0.42
05 March 1999	Seal/Sail Rock to Pillar Point	500	PM	15.19	6	1.97	1	0.33
05 March 1999	Seal/Sail Rock to Pillar Point	800	AM	14.43	33	11.43	1	0.35
05 March 1999	Seal/Sail Rock to Pillar Point	800	PM	22.60	29	6.42	0	0.00
05 March 1999	Seal/Sail Rock to Pillar Point	Zig-Zag	AM	23.87	63	13.20	7	1.47
10 March 1999	Seal/Sail Rock to Pillar Point	1200	AM	13.00	44	16.92	1	0.38
10 March 1999	Seal/Sail Rock to Pillar Point	200	AM	14.72	0	0.00	2	0.68
10 March 1999	Seal/Sail Rock to Pillar Point	500	AM	15.29	0	0.00	1	0.33
10 March 1999	Seal/Sail Rock to Pillar Point	800	AM	13.65	15	5.49	0	0.00
10 March 1999	Seal/Sail Rock to Pillar Point	Zig-Zag	AM	25.13	14	2.79	0	0.00
10 March 1999	Seal/Sail Rock to Pillar Point	200	PM	22.36	0	0.00	2	0.45
10 March 1999	Seal/Sail Rock to Pillar Point	500	PM	20.66	1	0.24	0	0.00
10 March 1999	Seal/Sail Rock to Pillar Point	Zig-Zag	PM	31.18	35	5.61	5	0.80
11 March 1999	Seal/Sail Rock to Pillar Point	1200	AM	13.32	69	25.90	2	0.75
11 March 1999	Seal/Sail Rock to Pillar Point	200	AM	15.89	0	0.00	0	0.00
11 March 1999	Seal/Sail Rock to Pillar Point	800	AM	13.99	58	20.73	0	0.00
17 March 1999	Seal/Sail Rock to Pillar Point	200	AM	14.95	0	0.00	0	0.00
17 March 1999	Seal/Sail Rock to Pillar Point	500	AM	14.64	3	1.02	0	0.00
17 March 1999	Seal/Sail Rock to Pillar Point	800	AM	14.00	1	0.36	1	0.36
17 March 1999	Seal/Sail Rock to Pillar Point	1200	PM	13.23	5	1.89	0	0.00
18 March 1999	Seal/Sail Rock to Pillar Point	1200	AM	13.19	13	4.93	0	0.00
18 March 1999	Seal/Sail Rock to Pillar Point	500	AM	14.40	0	0.00	0	0.00
18 March 1999	Seal/Sail Rock to Pillar Point	800	AM	13.99	2	0.71	0	0.00
18 March 1999	Seal/Sail Rock to Pillar Point	Zig-Zag	AM	23.26	67	14.40	2	0.43

Total kilometers surveyed: 789.37

Table 6. Dates, locations and lengths of transects used in statistical power analyses of Marbled Murrelet density in relation to location, year, season, time of day and distance to shore.

Survey Date	Location of transect	Strait of Juan de Fuca or outer coast	Tran-sect length (km)	Number of Common Murres	Common Murre Density per km^2	Number of Marbled Murrelets	Common Murre Density per km^2
01 August 1995	Neah Bay to Pillar Point, 200 M, AM	S	49.08	0	0.00	23	2.34
01 August 1995	Neah Bay to Pillar Point, 400 M, PM	S	42.21	0	0.00	14	1.66
01 August 1995	Neah Bay to Pillar Point, 800 M, AM	S	41.64	0	0.00	4	0.48
01 August 1995	Neah Bay to Pillar Point, 1200 M, AM	S	42.18	0	0.00	1	0.12
02 August 1995	Neah Bay to Pillar Point, 200 M, AM (Partial)	S	16.43	0	0.00	12	3.65
02 August 1995	Neah Bay to Pillar Point, 800 M, PM	S	43.08	0	0.00	6	0.70
08 August 1995	Neah Bay to Pillar Point, 200 M, PM (Partial)	S	29.20	0	0.00	1	0.17
09 August 1995	Neah Bay to Sekiu, 200 M, AM	S	35.35	0	0.00	40	5.66
09 August 1995	Neah Bay to Sekiu, 400 M, PM	S	34.21	0	0.00	40	5.85
09 August 1995	Neah Bay to Sekiu, 800 M, PM	S	30.99	0	0.00	5	0.81
09 August 1995	Neah Bay to Sekiu, 1200 M, AM	S	28.77	0	0.00	0	0.00
10 August 1995	Neah Bay to Sekiu, 200 M, AM	S	32.94	0	0.00	17	2.58
10 August 1995	Neah Bay to Sekiu, 200 M, PM	S	34.64	0	0.00	27	3.90
10 August 1995	Neah Bay to Sekiu, 400 M, AM	S	31.54	0	0.00	19	3.01
10 August 1995	Neah Bay to Sekiu, 800 M, PM	S	29.40	0	0.00	0	0.00
10 August 1995	Neah Bay to Sekiu, 1200 M, PM	S	29.34	0	0.00	0	0.00
11 August 1995	Neah Bay to Sekiu, 400 M, AM (length?)	S	56.29	0	0.00	28	2.49
11 August 1995	Neah Bay to Sekiu, 800 M, AM (Partial)	S	17.72	0	0.00	7	1.98
20 August 1995	Tatoosh Island to Cape Alava, 400 M, PM	OC	26.24	0	0.00	11	2.10
21 August 1995	Tatoosh Island to Cape Alava, 400 M, PM	OC	26.05	0	0.00	12	2.30
22 August 1995	Tatoosh Island to Cape Alava, 400 M, AM	OC	26.73	0	0.00	20	3.74
22 August 1995	Tatoosh Island to Cape Alava, 1200 M, PM	OC	25.89	0	0.00	0	0.00
23 August 1995	Tatoosh Island to Cape Alava, 400 M, AM	OC	26.90	0	0.00	19	3.53
23 August 1995	Tatoosh Island to Cape Alava, 1200 M, AM	OC	26.05	0	0.00	0	0.00
23 August 1995	Tatoosh Island to Cape Alava, 1200 M, PM	OC	25.88	0	0.00	0	0.00
24 August 1995	Tatoosh Island to Cape Alava, 1200 M, AM	OC	28.79	0	0.00	0	0.00
12 Mar 1996	Sekiu to Neah Bay	S	31.51	0	0.00	7	0.98
12 Mar 1996	Sekiu to Neah Bay	S	29.83	48	17.27	5	1.80
12 Mar 1996	Sekiu to Neah Bay	S	27.00	21	6.67	7	2.22
12 Mar 1996	Sekiu to Neah Bay	S	28.08	85	28.07	0	0.00
13 Mar 1996	Sekiu to Neah Bay	S	32.40	4	1.36	33	11.19
13 Mar 1996	Sekiu to Neah Bay	S	31.55	0	0.00	21	4.37
13 Mar 1996	Sekiu to Neah Bay	S	26.48	7	2.17	16	4.95
13 Mar 1996	Sekiu to Neah Bay	S	27.54	11	3.53	1	0.32
14 Mar 1996	Sekiu to Neah Bay	S	31.69	0	0.00	40	8.72
14 Mar 1996	Sekiu to Neah Bay	S	29.42	0	0.00	11	3.35
14 Mar 1996	Sekiu to Neah Bay	S	26.40	117	36.79	0	0.00
14 Mar 1996	Sekiu to Neah Bay	S	26.32	16	4.96	5	1.55
23 May 1996	Sekiu to Neah Bay	S	13.95	19	6.74	3	1.06
23 May 1996	Sekiu to Neah Bay	S	14.08	23	26.20	9	10.25
23 May 1996	Sekiu to Neah Bay	S	14.29	6	2.39	5	1.99
23 May 1996	Sekiu to Neah Bay	S	14.28	9	3.10	7	2.41
23 May 1996	Sekiu to Neah Bay	S	15.07	40	8.45	3	0.63
23 May 1996	Sekiu to Neah Bay	S	14.98	9	4.76	2	1.06

23 May 1996	Sekiu to Neah Bay	S	18.14	46	15.60	21	7.12
23 May 1996	Sekiu to Neah Bay	S	18.32	8	2.90	5	1.81
24 July 1996	Seal/Sail Rock to Kydaka Point	S	13.79	8	2.85	2	0.71
24 July 1996	Seal/Sail Rock to Kydaka Point	S	14.24	18	6.47	0	0.00
24 July 1996	Seal/Sail Rock to Kydaka Point	S	15.03	12	4.29	0	0.00
24 July 1996	Seal/Sail Rock to Kydaka Point	S	17.67	17	6.23	1	0.37
24 July 1996	Seal/Sail Rock to Kydaka Point	S	17.89	14	5.50	0	0.00
25 July 1996	Seal/Sail Rock to Kydaka Point	S	11.59	62	25.16	18	7.31
25 July 1996	Seal/Sail Rock to Kydaka Point	S	14.24	30	11.48	4	1.53
25 July 1996	Seal/Sail Rock to Kydaka Point	S	14.32	12	4.47	1	0.37
25 July 1996	Seal/Sail Rock to Kydaka Point	S	15.00	16	5.35	0	0.00
25 July 1996	Seal/Sail Rock to Kydaka Point	S	18.00	18	6.27	7	2.44
25 July 1996	Seal/Sail Rock to Kydaka Point	S	17.88	33	10.08	3	0.92
26 July 1996	Seal/Sail Rock to Kydaka Point	S	13.20	16	7.35	13	5.97
13 February 1997	Neah Bay to Slip Point	S	31.40	0	0.00	44	17.52
13 February 1997	Neah Bay to Slip Point	S	30.10	0	0.00	9	3.47
13 February 1997	Neah Bay to Slip Point	S	29.69	0	0.00	1	0.24
13 February 1997	Neah Bay to Slip Point	S	27.36	0	0.00	2	0.80
11 June 1997	Fuca Pillar to Point of Arches	OC	10.42	39	18.71	2	0.53
11 June 1997	Fuca Pillar to Point of Arches	OC	17.28	140	40.51	5	0.62
12 June 1997	Fuca Pillar to Point of Arches	OC	16.98	53	15.61	8	2.56
12 June 1997	Fuca Pillar to Point of Arches	OC	16.73	73	21.82	10	2.29
12 June 1997	Fuca Pillar to Point of Arches	OC	12.52	107	42.73	3	0.35
12 June 1997	Fuca Pillar to Point of Arches	OC	12.27	78	31.78	3	0.47
12 June 1997	Fuca Pillar to Point of Arches	OC	16.06	81	25.22	6	1.19
12 June 1997	Fuca Pillar to Point of Arches	OC	13.91	38	13.66	0	0.00
12 June 1997	Fuca Pillar to Point of Arches	OC	15.74	37	11.75	7	2.98
12 June 1997	Fuca Pillar to Point of Arches	OC	16.41	119	36.26	0	0.00
24 June 1997	Fuca Pillar to Point of Arches	OC	16.53	102	30.85	6	0.97
24 June 1997	Fuca Pillar to Point of Arches	OC	17.08	72	21.08	17	4.03
24 June 1997	Fuca Pillar to Point of Arches	OC	12.46	44	17.66	2	0.57
24 June 1997	Fuca Pillar to Point of Arches	OC	12.81	129	50.35	3	0.30
24 June 1997	Fuca Pillar to Point of Arches	OC	14.57	138	47.36	0	0.00
24 June 1997	Fuca Pillar to Point of Arches	OC	16.10	109	33.85	0	0.00
24 June 1997	Fuca Pillar to Point of Arches	OC	17.41	113	32.45	2	0.31
24 June 1997	Fuca Pillar to Point of Arches	OC	19.21	144	37.48	2	0.27
25 June 1997	Fuca Pillar to Point of Arches	OC	16.31	111	34.03	1	0.15
25 June 1997	Fuca Pillar to Point of Arches	OC	12.64	29	11.47	1	0.44
25 June 1997	Fuca Pillar to Point of Arches	OC	14.74	244	82.77	0	0.00
25 June 1997	Fuca Pillar to Point of Arches	OC	17.93	99	27.61	2	0.36
09 July 1997	Fuca Pillar to Point of Arches	OC	18.08	240	66.37	6	0.45
09 July 1997	Fuca Pillar to Point of Arches	OC	16.26	256	78.72	27	1.71
09 July 1997	Fuca Pillar to Point of Arches	OC	9.42	65	34.50	11	1.59
09 July 1997	Fuca Pillar to Point of Arches	OC	10.59	130	61.38	5	0.41
09 July 1997	Fuca Pillar to Point of Arches	OC	14.07	144	51.17	12	1.17
09 July 1997	Fuca Pillar to Point of Arches	OC	14.22	191	67.16	3	0.22
09 July 1997	Fuca Pillar to Point of Arches	OC	16.04	277	86.35	15	0.87
09 July 1997	Fuca Pillar to Point of Arches	OC	17.00	224	65.88	14	1.06
10 July 1997	Fuca Pillar to Point of Arches	OC	11.44	160	69.93	4	0.29
10 July 1997	Fuca Pillar to Point of Arches	OC	15.97	92	28.80	27	4.69

10 July 1997	Fuca Pillar to Point of Arches	OC	13.03	103	39.52	3	0.38
10 July 1997	Fuca Pillar to Point of Arches	OC	14.04	171	60.90	6	0.49
10 July 1997	Fuca Pillar to Point of Arches	OC	13.97	93	33.29	12	1.80
10 July 1997	Fuca Pillar to Point of Arches	OC	16.82	160	47.56	17	1.79
22 July 1997	Seal Rock to Kydaka Point	S	14.48	1	0.35	30	434.40
22 July 1997	Seal Rock to Kydaka Point	S	14.40	11	3.82	8	10.47
22 July 1997	Seal Rock to Kydaka Point	S	14.14	27	9.55	9	4.71
22 July 1997	Seal Rock to Kydaka Point	S	14.74	9	3.05	1	1.64
22 July 1997	Seal Rock to Kydaka Point	S	14.39	31	10.77	3	1.39
22 July 1997	Seal Rock to Kydaka Point	S	14.28	34	11.90	1	0.42
22 July 1997	Seal Rock to Kydaka Point	S	17.30	52	15.03	0	0.00
22 July 1997	Seal Rock to Kydaka Point	S	16.72	52	15.55	12	3.86
23 July 1997	Seal Rock to Kydaka Point	S	14.68	324	110.35	9	0.41
23 July 1997	Seal Rock to Kydaka Point	S	14.10	69	24.47	1	0.20
23 July 1997	Seal Rock to Kydaka Point	S	14.10	256	90.78	2	0.11
23 July 1997	Seal Rock to Kydaka Point	S	21.03	131	31.15	2	0.32
24 July 1997	Seal Rock to Kydaka Point	S	15.04	41	13.63	19	6.97
24 July 1997	Seal Rock to Kydaka Point	S	15.03	14	4.66	23	24.69
24 July 1997	Seal Rock to Kydaka Point	S	14.28	159	55.67	5	0.45
24 July 1997	Seal Rock to Kydaka Point	S	14.33	51	17.79	4	1.12
24 July 1997	Seal Rock to Kydaka Point	S	13.93	42	15.08	0	0.00
24 July 1997	Seal Rock to Kydaka Point	S	14.00	29	10.36	0	0.00
24 July 1997	Seal Rock to Kydaka Point	S	19.68	208	52.85	16	1.51
24 July 1997	Seal Rock to Kydaka Point	S	20.78	183	44.03	8	0.91
25 July 1997	Seal Rock to Kydaka Point	S	14.05	115	40.93	2	0.24
19 Aug 1997	Seal Rock to Kydaka Point	S	14.63	40	13.67	13	4.75
19 Aug 1997	Seal Rock to Kydaka Point	S	15.52	17	5.48	1	0.91
19 Aug 1997	Seal Rock to Kydaka Point	S	14.67	40	13.63	1	0.37
19 Aug 1997	Seal Rock to Kydaka Point	S	18.98	58	15.28	2	0.65
20 Aug 1997	Seal Rock to Kydaka Point	S	14.99	31	10.34	1	0.48
20 Aug 1997	Seal Rock to Kydaka Point	S	20.69	67	16.19	4	1.24
25 Aug 1997	Seal Rock to Kydaka Point	S	14.99	55	18.35	6	1.64
25 Aug 1997	Seal Rock to Kydaka Point	S	14.87	26	8.74	3	1.72
25 Aug 1997	Seal Rock to Kydaka Point	S	14.17	10	3.53	0	0.00
25 Aug 1997	Seal Rock to Kydaka Point	S	13.73	25	9.10	0	0.00
25 Aug 1997	Seal Rock to Kydaka Point	S	13.89	19	6.84	0	0.00
25 Aug 1997	Seal Rock to Kydaka Point	S	20.60	25	6.07	3	2.47
22 January 1998	Seal/Sail Rock to Kydaka Point, 200 M, AM	S	15.52	1	0.32	10	3.22
22 January 1998	Seal/Sail Rock to Kydaka Point, 500 M, AM	S	15.11	10	3.31	10	3.31
27 January 1998	Seal/Sail Rock to Kydaka Point, 200 M, AM	S	15.98	1	0.31	5	1.56
27 January 1998	Seal/Sail Rock to Kydaka Point, 500 M, PM	S	13.98	29	10.37	10	3.58
27 January 1998	Seal/Sail Rock to Kydaka Point, 800 M, AM	S	14.07	20	7.11	1	0.36
27 January 1998	Seal/Sail Rock to Kydaka Point, Zig-Zag, AM	S	20.62	24	5.82	10	2.42
29 January 1998	Seal/Sail Rock to Kydaka Point, 200 M, AM	S	15.22	1	0.33	32	10.51
29 January 1998	Seal/Sail Rock to Kydaka Point, 200 M, PM	S	15.42	2	0.65	33	10.70
29 January 1998	Seal/Sail Rock to Kydaka Point, 500 M, AM	S	14.62	5	1.71	19	6.50
29 January 1998	Seal/Sail Rock to Kydaka Point, 500 M, PM	S	14.54	8	2.75	48	16.51
29 January 1998	Seal/Sail Rock to Kydaka Point, 800 M, AM	S	14.08	19	6.75	7	2.49
29 January 1998	Seal/Sail Rock to Kydaka Point 800 M, PM	S	13.98	24	8.58	1	0.36
29 January 1998	Seal/Sail Rock to Kydaka Point, Zig-Zag, AM	S	21.33	9	2.11	26	6.09

29 January 1998	Seal/Sail Rock to Kydaka Point, Zig-Zag, PM	S	21.81	58	13.30	28	6.42
04 February 1998	Seal/Sail Rock to Kydaka Point, 200 M, PM	S	15.65	0	0.00	5	1.60
04 February 1998	Seal/Sail Rock to Kydaka Point, Zig-Zag, PM	S	21.13	1	0.24	11	2.60
05 February 1998	Seal/Sail Rock to Kydaka Point, 200 M, PM	S	15.75	0	0.00	8	2.54
05 February 1998	Seal/Sail Rock to Kydaka Point, 500 M, AM	S	15.13	0	0.00	10	3.30
05 February 1998	Seal/Sail Rock to Kydaka Point, 500 M, PM	S	15.14	0	0.00	21	6.94
05 February 1998	Seal/Sail Rock to Kydaka Point, 800 M, AM	S	13.90	10	3.60	0	0.00
05 February 1998	Seal/Sail Rock to Kydaka Point, 800 M, PM	S	14.74	1	0.34	2	0.68
05 February 1998	Seal/Sail Rock to Kydaka Point, Zig-Zag, AM	S	35.80	6	0.84	4	0.56
05 February 1998	Seal/Sail Rock to Kydaka Point, Zig-Zag, PM	S	24.03	0	0.00	11	2.29
11 February 1998	Seal/Sail Rock to Kydaka Point, 200 M, PM	S	15.90	1	0.31	0	0.00
11 February 1998	Seal/Sail Rock to Kydaka Point, 200 M, PM	S	16.41	3	0.91	3	0.91
11 February 1998	Seal/Sail Rock to Kydaka Point, 500 M, AM	S	16.15	1	0.31	20	6.19
11 February 1998	Seal/Sail Rock to Kydaka Point, 500 M, PM	S	16.12	4	1.24	25	7.75
11 February 1998	Seal/Sail Rock to Kydaka Point, 800 M, AM	S	15.57	6	1.93	17	5.46
11 February 1998	Seal/Sail Rock to Kydaka Point, 800 M, PM	S	14.74	1	0.34	2	0.68
11 February 1998	Seal/Sail Rock to Kydaka Point, Zig-Zag, AM	S	22.93	14	3.05	26	5.67
11 February 1998	Seal/Sail Rock to Kydaka Point, Zig-Zag, PM	S	23.66	28	5.92	25	5.28
17 February 1998	Fuca Pillar to Point of Arches (Partial), 700 M, AM	OC	9.45	152	80.42	9	4.76
17 February 1998	Fuca Pillar to Point of Arches, 700 M, AM	OC	12.55	32	12.75	7	2.79
17 February 1998	Fuca Pillar to Point of Arches, 1000 M, AM	OC	14.10	76	26.95	12	4.26
18 February 1998	Kydaka Point to Waadah Island, 1000 M, PM	OC	4.39	1	1.14	2	2.28
24 February 1998	Fuca Pillar to Point of Arches, 200 M, AM	OC	12.72	0	0.00	10	3.93
24 February 1998	Fuca Pillar to Point of Arches, 700 M, AM	OC	13.90	0	0.00	23	8.27
24 February 1998	Fuca Pillar to Point of Arches, 700 M, AM	OC	13.07	1	0.38	23	8.80
24 February 1998	Fuca Pillar to Point of Arches, 700 M, PM	OC	13.42	2	0.75	11	4.10
24 February 1998	Fuca Pillar to Point of Arches, 700 M, PM	OC	12.32	10	4.06	16	6.49
24 February 1998	Fuca Pillar to Point of Arches, 1000 M, AM	OC	13.78	0	0.00	14	5.08
24 February 1998	Fuca Pillar to Point of Arches, 1000 M, AM	OC	14.50	0	0.00	13	4.48
24 February 1998	Fuca Pillar to Point of Arches, 1000 M, PM	OC	14.04	1	0.36	27	9.62
24 February 1998	Fuca Pillar to Point of Arches, 1000 M, PM	OC	14.00	6	2.14	14	5.00
24 February 1998	Fuca Pillar to Point of Arches, 1000 M, PM	OC	13.65	0	0.00	17	6.23
25 February 1998	Fuca Pillar to Point of Arches, 700 M, AM	OC	10.88	4	1.84	15	6.89
25 February 1998	Fuca Pillar to Point of Arches, 700 M, PM	OC	12.56	0	0.00	19	7.56
25 February 1998	Fuca Pillar to Point of Arches, 700 M, PM	OC	12.98	2	0.77	17	6.55
25 February 1998	Fuca Pillar to Point of Arches, 1000 M, AM	OC	14.36	3	1.04	15	5.22
25 February 1998	Fuca Pillar to Point of Arches, 1000 M, PM	OC	14.96	2	0.67	14	4.68
25 February 1998	Fuca Pillar to Point of Arches, 1000 M, PM	OC	16.37	10	3.05	6	1.83
02 June 1998	Neah Bay to Kydaka Point, 500 M, AM	S	21.20	9	2.12	26	6.13
03 June 1998	Point of Arches to Skagway Rocks, 500 M, AM	OC	16.49	36	10.92	6	1.82
03 June 1998	Point of Arches to Skagway Rocks, 700 M, PM	OC	12.52	97	38.74	2	0.80
04 June 1998	Neah Bay to Kydaka Point, 500 M, PM	S	19.70	7	1.78	32	8.12
04 June 1998	Kydaka Point to Neah Bay, 500 M, PM	S	19.91	12	3.01	27	6.78
04 June 1998	Kydaka Point to Neah Bay, 1200 M, AM	S	19.88	16	4.02	22	5.53
04 June 1998	Neah Bay to Kydaka Point, 1200 M, PM	S	21.07	16	3.80	17	4.03
16 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	S	15.15	0	0.00	129	42.57
16 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, PM	S	15.72	1	0.32	93	29.58
16 June 1998	Seal/Sail Rock to Kydaka PT., 500 M, AM	S	14.43	4	1.39	8	2.77
16 June 1998	Seal/Sail Rock to Kydaka PT., 500 M, AM	S	14.41	10	3.47	41	14.23
16 June 1998	Seal/Sail Rock to Kydaka PT., 800 M, AM	S	13.81	9	3.26	0	0.00

16 June 1998	Seal/Sail Rock to Kydaka PT., 800 M, PM	S	8.75	54	30.86	0	0.00
16 June 1998	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	S	21.34	16	3.75	74	17.34
17 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	S	15.01	3	1.00	126	41.97
17 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, PM	S	15.06	4	1.33	125	41.50
17 June 1998	Seal/Sail Rock to Kydaka PT., 500 M, AM	S	14.43	1	0.35	56	19.40
17 June 1998	Seal/Sail Rock to Kydaka PT., 500 M, PM	S	14.50	12	4.14	15	5.17
17 June 1998	Seal/Sail Rock to Kydaka PT., 800 M, AM	S	13.99	19	6.79	11	3.93
17 June 1998	Seal/Sail Rock to Kydaka PT., 800 M, AM	S	13.98	9	3.22	4	1.43
17 June 1998	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	S	20.89	20	4.79	70	16.75
17 June 1998	Seal/Sail Rock to Kydaka PT., Zig-Zag, PM	S	20.36	14	3.44	50	12.28
18 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	S	15.25	3	0.98	239	78.36
18 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, PM	S	15.11	4	1.32	195	64.53
18 June 1998	Seal/Sail Rock to Kydaka PT., 200 M, PM	S	13.77	35	12.71	6	2.18
18 June 1998	Seal/Sail Rock to Kydaka PT., 500 M, AM	S	14.33	7	2.44	32	11.17
18 June 1998	Seal/Sail Rock to Kydaka PT., 500 M, PM	S	14.64	6	2.05	7	2.39
18 June 1998	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	S	21.49	17	3.96	40	9.31
18 June 1998	Seal/Sail Rock to Kydaka PT., Zig-Zag, PM	S	21.28	24	5.64	36	8.46
07 July 1998	Outer Coast, Neah Bay south, 400M, AM	OC	17.61	310	88.02	20	5.68
07 July 1998	Outer Coast, Neah Bay south, 400M, AM	OC	17.14	126	36.76	11	3.21
07 July 1998	Outer Coast, Neah Bay south, 700M, AM	OC	12.44	89	35.77	3	1.21
07 July 1998	Outer Coast, Neah Bay south, 700M, PM	OC	12.61	212	84.06	0	0.00
07 July 1998	Outer Coast, Neah Bay south, 1000M, AM	OC	14.35	96	33.45	2	0.70
07 July 1998	Outer Coast, Neah Bay south, 1000M, PM	OC	14.22	146	51.34	0	0.00
07 July 1998	Outer Coast, Neah Bay south, Zig-Zag, AM	OC	17.57	75	21.34	0	0.00
07 July 1998	Outer Coast, Neah Bay south, Zig-Zag, AM	OC	18.42	111	30.13	0	0.00
09 July 1998	Outer Coast, Neah Bay south, 400M, AM	OC	16.61	36	10.84	22	6.62
09 July 1998	Outer Coast, Neah Bay south, 700M, PM	OC	12.80	42	16.41	5	1.95
09 July 1998	Outer Coast, Neah Bay south, 1000M, PM	OC	13.67	38	13.90	0	0.00
09 July 1998	Outer Coast, Neah Bay south, Zig-Zag, AM	OC	18.43	41	11.12	4	1.09
18 July 1998	Seal/Sail Rock to Kydaka PT., 800 M, AM	S	14.30	5	1.75	2	0.70
21 July 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	S	14.63	26	8.89	54	18.46
21 July 1998	Seal/Sail Rock to Kydaka PT., 200 M, PM	S	15.56	112	35.99	32	10.28
21 July 1998	Seal/Sail Rock to Kydaka PT., 500 M, AM	S	13.89	91	32.76	13	4.68
21 July 1998	Seal/Sail Rock to Kydaka PT., 500 M, PM	S	14.48	31	10.70	19	6.56
21 July 1998	Seal/Sail Rock to Kydaka PT., 800 M, PM	S	14.57	57	19.56	3	1.03
21 July 1998	Seal/Sail Rock to Kydaka PT., 800 M, PM	S	14.18	112	39.49	2	0.71
21 July 1998	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	S	21.95	194	44.19	31	7.06
21 July 1998	Seal/Sail Rock to Kydaka PT., Zig-Zag, PM	S	22.57	186	41.21	27	5.98
22 July 1998	Seal/Sail Rock to Kydaka PT., 200 M, AM	S	15.57	22	7.06	43	13.81
22 July 1998	Seal/Sail Rock to Kydaka PT., 500 M, AM	S	14.23	94	33.03	5	1.76
22 July 1998	Seal/Sail Rock to Kydaka PT., 800 M, AM	S	13.27	181	68.20	4	1.51
22 July 1998	Seal/Sail Rock to Kydaka PT., Zig-Zag, AM	S	21.50	395	91.86	24	5.58
23 July 1998	Outer Coast, Neah Bay south, 400M, AM	OC	16.40	49	14.94	6	1.83
23 July 1998	Outer Coast, Neah Bay south, 700M, AM	OC	12.57	31	12.33	3	1.19
23 July 1998	Outer Coast, Neah Bay south, 1000M, AM	OC	14.19	42	14.80	1	0.35
23 July 1998	Outer Coast, Neah Bay south, Zig-Zag, AM	OC	16.59	177	53.35	5	1.51
11 Aug 1998	Neah Bay to Kydaka Point, 500M, AM	S	19.63	4	1.02	10	2.55
13 Aug 1998	Neah Bay to Kydaka Point, 500M, AM	S	20.86	12	2.88	11	2.64
26 Aug 1998	Kydaka Point to Neah Bay, Zig-Zag, PM	S	25.47	25	4.91	0	0.00
27 Aug 1998	Fuca Pillar to Point of Arches, 400 M, AM	OC	18.84	22	5.84	3	0.80

27 Aug 1998	Point of Arches to Fuca Pillar, 1000 M, PM	OC	17.46	33	9.45	4	1.15
28 Aug 1998	Neah Bay to Kydaka Point, Zig-Zag, AM	S	25.41	31	6.10	3	0.59
01 Sept 1998	Fuca Pillar to Point of Arches, 400 M, PM	OC	46.21	49	5.30	0	0.00
01 Sept 1998	Neah Bay to Kydaka Point, Zig-Zag, AM	S	22.98	9	1.96	6	1.31
17 February 1999	Seal/Sail Rock to Kydaka Point	S	15.68	0	0.00	1	0.32
17 February 1999	Seal/Sail Rock to Kydaka Point	S	16.81	4	1.19	0	0.00
17 February 1999	Seal/Sail Rock to Kydaka Point	S	14.46	0	0.00	0	0.00
17 February 1999	Seal/Sail Rock to Kydaka Point	S	13.97	8	2.86	0	0.00
17 February 1999	Seal/Sail Rock to Kydaka Point	S	24.86	15	3.02	4	0.80
19 February 1999	Seal/Sail Rock to Kydaka Point	S	18.28	0	0.00	3	0.82
19 February 1999	Seal/Sail Rock to Kydaka Point	S	14.59	1	0.34	3	1.03
19 February 1999	Seal/Sail Rock to Kydaka Point	S	13.82	43	15.56	1	0.36
19 February 1999	Seal/Sail Rock to Kydaka Point	S	13.53	14	5.17	1	0.37
19 February 1999	Seal/Sail Rock to Kydaka Point	S	24.11	24	4.98	8	1.66
19 February 1999	Seal/Sail Rock to Kydaka Point	S	13.90	11	3.96	0	0.00
19 February 1999	Seal/Sail Rock to Kydaka Point	S	13.27	43	16.20	1	0.38
19 February 1999	Seal/Sail Rock to Kydaka Point	S	24.62	33	6.70	1	0.20
04 March 1999	Seal/Sail Rock to Kydaka Point	S	15.42	0	0.00	4	1.30
04 March 1999	Seal/Sail Rock to Kydaka Point	S	14.47	56	19.35	1	0.35
04 March 1999	Seal/Sail Rock to Kydaka Point	S	26.19	28	5.35	6	1.15
04 March 1999	Seal/Sail Rock to Kydaka Point	S	16.78	0	0.00	5	1.49
04 March 1999	Seal/Sail Rock to Kydaka Point	S	16.74	12	3.58	0	0.00
04 March 1999	Seal/Sail Rock to Kydaka Point	S	7.21	0	0.00	1	0.69
05 March 1999	Seal/Sail Rock to Kydaka Point	S	13.26	20	7.54	0	0.00
05 March 1999	Seal/Sail Rock to Kydaka Point	S	21.24	0	0.00	12	2.82
05 March 1999	Seal/Sail Rock to Kydaka Point	S	15.25	1	0.33	14	4.59
05 March 1999	Seal/Sail Rock to Kydaka Point	S	23.97	49	10.22	2	0.42
05 March 1999	Seal/Sail Rock to Kydaka Point	S	15.19	6	1.97	1	0.33
05 March 1999	Seal/Sail Rock to Kydaka Point	S	14.43	33	11.43	1	0.35
05 March 1999	Seal/Sail Rock to Kydaka Point	S	22.60	29	6.42	0	0.00
05 March 1999	Seal/Sail Rock to Kydaka Point	S	23.87	63	13.20	7	1.47
10 March 1999	Seal/Sail Rock to Kydaka Point	S	13.00	44	16.92	1	0.38
10 March 1999	Seal/Sail Rock to Kydaka Point	S	14.72	0	0.00	2	0.68
10 March 1999	Seal/Sail Rock to Kydaka Point	S	15.29	0	0.00	1	0.33
10 March 1999	Seal/Sail Rock to Kydaka Point	S	13.65	15	5.49	0	0.00
10 March 1999	Seal/Sail Rock to Kydaka Point	S	25.13	14	2.79	0	0.00
10 March 1999	Seal/Sail Rock to Kydaka Point	S	22.36	0	0.00	2	0.45
10 March 1999	Seal/Sail Rock to Kydaka Point	S	20.66	1	0.24	0	0.00
10 March 1999	Seal/Sail Rock to Kydaka Point	S	31.18	35	5.61	5	0.80
11 March 1999	Seal/Sail Rock to Kydaka Point	S	13.32	69	25.90	2	0.75
11 March 1999	Seal/Sail Rock to Kydaka Point	S	15.89	0	0.00	0	0.00
11 March 1999	Seal/Sail Rock to Kydaka Point	S	13.99	58	20.73	0	0.00
17 March 1999	Seal/Sail Rock to Kydaka Point	S	14.95	0	0.00	0	0.00
17 March 1999	Seal/Sail Rock to Kydaka Point	S	14.64	3	1.02	0	0.00
17 March 1999	Seal/Sail Rock to Kydaka Point	S	14.00	1	0.36	1	0.36
17 March 1999	Seal/Sail Rock to Kydaka Point	S	13.23	5	1.89	0	0.00
18 March 1999	Seal/Sail Rock to Kydaka Point	S	13.19	13	4.93	0	0.00
18 March 1999	Seal/Sail Rock to Kydaka Point	S	14.40	0	0.00	0	0.00
18 March 1999	Seal/Sail Rock to Kydaka Point	S	13.99	2	0.71	0	0.00
18 March 1999	Seal/Sail Rock to Kydaka Point	S	23.26	67	14.40	2	0.43

Table 7a. Densities of Marbled Murrelets along the western Strait of Juan de Fuca between Seal and Sail Rock and Kydaka Point in 1995 and 1996.

Distance (m) of transect from shore	1995				1996			
	Summer		Winter[1]		Summer		Winter[2]	
	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)
200	3.56 ± 0.76 (4, 42.5)	2.04 ± 1.87 (2, 130)	9.96 ± 1.24 (2, 17.5)	2.68 ± 1.70 (2, 89.6)	7.31 (1, --)	5.97 (1, --)	17.52 (1, --)	--
500	2.75 ± 0.26 (2, 13.4)	3.76 ± 2.10 (2, 78.9)	3.38 ± 1.58 (2, 66.0)	2.79 ± 0.57 (2, 28.7)	1.30 ± 0.24 (2, 25.7)	5.48 ± 4.77 (2, 123)	3.47 (1, --)	--
800	1.23 ± 0.75 (2, 86.2)	0.50 ± 0.25 (3, 87.3)	0 (2, --)	0.94 ± 0.62 (2, 93.0)	1.18 ± 0.81 (2, 97.1)	1.21 ± 1.21 (2, 141)	0.24 (1, --)	--
1200	0.06 ± 0.06 (2, 141)	0 (1, --)	--		0.32 ± 0.32 (2, 141)	0.53 ± 0.53 (2, 141)	--	0.80 (1, --)
Zig-Zag	--	--	--		3.31 ± 2.00 (3, 104)	0.91 ± 0.52 (3, 99.5)	--	--

[1] Winter of 1995-1996
[2] Winter of 1996-1997

Table 7b. Densities of Marbled Murrelets along the western Strait of Juan de Fuca between Seal and Sail Rock and Kydaka Point in 1997 and 1998.

Distance (m) of transect from shore	1997				1998			
	Summer		Winter[1]		Summer		Winter[2]	
	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)
200	147.7 ± 143.4 (3, 168)	8.41 ± 4.42 (5, 118)	5.10 ± 2.75 (3, 93.4)	3.15 ± 1.93 (5, 137)	39.0 ± 11.5 (5, 65.7)	29.6 ± 11.2 (5, 84.2)	1.15 ± 0.72 (6, 153)	1.11 ± 0.49 (5, 98.4)
500	1.70 ± 1.02 (4, 121)	0.69 ± 0.37 (4, 108)	4.83 ± 0.88 (4, 36.5)	8.70 ± 2.76 (4, 63.4)	7.26 ± 2.09 (9, 86.2)	5.80 ± 0.97 (5, 37.5)	0.28 ± 0.16 (6, 141)	0.36 ± 0.14 (4, 79.1)
800	0.35 ± 0.26 (5, 170)	0.20 ± 0.11 (4, 116)	2.08 ± 1.25 (4, 121)	0.57 ± 0.11 (3, 32.2)	1.51 ± 0.66 (5, 98.0)	0.58 ± 0.30 (3, 90.9)	0.18 ± 0.08 (6, 110)	0 ± 0 (3, --)
1200	--	--	--	--	5.53 (1, --)	4.03 (1, --)	0.25 ± 0.12 (6, 122)	0.19 ± 0.19 (2, 141)
Zig-Zag	1.74 ±0.37 (3, 37.2)	1.15 ± 0.70 (5, 135)	3.69 ± 1.33 (4, 72)	4.15 ± 1.01 (4, 48.8)	8.28 ± 2.54 (7, 81.3)	6.68 ± 2.58 (4, 77.1)	0.94 ± 0.32 (5, 74.8)	0.60 ± 0.20 (3, 57.7)

[1] Winter of 1997-1998
[2] Winter of 1998-1999

Table 8a. Densities of Marbled Murrelets along the outer coast of Washington between Fuca Pillar and Point of Arches in 1995 and 1996.

Distance (m) of transect from shore	1995				1996			
	Summer		Winter[1]		Summer		Winter[2]	
	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)
400	3.64 ± 0.10 (2, 4.10)	2.20 ± 0.10 (2, 6.40)	--	--	--	--	--	--
700	--	--	--	--	--	--	--	--
1200	0 (2, --)	0 (2, --)	--	--	--	--	--	--

[1] Winter of 1995-1996
[2] Winter of 1996-1997

Table 8b. Densities of Marbled Murrelets along the outer coast of Washington between Fuca Pillar and Point of Arches in 1997 and 1998.

Distance (m) of transect from shore	1997				1998			
	Summer		Winter[1]		Summer		Winter[2]	
	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)	AM Mean ± SE (n, cv)	PM Mean ± SE (n, cv)
400	0.96 ± 0.42 (5, 96.8)	2.57 ± 0.82 (5, 71.0)	3.93 (1, --)	--	3.33 ± 0.95 (6, 70.2)	0 (1, --)	--	--
700	0.67 ± 0.23 (5, 78.6)	0.39 ± 0.05 (3, 21.9)	6.30 ± 1.12 (5, 39.8)	6.18 ± 0.73 (4, 23.8)	1.20 ± 0.01 (2, 1.20)	0.92 ± 0.57 (3, 107)	--	--
1200	0.71 ± 0.29 (4, 80.8)	0.40 ± 0.35 (5, 195)	4.76 ± 0.23 (4, 9.70)	4.94 ± 1.16 (6, 57.5)	0.52 ± 0.18 (2, 47.1)	0.38 ± 0.38 (3, 173)	--	--
Zig-Zag	1.16 ± 0.43 (6, 90.4)	0.44 ± 0.32 (3, 124)	--	--	0.65 ± 0.39 (4, 118)	--	--	--

[1] Winter of 1997-1998
[2] Winter of 1998-1999

Although these data may be used to address many issues including variation in murrelet density in relation to year, season, time of day, distance from shore, and geographic location, the immediate reason this research was funded was to complete two tasks: (1) to compare the mean, variance, and coefficient of variation in zig-zag transects to those of each parallel transect distance (e.g. 200m vs. 500m), and to recommend which type of transect (parallel or zig-zag) is best for long-term monitoring of murrelets.

Zig-zag transects have two advantages over parallel transects. First, as documented previously (Thompson 1997a, 1997b), murrelets tend to occur in higher densities in morning versus afternoon in summer (Tables 6 and 7, Figures 1 and 3); a similar but less pronounced pattern exists in winter (Tables 6 and 7, Figures 2 and 4). Thus, differences between parallel transects conducted at different distances from shore may be confounded by time-of-day effects unless they are conducted at the same time of day. This is not an issue with zig-zag transects because the temporal distribution of effort is the same across all distances from shore within the area surveyed. Second, it is well known that murrelet density decreases with perpendicular distance from shore (Thompson 1997a, 1997b); This is further documented here (Tables 6 and 7, Figures 1-5); however, the peak in this density is also known to vary among geographic locations, and, more importantly, over time within and between seasons and years within geographic areas (Tables 6 and 7, Figure 5). Thus, surveys conducted along a specific parallel transect may vary over time due to changes in the overall density distribution of murrelets in relation to distance from shore (e.g., a shift in the distance at which maximum density of muurelets occurs) rather than to actual changes in total murrelet abundance. Because zig-zag transects sample a much wider range of distances from shore, they are less likely to be affected by such changes in the density distribution of murrelets in relation to distance from shore. These advantages aside, comparison of coefficients of variation between zig-zag and parallel transects do not clearly indicate that one kind of transect (i.e. zig-zag vs. parallel) is superior for maximizing statistical power for detecting changes in population density. This issue is currently being discussed by the "Population Core Group," a group of four biologists (myself, Steve Beissinger [University of California at Berkeley], C.J. Ralph [U.S. Forest Service, Pacific Southwest Region], Marty Rafael [U.S. Forest Service, Pacific Northwest Region]) and two statisticians (Tim Max and Jim Baldwin) who are coordinated by the U.S. Fish and Wildlife Service; the charge of this group is to develop a protocol for surveying for murrelets at sea, the data from which will be suitable for monitoring population trends of murrelets at sea. Jim Baldwin and Steve Beissinger are currently using empirical data to run simulation models to evaluate the relative strengths and weaknesses of parallel versus zig-zag transects. We anticipate an answer from them this summer.

The second reason for conducting replicate sets of these various transects was to determine how many replicates of a given transect should be done, on average, in a given area (e.g. outer coast versus Strait of Juan de Fuca) and season (winter vs. summer) in order to achieve the statistical power required to detect a change in density of murrelets of a given magnitude over a specified time interval. As briefly explained above, the Population Core group has not yet decided how transects should be oriented (e.g. zig-zag versus parallel), at what distance from shore they should be placed, or how long they should be. Nor has any state or federal agency stated a specific percent change in murrelet populations that they want to be able to detect over a given number of years. As a result, I can not present a power analysis for a generally accepted sampling scheme, because no such consensus currently exists. Instead, I present a preliminary power analysis for the summer season for a subset of transect types and lengths that WDFW conducted between 1995 and 1998. As mentioned above, transects along the Strait of Juan de Fuca were conducted parallel to shore at 200, 500, 800, and 1200 meters, and in a zig-zag orientation between 100 and 1300 meters from shore. Statistical power increases as the coefficient of variation (CV) within each of the two or more samples being compared decreases. Thus, for the power analysis presented below, I chose the 500 m and 400 m parallel transects on the Strait of Juan de Fuca and outer coast, respectively, to compare to zig-zag transects conducted in the same location because these transects had lower CVs than other parallel transects (see Table 9 below). Using values from Tables 7 and 8 above, I calculated the grand mean murrelet density for each transect type and location, and the standard deviation of individual means (rather than the mean of the standard deviations of the individual means) included in the calculation of each grand mean; these values were as follows: 500m SJF: 3.59 ± 2.39, zig-zag SJF: 3.68 ± 3.10; 400m OC: 2.54 ± 1.05; zig-zag OC: 0.75 ± 0.37.

Table 9. Coefficients of variation of strip transects conducted along the western Strait of Juan de Fuca and the northern outer Washington coast in 1995-1998 (years and time of day combined)

	Season		
Transect Type	Summer mean (SD, n)	Winter mean (SD, n)	Location[1]
200m	101 (45.3, 6)	98.2 (47.1, 6)	SJF
500m	74.2 (43.5, 8)	69.1 (40.0, 6)	SJF
800m	111 (30.1, 8)	89.0 (19.8, 4)	SJF
1200m	141 (0, 3)	132 (9.5, 2)	SJF
Zig-Zag	89.0 (13.3, 6)	63.3 (12.2,4)	SJF
400m	49.7 (41.9, 5)	--	OC
700m	52.2 (49.0, 4)	31.8 (11.3, 2)	OC
1000m	124 (71.1, 4)	33.6 (33.8, 2)	OC
Zig-Zag	111 (18.1, 3)	--	OC

[1] SJF = western Strait of Juan de Fuca; OC = northern outer Washington coast.

Based on these data, I did a calculated the power of detecting changes in population density between two sampling periods (e.g. successive years) in 10% increments from 10% to 90% along the western Strait of Juan de Fuca and the northern outer Washington coast using 5, 10, 15 and 20 replicates during each survey period. Along the western Strait of Juan de Fuca, 500 meter transects parallel to shore have greater power for the same number of replicates than do zig-zag transects (Figs. 6-7); interestingly, however, the opposite is true for the northern outer Washington coast (Figs. 8-9).

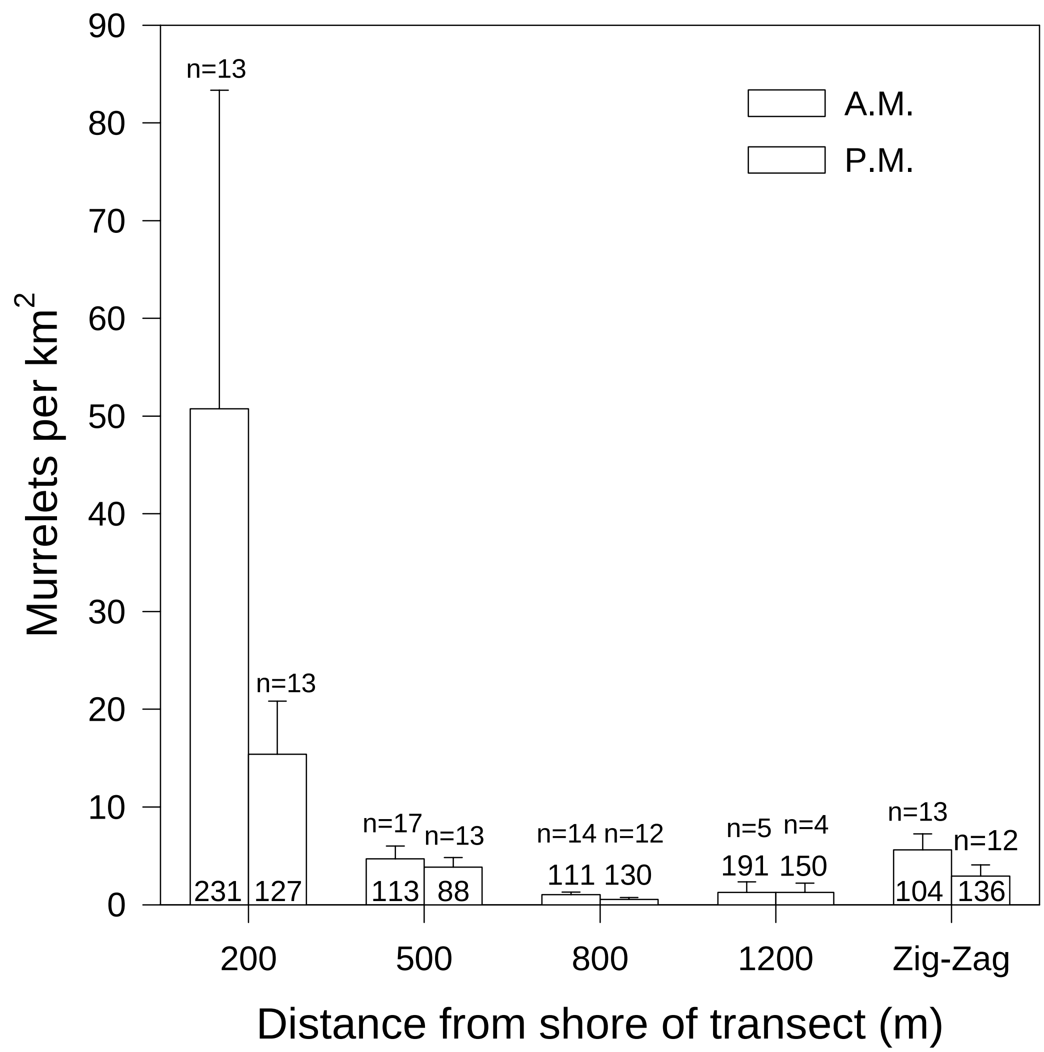


Figure 1. Density of Marbled Murrelets along the western Strait of Juan de Fuca in summer 1995 through summer of 1998 in relation to distance from shore and time of day. Numbers below sample sizes indicate coefficients of variation.

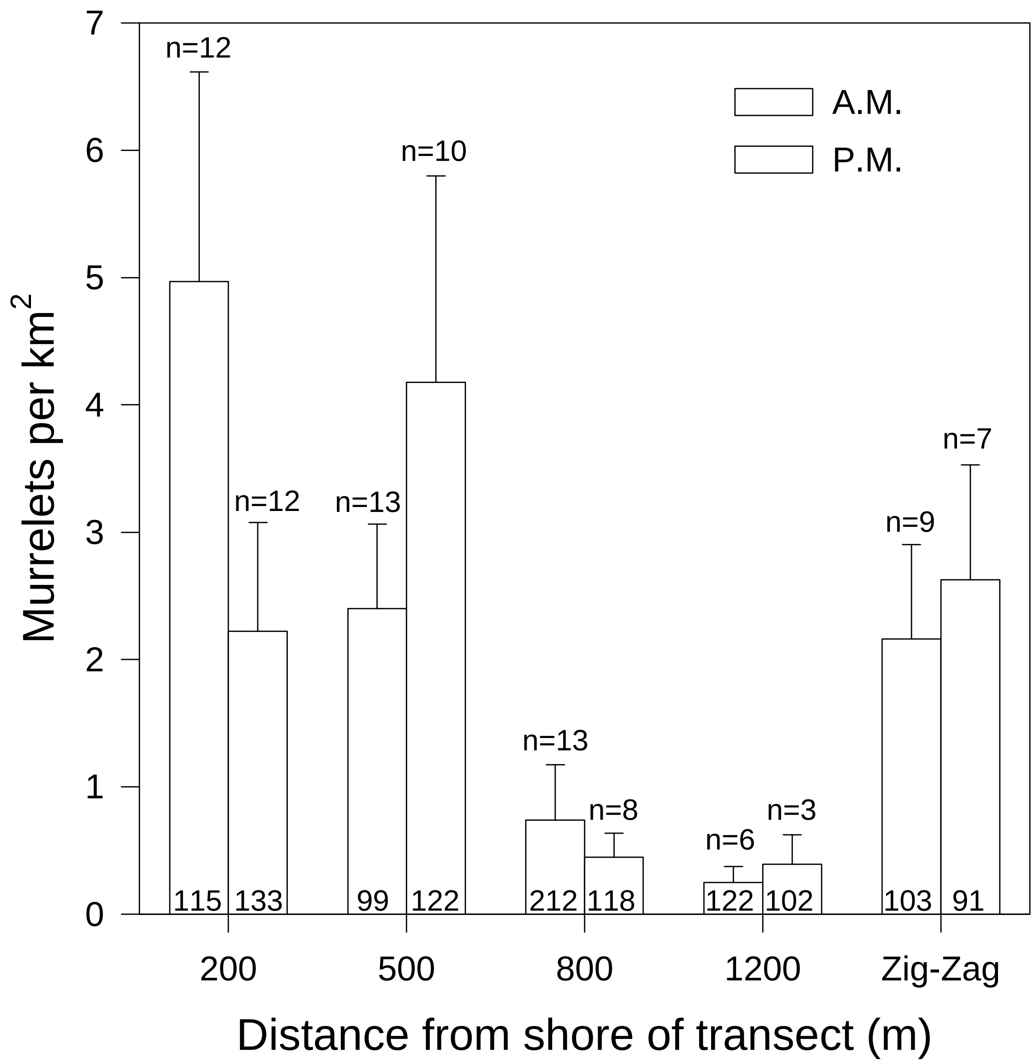


Figure 2. Density of Marbled Murrelets along the western Strait of Juan de Fuca in winter 1995 through winter of 1998 in relation to distance from shore and time of day. Numbers below sample sizes indicate coefficients of variation.

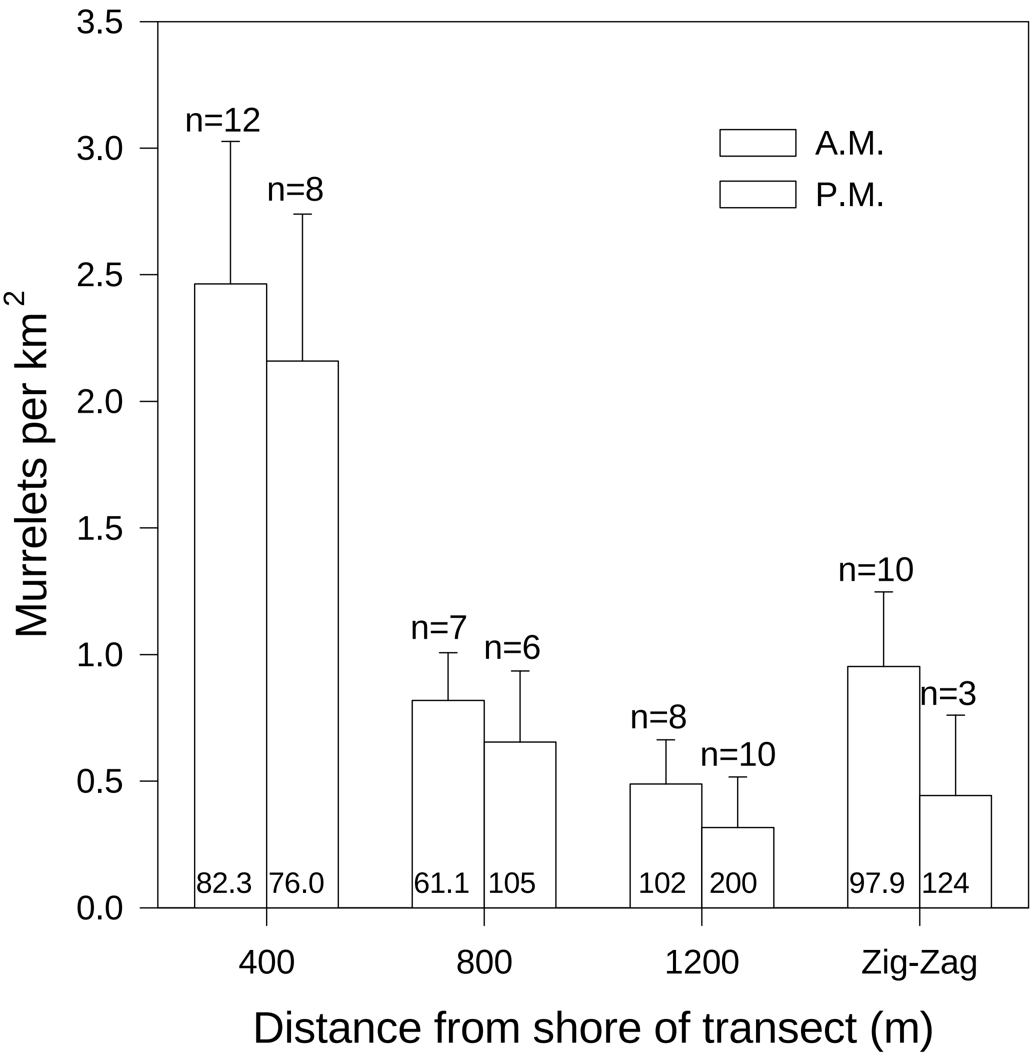


Figure 3. Density of Marbled Murrelets along the northern outer coast of Washington in summer 1995 through summer of 1998 in relation to distance from shore and time of day. Numbers below sample sizes indicate coefficients of variation.

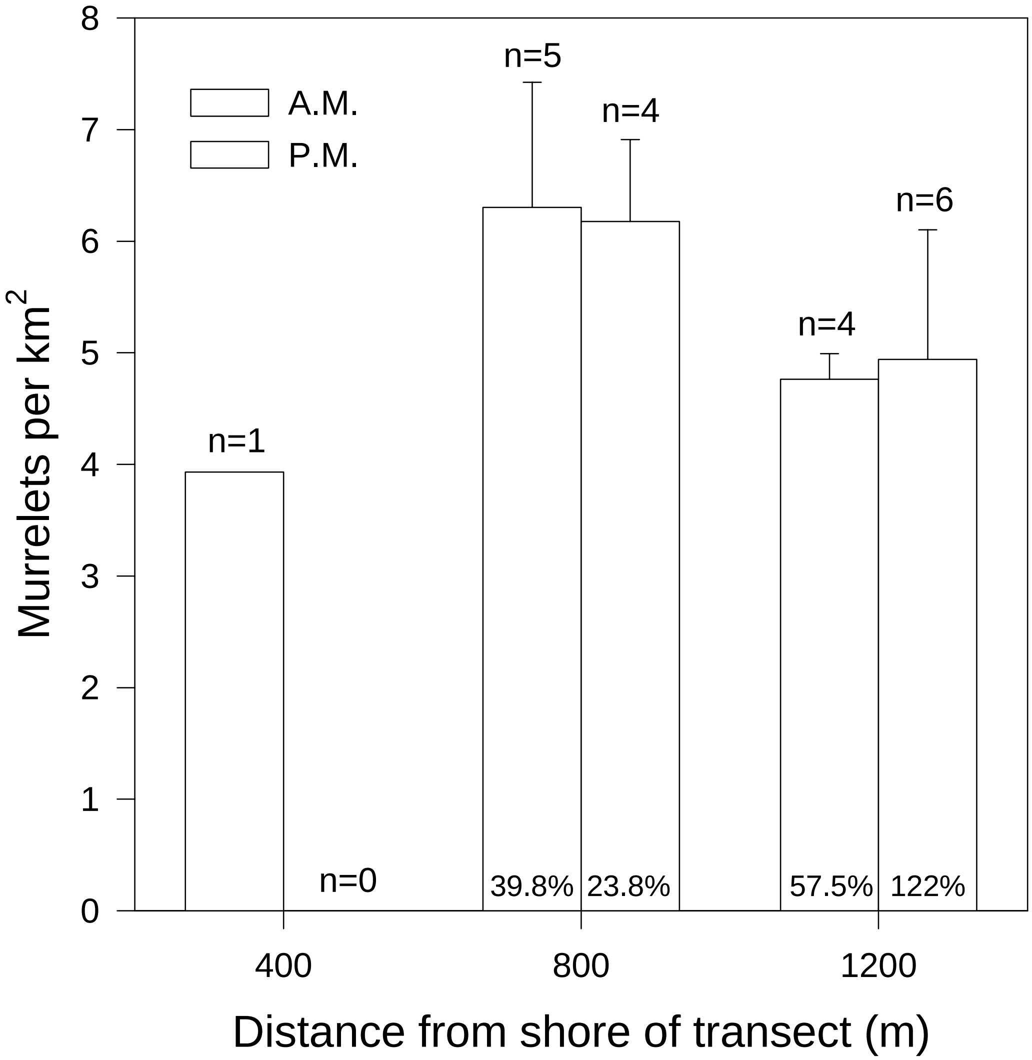


Figure 4. Density of Marbled Murrelets along the northern outer coast of Washington in winter 1995 through winter of 1998 in relation to distance from shore and time of day. Numbers below sample sizes indicate coefficients of variation.

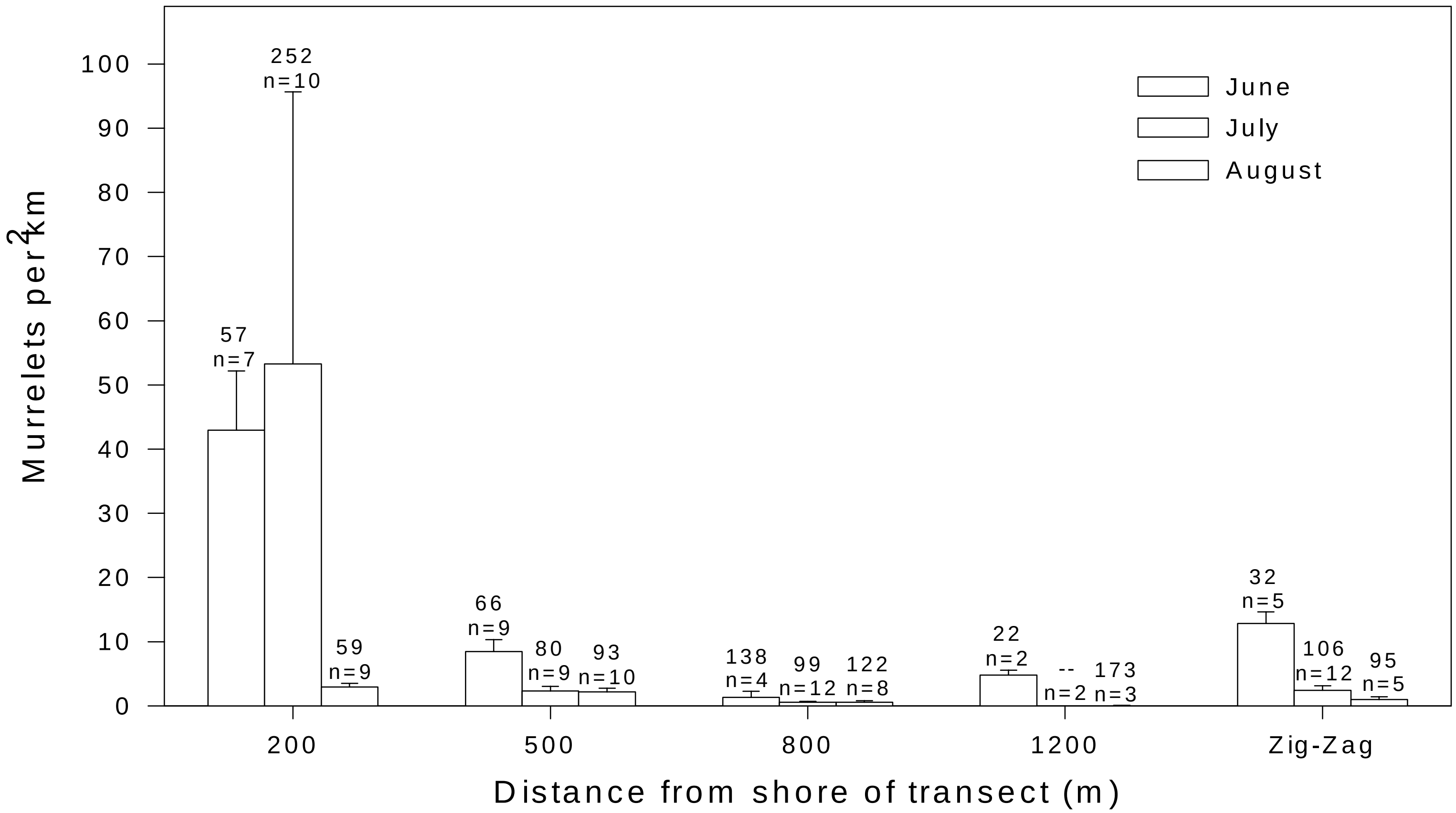


Figure 5. Density of Marbled Murrelets along the western Strait of Juan de Fuca in summer 1995 through summer of 1998 in relation to distance from shore and time of year. Numbers above sample sizes indicate coefficients of variation.

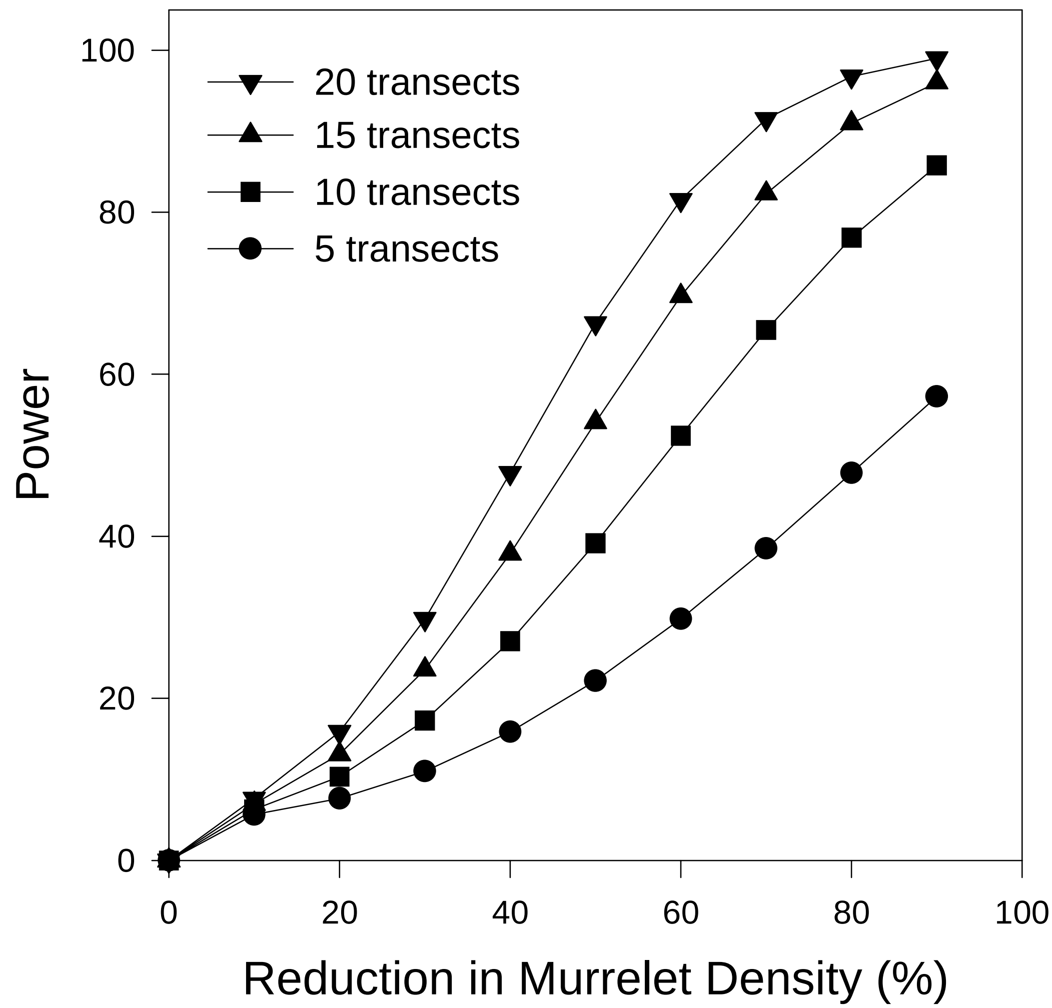


Figure 6. Statistical power of detecting changes in murrelet density along the western Strait of Juan de Fuca by conducting two sets of the same number of transects (5, 10, 15 or 20 replicates) 500 m parallel to shore as a function of the percent change in murrelet density and number of replicates conducted in each set of transects.

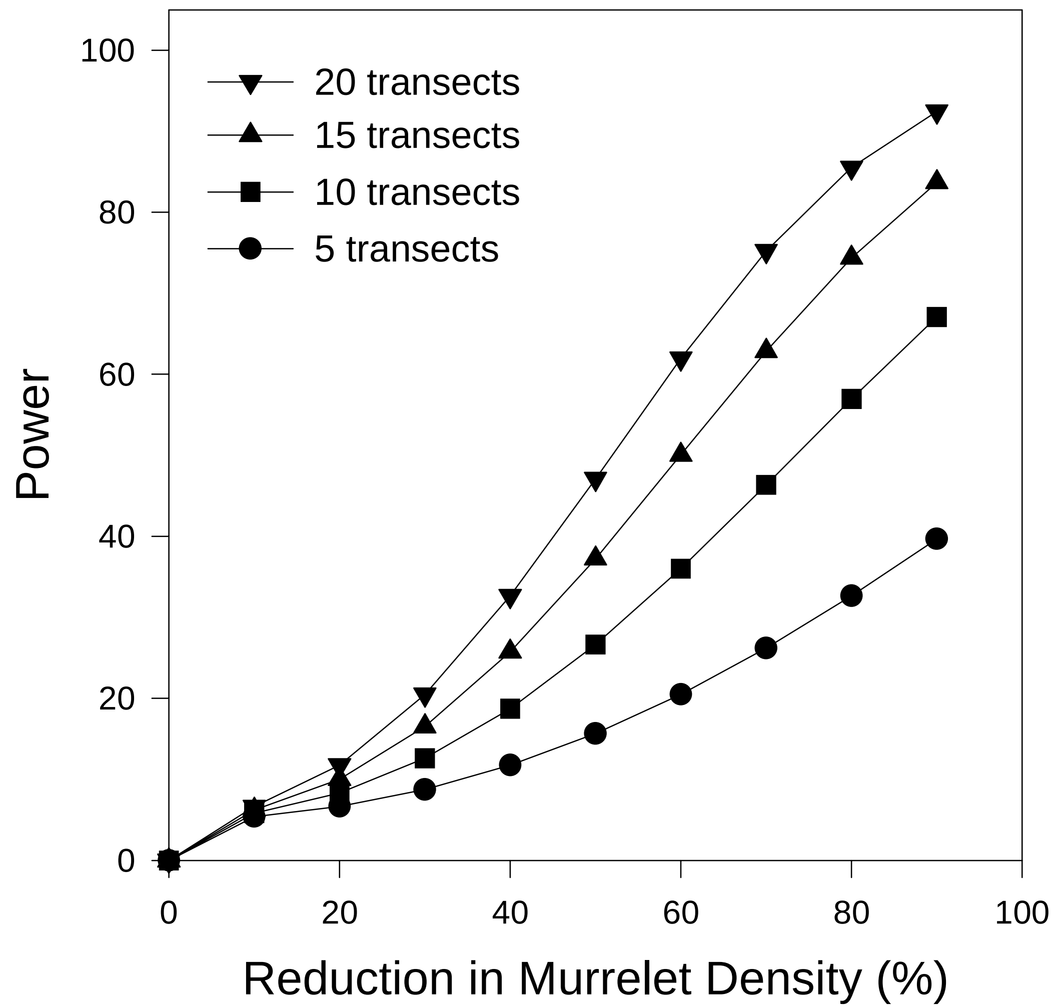


Figure 7. Statistical power of detecting changes in murrelet density along the western Strait of Juan de Fuca by conducting two sets of the same number of zig-zag transects (5, 10, 15 or 20 replicates) as a function of the percent change in murrelet density and number of replicates conducted in each set of transects.

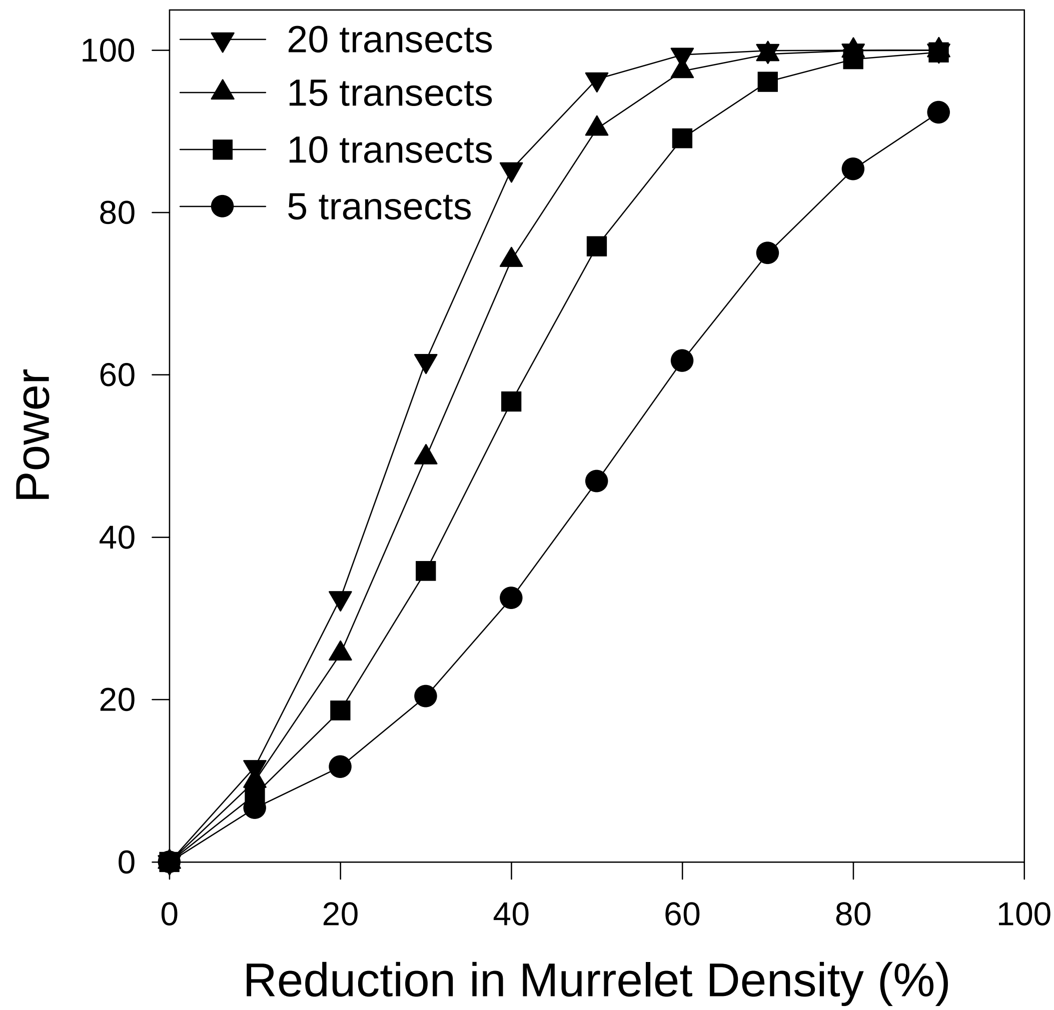


Figure 8. Statistical power of detecting changes in murrelet density along the northern outer coast of Washington by conducting two sets of the same number of transects (5, 10, 15 or 20 replicates) 400 m parallel to shore as a function of the percent change in murrelet density and number of replicates conducted in each set of transects.

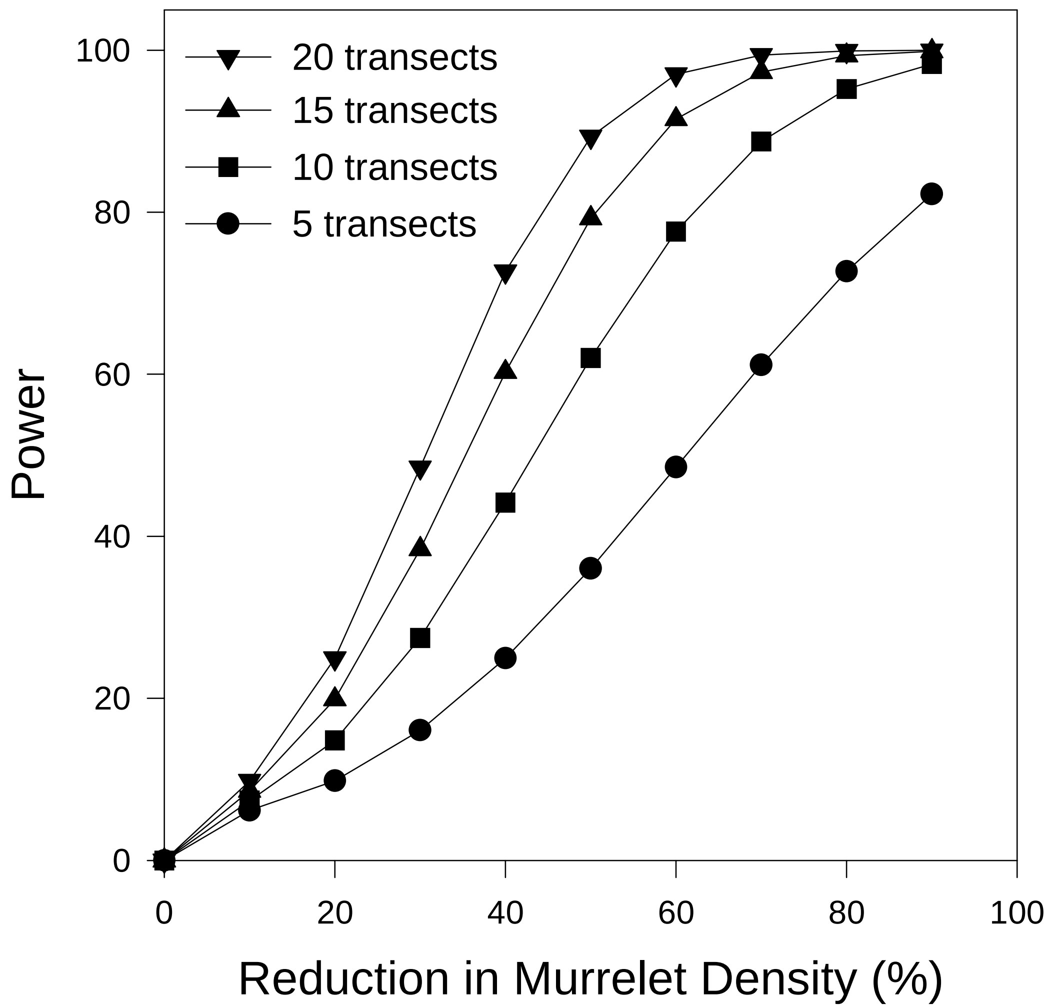


Figure 9. Statistical power of detecting changes in murrelet density along the northern outer coast of Washington by conducting two sets of the same number of zig-zag transects (5, 10, 15 or 20 replicates) as a function of the percent change in murrelet density and number of replicates conducted in each set of transects.

Task 2

We know from past research that numbers of seabirds, including murrelets, are tremendously variable in time and space. This is unfortunate because their inherent variability makes detecting meaningful changes in population levels of these birds very difficult, e.g., in the short-term (within as much as a few years), apparent increases or decreases in population levels may simply reflect variability in numbers of birds breeding, or migrating/dispersing, but not total numbers of birds in a "population." To detect real population changes, these birds must be monitored over many years in order to measure within- and between-year variability in their numbers, and thereby discriminate short-term fluctuations in apparent population numbers from long-term real changes in population numbers. Thus, as indicated in Tables 1-4 (above), since my last report to the TMTC, we have conducted an additional 3374 km of transects in winter and 7680 km of transects in summer. Comparison of mean densities and variances of murres and murrelets from the same transect areas within-season and among years gives us an estimate of interannual variability in murre and murrelet densities within and among geographic areas (Figs. 1-4). Similarly, comparison of mean densities and variances of murres and murrelets from the same transect areas between winter and summer among years gives us an estimate of seasonal variability in murre and murrelet densities within and among geographic areas. Also, comparison of mean densities and variances of murres and murrelets from the same transect areas among months within the same season indicates the extent of within-season variation in their densities. These data and results greatly improve our baseline knowledge of the distribution and abundance of murrelets and other seabirds in Washington.

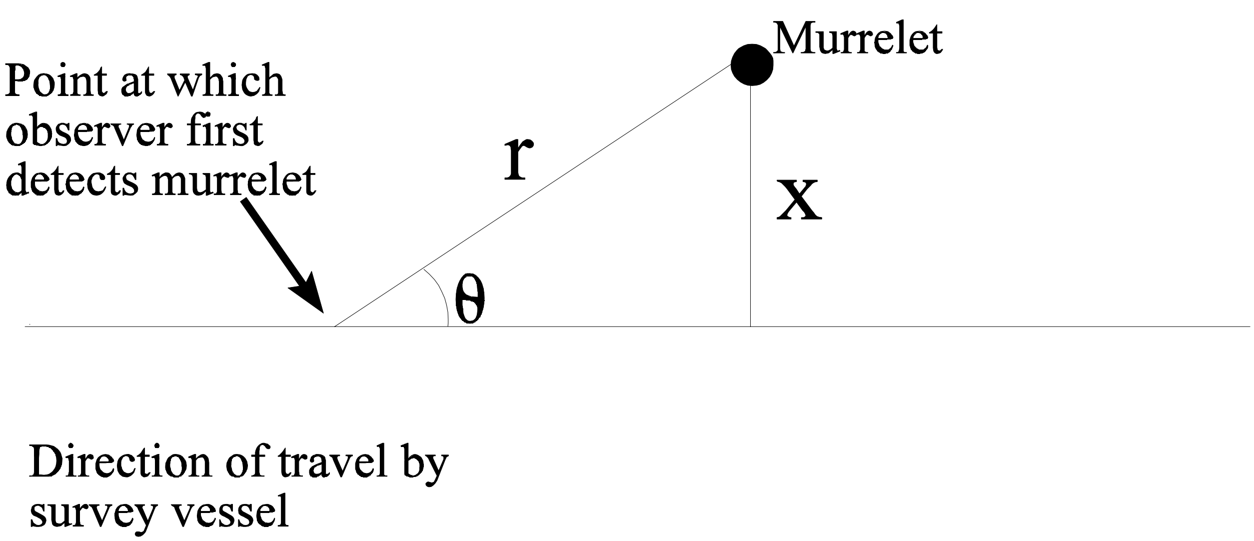
Task 3

The third task was designed to evaluate transect methodology that could improve our statistical power. In 1995 and 1996 WDFW used "strip" transects for collecting seabird abundance and distribution data; in this method, all birds are counted within a "strip" of 100 meters on each side of our various research vessels. This method has two basic errors: (1) observers must be able to accurate estimate the distance of 100 meters from the vessel in order to accurately determine which birds are inside versus outside the "strip," and (2) the detectability of birds in relation to distance from the vessel differs among transects due to differences in observers, weather (sun, glare, cloud cover, wind, rain), sea conditions (swell height and period, wind waves, etc.), and platform (i.e., vessel height, size, etc.).

An alternative transect method is the "line" transect (Buckland et al. 1993). This method is very similar to the strip transect method, but differs in a few critical ways. In a line transect, like a strip transect, birds are counted only within a specified distance on each side of a vessel; however, in a line transect, the perpendicular distance to each bird from the vessel is also estimated and recorded. By doing so, a detectability curve of the percentage of observations as a function of distance from the boat may be generated. From this, one may empirically determine the percentage of birds being missed on any given transect or set of transects. In turn, this may be used to "correct" transects to reflect the total number of birds that would have been seen if all birds had been detected. By largely eliminating differences in the detectability between transects, this method has the potential to vastly reduce variability in our data, thereby increasing our statistical power. However, the accuracy of this method relies on two critical assumptions being met: (1) all birds must be detected that are “close” (i.e., within about 30 meters) to the transect line of the boat, and (2) the boat must not cause birds to dive, fly or move away from the transect line before being detected. If either of these assumptions are seriously violated, then subsequent analyses of line transect data will yield erroneous results.

During the summer of 1998, we empirically measured (1) the percentage of murrelets on or near the transect line that are not detected, for whatever reason, by standard observers, and (2) the extent to which birds move away from the transect line. We did this by placing an extra “independent” observer on the bow of our vessel who focused most of her effort on or near the transect line. She searched for murrelets well in excess of 100 meters in front of the survey vessel. Once seen, she estimated the angle of the bird off the transect line and its radial distance from the vessel; perpendicular distance of the bird from the transect line is calculated as $X = r*\sin\theta$ where X = perpendicular distance, r = radial distance, and θ = angle from the transect line (Fig. 10). She then followed the bird, noting all behaviors such as flying and diving, and noting

Figure 10. Diagrammatic representation of how line transect observations are made



the position of these behaviors, until it was seen by one of the standard observers. At that time, she took a second set of radial distance and angle estimates. By comparing the perpendicular distance of each murrelet when it was sighted initially by our independent observer to its distance when sighted subsequently by a standard observer, the perpendicular distance that it moved toward or away from the transect line was calculated. If a murrelet was not seen by a standard observer, but was still visible within the transect area (100 radius of the boat), it’s position was noted when it was directly abeam of the vessel. If a murrelet was not seen by a standard observer because it dove or flew away, the position at which it dove or flew away was noted by the independent observer.

Results

Percentage of birds not detected by standard observers. This study was designed to allow us to answer a large suite of questions. As a result, the entire data analysis is rather long and complex and are in the process of be prepared as a manuscript for publication (published abstracts of our results will appear in Pacific Seabirds volume 26). However, for the TMTC, we addressed two specific questions: (1) what percentage of murrelets are not detected by standard observers as a function of perpendicular distance from the transect line?, and (2) of murrelets that are detected by standard observers, how far do they move perpendicularly toward or away from the transect line before being detected?

The percentage of murrelets that were not detected by standard observers as a function of perpendicular distance from the transect line is summarized in Table 10 and Figures 11 and 12 below.

Table 10. Percentage of murrelets that were not detected by standard observers as a function of perpendicular distance from the transect line.

Perpendicular Distance (m) from transect line	Birds that dove and were missed	Birds that flew and were missed	Birds that did not fly or dive and were missed	Total birds missed	Total birds not missed	Percent missed from diving	Percent missed from flying	Percent missed that did not fly or dive	Total percent missed	Percent of birds detected
0-10	5	0	3	8	70	6.41	0.00	3.85	10.26	89.74
11-20	9	0	3	12	67	11.39	0.00	3.80	15.19	84.81
21-30	3	0	0	3	48	5.88	0.00	0.00	5.88	94.12
31-40	4	0	2	6	58	6.25	0.00	3.13	9.38	90.63
41-50	1	0	1	2	21	4.35	0.00	4.35	8.70	91.30
51-60	2	0	1	3	19	9.09	0.00	4.55	13.64	86.36
61-70	1	0	3	4	11	6.67	0.00	20.00	26.67	73.33
71-80	0	0	0	0	6	0.00	0.00	0.00	0.00	100.00
81-90	1	0	0	1	3	25.00	0.00	0.00	25.00	75.00
91-100	0	0	0	0	2	0.00	0.00	0.00	0.00	100.00

In collaboration with Tom Hamer (Hamer Environmental, Mt. Vernon, WA), Jeff Laake (National Marine Mammal Lab, NOAA), and Kirsten Brennan (College of Forestry Resources, University of Washington), we used DISTANCE software to estimate the density of murrelets based on the independent observers data (i.e., of murrelets observed presumably before they were disturbed by one of our oncoming survey vessels). We refer to this as the unbiased model meaning that the data are presumably unbiased by any movement by the murrelets caused by disturbance due to our survey vessels. We compared these density estimates to those obtained using the standard observers data (i.e., of murrelets observed presumably after they may have been disturbed by one of our oncoming survey vessels). We refer to this as the biased model meaning that the data may be biased by movement by murrelets away from the transect line in response to oncoming survey vessels. This comparison indicated that densities differed little (10-20%) between these models depending on how parameters were chosen for the DISTANCE software, suggesting that the combination of missed birds and movement of birds does not constitute a large error relative to the magnitude of natural variation in the distribution and abundance of murrelets.

Distance moved toward or away from the transect line by murrelets prior to detection by standard observers. Overall, murrelets do not appear to react strongly to the oncoming approach of survey vessels. Murrelets were initially spotted by the independent observer at 154.4 ± 2.3 m (mean ± SE), and subsequently observed by standard observers at 59.4 ± 1.7 m in front of the vessels. During this interval, murrelets moved, on average, 3.8 ± 1.2 m away from the transect line. However, murrelets closest to the transect line moved away from the transect line a greater absolute distance, and at a greater rate than murrelets further from the transect line (Figures 13 and 14). For example, murrelets within 40m and 20m of the transect line moved 7.3 ± 0.8 m, and 9.7 ± 1.1 m away from the transect line, respectively. We have no explanation for the apparent approach toward the transect line of murrelets initially seen at distances greater than 50 meters perpendicular to the transect line. The most likely explanation is that it reflect a systematic bias in the way the independent observer estimated radial angles and distances of murrelets from the transect line and survey vessel, respectively. However, we tested the independent observer for such biases (Figures 15 and 16), and corrected the raw data to reflect her biases thereby removing most to all bias introduced to the data by her biased data collection.

Discussion

Percentage of birds not detected by standard observers. Overall, these data indicate that 12.7% of murrelets were missed between 0 and 20 meters of the transect line, and 10.7% were missed between 0 and 40 meters of the transect line. As a result, g(0) is significantly less than one, thereby potentially seriously violating one of the basic assumptions of line transect methodology and the DISTANCE software used to analyze such data. The USFWS Population Core group is currently discussing how to deal with this problem. There are two alternatives: (1) ignore the problem and live with the error, or (2) determine and implement a mechanism for estimating a correction factor to reduce the magnitude of the error. The second alternative could be achieved, theoretically, by placing an independent observer on each survey vessel each season for a period of time sufficient to estimate the percentage of birds missed on each vessel. The concern is that this might introduce more error than it corrects for. This was discussed at a meeting of the Population Core Group in mid-May; the consensus was that an independent observer will probably be employed in the summer of 2000 to begin research into the feasibility of using independent observers to estimate percentages of undetected murrelets by various marine murrelet survey crews.

Distance moved away from the transect line by murrelets prior to detection by standard observers. At all distances away from the transect line (e.g., 0-10m, 11-20m, etc.), murrelets moved less than 10 meters away from the transect line, on average, between the time they were were initially spotted by the independent observer and subsequently observed by standard observers. This result is similar to the results of our pilot study in 1997 in which we found that murrelets moved an average of 9.6 ± 1.5m (mean ± SE) away from the transect line (Hamer and Thompson 1997). Calculation of murrelet densities based on data from the biased and unbiased models (described above) indicated that biased data would underestimate unbiased data by about 10-20% depending on values we chose for various parameter inputs into the DISTANCE program (Buckland et al. 1993, Laake et al. 1996) and the perpendicular distance from the transect line at which the data were truncated. Relative to the magnitude of errors introduced into the data from many other sources (e.g. variability among observers and weather conditions such as glare, beaufort magnitude, swell height), it is my opinion, and that of other experts on the subject (e.g., Jeff Laake) that this is not an effect worth trying to control or correct for.

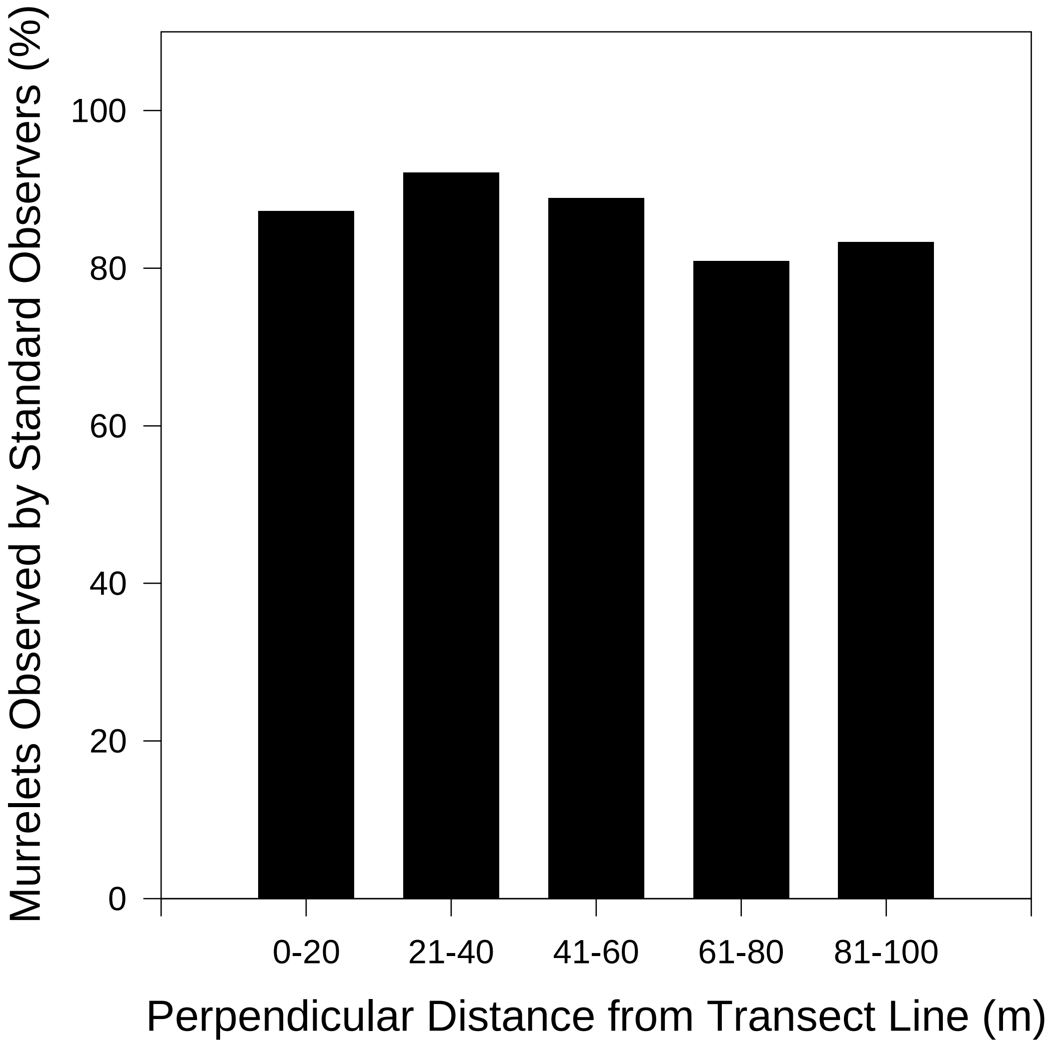


Figure 11. Percentage of murrelets detected by standard observers in relation their perpendicular distance from the transect line.

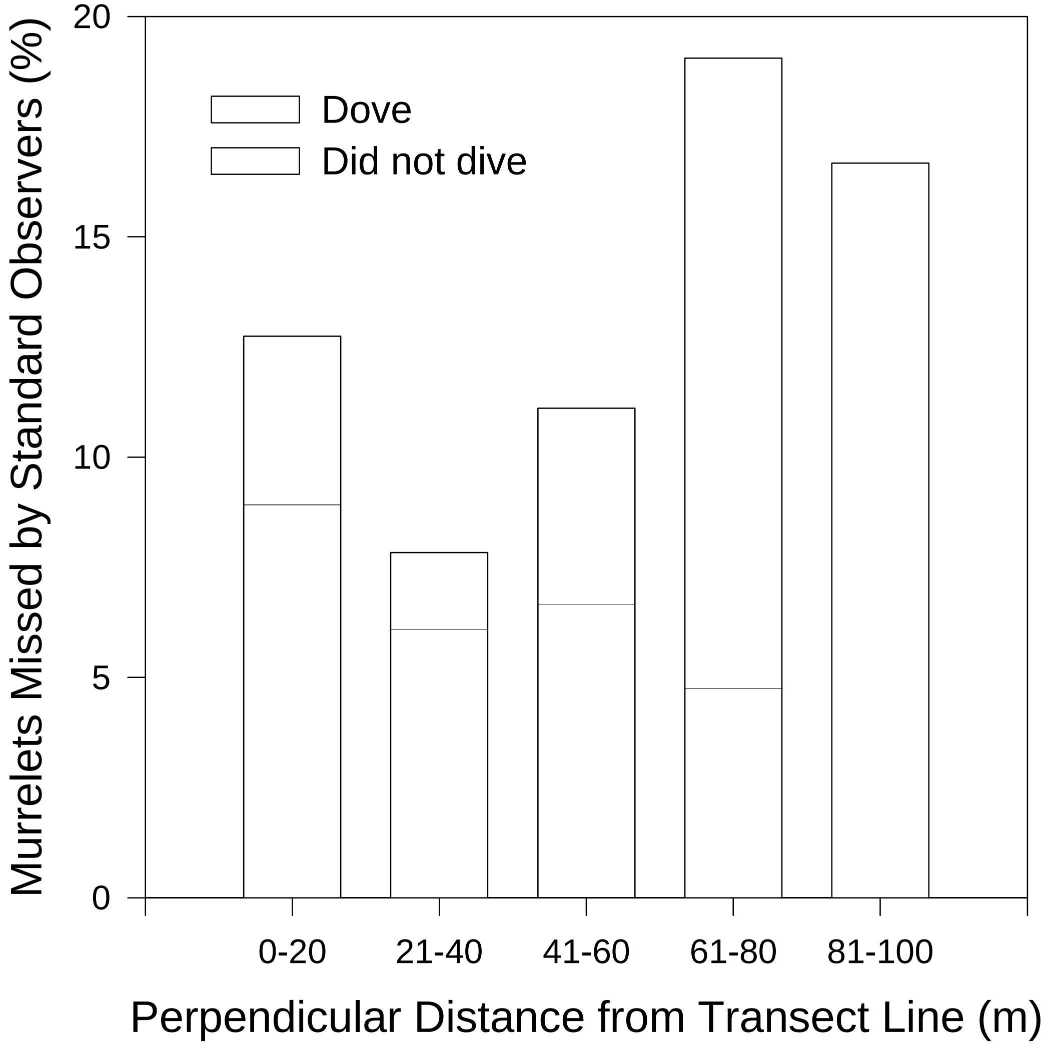


Figure 12. Percentage of murrelets that were not detected by standard observers as a function of murrelet behavior and perpendicular distance from the transect line.

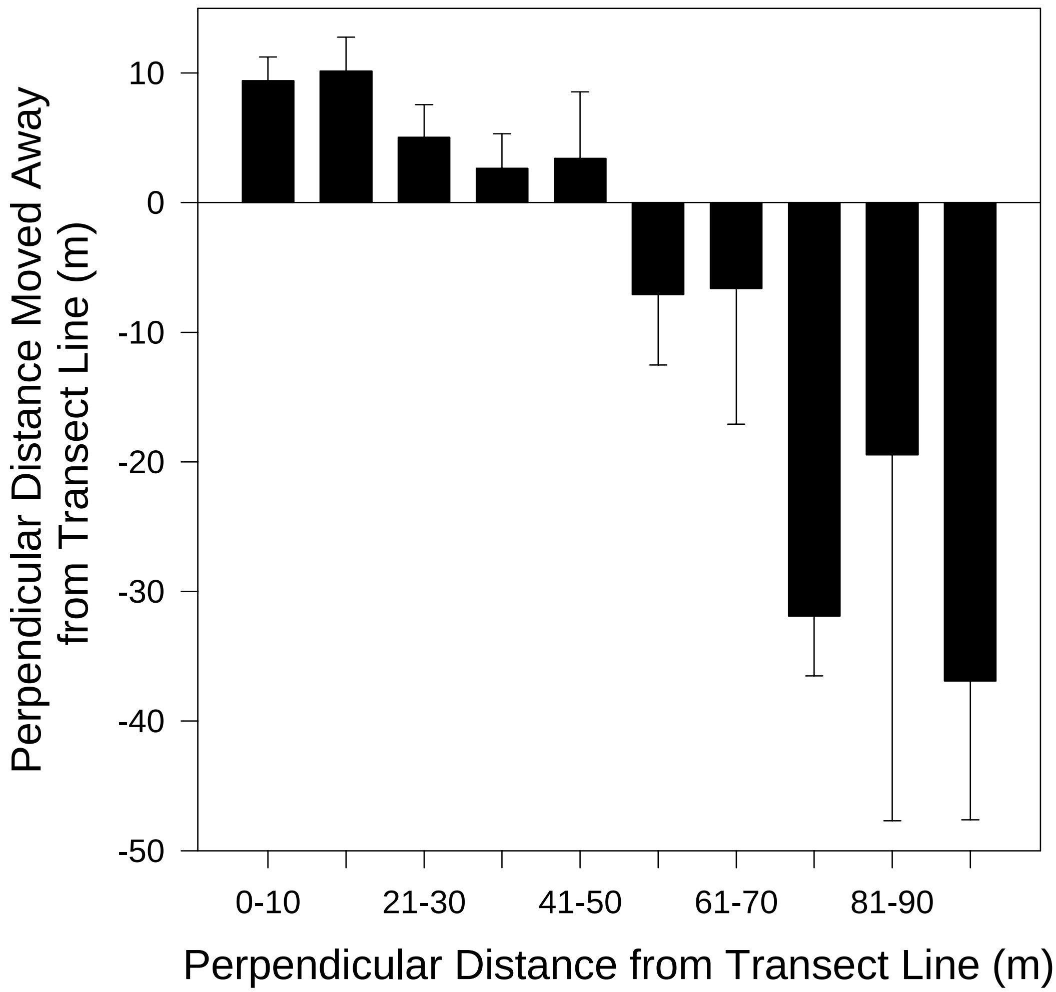


Figure 13. Absolute distance moved perpendicularly away from the transect line by murrelets between their initial sighting by the independent observer and their subsequent sighting by standard observers.

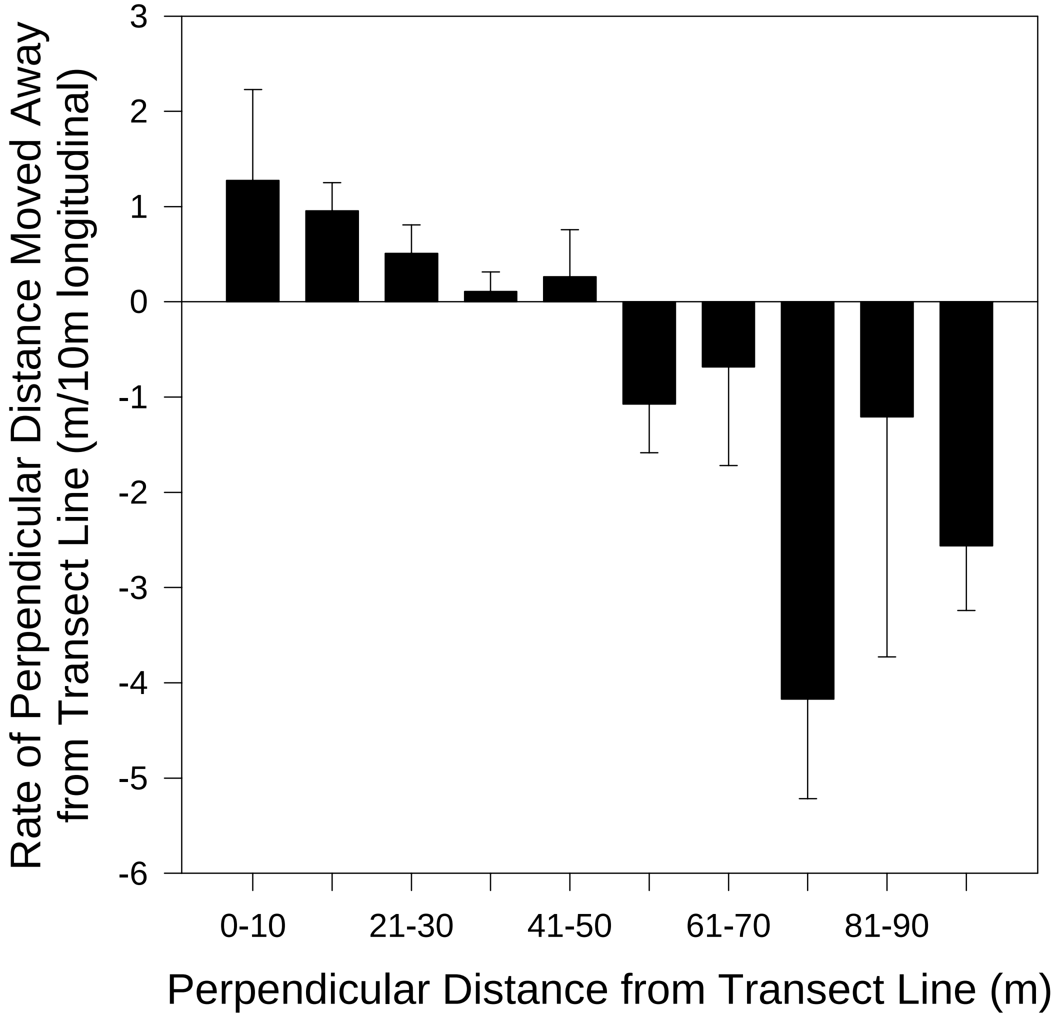


Figure 14. Rate of movement perpendicularly away from the transect line by murrelets between their initial sighting by the independent observer and their subsequent sighting by standard observers.

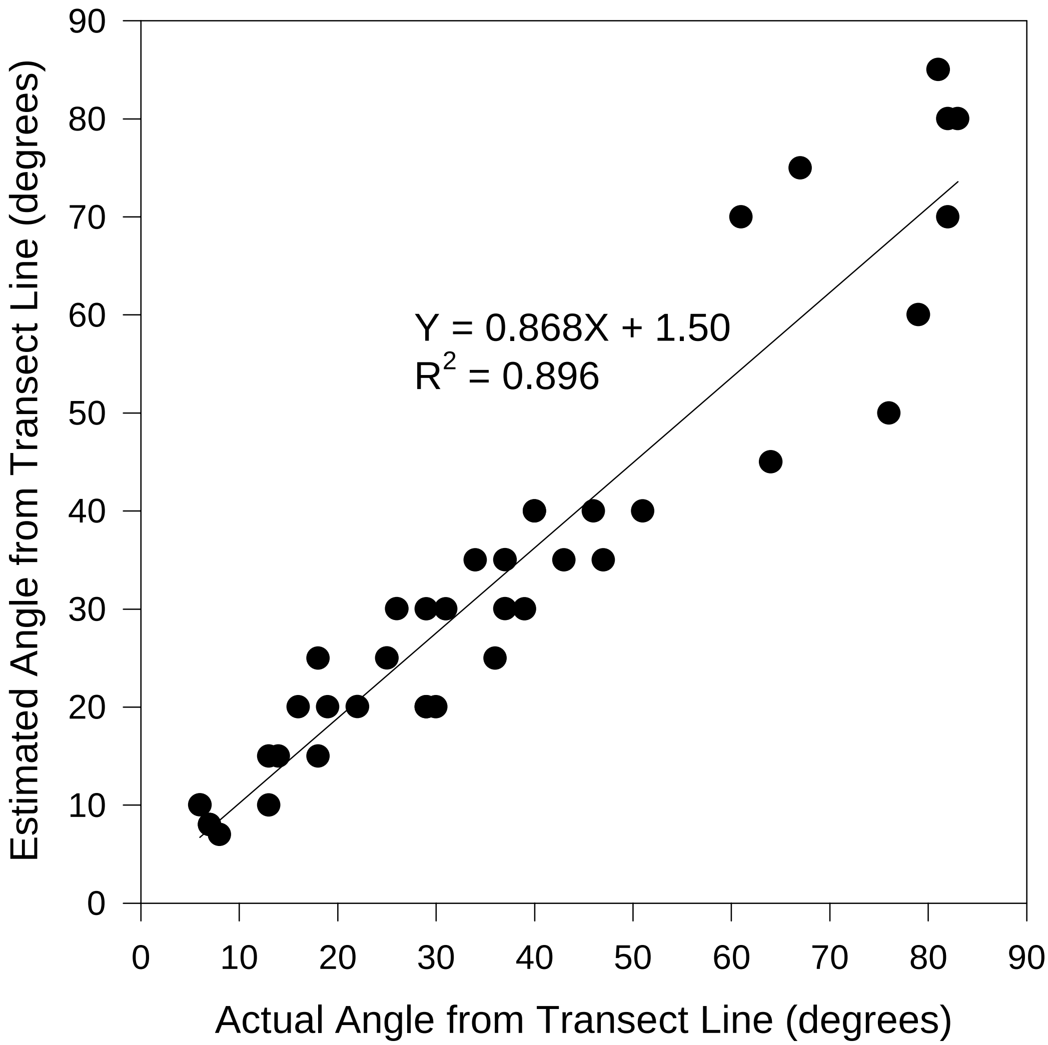


Figure 15. Linear regression of the independent observer's estimated angle from the transect line to buoys (simulating murrelets) on actual angles buoys measured using digital compasses.

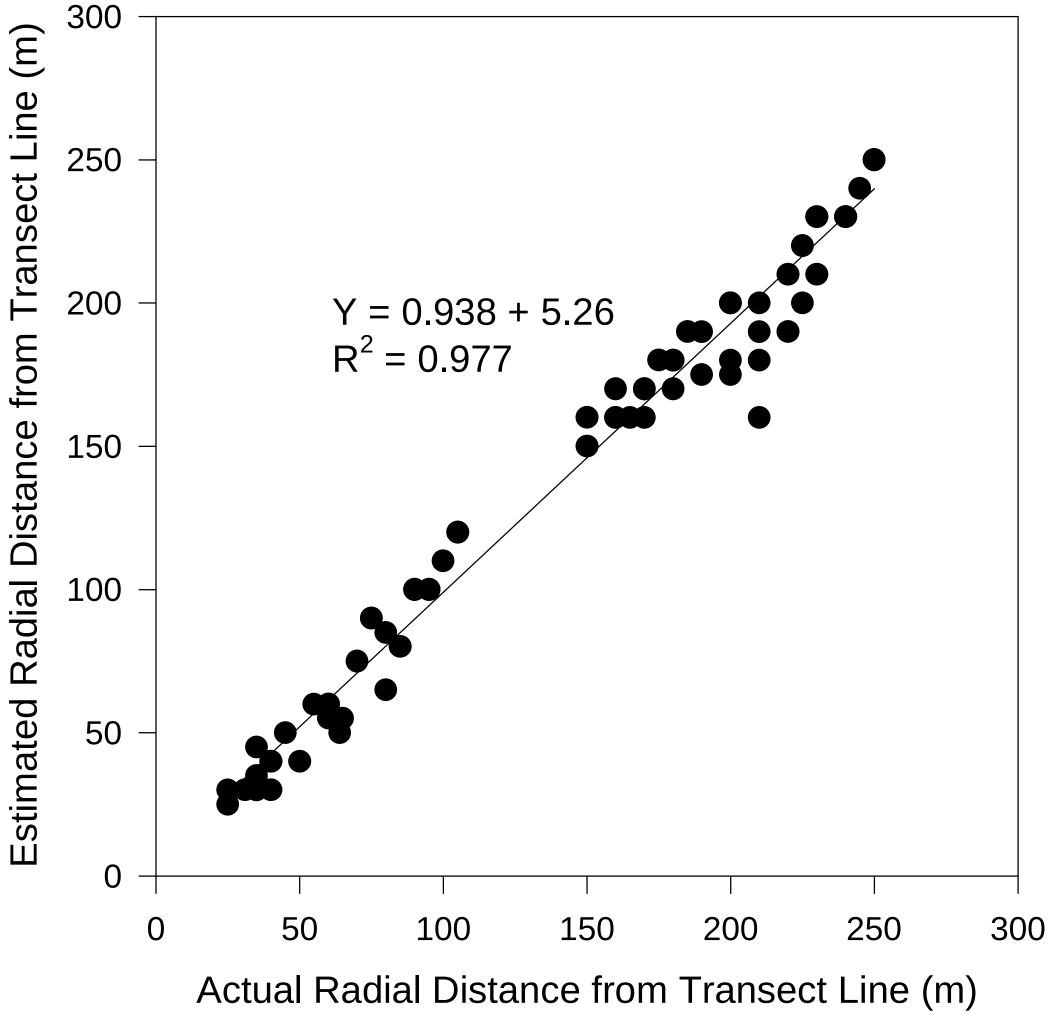


Figure 16. Linear regression of the independent observer's estimated radial distance from the survey vessel to buoys (simulating murrelets) on actual distance to buoys.

Objective 2: Surveys of potential murre breeding colonies.

Historically, murres are known to have bred on many rocks and islands along the outer Washington coast south of Tatoosh Island (Speich and Wahl 1989). However, in the last decade or so, Tatoosh Island is the only colony at which murres are well documented to currently breed annually. Ulrich Wilson (USFWS, unpubl. data) has observed chicks recently on various other colonies (e.g., Huntington Island in mid-June 1995) on which murres are known to have bred previously. These data clearly indicate that murres are breeding in at least small numbers at some other locations in Washington and, in at least some of these colonies, may be doing so earlier than on Tatoosh Island, i.e., the timing of their breeding may be closer to that of Oregon than Washington murre colonies. As a result, better documentation, and estimates of numbers, of breeding pairs of murres at potential Washington Murre colonies other than Tatoosh Island are necessary. In addition, individual murre breeding colonies vary tremendously in their phenology as well as their relative attendance and reproductive success. This variation presumably reflects both local and regional differences among colonies, especially with regard to prey availability. With regard to the breeding of murres at colonies in Washington other than Tatoosh Island, it is unclear whether they tend to more closely follow the phenology of Oregon or Washington colonies (i.e. Tatoosh Island). As a result, the objective of this study was to complete two specific tasks:

(1) Conduct land-based surveys of the Grenville complex (Erin, Erin's Bride, Grenville Arch and Big Stack) for possible breeding activity.
(2) If murres are breeding at the Grenville complex, determine whether their breeding phenology is closer to that of Oregon colonies versus Tatoosh Island for the same season.

Tasks 1 and 2

Every one to seven days between 10 July - 7 August, 1997, and 2 July - 29 July 1998, we used a Questar telescope to observe the Grenville complex from the old naval base on the Quinault Indian Nation for potential murre attendance and breeding activity (Table 11). The structure of the Grenville Complex rocks is such that very little of the suitable habitat available to murres is visible from this observation point; most of the available nesting area is on the west side of these rocks that is not visible from the old naval base. As a result, aerial surveys conducted by Ulrich Wilson (USFWS) and others (e.g. Steve Jeffries, WDFW) have yielded counts in the thousands in recent years. However, the main objective of this study was not to obtain absolute numbers of murres attending and/or breeding on these rocks, but rather to determine whether they were attempting to breed and successfully rearing young. Although it is rarely possible to identify chicks from airplanes during aerial surveys, land-based observations are clearly superior for monitoring potential reproductive activity.

In general, attendance was lowest early in the morning and greatest at the end of the day; attendance typically increased to an initial maximum by 1030 h, subsequently decreased until 1230 h, and then increased again to a daily maximum at about 1730 h. As indicated in Table 11, eggs were first observed in early July and last seen on 5 August; in addition, chicks were first observed on 22 July, and first fledged about 5 August. This phenology is essentially identical to that of Tatoosh Island (J. Parrish, unpubl. data). In contrast, murres at Oregon colonies typically begin egg-laying in late April to early May, and fledge young by late June to early July (J. Parrish unpubl. data).

Table 11. Locations and maximum daily numbers of Common Murre adults, chicks and eggs at the Grenville Complex in the summers of 1997 and 1998.

	Location			
Date	Big Stack (adults, eggs, chicks)	Erin (adults, eggs, chicks)	Erin's Bride (adults, eggs, chicks)	Grenville Arch (adults, eggs, chicks)
10 July 1997	46, 2*, 0	--	--	--
14 July 1997	106, 0, 0	--	--	--
21 July 1997	103, 0, 0	--	--	--
22 July 1997	102, 0, 1	--	--	--
23 July 1997	105, 0, 2-4(?)	--	--	--
28 July 1997	71, 0, 9	--	--	--
1 August 1997	52, 1, 3	--	--	--
5 August 1997	90, 1, 1	--	--	--
7 August 1997	115, 1, 2	--	--	--
2 July 1998	91, 0, 0	19, 0, 0	24, 0, 0	35, 0, 0
8 July 1998	68, 0, 0	51, 0, 0	13, 0, 0	0, 0, 0
15 July 1998	47, 0, 0	10-15, 0, 0	0, 0, 0	40-50, 0, 0
21 July 1998	57, 0, 0	20, 0, 0	1, 0, 0	3, 0, 0
29 July 1998	40, 0, 0	29, 0, 0	3, 0, 0	24, 0, 0

* Two eggs initially observed about 1 July by Ken Warheit (WDFW) and subsequently on about 5 July by C. Thompson (WDFW).

Objective 3: Immigration of murres from Oregon.

Murres breed in huge numbers (approximately 700,000 total murres in Oregon, R. Lowe, USFWS, Pers. comm.) in Oregon compared to Washington where only a few thousand pairs breed. Thus, when murre mortality results from natural or anthropogenic events, it is a goal of management to be able to estimate as best as possible the percentage of mortality to Oregon versus Washington murres. Documenting the magnitude and geographic extent of summer and fall immigration of post-reproductive adult murres and their chicks from Oregon breeding colonies northward into Washington is a first step toward this goal.

Murres fledge with their fathers from breeding colonies in Oregon in late June or early July, on average, and disperse as far north as Cape Flattery and the outer Strait of Juan de Fuca by late July to early August (Thompson 1997a). In contrast, young murres do not fledge from Tatoosh Island, the only colony at which murres are known to breed annually in Washington, until early August or later. As a result, the distribution and abundance pattern of murres in Washington changes over the course of the summer. Murre chicks are accompanied by their fathers for at least a month after fledging. Thus, we speculated that the most definitive and least costly way to monitor the immigration of post-reproductive Oregon murres into Washington is by documenting the distribution and abundance of dad-chick murre pairs along the outer coast of Washington from late June through late August or early September.

We attempted to do this in summer 1996; however, extremely low reproductive success of Oregon murres resulted in very low rates of dad-chick pair immigration into Washington in July and August (Thompson 1997a). Thus, in the summers of 1997 and 1998, we surveyed the outer Washington coast for dad-chick pairs every other week from early June through early to mid-September (Tables 2, 4, 12).

Table 12. Observations of dad-chick pairs of murres along the outer Washington coast and Strait of Juan de Fuca in summer 1997.

Date	General Geographic Location	Transect Location	Distance from shore	Transect Length (km)	Number of dad/ chick pairs	Density per 10 linear kilometer
06 AUG	North Coast	Lapush to Neah Bay	offshore*	80.25	4	0.25
06 AUG	North Coast	Neah Bay to Lapush	nearshore**	80.11	5	0.31
13 AUG	North Coast	Umatilla to Lapush	offshore	133.56	7	0.26
13 AUG	North Coast	Westport to Lapush	nearshore	161.06	14	0.43
14 AUG	North Coast	Lapush to Westport	offshore	124.66	21	0.84
05 AUG	Strait	Port Angeles- Neah Bay	nearshore	102.41	0	0.00
07 AUG	Strait	Neah Bay to Port Angeles	offshore	97.95	1	0.05
19 AUG	Strait	Port Angeles east 15 km	200 M	14.63	0	0.00
19 AUG	Strait	Port Angeles to Neah Bay	offshore	97.08	1	0.05
19 AUG	Strait	Seal Rock to Kydaka Point	500 M	15.52	0	0.00
19 AUG	Strait	Seal Rock to Kydaka Point	zig-zag	18.97	0	0.00
19 AUG	Strait	Seal Rock to Kydaka Point	800 M	14.67	0	0.00
20 AUG	Strait	Seal Rock to Kydaka Point	500 M	14.99	0	0.00
20 AUG	Strait	Seal Rock to Kydaka Point	zig-zag	20.69	1	0.24
20 AUG	Strait	Neah Bay to Port Angeles	nearshore	102.9	4	0.19
25 AUG	Strait	Seal Rock to Kydaka Point	200 M	14.88	2	0.67
25 AUG	Strait	Seal Rock to Kydaka Point	500 M	14.17	0	0.00
25 AUG	Strait	Seal Rock to Kydaka Point	200 M	14.99	0	0.00
25 AUG	Strait	Seal Rock to Kydaka Point	800 M	13.73	1	0.36
25 AUG	Strait	Seal Rock to Kydaka Point	800 M	13.9	1	0.36
25 AUG	Strait	Seal Rock to Kydaka Point	zig-zag	20.6	1	0.24
16 JUL	South Coast	Willapa Bay to Columbia River	nearshore	76.34	0	0.00
16 JUL	South Coast	Mouth of Willapa Bay		6.49	0	0.00

17 JUL	South Coast	Willapa Bay to Columbia River	nearshore	75.48	1	0.07
30 JULY	South Coast	Willapa Bay to Columbia River	nearshore	80.88	3	0.19
30 JULY	South Coast	Willapa Bay to Columbia River	offshore	81.09	7	0.43
31 JULY	South Coast	Willapa Bay to Columbia River	offshore	82.91	11	0.66
31 JULY	South Coast	Willapa Bay to Columbia River	nearshore	77.06	4	0.26
12 AUG	South Coast	Willapa Bay to Columbia River	nearshore	76.79	14	0.91
12 AUG	South Coast	Columbia River to Willapa Bay	offshore	77.03	19	1.23
12 AUG	South Coast	Mouth of Gray's Harbor		4.26	0	0.00
14 AUG	South Coast	Mouth of Gray's Harbor		8.15	1	0.61

* "nearshore" approximates 400 meters from shore, except in locations where hazards exist.

** "offshore" approximates 1200 meters from shore

No dad/chick pairs found during surveys of SOUTH COAST (south of Gray's Harbor) on 19-20 June and 02 July

No dad/chick pairs found during surveys of NORTH COAST (north of Gray's Harbor) on 11-12 June, 24-25 June, 9-10 July, and 15 July

No dad/chick pairs found during surveys of STRAITS on 22-25 July

Figures 17 and 18 (below) illustrate the density of dad-chick pairs of murres immigrating northward along the outer coast of Washington and eastward down the Strait of Juan de Fuca in the summers of 1997 and 1998. Based on data from other researchers who observed the breeding of murres at Oregon colonies in 1997 and 1998 (Roy Lowe, USFWS; J. Parrish, Univ. Of Washington), we know that murres achieved much greater reproductive success in 1998 than in 1997. Correspondingly, the mean density of dad-chick pairs in 1998 was about seven times that of 1997. This suggests that this method of monitoring murre immigration is both sensitive and accurate, and may be used in future years to forecast the magnitude of murre immigration into the Strait of Juan de Fuca and Puget Sound during Tribal and non-tribal gill-net fisheries.

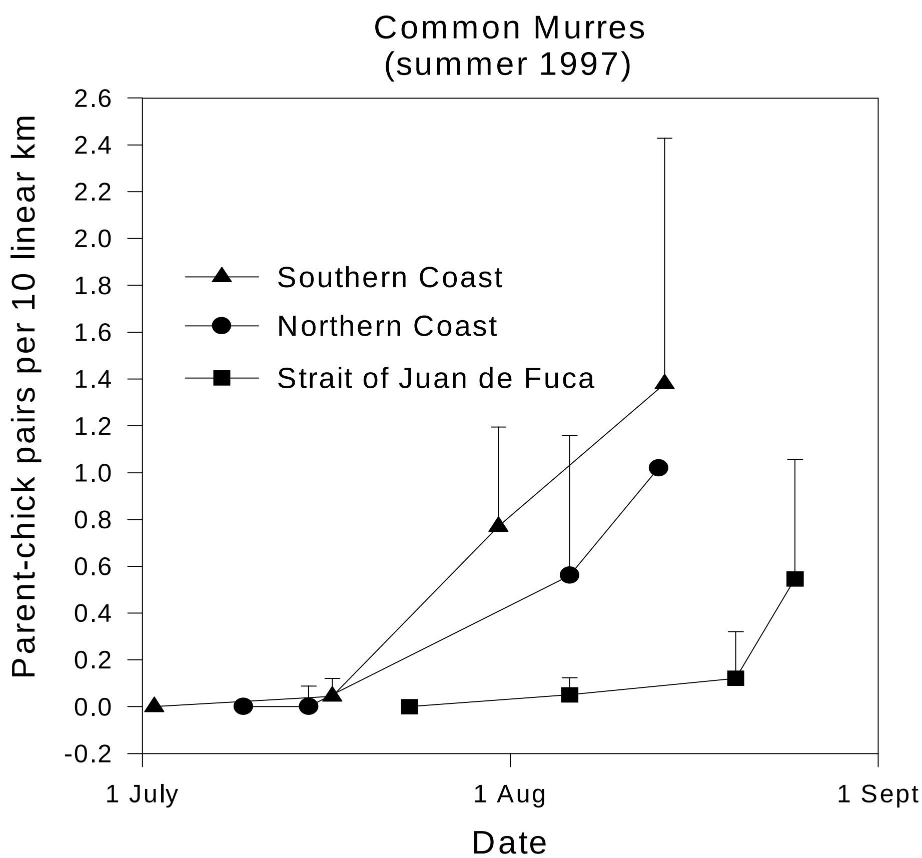


Figure 17. Density of dad-chick pairs of Common Murres along the outer coast and Strait of Juan de Fuca of Washington in the summer of 1997.

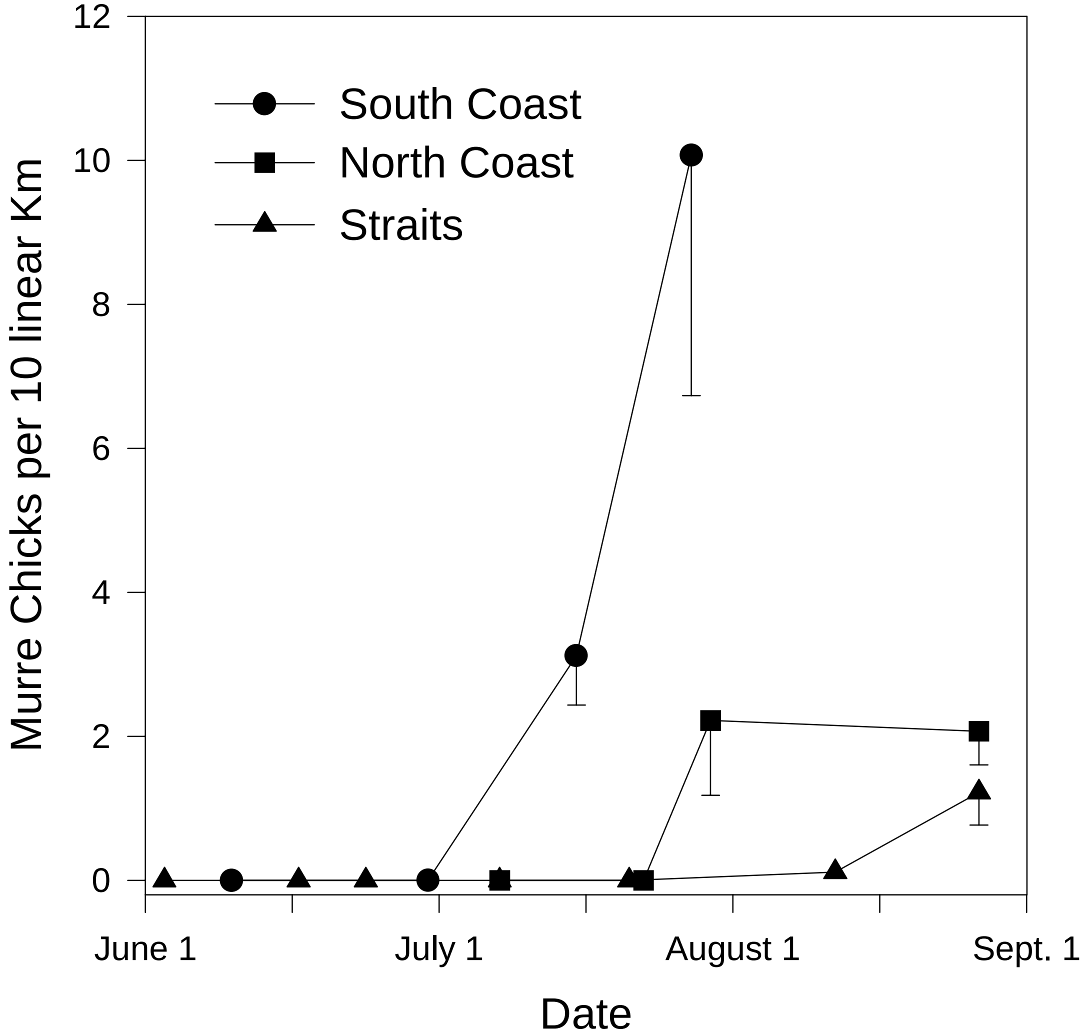


Figure 18. Density of dad-chick pairs of Common Murres along the outer coast and Strait of Juan de Fuca of Washington in the summer of 1998.

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