Attendance and Reproductive Success of Tatoosh Island Common Murres
Final Report 1996
November 1997

Julia K. Parrish
Zoology Department, Box 351800
University of Washington
Seattle, WA 98195
jparrish@u.washington.edu

prepared for the *Tenyo Maru* Trustees Council
Principal Investigator: Julia K. Parrish
Technician: Karen Jensen
Student Employees: Jennifer Piel
Laura South-Oryshchyn
Suzanne Romaine
Student Volunteers: Anne Edwards

(11) Specifics of aircraft disturbance. I report aircraft disturbance, among a variety of other disturbance factors, because it is something the Trustees, as members of State and Federal stewardship agencies, may be able to address. However, I believe it is inappropriate to lay blame at the feet of specific individuals in a report of this nature. As per my agreement with the Olympic Coast National Marine Sanctuary, I send a more detailed recording of all aircraft disturbance witnessed by me or my staff during the season. On occasion, I have also sent copies to the Makah and the U. S. Fish and Wildlife Service Refuge Office in Nisqually. If the Trustees would like this level of detail, I will provide it under separate cover. However, I believe it is beyond the bounds of my data collection agreement with the Trustees.

Acknowledgments

The author wishes to thank the Makah Tribal Nation and the U. S. Coast Guard for continued access to Tatoosh Island. Tom Good provided information on carcass recoveries in southern Washington. Ed Melvin provided information on gillnet modification experiments in Puget Sound as well as information on the number and species of carcasses being recovered by U. S. Fish and Wildlife personnel in Oregon (Roy Lowe). Bill Sydeman provided information on the status of Common Murre nesting on the Farallon Islands. Chris Thompson provided information on murre chick sightings along the Washington coast, and was gracious enough to alter his survey schedule to accomodate our use of the *R/V Tatoosh*. Dr. Robert T. Paine provided needed field and laboratory assistance, logistics, and accomodations. Additional logistical support was provided by the Olympic Coast National Marine Sanctuary (OCNMS) in the form of vessel, *R/V Tatoosh*, support and trailer accomodations. Funding for this study was provided by the *Tenyo Maru* Trustees Council to the University of Washington. Additional financial support was provided by Washington Sea Grant and Olympic Coast National Marine Sanctuary grants to JKP and an NSF grant to RTP.

Table of Contents

Cover Page	i
Acknowledgments	ii
Table of Contents	iii
List of Figures and Tables	iv
Introduction	1
Methods	1
Attendance	2
Breeding Phenology and Reproductive Success	5
Factors Affecting Murre Demographics	6
Results and Discussion	6
Attendance	6
Breeding Phenology and Reproductive Success	11
Factors Affecting Murre Demographics	15
Eagles	15
Aircraft	16
Oil	17
Food Availability	17
Conclusions	17
Citations	19

List of Figures and Tables

Figure 1. Schedule of island visitation and Tatoosh Island Common Murre breeding phenology, 1996.

Figure 2. Attendance of Tatoosh Island Common Murres on nine index crevice subcolonies as a function of time of day, 1996.

Figure 3. Daily attendance of Tatoosh Island Common Murres on nine index crevice subcolonies, 1996.

Figure 4. Schematic representation of blind placement on a cliff-top subcolony.

Table 1. Estimated annual afternoon attendance of Tatoosh Island Common Murres, 1991-1996.

Table 2. Average annual attendance counts from BBPT of index crevice subcolonies, 1991-1996.

Table 3. Reproductive output of Tatoosh Island Common Murres in crevice (1992-1996) and cliff-top (1996) index subcolonies.

Table 4. Aircraft type and response of Tatoosh Island Common Murres, 1996.

Introduction

In 1996, data collection on Common Murre, *Uria aalge*, attendance and reproductive success on Tatoosh Island continued as a pilot project of the *Tenyo Maru* Trustees Council. Data collection was specific to murre demographics in an attempt to identify: 1.) whether this colony is increasing, decreasing, or stable in size, 2.) whether this colony continues to be reproductively active and to what degree habitat type affects reproductive success, and 3.) identification of some of the factors likely to affect population demography, specifically adult mortality and reproductive success. In the past, this colony has been affected by the increasing presence of Bald Eagles, *Halieetus leucocephalus,* and their indirect effects on reproductive success. This colony was also the closest murre colony to the site of the *Tenyo Maru* oil spill of 1991, and it is likely that some proportion of the murre carcasses recovered after this event were from the Tatoosh population. This report documents the data collected during the 1996 field season, provides an analysis of the patterns of murre demography relative to previous years, and summarizes the potential for restoration activities on the Tatoosh population.

Methods

Data documenting murre attendance, phenology, and breeding success were collected on the Tatoosh Island Common Murre population during the period spanning 12 June through 17 September. In total 51 calendar days and 96 man-days were spent on the island (Figure 1). Data on monitored subcolonies were collected from two principal locations. Burning Barrel Point (BBPT) is a promontory which affords a simultaneous view of eleven spatially distinct crevice subcolonies (CC1-5, TC1-4, WBMCT). In previous years, this location also afforded a view of the MCT (Main Cliff-top), a cliff-top subcolony which was abandoned in 1996. Observations from BBPT ranged in time from 0500H to 2200H, in a minimum of 1/2hr blocks evenly spaced throughout the day (approximately 121 hrs in total). To collect equivalent data on cliff-top subcolonies, two plywood and one-way glass blinds were constructed on MCT-EXT (Main Cliff-top extension), a new subcolony situated between MCT and TPCT2 (Toad Point Cliff-top 2), and PetCol (Petrified subcolony). Because the PetCol was used as an experimental subcolony, data collected on the MCT-EXT plot were used to monitor cliff-top reproductive success, although PetCol data are also reported here. Observations ranged in time from 0530H to 2200H, in a minimum of 1/2 hr blocks evenly spaced throughout the day (approximately 160 hrs on MCT-EXT). Additional data were collected on attendance, chick presence, and adult mortality from a variety of locations around the island, as well as from boats. No specific

record of hours spent was kept in these situations, although all data was recorded as a specific function of when (both date and time of day) it was collected.

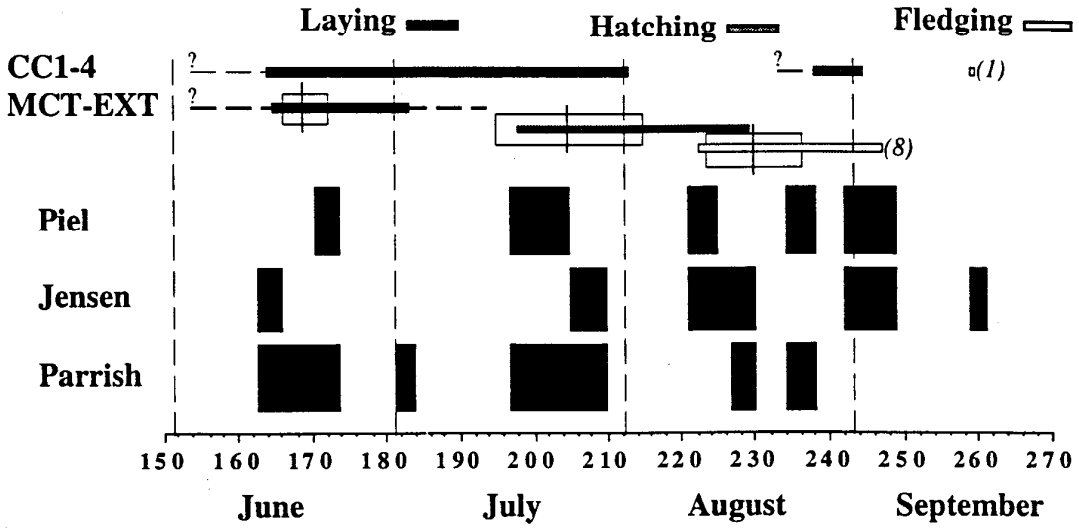

Figure 1. Days spent on Tatoosh Island during the 1996 field season, and Common Murre breeding phenology as assessed during those trips. Top panel is a box and whisker plot of breeding phenology for the index crevice subcolonies, CC1-4, and the index cliff-top subcolony, MCT-EXT. Vertical bars are means, horizontal bars are range, and boxes are standard deviation. Numbers in () following fledging ranges indicate how many chicks remained on the subcolonies on the last day of the last trip in which chicks were seen. Dashed lines indicate probable range of laying, based on extrapolation of incubation time or evidence of egg presence (see text for details).

Attendance

Subcolony attendance was assessed for all locations housing breeding or roosting murres, such that an annual attendance estimate could be produced. Attendance was defined as the number of murres on the subcolony (direct count), after eggs had been laid but before chicks began to fledge.

Nine index subcolonies (CC1-5, TC1-4) were counted repeatedly from the BBPT location throughout the season to assess patterns of attendance as a function of time of day and phenology. (It should be noted that several of these subcolonies, specifically CC4 and 5, are only partially visible from BBPT, thus the BBPT attendance index counts do not represent the total number of murres in these locations; see differences in attendance values between Tables 1 and 2). Annual comparisons between the index subcolonies are made in the afternoon, defined in 1996 as the period from 1400H on (Figure 2). Morning data points which fell well below the average (see 0900H and 1000H on Figure 2) were deleted from the analysis due to the high probability that these data had been collected following an eagle-induced temporary evacuation (Parrish unpub. data) and so do not represent true attendance. Differences in attendance as a function of time of day on the index subcolonies were used to standardize counts of other subcolonies which could only be made at specific

times of day due to tidally-mediated inaccessibility. In 1996, afternoon index subcolony counts were 1.35 higher than the morning counts; thus, all attendance data collected on other subcolonies before 1400H were standardized to "afternoon" estimates with the use of this correction factor to produce the annual attendance estimates reported in Table 1.

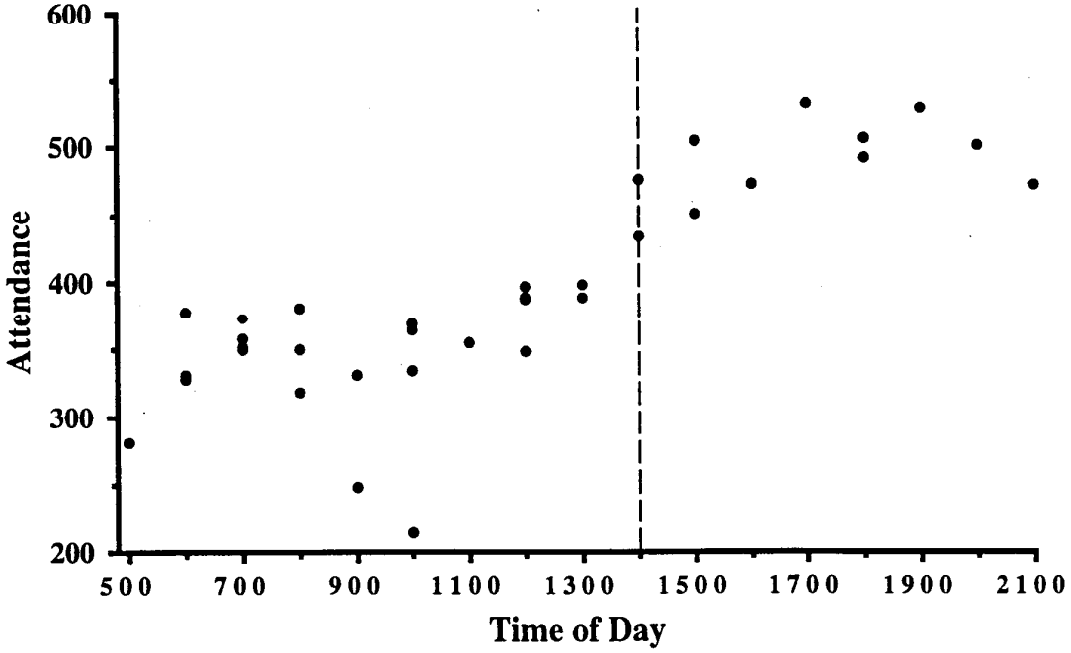

Figure 2. The pattern of diurnal variation in attendance in common Murre crevice subcolonies (CC1-5+TC1-4), as counted from the BBPT location, between 12 June and 3 July 1996. After this period, subcolony attendance became unstable due to egg loss-induced abandonment of adults. The dashed line indicates the split between morning and afternoon classification in this report.

Attendance patterns on the index subcolonies as a function of phenology were used to indicate when attendance was unstable and thus not a valid representation of annual attendance. In 1996, index subcolonies became unstable by mid-July (Figure 3), indicating that data collected during June only were suitable for annual attendance estimate assessments. Therefore, although data were collected throughout the breeding season, both the annual attendance estimate (i.e. Table 1) and the index attendance averages (i.e. Table 2) are constrained to data collected prior to 16 July.

Attendance data were almost always direct counts. Occasionally, a subcolony could not be counted from a single location (e.g. CC4, CC5). In these cases, counts were made from multiple locations and degree of spatial overlap was estimated by mapping physical features of the surrounding rock. The annual estimate is an amalgam of these site-specific values. Counts made from the BBPT location were usually made with a spotting scope, while counts from other locations were made with binoculars. To insure equivalency, several

sets of BBPT counts, arrayed across time of day, were made with both types of optics. No significant differences were found, so counts were considered equivalent regardless of optics used. In 1996, three observers collected attendance data: Julia Parrish, Karen Jensen, and Jennifer Piel. To insure all counts were equivalent, Piel and Jensen were required to count in my presence and attendance data were compared until values were within 10%. Periodic checks were made throughout the season to insure that all observers remained within a 10% margin of error. Several crevice subcolonies were most reliably counted from a boat (RR-U, RR-L, TP 1-3). In these cases, photographs were used to ground truth counts. Cliff-top subcolonies were almost always impossible to count either repeatedly and/or in total, without major disturbance to the birds. For Pole Island (PI), approximately 25% of the subcolony was regularly counted from a remote location and multiplied by four to generate the annual estimate. For TPCT1, only the exterior murres visible from below and/or from a boat on the water were counted, even though the subcolony probably contained many more birds. The preceding methods did not differ from previous years. For MCT-EXT and the PetCol, all birds visible from the blinds were counted and used to estimate attendance. In the latter two cases, these estimates probably accounted for the vast majority of the birds (Parrish, pers. obs.) and did differ from previous years, as blinds allowing observers to "enter" the colony had never been used.

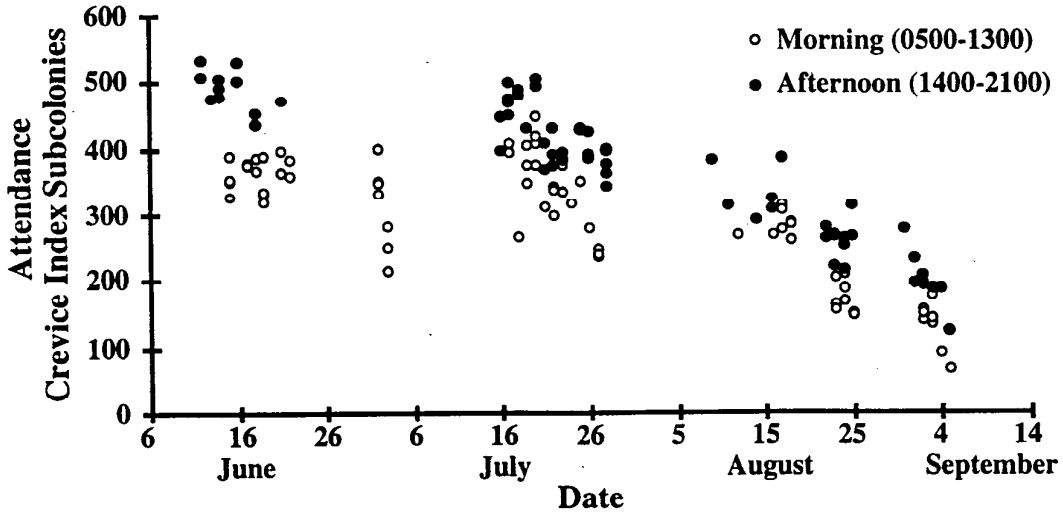

Figure 3. Daily attendance of Tatoosh Island Common Murres on nine index crevice subcolonies (CC1-5; TC1-4) during the morning (open circles) and afternoon (filled circles) hours, 1996. See text for time of day definitions. By mid to late July attendance became unstable, such that only data collected in June were used to determine estimated annual island attendance (i.e. Tables 1 and 2).

Breeding Phenology and Reproductive Success

The timing of breeding was assessed by daily checks for the presence of eggs and chicks on four index crevice subcolonies (CC1-4) and one index cliff-top subcolony (MCT-EXT). One additional cliff-top subcolony, PetCol, was monitored for reproductive success. Both cliff-top subcolonies were monitored with the use of plywood blinds fitted with one-way mirrored glass. Blinds resembled bay windows jutting from existing vegetation (salmonberry, *Rubus spectabilis*) out into the area utilized by the murres (Figure 4). Breeding murres nested against all windows and regularly interacted with their images. Once eggs had been laid, pairs closest to the mirrors were the first to remain on their eggs during disturbances causing the majority of the pairs to evacuate. Although observer presence was known to the murres (based on visual fixation on the plywood wall during observer approach), no evacuations or even movement away from the blind occurred when observers were present, including entering and leaving the blind. Other than occasional headbobbing early in the nesting season before the majority of eggs had been laid, the murres showed no overt signs of distress at observer presence. Therefore, it is possible that the presence of the blinds affected reproductive success, albeit positively.

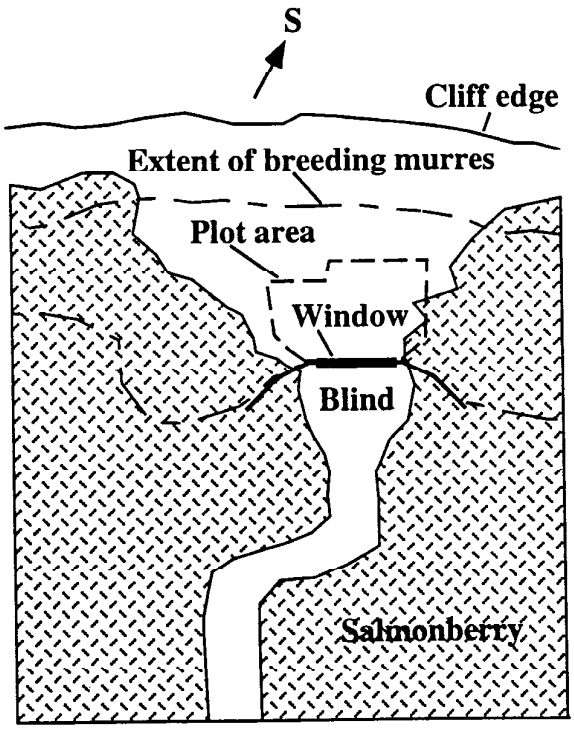

Figure 4. Schematic drawing of blind placement on the MCT-EXT subcolony. Blind is made of plywood sheets hinged together and placed in an arc at the end of a path cut through live salmonberry to the edge of known murre nesting area. A one-way, mirrored glass is set into the central plywood panel. A tarp (not shown) was used to darken the blind and prevent patrolling gulls and crows from discovering observers, which prompted alarm cries. The path was fenced to prevent murres and gulls from entering through the salmonberry. When not in use, the window was covered to prevent distress should a bird enter the blind (i.e. a murre in the blind would see other murres but not be able to reach them).

At the beginning of the season, likely pairs within a plot defined by geographically distinct boundaries (crevice subcolonies - entire crevice visible from BBPT; cliff-top subcolonies -

plot in view of windows defined by stakes) were identified by behavior and/or the presence of an egg. Eggs were identified by location, color, and spotting pattern. When possible, the fate of individual eggs and chicks were followed. This was easier on the clifftop subcolonies where blind proximity allowed observers to record the presence of very young chicks (e.g., hatching day). In crevice subcolonies, young chicks were harder to see and may have been missed. Therefore, for these nesting areas, chicks are reported as chicks greater than 15 days of age to allow for the possibility of missed mortality of very young chicks. Drawings were made of the plumage pattern of each chick on the last day of each trip, such that subsequent identifications could be made even if chicks wandered. In practice, all subsequent identifications were confirmed by watching the parents, who remained faithful to specific locations, feed the chick. Fledging was defined either by watching the chick leave (known fledging date), or by inferring its departure (for chicks older than 15D), although only known events (e.g. witnessed laying, hatching, and fledging) were used to assess breeding phenology statistics. Incubation length and average chick age to fledging were calculated for eggs/chicks of known age. In addition, chick presence was noted on all other subcolonies. No chicks or adults were banded.

Factors Affecting Murre Demographics

Adult mortality was assessed by observing the number of murres successfully attacked by predators (Bald Eagles) as a function of hours of observation over the period eagles were present on the island. In addition, daily walks of the beach and accessible eagle perches were conducted to look for murre carcasses. All carcasses were marked with fingernail polish (one color for each calendar month) and left in place to assess residence time and scavenging. The number of murre eggs found outside of the subcolonies (usually broken below crevices and cliff-tops) or removed from subcolonies by predators was also opportunistically assessed as a surrogate measure of mortality pressure on young-of-the-year. Observations on murre response to aircraft were made opportunistically.

Results and Discussion

Attendance

The 1996 season was marked by extremely low reproductive success which translated into early departure of some of the breeding population and increasing variance in general attendance of the remaining population after the loss of the majority of the eggs. Index counts of the crevice subcolonies (CC1-5, TC1-4) began to decline in mid-July (Figure 3; majority egg loss by July 18), although birds were still present in September. However, if only June counts (i.e., before substantial egg loss) are used to estimate annual afternoon

attendance, the crevice index subcolonies rose by 8% (from 446 to 484 birds) and the overall colony figure rose 6% (from 3270 to 3467), relative to 1995 counts, respectively. In total, 27 subcolonies increased in size from the previous year, while only 7 declined, and one remained stable (Sign test (H_o: p = .5), $C_{0.05(2),34} = 10$, $P < 0.005$; Table 1). The majority of the increases were moderate (i.e. ones to tens of birds). Annual estimates of afternoon attendance have been relatively stable since 1993, fluctuating between approximately 3300 (1995) and 3700 (1994) birds. Although these estimates have not reached those of earlier years (approximately 3900-4200 birds prior to 1993), the colony does not appear to be in a pattern of constant decline.

Several colonization trends begun earlier in the decade continued. The total number of discrete breeding areas continued to increase. Four new crevice subcolonies were "born" in 1996 (Table 1), most adjacent to existing crevices (e.g. RCC-L immediately below RCC; Table 1). However, WBMCT (Way Below Main Cliff-Top) is on a previously unoccupied cliff-face. Cliff-top subcolonies continued to fluctuate, exemplified by the total abandonment of the MCT, which had been declining for several years (Table 1), after a meteoric rise in the 1980's (Parrish & Paine 1996). A new breeding cliff-top subcolony was "born" this year, for the first time since observations began in 1991. MCT-EXT is a smaller area located in salmonberry cover immediately between the former MCT and TPCT2.

Total attendance in crevice subcolonies continued to rise for the fourth year, increasing 19% over 1995 to 1614 birds (Table 1). Index crevice subcolony counts showed an identical pattern: afternoon averages have been consistently higher each year since 1993, and are significantly higher than 1995 (two-tailed T-test of means, T = -2.585, V = 19, P < 0.02; Table 2). The 1996 afternoon count, 484 birds, is only 26 birds lower than the original 1991 pre-spill estimates (Table 2), a statistically indistinguishable difference. Cliff-top attendance declined slightly, a fairly steady trend since counts began in 1991. As a result of these two opposing trends, the ratio of crevice to cliff-top attendance shifted closer to equality (47% crevice:53% cliff-top; 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

	Subcolony	Rk#	Hab.	1991	1992	1993	1994	1995	1996	Chks?	Comments
a	rainbow rock - u	035	cr					212	200	n	born in 1995
a	rainbow rock - l	035	cr	50	63	24	35	38	15	p	
	boom	021	ct	50	0	0	0	0	0		died in 1991
m	north island	022	cr	99	134	100	150	136	139	p	
m	north island ridge	022	ct				22	0	0		born in 1993
m	north island 2	022	cr					27	28	n	born in 1995
m	finger	022	cr				31	16	38	n	born in 1994
m	pole island	023	ct	1300	1532	1176	1264	1108	1284	p	plot est. @ 25%
m	lighthouse 1	021	cr	89	75	27	101	110	132		
m	lighthouse 2	021	cr	3	0	1	8	6	9		
m	lighthouse 3	021	cr	23	15	0	25	19	15		
m	lighthouse 4	021	cr	11	25	8	6	28	35	n	
m	lighthouse 5	021	cr					17	28	y	born in 1995
m	submarine	021	cr	50	30	42	43	44	51	y	
m	below submarine	021	cr						5	n	born in 1996
m	burning barrel	021	cr	6	9	0	6	2	16	n	
m	burning barrel 2	021	cr					32	64	n	born in 1995
m	burning barrel 3	021	cr					2	13	n	born in 1995
a	above crisscross	021	cr				3	6	10	n	born in 1994
a	crisscross 1	021	cr	39	32	28	29	38	52	y	
a	crisscross 2	021	cr	45	37	30	36	54	59	n	
a	crisscross 3	021	cr	27	31	17	27	57	59	n	
a/m	crisscross 4	021	cr	60	35	34	52	50	54	p	
a/m	crisscross 5	021	cr	173	94	85	104	141	173	y	
m	r-crisscross	021	cr	15	21	10	26	36	9		
m	r-crisscross lower	021	cr						21		born in 1996
m	fr-crisscross	021	cr	20	19	12	22	12	35		
m	fr-crisscross 3	021	cr						15		born in 1996
a	tenniscourt 1	021	cr	79	36	30	29	40	40	y	
a	tenniscourt 2	021	cr	50	29	23	20	26	30	y	
a	tenniscourt 3	021	cr	82	91	71	64	77	95	y	
a	tenniscourt 4	021	cr	25	23	21	21	19	20	y	
	moustache	021	cr					3	0		born in 1995
m	toadpoint 1	021	cr	50	27	25	43	60	61	p	
m	toadpoint 2	021	cr	50	22	35	24	24	27	p	
m	toadpoint 3	021	cr	50	15	15	19	23	35	p	
m	tpclifftop 1	021	ct	48	30	26	7	15	19		partial count
	tpclifftop 2	021	ct	24	46	30	4	17	0		partial count
	main clifftop	021	ct	1500	1200	1300	1200	600	0		max count
a	mct-extension	021	ct						300	y	born in 1996
	below mct	021	cr				10	0	0		born in 1994
a	way below mct	021	cr						31	y	born in 1996
a	petrified	021	ct	200	200	200	260	175	250	y	estimate
	total			**4214**	**3871**	**3370**	**3691**	**3270**	**3467**		
	morn-aft multiplier			1.6	1.5	1.2	1.3	1.13	1.35		
	crev total			1092	863	638	934	1355	1614		
	ct total			3122	3008	2732	2757	1915	1853		
	crevice %			26	22	19	25	41	47		

Table 2 - Average of attendance counts made from BBPT (1991-1996) 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 (1991-1996) 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: In 1996, the counts for CC1, 4, and 5 are lower than in Table 1 because neither crevice was entirely visible from BBPT.

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

Note: Low counts (see Figure 1) were removed before calculating statistics.

Because the number of murres attending crevice subcolonies is higher than it has been since 1991, and new crevice subcolonies have been "born" consistently since 1994, it appears that the Tatoosh population may be rearranging itself. It is impossible to tell to what degree the birth of new subcolonies may represent immigration, rather than returning first-time breeders from the Tatoosh population. Although other studies have shown that subcolonies may die out, this is usually a gradual phenomenon during which the abundance (i.e. absolute number) as well as density (i.e. interpair spacing) of murres declines, often with resultant depression of reproductive success (e.g. Birkhead 1977). By comparison, subcolony birth and death on Tatoosh is often dynamic (e.g. the birth of RR-U in 1995 and WBMCT in 1996, both of which produced fledglings in the first year) and does not appear to involve differences in density (e.g. the abandonment of the MCT, although it happened over several years, never produced a fragmented set of nesters but instead a single steadily shrinking and maximally dense group; Parrish pers. obs.). As several of the extant crevice subcolonies have additional unused space, and there are several unused but habitable crevices, the Tatoosh population could continue to expand, even if cliff-top subcolonies continue to shrink.

Breeding Phenology and Reproductive Success

In 1996, eggs appeared on the crevice (CC1-4) and cliff-top (MCT-EXT) index subcolonies on the morning of 13 June, the first full day of our field season. By afternoon, all of these eggs had been lost. Thus, it is highly likely that laying had begun on an earlier date, and that these earlier eggs had been lost as well. Additional support for this hypothesis comes from the fact that on the afternoon of 12 June, several smashed eggs were observed below the crevice subcolonies, and a single egg was found on the main beach, presumably transported there by gulls or crows. In previous years, eggs have been present in crevice subcolonies as early as 1 June (Parrish 1996a).

Egg loss was extremely heavy in 1996. A total of 239 eggs were observed either smashed below breeding crevices, on the main beach or island top, or being taken from breeding areas by Glaucous-winged Gulls, *Larus glaucenscens*, or Northwestern Crows, *Corvus caurinus*. Although this total is absolutely lower than that of 1994 (278), this comparison is misleading as the 1994 figure contains a majority of eggs from the MCT, which was abandoned by 1996. In 1996, the majority of smashed eggs were sighted under the Crisscross crevice subcolonies (Parrish, pers. obs.).

Of 17 eggs on CC1 and CC2 where we were able to observe both lay and loss date, mean and standard deviation of residence time was only 6.6 ± 5.4 days. On the index crevice subcolonies, eggs were lost on every day of observation, through 18 July, after which occasional remaining eggs were taken by gulls. This early, intense period of egg loss resulted in the lowest reproductive success in the crevice subcolonies of any year since observations began (1992) and was the reason that attendance began to fall off in July. Of 71 pairs followed on CC1-4 (the highest number of pairs since observations began), only three produced chicks, all on CC1 (Table 3). Because egg loss was so high, accurate measures of breeding phenology were impossible to determine for the crevice subcolonies. Therefore, laying, hatching, and fledging periods are represented by bars encompassing known events, and do not indicate central tendency (Figure 1).
Based on the three chicks produced in CC1, breeding phenology in the crevices was later than that of the cliff-top index subcolony, a reversal of the trend in earlier years (Parrish 1996a). Chick hatching began at the end of August, two chicks fledged on 16 September (Figure 1), and a single chick (aged 13 days) was still present on CC1 on 17 September (the last known murres on the island). This is later than any known fledging since 1991 (Parrish 1996a). It should be noted that several other crevice subcolonies which are not specifically monitored for reproductive success, did produce chicks which eventually fledged. Although no record of individual chicks were kept, all chicks seen were noted so that reproductive success could be assessed as a 0/1 variable by subcolony (Table 1).

Ironically, the index cliff-top subcolony, MCT-EXT, had relatively high reproductive success, 0.54 to 0.63 chicks per pair (depending on whether the 6 chicks remaining on the plot are counted as having fledged; Table 3), a statistic approaching crevice reproductive success in earlier years, and significantly higher than reproductive success on the former MCT (i.e. 0.0 chicks per pair; Parrish 1996a). It should be noted that measurements of reproductive success on this subcolony are more accurate than any collected on the Tatoosh population to date, as observers were extremely close to the plot (i.e. less than 1 meter away) and were able to accurately gauge the number of pairs as well as record the presence of all eggs and chicks daily. Therefore, the chicks per pair figure is probably lower than comparable crevice subcolony numbers from previous years, as the latter values minimized the number of "eggless" pairs.

Table 3 - Tatoosh Island Common Murre reproductive output in crevice subcolonies (1992-1996) as monitored from BBPT and cliff-top subcolonies (1996) 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, in cases where observers were not present during fledging, chicks greater than 15 days old (crevices - early years).

	1992	1993	1994	1995	1996
CC1					
Attendance (aft)	31	28	29	38	39
Known Pairs	15	11	22	18	19
Known Lost Eggs	2	1	1	1	10
Chicks > 15D	11	7	20	17	2*
Fledglings/Pair	0.73	0.64	0.91	0.94	0.11
CC2					
Attendance (aft)	36	30	35	54	59
Known Pairs	17	9	21	15	18
Known Lost Eggs	2	4	2	12	17
Chicks > 15D	16	2	18	11	0
Fledglings/Pair	0.94	0.22	0.86	0.73	0.0
CC3					
Attendance (aft)	30	17	27	57	60
Known Pairs	11	2	7	20	24
Known Lost Eggs	0	2	6	3	15
Chicks > 15D	7	0	1	17	0
Fledglings/Pair	0.64	0.0	0.14	0.85	0.0
CC4					
Attendance (aft)		13	17	21	21
Known Pairs		6	7	7	10
Known Lost Eggs		1	0	0	10
Chicks > 15D		3	6	7	0
Fledglings/Pair		0.50	0.86	1.00	0.0
MCT-EXT					
Known Pairs					65
Eggs Seen					64
Known Lost Eggs					22
Chicks					42
Fledgers (known;suspected)					35;6
Fledglings/Pair					0.54-0.63
PetCol					
Known Pairs					39
Eggs Seen					45*
Known Lost Eggs					26
Chicks					13
Fledgers (known;suspected)					7;4
Fledglings/Pair					0.18-0.28

** In 1996, 3 chicks were hatched on CC1; however, by the last day of the field season, 17 September, one chick aged less than 15 days still remained.*

** Six abandoned eggs were present on the first day of observations. They are not included in the calculations of fledglings per pair (i.e. as extra pairs).*

Early egg loss was also considerable on this subcolony (17 of 38 eggs laid between 14 and 23 June were lost). Eggs began to remain on this subcolony by 14 June, and by 17 June the majority of laid eggs were safe. Laying continued through approximately 9 July (based on hindcasts from known age eggs); the last observed laying was 2 July (Figure 1). Mean lay date for known-age eggs was 18 June (Figure 1), and the incubation period was 32.2 ± 0.9 days (N=17). At least 6 eggs were relaid (we could not tell whether any of the eggs laid in the latter part of June were relays of eggs lost before our first day of observation), of which 5 produced fledglings. Three lost eggs were replaced in space by a second pair (based on egg coloration differences), perhaps indicating that this new subcolony was subject to some amount of intraspecific competition for limited (quality?) nesting sites.

Hatching began on 17 July and continued through 17 August (Figure 1), with a mean hatch date of 24 July for known-age chicks (Figure 1). Hatching was not; however, unimodal. The first peak in hatching occurred on 19-20 July (11 chicks out of 18 produced between 17 and 22 July), with a second peak occurring in the first week in August (13 chicks out of 22 produced between 27 July and 12 August). Two additional chicks were born on 17 August. Including known relays, hatching success was 0.66 chicks per egg (relay hatching = 0.83 chicks per egg for 6 eggs). Fledging began on 10 August and ran through the end of the last trip during which chicks were present: there were 6 chicks all in good condition remaining on the plot on 6 September. Average chick age at fledging was 25.2 ± 1.6 days (N = 17). Mean observed fledging date was 17 August (Figure 1): however, this distribution was apparently trimodal. Sixteen chicks fledged between 10 and 16 August (peak 13-15 August); eighteen chicks fledged between 18 August and 1 September (peak 28-30 August); seven chicks presumably fledged between 4 September and before 16 September. By 6 September, all 6 remaining chicks were 20 days or greater (mean minimum age = 23.8 ± 3.2 days). Based on the average fledging age, it is likely that these chicks left within the next few days. The single chick which died was actually of fledging age, but seemed to have been abandoned by its parents (Parrish pers. obs.).

Reproductive success on other cliff-top subcolonies was variable. Pole Island, now the largest cliff-top subcolony on Tatoosh (1284 in attendance, Table 1), failed to produce any chicks on the attendance subplot in 1996. As the general attendance pattern on this subcolony was even across the entire area (i.e. not just specific to the subplot counted) and total evacuations were observed through late July, by which time laying had ceased in all index subcolonies, it is unlikely that any fledglings were produced from Pole Island. The PetCol was reproductively active, although egg loss was high (Table 3). Twenty-six of 39

pairs followed lost eggs which were not replaced. Six additional eggs were found abandoned at the onset of observations (20 June). Assuming these six eggs represented six additional pairs, hatching success was 0.29 chicks per pair, and fledging success was 0.53 to 0.84 fledglings per chick (depending on whether the 4 chicks remaining on the subcolony at the end of the field season, 5 September, are presumed to have fledged or not).

Factors Affecting Murre Demographics

Eagles

Adult mortality was affected by Bald Eagle predation; 5 kills were witnessed and 20 carcasses (including the witnessed kills) were found. These numbers are absolutely comparable to 1994; however, kills were witnessed over more hours, making the standardized value lower. As more days were spent on Tatoosh in 1996, the number of carcasses found might also be relatively lower, although carcass residence time is days to weeks (Parrish, unpub. data). For the first time, eagles were witnessed taking adult murres from both cliff-top and crevice subcolonies. If witnessed kills are standardized by number of observation hours, the number of days in the season during which both murres and eagles are present throughout the day, and the number of hours over which eagles are present per day, a maximum of 63 kills would have been made, or almost 2% of estimated afternoon attendance (Parrish and Paine, unpub. manuscript).

Eagles also exerted an increasing indirect effect on murre reproductive success, through the facilitation of egg predation by gulls and crows (Parrish 1995). Because eagles were successful in attacking murres nesting in crevice subcolonies, these areas were subject to much higher levels of eagle-induced evacuation, which ultimately resulted in severe depression of reproductive success (Table 3). In previous years, the indirect effect of eagles has been contained to cliff-top subcolonies (Parrish 1995, 1996). However, in 1996 an apparent reversal occurred - eagle influences, as assessed by reproductive success, were stronger in the crevice subcolonies, even though eagle kills were also witnessed on both monitored cliff-top subcolonies. It is possible that cliff-top nesters are becoming more habituated to the presence of eagles (Parrish, unpub. data), while crevice nesters are experiencing a "new" threat. Regardless, it is apparent that nesting habitat quality, relative to adult security, is more a function of the behavioral repertoire of the predators than to any physical quality of the habitat itself. Future trends in eagle-murre interactions are hard to predict, as the number of eagles visiting Tatoosh is not a linear function of their presence

on the mainland, not all eagles visiting Tatoosh attack murres, and murre response appears to change over time (Parrish and Paine, unpub. manuscript).

Table 4 - Aircraft disturbance of breeding Common Murres on Tatoosh Island. Of 31 recorded incidents in which aircraft flew over the island (9 helicopters; 21 planes, 1 jet), 10 provoked an alarm response.

Aircraft Type	Height*	Duration of Stay**	Murre Response
jet	high	short	headbob
plane	unk	unk	headbob
plane	unk	unk	move to edge
helicopter	low	long	move to edge
plane	low	short	partial evacuation
plane	low	short	partial evacuation
helicopter	low	long	partial evacuation
helicopter	low	long	partial evacuation
helicopter	low	short	evacuation, egg loss
plane	low	long	evacuation, chicks trampled

**Height estimated relative to the OCNMS 2,000 foot ceiling*
*** Duration arbitrarily divided into less than two minutes (short) or greater (long).*

Aircraft

Murres were also affected by the presence of aircraft. A total of 31 aircraft were recorded flying over the island during the 1996 season (Table 4). This number should be regarded as a minimum because observers did not always record aircraft presence, and observers were only on the island a portion of the nesting season. On many days no aircraft were recorded; however, on several days multiple aircraft were reported (13 days with one event; 2 days with two events; 4 days with 3 or more events). A summary report of overflights suspected to be beneath the 2000 foot ceiling and/or disturbing the birds regardless of height was provided to the Olympic Coast National Marine Sanctuary (OCNMS) office in Port Angeles. Distress responses, including headbobbing, movement towards cliff/crevice edge, and evacuation, were more likely to occur earlier in the nesting season (see also Parrish 1995) and among nonbreeders (or failed breeders during 1996) throughout the season. Low-flying aircraft elicited a higher level of response than high-flying ones (Table 4). Helicopters elicited a higher level of response than planes (44% of all helicopters caused at least movement to edge while only 19% of all planes did so). This pattern of response is not new. Parrish (1996a) reported temporary evacuation in response to aircraft overflight. Mehlum and Bakken (1994) reporting on two helicopter disturbance

highly productive area (Parrish 1996b and references therein) which may account for the relatively high diversity of nesting seabirds (Paine et. al. 1990), as well as the persistence of murres when other Washington colonies appear to have undergone massive declines (Wilson 1991). Known threats to the Tatoosh colony include marine pollution, specifically oil, disturbance by aircraft, and predation and associated egg-predator facilitation by Bald Eagles. Suspected threats include fishery by catch mortality. The Tatoosh colony is also responsive to changes in ocean temperature and presumably the associated changes in food supply. The extent, or even existence, of ocean-mediated change in murre food supplies (e.g. schooling planktivores) is unknown for the Washington and Oregon coasts.

In conjunction with coastwide censuses, continued monitoring of this colony, to insure that adequate measures are being taken to safeguard existing murres, would seem to be paramount. Demographic data would also serve as an indicator of local to regional coastal productivity relative to seabirds as well as a potential early warning for Puget Sound gillnet fisheries (Parrish and Melvin, unpub. data). Additional data on forage fish species and delivery rate could provide baseline data on food availability (Parrish, unpub. data). These data, even locally collected, would seem to be necessary groundwork for any more extensive program of forage fish restoration. The Tatoosh colony has also been the site of several small-scale restoration experiments (Parrish and Paine 1996, Parrish unpub. data) and could continue to be used in this capacity. Finally, population levels of Bald Eagles and Glaucous-winged Gulls, should be monitored. Attempts should be made to minimize the positive effects humans can have on these predators (i.e. access to additional sources of food as a consequence of human actions).

On a regional scale, mitigation of known, particularly anthropogenic, threats to murre survival and reproductive success should be addressed, when possible. Direct disturbance by humans could be minimized, perhaps incrementing reproductive success and possibly facilitating additional colonization. Public education programs designed to inform coastal user groups about human impact on seabirds might be directed at boaters, aircraft pilots, and ecotourist organizations to start. Because many seabird species, including murres, use inland waters during the non-breeding season (e.g. Puget Sound), education programs should cover summering as well as wintering grounds. Fishery by-catch solutions, already under consideration in Puget Sound, might be extended to other fishery regions. Finally, factors responsible for the decline of Washington's southern colonies need to be identified, if possible, in order to determine the most plausible course of potential restoration efforts on these colonies.

Citations

Birkhead, T. R. 1977. The effect of habitat and density on breeding success in the Common Guillemot (*Uria aalge*). J. Anim. Ecol. 46:751-764.

Mehlum, F. and Bakken, V. 1994. Seabirds in Svalbard (Norway): status, recent changes and management. Birdlife Conservation Series (1994) 1:155-171.

Paine, R. T., Wootton, J. T., and Boersma, P. D. 1990. Direct and indirect effects of Peregrine Falcon predation on seabird abundance. Auk 107:1-9.

Parrish, J. K. 1995. The influence of group size and habitat type on reproductive success in Common Murres (*Uria aalge*). Auk 112:390-401.

Parrish, J. K. 1996a. Continued monitoring of Common Murres on Tatoosh Island, Unpublished Final Report to the *Tenyo Maru* Trustees Council, 1995.

Parrish, J. K. 1996b. Seabird-preybase interaction, Final Report to the *Tenyo Maru* Trustees Council, 1995.

Parrish, J. K., and Paine, R. T. 1996. Ecological interactions and habitat modification in nesting Common Murres, *Uria aalge*. Bird Conserv. Internatl. 6:261-269.

Wilson, U. W. 1991. Responses of three seabird species to El Niño events and other warm water episodes on theWashington Coast, 1979-1990. Condor 93:853-858.