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DATE:	March 22, 2019
MEMORANDUM FOR:	Tom Gelatt (Program Leader, AEP, MML)
FROM:	Rolf Ream (Research Biologist, AEP, MML) and Jeremy Sterling (Research Biologist, AEP, MML)
SUBJECT:	Effects of human disturbance on the northern fur seal population at St. George Island, AK, during 2015

Summary

In response to a request from the NMFS Alaska Regional Office, the Marine Mammal Laboratory (MML) conducted a study during the fall of 2015 to assess the effects of human disturbance on the northern fur seal population at St. George Island, Alaska. The specific goals of this research were to document and characterize human disturbance occurring at northern fur seal resting sites, to identify measurable seal responses to disturbance that have the potential to reduce survival or reproductive rates, and to provide managers with information that could help guide and refine harvest practices. Human disturbance events related to subsistence harvest and research activities were documented during 2015; these disturbance events did not follow expected patterns. In particular, beneficial harvest strategies were adapted on St. George that resulted in more than half of the harvests occurring outside of rookery habitat. However, the remaining number and distribution of disturbance events, and of the associated study animals, reduced the sample size at the experimental and control sites established for assessing the effects of disturbance. Using a variety of possible fur seal responses, we were unable to detect any effects of human disturbance on adult females. Though results were less clear, we were also unable to detect any obvious or consistent effects of human disturbance on pups. Some caution is advised in interpreting these results, and we recommend additional studies for consilience. Here we report on the results of this study.

Human Disturbance of Northern Fur Seals at St. George Island during 2015

Background and Approach

Regulations governing the take of northern fur seals on the Pribilof Island for subsistence purposes are found in 50 CFR 216, subpart F, and restrict the harvest of male young of the year fur seals on St. George Island, Alaska, from September 16 to November 30 annually. These late season harvests of northern fur seals on St. George Island, along with other human disturbances (e.g., research activities), have the potential to disturb adult females and pups resting and nursing at the breeding colonies until their departure from the island for their annual winter migration, which typically occurs before early December. Previous efforts to assess effects of human disturbance at the breeding colonies have compared onshore attendance patterns of adult females during July and August with their time onshore immediately following research related disturbances. There is a similar paucity of information regarding consequences of disturbance to pups late in the lactation period after they molt in September and as they near weaning. During the fall of 2015, we expanded and refined previous effects analysis using satellite telemetry to assess and compare adult female responses among disturbed (experimental) and non-disturbed (control) sites on St. George Island: onshore attendance, foraging trip durations, movement among sites, aquatic behavior, and timing of departure for the winter migration. We also explored a similar range of potential responses by pups to human disturbance at the experimental and control sites: duration of time spent during bouts on land and in the water, movements to non-natal sites, and timing of departure for the winter migration (weaning). Our goals were to document and characterize the human disturbance occurring at northern fur seal resting sites, and to identify measurable responses of northern fur seals that have the *potential* to reduce survival or reproductive rates at the disturbed breeding colonies. The ultimate objective of this, and other related, research is to provide harvest managers (NMFS and the Traditional Council of St. George) with information that can be used to guide and refine best harvest practices (e.g., through adjustments in the location, timing, duration or frequency of subsistence harvests).

<u>Study locations and distribution of satellite tags</u>

Due to the timing of issuance of the regulations, the inaugural harvest of young of the year seals on St. George Island under these regulations was limited to a short window during November 2014. As a result, best harvest practices were not fully established prior to the first full young of the year harvest season during 2015. Nevertheless, knowledge of harvest practices, as well as harvester preferences, were used inform the study design and selection of study sites. Subsistence harvest practices relevant to the study design include the distribution of harvests in time and space to minimize the possible concentration of detrimental effects from harvests at a given site. Harvester preferences include accessibility to animals and use of terrain/substrate amenable to the conduct of harvests. Zapadni and East Reef rookeries were selected as the experimental ("disturbed") sites, and South and North rookeries were selected as the control ("undisturbed") sites. Zapadni and South rookeries are located on the south side of St. George Island, while East Reef and North rookeries are located on the north side of the island.

Between September 30 and October 3 of 2015, 5 adult females and 5 female pups were captured and weighed at each of the four rookeries (Table 1). Lactating adult females with white vibrissae were selected in order to attach tags to mature females that were likely to have a dependent pup at that rookery. Pups larger than 10 kg were selected to minimize possible impacts of the satellite tags on the pups' mobility and health. For each exposure group (disturbed sites and non-disturbed control sites), 10 adult females and 10 female pups were selected for attachment of satellite tags and subsequent statistical analysis.

Table 1. Location, date, animal ID, and mass of pup and adult female northern fur seals captured for attachment of satellite tags at St. George Island during 2015.

	Pups			Adult females		
Rookery	Date	Animal ID	Mass	Date	Animal ID	Mass
East Reef	10/3/15	AN5467EW	13.8	10/1/15	ANG206HG	32.6
		AN5468EW	10.4		ANG207HG	34.8
		AN5469EW	11.2		ANG208HG	37.2
		AN5470EW	15.0		ANG209HG	37.4
		AN5471EW	13.0		ANG210HG	31.0
North	10/1/15	AN5462EW	14.2	10/1/15	ANG201HG	39.0
		AN5463EW	12.0		ANG202HG	46.4
		AN5464EW	14.6		ANG203HG	34.4
		AN5465EW	14.4		ANG204HG	42.6
		AN5466EW	13.2		ANG205HG	39.8
South	9/30/15	AN5119EW	14.2	9/30/15	ANG194HG	37.0
		AN5176EW	17.0		ANG196HG	41.6
		AN5178EW	15.0		ANG198HG	44.6
		AN5179EW	13.8	10/2/15	ANG218HG	34.4
		AN5246EW	15.0		ANG219HG	46.2
Zapadni	10/3/15	AN5472EW	15.2	10/1/15	ANG213HG	26.4
		AN5473EW	12.6		ANG214HG	31.2
		AN5475EW	13.8		ANG215HG	41.6
		AN5474EW	10.4		ANG217HG	37.2
		AN5476EW	12.6		ANG211HG	37.0

Satellite tag programming and performance

MK10 satellite tags (Wildlife Computers, Redmond, WA, USA) were attached to the fur seals' dorsal pelage using quick setting epoxy. The tags were programmed to transmit every 43 seconds while at sea, and every 88 seconds while on land. To conserve battery life, transmission periods were cycled to be on for four hours and off eight hours, and a saltwater switch prevented transmission when underwater. The tags were further programmed to prioritize the collection and transmission of two land/sea indicator messages. The first, called "hourly % timeline", is a single transmitted message containing the percentage of time the tag is dry for each hour in a single day. The second message, called "20-minute timeline" indicates if the tag is wet for more than 10 minutes during a 20-minute interval resulting in a single transmitted message containing 72 wet/dry indicators for a 24-hour period. The depth threshold for each timeline message was programmed to "Wet/Dry". Both messages, for a particular date, were stored in a 3-day buffer and were part of the tags transmission cycle of sending dive summaries and tag status data. A complete record of satellite tag programming is detailed in a deployment report for one of the tags (Appendix 1).

For adult females at East Reef, one satellite tag stopped transmitting prior to her first foraging trip, and another female departed on her migration a day after tagging. At South, one satellite tag stopped transmitting after a few trips, but prior to migration. For pups, three satellite tags stopped transmitting prior to migration, including one at East Reef, one at South, and one at Zapadni. These performance issues of the satellite tags notably reduced the sample sizes of adults and pups for all of the comparisons, but data was used where it was available (e.g., trip and shore durations prior to tags ceasing transmissions).

Characterization of human disturbance during late 2015

During late September through November of 2015, human presence was documented at northern fur seal resting sites, and consisted of 13 harvest-related disturbances and 9 research-related disturbances (Table 2). Harvest-related events involved disturbances in rookery habitat (n=6), in haul-outs adjacent to rookery habitat (n=2), and in areas removed entirely from rookery habitat (n=5). The latter areas involved habitat in and around the city harbor that young fur seals used during 2015; harvest events in these areas were possible due to the ephemeral use of non-traditional habitat by northern fur seals—the location of which apparently varies among areas and years. These harvests in and around the city harbor during 2015 eliminated the need for subsistence harvests at the closest rookery, Zapadni rookery, and were also not considered in our assessment of disturbance there. As a result, no harvest events were associated with the experimental "disturbed" site at Zapadni rookery. Another 4 harvest events at or nearby the East Reef study site occurred *after* all satellite tagged animals from that rookery had left the island for the year, leaving only 4 harvest events that occurred during the time, and in areas where, it was possible that satellite tagged animals were present and for which assessment of effects was possible.

The mean duration for all harvest events was 53 minutes (SE=11 min). Mean duration of harvest events in rookery habitat and their adjacent haul-outs was 66 minutes (SE=17 min) and in areas removed from rookery habitat was 33 minutes (SE=4 min). The 4 harvest events that were considered in assessment of disturbance had a mean duration of 95 minutes (SE=30 min), and included one harvest at North rookery, a control site.

Of the 9 research-related disturbances, 7 were related to the deployment of satellite tags for this project; multiple days were required to deploy all of the tags on pups and adult females at some of the study sites. The mean duration of all research events was 99 minutes (SE=31 min), and the mean duration for research events that did not involve the deployment of tags was 33 minutes (SE=2 min).

Table 2. Date, location and characterization of late-season disturbance events on St. George Island during 2015.

Date	Location	Duration	Research	Harvest (# taken)	Disturbance level
9/30/2015	South Rookery, Section 1	5:25	Sat. tag 5 pups, 3 AF, plus pup flipper tagging		+
10/1/2015	East Reef Rookery	1:20	Sat. tag 5 AF		+
10/1/2015	Zapadni	1:08	Sat. tag 5 AF		+
10/1/2015	North Rookery, Section 3	2:44	Sat. tag 5 pups & 5 AF		+
10/2/2015	South Rookery	0:44	Sat. tag 2 AF		++
10/3/2015	Zapadni	1:05	Sat. tag 5 pups		++
10/3/2015	East Reef	1:20	Sat. tag 5 pups		++
10/6/2015	East Reef Haulout	0:35	Round-up, resighting, weighing		+++
10/20/2015	South Rookery, Section 1	0:30	Disentanglement		+++
10/6/2015	East Reef Haulout	0:33		6	+++
10/16/2015	East Reef Haulout	2:45		6	+++
10/19/2015	North Rookery, Section 3	2:05		6	+++
11/6/2015	East Reef Rookery	1:00		4	+++
11/18/2015	East Reef & Cliffs Rookery	0:25		3	-
11/20/2015	East Reef Rookery	0:45		3	-
11/24/2015	East Cliffs Rookery	0:40		6	-
11/25/2015	East Reef Rookery (between sea lion rock and pond)	0:40		5	-
9/24/2015	Zapadni old dock	0:22		5	-
10/2/2015	Zapadni Harbor	0:45		4	-
10/9/2015	Zapadni old dock	0:39		5	-
10/23/2015	Zapadni Harbor	0:30		3	-
10/30/2015	Zapadni Harbor	0:30		1	-

+ initial disturbance during attachment of satellite tags

++ disturbance during attachment of satellite tags, but where some tags were already deployed

+++ disturbance where all tags were already deployed

- disturbance when or where no deployed satellite tags were present

Adjustments to the study based on the patterns of human disturbance documented during 2015

The number of disturbance events at each site did not follow expected patterns, and therefore did not match the assumptions of the study design. Including the disturbance events to deploy tags, and excluding disturbances after all tagged animals had departed, there were 13 disturbance events at or nearby a study site, including 2 at Zapadni, 6 at East Reef, 3 at South, and 2 at North. Not including the disturbance events related to the deployments of tags for this project, comparisons between the experimental (disturbed) and control (undisturbed) sites of the original study design involved 4 disturbance events at the experimental sites (0 at Zapadni and 4 at East Reef) and 2 events at the control sites (1 at South and 1 at North). Given the actual distribution of disturbance events documented among these sites, the inclusion of Zapadni as an experimental site was clearly not warranted. Moreover, the limited number of disturbance events (and of functioning satellite tags, determined by tag performance measures described above) at the sole remaining experimental site (East Reef) makes most subsequent statistical comparisons tenuous, at best. Acknowledging these substantial shortcomings, and with a goal to guide future research efforts, we completed statistical comparisons as follows:

1. Zapadni and East Reef vs. South and North; the original selection of experimental vs control sites in the study design.
2. East Reef and North vs. Zapadni and South. This comparison addressed possible effects on animal behavior from inherent differences in environmental exposure between the north and south sides of the islands.
3. East Reef vs. all other sites. If no significant differences were found in comparison 2., above, North, South, and Zapadni were considered the control sites and compared to East Reef as the experimental site.

Northern fur seal response variables to disturbance events

Because a primary goal of this study was to identify measurable responses of northern fur seals that have the potential to reduce survival or reproductive rates as a result of disturbance events, we selected response variables that would indicate longer-term seasonal population effects of disturbance. As such, we did not attempt to measure or describe the immediate and short-term reaction of individuals when a disturbance occurred.

Response of adult female fur seals to disturbance events

Adult females with dependent pups spend the summer and fall alternating between nursing their pups on shore and foraging on extended trips to sea. Variability in attendance patterns (duration of shore visits and duration of foraging trips) were assessed as measures of adult female responses to human disturbance compared to undisturbed females. In addition to these attendance responses by adult females, we also attempted to measure the effect of disturbance in nearshore diving indicative of foraging, displacement to alternative site(s) on shore, and the timing of departure for the winter migration. The following hypotheses were tested ($\alpha = 0.05$) to examine possible effects of disturbance events on adult female northern fur seals:

a. H_0 1a: Adult female foraging trip duration at disturbance sites is the same as at control sites.

Extensive data processing was required to achieve the required resolution for measures of attendance; for each individual, we constructed an hourly timeline of land and sea attendance from the tag deployment date to the start of the migration (Figure 1). We prioritized and used all of the “hourly % timeline” messages received, and then supplemented the missing “hourly % timeline” messages with the “20-minute timeline” messages converted into an “hourly % timeline” format. The “20-minute timeline” messages only indicate if the tag is predominantly wet or dry during a 20-minute interval. As a result, we calculated the equivalent of the “hourly % timeline” message for each hour as 100%, 66%, 33%, or 0% ***dry*** if 3 of 3, 2 of 3, 1 of 3, or 0 of 3 “20-minute timeline” messages for a single hour, respectively, indicated the tag was dry. The percentages of each hour dry allowed us to estimate the start and end times of each individual’s foraging trip. Land/sea indicator messages were not received on all days, however, resulting in gaps in each seals record prior to the seals winter migration. In these situations, and owing to the extensive duration of adult female foraging trips to sea, the Service Argos Inc. location estimates were used to determine if a tag was wet or dry and/or to estimate the timing of foraging trip departures and arrivals. There were a total of 115 adult female foraging trips identified, and for which durations were calculated. Mean foraging trip durations were calculated and summarized by individual and site (Table 3). We used a generalized linear mixed-effects models, with and without an AR(1) autocorrelation structure, where we specified in both models individual seal as a random effect. Model selection was done by comparing AIC values. We cannot reject H_0 for any of the comparisons.

b. *H_0 1b: Adult female duration of onshore attendance at disturbance sites is the same duration as at control sites.*

Using the methods described for *H_0 1a*, mean durations of shore visits were calculated and summarized by individual and site, and the data were analyzed with generalized linear mixed-effects models (Table 3). We cannot reject H_0 for any of the comparisons.

c. *H_0 1c: Adult females at disturbance sites move (temporarily or permanently) to alternative sites at the same frequency as females at control sites.*

Service Argos Inc. provided point estimates of each animal’s locations, as well as estimates of latitudinal and longitudinal error, that were determined though the utilization of a Kalman filtering position algorithm. We used R-packages in the R Statistical Computing Platform v. 3.3.2 to further filter the location data and to model animal movements. Unrealistic locations were first removed using the Argos location filtering algorithm in the argosfilter v. 0.63 package (Freitis et al. 2008). The remaining location data and associated error estimates were then fed into a continuous time-correlated random walk model in the crawl v. 2.2.0 package to estimate the animals’ locations at hourly time steps. Each animal’s location estimates were plotted from the time of tag deployment until departure on the winter migration to identify movements, and to quantify duration of any movements, to alternative sites. No females from either the experimental or control sites moved to alternative sites for long durations or permanently. It should be noted that due to the resolution of the Argos data it was not possible to determine with 100% certainty whether any females had made short visits to alternative sites that are located immediately adjacent to the tag deployment sites (separated by approximately 200 meters or less; i.e., among South and Zapadni rookeries, or between East Reef and East Cliffs rookeries). There were no locations observed at alternative sites not found immediately adjacent to the deployment site, however, all of which are greater than a few kilometers apart. We cannot reject H_0.

d. *H_0 1d: Adult female nearshore diving behavior at disturbance sites is the same as at control sites.*

We could not assess this null hypothesis, as there were only 100 hours of near shore diving recorded and transmitted via satellites over the duration of the study, and these data were only recorded at North and

South rookeries (which are control sites in both the original and adjusted study design).

e. *H_0 1e: The mean date of departure on the winter migration by adult females at disturbance sites is the same as at control sites.*

Final departure dates from the island were determined for individual adult females who left the island and did not return that calendar year, and mean departure dates were summarized by site (Table 3). Disturbance effects for each comparison was assessed in ANOVA, using F-statistics on 1 and 16 degrees of freedom. We cannot reject H_0 for any of the comparisons.

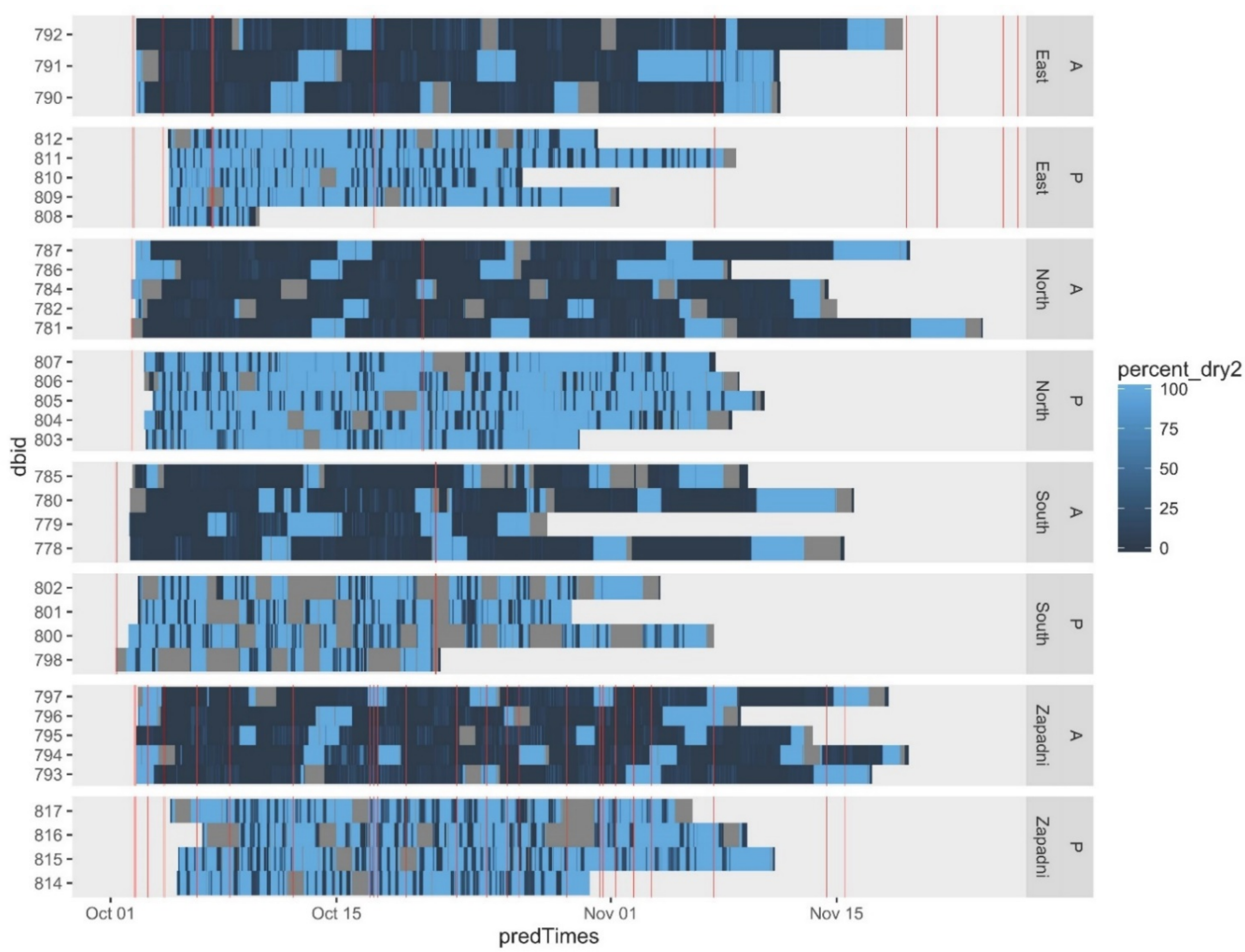

Figure 1. Hourly timeline of attendance patterns of individual adult females (A) and pups (P) at each of the rookeries during late 2015. Dark blue indicates wet (foraging trip), light blue indicates dry (on shore), gray indicates missing attendance data, and red bars indicate a disturbance event at or near the rookery.

Table 3. Results of comparisons of adult female migration departure date, trip duration and shore duration.

	Departure (Julian day)			Trip Duration (d)			Shore Duration* (d)		
Comparison	mean	SE	p	mean	SE	p	mean	SE	p
#1									
E&Z disturbed	313.7	6.8	0.61	7.19	0.89	0.81	2.09	0.55	0.33
N&S control	316.6	3.9		7.01	0.49		2.54	0.31	
#2									
North side	314.1	3.9	0.72	7.74	0.51	0.11	2.40	0.34	0.79
South side	316.1	6.8		6.57	0.86		2.28	0.57	
#3									
E disturbed	307.0	6.8	0.11	7.45	1.07	0.67	2.05	0.66	0.58
N,S,Z control	317.4	2.9		7.02	0.40		2.39	0.25	

*All three shore duration models for adults were the only models to include an AR(1) autocorrelation structure

Response of pup fur seals to disturbance events

Dependent pups are highly mobile by September and spend significant and increasing time in the water as they approach weaning. During this time, pups may use sites away from the traditional breeding and resting areas, making them difficult to observe visually. Variability in the duration of bouts on shore and in the water were assessed as measures of pup responses to human disturbance compared to undisturbed pups. We also attempted to measure the effect of disturbance events on displacement of pups to alternative site(s) on shore, and the timing of departure for the winter migration (at which time the pups are considered weaned). The following hypotheses were tested ($\alpha = 0.05$) to examine possible effects of disturbance events on female pups:

a. *H_0 2a: The duration of time spent during bouts in the water by pups at disturbance sites is the same as at control sites.*

Similar to the measures of attendance for adult females, we constructed an hourly timeline of pup land and sea attendance from the tag deployment date to the start of the migration (Figure 1). We prioritized and used all the “hourly % timeline” messages received, and then supplemented the missing “hourly % timeline” messages with the “20-minute timeline” messages converted into an “hourly % timeline” format. The “20-minute timeline” messages only indicate if the tag is predominantly wet or dry during a 20-minute interval. As a result, we calculated the equivalent of the “hourly % timeline” message for each hour as 100%, 66%, 33%, or 0% *dry* if 3 of 3, 2 of 3, 1 of 3, or 0 of 3 “20-minute timeline” messages for a single hour, respectively, indicated the tag was dry. The percentages of each hour dry allowed us to estimate the start and end times of each pup’s foray in the water, described henceforth as a “trip”. Subsequent analysis and interpretation of the land/sea indicator data differed slightly for pups (from that of the adult females). Pups often moved in and out of the water repeatedly between the start and end of a trip, and these movements were assigned as 100% part of that pup’s trip. Land/sea indicator messages were not received on all days, resulting in gaps in each seals record prior to the seals winter migration. In these situations, a pup trip would start at the end of the day and the next day’s message would be missing or at the start of day the pup would be on a trip with the previous day’s message missing. In either case, the trip was omitted due to the missing arrival or departure times of that trip. Durations were calculated for total of 602 pup trips. Mean duration of time spent during bouts in the water was calculated from the "trip" durations, and summarized by individual and site (Table 4). We used a generalized linear mixed-effects models, with and without an AR(1) autocorrelation structure, where we specified in both models individual seal as a random effect. Model selection was done by comparing AIC values. We cannot reject H_0 for the initial comparison (comparison #1 above; Zapadni and East Reef vs. South and North). However, trip durations were *shorter* at East Reef when compared to all other sites combined (P=0.00).

b. *H_0 2b: The duration of time spent during bouts on land by pups at disturbance sites is the same as at control sites.*

Using the methods described for *H_0 2a*, mean on-shore durations were calculated and summarized by individual and site, and the data were analyzed with generalized linear mixed-effects models (Table 4). Shore durations were shorter (p=0.00) for the original experimental sites (East Reef and Zapadni in comparison #1 above) compared to North and South. East Reef shore durations were marginally shorter (p=0.053) when compared to all other sites combined (comparison 3).

c. *H_0 2c: Pups at disturbance sites move (temporarily or permanently) to alternative sites at the same frequency as pups at control sites*

Service Argos Inc. provided point estimates of each animal's locations, as well as estimates of latitudinal and longitudinal error, that were determined though the utilization of a Kalman filtering position algorithm. We used R-packages in the R Statistical Computing Platform v. 3.3.2 to further filter the location data and to model animal movements at sea. Unrealistic locations were first removed using the Argos location filtering algorithm in the argosfilter v. 0.63 package (Freitis et al. 2008). The remaining location data and associated error estimates were then fed into a continuous time-correlated random walk model in the crawl v. 2.2.0 package to estimate the animals' locations at hourly time steps. Each pup's location estimates were plotted from the time of tag deployment until departure on the winter migration to identify movements, and to quantify duration of any movements, to alternative sites (Figure 2). We also determined the distance of each location from the respective deployment site and, for each animal, assessed the distribution of these location distances to identify patterns indicating movements. No pups from either the experimental or control sites moved to alternative sites for long durations or permanently. It should be noted that due to the resolution of the Argos data it was not possible to determine with 100% certainty whether any of the pups had made short visits to alternative sites that are located immediately adjacent to the tag deployment sites (separated by approximately 200 meters or less; i.e., among South and Zapadni rookeries, or between East Reef and East Cliffs rookeries). There were no locations observed at alternative sites not found immediately adjacent to the deployment site, however, all of which are greater than a few kilometers apart. We cannot reject H_0.

d. *H_0 2d: The mean date of departure on the winter migration by pups at disturbance sites is the same as at control sites.*

Final departure dates from the island were determined for individual pups who did not return that calendar year, and were summarized by site (Table 4). Disturbance effects for each comparison was assessed in ANOVA, using F-statistics on 1 and 16 df. We cannot reject H_0 for any of the comparisons.

Table 4. Model results for comparisons of pup migration departure date, “trip” duration, and shore duration.

	Departure (Julian day)			“Trip” Duration (d)			Shore Duration (d)		
Comparison	mean	SE	p	mean	SE	p	mean	SE	p
#1									
E&Z disturbed	304.9	4.9	0.55	0.23	0.02	0.15	0.59	0.11	0.00
N&S control	307.3	2.8		0.26	0.01		0.90	0.06	
#2									
North side	305.5	2.7	0.74	0.23	0.01	0.12	0.72	0.08	0.56
South side	306.9	4.9		0.26	0.02		0.79	0.15	
#3									
E disturbed	300.6	4.6	0.08	0.20	0.02	0.00	0.56	0.14	0.05
N,S,Z control	308.2	2.2		0.26	0.01		0.82	0.06	

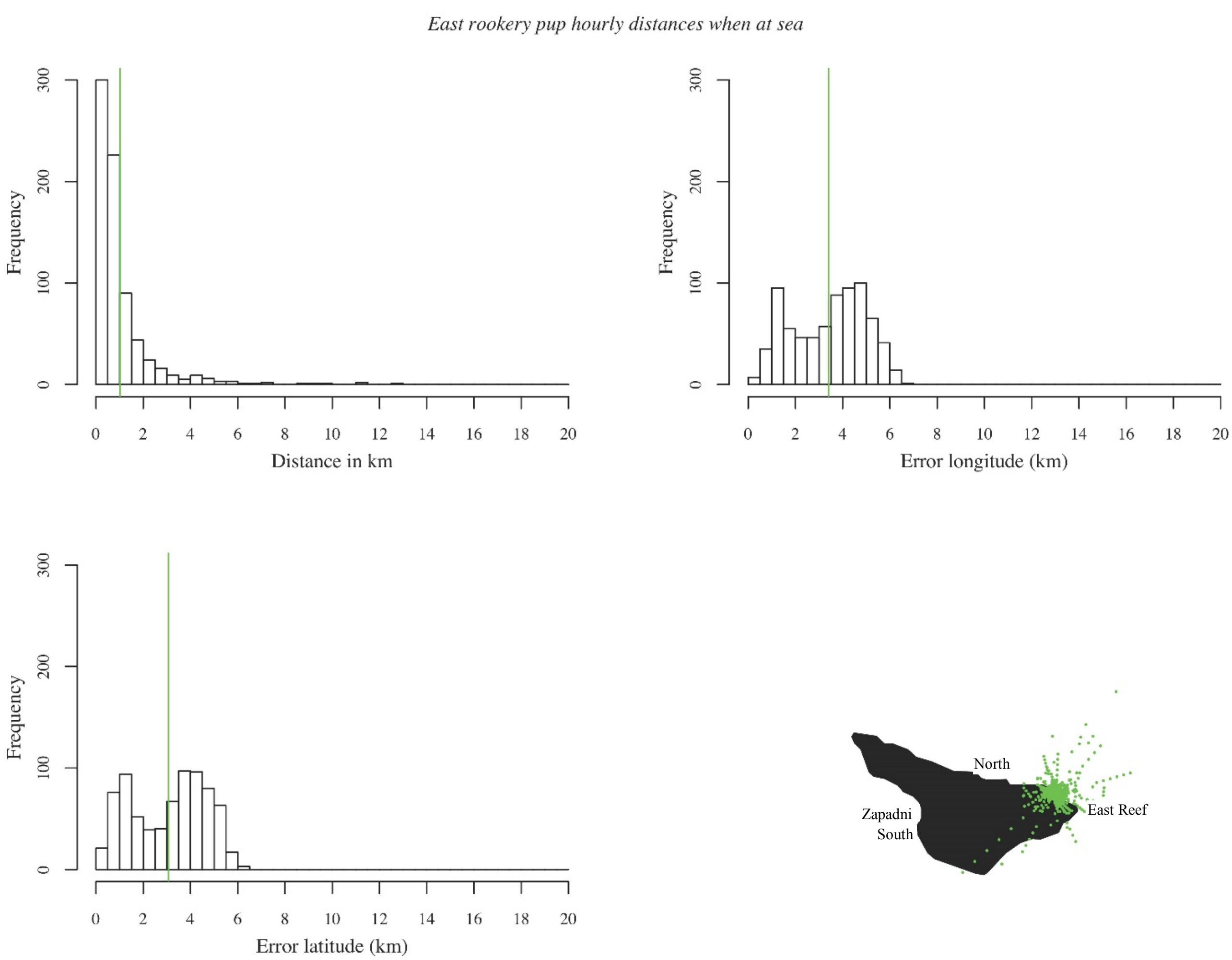

Figure 2. Example of Service Argos Inc. location data and plot from East Reef rookery, including histograms of the estimated distances from the tag deployment site and of the estimated latitudinal and longitudinal error of the locations. In this example, green dots are individual locations, and the green lines in the histograms represents median values of the pups’ positions.

Discussion

The goals of this research were to document and characterize human disturbance occurring at northern fur seal resting sites on St. George Island during 2015, to identify measurable responses of northern fur seals that have the *potential* to reduce survival or reproductive rates at disturbed breeding colonies, and to provide managers with information on detrimental (or, alternatively, negligible) effects of human disturbance that could be used to guide and refine harvest practices.

The number and distribution of human disturbances during the conduct of this study did not follow expected patterns or the assumptions of the study design. The number of harvest-related disturbances that occurred in the rookeries that were designated as experimental sites were fewer than anticipated. Fewer yet occurred in a manner that would allow the effects on fur seals to be measured by this study, as 50% of the harvests at one rookery (East Reef) occurred so late in the season that many animals, included all of the satellite tagged animals at that site, had already departed on the winter migration. The duration of harvest activities were also shorter than expected, suggesting that the disturbance exposure may have been tempered to some degree by lower intensity of disturbance. Perhaps the most notable deviation from expectation, however, was the documentation of harvests that occurred either in areas entirely removed from the rookeries or in haul-out areas adjacent to the rookeries; less than half of all harvests occurred in rookery habitat. An obvious consequence of this harvest decision and practice by the St. George harvest managers was the reduction in the overall number of animals that had the potential to be disturbed and, moreover, a complete elimination of disturbance to adult females resting and nursing their pups in rookery habitat during the majority of those harvests. A less obvious consequence of these practices was that research-related disturbances, primarily related to this study, accounted for a large proportion of all documented human disturbance (9 of 22 events), and of disturbance occurring in or near rookery habitat (9 of 17 events) during the fall of 2015 on St. George Island.

When disturbed on land, northern fur seals may react by fleeing to the water, and be cautious in returning to land and/or wary of settling into their natural resting and nursing behaviors. The detrimental effects (i.e., those that have the potential to reduce individual and population fitness) of increased frequency and/or intensity of disturbance events are assumed to manifest through a decrease in the duration of shore visits and, possibly, through a corresponding increase in the duration of time these individuals spend at sea. Detrimental effects of disturbance could also be assumed to involve a higher rate of displacement or emigration to sites other than their pupping/natal site, earlier departure dates for the winter migration, and an increase in adult female nearshore diving effort. While we measured these behaviors in adult female and female pup northern fur seals, there were a number of shortcomings of this analysis that arose during the conduct of the study, and we urge caution in interpreting the results. These shortcomings, involving the level of exposure to disturbance events and sample sizes at the experimental sites, did not meet the assumptions of the original study design. Because disturbance exposure was lacking at one experimental site, we adjusted the study to make additional, and more appropriate, comparisons among re-classified experimental and control sites. However, the additional comparisons were still influenced by unforeseen circumstances at the remaining experimental site: infrequent and low intensity disturbances, disturbances that occurred after all satellite tagged animals had departed on the migration and, due to satellite tag performance issues, a reduction in sample size (i.e., the number of animals with functioning satellite tags at that site).

Acknowledging the above shortcomings of this study, we found no differences (i.e., we could not reject the null hypotheses) in adult female foraging trip duration, on-shore attendance duration, and time of departure on the winter migration between experimental and control sites using the comparisons identified in either the original or the adjusted study design. We could not assess comparisons of near-shore diving behavior due to a lack of data recorded at the experimental site(s). Due to the resolution of the Argos location data, we were also unable to determine whether females were temporarily displaced or moved to sites *immediately adjacent* to the tag deployment sites. Adult female locations were not observed at the other sites (not found immediately adjacent to the deployment site), however, and no animals moved from their tag deployment site to any alternative site for long durations or permanently. For adult females, the results of these analyses imply that either there were no effects, or that we were simply unable to detect any effects, of human disturbance.

While most of the results for female pups were similar to those for adult females (no difference between experimental and control sites), there were a few exceptions. On-shore durations were shorter for the experimental sites using the original study design comparison (with Zapadni classified as an experimental site), but were only marginally shorter using the more appropriate, adjusted study design comparison (with East Reef as the lone experimental site; p=0.053). The one other finding of significance, also under the adjusted study design comparison, was the duration of bouts in the water. Interestingly, the duration of these "trips" were *shorter* at the experimental site. This finding is perhaps contrary to conventional wisdom which, at least for adult females, would suggest that the duration of time in water should increase in response to disturbance. It is possible that the result is simply an artifact of the small sample size at East Reef, driven by the random selection of a few individuals with a predilection for short in-water bouts. Shorter bouts could also be related to inherent differences in environmental exposure and shoreline characteristics found at East Reef that have an unidentified influence on aquatic behavior. Given the shorter duration of in-water bouts at East Reef, as well as some limited support for shorter on-land bouts there, we also calculated and compared the total proportion of time pups spent in the water at East Reef (0.24) and the control sites (0.26), and found that over the course of the season, experimental and control pups were spending a similar amount of time in the water (and, conversely, on shore). As with the adult females, there was no obvious (long duration) movements of pups from their tag deployment site to other sites, and we did not observe any pup locations at sites beyond immediately adjacent rookeries. Again, we were unable to determine if any pups moved temporarily to immediately adjacent sites due to the resolution of the Argos location data. For female pups, the results of the analyses are less conclusive than for adult females, but seem to suggest little, if any, detectable effects of human disturbance (or, again, that we were unable to detect effects as a result of the above identified shortcomings).

Following decades of declining abundance at St. George Island, the northern fur seal population stabilized during the early 2000's and pup production increased steadily there since 2012. Though this apparent recovery in fur seal abundance occurred concomitantly with changes to the subsistence harvest regulations and practices, human activities at or near fur seal resting sites remain a top management concern due to the potential for negative impacts from increased levels of exposure to disturbance. We advise caution on the interpretation and utilization of the results from the research presented here on the effects of human disturbance to northern fur seals, and recommend assessing evidence from other independent studies (on-going or future efforts) for consilience. Due to limitations of the current study, we initiated a follow-up project at St. George during the fall of 2016 to specifically examine the attendance behavior (including trip and shore durations, timing of departure on migration, and displacement to alternate sites) of adult females. We attached pulse-coded VHF flipper tags to adult females that allow larger sample sizes and multiple years of observations, and provide finer resolution data to assess the effects of human disturbance on the fur seals. In addition to evaluating the possible long-term population level effects of human disturbance, the study will also provide information needed to describe and characterize the immediate behavioral responses of individual fur seals to disturbance events, address near-term impacts on individuals' attendance patterns (e.g. the trip/shore duration immediately following a disturbance event), and allow seasonal assessment of disturbance throughout the duration of their tenure at St. George (i.e., from early summer through late fall). These improvements in the study design should provide managers with additional knowledge and tools to understand the range of animal reactions to human disturbance events and, ultimately, whether these short-term reactions result in long-term consequences to northern fur seal vital rates.

Appendix 1. An example of a “Deployment Report” detailing the satellite tag programming used on tags deployed at St. George Island during 2015.

Automatically Generated Abreviated Deployment Report

PRINT

Host Settings	
MK10Host version	1.26.2008
User Name	Jeremy.sterling
Time And Date Settings	
PC Date (UTC)	22 Sep 2015 at 21:11:03
Tag Date	22 Sep 2015 at 21:10:43
PC UTC offset	7 hours
Last deployment date	16 Sep 2015 at 20:14:00
General Settings	
Tag's Serial Number	15A0592
Password	MK10
User's Identifier	NFS2015_15A0592
Argos Ptt number	8267 (812EC Hex)
Repetition Intervals	43s (at-sea); 88s (haulout)
Number of Argos transmissions	453
Tagware version	1.26m
Hardware version	10.5
Battery Configuration	2 x AA
Battery Capacity (from manufacturer's datasheet)	4000mAh
Battery is not classified as dangerous goods	
Deploy from Standby on Depth Change?	Yes
Owner	Wildlife Computers 8345 154th Ave NE Redmond, WA 98052 USA +1-425-881-3048
Bytes of archive data collected	4096
Bytes of histogram and profile data collected	0
Data to Archive Settings	
Depth	5 seconds
Internal Temperature	never
External Temperature	5 seconds
Depth Sensor Temperature	never
Battery Voltage	60 seconds
Wet/Dry	5 seconds
Wet/Dry Threshold	Dynamic (initial value = 80)
Sampling Mode	Wet or Dry

Automatic Correction of Depth Transducer Drift	Using first dry reading
Data to Transmit Settings	
Histogram Selection	
Histogram Data sampling interval	1 seconds
Dive Maximum Depth (m), 14 bins	2; 5; 10; 20; 35; 50; 75; 100; 125; 150; 175; 200; 225; >225
Dive Duration, 14 bins	15secs; 30secs; 1 min ; 1 min 30secs; 2 mins ; 2 mins 30secs; 3 mins ; 3 mins 30secs; 4 mins ; 4 mins 30secs; 5 mins ; 5 mins 30secs; 6 mins ; >6 mins
Time-at-Temperature (C)	disabled
Time-at-Depth (m)	disabled
20-min time-line	enabled
Hourly % time-line (low resolution)	disabled
Hourly % time-line (high resolution)	enabled
Dry/Deep/Neither time-lines	Disabled
PAT-style depth-temperature profiles	disabled
Deepest-depth-temperature profiles	disabled
Light-level locations	disabled
Histogram Collection	
Hours of data summarized in each histogram	6
Histograms start at GMT	00:00
Do not create new Histogram-style messages if a tag is continuously dry throughout a Histogram collection period	is disabled
Time-Series Messages	
Generation of time-series (TS) messages	is enabled
Time interval between TS samples	10 mins
Channels sampled	Depth, External Temperature
Start with	75 days on
then Duty Cyle with	255 days off
and	0 days on
Dive & Timeline Definition	
Depth reading to determine start and end of dive	1.5m
Ignore dives shallower than	1.5m
Ignore dives shorter than	0s
Depth threshold for timelines	Wet/Dry
Behavior Messages	
Generation of behavior messages	is disabled
Stomach Temperature Messages	
Generation of stomach temperature messages	is disabled
Haulout Definition	
A minute is "dry" if Wet/Dry sensor is dry for any ***value*** seconds in a minute	30

Enter haulout state after ***value*** consecutive dry minutes	5
Exit haulout state if wet for any ***value*** seconds in a minute	30
Transmission Control	
Transmit data collected over these last days	3
Pause transmissions if haulout exceeds	never pause
Transmit every eighth day if transmissions are paused	is enabled
Collection days	
January	1 - 31
February	1 - 29
March	1 - 31
April	1 - 30
May	1 - 31
June	1 - 30
July	1 - 31
August	1 - 31
September	26 - 30
October	1 - 31
November	1 - 30
December	1 - 31
Relative transmit Priorities	
Histogram, Profiles, Time-lines, Stomach Temperature	med (2 transmission(s))
Fastloc and Light-level Locations	none (0 transmission(s))
Behavior and Time-Series	med (2 transmission(s))
Status	Every 20 transmissions
When to Transmit Settings	
Initially transmit for these hours regardless of settings below	24
Transmit hours	1 - 4, 12 - 17,
Transmit days	
January	1 - 31
February	1 - 29
March	1 - 31
April	1 - 30
May	1 - 31
June	1 - 30
July	1 - 31
August	1 - 31
September	26 - 30
October	1 - 31
November	1 - 30
December	1 - 31

Daily Transmit Allowance	
January	275 [Accumulate, Optimize for battery life]
February	275 [Accumulate, Optimize for battery life]
March	275 [Accumulate, Optimize for battery life]
April	275 [Accumulate, Optimize for battery life]
May	275 [Accumulate, Optimize for battery life]
June	275 [Accumulate, Optimize for battery life]
July	275 [Accumulate, Optimize for battery life]
August	275 [Accumulate, Optimize for battery life]
September	375 [Accumulate, Optimize for battery life]
October	375 [Accumulate, Optimize for battery life]
November	375 [Accumulate, Optimize for battery life]
December	275 [Accumulate, Optimize for battery life]

Channel Settings	
Depth	Channel: 0; Range: -40m to 1000m; Resolution: 0.5m; ADaddress: 02; Settling Delay: 1.5ms
Internal Temperature	Channel: 1; Range: -40C to 60C; Resolution: 0.05C; ADaddress: 04; Settling Delay: 0.5ms
External Temperature	Channel: 2; Range: -40C to 60C; Resolution: 0.05C; ADaddress: 03; Settling Delay: 0.5ms
Depth Sensor Temperature	Channel: 3; Range: -40C to 60C; Resolution: 0.05C; ADaddress: 05; Settling Delay: 0.5ms
Battery Voltage	Channel: 14; Range: 0V to 5V; Resolution: 0.0048V; ADaddress: 13; Settling Delay: 1.5ms
Wet/Dry	Channel: 15; Range: 0 to 255; Resolution: 1; ADaddress: 21; Settling Delay: 1.5ms

Messages: