Attendance and Reproductive Success of Tatoosh Island Common Murres

Final Report 1997

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Executive Summary

In 1997, Common Murres (*Uria aalge*) nested on Tatoosh Island, Washington and successfully produced fledglings. The colony-wide attendance estimate was 3204, 8% lower than 1996, and the lowest figure since attendance estimates started in 1991. Multiply-counted subcolonies were also depressed in mean afternoon attendance (down 24% from 1996) a highly significant decline. The breeding season was slightly delayed relative to the 1996 season, but was not unusually late. Phenology appeared to be synchronized within a subcolony but not necessarily between subcolonies. For pairs nesting on monitored cliff-top subcolonies, laying peaked between 15 and 29 June, hatching between 17 and 30 July, and fledging between 10 and 28 August. Several subcolonies lost eggs in late June/early July and relaid such that chicks were still hatching in late August. Although murre numbers appeared to be lower than in previous years, reproductive success was uniformly high in all monitored subcolonies. Fledglings per pair ranged from 0.87 in the monitored crevice subcolonies to 0.74-0.78 in the monitored cliff-top subcolonies. These are the highest reproductive success values recorded on the cliff-top subcolonies since monitoring began (1992). The main factors most likely to influence patterns of murre attendance and reproduction: Bald Eagle (*Haliaeetus leucocephalus*) visitation and the onset of an intense El Niño, did not appear to manifest significant colony-wide effects. Although eagles were responsible for poor attendance and reproductive performance of one cliff-top subcolony, they were present in lower numbers than in previous years and did not hunt along the crevice subcolonies as they had in 1996. The fact that only 25 stolen murre eggs were observed/recovered (as opposed to 239 in 1996) provides indirect evidence that eagle effects were lower. El Niño effects would most likely be manifested as depressed reproductive success, including egg abandonment and chick starvation. Although several chicks on monitored plots died (11 out of 128), the vast majority fledged in a mean of 25.7 days, an equivalent value to fledging age in 1996.

INTRODUCTION

In 1997, we continued to collect basic demography data on the Common Murre (*Uria aalge*) population nesting on Tatoosh Island, Washington. Data collection specifically addressed colony size (annual attendance) and reproductive success. To that end, data were collected which overlapped the methods and sites used in previous years (1991-1996) to maximize comparative accuracy. As the Tatoosh murre colony was the closest colony to the *Tenyo Maru* oil spill, murres were the largest fraction of avian carcasses recovered immediately following the spill, and the estimate of murre attendance fell in the years following the spill there is good circumstantial evidence that the oil spill affected this colony. However, there are other factors which have had significant influence on the health of the Tatoosh colony, notably the presence of Bald Eagles (*Haliaeetus leucocephalus*) which prey upon adults murres and indirectly facilitate substantial egg loss to Glaucous-winged Gulls (*Larus glaucescens*) and Northwestern Crows (*Corvus caurinus*; Parrish 1995). In past years, eagle-facilitated egg predation has led to chronic reproductive failure of at least one of the largest subcolonies on Tatoosh (Parrish 1995, Parrish and Paine 1996) and may be responsible for the high degree of volatility in cliff-top subcolony attendance seen on Tatoosh (Parrish, unpub. data). Nevertheless, the colony as a whole has remained fairly stable in size and has produced fledglings in all years since observations began (1991).

In addition, there is concern that physical oceanographic changes may affect colony attendance and reproductive success. Cyclic anomalies exemplified by the El Niño-Southern Oscillation (ENSO) periodically warm ocean temperatures (the El Niño half of the cycle) to several degrees above normal. Such conditions were apparent in 1992 and 1993 and again in 1997. Because ocean warming is a harbinger of lessened upwelling, there is a correlation between warmer temperatures and less productive oceanic systems (Barber & Chavez 1986). Trophic dynamics may be altered as the effects of bottom-up control ripple through the system essentially depressing the food resources for upper-level trophic predators such as seabirds (Ainley et al. 1995, Hodder & Graybill 1985, Wilson 1991). Continual monitoring of a colony such as Tatoosh is valuable to document the effects of such large scale perturbations as El Niño, as well as to collect baseline information on murre numbers and long-term reproductive output in a sensitive area of coastline.

This report documents the data collected during the 1997 nesting season, presents a comparison to earlier years, and provides a brief analysis of the factors influencing the Tatoosh murre population relative to other known murre colonies along the Pacific Coast.

METHODS

Methods used in 1997 to collect data on Common Murre attendance, phenology, and reproduction on Tatoosh Island were not substantively different from previous years. As these have been covered in detail elsewhere (Parrish 1997 and earlier reports), only year-specifics will be covered herein.

Personnel - In addition to Parrish, two technicians (Karen Jensen and Suzanne Romain) and three students (Brian Walker, Karen Mabry, and Jessica Tam) collected murre data in 1997 (Figure 1). An additional student (Monica Carneiro Da Silva) assisted in pre-nesting period trips to erect blinds and check for early eggs (total pre-season: 2 trips, 6 calendar days, 12 person days). A trip was also made in mid-September in the company of RT Paine and his students, to take down blinds for the season (total post-season: 1 trip, 2 calendar days, 2 person days). These latter trips are not recorded on Figure 1. Two additional students (Teresa Bomersbach and Laura South-Oryshchyn) helped with data entry and analysis.

Seasonal Coverage - During the breeding season, data were collected between 10 June and 29 August for a total of 51 calendar days and 115 person days (Figure 1). This coverage approximates the 1996 season. Our three main observation posts were Burning Barrel Point (BBPT), a set of plywood and one-way mirrored blinds (see Figure 4 Parrish 1997) situated along the live salmonberry edge of the Main Cliff-top Extension subcolony (MCT-EXT), and a second set of plywood and one-way mirrored blinds similarly situated at the Petrified subcolony (PETCOL). Observations were made for in units of 1/2hr blocks, spaced evenly throughout the day and season. BBPT was the site from which we collected hourly attendance data on the monitored crevice subcolonies (Crisscross: CC1-5; Tenniscourt: TC1-4) as well as phenology and reproduction data on CC1-4 (91hr of observation between 0600H and 2200H). Blinds were used as observation sites from which phenological and reproductive data on all pairs within defined subplots of the subcolony were collected (MCT-EXT: 124hr of observation between 0600H and 2000H; PETCOL: 113hr of observation between 0600H and 2000H). Note that lower light levels as a consequence of salmonberry shading and darkened mirror glass prevented observation past 2000H. Additional data on attendance and reproduction were collected at sites throughout the Island; however, no specific record of hours were kept.

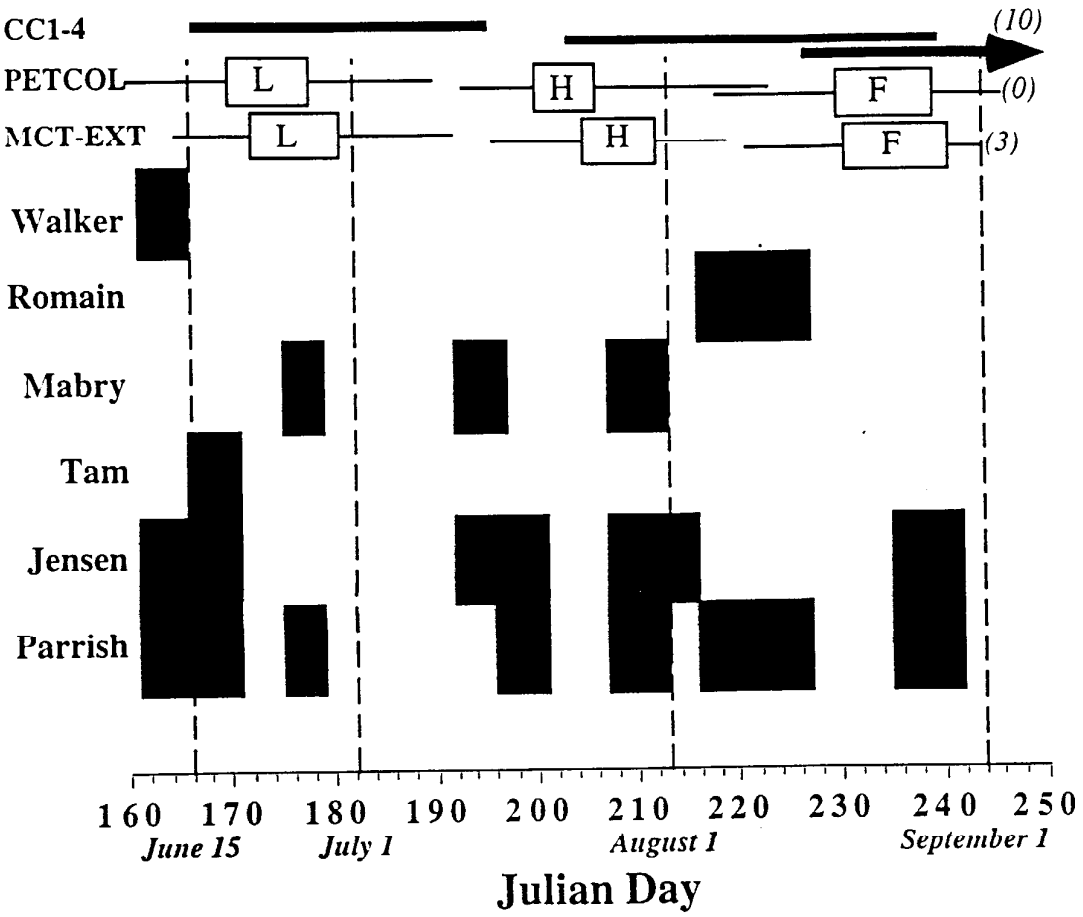


Figure 1. Days spent on Tatoosh Island during the 1997 Common Murre breeding season and murre breeding phenology (L=laying, H=hatching, F=fledging) as assessed during those trips. Dashed lines are dates noted below the Julian Day axis. Filled boxes indicate presence of specified observers. For the two cliff-top subcolonies (MCT-EXT, PETCOL), range and middle two quartiles (50%) are indicated. For the crevices subcolonies (CC1-4), only range is indicated. The arrow indicates probable fledging beyond 29 August. Numbers in () indicate how many chicks were left in the nesting area survey plot after 29 August. There were also additional chicks outside of the survey plot on MCT-EXT after 29 August.

Attendance - All observers who collected attendance data were required to count in the presence of an experienced counter (Parrish, Jensen) until counts were within a maximum difference of 10%. In practice, most counts were more similar. In addition, all counters were required to make spot multiple counts, to check for intra-observer accuracy. For experienced observers counting large (defined as over 100) subcolonies, accuracy was consistently at or less than 2% difference. For in-experienced observers, accuracy was at or less than 5% difference. Because in-experienced observers were more variable, all of their counts were lower than the experienced observers, and their intra- and inter-counting

accuracy increased over time (i.e. a learning curve), early counts (defined as the first three full days of counting a given set of subcolonies) were not included in the final dataset.

In 1997, all attendance data were direct counts, except for Pole Island (PI) at which an approximate 1/4 of the total subcolony was visible. As in previous years, the PI count was multiplied by 4 to obtain the PI attendance estimate. All subcolonies were counted from locations on Tatoosh Island with the exception of the Toadpoint crevice and cliff-top subcolonies (TP1-4, TPCT1-2), and Rainbow Rock (RR) 1-2 which were counted from the deck of the OCNMS *RV Tatoosh* and a smaller private boat. During these boat trips, photographs were taken for later counting and verification. The photographic counts were used instead of direct counts for the TP and TPCT subcolonies as the latter were of lesser quality (greater than 10% variation both within and between observers) due to wave action close to the Island. Photographs of all other subcolonies were only used for verification and documentation purposes. Although counts were made in both the morning and the afternoon (as in previous years), during 1997 all subcolonies were counted more than once during the afternoon. To minimize errors introduced during standardizations, only afternoon counts were used to estimate annual colony attendance.

As in previous years, it was necessary to count several subcolonies from multiple locations as the entire crevice could not be seen from any one place. These included: CC 4 and 5, and TC 3. For these subcolonies, distinctive rock features were used to mentally mark the limits of observation from the main counting platform (BBPT) and the remaining birds were counted from additional sites. Because these subcolonies are part of the monitored crevice subcolony complex (CC1-5; TC 1-4), different attendance values are reported herein depending on analysis. For the Island-wide annual attendance estimate, totals (that is, a combination of counts from more than one location) were used. For the daily and seasonal attendance patterns analysis, only the BBPT counts were used.

Breeding Phenology & Reproductive Success - In 1997, laying was fairly synchronous within subcolony, but not among subcolonies. Consequently, there was virtually no day during which laying, hatching, and/or fledging were not occurring. Because the field accommodations on the island are shared with RT Paine and his colleagues, we were not able to remain on the island throughout the season and there are gaps in our records (Figure 1). This prevented us from accurately estimating mean laying, hatching, and fledging as was the case in 1996. Instead, the 1997 measure includes the actual or estimated range of laying, hatching, and fledging (comparable to 1996 data) and the calendar days over which

the middle 50% of each breeding period took place. In practice, this measure was estimated rather than measured, according to forward (for hatching) or backward (for laying) calculations using average egg incubation time or average chick fledging time (for fledging). Incubation period and fledging age were calculated for known-age eggs/chicks.

Reproductive success was assessed as fledglings per pair, as in previous years. For crevice subcolonies (CC1-4) all distinguishable pairs were followed and the fate of eggs and chicks determined. Because it was often impossible to clearly see eggs or young chicks, due to remote observation and inclement weather, strict measures of breeding phenology (that is, known-age eggs/chicks) and accurate egg loss were impossible to determine. As in past years, fledging was defined as either actual fledging observed or chick healthy and older than 15 days (a probable fledger). The majority of the chicks actually fledged unless otherwise noted. For the cliff-top subcolonies (MCT-EXT and PETCOL), the reproductive fate of all pairs within plots adjacent to the blinds were followed. Due to observer proximity, daily presence of eggs or chicks was easy to determine and measures of both breeding phenology and hatching success are correspondingly stronger as compared to the crevice subcolonies.

Results

ATTENDANCE

Colony Estimate & Trends - In 1997, the colony-wide attendance estimate for afternoon counts after egg laying began but before chick fledging started, was 3204 the lowest value since we started estimating colony attendance (1991) and an 8% decrease from 1996 (3467; Table 2; 1996 divided by 1997). Unlike in past years, we were able to count all subcolonies during the afternoon and did not have to apply morning-to-afternoon correction factors in determining our estimate.

All 39 subcolonies present in 1996 were also attended in 1997. Of these, the majority (22) had lower attendance (sign test, $C_{.05(2),39}=12$, $0.5<p<0.2$). The majority of these attendance declines were small. The drop in colony-wide attendance was primarily driven by a large decrease (-632) in attendance on PI which went from 1284 birds in 1996 to only 652 in 1997. This decline was balanced, to some degree by an dramatic increase in the number of birds attending PETCOL (+450) and a smaller increase in birds attending MCT-EXT (+50). In general, the cliff-top subcolonies appeared more volatile in attendance relative to the crevice subcolonies, a pattern typical of previous years (Table 1).

Table 1 Average estimated annual attendance (afternoon counts during the egg/chick period) - Tatoosh Island Common Murres. a=afternoon, m=morning, Rk#=USFWS rock number, cr=crevice, ct=clifftop, n=no, y=yes, p=probably

M/A	Subcolony	Rk#	Hab.	1991	1992	1993	1994	1995	1996	1997	97-96	Chks?	Comments
a	rainbow rock 2	035	cr					212	200	193	-	y	born 1995
a	rainbow rock 1	035	cr	50	63	24	35	38	15	43	+	y	
a	rainbow rock - top	035	ct							4		y	born 1997
a	boom	021	ct	50									died 1991
a	north island	022	cr	99	134	100	150	136	139	89	-	y	
a	north island ridge	022	ct				22						born 1994; died 1995
a	north island 2	022	cr					27	28	25	-	y	born 1995
a	finger 1	022	cr				31	16	38	30	-	y	born 1994
a	finger 2	022	cr							31		y	born 1997
a	pole island	023	ct	1300	1532	1176	1264	1108	1284	652	-	y	plot est. @ 25%
a	lighthouse 1	021	cr	89	75	27	101	110	132	89	-	y	
a	lighthouse 2	021	cr	3	0	1	8	6	9	8	-	y	
a	lighthouse 3	021	cr	23	15	0	25	19	15	13	-	y	
a	lighthouse 4	021	cr	11	25	8	6	28	35	25	-	y	
a	lighthouse 5	021	cr					17	28	31	+	y	born 1995
a	submarine	021	cr	50	30	42	43	44	51	46	-	y	
a	below submarine	021	cr						5	0	+		born 1996
a	burning barrel	021	cr	6	9	0	6	2	16	13	+	y	
a	burning barrel 2	021	cr					32	64	4	+	y	born 1995
a	burning barrel 3	021	cr					2	13	13	0	y	born 1995
a	above crisscross	021	cr				3	6	10	0	-		born 1994
a	crisscross 1	021	cr	39	32	28	29	38	52	46	-	y	
a	crisscross 2	021	cr	45	37	30	36	54	59	36	-	y	
a	crisscross 3	021	cr	27	31	17	27	57	59	42	-	y	
a	crisscross 4	021	cr	60	35	34	52	50	54	43	-	y	
a	crisscross 5	021	cr	173	94	85	104	141	173	125	-	y	
a	r-crisscross	021	cr	15	21	10	26	36	9	22	+	p	
a	r-crisscross lower	021	cr						21	0	-		born 1996
a	fr-crisscross	021	cr	20	19	12	22	12	35	21	-	p	
a	fr-crisscross 3	021	cr						15	3	-	n	born 1996

Table 1 Average estimated annual attendance (afternoon counts during the egg/chick period) - Tatoosh Island Common Murres. a=afternoon, m=morning, Rk#=USFWS rock number, cr=crevice, ct=clifftop, n=no, y=yes, p=probably

a	tenniscourt 1	021	cr	79	36	30	29	40	40	31	-	y	
a	tenniscourt 2	021	cr	50	29	23	20	26	30	26	-	y	
a	tenniscourt 3	021	cr	82	91	71	64	77	95	90	-	y	
a	tenniscourt 4	021	cr	25	23	21	21	19	20	26	+	y	
a	moustache	021	cr					3	0	11	+	p	born 1995
a	toadpoint 1	021	cr	50	27	25	43	60	61	99	+	y	
a	toadpoint 2	021	cr	50	22	35	24	24	27	56	+	y	
a	toadpoint 3	021	cr	50	15	15	19	23	35	38	+	y	
a	toadpoint 4	021	cr							12		p	born 1997
a	tpclifftop 1	021	ct	48	30	26	7	15	19	38	+	p	partial count
a	tpclifftop 2	021	ct	24	46	30	4	17	0	12	+	p	partial count
a	main clifftop	021	ct	1500	1200	1300	1200	600					max count; died 1996
a	mct-extension	021	ct						300	350	+	y	born in 1996; estimate
a	below mct	021	cr				10						born 1994; died 1995
a	way below mct	021	cr						31	68	+	y	born 1996
a	petrified	021	ct	200	200	200	260	175	250	700	+	y	estimate
	TOTAL			**4214**	**3871**	**3370**	**3691**	**3270**	**3467**	**3204**	16 (-)	32(y)	
	# of nesting areas			28	27	27	31	35	39	42	22 (+)	6(p)	
	morn-aft multiplier			1.6	1.5	1.2	1.3	1.13	1.35	1.19	1 (0)	1(n)	
	crev total			1092	863	638	934	1355	1614	1448			
	ct total			3122	3008	2732	2757	1915	1853	1756			
	crevice %			26	22	19	25	41	47	45			

There were three new subcolonies born in 1997: two crevices - Toadpoint (TP) 4, Finger (F) 2, and one cliff-top - Rainbow Rock Top (RR-TOP). Although all of these subcolonies were small (total additional attendance of 47 birds), at least two (RR-TOP, F2) produced chicks (Table 1).

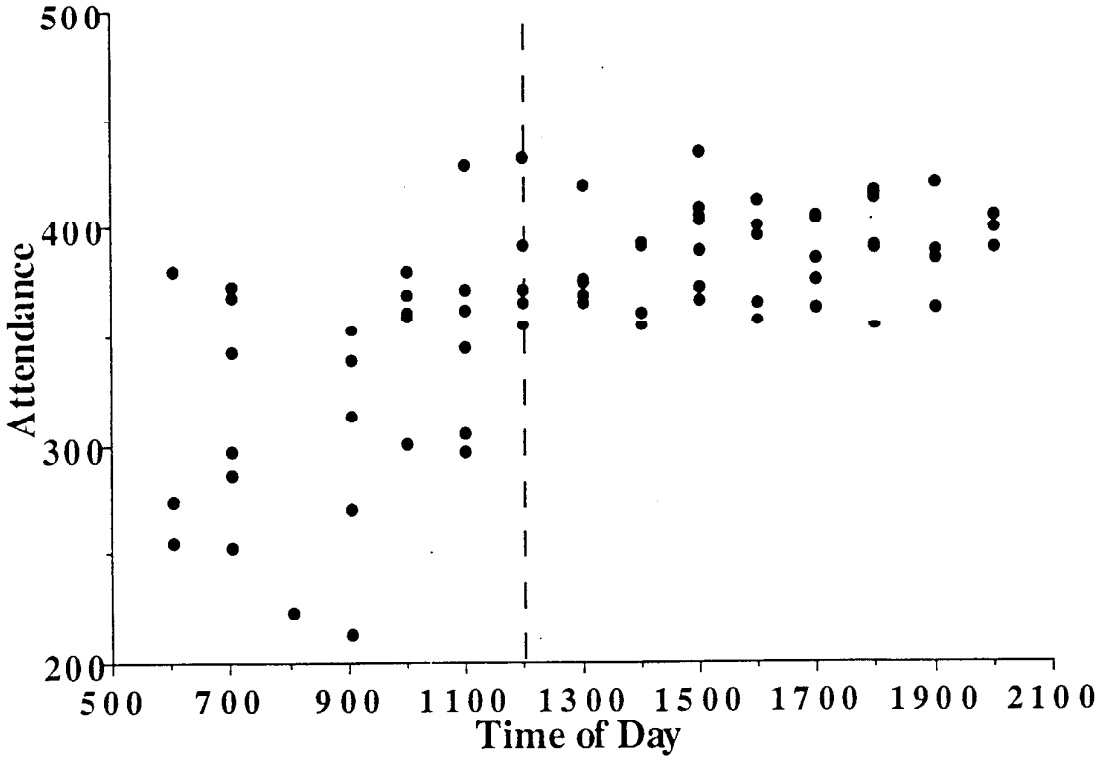


Figure 2. Attendance summed across CC1-5 and TC1-4, as counted hourly. Data are from the period after murres remained on the crevices throughout the day and before fledging from the crevices (17 June - 10 August 1997), and are limited to only those hours in which all relevant crevices were counted (i.e., no partial counts). A Student's t-test on morning versus afternoon means indicates there were significantly fewer murres in attendance in the morning (see text for complete statistics). The dashed line indicates the morning-afternoon division.

Multiple Count Subcolony Attendance - As in past years, the CC and TC crevices were counted on the hour over the day and season to determine patterns of attendance as a function of time of day, breeding phenology, and to statistically test interannual differences. For counts made after the onset of egg laying but before the onset of chick fledging (17 June through 10 August - the nesting period), morning values (326.2 ± 54.3; N=27) were significantly lower than afternoon values (390.7 ± 21.9; N=44; T = -5.882, df = 31,2; $p < 0.001$, separate variances; Figure 2), a pattern repeated in all earlier years

(Table 2). Note that there are slight differences in mean test values and values presented in Table 2, due to slight variations in samples used (Table 2 - all samples; statistics - only full counts). Afternoon counts were 24% lower in aggregate than in 1996 (1996 divided by 1997), a highly significant decline (two-sided t-test, T=10.034, df=54, p<0.001). The daily pattern of attendance was similar to previous years but more variable (Figure 2). Although attendance was definitely lower in the morning, there was not the clear sigmoidal attendance curve displayed in earlier years (compare, for instance, Figure 2 from Parrish 1997).

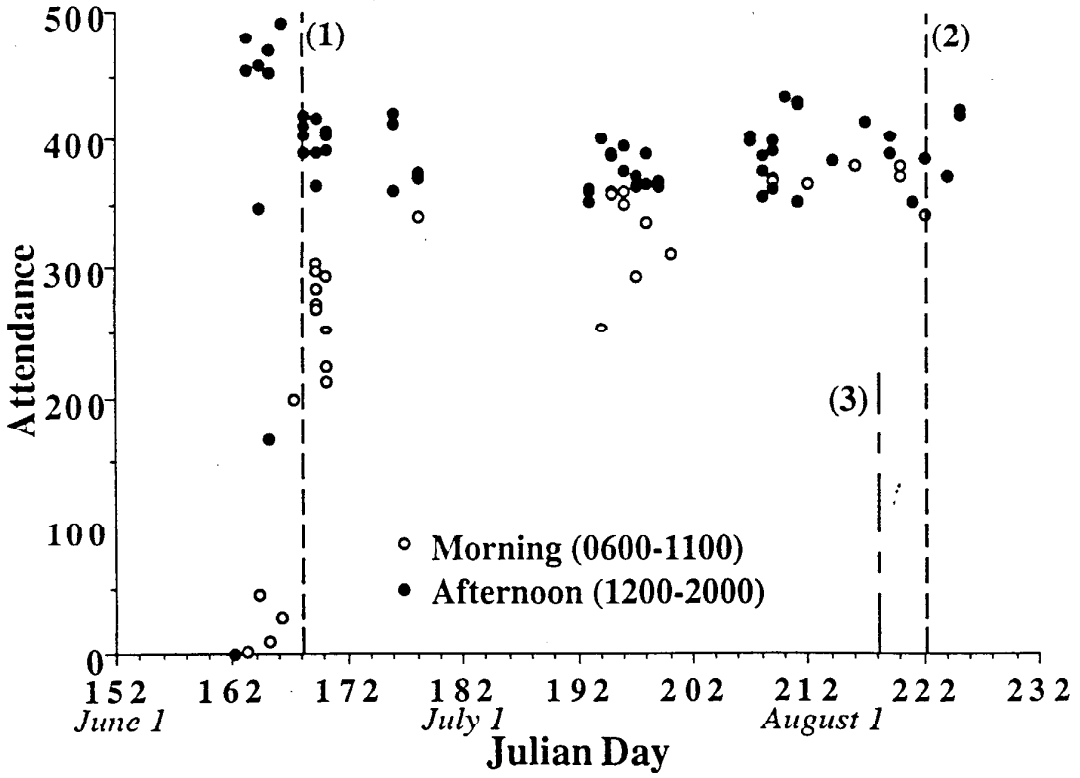


Figure 3. Daily patterns of attendance summed over CC1-5 plus TC1-4 as counted hourly. Data are from 11 June through 14 August 1997 and include only counts of all relevant crevices (i.e., no missing data). Regular dashed lines indicate the period over which attendance as a function of time of day was assessed (see Figure 2). (1) The first day murres were observed on crevices throughout the day. (2) Fledging begins in the crevices. (3) Fledging begins in the cliff-top subcolonies.

Table 2 - Average of attendance counts made from BBPT (1991-1997) during egg/chick period for monitored crevice subcolonies.

		Morn X	Morn SD	Morn N	Aft X	Aft SD	Aft N
1991	crisscross 1	24.50	8.67	3	38.50	16.26	2
	crisscross 2	16.83	4.54	3	44.83	28.06	3
	crisscross 3				27.00		1
	crisscross 4	42.00	19.67	3	59.75	14.50	2
	crisscross 5	110.00	8.66	3	173.33	66.82	3
	tenniscourt 1	30.00		1	78.50	30.41	2
	tenniscourt 2	30.00		1	50.00		1
	tenniscourt 3	60.00		1	81.50	26.16	2
	tenniscourt 4	10.00		1	25.00	7.07	2
	TOTAL	323.33			578.42		
	ADJUSTED	291.73			505.21		

Note: The 1991 counts were made from SB and TP NOT BBPT; pre-spill only
Adjusted totals: BBPTCC4=CC4.5; BBPTCC5=CC5*.75; AFT=MORN*1.6*

1992	crisscross 1	21.20	9.36	5	31.25	5.73	8
	crisscross 2	25.20	7.46	5	36.00	9.74	8
	crisscross 3	15.80	9.36	5	30.25	6.86	8
	crisscross 4	10.60	3.13	5	15.88	1.81	8
	crisscross 5	76.40	22.81	5	93.88	18.14	8
	tenniscourt 1	26.40	12.10	5	34.88	3.40	8
	tenniscourt 2	19.60	10.24	5	27.50	3.42	8
	tenniscourt 3	66.40	34.26	5	90.88	10.26	8
	tenniscourt 4	17.00	7.07	5	23.38	4.00	8
	TOTAL	278.60			383.88		
1993	crisscross 1	19.00		1	28.43	5.13	7
	crisscross 2	5.00		1	30.29	11.76	7
	crisscross 3	0.00		1	16.71	11.00	7
	crisscross 4	8.00		1	13.43	2.99	7
	crisscross 5	56.00		1	84.71	16.85	7
	tenniscourt 1	28.00		1	30.33	5.28	6
	tenniscourt 2	14.00		1	22.50	5.17	6
	tenniscourt 3	49.00		1	70.83	9.41	6
	tenniscourt 4	19.00		1	21.00	2.76	6
	TOTAL	198.00			318.24		
1994	crisscross 1	27.13	4.64	15	29.31	5.25	16
	crisscross 2	31.50	13.75	14	35.50	9.17	16
	crisscross 3	21.07	8.18	15	26.69	9.67	16
	crisscross 4	11.33	5.42	15	17.35	13.53	17
	crisscross 5	76.47	16.17	15	85.53	12.80	15
	tenniscourt 1	20.43	8.71	14	28.53	7.76	17
	tenniscourt 2	12.71	8.43	14	19.53	9.68	17
	tenniscourt 3	35.29	23.45	14	64.35	26.34	17
	tenniscourt 4	18.77	4.51	13	21.25	4.80	16
	TOTAL	254.70			328.05		

Table 2 - Average of attendance counts made from BBPT (1991-1997) during egg/chick period for monitored crevice subcolonies.

1995	crisscross 1	36.57	4.72	7	37.82	3.84	11
	crisscross 2	41.43	8.62	7	53.82	12.29	11
	crisscross 3	49.71	11.79	7	57.09	8.07	11
	crisscross 4	19.57	5.09	7	21.00	5.51	11
	crisscross 5	100.52	13.61	7	114.00	14.81	11
	tenniscourt 1	35.57	6.21	7	40.09	3.94	11
	tenniscourt 2	20.86	3.98	7	25.73	3.44	11
	tenniscourt 3	72.00	12.68	7	77.00	8.45	11
	tenniscourt 4	15.86	2.97	7	19.45	5.57	11
	TOTAL	392.10			446.00		
1996	crisscross 1	31.00	3.49	23	39.36	4.84	14
	crisscross 2	37.52	3.61	23	58.93	9.03	14
	crisscross 3	38.74	7.94	23	59.57	6.41	14
	crisscross 4	14.68	2.55	22	21.08	4.25	12
	crisscross 5	95.50	7.49	22	119.90	8.69	13
	tenniscourt 1	31.45	4.07	22	39.92	4.80	13
	tenniscourt 2	20.27	3.95	22	29.92	4.80	13
	tenniscourt 3	72.91	8.85	22	95.31	8.12	13
	tenniscourt 4	14.82	3.14	22	20.08	2.14	13
	TOTAL	356.89			484.07		

Note: Attendance data for 1996 from 12 June through 3 July 1996 only.

1997	crisscross 1	30	4.9	28	34.64	3.15	47
	crisscross 2	29.32	7.46	28	35.87	6.85	47
	crisscross 3	35.64	11.14	28	42.17	5.35	47
	crisscross 4	10.64	2.7	28	13.21	2.13	47
	crisscross 5	88.46	10.79	28	97.6	8.73	47
	tenniscourt 1	24.15	7.04	27	31.38	3.03	45
	tenniscourt 2	19.04	6.19	27	26.4	3.43	45
	tenniscourt 3	67.18	10.56	27	83.91	6.68	45
	tenniscourt 4	21.74	3.97	27	26.29	3.51	45
	TOTAL	326.17			391.47		

Note: Attendance data for 1997 from 17 June through 10 August only

Note: TC3 attendance is smalle than in Table 1 because a newly colonized portion of this crevice was not visible from BBPT.

General Note: The counts for CC1, 4, and 5 are lower than in Table 1 because none of these crevices were entirely visible from BBPT.

Seasonal attendance patterns in 1997 differed widely from 1996, no surprise given the intense eagle harassment of the crevices in 1996 but not in 1997. Afternoon attendance was stable throughout the nesting period, while morning attendance was depressed primarily during the egg laying period (Figure 3). Note the extreme variability in attendance prior to egg laying, both well below and above the mean (390.7).

PHENOLOGY

Egg Laying Phenology - Nine eggs were present on MCT-EXT on 12 June and eggs appeared on PETCOL by 14 June and the CC crevice subcolonies by 16 June (Figure 1). Final eggs appeared sometime after 27 June on the cliff-top subcolonies (MCT-EXT 7 additional eggs; PETCOL 25 additional eggs) and 14 July on the CC crevice subcolonies. Figure 1 indicates laying range and the days over which the middle 50% of the eggs were laid (cliff-top subcolonies only). Mean lay dates were not calculated as a significant fraction of followed eggs were laid in our absence. In 1996, egg laying appeared to be slightly earlier. Mean lay date on MCT-EXT was 18 June in 1996, as compared to between 21 and 29 June in 1997. However, PETCOL laying phenology was slightly accelerated - the middle 50% of followed eggs were laid between 15 and 22 June.

Although laying was marginally earlier in 1996, it was also more protracted due to exceedingly high egg loss (last egg laid on 1 August). In 1997, only 25 eggs were observed taken by predators, smashed below subcolonies, or as eggshell fragments in paths in the interior of the island (probable crow food), as compared to 239 eggs in 1996 (observations collected over a comparable period of effort).

Egg Incubation Period - Mean egg incubation was 31.7 days with a standard deviation of 1.3 days for known-age eggs on both the MCT-EXT (N=9) and PETCOL (N=16). This is slightly shorter than mean incubation period for 1996 (32.2 ± 0.9; N=17), albeit not significantly so (two-tailed t-test, T=1.473, df=40, 0.2>p>0.1). Biologically, however, this difference translates into less than a single day.

Chick Hatching Phenology - Chicks appeared on the PETCOL on 12 July and 15 July for MCT-EXT. On the crevice subcolonies, no chicks were present on 19 July although several had hatched by 26 July (Figure 1). Mid-range of hatching occurred between 17 and 23 July on the PETCOL and 24-30 July on MCT-EXT. In 1996, mean hatching on MCT-EXT was 24 July, perhaps slightly earlier than in 1997. Final eggs hatched on 7 August

on MCT-EXT, 11 August on PETCOL, and 27 August on the CC crevices. The pattern of extended laying and demonstrably later hatching on the crevice as compared to the cliff-top subcolonies was also the case in 1996.

Chick Fledging Period - Known aged chicks fledged after 26.5 ± 2.8 days from MCT-EXT (N=17) and 25.2 ± 1.9 days from PETCOL (N=24). These periods are not statistically distinguishable (two-sided t-test, T=1.6624, df=39, 0.2>p>0.1). Fledging age of the MCT-EXT chicks was also marginally longer than mean chick age in 1996, albeit not statistically so (25.2 ± 1.6 days; N=17; two-sided t-test, T=1.6619, df=32, 0.2>p>0.1).

Chick Fledging Phenology - The first chick fledged on 6 August from PETCOL, six days before the last egg hatched. First fledging on MCT-EXT occurred on 9 August. Fledging on the CC crevices had not started by 14 August, although several chicks had fledged by 23 August. Based on mean age on known-aged chicks, we estimate fledging began by 15 or 16 August. Mid-range fledging occurred between 10 and 18 August on PETCOL and 19 to 28 August on MCT-EXT. In 1996, mean fledging on MCT-EXT occurred on 18 August, slightly earlier than in 1997. The last chick fledged from PETCOL on 29 August. After 30 August, 3 chicks remained on MCT-EXT and nine chicks remained on the CC crevices. No birds were present on the colony when blinds were removed on 18 September.

REPRODUCTIVE SUCCESS

Cliff-top Subcolonies - On MCT-EXT 66 pairs were followed, all of which laid eggs. Nine eggs were lost or abandoned late in the season as probable duds, the remaining 57 eggs hatched into chicks. Gulls were observed taking three eggs. Of the chicks, 5 died, 49 definitely fledged and 3 chicks remained - two of which were probable fledgers and one of which certainly died as it was 45 days old when we left and had been abandoned for several days. Fledglings per pair ranged from 0.74-0.77, well above 1996 (0.54-0.63; Table 3).

Reproductive success on PETCOL was similarly high. Of 85 pairs followed (all of which laid eggs), 14 were lost or abandoned and the remaining 71 hatched as chicks. Gulls were suspected of taking one egg. Five chicks died and the remaining 66 fledged. Fledglings per pair was 0.78, significantly higher than in 1996 (0.18-0.28; Table 3).

Table 3 - Tatoosh Island Common Murre reproductive output in crevice subcolonies (1992-1997) as monitored from BBPT and cliff-top subcolonies (1996-1997) as monitored from blinds. Known pairs are defined as all pairs (assessed by location) which did or were suspected to have eggs. Known lost eggs were either observed abandoned, stolen, smashed, or failing to hatch. Both measures are minimum estimates of pairs and lost eggs, respectively. Fledglings are defined as chicks known to have fledged or chicks greater than 15 days old (crevices - early years). A range of fldglings/pair encompasses known to have fledged to known + probable fledging.

	1992	1993	1994	1995	1996	1997
CC1						
Attendance (aft)	31	28	29	38	39	35
Known Pairs	15	11	22	18	19	17
Known Lost Eggs	2	1	1	1	10	4
Chicks > 15D	11	7	20	17	2	13
Fledglings/Pair	.73	.64	.91	.94	.11	.59-.76
CC2						
Attendance (aft)	36	30	35	54	59	36
Known Pairs	17	9	21	15	18	21
Known Lost Eggs	2	4	2	12	17	3
Chicks > 15D	16	2	18	11	0	17
Fledglings/Pair	.94	.22	.86	.73	0.0	.81
CC3						
Attendance (aft)	30	17	27	57	60	42
Known Pairs	11	2	7	20	24	29
Known Lost Eggs	0	2	6	3	15	1
Chicks > 15D	7	0	1	17	0	28
Fledglings/Pair	.64	0.0	.14	.85	0.0	.93-.97
CC4						
Attendance (aft)		13	17	21	21	13
Known Pairs		6	7	7	10	8
Known Lost Eggs		1	0	0	10	1
Chicks > 15D		3	6	7	0	? (6)
Fledglings/Pair		.50	.86	1.0	0.0	0.0-.75
MCT-EXT						
Known Pairs					65	66
Eggs Seen					64	66
Known Lost Eggs					22	9
Chicks					42	57
Fledgers (known;suspected)					35;6	49;2
Fledglings/Pair					.54-.63	.74-.77
PETCOL						
Known Pairs					39	85
Eggs Seen					45	85
Known Lost Eggs					26	14
Chicks					13	71
Fledgers (known;suspected)					7;4	66
Fledglings/Pair					.18-.28	.78

Crevice Subcolonies - Crevice subcolony reproductive success was variable, but well above 1996 levels (0.03 for CC1-3; Table 3). Excluding CC4 (for which accurate fledging numbers are not available due to a probable complete set of relayings which pushed breeding phenology into September), 67 pairs were followed. Assuming all chicks older than 15 days successfully fledged, fledglings per pair was 0.87.

Non-monitored Subcolonies - Incidental observations of all other subcolonies visible from an island-based locations (i.e., not TP1-4, TPCT1-2, RR1-2) indicated that the vast majority of these nesting areas produced chicks (Table 1). Over the 42 subcolonies attended in 1997, chicks were definitely produced in 32, probably produced in an additional 6, and definitely not produced in 1 (FRCC3; Table 1). Nevertheless, there were grossly apparent differences in production rate in some locations. Pole Island and North Island (NI) sustained eagle harassment through mid-July. Pole Island was empty through 13 June and complete evacuations were observed through 18 June; near total evacuations were observed as late as 26 June. Beyond this date, some number of murres (greater than 50) always remained on PI when eagles flew by or landed, presumably to attack the adults. No successful kills were witnessed. The effect of this harassment, other than a decline in attendance, was a delay and a depression of breeding. By late July, no chicks were visible on either PI or NI, and adults returning to PI rarely brought fish, an indirect measure of the presence of chicks (for 15 minute watches, adults with fish/total adults returning: 26 July - 1/38; 28 July 0/70; 30 July 0/71). However, by late August, during or after peak fledging in the monitored cliff-top subcolonies, adults were returning with fish (PI fish watch: 24 August 43/81) and young chicks (estimated age 5-8 days) were visible on both subcolonies. I estimate that fledgling production from PI was lower than most or all other nesting areas on Tatoosh, and was significantly lower than either the monitored cliff-top or crevice subcolonies.

Factors Affecting Murre Demographics

Eagles - In 1997, eagle presence on Tatoosh was markedly lower than in previous years (Parrish unpub. data). Fewer eagles were seen either roosting on the island or flying by regular observation locations (e.g., BBPT). Indirect evidence of lessened eagle presence is the dramatically lower number of recovered murre carcasses with signs of raptor attack (given relatively equal effort). In 1997, only two murres were killed by eagles and an additional two carcasses were found (total of 3 observed or inferred eagle kills). One was a presumed raptor kill; however, the other was an intact, emaciated carcass which floated ashore. Instead, eagles appeared to concentrate their attacks on adult Glaucous-winged

Gulls (early in the season) and their chicks (later in the season). By comparison, in 1996, 25 murre kills were either observed or inferred (Parrish 1997). Eagles were also not observed harassing the crevice subcolonies, as was the case in 1996, and reproductive success in these nesting areas rebounded from a low of 3% to a high of 87%. No temporary evacuations of murres from the monitored crevices as a result of eagle presence were witnessed.

However, eagles were observed continually harassing the PI subcolony and daily evacuations were witnessed through late June. Eagles landed on this subcolony several times and established two regular roosts to the immediate south and east of the nesting area, within sight of the murres. On several occasions, I witnessed an immature eagle flying from the south perch into the PI nesting area, landing in the area, and returning to the roost several minutes later. This behavior was repeated several times over the course of an hour, until no murres remained on PI.

Aircraft - In 1997, we recorded 25 aircraft overflights (9 helicopters, 15 planes, and one unknown craft; Table 4) from 11 June through 25 August. This is a minimum number as all overflights with the potential to disturb seabirds were not recorded and we did not have complete temporal coverage over the nesting season. Planes and helicopters traveling adjacent to or over the island above the 2000 ft ceiling maintained by the Olympic Coast National Marine Sanctuary also were not recorded. Of the 25 recorded overflights, 15 provoked an alarm response by the murres and/or other species nesting on or using the island, including: Glaucous-winged Gulls, Pelagic Cormorants, Peregrine Falcons, and Bald Eagles. The majority of these responses were minor, involving standing and headbobbing (murres). On four occasions, aircraft provoked partial or total evacuations of one or more species (Table 4). In general, higher levels of response were provoked by low-flying craft which remained in the area for greater than 2 minutes. Louder craft (e.g., helicopters as opposed to planes) also tended to provoke elevated levels of response, given the above conditions. Although the number of recorded overflights was lower than in 1996 (31), the number of incidents provoking response was both absolutely and relatively higher (15 compared to 10, 60% compared to 32%). However, the general level of response in 1997 was lower (headbob as opposed to movement or evacuation) and no murre egg or chick loss was observed.

Oil - There was no sign of oiling during the 1997 nesting season.

Table 4 - Aircraft disturbance of breeding Common Murres on Tatoosh Island in 1997. Of 25 recorded incidents in which aircraft flew over the island (9 helicopters; 15 planes, 1 unknown), 15 provoked an alarm response.

Aircraft Type	Height*	Duration of Stay**	Murre Response
unk+	unk	short	headbob
helicopter	unk	long	headbob
helicopter	unk	short	headbob
helicopter	unk	short	headbob
helicopter	unk	unk	headbob
plane	low	short	headbob
plane	low	short	headbob
plane	low	unk	headbob
plane	unk	short	headbob
plane	unk	unk	headbob
plane	unk	unk	headbob
helicopter	low	long	partial evacuation
helicopter	low	long	partial evacuation
plane	low	long	partial evacuation++
helicopter	lands	long	partial/total evacuation+++

**Height estimated relative to the OCNMS 2,000 foot ceiling*
*** Duration arbitrarily divided into less than two minutes (short) or greater (long).*
+ Heard only.
++ Murres, gulls, and cormorants - partial evacuation; one Peregrine Falcon and one juvenile Bald Eagle flushed.
+++ Partial evacuation by murres, total evacuation by gulls and cormorants.

Food Availability - Early in 1997 the tropical Pacific experienced a significant increase in sea surface temperatures associated with what is now being called the most significant El Niño of the century (NOAA, www.ogp.noaa.gov/enso). Persistently elevated sea surface temperature can be a harbinger of depressed primary production and ensuing trophic collapse because the former is indicative of a shift in upwelling strength, the phenomenon which drives much west coast productivity. The 1982-83 El Niño was associated with dramatic depressions in murre attendance, breeding phenology, and reproductive success (Boekelheide et. al. 1990, Sydeman 1993), colony abandonment (Wilson 1991), and death (Hodder & Graybill 1985) throughout the Pacific coast of North America, albeit primarily in the second season (1983) and thereafter (1984). Elevated sea surface temperatures and a significant shortening of the upwelling season along the Oregon coast were recorded in 1997 (Newport line data; R Smith pers. comm. to JKP). Thousands of murre and Cassin's Auklet, *Ptychoramphus aleutica*, carcasses were recovered on Washington outer coast beaches during the summer of 1997 (CW Thompson pers. comm. to JKP 1997), an

indication that changing upwelling structures along the Pacific coast might be depressing zooplankton and baitfish populations normally the prey of many seabird species.

However, on Tatoosh the murre population did not appear to be overtly affected by this growing physical anomaly. On the contrary, breeding phenology and fledging age was not markedly different from previous years and reproductive success was markedly higher in all monitored subcolonies. Data on murre chick feeding rates, prey species identification and size, and adult foraging range collected during 1997 all indicate that food was not limiting in the Tatoosh area (Parrish unpub. data). This supports the theory that the area around Tatoosh is an oceanographic "hotspot" which may buffer regional events, at least initially (Parrish et al. 1998). However, as the majority of demographic change associated with the 1982-83 El Niño did not manifest itself until the second season, it is not at all clear that the seabirds nesting on Tatoosh are immune to oceanographic dynamics. Monitoring of the 1998 nesting season will provide crucial information on the point.

Conclusions

In 1997, the Common Murre population nesting on Tatoosh Island experienced a slight depression in attendance but a dramatic increase in reproductive success relative to the 1996 season. Levels of eagle harassment were lower, as indicated by lower numbers of witnessed kills, recovered carcasses, and stolen murre eggs. The growing El Niño also did not appear to significantly, or even marginally, affect the colony's demographics. Aircraft disturbance, although slightly elevated in occurrence from 1996, appeared to provoke a lesser response in general. There was no sign of oil-related disturbance. Finally, we did not witness disturbance due to human visitation, a consequence we attribute to the near continuous presence of researchers (both seabird and intertidal) on the island, as we did receive ten's of visitors during the 1997 season.

The Tatoosh murre population has been monitored since 1991, providing the longest record of attendance and reproductive data for murres nesting in Washington State. These data are useful, in conjunction with the outer coast attendance data collected by US Fish & Wildlife Service (Ulrich Wilson) and the at-sea distribution and abundance data collected by Washington Department of Fish & Wildlife (Chris Thompson), in providing managers tasked with stewardship and restoration basic information on the stability and long-term integrity of one of the State's species of concern. These data are also useful, in conjunction with similar colony data collected at long-term monitoring sites in California (Farallon

Islands - Point Reyes Bird Observatory) and Alaska (Middleton Island, Barren Islands, Semidi Islands - US Fish & Wildlife Service), for metapopulation- level analyses of local, regional, and global forces (e.g., El Niño) affecting murre distribution and abundance.

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