Auto-Detection of Gray Whales (*Eschrichtius robustus*) Off Sakhalin Island, Russia Using Shore-Based Infrared

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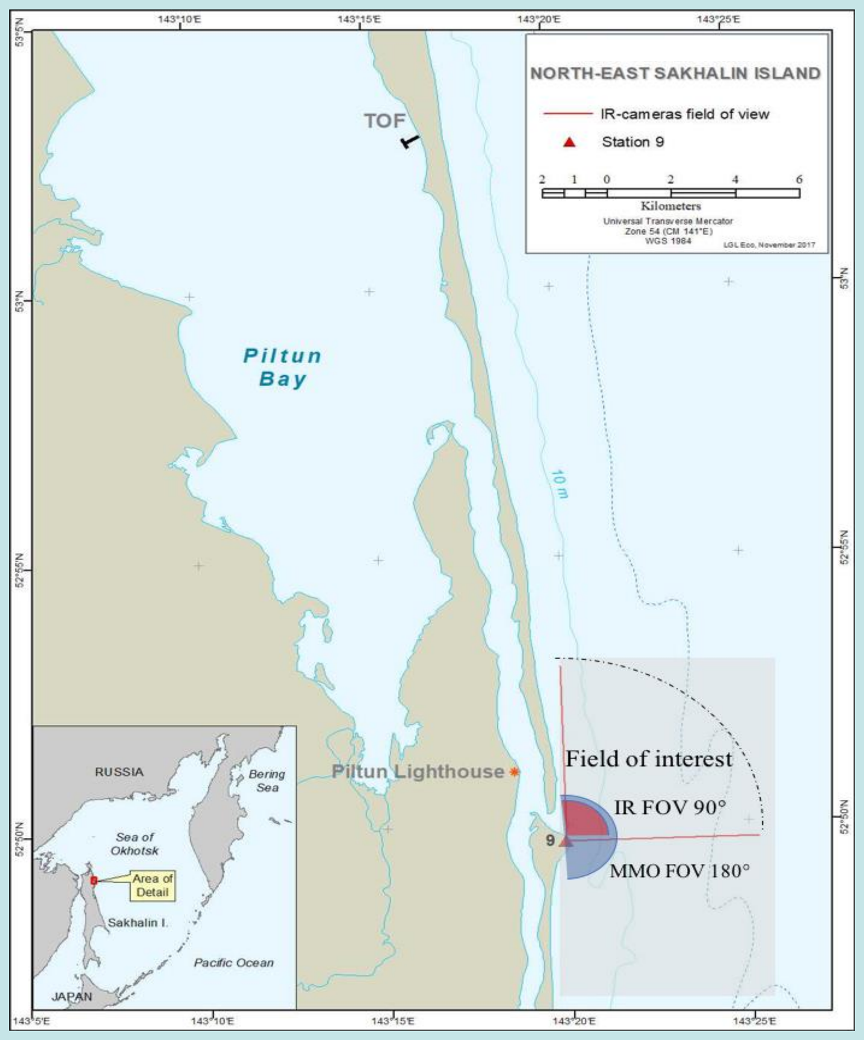
Photo by Peter van der Wolf

Introduction

In 2017, a 28 km^2 section of the gray whale (*Eschrichtius robustus)* Sakhalin nearshore feeding area at the mouth of Piltun Bay, Russia (Fig.1), was monitored for more than three months using a shore-based infrared automated whale detection system (WDS).



Map of study area around Station 9, off Sakhalin Island, Russia

Whale Detection System

The WDS was comprised of nine thermal cameras that covered a 90^{0} field of view (FOV) and displayed whale blows on screen for real-time viewing during the day or night. Long-wave infrared video data were collected 24 hours/day for 98 days (May 28-Sept 3). Each camera has a horizontal 10^{0} FOV providing a 90^{0} contiguous FOV. The cameras were mounted 2m above the observation platform, 6m above sea level which provided an effective detection range of 5-7km. The video feed from the cameras was streamed live to three desktop computer systems running the WhaleSpoutDetector software. The computers were located in a field laboratory adjacent to the observation platform. The software provided real-time detection results presenting MMOs on-site with putative whale blows to confirm or deny. The confirmed detections were logged and tracked to provide researchers with real-time locations of the whale blows. The MMOs were stationed on the platform with the cameras during daylight hours and conducted independent, systematic hourly scans of the area to record whale sightings and weather conditions, including sea state and visibility.

Photo by Dan Loman

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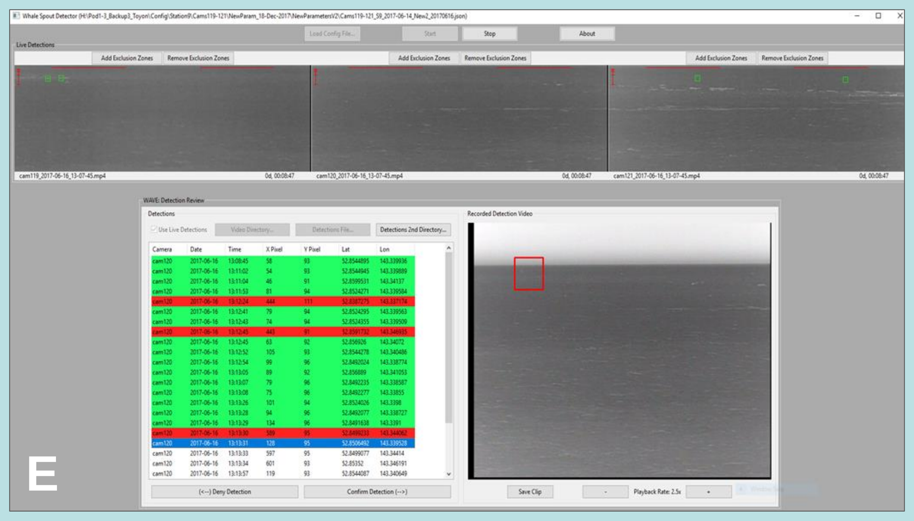
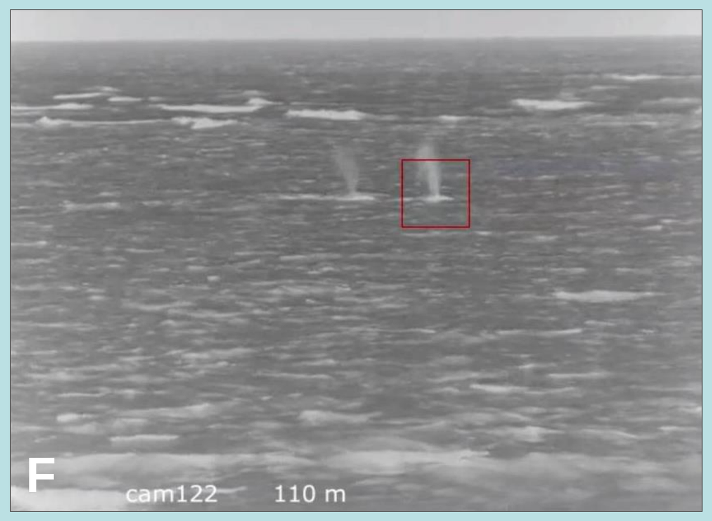




A. The observation platform and lab at Station 9. **B.** The nine-camera WDS covering a 90^{o} FOV. **C.** The MMOs stationed on the platform. **D.** Inside the lab where the three computers processed the live streaming video. **E.** Screenshot of the user interface for the WhaleSpoutDetector software. Along the top, the software displays the live streaming video for a set of three cameras. The lower left displays a log of putative blows. As each detection is selected a short 8-second video clip is played on the right. The user can quickly review the clip and confirm (highlighted green) or deny (highlighted red) each detection in the log. Confirmed detections are then saved into a separate output file. **F.** An example of an auto-detected whale blow is indicated by the red box. In this image there are simultaneous blows from two gray whales. The 2nd blow was captured in a subsequent detection by the system.

Results

A total of 54,493 whale blows were detected by the system. An average of 30-70 blows were detected each hour during the study period, with detections occurring at all hours of the day. The average hourly number of blows was lowest from late morning to midday (0900-1300) and peaked from late afternoon to early morning (1600-0200). The effective detection distance for the WDS was 5-6 km. The average whale distance was 1.66 km which is consistent with the whales' utilization of the nearshore foraging area. As expected from historical distribution studies of the area, the maximum number of detections occurred in July when mothers return to the area with their calves. Successful monitoring was weather-dependent. Dense fog prevented detections, but whale blows were detected by the WDS during periods of light fog, rain and high sea state (≧Beaufort 4-5) that marine mammal observers declared as poor visibility.

MMO Whale Counts 11Jun-11July

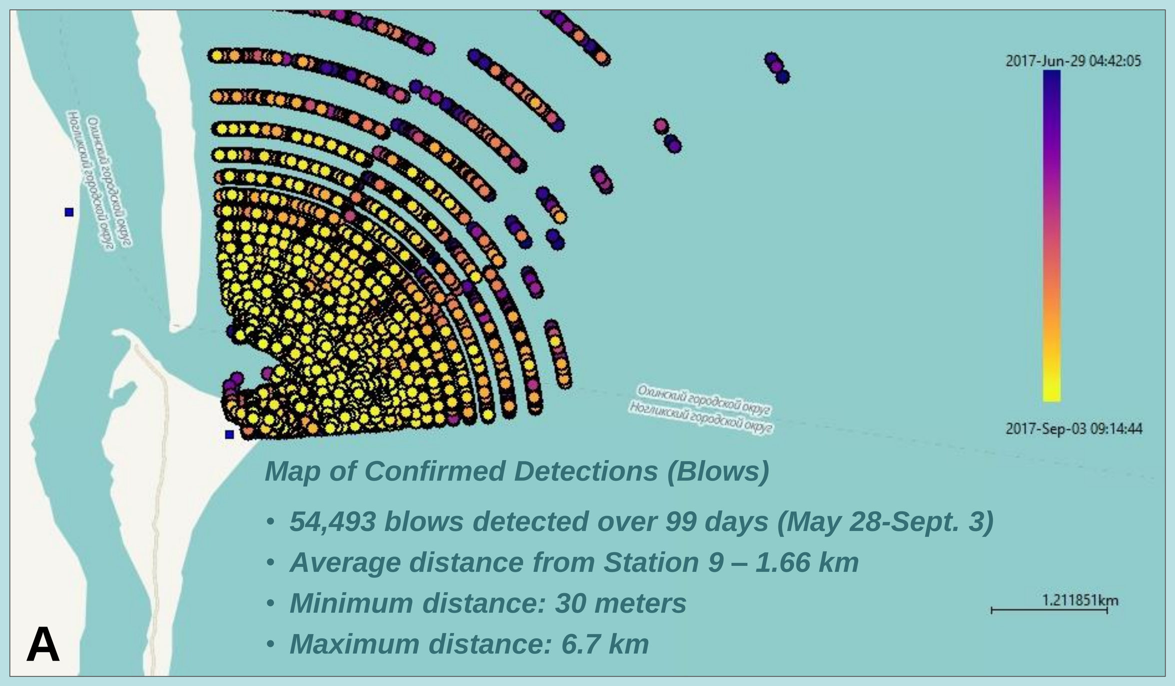
Date	Time of Day (hr)																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
11-Jun										3	1		1		2	2	3	2	2	3	4			
12-Jun								2	1	2	2		1	1				8	3	4	5			
13-Jun								1	2	1	1	1	2	3	5	3	3	4	5					
14-Jun										4	2	2	1	2	3	4	4	3	6	4	3			
15-Jun								1	1	3	2	4	2	3	7	1								
16-Jun								9	11	7														
17-Jun																		1	3	4	4			
18-Jun																								
19-Jun									4	1	3	3	3	0	6	0	2	3	4	2	5			
20-Jun								4	2	3	3	3	2	1	0	3	3	2	2	3	2			
21-Jun																								
22-Jun								0																
23-Jun								2	1	1	4	3	1	0	0	2	0							
24-Jun								4	7	4				4	4		1	4						
25-Jun								0	1	1	2	1	2	2			0	1	1	1	1			
26-Jun																	2	3	5	3	2			
27-Jun																								
28-Jun											2	4	3											
29-Jun								5	8	6	5	2	1	4										
30-Jun																		4	4	3	2			
1-Jul																								
2-Jul												2	3	4										
3-Jul								4	4	4	4	1												
4-Jul								4	3	2	3	3							3					
5-Jul									2	3	1	4	3	4	9	6	7	7	6	7				
6-Jul								8	8	10	6	7									11			
7-Jul								6	4	2	4	3	5						6	6				
8-Jul								2	3	4	1	3	3	2	5	3	4	4	4	6	4			
9-Jul									2	4	6	3	2	6	5	4	4	7	7	8	12			
10-Jul								3	4	7	5	2	7	6	6	7	6	5	10	10	12			
11-Jul								6	1	3	6	5	7	3										

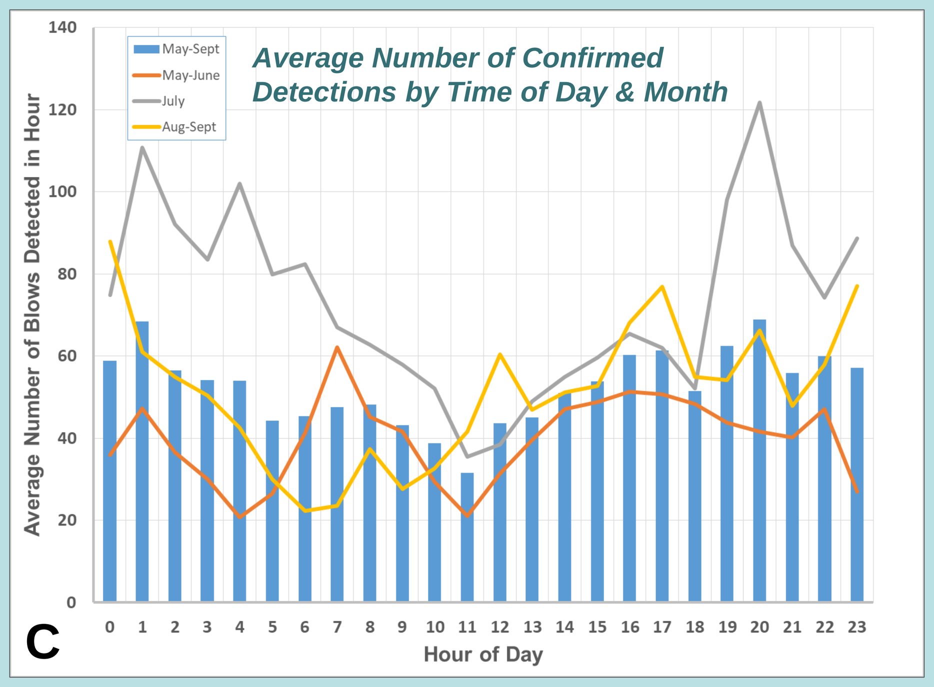
WDS Confirmed Blows 11Jun-11July

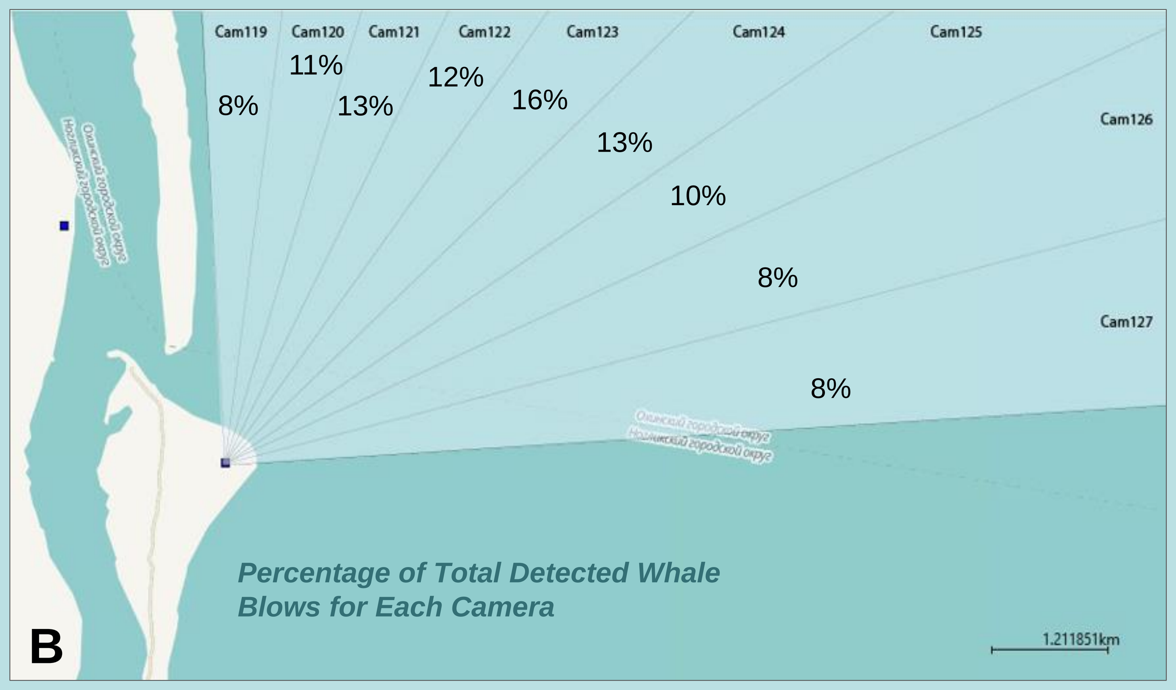
Date	Time of Day (hr)																								Daily Total
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
11-Jun							2	19	9	69	80	64	85	114	116	113	79	70	72	72	57	73	54	22	1170
12-Jun	79	105	113	32		21	13	39	10		9	4			24	85	173	209	148	144	153	128	132	116	1737
13-Jun	59	12	42	77	45	54	5		18	1		17	40	59	65	92	160	171	68						985
14-Jun									149	92	72	52	8	33	32	61	103	94	125	182	215	201	144	57	1620
15-Jun	17	2	18	23	8	1						1			15	50	18	51	55	45	44	20	67	43	478
16-Jun	36	70	56	36	65	109	194	217	218	193	113	85	126	110	189	69	40	45	36	54	28	24	25	2	2140
17-Jun	37	14	18	2														15	43	32	50	83	78	23	395
18-Jun	58	10												1	8										77
19-Jun											1	4	3	4			31	38	17	1		1	12	24	136
20-Jun	16					35	4							43	129	50	35	15	30	33	30	5		18	443
21-Jun	87	72	23	28	23	6								5		5	7		2	3	18	34	11	47	371
22-Jun	76	85	39	61	10	8						8	8			61	11				16	15	34	12	444
23-Jun							8	1			28	10					32	1	4	8	20	8	4	1	125
24-Jun	19	17	7		4	6	23	57	8	4		15	9	17	35	28	7	1	1					16	274
25-Jun	5	13	9	7	3		3		5	6	4			23	47	6		1	19	32	32	22	22	19	278
26-Jun	26	32										31	67	88	56	118	124	104	55	4	12	1	1		719
27-Jun		10						30	9			1	13		15	5	34	34	1		26	6	6		190
28-Jun											15	3		14	14	7	39	71	55	99	77	59	29	31	513
29-Jun	114	149	78	60	35	60	204	235	50	16		1													1002
30-Jun																									0
1-Jul																							62		62
2-Jul												5	89	138	99	231	101	5	114	150	145	134	221	241	1673
3-Jul	343	431	344	286	310	277	204	133	132	157	225	99	109	75	27	3		2				14	1	2	3174
4-Jul	11								1		6	9	10	19			39	30	2	18	103	125	93	86	552
5-Jul	87	165	48	55	18	28		1		7	5			20	72	51	105	117	47	37	12	34	40	31	980
6-Jul	38	22	50	106	138	113	152	139	149	156	125	17	19	86	77	65	53	52	152	237	181	166	160	105	2558
7-Jul	95	96	80	63	43	12		2	5	15	2	3	10	15	41	69	28	39	8				1	25	652
8-Jul	10	38	29	37	14				1				14	2	2	33	103	137	92	50	87	1	46	4	700
9-Jul	4	46	3	72	20	65	34		77	15		15	20	70	128	121	75	125	161	193	77	52	98	114	1585
10-Jul	148	142	104	74	17	37	62	47	56	20	16	6	1	29	86	106	172	71	29	75	150	114	98	121	1781
11-Jul	85	81	63	53	39	77	133	64	42	21	11	19	4	46	104	42	87	32	16	9	21	12	2		1063

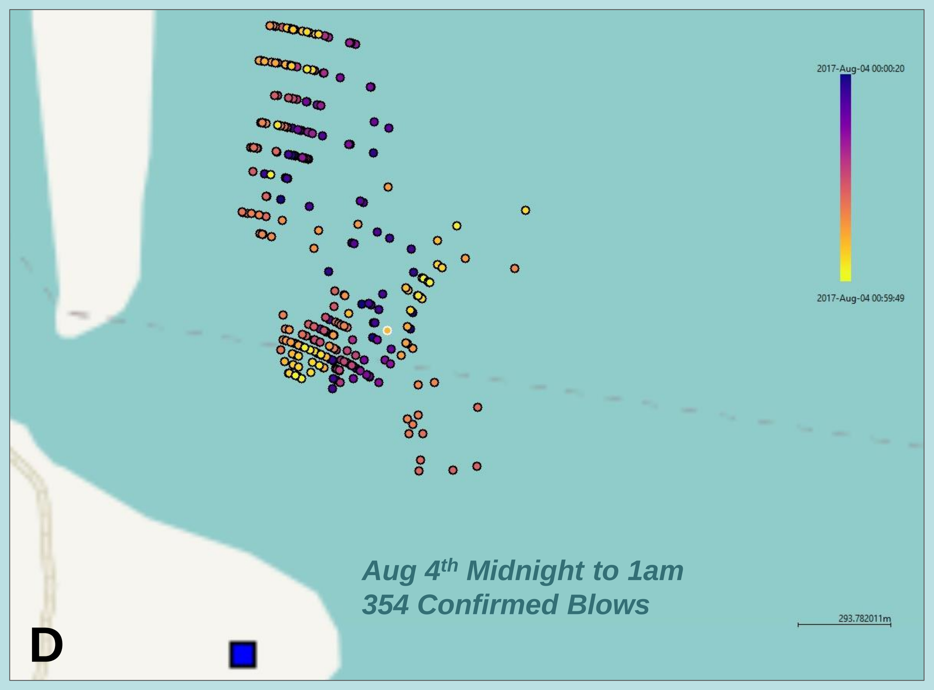
Fog | Rain | High Sea State | # includes 1 calf | # includes 2 calves

The MMO and WDS Summary data for the peak month of good visibility from 11 Jun to 11 July 2017. The MMOs conducted a scan at the top of each hour between 0700 and 2000 and reported whale counts and weather conditions. The WDS collected data 24 hrs/day. WDS data is summarized as hourly counts of confirmed whale blows including many detections during fog and Beaufort Sea States ≧ 4, when MMOs were off effort due to poor conditions. The infrared cameras cannot penetrate fog, but the detector "looks" indiscriminately for whale blows and can take advantage of quickly changing weather conditions, i.e. as fog rolls in and out.









A. Map of blows detected by the Whale Detection System over 98 days, darker points indicate older data, lighter indicate newer detections. **B.** The percentage of total whale blows over the season detected for each camera. **C.** The total number of detections broken down by time of day. **D.** An example of 1 hour of data: A total of 345 confirmed blows were detected on August 4 from midnight to 1 am. The clustering of the blows shows individual whale foraging behavior. By considering time and distance differences between blows, it is estimated that there were 6-8 individual whales in the area during this hour.

Photo by Peter van der Wolf

Conclusions

- Shore-based automated infrared detection systems are useful long-term day and nighttime monitoring of nearshore whale presence.
- Neither MMOs nor WDS can detect whales in extreme weather conditions (fog, rain, high seas), but the WDS can detect whales in some marginal conditions during which MMOs cannot. The WDS can also detect whales at night.
- Individual whales can be identified by the WDS by clustering blows in space and time and by considering appropriate respiration rates and travel velocities.