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Interim Report to the Blake-Nuttall Fund Mass Audubon Coastal Waterbird Program
2017-2018

Project Title: Nesting Site Characteristics Affecting Piping Plover Brood Range

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Introduction

Unlike many other bird species, Piping Plover (*Charadrius melodus*) chicks are never fed by their parents – from a few hours after hatching, chicks are moving around their natal beach and foraging for themselves. While it is important that adults have appropriate space to nest, roost, and forage, Piping Plover chicks, who are unable to fly for the first 4 to 5 weeks of life, are even more vulnerable to disturbance, exposure to the elements, predators, human impacts, and inadequate forage. Having access to adequate feeding areas is very important for chicks (Elliott-Smith and Haig 2004). According to Cairns (1982), Piping Plover chicks spend a majority of their time feeding and typically triple their weight in the first two weeks after hatching. Those that have not reached 60% of that weight gain by day 12 are unlikely to survive. Therefore, understanding what habitat broods use at a site and what impacts the space that a brood uses will help wildlife managers better protect chicks and increase productivity.

Limited studies suggest there is large variation in the amount of space a brood will use or the distance they travel from the nest site. For example, a study on Assateague Island showed that broods moved between 131-850 m from the nest (Patterson 1988). Brood movement may occur only a day or two after hatching in some cases. Human disturbance has been observed to influence brood movement and may force broods to lower quality foraging areas. In Barnstable, where human disturbance was the suspected cause of brood movement away from the nest, scientists observed that the probability of fledging of broods that moved less than 200m from the nest was almost twice that of broods that moved farther (E. Strauss pers comm; Patterson 1988). Beach maintenance, including re-nourishment and raking, is another potential variable that may impact how much space a brood uses and what part of the habitat they utilize. If done in a way that increases good habitat for nesting Piping Plovers, such as minimizing vegetation and providing suitable substrate and beach topography, beach maintenance can provide prime nesting sites for plovers. On the other hand, in the

case of brood forage and nesting site availability, where prime habitats include mudflats, ephemeral pools, bayside tidal flats and scoured sandy landscapes, coastal management projects such as jetty construction, breach filling, dune building, and sand renourishment may be partly responsible for preventing the renewal of these habitat types (Elias et al 2000). Beach raking or cleaning may decrease the meiofauna present on the beach, thereby decreasing available prey for Piping Plovers (Wilmott and Smith 2003, Schlacher et al 2007).

Brood range determinants of the federally-threatened Piping Plover have not been studied in Massachusetts where 40% of the Atlantic Coast population breeds. We used spatial data to characterize Piping Plover brood range at multiple nesting beaches on the Massachusetts coast. Our objectives were to quantify several attributes of brood range and model the relative importance of habitat availability, nesting density, and human presence as determinants of brood range. In addition, we evaluated brood range characteristics on beaches undergoing different maintenance regimes such as renourishment and raking.

Study Sites

The CWP monitors approximately 100 beaches each season with active nesting. We selected a sample of beaches for quantifying brood range based on the following: successful hatching, hatching chronology, recent history of beach renourishment, available habitat, raking, and nest density.

Methods

Hand-drawn brood range maps were created weekly at 15 sites with varied characteristics, including some beaches that have been renourished or will be in the future, or regularly raked, of varying size and nesting density. To create brood maps, monitors recorded location information of chicks during each site visit, which occurred 4-6 times per week over a 4-6 week brood phase. Monitors collected spatial data using a combination of GPS units and hand-drawn maps transferred to Google Earth Pro. We digitized maps to produce the following metrics: brood range area, maximum distance of brood from nest location, area of brood range in the intertidal zone, area of beach vegetation cover. Brood range data were transferred to ArcMap. Daily site visit data collected included: number of beach goers, dogs and vehicles, beach width, brood activity, and interactions with other plovers.

The raw data collected by monitors in the field was processed to digital form using Google Earth Pro software by visual evaluation, meaning, visual cues such as land formations and tidal lines on the

hand drawn map were used to recreate a digital version. This was done by an analyst using the polygon tool within Google Earth, creating vertices in locations with visual cues mentioned above. The coast is an extremely dynamic habitat and in order to keep the recreation of the brood area as accurate as possible, the Historical Imagery tool within Google Earth was utilized. When digitizing the 2015 brood areas, this tool was used to display imagery of each site that matched that of the raw data maps. This process was repeated for the 2016 and 2017 raw data transcriptions. Finally, the polygons created in Google Earth, were converted to shape files, and loaded into a geodatabase as feature classes for spatial analysis within ArcGIS.

As polygons were generated in Google Earth, measured variables were collected. The variables included area (m^2), furthest distance from nest (m), length of brood area (m), and if the nest bowl was within the foraging area of the brood. Area was calculated by Google Earth, furthest distance from nest and length of brood area were measured using the Measure tool.

The original feature classes within the geodatabase include files for both the polygons created in Google Earth and the GPS coordinates for nest locations for each year. Each of the polygon layers were split into 4 separate layers, representing weeks 1 – 4 of the broods' foraging behavior. We used the "Intersect" tool to determine the location on each site where the brood was observed most frequently. The intersected layers were utilized to represent the entire area the broods were observed foraging over 4 weeks as well as relative frequency of use to identify foraging "hot spots."

Results

1) Brood range and nesting site attributes for selected beaches are shown in Table 1. Brood range attributes include site, year, pair, chick age, brood range area, max length of range, and max distance from nest location. Nesting site attributes total beach length, occurrence of raking, history of renourishment, and level of human disturbance (n parking spaces).
2) We ran an R analysis to determine if any of the nesting site variables were related to brood range. We constructed linear models to determine correlation and found that farthest distance from nest, raking, parking capacity and beach length all affect brood area (Figure 1). We found no evidence that beach nourishment and distance from nest are related to brood range.

   Results:

- Dist_nest: $p < 0.05$, R-squared = 0.4309, 43% of brood range area explained by distance from nest
- Range_of_nest: $p > 0.05$, Does not affect brood range area
- Raked: $p < 0.05$, R-squared = .04796, 4.8% of brood range area explained by raking
- Parking_lot: $p < 0.05$, R-squared = 0.1205, 12% of brood range area explained by parking lot capacity
- Beach_length: $p < 0.05$, R-squared = 0.1965, 19.6% of brood range area explained by beach length
- Nourished: $p > 0.05$, Does not affect brood range area

3) We conducted spatial analyses in ESRI ARC to identify areas of nesting beaches that are used by plover broods during each week of life. This "hotspot" analysis will allow us to better manage critical areas of beach used throughout the chick phase of nesting. An example of this is shown in Figure 2.

Discussion

Understanding the beach area used by broods of Piping Plovers is essential to their protection. Once hatched, plover chicks move from a few meters to hundreds of meters from their nest site to forage and find refuge. Beach goers and land owners have a difficult time seeing the adults, eggs and chicks, and are often surprised to learn that the birds ever leave the fencing erected to protect nests. This is a strong indication that protection of brood range is nearly as important as protecting the eggs with symbolic fencing. Quantifying brood range will help increase biological knowledge of Piping Plovers, and will help in their management and protection. Beach nourishment and other beach maintenance practices are expected to increase in the future due to climate change impacts to the coast. Very little information is available to assist in guiding these practices with regard to optimizing habitat for plovers. Evaluating the importance of categorical and continuous variables such as raking, renourishing, beach size, nesting density, and beach goer presence will allow the CWP to advocate for best practices with regard to beach maintenance and management. Maps of brood range will help us communicate with land owners about the need for continued protection after hatching including erecting fencing for chick refuge.

Literature cited:

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Table 1. Piping Plover brood range attributes for selected nesting sites in Massachusetts, 2015-2017.

Week	Year	Town	Site	Pair	Brood Range Area (m2)	Farthest Distance From Nest (m)	Linear Distance of Brood Area (m)	Raked	Parking Capacity	Beach Length (mi)	Nourished 2014-2017
1	2015	Barnstable	BCBA	01a	40254	1408.01	1408.01	Y	564	0.4	N
2	2015	Barnstable	BCBA	01a	14897	1543.48	616.05	Y	564	0.4	N
3	2015	Barnstable	BCBA	01a	16755	1260.06	666.35	Y	564	0.4	N
4	2015	Barnstable	BCBA	01a	14491	1546.28	589.83	Y	564	0.4	N
1	2015	Barnstable	DNSI	01a	5449	340.43	347.16	N	0	2.1	N
2	2015	Barnstable	DNSI	01a	3185	339.51	172.43	N	0	2.1	N
1	2015	Barnstable	DNSI	03a	2219	51	71	N	0	2.1	N
2	2015	Barnstable	DNSI	03a	1994	63.44	78	N	0	2.1	N
3	2015	Barnstable	DNSI	03a	2305	60.78	67.44	N	0	2.1	N
4	2015	Barnstable	DNSI	03a	1022	50.62	50.42	N	0	2.1	N
1	2015	Barnstable	DNSI	05a	14563	738.49	755.8	N	0	2.1	N
2	2015	Barnstable	DNSI	05a	3236	304.4	166.67	N	0	2.1	N
1	2015	Barnstable	DNSI	08b	1276	47.19	86.2	N	0	2.1	N
1	2015	Yarmouth	YSB	02a	5323	108.68	123.88	Y	474	0.5	N
2	2015	Yarmouth	YSB	02a	3299	104.71	146.59	Y	474	0.5	N
3	2015	Yarmouth	YSB	02a	4689	157.74	198.74	Y	474	0.5	N
4	2015	Yarmouth	YSB	02a	1811	115.64	117.95	Y	474	0.5	N
1	2015	Yarmouth	YSB	04a	14883	291.3	356.99	Y	474	0.5	N
2	2015	Yarmouth	YSB	04a	14883	291.3	291.3	Y	474	0.5	N
3	2015	Yarmouth	YSB	04a	3313	197.21	188	Y	474	0.5	N
4	2015	Yarmouth	YSB	04a	3651	287.75	226.28	Y	474	0.5	N
1	2016	Dartmouth	DAP	01a	1794	79.94	83.13	N	50	2.7	N
2	2016	Dartmouth	DAP	01a	1812	70.92	70.65	N	50	2.7	N
3	2016	Dartmouth	DAP	01a	1044	102.68	105.31	N	50	2.7	N
4	2016	Dartmouth	DAP	01a	1017	106.66	106.66	N	50	2.7	N
1	2016	Dartmouth	DAP	03a	2063	104.6	106.46	N	50	2.7	N
2	2016	Dartmouth	DAP	03a	1746	101.57	76.5	N	50	2.7	N
3	2016	Dartmouth	DAP	03a	1694	120.28	111.78	N	50	2.7	N
4	2016	Dartmouth	DAP	03a	1454	84.11	129.34	N	50	2.7	N
1	2016	Dartmouth	DAP	04a	670	67.85	67.85	N	50	2.7	N
2	2016	Dartmouth	DAP	04a	622	41.24	58.91	N	50	2.7	N
3	2016	Dartmouth	DAP	04a	317	31.38	31.38	N	50	2.7	N
4	2016	Dartmouth	DAP	04a	2357	275.48	203.17	N	50	2.7	N
1	2016	Dartmouth	DAP	07a	5226	267.73	267.73	N	50	2.7	N
2	2016	Dartmouth	DAP	07a	3313	262.95	229.52	N	50	2.7	N
3	2016	Dartmouth	DAP	07a	3141	307.63	195.92	N	50	2.7	N
4	2016	Dartmouth	DAP	07a	1735	360.48	132.41	N	50	2.7	N
1	2016	Dartmouth	DAP	08a	624	71.24	82.53	N	50	2.7	N
2	2016	Dartmouth	DAP	08a	464	108.59	76.53	N	50	2.7	N
3	2016	Dartmouth	DAP	08a	736	101.37	108.89	N	50	2.7	N
4	2016	Dartmouth	DAP	08a	897	75.29	77.29	N	50	2.7	N
1	2016	Dartmouth	DAP	10a	366	32	79.28	N	50	2.7	N
2	2016	Dartmouth	DAP	10a	1102	57.28	105.22	N	50	2.7	N
3	2016	Dartmouth	DAP	10a	643	65.74	95.75	N	50	2.7	N
4	2016	Dartmouth	DAP	10a	613	44.58	52.56	N	50	2.7	N
1	2016	Dartmouth	DAP	11a	2195	85.49	151.37	N	50	2.7	N

2	2016	Dartmouth	DAP	11a	946	128.83	196.17	N	50	2.7	N
1	2016	Dartmouth	DAP	12a	414	50.6	50.6	N	50	2.7	N
2	2016	Dartmouth	DAP	12a	615	49.4	49.4	N	50	2.7	N
3	2016	Dartmouth	DAP	12a	1113	89.2	72.62	N	50	2.7	N
4	2016	Dartmouth	DAP	12a	1097	78.55	62.67	N	50	2.7	N
1	2016	Dartmouth	DAP	18a	195	25.78	43.2	N	50	2.7	N
2	2016	Dartmouth	DAP	18a	147	24.84	34.32	N	50	2.7	N
3	2016	Dartmouth	DAP	18a	862	72.74	110.24	N	50	2.7	N
4	2016	Dartmouth	DAP	18a	431	41.91	36.94	N	50	2.7	N
1	2016	Barnstable	BCBA	01a	26784	1030.2	1030.2	Y	564	0.4	N
1	2016	Barnstable	BCBA	01a	26784	1030.2	1030.2	Y	564	0.4	N
2	2016	Barnstable	BCBA	01a	17267	1209.13	714.72	Y	564	0.4	N
2	2016	Barnstable	BCBA	01a	17267	1209.13	714.72	Y	564	0.4	N
3	2016	Barnstable	BCBA	01a	24844	1470.97	972.75	Y	564	0.4	N
3	2016	Barnstable	BCBA	01a	24844	1470.97	972.75	Y	564	0.4	N
4	2016	Barnstable	BCBA	01a	13175	1354.33	561.6	Y	564	0.4	N
4	2016	Barnstable	BCBA	01a	13175	1354.33	561.6	Y	564	0.4	N
1	2016	Barnstable	DNSI	01b	2023	97.48	108.5	N	0	2.1	N
1	2016	Barnstable	DNSI	01b	2023	97.48	108.5	N	0	2.1	N
2	2016	Barnstable	DNSI	01b	735	46.6	18.89	N	0	2.1	N
2	2016	Barnstable	DNSI	01b	735	46.6	18.89	N	0	2.1	N
3	2016	Barnstable	DNSI	01b	1645	63.29	62.73	N	0	2.1	N
3	2016	Barnstable	DNSI	01b	1645	63.29	62.73	N	0	2.1	N
4	2016	Barnstable	DNSI	01b	977	64.86	45.14	N	0	2.1	N
4	2016	Barnstable	DNSI	01b	977	64.86	45.14	N	0	2.1	N
1	2016	Barnstable	DNSI	02b	959	46.11	55.98	N	0	2.1	N
1	2016	Barnstable	DNSI	02b	959	46.11	55.98	N	0	2.1	N
2	2016	Barnstable	DNSI	02b	1119	27.82	39.42	N	0	2.1	N
2	2016	Barnstable	DNSI	02b	1119	27.82	39.42	N	0	2.1	N
3	2016	Barnstable	DNSI	02b	3928	183.38	226.34	N	0	2.1	N
3	2016	Barnstable	DNSI	02b	3928	183.38	226.34	N	0	2.1	N
4	2016	Barnstable	DNSI	02b	2250	5542	5542	N	0	2.1	N
4	2016	Barnstable	DNSI	02b	2250	5542	5542	N	0	2.1	N
1	2016	Chatham	CMI	01a	4950	189.7	189.7	N	0	1.0	N
2	2016	Chatham	CMI	01a	11691	298.76	571.43	N	0	1.0	N
3	2016	Chatham	CMI	01a	5511	115.73	194.63	N	0	1.0	N
1	2016	Chatham	CMI	02a	2820	91.15	107.31	N	0	1.0	N
2	2016	Chatham	CMI	02a	2442	101.02	103.28	N	0	1.0	N
3	2016	Chatham	CMI	02a	11591	351.17	364.11	N	0	1.0	N
4	2016	Chatham	CMI	02a	29893	982.29	986.57	N	0	1.0	N
1	2016	Chatham	CSBN	02a	14258	335.24	335.24	N	51	2.3	N
2	2016	Chatham	CSBN	02a	38683	677.92	450	N	51	2.3	N
3	2016	Chatham	CSBN	02a	33230	645.03	481.53	N	51	2.3	N
4	2016	Chatham	CSBN	02a	45063	498.8	426.41	N	51	2.3	N
1	2016	Chatham	CSBN	03b	13182	507.32	523.95	N	51	2.3	N
2	2016	Chatham	CSBN	03b	7227	286	244.8	N	51	2.3	N
1	2016	Dennis	DHB	01c	25134	570.46	570.46	N	455	0.7	N
2	2016	Dennis	DHB	01c	25134	419.63	570.46	N	455	0.7	N
3	2016	Dennis	DHB	01c	18829	268.65	438.87	N	455	0.7	N
4	2016	Dennis	DHB	01c	28202	483.43	654.28	N	455	0.7	N
1	2016	Falmouth	FTR	01a	4045	140.13	194.47	N	55	0.3	N
2	2016	Falmouth	FTR	01a	11111	494.77	559.66	N	55	0.3	N
3	2016	Falmouth	FTR	01a	11559	508.23	573.36	N	55	0.3	N
4	2016	Falmouth	FTR	01a	11559	508.23	573.36	N	55	0.3	N

1	2016	Falmouth	FWI	01c	750	20.67	37.16	N	0	1.1	N
2	2016	Falmouth	FWI	01c	2347	83.68	129.96	N	0	1.1	N
3	2016	Falmouth	FWI	01c	1293	46.36	63.37	N	0	1.1	N
4	2016	Falmouth	FWI	01c	7371	333.42	395.91	N	0	1.1	N
1	2016	Falmouth	FWI	03a	803	NA	56.4	N	0	1.1	N
2	2016	Falmouth	FWI	03a	1617	NA	115	N	0	1.1	N
3	2016	Falmouth	FWI	03a	2616	NA	183.6	N	0	1.1	N
4	2016	Falmouth	FWI	03a	2146	NA	164.1	N	0	1.1	N
1	2016	Mashpee	MNS	01a	1230	42.11	49.47	N	40	1.0	N
2	2016	Mashpee	MNS	01a	4307	132.9	154.59	N	40	1.0	N
3	2016	Mashpee	MNS	01a	3955	132.9	142.3	N	40	1.0	N
4	2016	Mashpee	MNS	01a	6279	150.51	228.43	N	40	1.0	N
1	2016	Mashpee	MNS	02b	6464	313.72	313.72	N	40	1.0	N
2	2016	Mashpee	MNS	02b	3001	386.15	130.62	N	40	1.0	N
3	2016	Mashpee	MNS	02b	4682	357.76	276.19	N	40	1.0	N
4	2016	Mashpee	MNS	02b	7979	368.77	378.81	N	40	1.0	N
1	2016	Mashpee	MSC	01a	7775	283.83	374.49	N	300	1.2	N
2	2016	Mashpee	MSC	01a	6195	239.37	283.39	N	300	1.2	N
3	2016	Mashpee	MSC	01a	4716	193.5	229.51	N	300	1.2	N
4	2016	Mashpee	MSC	01a	1843	188.71	89.62	N	300	1.2	N
1	2016	Mashpee	MSC	02a	6421	290.09	290.09	N	300	1.2	N
2	2016	Mashpee	MSC	02a	11291	426.92	465.79	N	300	1.2	N
3	2016	Mashpee	MSC	02a	6667	309.89	309.89	N	300	1.2	N
4	2016	Mashpee	MSC	02a	6940	225.66	295.1	N	300	1.2	N
1	2016	Mashpee	MSC	03a	6629	273.72	287.75	N	300	1.2	N
2	2016	Mashpee	MSC	03a	3154	275.51	142.48	N	300	1.2	N
3	2016	Mashpee	MSC	03a	7023	274.54	306.33	N	300	1.2	N
4	2016	Mashpee	MSC	03a	6618	254.49	285.68	N	300	1.2	N
1	2016	Mashpee	MSC	04a	2622	103.38	103.38	N	300	1.2	N
2	2016	Mashpee	MSC	04a	5445	223.55	223.55	N	300	1.2	N
3	2016	Mashpee	MSC	04a	6488	156.9	250.23	N	300	1.2	N
4	2016	Mashpee	MSC	04a	9834	302.07	385.24	N	300	1.2	N
1	2016	Sandwich	SES	02a	19747	411.83	411.83	N	40	1.5	N
2	2016	Sandwich	SES	02a	22509	541.36	476.63	N	40	1.5	N
3	2016	Sandwich	SES	02a	11427	485.81	260.55	N	40	1.5	N
4	2016	Sandwich	SES	02a	5972	518.02	128.42	N	40	1.5	N
1	2016	Sandwich	SSB	02a	21484	292.72	292.72	N	485	1.5	N
2	2016	Sandwich	SSB	02a	34229	348.76	452.97	N	485	1.5	N
3	2016	Sandwich	SSB	02a	34229	348.76	452.97	N	485	1.5	N
4	2016	Sandwich	SSB	02a	30299	289.84	371	N	485	1.5	N
1	2016	Sandwich	SSH	01b	2603	56.77	84.76	N	0	1.3	N
2	2016	Sandwich	SSH	01b	7138	108.27	174.63	N	0	1.3	N
3	2016	Sandwich	SSH	01b	11091	155.9	259.08	N	0	1.3	N
4	2016	Sandwich	SSH	01b	4874	92.21	113.98	N	0	1.3	N
1	2016	Sandwich	SSH	02a	8040	136.27	195.58	N	0	1.3	N
2	2016	Sandwich	SSH	02a	901	110.24	62.87	N	0	1.3	N
3	2016	Sandwich	SSH	02a	11593	261.29	304.98	N	0	1.3	N
4	2016	Sandwich	SSH	02a	4490	150.9	210.8	N	0	1.3	N
1	2016	Sandwich	SSN	01a	21501	386.05	386.05	N	20	0.7	N
2	2016	Sandwich	SSN	01a	32426	611.43	611.43	N	20	0.7	N
3	2016	Sandwich	SSN	01a	29422	864.54	708.36	N	20	0.7	N
4	2016	Sandwich	SSN	01a	22229	603.12	488.07	N	20	0.7	N
1	2016	Sandwich	SSN	02a	13470	485.02	485.02	N	20	0.7	N
2	2016	Sandwich	SSN	02a	3832	183.2	82.39	N	20	0.7	N

3	2016	Sandwich	SSN	02a	17680	588.66	336.04	N	20	0.7	N
4	2016	Sandwich	SSN	02a	9316	426.13	175.6	N	20	0.7	N
1	2016	Sandwich	SSS	01a	52288	691.41	765.85	N	20	1.5	N
2	2016	Sandwich	SSS	01a	28551	216.49	401.43	N	20	1.5	N
3	2016	Sandwich	SSS	01a	32580	272.71	461.51	N	20	1.5	N
4	2016	Sandwich	SSS	01a	13271	326.76	184.47	N	20	1.5	N
1	2016	Sandwich	STN	01b	16200	312.45	345.21	N	160	1.2	Y
2	2016	Sandwich	STN	01b	11656	277.08	313.2	N	160	1.2	Y
3	2016	Sandwich	STN	01b	20679	306.59	601	N	160	1.2	Y
4	2016	Sandwich	STN	01b	33634	329.77	662.78	N	160	1.2	Y
1	2016	Yarmouth	YSB	01a	5077	164.3	215.55	Y	474	0.5	N
1	2016	Yarmouth	YSB	01a	5077	164.3	215.55	Y	474	0.5	N
2	2016	Yarmouth	YSB	01a	2552	57.95	79.77	Y	474	0.5	N
2	2016	Yarmouth	YSB	01a	2552	57.95	79.77	Y	474	0.5	N
3	2016	Yarmouth	YSB	01a	4050	90.46	146.11	Y	474	0.5	N
3	2016	Yarmouth	YSB	01a	4050	90.46	146.11	Y	474	0.5	N
4	2016	Yarmouth	YSB	01a	2283	61.51	72.81	Y	474	0.5	N
4	2016	Yarmouth	YSB	01a	2283	61.51	72.81	Y	474	0.5	N
1	2016	Yarmouth	YSB	02a	4524	234.73	248.94	Y	474	0.5	N
1	2016	Yarmouth	YSB	02a	4524	234.73	248.94	Y	474	0.5	N
2	2016	Yarmouth	YSB	02a	5124	178.67	277.02	Y	474	0.5	N
2	2016	Yarmouth	YSB	02a	5124	178.67	277.02	Y	474	0.5	N
3	2016	Yarmouth	YSB	02a	6926	177.66	327.22	Y	474	0.5	N
3	2016	Yarmouth	YSB	02a	6926	177.66	327.22	Y	474	0.5	N
4	2016	Yarmouth	YSB	02a	6927	455.94	392.89	Y	474	0.5	N
4	2016	Yarmouth	YSB	02a	6927	455.94	392.89	Y	474	0.5	N
1	2016	Yarmouth	YSB	03a	4086	97.98	133.29	Y	474	0.5	N
1	2016	Yarmouth	YSB	03a	4086	97.98	133.29	Y	474	0.5	N
2	2016	Yarmouth	YSB	03a	5880	336.46	420.57	Y	474	0.5	N
2	2016	Yarmouth	YSB	03a	5880	336.46	420.57	Y	474	0.5	N
3	2016	Yarmouth	YSB	03a	2650	428.06	215.15	Y	474	0.5	N
3	2016	Yarmouth	YSB	03a	2650	428.06	215.15	Y	474	0.5	N
4	2016	Yarmouth	YSB	03a	3731	433.58	306.33	Y	474	0.5	N
4	2016	Yarmouth	YSB	03a	3731	433.58	306.33	Y	474	0.5	N
1	2017	Barnstable	DNSI	03a	667	72.78	72.78	N	0	2.1	N
2	2017	Barnstable	DNSI	03a	1706	119.84	193.76	N	0	2.1	N
3	2017	Barnstable	DNSI	03a	2004	141.47	220.87	N	0	2.1	N
4	2017	Barnstable	DNSI	03a	4686	123.15	324	N	0	2.1	N
1	2017	Barnstable	DNSI	04a	1832	93.13	93.13	N	0	2.1	N
2	2017	Barnstable	DNSI	04a	5294	181.22	288.73	N	0	2.1	N
3	2017	Barnstable	DNSI	04a	8733	354.19	465.57	N	0	2.1	N
4	2017	Barnstable	DNSI	04a	4877	425.48	269.12	N	0	2.1	N
1	2017	Barnstable	DNSI	05a	2061	47.55	71.38	N	0	2.1	N
2	2017	Barnstable	DNSI	05a	6650	194.26	220.75	N	0	2.1	N
1	2017	Yarmouth	YSB	01b	9414	207.74	320.55	Y	474	0.5	N
2	2017	Yarmouth	YSB	01b	9856	202.87	316.81	Y	474	0.5	N
3	2017	Yarmouth	YSB	01b	26436	537.32	738.88	Y	474	0.5	N
4	2017	Yarmouth	YSB	01b	27421	551.19	749.22	Y	474	0.5	N
1	2017	Yarmouth	YSB	02b	1832	69.07	132.84	Y	474	0.5	N
2	2017	Yarmouth	YSB	02b	3629	73.77	134.78	Y	474	0.5	N
3	2017	Yarmouth	YSB	02b	2327	86.4	158.68	Y	474	0.5	N
4	2017	Yarmouth	YSB	02b	2936	88.64	156.38	Y	474	0.5	N

Figure 1. Relationship between brood range area and a) raking and b) parking capacity at selected plover nesting sites, Massachusetts 2015-2017. Raking and increased parking were correlated with large brood range.

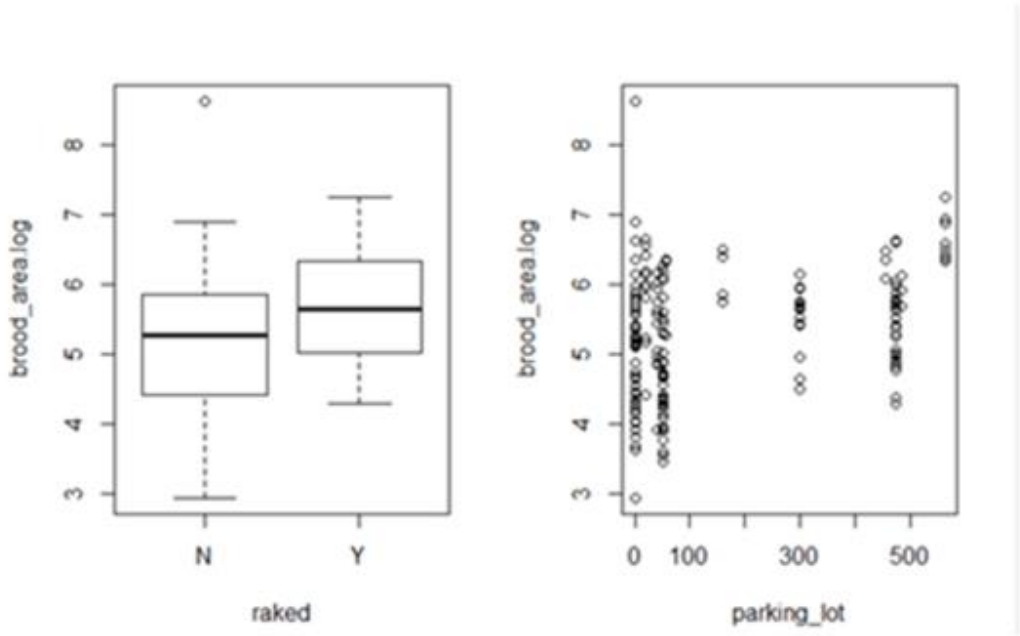

Figure 2. Example of intersect analysis of Piping Plover brood range. Area of brood range for nesting pair 1 at South Cape Beach, Mashpee 2016 is shown for weeks 1-4 after hatching, as well as the area of beach most frequently used by unfledged plovers.