SUPPLEMENTARY MATERIAL:

Kelp Mapping protocol

Floating kelp beds were mapped through an Object-Based Image Analysis framework (OBIA; Benz et al., 2004). With OBIA, image objects are created by grouping adjacent pixels based on contextual information like shape, scale, and compactness as a previous step before classification (Schroeder et al., 2019; Gendall et al., 2023). OBIA shows some advantages over pixel-based approaches as it tends to reduce the effects of imagery noise (Blaschke, 2010) and, therefore, produces classifications with better accuracy when using high spatial resolution images (Gao and Mas, 2008). More importantly, the object (polygon) aggregates kelp fronds, inner water patches, or partially submerged kelp into the same floating bed polygon (Gendall et al., 2023), outlining a floating kelp bed as an actual ecological entity.

The framework is as follows: First, the images were geometrically and atmospherically corrected using the dark object subtraction algorithm (Chavez, 1998). Then, spectral bands were used to calculate the Green Normalized Difference Vegetation Index (GNDVI; Gitelson et al., 1996) and the Normalized Difference Vegetation Index (NDVI; Kriegler, 1969). Next, images were masked considering the potential kelp niche habitat (Soberón and Nakamura, 2009) according to substrate type and depth (Springer et al., 2010), selecting rocky and mixed substrate areas from the model by Gregr et al. (2021), and excluding the land above the low-water mark and bathymetry below 40 m (Springer et al., 2010). Corrected, enhanced, and masked bands and indices were then classified using a supervised OBIA in the Trimble eCognition software (Trimble Germany GmbH, 2021), which involved multi-resolution segmentation and feature space optimization. Subsequently, the objects were classified as either kelp (as floating beds) or no-kelp classes using a supervised Maximum Likelihood classification following methods developed by Gendall et al. (2023). The size of the kelp beds was a crucial component of the classification, given that sparse bulbs or fronds could not be detected with this method, whereas kelp beds wider than 10–15 m were usually well detected with very high-resolution imagery.

The accuracy of the classification was assessed qualitatively and quantitatively. The qualitative analysis applied expert knowledge by comparing the mapped kelp with the higher resolution orthomosaics, Google Earth imagery, ancillary data (BC ShoreZone 2007, 2017 by Howes et al., 1994) and field observations, such as georeferenced video recordings of the Southern Vancouver Island coastline (NWRC, 'pers. comm.'). The qualitative analysis considered ground-truth data available from a standardized mapping approach developed by citizen scientists of Mayne Island and surrounding islands. This approach is based on recording floating kelp beds as points, lines and polygons depending on their size and shape, using handheld GPS units carried on kayaks (Mayne Island Conservancy, 2010). The accuracy assessment compared image-derived polygons with kayak-derived polygons through expert knowledge, resulting in a mean accuracy of 70%. This analysis provides an approximation of the accuracy of the mapped kelp; however, it is important to emphasize that the kayak surveys were conducted at different dates compared to the imagery acquisition. Considering that other studies in BC with similar methods provide accuracy between 88% to 94% (Gendall et al., 2023) and the qualitative assessment of the kelp classifications, we trust that the final accuracy of the produced kelp maps is higher than 70%.

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Table SM1. Mean and median of the environmental variables and total area per cluster.

	Cluster			
Variable	**1**	**2**	**3**	**4**
SpringSST.mean (°C)	9.8	11.3	12.8	13.2
SpringSST.median (°C)	9.8	11.1	12.8	13.2
SummerSST.mean (°C)	12.0	14.4	17.4	16.8
SummerSST.median (°C)	12.0	14.2	17.8	16.5
Fetch.mean (m)	549251	195482	1083354	132868
Fetch.median (m)	534032	189475	1098520	131059
Tidal.mean (m/s)	0.3	0.2	0.2	0.1
Tidal.median (m/s)	0.3	0.2	0.2	0.1
Wind.mean (W/m2)	133.82	84.11	122.26	65.91
Wind.median (W/m2)	148.37	89.56	140.01	71.03
SpringTSM.mean (mg/L)	0.7	0.8	1.4	0.7
SpringTSM.median (mg/L)	0.7	0.8	1.4	0.7
SummerTSM.mean (mg/L)	0.8	1.2	2.5	1.3
SummerTSM.median (mg/L)	0.8	1.3	2.6	1.3
Area Niche total (hectare)	1116.4	444.5	83.6	10.5

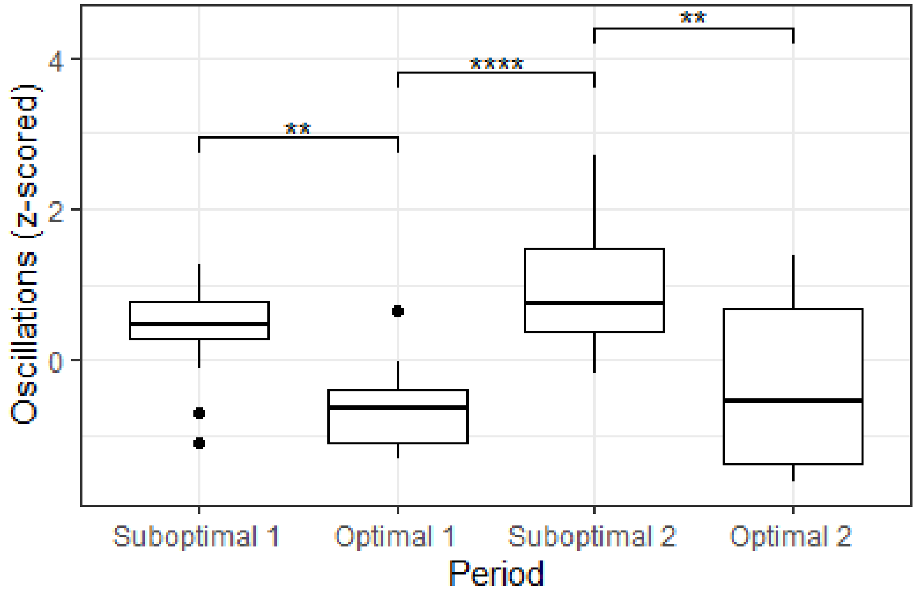

Figure SM1. Kruskal-Wallis Dunn Test for significant differences among optimal and suboptimal periods for ONI, PDO, and NPGO (z-scored) in the 2002–2022 period. The (*) symbol indicates the level of significance ($p < 0.05$).

Table SM2. Landsat imagery used to derive nearshore SST in spring and summer.

Sensor	Image_Resolution	Date	Year	Season	Month
Landsat 5- band 6	30	1984-07-26	1984	Summer	Jul
Landsat 5- band 6	30	1985-08-14	1985	Summer	Aug
Landsat 5- band 6	30	1986-08-01	1986	Summer	Aug
Landsat 5- band 6	30	1987-07-10	1987	Summer	Jul
Landsat 5- band 6	30	1988-07-21	1988	Summer	Jul
Landsat 5- band 6	30	1989-07-24	1989	Summer	Jul
Landsat 5- band 6	30	1990-08-12	1990	Summer	Aug
Landsat 5- band 6	30	1991-08-15	1991	Summer	Aug
Landsat 5- band 6	30	1992-08-17	1992	Summer	Aug
Landsat 5- band 6	30	1993-08-20	1993	Summer	Aug
Landsat 5- band 6	30	1994-07-22	1994	Summer	Jul
Landsat 5- band 6	30	1995-07-16	1995	Summer	Jul
Landsat 5- band 6	30	1996-07-27	1996	Summer	Jul
Landsat 5- band 6	30	1997-08-15	1997	Summer	Aug
Landsat 5- band 6	30	1998-08-09	1998	Summer	Aug
Landsat 7- band 6	30	1999-07-28	1999	Summer	Jul
Landsat 5- band 6	30	2000-08-23	2000	Summer	Aug
Landsat 5- band 6	30	2001-08-10	2001	Summer	Aug
Landsat 7- band 6	30	2002-08-12	2002	Summer	Aug
Landsat 5- band 6	30	2003-07-22	2003	Summer	Jul
Landsat 5- band 6	30	2004-07-17	2004	Summer	Jul
Landsat 5- band 6	30	2005-07-27	2005	Summer	Jul
Landsat 5- band 6	30	2006-07-23	2006	Summer	Jul
Landsat 5- band 6	30	2008-08-04	2008	Summer	Aug
Landsat 5- band 6	30	2009-08-16	2009	Summer	Aug
Landsat 5- band 6	30	2010-07-25	2010	Summer	Jul
Landsat 5- band 6	30	2011-07-05	2011	Summer	Jul
Landsat 7- band 6	30	2012-08-16	2012	Summer	Aug
Landsat 8- band 10	30	2013-07-26	2013	Summer	Jul
Landsat 8- band 10	30	2015-07-16	2015	Summer	Jul
Landsat 8- band 10	30	2016-08-19	2016	Summer	Aug
Landsat 8- band 10	30	2017-08-22	2017	Summer	Aug
Landsat 8- band 10	30	2018-08-16	2018	Summer	Aug
Landsat 8- band 10	30	2019-08-03	2019	Summer	Aug
Landsat 8- band 10	30	2020-08-14	2020	Summer	Aug
Landsat 8- band 10	30	2021-08-24	2021	Summer	Aug
Landsat 8- band 10	30	2022-07-26	2022	Summer	Jul
Landsat 5- band 6	30	1984-06-24	1984	Spring	Jun
Landsat 5- band 6	30	1985-05-26	1985	Spring	May

Landsat 5- band 6	30	1986-05-29	1986	Spring	May
Landsat 5- band 6	30	1987-06-17	1987	Spring	Jun
Landsat 5- band 6	30	1988-06-19	1988	Spring	Jun
Landsat 5- band 6	30	1989-06-22	1989	Spring	Jun
Landsat 5- band 6	30	1990-05-08	1990	Spring	May
Landsat 5- band 6	30	1991-05-02	1991	Spring	May
Landsat 5- band 6	30	1992-06-21	1992	Spring	Jun
Landsat 5- band 6	30	1993-05-23	1993	Spring	May
Landsat 5- band 6	30	1994-06-20	1994	Spring	Jun
Landsat 5- band 6	30	1995-05-06	1995	Spring	May
Landsat 5- band 6	30	1996-06-25	1996	Spring	Jun
Landsat 5- band 6	30	1997-05-18	1997	Spring	May
Landsat 5- band 6	30	1998-06-06	1998	Spring	Jun
Landsat 5- band 6	30	1999-05-24	1999	Spring	May
Landsat 7- band 6	30	2000-06-28	2000	Spring	Jun
Landsat 5- band 6	30	2001-05-22	2001	Spring	May
Landsat 7- band 6	30	2002-06-09	2002	Spring	Jun
Landsat 7- band 6	30	2003-05-11	2003	Spring	May
Landsat 5- band 6	30	2004-05-14	2004	Spring	May
Landsat 5- band 6	30	2005-05-24	2005	Spring	May
Landsat 7- band 6	30	2006-05-03	2006	Spring	May
Landsat 5- band 6	30	2007-05-30	2007	Spring	May
Landsat 5- band 6	30	2008-05-09	2008	Spring	May
Landsat 5- band 6	30	2009-05-28	2009	Spring	May
Landsat 7- band 6	30	2010-05-14	2010	Spring	May
Landsat 7- band 6	30	2011-05-01	2011	Spring	May
Landsat 7- band 6	30	2012-05-12	2012	Spring	May
Landsat 7- band 6	30	2013-05-06	2013	Spring	May
Landsat 8- band 10	30	2014-05-01	2014	Spring	May
Landsat 8- band 10	30	2015-05-29	2015	Spring	May
Landsat 8- band 10	30	2016-05-06	2016	Spring	May
Landsat 8- band 10	30	2017-05-25	2017	Spring	May
Landsat 8- band 10	30	2018-05-12	2018	Spring	May
Landsat 8- band 10	30	2019-05-31	2019	Spring	May
Landsat 8- band 10	30	2020-05-10	2020	Spring	May
Landsat 8- band 10	30	2021-05-29	2021	Spring	May
Landsat 8- band 10	30	2022-06-24	2022	Spring	Jun

Table SM3. Sensors and resolutions employed to map floating kelp canopies in the study area. Bidecadal time series, 2004-2022.

Sensor	**Resolution**	**Years**	**Season**
Aerial photos	< 1m	2004, 2005, 2009, 2013	Summer
Pansharpened	< 1m	2008, 2009, 2014, 2015, 2016, 2017, 2018, 2019	Summer
Quickbird	2.5 m	2006, 2007, 2008	Summer
WorldView02	2.5 m	2011, 2012, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022	Summer
Ikonos	3.2 m	2005	Summer
Planet	4 m	2018, 2019, 2020, 2021, 2022	Summer
Kompsat	4.4 m	2007, 2017	Summer
RapidEye	5 m	2009, 2010, 2011, 2012, 2014, 2015, 2017	Summer
Spot-6	6 m	2019	Summer
Spot-4	10 m	2006	Summer
Spot-5	20 m	2006	Summer

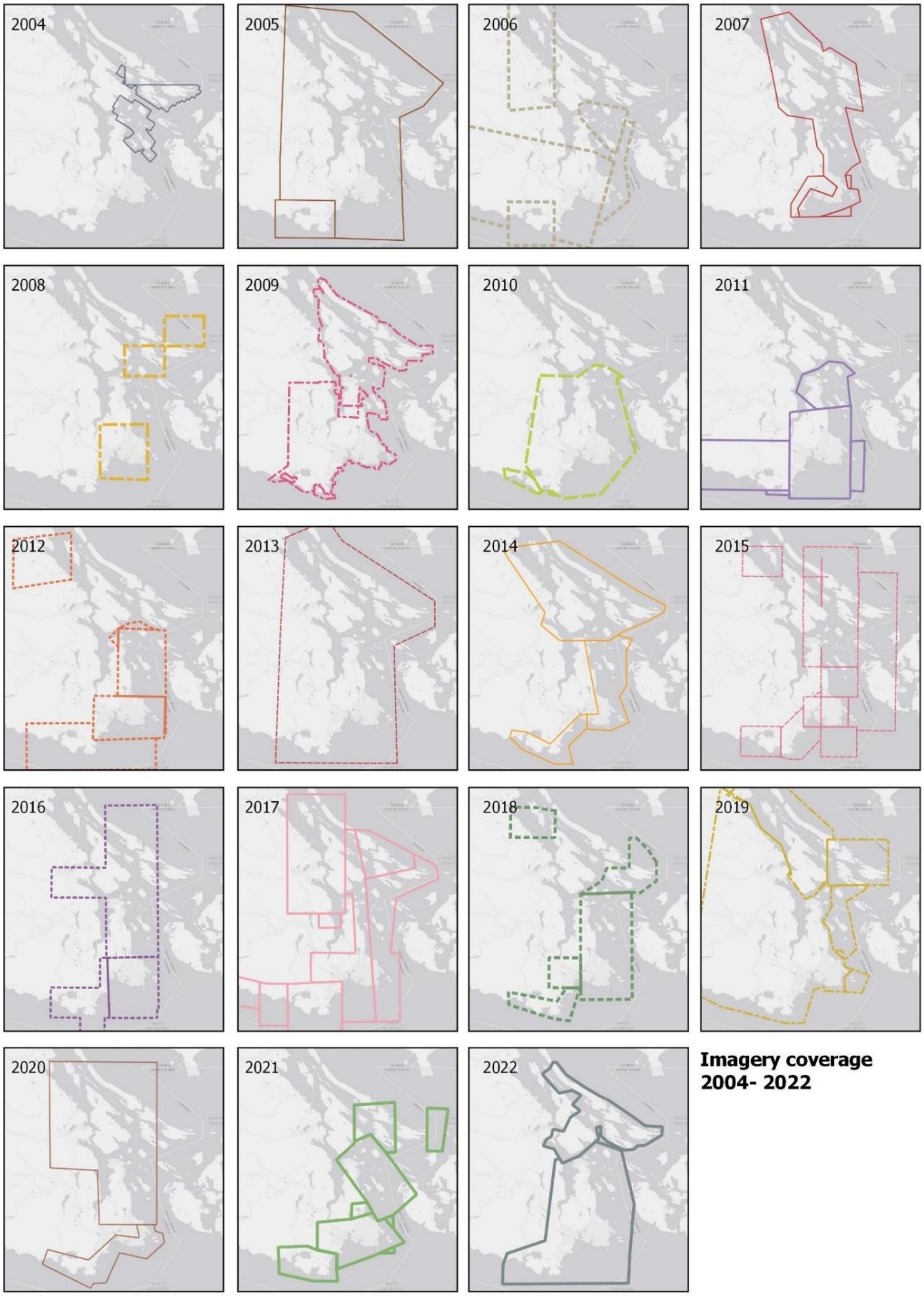

Figure SM2. Imagery coverage for the bidecadal analysis (2004–2022). The polygons indicate the image coverage of the high-resolution images. Please refer to Table SM3 for more details on the sensors per year.

Table SM4. Landsat dataset employed to map floating kelp canopies in the Ella Beach site, 1972–2022.

Sensor	Image Resolution	Date	Year	Total Area km^2	Tide	Month
Landsat 1	60	1972-07-30	1972	0.61	1	jul
Landsat 1	60	1973-08-12	1973	0.73	0.9	aug
Landsat 1	60	1974-08-07	1974	0.56	1.3	aug
Landsat 1	60	1975-08-12	1975	0.76	1.4	aug
Landsat 1	60	1976-07-27	1976	0.66	0.9	jul
Landsat 1	60	1977-08-19	1977	0.63	1.4	aug
Landsat 1	60	1978-07-18	1978	0.31	1.4	jul
Landsat 1	60	1979-09-14	1979	0.63	2.1	sep
Landsat 1	60	1980-08-29	1980	0.67	1	aug
Landsat 1	60	1981-08-15	1981	0.52	1.1	aug
Landsat 1	60	1982-08-20	1982	0.73	0.9	aug
Landsat 1	60	1983-09-09	1983	0.83	1.2	sep
Landsat 5	30	1984-07-26	1984	0.71	1.28	jul
Landsat 5	30	1985-08-14	1985	0.62	1.12	aug
Landsat 5	30	1986-08-08	1986	0.70	0.74	aug
Landsat 5	30	1987-08-20	1987	0.56	1.58	aug
Landsat 5	30	1988-08-29	1988	0.72	1.06	aug
Landsat 5	30	1989-07-15	1989	0.22	1.6	jul
Landsat 5	30	1990-09-04	1990	0.74	1.38	sep
Landsat 5	30	1991-08-15	1991	0.62	1.85	aug
Landsat 5	30	1992-09-09	1992	0.68	1.5	sep
Landsat 5	30	1993-08-20	1993	0.47	1.11	aug
Landsat 5	30	1994-08-03	1994	0.69	1.6	aug
Landsat 5	30	1995-09-11	1995	0.45	1	sep
Landsat 5	30	1996-08-12	1996	0.66	1.22	aug
Landsat 5	30	1997-09-07	1997	0.84	1.78	sep
Landsat 5	30	1998-08-25	1998	0.82	1.16	aug
SPOT 4	20	1999-09-18	1999	0.94	2.1	Sept
Landsat 5	30	2000-07-09	2000	0.67	1.6	jul
Landsat 5	30	2001-08-10	2001	0.64	1.46	Aug
SPOT 4	20	2002-08-14	2002	0.86	1.77	Aug
Landsat 5	30	2003-09-08	2003	0.53	1.1	sep
Landsat 5	30	2004-07-17	2004	0.32	1	jul
Ikonos	3.2	2005-07-30	2005	0.77	1.7	jul
QB2	2	2006-09-12	2006	0.77	2.05	Sept

SPOT 2	30	2007-08-14	2007	0.44	0.84	Aug
SPOT 4	20	2008-09-16	2008	0.82	1.69	sept
Rapid Eye	5	2009-07-11	2009	0.47	0.82	july
Rapid Eye	5	2010-08-19	2010	0.48	0.97	Aug
WV02	2.5	2011-07-24	2011	0.60	1.8	July
WV02	2.5	2012-09-12	2012	0.62	1.77	Sept
Ortho	0.5	unknown	2013	0.51	unknown	na
Rapid Eye	5	2014-07-14	2014	0.45	0.44	July
PSH	1	2015-08-18	2015	0.61	1.23	Aug
PSH	1	unknown	2016	0.77	unknown	na
WV2	2.5	2017-08-29	2017	0.65	2.13	Aug
Planet	4	2018-08-28	2018	0.47	1.11	Aug
Ortho	0.5	unknown	2019	0.36	unknown	na
Planet	4	2020-08-22	2020	0.37	0.95	Aug
Planet	4	2021-08-23	2021	0.70	0.83	Aug
Planet	4	2022-07-01	2022	0.41	0.5	July

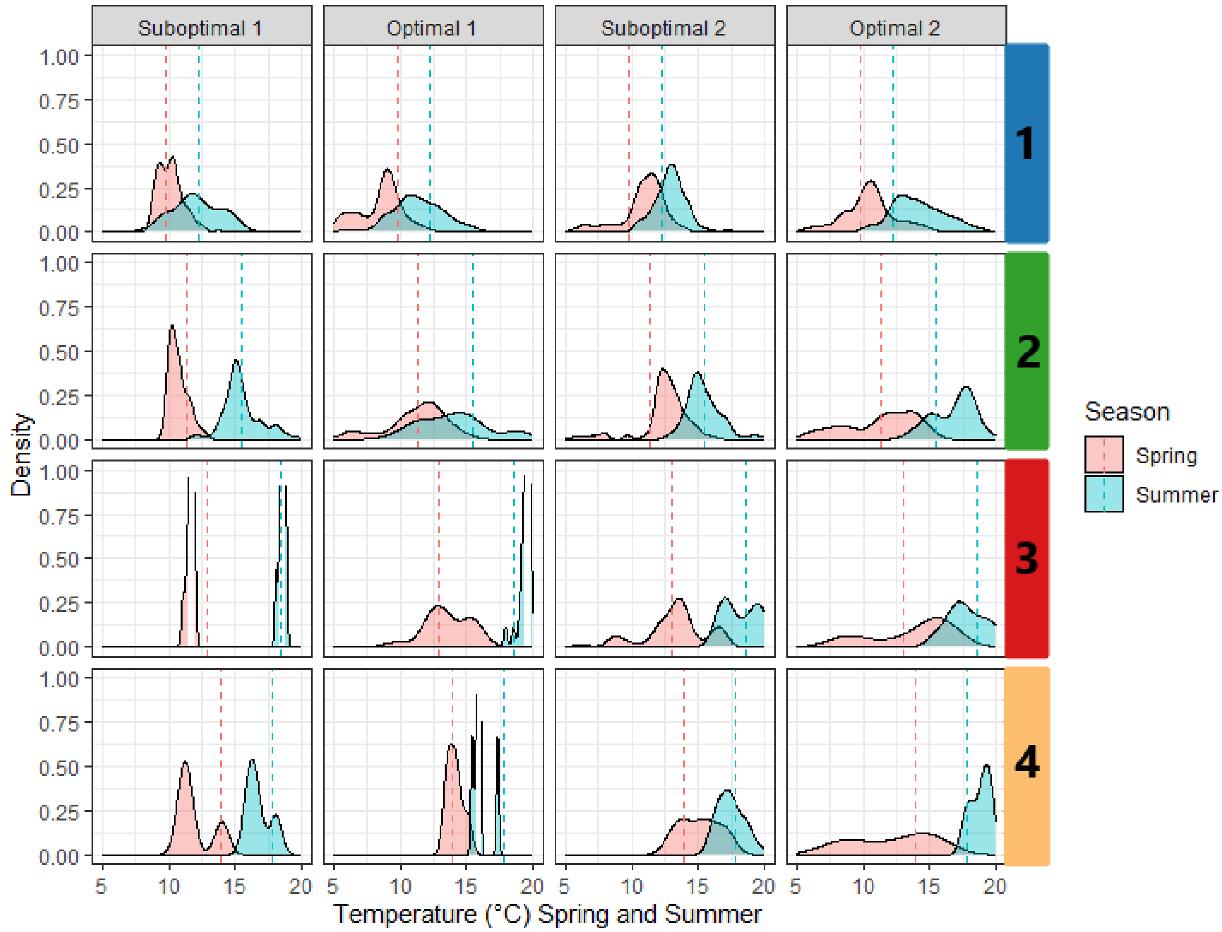

Figure SM3. Density plots for temperature (°C) for spring and summer, in the segments used in the time series per cluster and period (cluster identity indicated with colours). Dashed lines indicate mean climatology per season per cluster.

Table SM5. Spring and summer Landsat-derived SST detailed statistics per cluster and period (illustrated in Figures 4A and 4B).

Cluster	Season	Period	Mean SST	StDev SST	Median SST	Min SST	Max SST	Q25	Q75	n years cluster
1	Spring	Suboptimal 1	10.3	0.8	10.3	9.4	11.5	10.0	10.5	5
		Optimal 1	8.8	2.0	9.4	5.9	11.9	7.6	9.8	7
		Suboptimal 2	10.6	2.2	11.5	6.2	11.9	11.1	11.7	6
		Optimal 2	10.4	2.4	10.6	7.9	12.7	9.2	11.6	3
	Summer	Suboptimal 1	12.6	1.0	12.7	11.3	13.7	11.8	13.2	5
		Optimal 1	11.0	1.9	10.7	8.1	13.4	10.4	12.3	6
		Suboptimal 2	13.3	0.4	13.2	12.8	13.8	13.2	13.5	5
		Optimal 2	14.8	1.5	15.4	13.1	15.8	14.3	15.6	3
2	Spring	Suboptimal 1	11.3	1.1	10.9	9.9	12.9	10.9	12.0	5
		Optimal 1	10.2	2.3	10.6	7.4	13.4	8.3	11.5	7
		Suboptimal 2	12.6	2.2	13.0	8.3	14.4	12.8	13.9	6
		Optimal 2	11.7	2.9	12.5	8.5	14.1	10.5	13.3	3
	Summer	Suboptimal 1	15.1	0.9	15.5	14.0	15.9	14.4	15.8	5
		Optimal 1	14.1	1.7	14.5	12.0	16.0	12.7	15.5	6
		Suboptimal 2	16.2	0.8	15.9	15.4	17.5	15.9	16.5	5
		Optimal 2	17.5	1.5	17.8	15.9	18.8	16.8	18.3	3
3	Spring	Suboptimal 1	12.4	1.8	11.6	10.2	14.6	11.4	14.0	5
		Optimal 1	11.8	3.1	12.3	7.6	16.7	9.7	13.5	7
		Suboptimal 2	13.9	2.8	13.9	8.9	16.6	13.7	15.8	6
		Optimal 2	12.9	3.2	13.4	9.4	15.8	11.4	14.6	3
	Summer	Suboptimal 1	17.9	0.8	17.8	16.9	18.8	17.4	18.5	5
		Optimal 1	17.2	1.7	17.0	15.4	19.5	15.9	18.4	6
		Suboptimal 2	18.9	1.2	19.4	16.9	19.9	18.8	19.6	5
		Optimal 2	19.4	1.2	19.5	18.2	20.5	18.9	20.0	3
4	Spring	Suboptimal 1	13.3	1.7	13.1	11.0	15.1	12.4	14.9	5
		Optimal 1	12.3	3.3	12.4	6.9	16.4	10.7	14.6	7
		Suboptimal 2	16.1	2.1	15.7	12.9	18.6	15.4	17.8	6
		Optimal 2	14.6	2.5	14.8	12.0	17.0	13.4	15.9	3
	Summer	Suboptimal 1	19.1	1.1	18.9	17.6	20.5	18.9	19.7	5
		Optimal 1	18.0	2.4	18.7	14.6	20.3	16.2	19.8	6
		Suboptimal 2	19.9	1.6	19.2	18.3	21.8	18.7	21.3	5
		Optimal 2	20.5	2.2	20.0	18.6	22.9	19.3	21.4	3

Table SM6–9. Marine heatwaves per optimal versus suboptimal periods. N= number of events. (%)= percentage of events category I, II, III and IV compared to the total. Based on the 1984–2022 climatology per lighthouse. Suboptimal 1= 2002 to 2006; Optimal 1= 2007 to 2013; Suboptimal 2= 2014 to 2019; Optimal 2= 2020 to 2022.

Table SM6. Data: Race Rocks Lighthouse.

	Suboptimal 1 (N=12)	Optimal 1 (N=2)	Suboptimal 2 (N=13)	Optimal 2 (N=1)	Overall (N=28)
Category					
I Moderate	9 (75.0%)	0 (0%)	9 (69.2%)	1 (100%)	19 (67.9%)
II Strong	3 (25.0%)	2 (100%)	3 (23.1%)	0 (0%)	8 (28.6%)
IV Extreme	0 (0%)	0 (0%)	1 (7.7%)	0 (0%)	1 (3.6%)
Maximum Intensity (°C)					
Mean (SD)	1.51 (0.350)	1.95 (0.190)	1.63 (0.432)	1.76 (NA)	1.61 (0.385)
Median [Min, Max]	1.45 [1.17, 2.21]	1.95 [1.81, 2.08]	1.58 [1.11, 2.76]	1.76 [1.76, 1.76]	1.54 [1.11, 2.76]
Duration (days)					
Mean (SD)	7.58 (4.03)	7.00 (0)	12.5 (8.84)	5.00 (NA)	9.71 (6.95)
Median [Min, Max]	6.00 [5.00, 19.0]	7.00 [7.00, 7.00]	7.00 [6.00, 33.0]	5.00 [5.00, 5.00]	7.00 [5.00, 33.0]

Table SM7. Marine heatwaves per optimal versus suboptimal periods. Data: Entrance Island Lighthouse.

	Optimal 1 (N=7)	Optimal 2 (N=2)	Suboptimal 1 (N=17)	Suboptimal 2 (N=16)	Overall (N=42)
Category					
I Moderate	5 (71.4%)	2 (100%)	9 (52.9%)	7 (43.8%)	23 (54.8%)
II Strong	1 (14.3%)	0 (0%)	7 (41.2%)	9 (56.3%)	17 (40.5%)
III Severe	1 (14.3%)	0 (0%)	1 (5.9%)	0 (0%)	2 (4.8%)
Maximum Intensity (°C)					
Mean (SD)	3.69 (1.92)	3.02 (0.260)	3.45 (0.993)	2.90 (1.15)	3.26 (1.23)
Median [Min, Max]	2.86 [1.89, 6.50]	3.02 [2.84, 3.20]	3.31 [1.73, 5.29]	2.66 [1.31, 5.91]	2.87 [1.31, 6.50]
Duration (days)					
Mean (SD)	7.29 (2.29)	5.00 (0)	7.59 (3.50)	7.81 (3.10)	7.50 (3.07)
Median [Min, Max]	7.00 [5.00, 12.0]	5.00 [5.00, 5.00]	7.00 [5.00, 19.0]	6.50 [5.00, 14.0]	6.50 [5.00, 19.0]

Table SM8. Marine heatwaves per optimal versus suboptimal periods. Data: Departure Bay Lighthouse.

	Optimal 1 (N=2)	Optimal 2 (N=6)	Suboptimal 1 (N=6)	Suboptimal 2 (N=27)	Overall (N=41)
Category					
I Moderate	2 (100%)	3 (50.0%)	5 (83.3%)	12 (44.4%)	22 (53.7%)
II Strong	0 (0%)	3 (50.0%)	1 (16.7%)	13 (48.1%)	17 (41.5%)
III Severe	0 (0%)	0 (0%)	0 (0%)	2 (7.4%)	2 (4.9%)
Maximum Intensity (°C)					
Mean (SD)	2.64 (0.238)	3.89 (1.00)	2.55 (0.609)	2.83 (1.00)	2.94 (0.998)
Median [Min, Max]	2.64 [2.47, 2.81]	3.88 [2.58, 5.47]	2.56 [1.87, 3.26]	2.67 [1.16, 4.89]	2.80 [1.16, 5.47]
Duration (days)					
Mean (SD)	6.50 (2.12)	6.67 (1.86)	5.67 (0.816)	10.3 (7.95)	8.93 (6.76)
Median [Min, Max]	6.50 [5.00, 8.00]	6.50 [5.00, 9.00]	5.50 [5.00, 7.00]	7.00 [5.00, 39.0]	6.00 [5.00, 39.0]

Table SM9. Marine heatwaves per optimal versus suboptimal periods. Data: ALL.

	Suboptimal 1 (N=35)	Optimal 1 (N=11)	Suboptimal 2 (N=56)	Optimal 2 (N=9)	Overall (N=111)
Category					
I Moderate	23 (65.7%)	7 (63.6%)	28 (50.0%)	6 (66.7%)	64 (57.7%)
II Strong	11 (31.4%)	3 (27.3%)	25 (44.6%)	3 (33.3%)	42 (37.8%)
III Severe	1 (2.9%)	1 (9.1%)	2 (3.6%)	0 (0%)	4 (3.6%)
IV Extreme	0 (0%)	0 (0%)	1 (1.8%)	0 (0%)	1 (0.9%)
Maximum Intensity (°C)					
Mean (SD)	2.63 (1.16)	3.18 (1.66)	2.57 (1.07)	3.46 (1.09)	2.72 (1.19)
Median [Min, Max]	2.47 [1.17, 5.29]	2.64 [1.81, 6.50]	2.43 [1.11, 5.91]	3.23 [1.76, 5.47]	2.58 [1.11, 6.50]
Duration (days)					
Mean (SD)	7.26 (3.42)	7.09 (1.92)	10.1 (7.24)	6.11 (1.69)	8.59 (5.73)
Median [Min, Max]	6.00 [5.00, 19.0]	7.00 [5.00, 12.0]	7.00 [5.00, 39.0]	5.00 [5.00, 9.00]	7.00 [5.00, 39.0]
lighthouse					
Departure Bay	6 (17.1%)	2 (18.2%)	27 (48.2%)	6 (66.7%)	41 (36.9%)
Entrance Island	17 (48.6%)	7 (63.6%)	16 (28.6%)	2 (22.2%)	42 (37.8%)
Race Rocks	12 (34.3%)	2 (18.2%)	13 (23.2%)	1 (11.1%)	28 (25.2%)

Table SM10. Marine heatwaves, listed individually. Data: Race Rocks Lighthouse.

Event number	Event name	Peak date	category	Intensity max (°C)	Duration (days)	% moderate	% strong	% severe	% extreme	season
1	NA	1983-02-02	I Moderate	1.41	5	100	0	0	0	Winter
2	RR 1983a	1983-03-17	II Strong	2.17	6	50	50	0	0	Winter
3	RR 1983b	1983-03-25	II Strong	1.92	8	62	38	0	0	Winter/Spring
4	RR 1983c	1983-04-13	II Strong	2.27	7	14	86	0	0	Spring
5	RR 1983d	1983-06-07	III Severe	3.08	9	78	11	11	0	Spring
6	RR 1983e	1983-08-04	III Severe	3.10	5	20	60	20	0	Summer
7	RR 1983f	1983-08-21	III Severe	2.68	6	50	33	17	0	Summer
8	RR 1984	1984-07-24	IV Extreme	3.33	5	40	20	20	20	Summer
9	NA	1990-07-18	I Moderate	1.64	7	100	0	0	0	Summer
10	NA	1990-09-03	I Moderate	1.42	6	100	0	0	0	Summer
11	NA	1990-09-29	I Moderate	1.24	24	100	0	0	0	Summer/Fall
12	NA	1990-11-11	I Moderate	1.30	16	100	0	0	0	Fall
13	NA	1990-12-14	I Moderate	1.20	9	100	0	0	0	Fall
14	NA	1992-03-19	I Moderate	1.63	25	100	0	0	0	Winter
15	NA	1992-03-31	I Moderate	1.69	6	100	0	0	0	Winter/Spring
16	NA	1995-06-27	I Moderate	1.19	7	100	0	0	0	Spring
17	NA	1995-09-22	I Moderate	1.43	6	100	0	0	0	Summer
18	NA	1995-12-17	I Moderate	0.97	11	100	0	0	0	Fall
19	NA	1996-01-03	I Moderate	1.19	6	100	0	0	0	Fall/Winter
20	NA	1996-01-15	I Moderate	1.17	9	100	0	0	0	Winter
21	NA	1997-05-18	I Moderate	1.29	9	100	0	0	0	Spring
22	RR 1997a	1997-08-13	II Strong	2.17	11	55	45	0	0	Summer
23	RR 1997b	1997-10-12	II Strong	1.70	30	70	30	0	0	Fall
24	NA	1997-11-29	I Moderate	1.27	24	92	0	0	0	Fall
25	RR 1997c	1997-12-29	II Strong	1.82	29	90	10	0	0	Fall/Winter
26	RR 1998a	1998-03-02	II Strong	2.04	117	91	3	0	0	Winter/Spring
27	RR 1998b	1998-06-05	II Strong	1.83	5	60	40	0	0	Spring
28	NA	1998-06-21	I Moderate	1.34	5	100	0	0	0	Spring
29	RR 1998c	1998-09-04	II Strong	1.83	11	55	45	0	0	Summer
30	NA	1998-09-18	I Moderate	1.13	7	100	0	0	0	Summer
31	NA	1998-09-30	I Moderate	1.48	9	100	0	0	0	Summer/Fall
32	RR 1998d	1998-11-17	II Strong	1.69	34	82	6	0	0	Fall
33	RR 1999	1999-09-21	II Strong	2.00	8	75	25	0	0	Summer
34	RR 2000	2000-06-27	IV Extreme	3.89	5	60	0	20	20	Spring
35	NA	2002-12-25	I Moderate	1.05	7	100	0	0	0	Fall
36	NA	2003-01-04	I Moderate	1.20	9	100	0	0	0	Winter

37	NA	2003-02-01	I Moderate	1.31	19	95	0	0	0	Winter
38	NA	2003-02-18	I Moderate	1.18	5	100	0	0	0	Winter
39	RR 2003	2003-10-28	III Severe	2.01	10	70	20	10	0	Fall
40	NA	2004-05-16	I Moderate	1.45	6	100	0	0	0	Spring
41	NA	2004-06-30	I Moderate	1.32	5	100	0	0	0	Spring
42	NA	2004-07-28	I Moderate	1.37	5	100	0	0	0	Summer
43	RR 2004	2004-10-14	II Strong	1.87	7	86	14	0	0	Fall
44	RR 2005a	2005-04-25	II Strong	1.71	5	80	20	0	0	Spring
45	NA	2005-05-04	I Moderate	1.52	6	100	0	0	0	Spring
46	RR 2005b	2005-06-01	II Strong	2.23	17	65	24	0	0	Spring
47	NA	2006-02-02	I Moderate	1.21	5	100	0	0	0	Winter
48	NA	2006-08-04	I Moderate	1.20	5	100	0	0	0	Summer
49	NA	2006-09-02	I Moderate	1.50	5	100	0	0	0	Summer
50	RR 2009	2009-10-04	II Strong	1.81	7	86	14	0	0	Fall
51	RR 2010	2010-02-28	II Strong	2.08	8	88	12	0	0	Winter
52	RR 2014	2014-10-24	IV Extreme	2.76	22	41	55	0	5	Fall
53	NA	2014-12-24	I Moderate	1.13	12	100	0	0	0	Fall
54	NA	2015-01-06	I Moderate	1.12	7	100	0	0	0	Winter
55	NA	2015-02-14	I Moderate	1.40	26	100	0	0	0	Winter
56	NA	2015-04-03	I Moderate	1.03	5	100	0	0	0	Winter/Spring
57	NA	2015-06-24	I Moderate	1.57	9	100	0	0	0	Spring/Summer
58	NA	2015-07-26	I Moderate	1.40	7	100	0	0	0	Summer
59	RR 2015	2015-08-26	II Strong	1.82	13	92	8	0	0	Summer
60	RR 2016a	2016-04-20	II Strong	1.67	7	86	14	0	0	Spring
61	RR 2016b	2016-08-19	II Strong	1.67	10	70	30	0	0	Summer
62	NA	2016-09-11	I Moderate	1.47	6	100	0	0	0	Summer
63	RR 2016c	2016-11-10	II Strong	1.56	21	81	14	0	0	Fall
64	RR 2016d	2016-11-29	II Strong	1.57	9	78	22	0	0	Fall
65	NA	2017-06-22	I Moderate	1.61	6	100	0	0	0	Spring
66	NA	2019-06-25	I Moderate	1.24	5	100	0	0	0	Spring

Table SM11. Marine heatwaves, listed individually. Data: Entrance Island Lighthouse.

Event number	Event name	Peak date	category	Intensity max (°C)	Duration (days)	% moderate	% strong	% severe	% extreme	season
1	NA	1984-01-04	I Moderate	2.01	6	100	0	0	0	Fall/Winter
2	NA	1984-02-12	I Moderate	1.65	6	100	0	0	0	Winter
3	NA	1987-10-21	I Moderate	1.51	5	100	0	0	0	Fall
4	NA	1987-12-08	I Moderate	1.30	5	100	0	0	0	Fall
5	NA	1989-04-30	I Moderate	3.60	5	100	0	0	0	Spring
6	NA	1989-09-12	I Moderate	3.45	6	100	0	0	0	Summer
9	NA	1990-09-26	I Moderate	2.24	6	100	0	0	0	Summer/Fall
12	NA	1993-10-14	I Moderate	2.09	6	100	0	0	0	Fall
15	NA	1994-09-25	I Moderate	2.81	6	100	0	0	0	Summer
16	NA	1995-04-26	I Moderate	3.03	5	100	0	0	0	Spring
18	NA	1995-09-23	I Moderate	3.45	11	100	0	0	0	Summer
20	NA	1997-12-16	I Moderate	1.91	10	100	0	0	0	Fall
25	NA	2003-01-26	I Moderate	1.73	10	100	0	0	0	Winter
26	NA	2003-06-28	I Moderate	3.19	5	100	0	0	0	Spring
27	NA	2003-09-27	I Moderate	2.47	5	100	0	0	0	Summer
29	NA	2004-04-17	I Moderate	2.94	11	100	0	0	0	Spring
32	NA	2004-06-18	I Moderate	3.31	7	100	0	0	0	Spring
33	NA	2004-07-16	I Moderate	3.64	6	100	0	0	0	Summer
34	NA	2004-08-14	I Moderate	3.91	8	100	0	0	0	Summer
35	NA	2004-09-28	I Moderate	2.79	5	100	0	0	0	Summer
38	NA	2005-06-23	I Moderate	3.96	5	100	0	0	0	Spring
43	NA	2007-09-10	I Moderate	2.64	6	100	0	0	0	Summer
44	NA	2008-06-19	I Moderate	3.24	6	100	0	0	0	Spring
47	NA	2011-09-09	I Moderate	2.34	5	100	0	0	0	Summer
48	NA	2012-07-19	I Moderate	2.86	7	100	0	0	0	Summer
49	NA	2014-10-05	I Moderate	2.94	6	100	0	0	0	Fall
53	NA	2015-03-13	I Moderate	1.31	7	100	0	0	0	Winter
54	NA	2015-04-24	I Moderate	2.04	5	100	0	0	0	Spring
55	NA	2015-05-20	I Moderate	4.36	9	100	0	0	0	Spring
56	NA	2015-06-09	I Moderate	3.54	6	100	0	0	0	Spring
60	NA	2016-03-05	I Moderate	1.87	5	100	0	0	0	Winter
63	NA	2016-05-06	I Moderate	2.87	5	100	0	0	0	Spring
65	NA	2021-08-02	I Moderate	3.20	5	100	0	0	0	Summer
66	NA	2022-07-31	I Moderate	2.84	5	100	0	0	0	Summer
58	EI 2015d	2015-10-18	II Strong	2.42	14	93	7	0	0	Fall
46	NA	2010-01-12	I Moderate	1.89	12	92	0	0	0	Winter

21	EI 1998a	1998-05-04	II Strong	4.18	10	90	10	0	0	Spring
40	EI 2006a	2006-01-30	II Strong	2.12	8	88	12	0	0	Winter
7	EI 1990a	1990-04-07	II Strong	2.66	7	86	14	0	0	Spring
23	EI 1998c	1998-09-01	II Strong	4.42	7	86	14	0	0	Summer
52	EI 2015b	2015-02-09	II Strong	2.66	14	86	14	0	0	Winter
64	EI 2016c	2016-11-09	II Strong	1.72	7	86	14	0	0	Fall
13	EI 1994a	1994-05-07	II Strong	4.37	6	83	17	0	0	Spring
17	EI 1995	1995-05-28	II Strong	4.67	6	83	17	0	0	Spring
19	EI 1997	1997-11-28	II Strong	2.12	6	83	17	0	0	Fall
24	EI 2001	2001-07-04	II Strong	5.93	6	83	17	0	0	Spring/Summer
57	EI 2015c	2015-06-29	II Strong	5.91	6	83	17	0	0	Spring/Summer
8	EI 1990b	1990-08-03	II Strong	4.30	11	82	18	0	0	Summer
41	EI 2006b	2006-07-21	II Strong	4.36	5	80	20	0	0	Summer
30	EI 2004b	2004-04-30	II Strong	4.00	8	75	25	0	0	Spring
39	EI 2005b	2005-12-24	II Strong	2.75	19	74	26	0	0	Fall/Winter
10	EI 1991	1991-08-21	II Strong	4.07	7	71	29	0	0	Summer
11	EI 1992	1992-04-01	III Severe	3.51	23	70	17	9	0	Winter/Spring
14	EI 1994b	1994-07-20	II Strong	4.31	6	67	33	0	0	Summer
62	EI 2016b	2016-04-20	II Strong	4.30	5	60	40	0	0	Spring
37	EI 2005a	2005-04-26	II Strong	5.03	9	56	44	0	0	Spring
31	EI 2004c	2004-05-18	II Strong	5.29	6	50	50	0	0	Spring
51	EI 2015a	2015-01-24	II Strong	2.74	12	50	50	0	0	Winter
61	EI 2016a	2016-04-02	II Strong	2.66	6	50	50	0	0	Winter/Spring
45	EI 2009	2009-07-28	III Severe	6.50	8	50	12	38	0	Summer
59	EI 2015e	2015-12-06	II Strong	2.61	9	44	56	0	0	Fall
22	EI 1998b	1998-08-03	II Strong	4.50	7	43	57	0	0	Summer
50	EI 2014	2014-11-04	II Strong	2.46	9	33	67	0	0	Fall
28	EI 2004a	2004-04-03	II Strong	2.80	7	29	71	0	0	Spring
36	EI 2004d	2004-10-14	III Severe	4.39	5	20	60	20	0	Fall
42	EI 2007	2007-06-03	II Strong	6.37	7	14	86	0	0	Spring

Table SM12. Marine heatwaves, listed individually. Data: Departure Bay Lighthouse.

Event number	Event name	Peak date	category	Intensity max (°C)	Duration (days)	% moderate	% strong	% severe	% extreme	season
1	NA	1983-02-21	I Moderate	1.2115	6	100	0	0	0	Winter
2	NA	1983-03-16	I Moderate	1.9471	8	100	0	0	0	Winter
3	NA	1987-09-01	I Moderate	3.5891	8	100	0	0	0	Summer
4	DB 1987	1987-10-01	II Strong	3.2816	23	91	4	0	0	Summer/Fall
5	DB 1989a	1989-05-04	II Strong	4.1356	6	83	17	0	0	Spring
6	DB 1989b	1989-05-15	II Strong	4.053	5	80	20	0	0	Spring
7	NA	1989-09-14	I Moderate	3.007	7	100	0	0	0	Summer
8	NA	1989-09-24	I Moderate	2.6394	5	100	0	0	0	Summer
9	NA	1990-06-22	I Moderate	3.7289	5	100	0	0	0	Spring
10	NA	1990-07-11	I Moderate	2.8868	5	100	0	0	0	Summer
11	DB 1990	1990-08-12	II Strong	4.6548	16	75	19	0	0	Summer
12	NA	1990-09-29	I Moderate	2.7447	8	100	0	0	0	Summer/Fall
13	NA	1991-08-21	I Moderate	3.7367	8	100	0	0	0	Summer
14	DB 1991	1991-09-18	II Strong	3.6414	6	83	17	0	0	Summer
15	NA	1991-10-15	I Moderate	1.8987	5	100	0	0	0	Fall
16	NA	1992-03-02	I Moderate	1.8732	7	100	0	0	0	Winter
17	DB 1992	1992-04-01	II Strong	3.5771	25	88	8	0	0	Winter/Spring
18	NA	1993-02-11	I Moderate	1.437	5	100	0	0	0	Winter
19	NA	1993-03-06	I Moderate	1.9554	5	100	0	0	0	Winter
20	NA	1993-06-05	I Moderate	2.6514	6	100	0	0	0	Spring
21	DB 1993	1993-09-10	II Strong	4.012	8	88	12	0	0	Summer
22	NA	1993-10-11	I Moderate	2.2482	5	100	0	0	0	Fall
23	NA	1994-01-14	I Moderate	1.8445	5	100	0	0	0	Winter
24	DB 1994	1994-07-23	II Strong	4.4131	5	60	40	0	0	Summer
25	NA	1994-09-29	I Moderate	3.0447	5	100	0	0	0	Summer
26	DB 1995	1995-09-23	II Strong	3.9181	6	50	50	0	0	Summer
27	NA	1997-08-14	I Moderate	2.9469	5	100	0	0	0	Summer
28	DB 1998a	1998-05-06	II Strong	4.0188	6	83	17	0	0	Spring
29	NA	1998-08-03	I Moderate	3.5291	8	100	0	0	0	Summer
30	DB 1998b	1998-09-03	II Strong	3.7676	10	90	10	0	0	Summer
31	DB 2001	2001-07-04	II Strong	4.531	6	67	33	0	0	Spring/Summer
32	NA	2004-05-02	I Moderate	3.1502	6	100	0	0	0	Spring
33	NA	2004-06-19	I Moderate	3.2569	5	100	0	0	0	Spring
34	NA	2004-08-13	I Moderate	2.7995	5	100	0	0	0	Summer
35	NA	2005-01-24	I Moderate	1.8684	6	100	0	0	0	Winter

36	NA	2005-03-10	I Moderate	1.9106	7	100	0	0	0	Winter
37	DB 2005	2005-12-25	II Strong	2.3125	5	80	20	0	0	Fall
38	NA	2012-07-17	I Moderate	2.4693	8	100	0	0	0	Summer
39	NA	2013-09-13	I Moderate	2.8052	5	100	0	0	0	Summer
40	NA	2014-08-28	I Moderate	3.0398	6	100	0	0	0	Summer
41	NA	2014-10-08	I Moderate	2.7023	6	100	0	0	0	Fall
42	DB 2015a	2015-01-24	III Severe	4.1684	39	38	44	13	0	Winter
43	DB 2015b	2015-03-26	II Strong	2.8857	23	74	26	0	0	Winter
44	NA	2015-04-07	I Moderate	2.5044	5	100	0	0	0	Spring
45	DB 2015c	2015-06-08	II Strong	4.8926	24	38	46	0	0	Spring
46	DB 2015d	2015-06-30	II Strong	4.4196	7	71	29	0	0	Spring/Summer
47	DB 2015e	2015-10-26	II Strong	2.0727	14	86	7	0	0	Fall
48	NA	2015-11-06	I Moderate	1.4537	5	100	0	0	0	Fall
49	DB 2015f	2015-12-07	II Strong	2.2884	9	78	22	0	0	Fall
50	DB 2016a	2016-01-28	II Strong	2.6655	13	62	38	0	0	Winter
51	DB 2016b	2016-02-10	II Strong	2.1417	15	80	20	0	0	Winter
52	DB 2016c	2016-02-28	III Severe	3.3526	10	90	0	10	0	Winter
53	DB 2016d	2016-04-03	II Strong	2.8603	5	80	20	0	0	Winter/Spring
54	NA	2016-04-10	I Moderate	2.3999	5	100	0	0	0	Spring
55	DB 2016e	2016-04-21	II Strong	4.5112	16	69	19	0	0	Spring
56	NA	2016-07-26	I Moderate	3.2251	5	100	0	0	0	Summer
57	DB 2016f	2016-11-09	II Strong	2.1843	11	45	55	0	0	Fall
58	NA	2017-02-19	I Moderate	1.8476	5	100	0	0	0	Winter
59	DB 2017	2017-09-05	II Strong	4.4488	7	86	14	0	0	Summer
60	NA	2017-11-01	I Moderate	1.1592	5	100	0	0	0	Fall
61	DB 2018a	2018-01-13	II Strong	2.4404	15	73	20	0	0	Winter
62	DB 2018b	2018-02-04	II Strong	2.2558	9	78	22	0	0	Winter
63	NA	2018-05-26	I Moderate	3.1772	5	100	0	0	0	Spring
64	NA	2019-04-03	I Moderate	2.2603	5	100	0	0	0	Spring
65	NA	2019-06-14	I Moderate	3.7646	5	100	0	0	0	Spring
66	NA	2019-11-18	I Moderate	1.4076	5	100	0	0	0	Fall
67	DB 2020	2020-05-11	II Strong	4.179	5	60	40	0	0	Spring
68	NA	2020-05-29	I Moderate	3.2261	5	100	0	0	0	Spring
69	DB 2021a	2021-06-28	II Strong	5.4741	9	56	44	0	0	Spring
70	NA	2021-07-13	I Moderate	2.5765	5	100	0	0	0	Summer
71	DB 2021b	2021-08-02	II Strong	4.3279	8	62	38	0	0	Summer
72	NA	2022-08-26	I Moderate	3.58	8	100	0	0	0	Summer

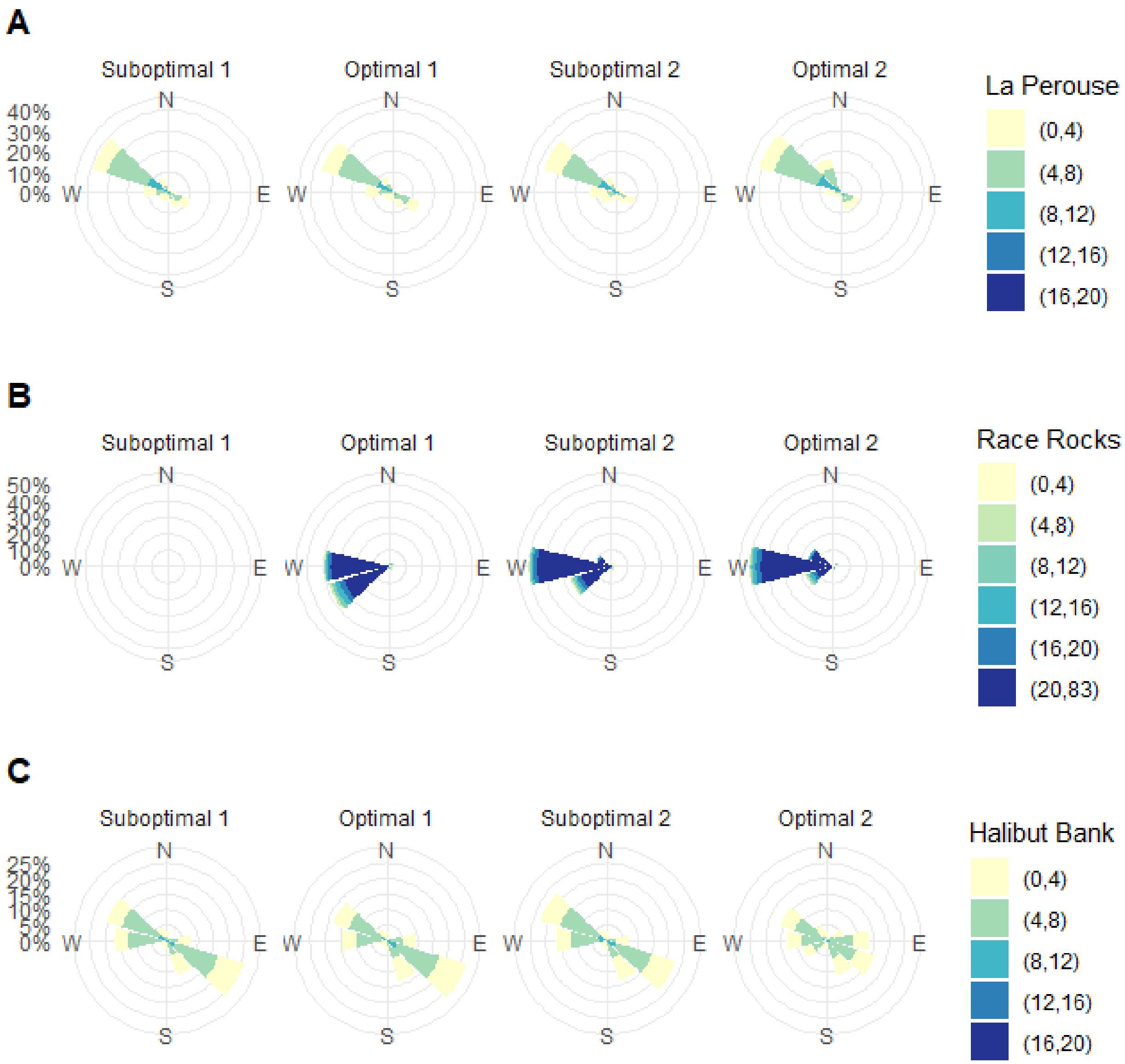

Figure SM4. Wind roses indicating main speeds (km/h) and predominant directions (%) for A) La Perouse Bank (Pacific Offshore), B) Race Rocks, C) Halibut Bank-Strait of Georgia. (Race Rocks wind data started in 2011.)

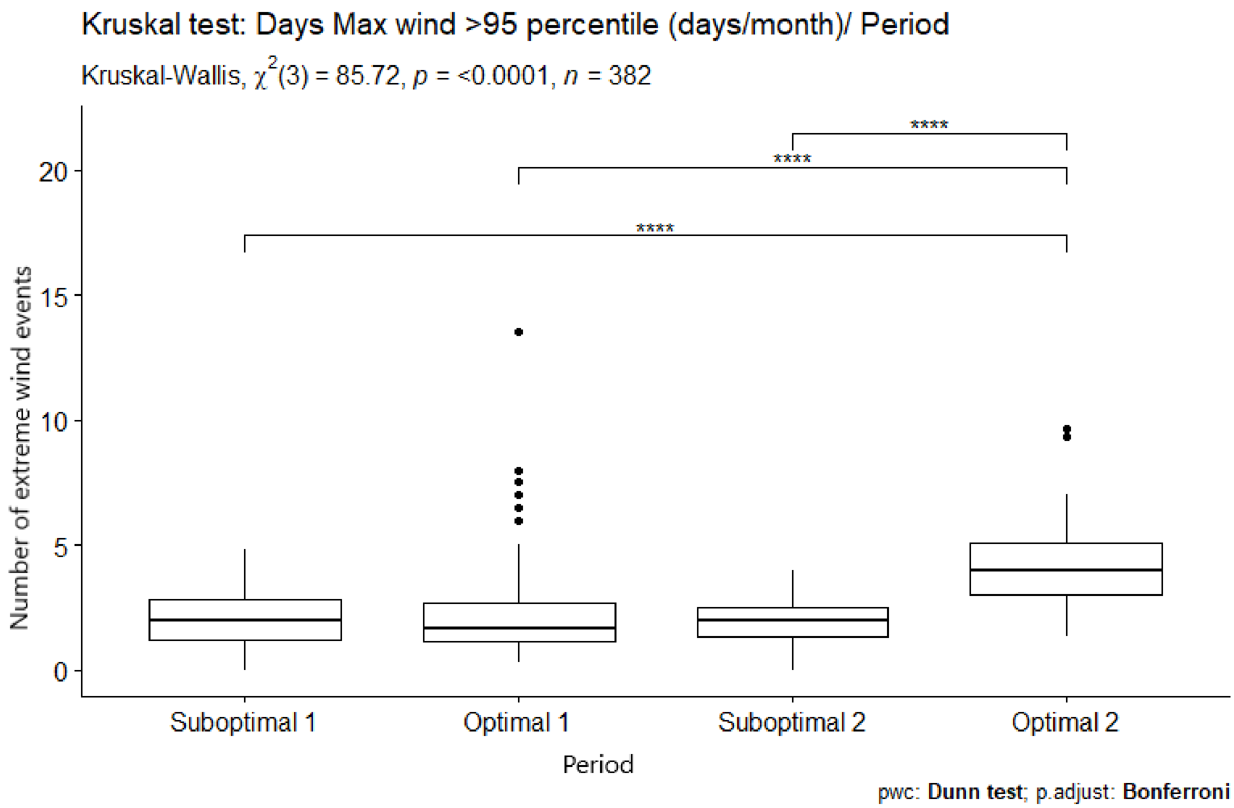

Figure SM5. Kruskal-Wallis and Dunn test for days with maximum wind above 2 StDev for optimal and suboptimal periods (Halibut Bank and Race Rocks). The (*) symbol indicates the level of significance ($p < 0.05$).

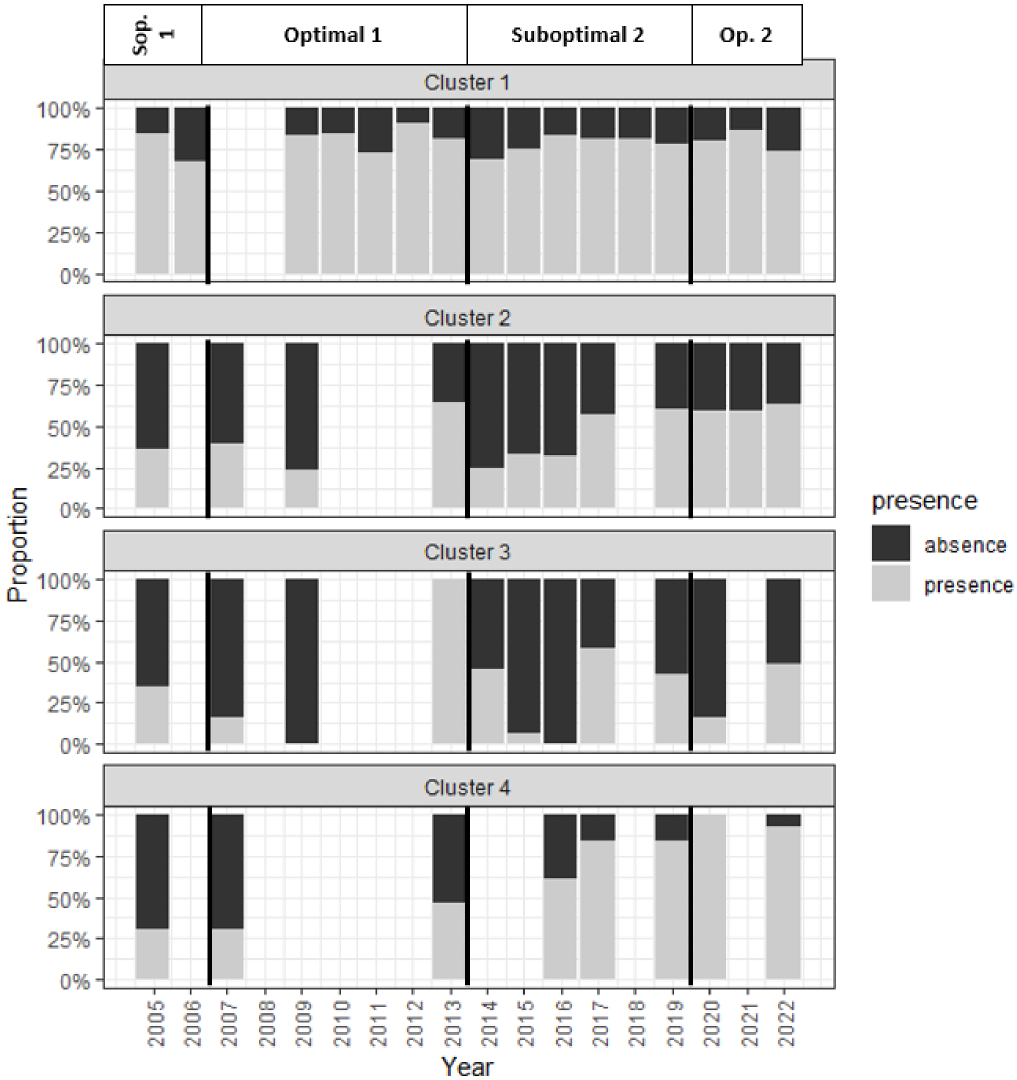

Figure SM6. Proportion of presence and documented absence of kelp records on segments per clusters and years. The absence of bars indicates that there is no satellite image/no data available.