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Fall-Winter 2013/2014 Marbled Murrelet At-Sea Densities For Five Strata Associated with U.S. Navy Facilities in Puget Sound and the Washington Coast:

Annual Research Progress Report

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INTRODUCTION

The overarching goal of this project is to estimate on-the-water marbled murrelet (*Brachyramphus marmoratus*) densities during the fall/winter (October-February) adjacent to five Navy facilities: (1) Pacific Beach, (2) Crescent Harbor on Naval Air Station Whidbey Island; (3) Fleet Logistics Center Manchester Fuel Department; (4) Naval Base Kitsap Bangor and Dabob Bay Range; and (5) Naval Magazine Indian Island. However, because the nearshore marine environment and murrelet densities adjacent to any one of these facilities is too small to derive reliable site-specific at-sea murrelet densities, Washington Department of Fish and Wildlife (WDFW) used a stratified sampling approach outlined in Pearson and Lance (2012; updated 31 October 2013) to derive stratum specific density estimates. This approach uses line-transect or distance sampling methods (Buckland et al. 1993) to derive murrelet density estimates for five strata using nearshore and offshore transects placed in 35 primary sampling units (PSUs) (Figure 1).

METHODS

We (WDFW) used the approach and methods from the survey effort described by Raphael et al (2007) and Miller et al. (2012) and modified by Pearson and Lance (2012; updated 31 October 2013). We use this approach because: (1) it addresses issues of detectability, (2) it is customized to murrelet distributions and densities in this region, (3) it uses pre-survey information to develop the sampling design, (4) the work was peer reviewed (Raphael et al. 2007, Miller et al. 2012), and because (5) we wanted our survey effort for this project to be consistent with the spring/summer murrelet monitoring effort funded by USFWS, which will ultimately allow us to compare estimates for the same sampling units between seasons.

Sampling Design and Survey Effort

The survey design that follows is described in detail in Pearson and Lance (2012). Thirty-five primary sampling units (PSUs) were split among 5 strata (see Fig. 1 and Table 1). To derive strata and PSUs, we segmented the entire coastline of Puget Sound into 20-km Primary Sampling Units (PSUs) within Puget Sound and on the outer coast adjacent to NAVFAC NW Pacific Beach. We then combined PSUs into appropriate management/ecological/density strata (Figure 1). The area adjacent to Pacific Beach was defined as Strata #1 (n = 3 PSUs) because it is subject to coastal influences (part of the California Current system) that are dramatically different from those associated with Puget Sound (e.g., swell, upwelling events, ENSO and PDO events, etc.). This ecological difference was also recognized by the Marbled Murrelet Effectiveness Monitoring program (Raphael et al. 2007) and the Federal recovery plan for the murrelet (U.S. Fish and Wildlife Service 1997) when they split the coast of Washington (Conservation Zone 2) from the Puget Sound (Conservation Zone 1). Within Puget Sound, we defined strata based on identified Puget Sound Basins that were distinct in bathymetry and tidal patterns and that have somewhat unique oceanographic conditions (Ebbesmeyer and Barnes 1980, Babson et al. 2006, Moore et al. 2008). Using this information, Puget Sound strata definitions are as follows: Strata #2 (Figure 2: west side of Whidbey Island Naval Air Station, Admiralty Inlet and Naval Magazine Indian Island) = 7 PSUs; Strata #3 (Figure 2: North Hood Canal and Dabob Bay) = 7 PSUs; Strata #4 (Figure 2: Crescent Harbor by Naval Air Station Whidbey Island and Naval Station Everett) = 10 PSUs; Strata #5 (Figure 2: Bremerton, Manchester, Bainbridge Island, Kingston) = 6 PSUs.

Average PSU area was 38.2 km^2 and covered about 20 km of shoreline (Figure 1). The average transect length per PSU was 34.5 km, split between a nearshore segment (average length = 20.4 km) and an offshore segment (average length = 14.7 km) with more effort (more transect traveled) in the nearshore where murrelet densities are higher (Miller et al. 2006, Raphael et al. 2007). We used the PSU numbers from the Marbled Murrelet Effectiveness Monitoring Program (Raphael et al. 2007) in order to make comparisons, if needed, with spring/summer derived encounter rates for these same PSUs. The Effectiveness Monitoring effort uses a similar survey design to this Navy effort but, because the area of interest is much larger in the Effectiveness Monitoring Program and the goals differ between these efforts, the geographic definitions of the strata are very different between programs but the geographic boundaries of the PSUs and their numbers are identical (Raphael et al. 2007). Although the Effectiveness Monitoring Program did not include a PSU in Dyes Inlet, the Navy requested this area be sampled. As a result, a new PSU was created and labeled "900" to avoid any confusion with those PSUs already established.

We conducted three replicate surveys of all PSUs in Strata 2-5 as follows:

Replicate 1 = 3 Oct 2013 – 1 Nov 2013
Replicate 2 = 13 Nov 2013 – 17 Dec 2013
Replicate 3 = 1 Jan 2014 – 14 Feb 2014

The survey team only conducted a single visit to Stratum 1 (Pacific Beach) which occurred on 15-16 October 2013. The goal was to conduct a second survey of the Pacific Beach PSUs during replicate 3 but, because of high winds and large seas, a survey window that met sea state criteria for conducting surveys was unavailable. In the hopes of finding a suitable window, the crew was held for an additional two weeks after completing the remainder of surveys within Puget Sound.

The survey schedule for each PSU is provided in Table 1. To derive this schedule, we randomly selected a Strata first. Within Strata, we then randomly selected the order of the Core PSUs (those adjacent to Navy facilities) and surveyed them prior to surveying the remainder of the PSUs in a Strata to make sure that those important PSUs were surveyed in each replicate should bad weather/sea conditions prevent us from surveying all PSUs. We also randomly determined whether we surveyed the nearshore or offshore segments first.

Observer Training

The crew consisted of one dedicated boat operator and three observers/data recorders. The data recorder and two observers (one responsible for each side of the boat) switched duties at the beginning of each primary sampling unit (PSU) to avoid survey fatigue. All of the observers had previous experience monitoring seabirds at sea. Observers had one week of training that consisted of office and on-water training. Office training included a presentation of background information, survey design and protocols, sampling methodology, line transect distance sampling methodology, and measurement quality objectives. On-water training included boat safety orientation, seabird identification, specific training on correctly assigning marbled murrelet plumages (Strong 1998), conducting transect surveys, and distance estimation testing using laser rangefinders. Boat safety training included instructions and reminders for weather and sea condition assessment, use of the radio, boat handling, proper boat maintenance, safety gear, rescue techniques, and emergency procedures. Observer training was designed to be consistent with training conducted by other groups within the Marbled Murrelet Effectiveness Monitoring Program (Raphael et al. 2007, Huff et al. 2003, Mack et al. 2003).

During practice transects, observers were taught how to scan, where to focus their eyes, and which portions of the scan area are most important. Distance estimates from the transect line are a critical part of the data collected and substantial time was spent practicing and visually 'calibrating' before surveys began. During distance trials, each individual's estimate of perpendicular distance was compared to a perpendicular distance recorded with a laser rangefinder. These trials were conducted using stationary buoys and bird decoys as targets, which were selected at a range of distances from the transect line and in locations in front of as well as to the sides of the boat where marbled murrelets would be encountered on real surveys (Raphael et al. 2007). Each observer completed 100 distance estimates during pre-survey training and was tested weekly. For the weekly tests, each observer estimated five perpendicular distances to floating targets and the actual perpendicular distance was measured with a laser rangefinder. After the first set of five, the observer's results were assessed. If all five estimates were within 15% of the actual distance, the trial was complete for that observer. If any of the five estimates were not within 15% of actual, the observer continued to conduct estimates in sets of five until all five distances were within 15% of the actual distance. In addition, one of the project leads accompanied the survey crew and observed their overall performance and ability to detect marbled murrelets during the survey season and completed an audit form created by the Murrelet Monitoring Program (Raphael et al. 2007, Huff et al. 2003). The results of the audit were shared with the observers after the survey day was completed for feedback and discussion.

Field Methods and Equipment

Two observers (one on each side of the boat) scanned from 0° off the bow to 90° abeam of the vessel. More effort was spent watching for marbled murrelets close to the transect line ahead of the boat (within 45° of line). Observers scanned continuously, not staring in one direction, with a complete scan taking about 4-8 seconds. Observers were instructed to scan far ahead of the boat for birds that flush in response to the boat and communicate between observers to minimize missed detections. Binoculars were used for species verification, but not for sighting birds. For each marbled murrelet sighting the following data were collected: group size (a collection of birds separated by less than or equal to 2 m at first detection and moving together, or if greater than 2 m the birds are exhibiting behavior reflective of birds traveling and foraging together and therefore not independent), plumage class (Strong 1998), and water depth (from boat depth finder).

Observers relayed data (species, number of birds, estimated perpendicular distance of the bird(s) from the trackline) via headsets to a person in the boat cabin who entered data directly onto a laptop computer with software (DLOG3 developed by R.G. Ford, Inc., Portland, OR.) that is interfaced with a GPS unit and collects real time location data. DLOG3 interfaces with a handheld GPS and GIS overlays of the Washington shoreline and adjacent bathymetry, and uses these data to record GPS coordinates and perpendicular distance to shore at operator-defined time intervals (e.g. every 30 seconds). Transect survey length was calculated from the GPS trackline recorded in DLOG3. Additional data such as PSU identification, weather and sea conditions, on/off effort, and names of observers were typed into the DLOG3 program on the computer during the survey.

The crew used a 26-foot Almar boat with twin-outboard engines. Survey speed was maintained at 8-12 knots, and survey effort was ended if glare obstructed the view of the observers, or if Beaufort wind scale was 3 or greater. Beaufort 3 is described as a gentle breeze, 7-10 knot winds, creating large wavelets, crests beginning to break, and scattered whitecaps (Beaufort scale is provided in Appendix I).

Data Analysis

We used transect distances, murrelet group size, and perpendicular distances for each marbled murrelet observation to derive density (birds/km^2) estimates by stratum using the program DISTANCE. For details about our analysis approach, see Miller et al. (2006) and Raphael et al. (2007). Briefly, the Distance or line transect survey approach requires observers to move along a fixed path (transect) and to count occurrences of the target animal (marbled murrelet) along the transect and, at the same time, obtain the distance of the object from the transect. This information, is then used to estimate of the area covered by the survey and to derive an estimate of the way in which detectability increases from probability 0 (far from the transect) towards 1 (near the transect). The shape of this detectability function can then be used in conjunction with the counts, distances to the birds, and the distance traveled (transect length) to derived an estimate of Density (birds/km^2). For details, please see Buckland et al. (1993). In the Results, we provide murrelet density estimates by Strata and by ecosystem: 1) California Current (Pacific Beach Stratum), and 2) Puget Sound (all other Strata) for each of the sampling periods (see above) and across all sampling periods (global model). The density provided can be viewed as the murrelet population on the water in a given day within the area and time period defined.

RESULTS

When examining density estimates by stratum (Table 2), higher densities were consistently found in Stratum 2. Murrelet densities were considerably lower in Stratum 1 and 5 and intermediate in

Stratum 3 and 4. There are very few birds in Stratum 5. Using overall densities across all three replicates, we estimated there were 1,237 (95% CI = 887-1,725) birds in all Puget Sound strata combined (Oct – Feb) which is lower than that of the fall/winter of 2012/2013, when we estimated there to be 2,081 (95% CI = 1,429-3,028) birds for the same time period and same area (Pearson and Lance 2013). The global model, by strata, indicated the following murrelet estimates during the Oct. – Feb. time period:

Stratum 1: 39 (12-131)
Stratum 2: 623 (358-1,084)
Stratum 3: 186 (121-288)
Stratum 4: 421 (259-683)
Stratum 5: 7 (2-28)

In addition, there appeared to be some decline in the population within the Puget Sound study area (Strata 2-5) during the Jan – Feb replicate (Table 2).

Although we cannot derive PSU scale density estimates because they represent a single sample and because relatively few birds are encountered within a PSU (also high variability at that spatial scale), we can qualitatively explore encounter rates (# murrelets encountered per kilometer of transect length sampled; Table 3) by PSU. It appears that PSUs on the western side of Admiralty Inlet have the highest murrelet encounter rates (Table 3). Some PSUs have no detections (e.g., 14, 26, 36), some are consistently low (e.g., 13, 15, 37), some consistently high (e.g., 30) and some are highly variable (e.g., 24). The variability that we are seeing within a given PSU throughout the fall/winter period suggests some movement of birds within the study area and perhaps in and out of the study area. Again, because birds can move large distances during our sampling effort, there may be considerable variation in encounter rates among seasons and years at this spatial scale.

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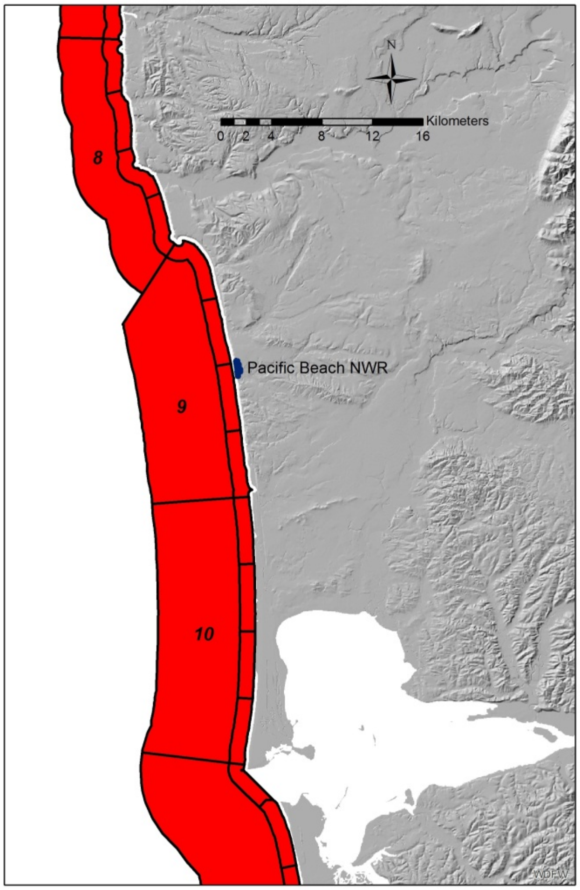
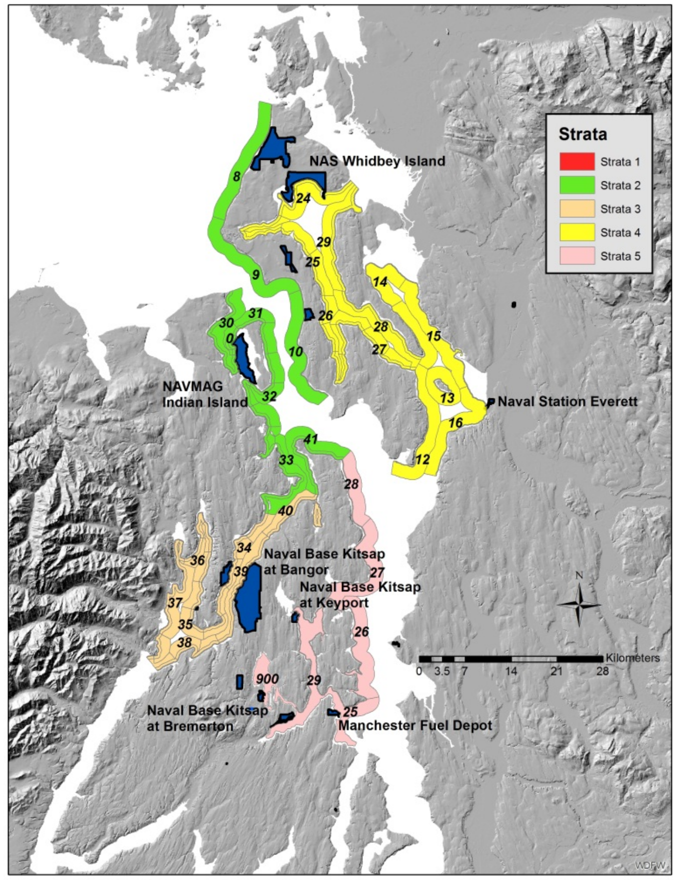
Figure 1. Stratum and primary sampling unit locations along the Washington coast (A) and in Puget Sound (B). Strata are defined in the figure Key and PSUs are numbered on the map.



A. Stratum 1



B. Strata 2 – Strata 5

Table 1. Dates of Primary sampling unit (PSU) surveys by replicate: replicate 1 = Oct-early November, replicate 2 = mid-Nov – mid-Dec, and replicate 3 = Jan. – Feb. Primary sampling units adjacent to Naval facilities are in bold. Geographic locations of each PSU can be determined by first identifying the Stratum number and then the PSU in Figure 1.

Stratum	PSU	Replicate 1	Replicate 2	Replicate 3
1	**8**	15-Oct	-	-
	9	16-Oct	-	-
	10	16-Oct	-	-
2	**8**	10-Oct	18-Nov	15-Jan
	9	10-Oct	4-Dec	7-Feb
	10	22-Oct	4-Dec	13-Jan
	30	22-Oct	18-Nov	10-Jan
	31	10-Oct	15-Nov	10-Jan
	32	1-Nov	20-Nov	13-Jan
	33	1-Nov	5-Dec	11-Feb
	41	22-Oct	20-Nov	14-Jan
3	34	24-Oct	25-Nov	6-Feb
	35	24-Oct	21-Nov	31-Jan
	36	17-Oct	21-Nov	30-Jan
	37	17-Oct	21-Nov	30-Jan
	38	17-Oct	25-Nov	31-Jan
	39	24-Oct	25-Nov	6-Feb
	40	1-Nov	5-Dec	11-Feb
4	12	29-Oct	11-Dec	13-Feb
	13	30-Oct	14-Nov	13-Feb
	14	30-Oct	11-Dec	28-Jan
	15	3-Oct	14-Nov	27-Jan
	16	3-Oct	14-Nov	27-Jan
	24	4-Oct	13-Nov	23-Jan
	25	29-Oct	17-Dec	23-Jan
	26	4-Oct	11-Dec	14-Feb
	27	29-Oct	13-Nov	13-Feb
	28	3-Oct	13-Nov	28-Jan
	29	4-Oct	17-Dec	14-Feb
5	**25**	8-Oct	26-Nov	22-Jan
	26	9-Oct	26-Nov	22-Jan
	27	9-Oct	9-Dec	14-Jan
	28	9-Oct	9-Dec	14-Jan
	29	8-Oct	19-Nov	21-Jan
	900	23-Oct	19-Nov	21-Jan

Table 2. October – Feb, Fall (Oct-early November), winter (mid-Nov – mid-Dec), and late-winter (January/February) estimates of marbled murrelet density (birds/km²) and population size for five Puget Sound Strata and all strata combined (global model). Strata are defined in Figure 1. No birds were detected in Stratum 5 during Replicate #2 resulting in no estimate for this period.

Year	Stratum	Density (birds /km²)	StdErr	%CV	Birds	Birds 95% CL Lower	Birds 95% CL Upper	Area (km^2)	f(0)	Std. Err. Of f(0)	E(s)	Std. Err. Of E(s)	Truncation Distance (m)
Global model (Oct - Feb)													
2014	**All but 1**	**1.31**		**16.86%**	**1,237**	**887**	**1,725**	**942.0**	**0.01**	**0.000**	**1.734**	**0.025**	**211**
2014	1	0.10	0.05	50.1%	**39**	12	131	395.0					
2014	2	2.43	0.68	28.1%	**623**	358	1084	256.7					
2014	3	1.15	0.25	21.8%	**186**	121	288	162.5					
2014	4	1.22	0.30	24.6%	**421**	259	683	345.1					
2014	5	0.04	0.03	76.1%	**7**	2	28	177.6					
Replicate 1 model (Oct – mid-Nov)													
2014	**All but 1**	**0.80**		**24.4%**	**1,066**	**661**	**1,718**	**942.0**	**0.01**	**0.001**	**1.62**	**0.058**	**211**
2014	1	0.11	0.06	52.2%	**45**	14	150	395.0					
2014	2	1.83	0.58	31.8%	**470**	248	890	256.7					
2014	3	1.62	0.55	34.1%	**263**	131	525	162.5					
2014	4	0.81	0.41	50.1%	**280**	106	742	345.1					
2014	5	0.04	0.05	106.0%	**8**	1	53	177.6					
Replicate 2 (mid-Nov – mid-Dec)													
2014	**All but 1**	**1.75**		**27.64%**	**1,651**	**955**	**2,854**	**942.0**	**0.01**	**0.001**	**1.78**	**0.03**	**211**
2014	2	2.87	1.35	47.0%	**736**	286	1,894	256.7					
2014	3	1.42	0.45	31.6%	**232**	121	445	162.5					
2014	4	1.98	0.74	37.2%	**683**	325	1,433	345.1					
2014	5	0			**0**			177.6					
Replicate 3 (Jan - Feb)													
2014	**All but 1**	**1.04**		**38.6%**	**978**	**450**	**2,125**	**942.0**	**0.01**	**0.001**	**1.84**	**0.05**	**211**
2014	2	2.49	1.38	47.1%	**639**	213	1,914	256.7					
2014	3	0.45	0.34	76.2%	**73**	17	311	162.5					
2014	4	0.73	0.26	34.8%	**253**	126	508	345.1					
2014	5	0.07	0.08	106.4%	**13**	2	91	177.6					

Table 3. October – February marbled murrelet encounter rate (# birds detected/km transect length sampled) by primary sampling unit. Replicates: replicate 1 = Oct-early November, replicate 2 = mid-Nov – mid-Dec, and replicate 3 = Jan. – Feb. Primary sampling units adjacent to Naval facilities are in bold. Refer to Figure 1 for PSU and strata locations.

Stratum	PSU	Replicate 1	Replicate 2	Replicate 3	Average
1	**8**	0.000	-	-	-
	9	0.017	-	-	-
	10	0.017	-	-	-
2	**8**	0.201	0.116	0.000	0.106
	9	0.277	0.536	0.392	0.402
	10	0.057	0.202	0.000	0.086
	30	0.647	4.136	4.221	3.001
	31	0.749	0.000	0.240	0.329
	32	0.598	0.254	0.000	0.284
	33	0.121	0.030	0.000	0.050
	41	0.259	0.470	0.460	0.396
3	**34**	0.559	0.829	0.000	0.463
	35	0.404	0.523	0.517	0.481
	36	0.000	0.000	0.000	0.000
	37	0.000	0.000	0.091	0.030
	38	0.260	0.488	0.000	0.249
	39	0.529	0.523	0.059	0.370
	40	0.342	0.134	0.000	0.159
4	12	0.427	0.315	0.282	0.341
	13	0.000	0.177	0.000	0.059
	14	0.000	0.000	0.000	0.000
	15	0.056	0.112	0.111	0.093
	16	0.000	0.148	0.319	0.156
	24	0.000	3.086	0.333	1.140
	25	0.691	0.256	0.600	0.516
	26	0.000	0.000	0.000	0.000
	27	0.000	0.511	0.084	0.198
	28	0.000	0.430	0.059	0.163
	29	0.201	0.633	0.000	0.278
5	**25**	0.000	0.000	0.000	0.000
	26	0.000	0.000	0.000	0.000
	27	0.000	0.000	0.000	0.000
	28	0.041	0.000	0.171	0.071
	29	0.000	0.000	0.000	0.000
	900	0.000	0.000	0.000	0.000

Appendix I.

BEAUFORT WIND SCALE WITH CORRESPONDING SEA STATE CODES					
Beaufort Number	Wind Velocity (Knots)	Wind Description	Sea State Description	Sea State	
				Term and Height of Waves (Feet)	Condition Number
0	Less than1	Calm	Sea surface smooth and mirror-like	Calm, glassy 0	0
1	1-3	Light Air	Scaly ripples, no foam crests		
2	4-6	Light Breeze	Small wavelets, crests glassy, no breaking	Calm, rippled 0 – 0.3	1
3	7-10	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Smooth, wavelets 0.3-1	2
4	11-16	Moderate Breeze	Small waves, becoming longer, numerous whitecaps	Slight 1-4	3
5	17-21	Fresh Breeze	Moderate waves, taking longer form, many whitecaps, some spray	Moderate 4-8	4
6	22-27	Strong Breeze	Larger waves, whitecaps common, more spray	Rough 8-13	5
7	28-33	Near Gale	Sea heaps up, white foam streaks off breakers	Very rough 13-20	6
8	34-40	Gale	Moderately high, waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks		
9	41-47	Strong Gale	High waves, sea begins to roll, dense streaks of foam, spray may reduce visibility		
10	48-55	Storm	Very high waves, with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	High 20-30	7
11	56-63	Violent Storm	Exceptionally high waves, foam patches cover sea, visibility more reduced	Very high 30-45	8
12	64 and over	Hurricane	Air filled with foam, sea completely white with driving spray, visibility greatly reduced	Phenomenal 45 and over	9

Figure 8-1. Beaufort wind scale.