EN.625.603.81.FA21 Statistical Methods and Data Analysis
5 December 2021

Modeling Kelp Observations as a Poisson Process in the Kelp Ecosystem Ecology Network (KEEN) Dataset

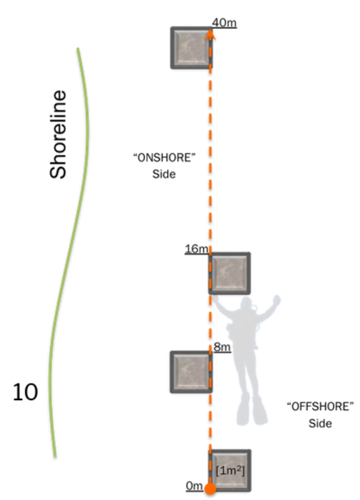
Dean Goldman
Whiting School of Engineering, Johns Hopkins University

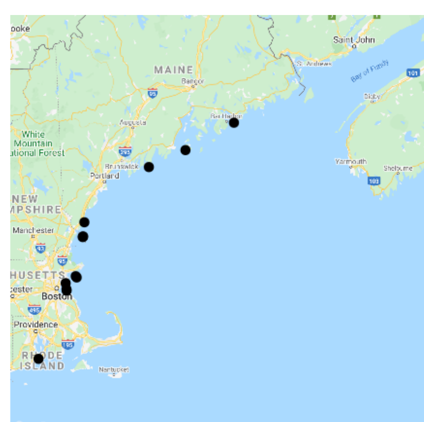
(i) Introduction

The Kelp Ecosystem Ecology Network (KEEN) dataset is a collection of observed marine life collected by divers under the KEEN protocol. The purpose of the KEEN dataset is to monitor population events in kelp forests over time, across different locations [1]. The objective of this paper is to describe kelp sightings as a random variable within a Poisson distribution, and use that probabilistic model to determine any statistically significant changes in kelp population over time. The first section of this paper (ii) gives a descriptive overview of the KEEN dataset. Section (iii) discusses the approach for modeling kelp sightings as a random variable in a Poisson distribution, and shares the results from a set of hypothesis tests to determine a statistically significant change over time in the rate of kelp sightings within the observed kelp forest sites.

(ii) KEEN Quadrat Dataset Overview

To create the KEEN dataset, divers collected marine life sightings from 13 kelp forest sites in regions around the Gulf of Maine between 2014 and 2018. The KEEN dataset captures a variety of wildlife including kelp, fish, algae, and invertebrates, this research will focus solely on the number of kelp sightings per "quadrat". In this dataset, a quadrat refers to a one square meter sample within a 40 meter transect of marine area at a general site. Each transect contains six quadrats spaced eight meters apart, alternating on either side of the transect line [2].



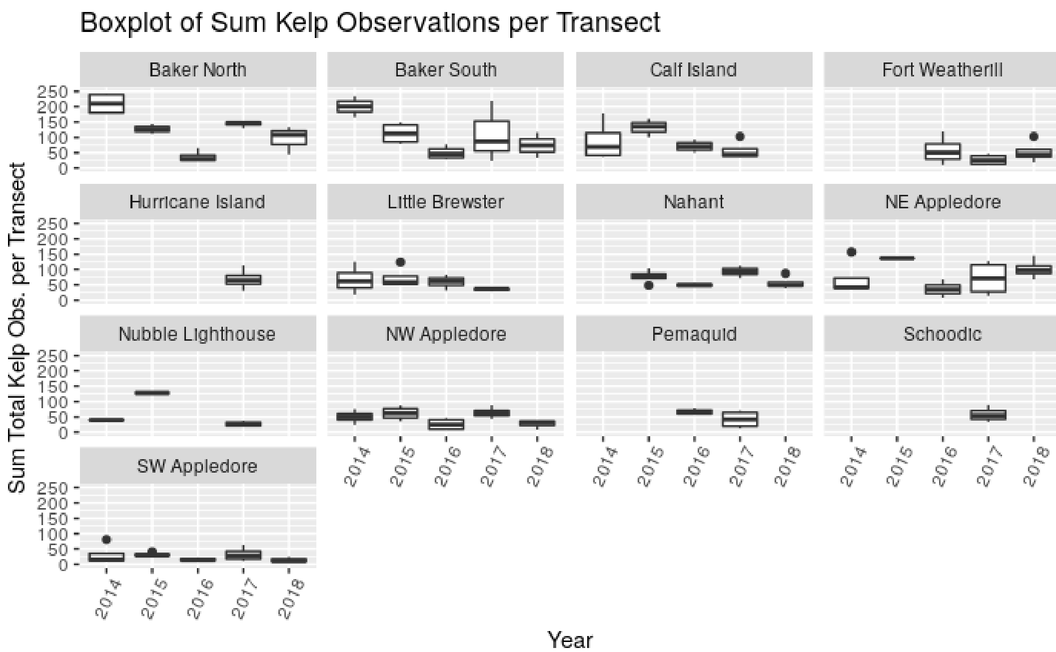


(Left) a visual diagram of how quadrats are constructed along transects. (Right) A map of the

different data collection sites in the Keen Dataset. The KEEN dataset can be found at: https://github.com/kelpecosystems/observational_data.

Description of Kelp Population Over Time at Each KEEN Site

Kelp population over time can be visualized with a boxplot of total kelp counts in a transect, split up by site and year. See appendix 3 for a full set of descriptive statistics.



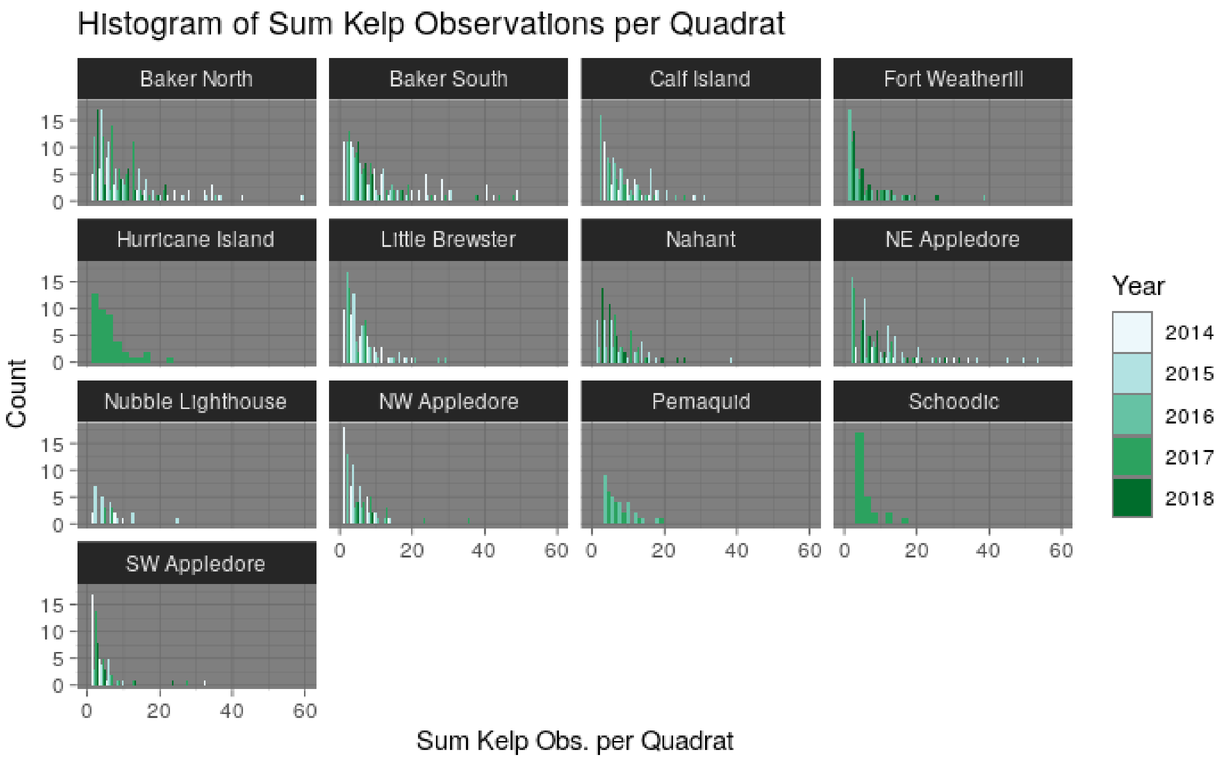
It is noticeable that for some sites (e.g. Baker North, Baker South), earlier years tend to have higher sum totals of kelp observations, although this is not always so. In any case it would be useful to have a statistically rigorous method for describing this change in population. This need is made clear when analyzing the confidence intervals (see

	SITE	YEAR	MEAN	N	CI_LOWER	CI_UPPER
1	Baker North	2014	210.25	4	175.99	244.51
2	Baker North	2015	187.5	4	68.88	306.12
3	Baker North	2016	37.75	4	19.41	56.09
4	Baker North	2017	143.75	4	134.44	153.06
5	Baker North	2018	163.75	4	25.43	302.07

appendix 2) around the true mean of sum kelp observations per transect across a site. Since the sample size is quite low, and the variance in sum of observations between transects high, the confidence interval around the true mean is wide enough to suggest there is too much uncertainty around these population means, and an alternative method for comparing the sum of kelp observations is needed. To mitigate the uncertainty around these sums, we can instead study the kelp population at the quadrat level. This will produce a more precise statistic- leading to a more certain conclusion.

(iii) **Modeling Kelp Sightings as a Poisson Random Variable**

A Poisson distribution expresses the probability of a number of independent events occurring in a fixed interval [3]. In this particular case, each kelp sighting can be considered an event, and each quadrat an interval. Therefore, the number of such events in each quadrat can be described by a Poisson distribution with a rate parameter to be estimated through maximum-likelihood estimation [4]. For some sites, the data show distinct differences between years. The rate estimation will quantify these differences, and they will be compared with statistical significance through a one-sided Exact test [5].



Estimating each year's rate parameter per site produces the following lambda values and their confidence intervals. Depending on the method of dividing the data, different rate parameters can be produced. In this example, the data are divided into sites, where one population contains events in 2014, and the other population contains events in 2018 (see appendix 3 for more rate parameter estimations).

SITE	YEAR	LAMBDA	CI_LOWER	CI_UPPER
Baker North	=2014	11.68	10.89	12.47
Baker North	=2018	6.06	5.6	6.53
Baker South	=2014	14.02	13.25	14.8
Baker South	=2018	2.61	2.31	2.9
NE Appledore	=2014	1.85	1.63	2.06
NE Appledore	=2018	4.52	4.08	4.96
NW Appledore	=2014	1.45	1.25	1.65
NW Appledore	=2018	1.5	1.22	1.78
SW Appledore	=2014	1.07	0.88	1.26
SW Appledore	=2018	1.21	0.96	1.47

Hypothesis Testing

An Exact test is a method of hypothesis testing that will determine if the null hypothesis that the rate parameter estimation for the earlier year(s) is not greater than the rate parameter estimation for the later year(s) can be rejected:

$$H_0: \hat{\lambda}_1 \le \hat{\lambda}_2 \; vs. \; H_1: \hat{\lambda}_1 > \hat{\lambda}_2$$

The following table displays the Poisson Exact test results using the rate parameter estimates derived from the rate parameter estimation table (appendix 2):

Given the grouping of observations into years 2014 and 2018, we can reject the null

SITE	DESC0	DESC1	LAMBDA0	LAMBDA1	PVAL	CI_LOWER	CI_UPPER
Baker North	=2014	=2018	11	3.5	0.001	6.8	19.2
Baker South	=2014	=2018	12	2.61	0	7.5	20.5
NE Appledore	=2014	=2018	2	4.52	0.9399	2.04	5.96
NW Appledore	=2014	=2018	2	1.5	0.4422	2.04	5.96
SW Appledore	=2014	=2018	2	1.21	0.341	2.04	5.96

hypothesis that in Baker North and Baker South the 2014 event rate is not greater than the 2018 event rate. We can expand our hypothesis test to include even more sites by subsetting the years less than or equal to 2015, from any year greater than 2015:
With this change, we can also reject the same null hypothesis for the Nahant site. Full results for all sets of hypothesis tests are in appendix 1.

SITE	DESC0	DESC1	LAMBDA0	LAMBDA1	PVAL	CI_LOWER	CI_UPPER
Baker North	<=2015	>=2016	7	2.96	0.0315	4.2	13.8
Baker South	<=2015	>=2016	7	2.97	0.032	4.2	13.8
Calf Island	<=2015	>=2016	4	1.9	0.1253	2.61	9.39
Little Brewster	<=2015	>=2016	3	1.57	0.2089	2.23	7.77
NE Appledore	<=2015	>=2016	4	3.41	0.4438	2.61	9.39
NW Appledore	<=2015	>=2016	2	2.04	0.6047	2.04	5.96
SW Appledore	<=2015	>=2016	1	1.16	0.6865	3	3
Nubble Lighthouse	<=2015	>=2016	3	1.02	0.084	2.23	7.77
Nahant	<=2015	>=2016	7	3.05	0.0361	4.2	13.8

We may accept the alternative hypothesis that in the Baker North, Baker South, and Nahant sites, there was evidence of a greater expected event rate of the sum of kelp observations in years 2014-2015 than in years 2016-2018. What we can say physically about these results is that for a quadrat in 2014-2015, the mentioned sites had a higher expected rate of kelp, than those same quadrats in 2016-2018.

(iv) Acknowledgements

I would like to thank the KEEN marine scientists for collecting an abundance of data on these sites, preparing them in a convenient format, and sharing via an open-source repository.

(v) References

[1] Byrnes, J. et al. Kelp Ecosystem Ecology Network: About. https://www.kelpecosystems.org/about/

[2] Byrnes, J. et al. KEEN Handbook. 2018. https://github.com/kelpecosystems/materials/blob/master/KEEN_Handbook_v0.9.5.docx

[3] Weisstein, Eric W. "Poisson Distribution." From Mathworld--A Wolfram Web Resource. https://mathworld.wolfram.com/PoissonDistribution.html

[4] Taboga, Marco (2021). "Poisson distribution - Maximum Likelihood Estimation", Lectures on probability theory and mathematical statistics. Kindle Direct Publishing. Online appendix. https://www.statlect.com/fundamentals-of-statistics/Poisson-distribution-maximum-likelihood.

[5] Krishnamoorthy, K., Thomson, J. "A more powerful test for comparing two Poisson means". 9 May 2002. https://userweb.ucs.louisiana.edu/~kxk4695/JSPI-04.pdf.

(vi) Appendix

1a. Exact Test: H_0: $\hat{\lambda}_1 \leq \hat{\lambda}_2$ $vs.$ H_1: $\hat{\lambda}_1 > \hat{\lambda}_2$ (Sites in 2014 vs. Sites in 2018)

SITE	DESC0	DESC1	LAMBDA0	LAMBDA1	PVAL	CI_LOWER	CI_UPPER
Baker North	=2014	=2018	11	3.5	0.001	6.8	19.2
Baker South	=2014	=2018	12	2.61	0	7.5	20.5
NE Appledore	=2014	=2018	2	4.52	0.9399	2.04	5.96
NW Appledore	=2014	=2018	2	1.5	0.4422	2.04	5.96
SW Appledore	=2014	=2018	2	1.21	0.341	2.04	5.96

1b. Exact Test: H_0: $\hat{\lambda}_1 \leq \hat{\lambda}_2$ $vs.$ H_1: $\hat{\lambda}_1 > \hat{\lambda}_2$ (Sites in 2014 vs. Sites in >2014)

SITE	DESC0	DESC1	LAMBDA0	LAMBDA1	PVAL	CI_LOWER	CI_UPPER
Baker North	=2014	>2014	11	3.48	0.001	6.8	19.2
Baker South	=2014	>2014	12	3.02	1e-04	7.5	20.5
Calf Island	=2014	>2014	3	2.48	0.451	2.23	7.77
Little Brewster	=2014	>2014	3	1.67	0.2349	2.23	7.77
NE Appledore	=2014	>2014	2	3.91	0.9016	2.04	5.96
NW Appledore	=2014	>2014	2	1.85	0.5519	2.04	5.96
SW Appledore	=2014	>2014	2	0.98	0.2569	2.04	5.96
Nubble Lighthouse	=2014	>2014	1	1.65	0.808	3	3

1c. Exact Test: H_0: $\hat{\lambda}_1 \leq \hat{\lambda}_2$ $vs.$ H_1: $\hat{\lambda}_1 > \hat{\lambda}_2$ (Sites in <=2015 vs. Sites in >=2016)

SITE	DESC0	DESC1	LAMBDA0	LAMBDA1	PVAL	CI_LOWER	CI_UPPER
Baker North	<=2015	>=2016	7	2.96	0.0315	4.2	13.8
Baker South	<=2015	>=2016	7	2.97	0.032	4.2	13.8
Calf Island	<=2015	>=2016	4	1.9	0.1253	2.61	9.39
Little Brewster	<=2015	>=2016	3	1.57	0.2089	2.23	7.77
NE Appledore	<=2015	>=2016	4	3.41	0.4438	2.61	9.39
NW Appledore	<=2015	>=2016	2	2.04	0.6047	2.04	5.96
SW Appledore	<=2015	>=2016	1	1.16	0.6865	3	3
Nubble Lighthouse	<=2015	>=2016	3	1.02	0.084	2.23	7.77
Nahant	<=2015	>=2016	7	3.05	0.0361	4.2	13.8

2a. Rate Parameter Estimation: Sites in 2014, 2018

SITE	YEAR	LAMBDA	CI_LOWER	CI_UPPER
Baker North	=2014	11.68	10.89	12.47
Baker North	=2018	6.06	5.6	6.53
Baker South	=2014	14.02	13.25	14.8
Baker South	=2018	2.61	2.31	2.9
NE Appledore	=2014	1.85	1.63	2.06
NE Appledore	=2018	4.52	4.08	4.96
NW Appledore	=2014	1.45	1.25	1.65
NW Appledore	=2018	1.5	1.22	1.78
SW Appledore	=2014	1.07	0.88	1.26
SW Appledore	=2018	1.21	0.96	1.47

2b. Rate Parameter Estimation: Sites in 2014, >2014

SITE	YEAR	LAMBDA	CI_LOWER	CI_UPPER
Baker North	=2014	11.68	10.89	12.47
Baker North	>2014	4.13	3.95	4.31
Baker South	=2014	14.02	13.25	14.8
Baker South	>2014	3.02	2.87	3.17
Calf Island	=2014	2.56	2.29	2.82
Calf Island	>2014	3.1	2.94	3.27
Little Brewster	=2014	2.79	2.46	3.13
Little Brewster	>2014	1.67	1.54	1.8
NE Appledore	=2014	1.85	1.63	2.06
NE Appledore	>2014	5.58	5.36	5.81
NW Appledore	=2014	1.45	1.25	1.65
NW Appledore	>2014	1.85	1.72	1.99
SW Appledore	=2014	1.07	0.88	1.26
SW Appledore	>2014	0.98	0.89	1.08
Nubble Lighthouse	=2014	0.95	0.66	1.25
Nubble Lighthouse	>2014	1.65	1.44	1.86

2c. Rate Parameter Estimation: Sites in <=2015, >=2016

SITE	YEAR	LAMBDA	CI_LOWER	CI_UPPER
Baker North	<=2015	6.87	6.52	7.23
Baker North	>=2016	2.96	2.79	3.14
Baker South	<=2015	6.4	6.08	6.73
Baker South	>=2016	2.97	2.79	3.15
Calf Island	<=2015	3.03	2.84	3.23
Calf Island	>=2016	1.9	1.74	2.07
Little Brewster	<=2015	2.16	1.98	2.34
Little Brewster	>=2016	1.57	1.41	1.74
NE Appledore	<=2015	3.33	3.13	3.53
NE Appledore	>=2016	3.41	3.18	3.64
NW Appledore	<=2015	1.52	1.38	1.66
NW Appledore	>=2016	2.04	1.85	2.22
SW Appledore	<=2015	0.88	0.77	0.99
SW Appledore	>=2016	1.16	1.02	1.3
Nubble Lighthouse	<=2015	2.15	1.83	2.48
Nubble Lighthouse	>=2016	1.02	0.83	1.21
Nahant	<=2015	6.46	5.74	7.18
Nahant	>=2016	3.05	2.82	3.27

3. Descriptive Statistics

	YEAR	SITE	TRANSECT	MEAN	SD	SE	N	CI_LOWER	CI_UPPER
1	2014	Baker North	1	9.94	14	3.3	18	3.47	16.41
2	2015	Baker North	1	10.22	12.8	2.13	36	6.04	14.4
3	2016	Baker North	1	1.81	6.17	1.03	36	-0.21	3.83
4	2017	Baker North	1	6.29	4.85	0.99	24	4.35	8.23
5	2018	Baker North	1	20.44	44.66	10.53	18	-0.19	41.07
6	2014	Baker North	2	10.06	12.85	3.03	18	4.12	16
7	2015	Baker North	2	3.11	2.9	0.48	36	2.16	4.06
8	2016	Baker North	2	0.97	2.57	0.43	36	0.13	1.81
9	2017	Baker North	2	4.14	4.7	0.78	36	2.61	5.67
10	2018	Baker North	2	4.54	5.88	1.2	24	2.19	6.89
11	2014	Baker North	3	13.44	14.57	3.43	18	6.71	20.17
12	2015	Baker North	3	4	5.79	0.96	36	2.11	5.89
13	2016	Baker North	3	0.69	1.64	0.27	36	0.16	1.22
14	2017	Baker North	3	4.33	4.27	0.78	30	2.8	5.86
15	2018	Baker North	3	1.88	3.08	0.63	24	0.65	3.11
16	2014	Baker North	4	13.28	13.13	3.1	18	7.21	19.35
17	2015	Baker North	4	3.5	6.3	1.05	36	1.44	5.56
18	2016	Baker North	4	0.72	1.88	0.31	36	0.11	1.33
19	2017	Baker North	4	4.83	5.78	1.05	30	2.76	6.9
20	2018	Baker North	4	3.17	5.28	0.81	42	1.57	4.77
21	2014	Baker South	1	9.79	8.93	1.82	24	6.22	13.36
22	2015	Baker South	1	2.42	3.07	0.51	36	1.42	3.42
23	2016	Baker South	1	2.14	4.17	0.69	36	0.78	3.5
24	2017	Baker South	1	8.67	12.33	2.25	30	4.26	13.08
25	2018	Baker South	1	1.97	3.55	0.65	30	0.7	3.24
26	2014	Baker South	2	6.92	9.74	1.99	24	3.02	10.82
27	2015	Baker South	2	2.22	4.64	0.77	36	0.7	3.74
28	2016	Baker South	2	0.86	1.74	0.29	36	0.29	1.43
29	2017	Baker South	2	2	2.86	0.83	12	0.38	3.62
30	2018	Baker South	2	1.42	2.32	0.47	24	0.49	2.35
31	2014	Baker South	3	20	19.51	3.98	24	12.19	27.81
32	2015	Baker South	3	4.11	5.76	0.96	36	2.23	5.99
33	2016	Baker South	3	1.58	3.31	0.55	36	0.5	2.66
34	2017	Baker South	3	2.42	3.96	0.66	36	1.13	3.71
35	2018	Baker South	3	3.87	7.38	1.35	30	1.23	6.51
36	2014	Baker South	4	21.17	36.03	8.49	18	4.52	37.82
37	2015	Baker South	4	3.83	8.05	1.34	36	1.2	6.46
38	2016	Baker South	4	0.97	2.13	0.36	36	0.27	1.67
39	2017	Baker South	4	7.3	10.22	1.87	30	3.64	10.96
40	2018	Baker South	4	2.93	3.07	0.56	30	1.83	4.03
41	2014	Calf Island	1	5.97	6.63	1.21	30	3.6	8.34
42	2015	Calf Island	1	3.83	5.82	0.9	42	2.07	5.59
43	2016	Calf Island	1	1.69	2.95	0.49	36	0.73	2.65
44	2017	Calf Island	1	2.72	3.43	0.81	18	1.14	4.3
45	2014	Calf Island	2	2.58	5.09	0.85	36	0.92	4.24
46	2015	Calf Island	2	11.94	28.45	4.74	36	2.65	21.23
47	2016	Calf Island	2	1.72	4.18	0.57	54	0.61	2.83
48	2017	Calf Island	2	3.43	6.17	1.13	30	1.22	5.64
49	2014	Calf Island	3	1.47	2.34	0.43	30	0.63	2.31
50	2015	Calf Island	3	3.21	4.7	0.72	42	1.79	4.63
51	2016	Calf Island	3	1.88	3.53	0.54	42	0.81	2.95
52	2017	Calf Island	3	1.58	1.93	0.39	24	0.81	2.35
53	2014	Calf Island	4	0.88	1.5	0.23	42	0.43	1.33
54	2015	Calf Island	4	2.4	3.57	0.55	42	1.32	3.48
55	2016	Calf Island	4	1.21	2.1	0.32	42	0.57	1.85
56	2017	Calf Island	4	1.67	2.51	0.51	24	0.66	2.68

57	2016	Fort Weatherill	1	4.96	8.93	1.82	24	1.39	8.53
58	2017	Fort Weatherill	1	0.67	1.08	0.26	18	0.17	1.17
59	2018	Fort Weatherill	1	2.39	2.75	0.65	18	1.12	3.66
60	2016	Fort Weatherill	2	2.71	3.39	0.69	24	1.35	4.07
61	2017	Fort Weatherill	2	1.08	1.16	0.34	12	0.42	1.74
62	2018	Fort Weatherill	2	8.58	5.74	1.66	12	5.33	11.83
63	2016	Fort Weatherill	3	0.56	0.78	0.18	18	0.2	0.92
64	2017	Fort Weatherill	3	1.96	4.11	0.84	24	0.31	3.61
65	2018	Fort Weatherill	3	1.58	2.15	0.62	12	0.36	2.8
66	2016	Fort Weatherill	4	1.5	2.95	0.6	24	0.32	2.68
67	2017	Fort Weatherill	4	1.58	2.65	0.54	24	0.52	2.64
68	2018	Fort Weatherill	4	2.56	5.86	1.38	18	-0.15	5.27
69	2017	Hurricane Island	1	1.67	2.89	0.68	18	0.33	3.01
70	2017	Hurricane Island	2	3.33	3.88	0.91	18	1.54	5.12
71	2017	Hurricane Island	3	3.77	5.95	1.09	30	1.64	5.9
72	2017	Hurricane Island	4	2.92	3.31	0.68	24	1.6	4.24
73	2014	Little Brewster	1	1.06	1.8	0.42	18	0.23	1.89
74	2015	Little Brewster	1	1.52	2.54	0.39	42	0.75	2.29
75	2016	Little Brewster	1	1.64	3.91	0.6	42	0.46	2.82
76	2017	Little Brewster	1	1.56	2.04	0.48	18	0.62	2.5
77	2014	Little Brewster	2	1.57	2.53	0.46	30	0.67	2.47
78	2015	Little Brewster	2	1.17	2.34	0.36	42	0.46	1.88
79	2016	Little Brewster	2	2.31	5.56	0.93	36	0.49	4.13
80	2017	Little Brewster	2	3.08	2.23	0.65	12	1.82	4.34
81	2014	Little Brewster	3	3.21	4.04	0.83	24	1.59	4.83
82	2015	Little Brewster	3	3.44	5.27	0.88	36	1.72	5.16
83	2016	Little Brewster	3	0.74	1.4	0.22	42	0.32	1.16
84	2017	Little Brewster	3	1.58	2.12	0.43	24	0.73	2.43
85	2014	Little Brewster	4	5.21	6.43	1.31	24	2.64	7.78
86	2015	Little Brewster	4	1.26	1.78	0.27	42	0.72	1.8
87	2016	Little Brewster	4	1.29	4.2	0.65	42	0.02	2.56
88	2015	Nahant	Canoe Beach 1	6.58	4.8	1.38	12	3.87	9.29
89	2016	Nahant	Canoe Beach 1	1.79	3.23	0.66	24	0.5	3.08
90	2017	Nahant	Canoe Beach 1	4.17	3.27	0.67	24	2.86	5.48
91	2015	Nahant	Canoe Beach 2	4	5.29	1.53	12	1.01	6.99
92	2016	Nahant	Canoe Beach 2	4.58	3.82	1.1	12	2.42	6.74
93	2017	Nahant	Canoe Beach 2	6.22	4.44	1.05	18	4.17	8.27
94	2018	Nahant	Canoe Beach 3	1.62	2.52	0.51	24	0.61	2.63
95	2018	Nahant	Canoe Beach 4	3.62	6.5	1.33	24	1.02	6.22
96	2015	Nahant	Pumphouse Beach 1	6.67	6.26	1.81	12	3.13	10.21
97	2018	Nahant	Pumphouse Beach 1	2.72	5.37	1.26	18	0.24	5.2
98	2015	Nahant	Pumphouse Beach 2	8.58	10.99	3.17	12	2.36	14.8
99	2018	Nahant	Pumphouse Beach 2	2.04	2.58	0.53	24	1.01	3.07
100	2017	Nahant	Pumphouse Beach 3	3.71	3.18	0.65	24	2.44	4.98
101	2017	Nahant	Pumphouse Beach 4	2	2.24	0.37	36	1.27	2.73

102	2014	NE Appledore	Broad Cove	4.36	9.57	1.59	36	1.23	7.49
103	2015	NE Appledore	Broad Cove	3.81	5	0.83	36	2.18	5.44
104	2016	NE Appledore	Broad Cove	1.12	1.98	0.41	24	0.33	1.91
105	2017	NE Appledore	Broad Cove	4.62	4.97	1.01	24	2.63	6.61
106	2018	NE Appledore	Broad Cove	5.56	8.15	1.92	18	1.8	9.32
107	2014	NE Appledore	Broadway and 42nd	0.88	1.8	0.28	42	0.34	1.42
108	2015	NE Appledore	Broadway and 42nd	7.15	22.5	3.25	48	0.78	13.52
109	2016	NE Appledore	Broadway and 42nd	0.67	1.15	0.33	12	0.02	1.32
110	2017	NE Appledore	Broadway and 42nd	0.83	1.98	0.47	18	-0.08	1.74
111	2018	NE Appledore	Broadway and 42nd	3.92	5.78	1.18	24	1.61	6.23
112	2014	NE Appledore	Devil's Dance Floor	1.08	1.79	0.3	36	0.49	1.67
113	2015	NE Appledore	Devil's Dance Floor	13.59	41.14	5.6	54	2.62	24.56
114	2016	NE Appledore	Devil's Dance Floor	3.78	4.98	1.17	18	1.48	6.08
115	2017	NE Appledore	Devil's Dance Floor	5.29	8.06	1.64	24	2.07	8.51
116	2018	NE Appledore	Devil's Dance Floor	2.83	3.87	0.79	24	1.28	4.38
117	2014	NE Appledore	Norwegian Cove	1.22	2.44	0.41	36	0.42	2.02
118	2015	NE Appledore	Norwegian Cove	7.79	14.6	2.25	42	3.37	12.21
119	2016	NE Appledore	Norwegian Cove	2.39	3.7	0.87	18	0.68	4.1
120	2017	NE Appledore	Norwegian Cove	1.78	3.17	0.75	18	0.31	3.25
121	2018	NE Appledore	Norwegian Cove	6.04	7.24	1.48	24	3.14	8.94
122	2014	Nubble Lighthouse	1	0.95	2.38	0.37	42	0.23	1.67
123	2015	Nubble Lighthouse	1	3.56	5	0.83	36	1.93	5.19
124	2017	Nubble Lighthouse	1	0.7	1.39	0.25	30	0.2	1.2
125	2017	Nubble Lighthouse	2	0.88	0.85	0.17	24	0.54	1.22
126	2017	Nubble Lighthouse	3	1.29	1.3	0.27	24	0.77	1.81
127	2017	Nubble Lighthouse	4	1.23	1.76	0.32	30	0.6	1.86
128	2017	NW Appledore	8 Ball	2.42	3.45	0.7	24	1.04	3.8
129	2018	NW Appledore	8 Ball	3	3.95	1.14	12	0.76	5.24
130	2014	NW Appledore	Larus Ledge	0.67	1.15	0.19	36	0.3	1.04
131	2015	NW Appledore	Larus Ledge	1.21	1.52	0.23	42	0.75	1.67
132	2016	NW Appledore	Larus Ledge	1.33	1.51	0.61	6	0.13	2.53
133	2017	NW Appledore	Larus Ledge	3.56	4.18	0.98	18	1.63	5.49
134	2018	NW Appledore	Larus Ledge	1.12	1.36	0.28	24	0.58	1.66
135	2014	NW Appledore	Magic 8 Ball	1.28	2.08	0.35	36	0.6	1.96
136	2015	NW Appledore	Magic 8 Ball	2.03	2.98	0.5	36	1.06	3
137	2016	NW Appledore	Magic 8 Ball	0.83	1.34	0.39	12	0.07	1.59
138	2014	NW Appledore	North Head	1.83	3.05	0.56	30	0.74	2.92
139	2015	NW Appledore	North Head	2.07	2.74	0.42	42	1.24	2.9
140	2016	NW Appledore	North Head	3.83	4.3	1.24	12	1.4	6.26
141	2017	NW Appledore	North Head	1.47	1.98	0.36	30	0.76	2.18
142	2018	NW Appledore	North Head	1.54	1.93	0.39	24	0.77	2.31
143	2014	NW Appledore	Sandpiper Beach	2.08	3.69	0.62	36	0.87	3.29
144	2015	NW Appledore	Sandpiper Beach	1	2.06	0.34	36	0.33	1.67
145	2016	NW Appledore	Sandpiper Beach	2.17	2.6	0.61	18	0.97	3.37
146	2017	NW Appledore	Sandpiper Beach	2.44	6.9	1.15	36	0.19	4.69
147	2018	NW Appledore	Sandpiper Beach	0.67	0.89	0.26	12	0.17	1.17
148	2016	Pemaquid	1	2.54	3.78	0.77	24	1.03	4.05
149	2017	Pemaquid	1	2.07	2.69	0.49	30	1.11	3.03
150	2016	Pemaquid	2	3.25	5.16	1.05	24	1.19	5.31
151	2017	Pemaquid	2	3.89	4.56	1.08	18	1.78	6
152	2016	Pemaquid	3	2.46	3.18	0.65	24	1.19	3.73
153	2017	Pemaquid	3	0.92	0.97	0.2	24	0.53	1.31
154	2016	Pemaquid	4	2.88	2.59	0.53	24	1.84	3.92
155	2017	Pemaquid	4	0.67	1.91	0.45	18	-0.21	1.55

156	2017	Schoodic	1	3.71	4.66	0.95	24	1.85	5.57
157	2017	Schoodic	2	1.75	2.62	0.44	36	0.89	2.61
158	2017	Schoodic	3	1.53	1.85	0.34	30	0.87	2.19
159	2017	Schoodic	4	0.94	1.51	0.25	36	0.45	1.43
160	2014	SW Appledore	North Pepperrell	0.79	1.1	0.23	24	0.35	1.23
161	2015	SW Appledore	North Pepperrell	1.11	1.95	0.33	36	0.47	1.75
162	2016	SW Appledore	North Pepperrell	0.31	1.06	0.18	36	-0.04	0.66
163	2017	SW Appledore	North Pepperrell	1.11	0.9	0.21	18	0.69	1.53
164	2018	SW Appledore	North Pepperrell	0.92	1.88	0.54	12	-0.14	1.98
165	2014	SW Appledore	North Smith's Cove	1.69	4.9	0.71	48	0.31	3.07
166	2015	SW Appledore	North Smith's Cove	0.6	1.72	0.25	48	0.11	1.09
167	2016	SW Appledore	North Smith's Cove	0.78	1.7	0.4	18	-0.01	1.57
168	2017	SW Appledore	North Smith's Cove	1.46	2.25	0.46	24	0.56	2.36
169	2018	SW Appledore	North Smith's Cove	314.25	1249.01	254.95	24	-185.46	813.96
170	2014	SW Appledore	South Pepperrell	0.75	1.76	0.51	12	-0.25	1.75
171	2015	SW Appledore	South Pepperrell	0.64	1.41	0.22	42	0.21	1.07
172	2016	SW Appledore	South Pepperrell	0.96	2.29	0.47	24	0.04	1.88
173	2017	SW Appledore	South Pepperrell	0.61	0.85	0.2	18	0.22	1
174	2018	SW Appledore	South Pepperrell	1.39	2.87	0.68	18	0.06	2.72
175	2014	SW Appledore	South Smith's Cove	0.43	0.77	0.14	30	0.15	0.71
176	2015	SW Appledore	South Smith's Cove	0.71	1.31	0.2	42	0.31	1.11
177	2017	SW Appledore	South Smith's Cove	3.5	6.71	1.58	18	0.4	6.6
178	2018	SW Appledore	South Smith's Cove	0.39	0.98	0.23	18	-0.06	0.84