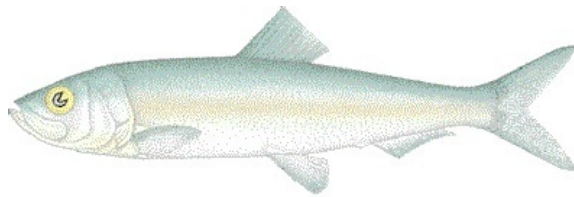


Pacific herring preliminary data summary for Strait of Georgia 2016

DFO Science*

June 16, 2017



Pacific herring (*Clupea pallasii*). Image credit: Fisheries and Oceans Canada (www.pac.dfo-mpo.gc.ca).

Disclaimer This report contains preliminary data. Therefore, the data may differ from data used and presented in the final Pacific herring stock assessment for Strait of Georgia 2016.

1 Context

Pacific herring (*Clupea pallasii*) in British Columbia are assessed as 5 major and 2 minor stock assessment regions (SARs), and data are collected and summarized on this scale (Table 1, Figure 1). The Pacific herring data collection program includes fishery-dependent and -independent data from 1951 to 2016. This includes annual time series of commercial catch data, biological samples (providing information on proportion-at-age and weight-at-age), and spawn index data (conducted using a combination of surface and SCUBA surveys). In some areas, industry- and/or First Nations-operated in-season soundings programs are also conducted, and this information is used by resource managers, First Nations, and stakeholders to locate fish and identify areas of high and low herring biomass to plan harvesting activities. In-season acoustic soundings are not used by stock assessment to inform the estimation of spawning biomass.

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The following is a description of data collected for Pacific herring in the Strait of Georgia major SAR in 2016 (Figure 2). Data collected outside the SAR boundary are not included in this summary, and are not used for the purposes of stock assessment. Note that we refer to ‘year’ instead of ‘herring season’ in this report; therefore 2016 refers to the 2015/2016 herring season.

2 Data collection programs

Biological samples were collected by the seine charter vessel “Denman Isle” for 29 days from February 22nd to March 21st. Four additional Industry test vessels collected biological samples between February 24th to March 11th. The primary purpose of the test charter vessel was to collect biological samples from main bodies of herring in Statistical Areas 14 and 17, identified from soundings.

Herring spawn locations were primarily identified with fixed-wing overflights conducted by DFO Resource Management Area staff. Twenty-seven flights were conducted this season, February-April. Four dive charter vessels operated in the SOG:

- The charter vessel “Viking Spirit” surveyed 21 days from March 14th to April 7th.
- The charter vessel “Ocean Cloud” surveyed 12 days from March 21st to March 23rd.
- The “Seaveyor” surveyed 3 days in the Strait of Georgia.
- The “Waterbear” surveyed 3 days in the Strait of Georgia.

All four dive vessels and the seine charter vessel “Denman Isle” were funded by DFO, through a contract to the Herring Conservation Research Society (HCRS). Additional sampling and sounding efforts conducted through the Industry Test Program were funded by the Herring Industry.

3 Catch and biological samples

There were commercial fishing opportunities for seine, gillnet, food and bait and special use in 2016 in the Strait of Georgia major stock area. The total landed commercial catch of Pacific herring from all fisheries in 2016 in the Strait of Georgia major SAR was 21,310 t, which is 6.7% more than last year (Table 2 and Figure 3). The total harvested spawn on kelp (SOK) in 2016 in the Strait of Georgia major SAR was 0 lb, which is associated with an estimated spawning biomass of 0 t (Table 3). We use the following equation to convert SOK harvest to spawning biomass [ref?]

$$SB = SOK \cdot 0.00832 \quad (1)$$

where SOK is SOK harvest in pounds, and SB is spawning biomass in tonnes.

In 2016, 161 Pacific herring biological samples were collected and processed for the Strait of Georgia major SAR (Table 4, Table 5), and a total of 8,853 Pacific herring

were aged in 2016. The locations in which the biological samples were collected are presented in Figure 4. Biological samples collected using seine gear shows that there is considerable variability in fish weight by year and sample type (Figure 5). Included herein are biological summaries of observed proportion-, number-, and weight-at-age (Figure 6, Table 6, and Figure 7, respectively). Biological summaries only include samples collected using seine nets (commercial and test) due to size-selectivity of other gear types such as gillnet.

4 Spawn survey data

Herring spawn surveys were conducted at 50 locations in 2016 in the Strait of Georgia major SAR (Table 7, Figure 8). Spawn surveys are conducted to estimate the spawn length, width, number of layers, and substrate type, and these data are used to estimate the index of spawning biomass (i.e., the spawn index; Figure 9, Figure 10, Figure 11, Figure 12, and Table 8). The ‘spawn index’ represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q . Therefore, these data do not represent model estimates of spawning biomass, and are considered the minimum observed spawning biomass derived from egg counts. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2016).

Some herring Sections contribute more than others to the total spawn index, and the percentage contributed by Section varies yearly (Figure 12b, Figure 13). For example, in 2016, Section 142 contributed the most to the spawn index (74%). As with Sections, some Groups contribute more than others to the total spawn index (Figure 12c, Figure 14).

5 General observations

General observations provide context to the data summary report. The following observations were reported by area DFO Resource Management staff, and DFO Science staff:

- StatArea 14: The majority of herring spawning occurred on the east-side of Denman Island ($\geq 55,000$ tonnes). This area saw an average ~ 2 to 4 layers. Transect width was larger than the average transect width.
- Total spawn length was below average (~ 40 km), but the average spawn width is the highest observed (165 m vs. 95 m average).
- An early spawn (January and early Feb) was reported at Rath Trevor, Booth Bay, Squamish and US side of Boundary Bay. These spawns were not surveyed and are recorded as incomplete records.
- StatArea 15: A spawn was reported on the Sunshine coast near Sechelt (between Wilson and Roberts Creek). This spawn was not surveyed and is recorded as an incomplete record.

Table 1. Pacific herring stock assessment regions (SARs) in British Columbia.

Name	Code	Type
Haida Gwaii	HG	Major
Prince Rupert District	PRD	Major
Central Coast	CC	Major
Strait of Georgia	SoG	Major
West Coast of Vancouver Island	WCVI	Major
Area 27	A27	Minor
Area 2 West	A2W	Minor

Table 2. Total landed commercial catch of Pacific herring in metric tonnes (t) by fishery in 2016 in the Strait of Georgia major stock assessment region (SAR).

Fishery	Use	Catch (t)
Gillnet	Roe	6,133
Seine	Bait	490
Seine	Food	7,060
Seine	Roe	7,627

Table 3. Total harvested Pacific herring spawn on kelp (SOK) in pounds (lb), and the associated estimate of spawning biomass in metric tonnes (t) from 2006 to 2016 in the Strait of Georgia major stock assessment region (SAR).

Year	Harvest (lb)	Spawning biomass (t)
2006	0	0
2007	0	0
2008	0	0
2009	0	0
2010	0	0
2011	0	0
2012	0	0
2013	0	0
2014	0	0
2015	0	0
2016	0	0

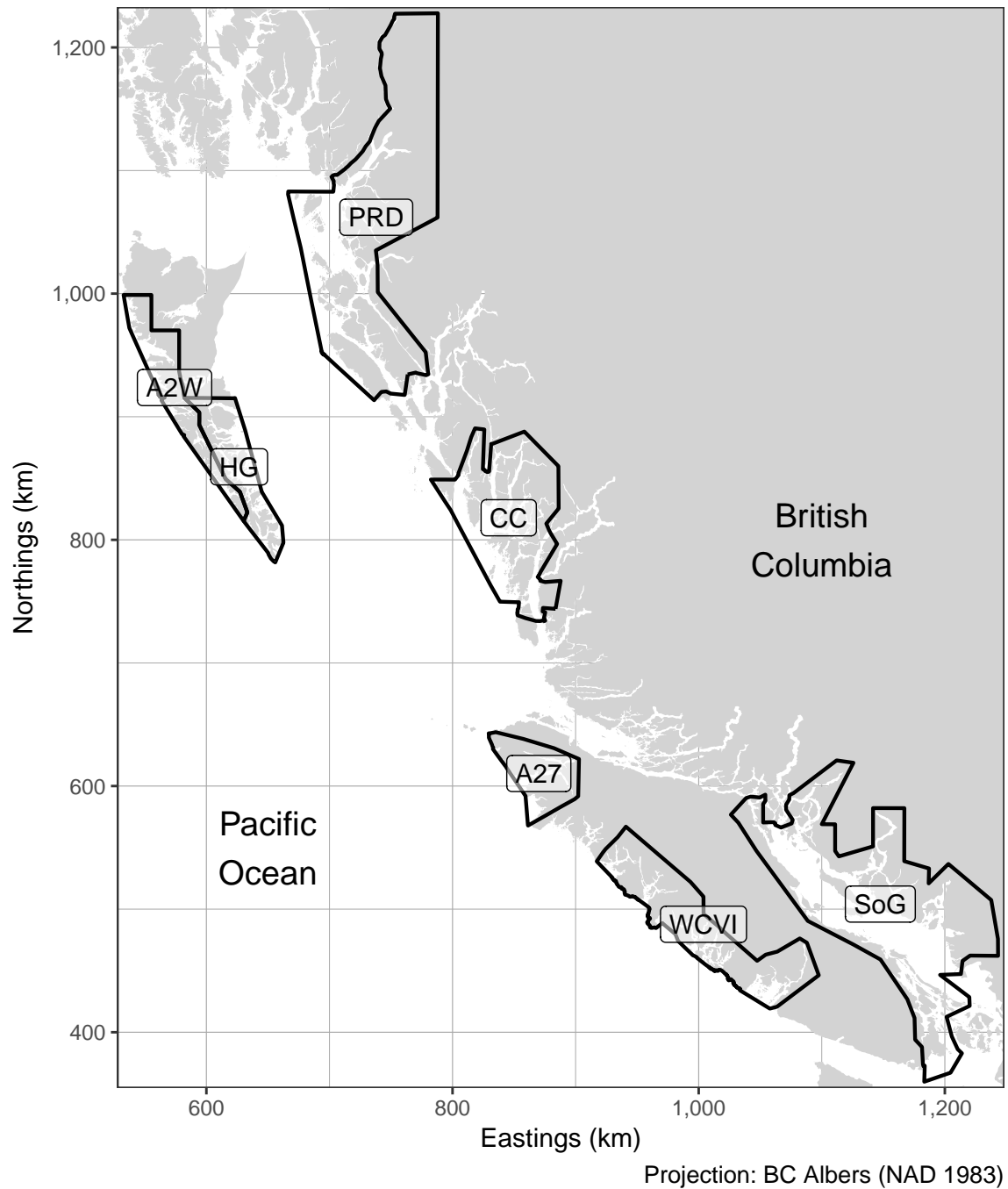


Figure 1. Boundaries for the Pacific herring stock assessment regions (SARs) in British Columbia: there are 5 major SARs (HG, PRD, CC, SoG, and WCVI), and 2 minor SARs (A27 and A2W). Units: kilometres (km). Also see Table 1.

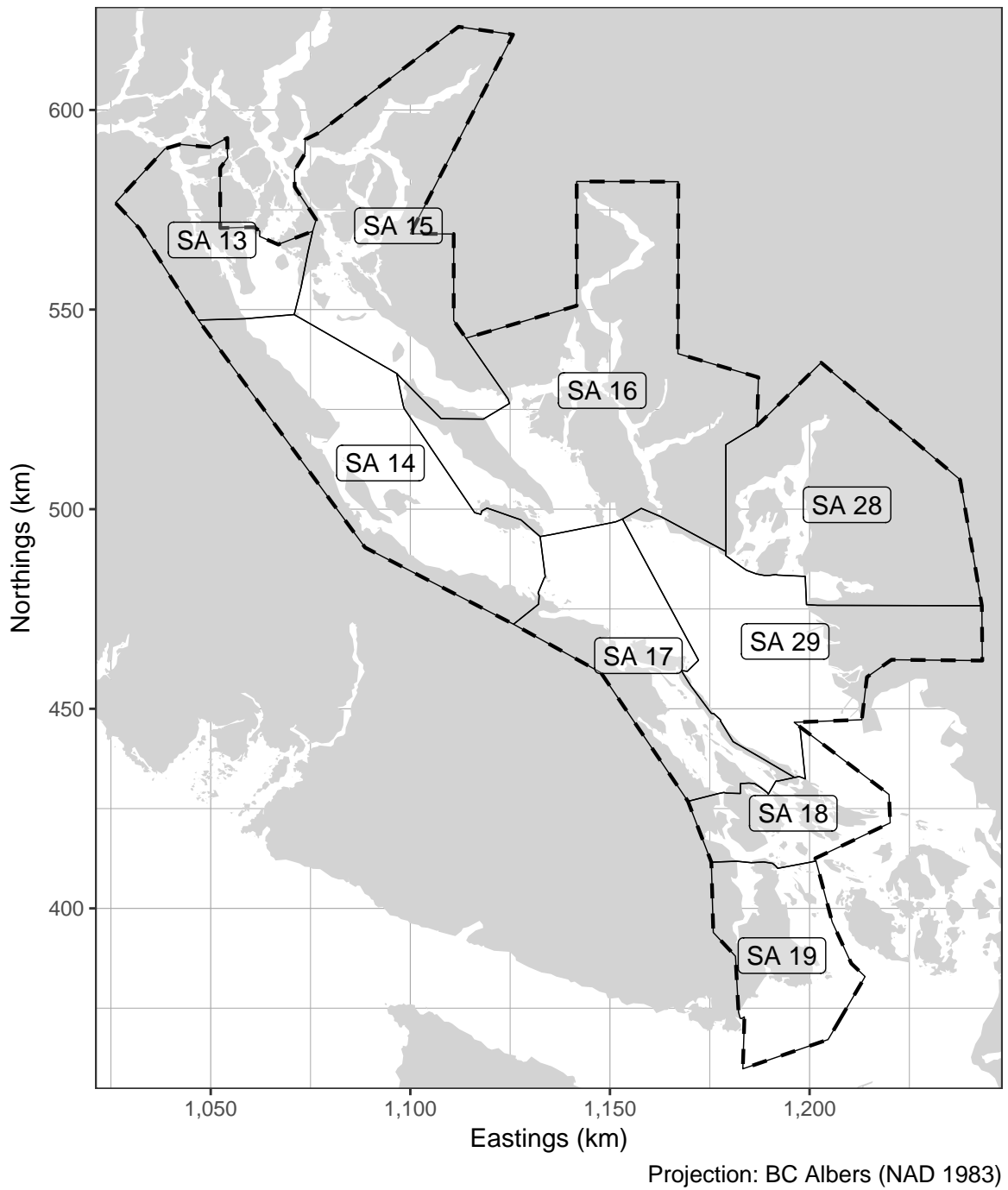


Figure 2. Boundaries for the Strait of Georgia major stock assessment region (SAR; thick dashed lines), and associated Statistical Areas (SA; thin solid lines). Units: kilometres (km).

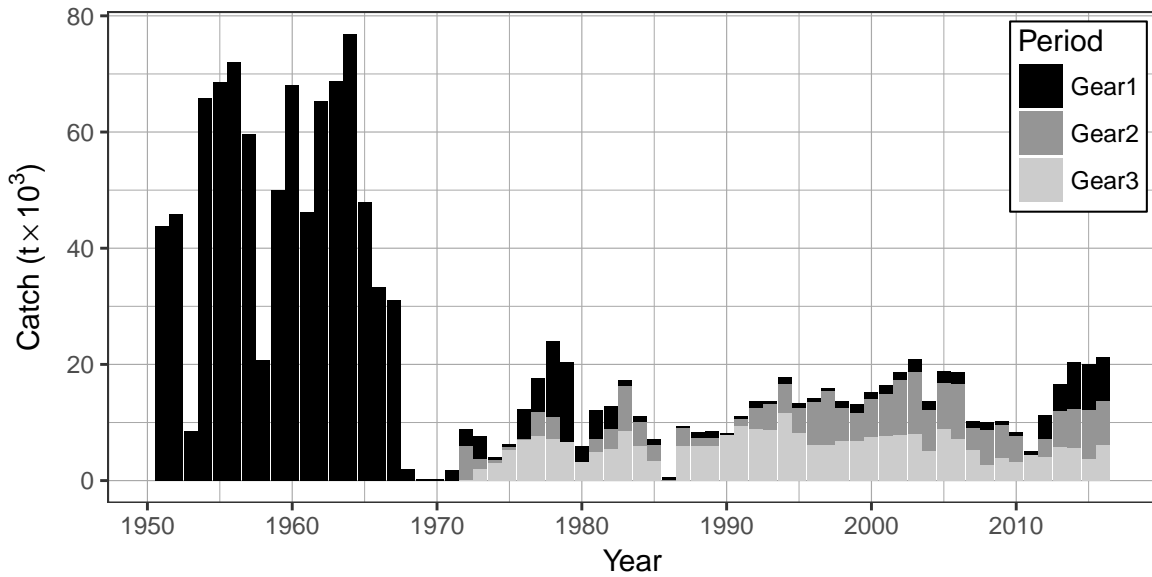


Figure 3. Time series of total landed catch in thousands of metric tonnes ($t \times 10^3$) of Pacific herring by gear type from 1951 to 2016 in the Strait of Georgia major stock assessment region (SAR). Legend: ‘Gear1’ represents the reduction, the food and bait, as well as the special use fishery; ‘Gear2’ represents the roe seine fishery; and ‘Gear3’ represents the roe gillnet fishery.

Table 4. Number of Pacific herring biological samples processed from 2006 to 2016 in the Strait of Georgia major stock assessment region (SAR). Each sample is approximately 100 fish.

Year	Number of samples		
	Commercial	Test	Total
2006	30	49	79
2007	79	40	119
2008	74	24	98
2009	43	28	71
2010	47	37	84
2011	48	60	108
2012	102	42	144
2013	97	25	122
2014	82	11	93
2015	120	38	158
2016	123	38	161

Table 5. Number and type of Pacific herring biological samples processed in 2016 in the Strait of Georgia major stock assessment region (SAR). Each sample is approximately 100 fish.

Type	Gear	Use	Number of samples
Commercial	Gillnet	Roe Fishery	42
Commercial	Seine	Bait Fishery	8
Commercial	Seine	Food Fishery	43
Commercial	Seine	Roe Fishery	30
Test	Seine	Test Fishery	33
Test	Trawl	Nearshore	5

Table 6. Observed proportion-at-age for Pacific herring from 2006 to 2016 in the Strait of Georgia major stock assessment region (SAR). The age-10 class is a ‘plus group’ which includes fish ages 10 and older.

Year	Proportion-at-age								
	2	3	4	5	6	7	8	9	10
2006	0.268	0.261	0.217	0.140	0.086	0.020	0.006	0.002	0.000
2007	0.024	0.484	0.275	0.122	0.057	0.031	0.007	0.002	0.000
2008	0.066	0.113	0.608	0.139	0.047	0.018	0.007	0.001	0.000
2009	0.005	0.672	0.144	0.123	0.037	0.012	0.005	0.002	0.000
2010	0.139	0.044	0.688	0.053	0.055	0.013	0.005	0.002	0.001
2011	0.096	0.610	0.101	0.164	0.016	0.009	0.003	0.001	0.000
2012	0.034	0.424	0.442	0.039	0.055	0.005	0.002	0.000	0.000
2013	0.124	0.304	0.299	0.230	0.018	0.023	0.002	0.000	0.000
2014	0.046	0.480	0.181	0.153	0.117	0.010	0.010	0.001	0.000
2015	0.103	0.374	0.362	0.088	0.046	0.023	0.002	0.001	0.000
2016	0.153	0.267	0.334	0.178	0.040	0.016	0.009	0.001	0.001

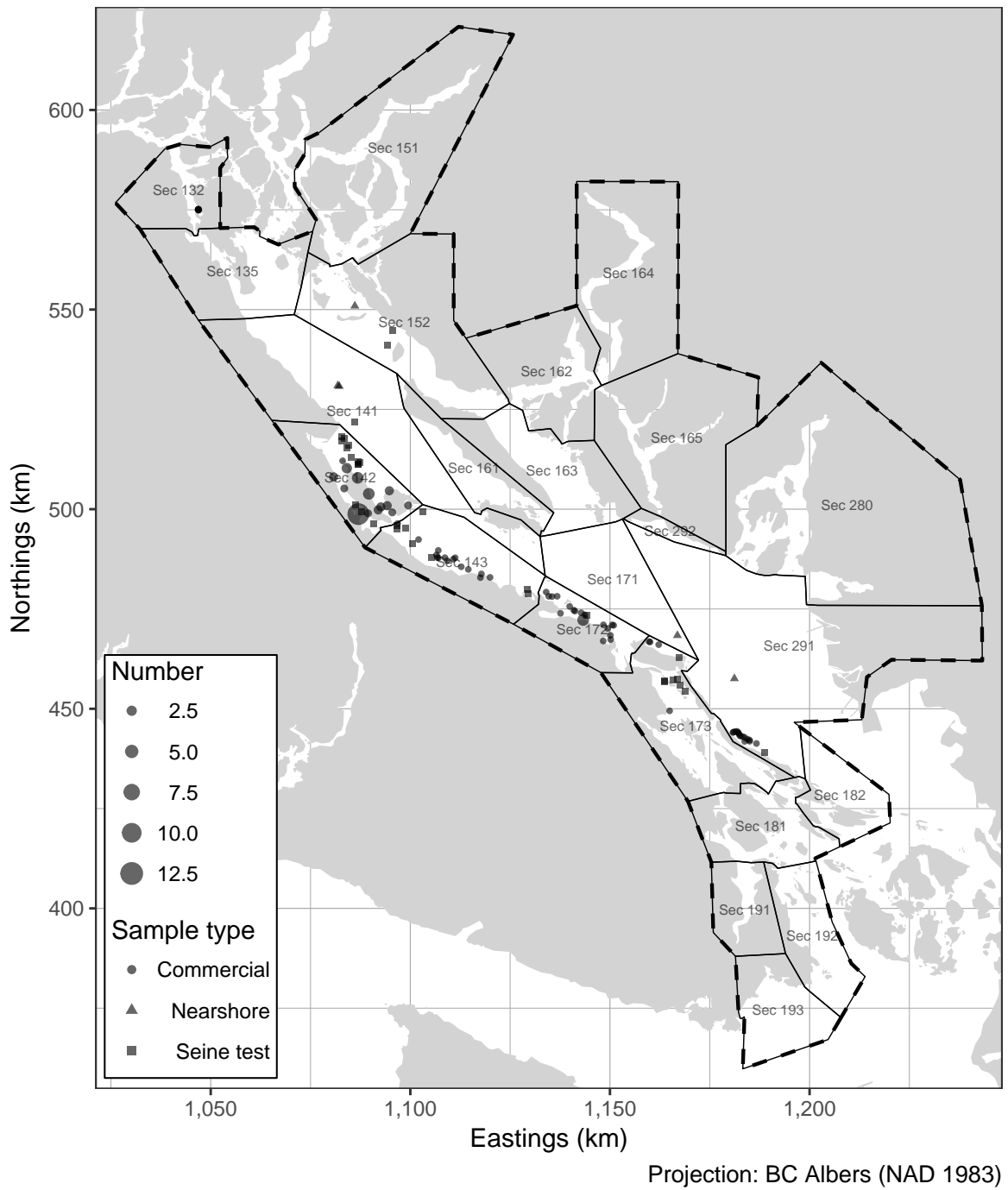


Figure 4. Location and type of Pacific herring biological samples collected in 2016 in the Strait of Georgia major stock assessment region (SAR; thick dashed lines), and associated Sections (Sec; thin solid lines). Units: kilometres (km).

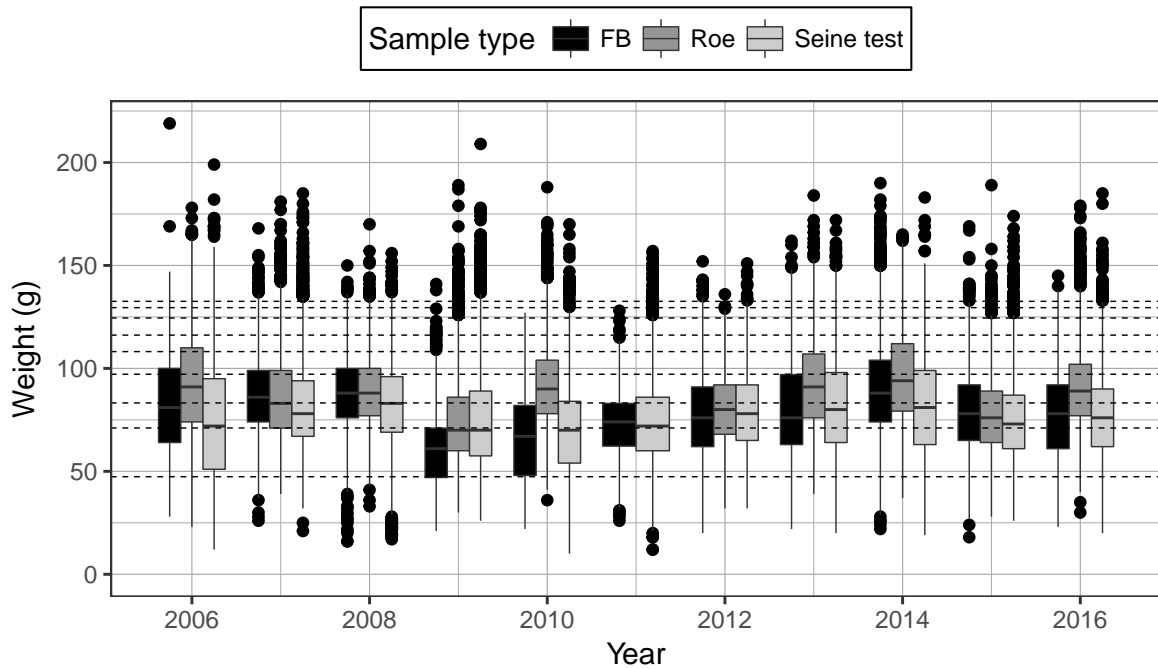


Figure 5. Time series of weight in grams (g) of Pacific herring by sample type from 2006 to 2016 in the Strait of Georgia major stock assessment region (SAR). The outer edges of the boxes indicate the 25th and 75th percentiles, and the middle lines indicate the 50th percentiles (i.e., medians). The whiskers extend to $1.5 \times \text{IQR}$, where IQR is the distance between the 25th and 75th percentiles, and dots indicate outliers. Horizontal dashed lines indicate the mean weight-at-age for age-2 (lowest line) to age-10 (incrementing higher from age-2) fish. Biological summaries only include samples collected using seine nets (commercial and test) due to size-selectivity of other gear types such as gillnet. The age-10 class is a 'plus group' which includes fish ages 10 and older. Legend: 'FB' is food and bait.

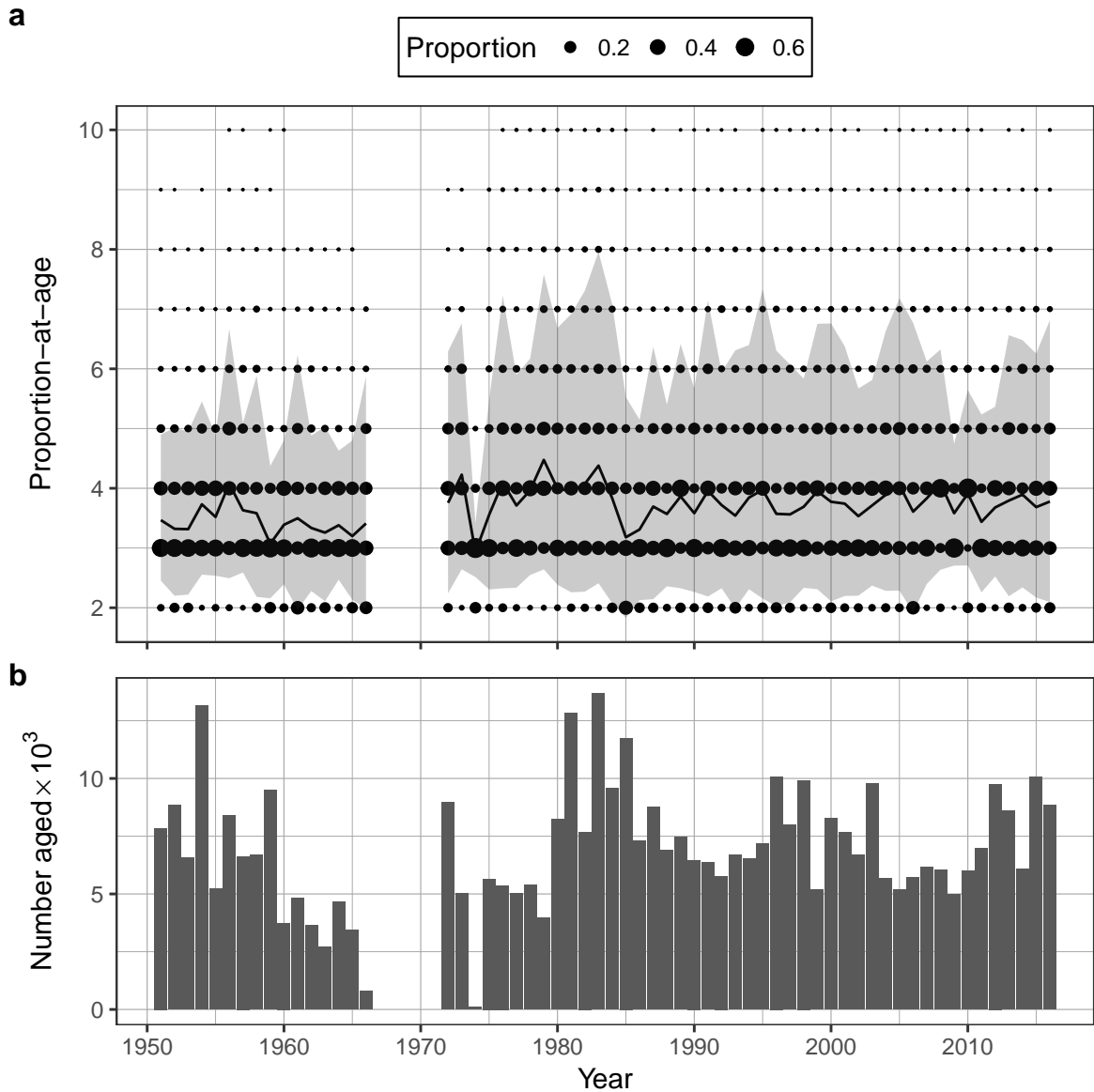


Figure 6. Time series of observed proportion-at-age (a) and number aged (b) of Pacific herring from 1951 to 2016 in the Strait of Georgia major stock assessment region (SAR). The black line is the mean age, and the shaded area is the approximate 90% distribution. Biological summaries only include samples collected using seine nets (commercial and test) due to size-selectivity of other gear types such as gillnet. The age-10 class is a 'plus group' which includes fish ages 10 and older.

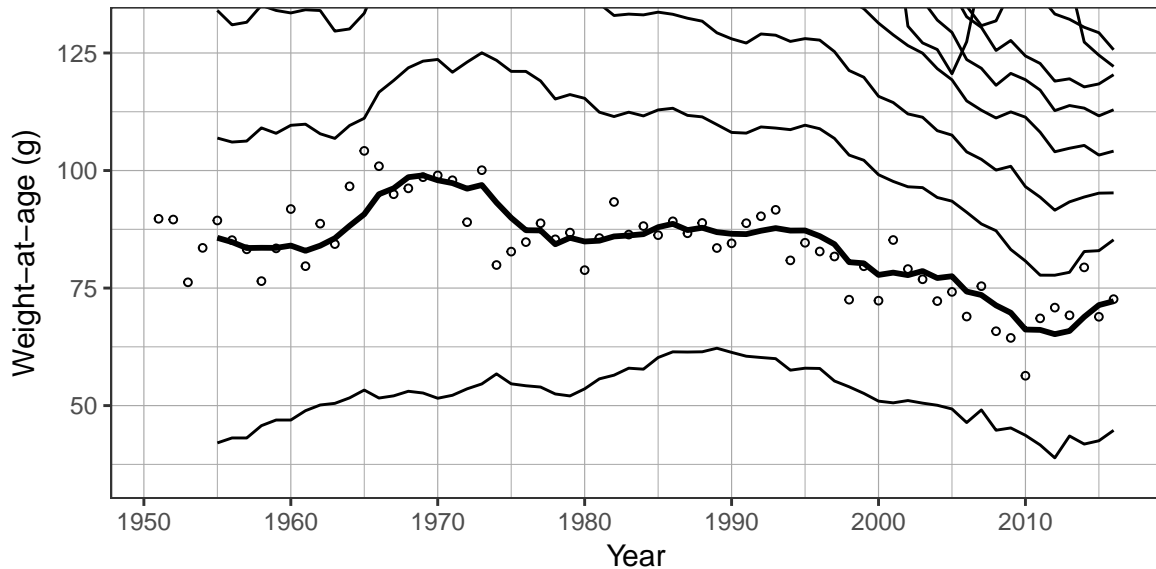


Figure 7. Time series of weight-at-age in grams (g) for age-3 (circles) and 5-year running mean weight-at-age (lines) for Pacific herring from 1951 to 2016 in the Strait of Georgia major stock assessment region (SAR). Lines show 5-year running means for age-2 to age-10 herring (incrementing higher from the lowest line); the thick black line highlights age-3 herring. Missing weight-at-age values (i.e., years where there are no biological samples) are imputed using one of two methods: missing values at the beginning of the time series are imputed by extending the first non-missing value backwards; other missing values are imputed as the mean of the previous 5 years. Biological summaries only include samples collected using seine nets (commercial and test) due to size-selectivity of other gear types such as gillnet. The age-10 class is a ‘plus group’ which includes fish ages 10 and older.

Table 7. Pacific herring spawn survey locations and spawn index in metric tonnes (t) in 2016 in the Strait of Georgia major stock assessment region (SAR). The ‘spawn index’ represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q . Missing spawn index values (i.e., NA) indicate incomplete spawn surveys.

Statistical Area	Section	Location code	Location name	Spawn index (t)
13	135	806	Rebecca Spit	58
14	141	815	Kye Bay	5,489
14	141	821	Oyster Rvr	NA
14	141	1627	Kitty Coleman Beach	3,967
14	141	1854	Little Rvr	2,102
14	142	812	Tribune Bay	945
14	142	814	Cape Lazo	4,150
14	142	830	Comox Bar	4,457
14	142	837	Komas Bluff	19,579
14	142	838	Shingle Spit	1,800
14	142	840	Seal Islets	11,904
14	142	1484	Boyle Pt	2
14	142	1530	Downes Pt	3,818
14	142	1558	Willemar Bluff	605
14	142	1560	Whaling Station Bay	1,055
14	142	1680	Fillongley Park	15,036
14	142	1713	Norman Pt	2,479
14	142	1754	Whalebone Pt	7,636
14	142	1769	Collishaw Pt	17,243
14	142	1770	Tralee Pt	2,540
14	142	1871	Henry Bay	337
14	142	1883	Gravelly Bay	855
14	142	1884	Goose Spit	103
14	142	1889	Ford Cv	1,368
14	143	810	Qualicum Beach	630
14	143	831	Big Qualicum Rvr	775
14	143	834	French Cr	2,282
14	143	835	Little Qualicum Rvr	46
14	143	1415	Parksville	16
14	143	1502	Rath Trevor Beach	NA
14	143	1908	Columbia Beach	3,926
15	151	1977	Toba Inlt	NA
17	172	920	Departure Bay	21
17	172	922	Neck Pt	1,285
17	172	930	Horswell Bluff	3,577
17	172	931	Hammond Bay	84
17	172	932	Nares Pt	390
17	172	933	McKay Pt	201

Table 7 continued

Statistical Area	Section	Location code	Location name	Spawn index (t)
17	172	997	Blunden Pt	333
17	172	998	Lantzville	208
17	172	1002	Icarus Pt	4,246
17	172	1573	Sunrise Beach +	2,646
17	172	3009	Southey Is	192
17	173	941	Yellow Pt	837
17	173	972	Hudson Is	153
17	173	988	Kulleet Bay	21
17	173	1771	Yellow Pt N	105
17	173	3039	Booth Bay	NA
28	280	1336	Squamish	NA
29	292	870	Sechelt	NA

Table 8. Summary of spawn survey data from 2006 to 2016 in the Strait of Georgia major stock assessment region (SAR). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2016). The ‘spawn index’ represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q . Units: metres (m), and metric tonnes (t).

Year	Total length (m)	Mean width (m)	Mean number of layers	Spawn index (t)
2006	116,065	139	1.091	50,258
2007	102,365	105	1.283	38,524
2008	125,980	75	0.963	34,507
2009	145,860	111	0.740	53,652
2010	143,520	84	0.975	50,454
2011	174,550	99	1.009	85,001
2012	130,405	112	1.227	52,636
2013	158,955	122	1.255	83,693
2014	137,090	146	1.331	120,468
2015	166,750	115	1.253	104,481
2016	118,300	157	1.229	129,502

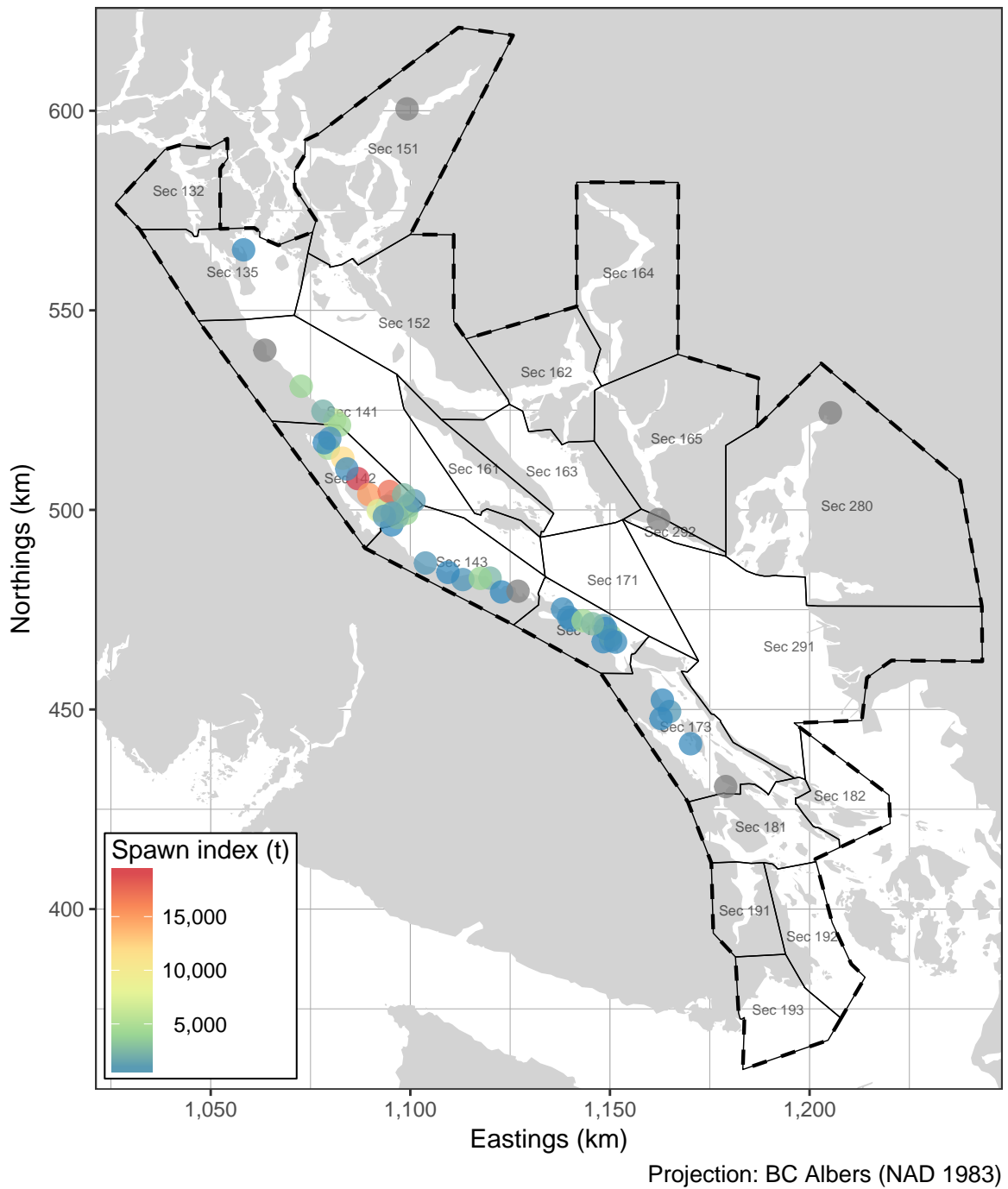


Figure 8. Location of Pacific herring spawning locations in 2016 in the Strait of Georgia major stock assessment region (SAR; thick dashed lines), and associated Sections (Sec; thin solid lines). The 'spawn index' represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q . Missing spawn index values (grey circles) indicate incomplete spawn surveys. Units: kilometres (km), and metric tonnes (t).

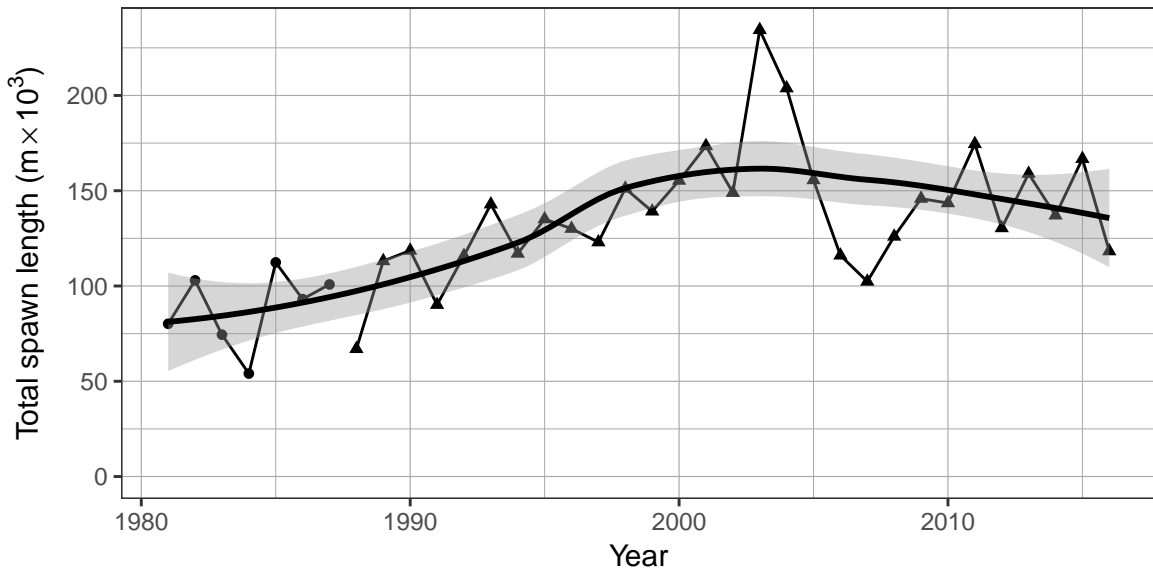


Figure 9. Time series of total spawn length in thousands of metres ($m \times 10^3$) for Pacific herring from 1981 to 2016 in the Strait of Georgia major stock assessment region (SAR). The thick black line is a loess curve, and the shaded area is the 90% confidence interval. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2016).

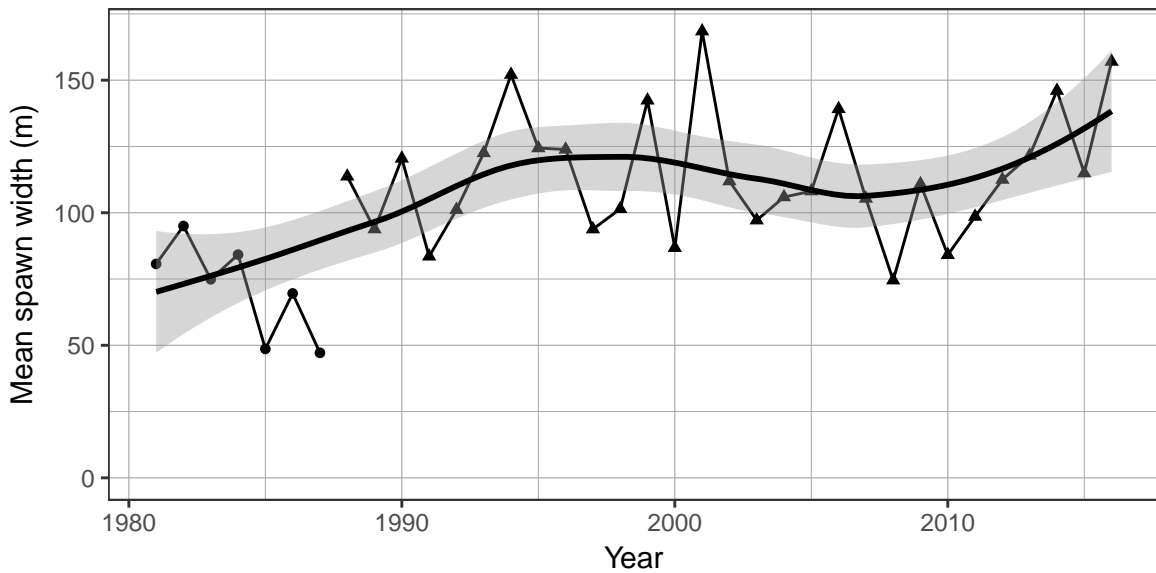


Figure 10. Time series of mean spawn width in metres (m) for Pacific herring from 1981 to 2016 in the Strait of Georgia major stock assessment region (SAR). The thick black line is a loess curve, and the shaded area is the 90% confidence interval. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2016).

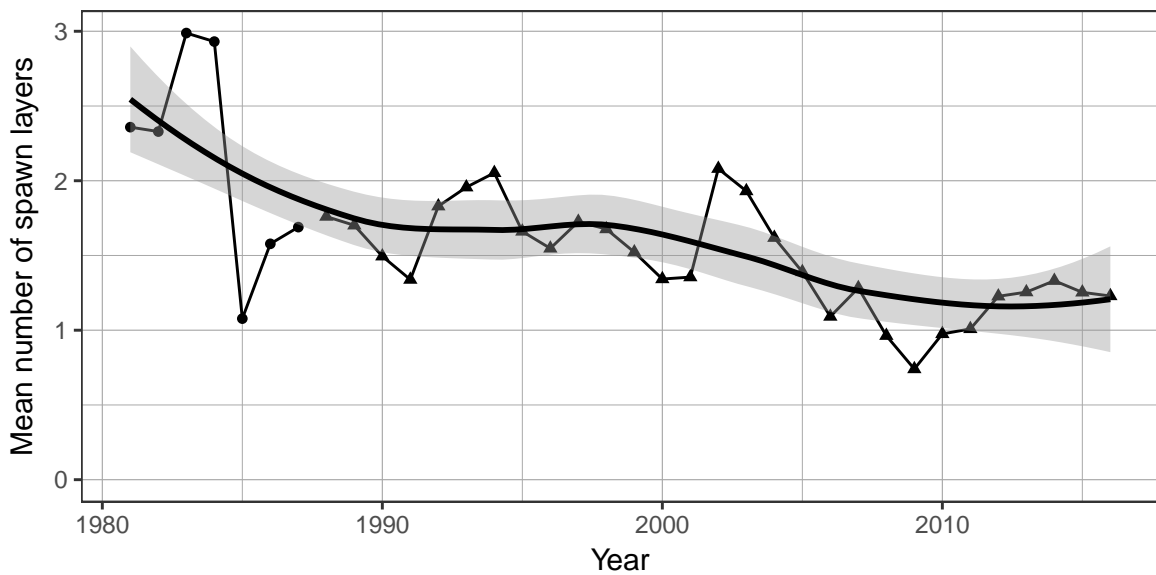


Figure 11. Time series of mean number of spawn layers for Pacific herring from 1981 to 2016 in the Strait of Georgia major stock assessment region (SAR). The thick black line is a loess curve, and the shaded area is the 90% confidence interval. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2016).

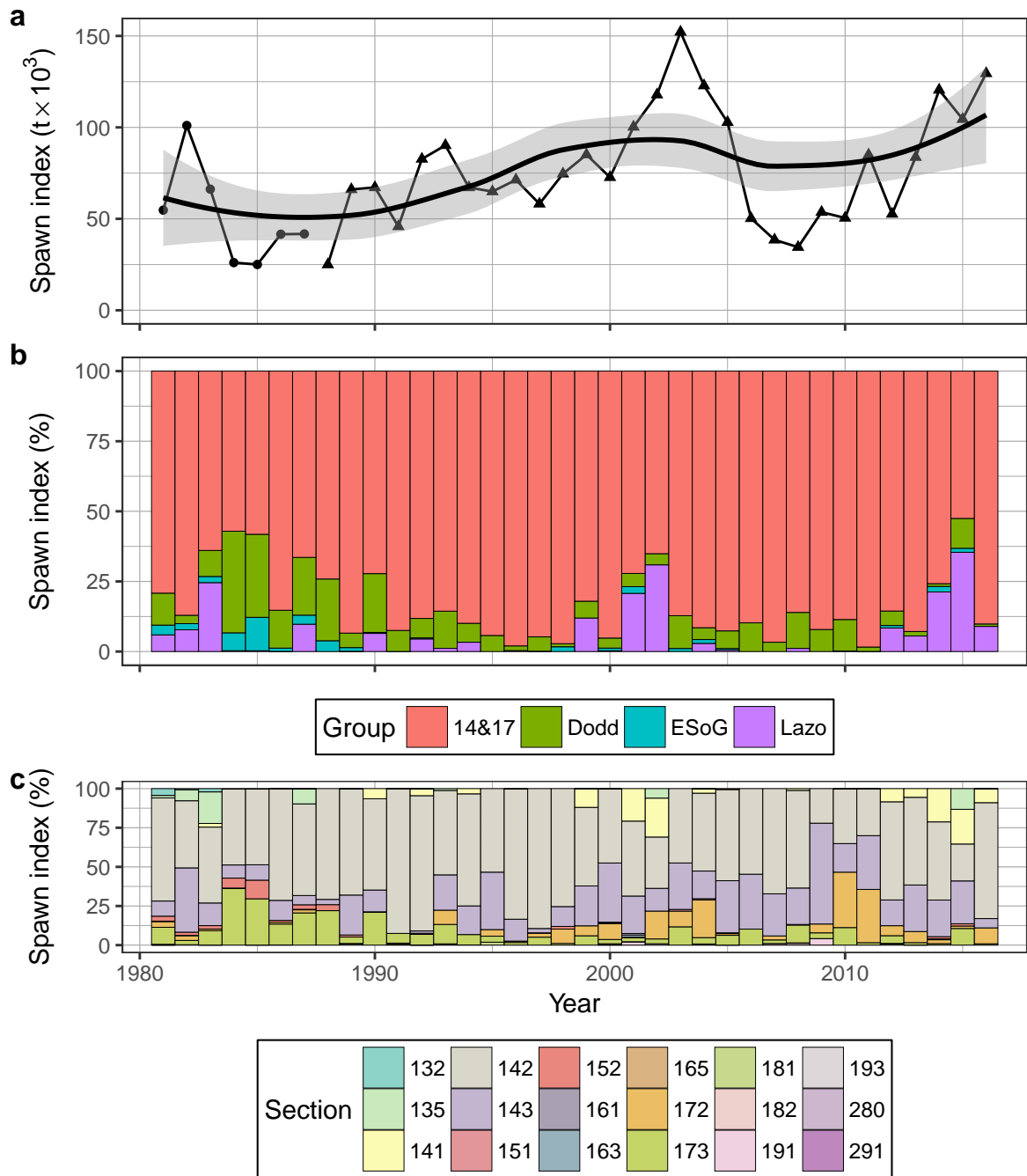


Figure 12. Time series of spawn index in thousands of metric tonnes ($t \times 10^3$) for Pacific herring from 1981 to 2016 in the Strait of Georgia major stock assessment region (SAR; a), as well as percent contributed by Group, and Section (b, & c, respectively). The thick black line is a loess curve, and the shaded area is the 90% confidence interval. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2016). The ‘spawn index’ represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q . Legend: ‘14&17’ is Statistical Areas 14 and 17 (excluding Section 173); ‘Dodd’ is below Dodd Narrows; ‘ESoG’ is eastern Strait of Georgia; and ‘Lazo’ is above Cape Lazo.

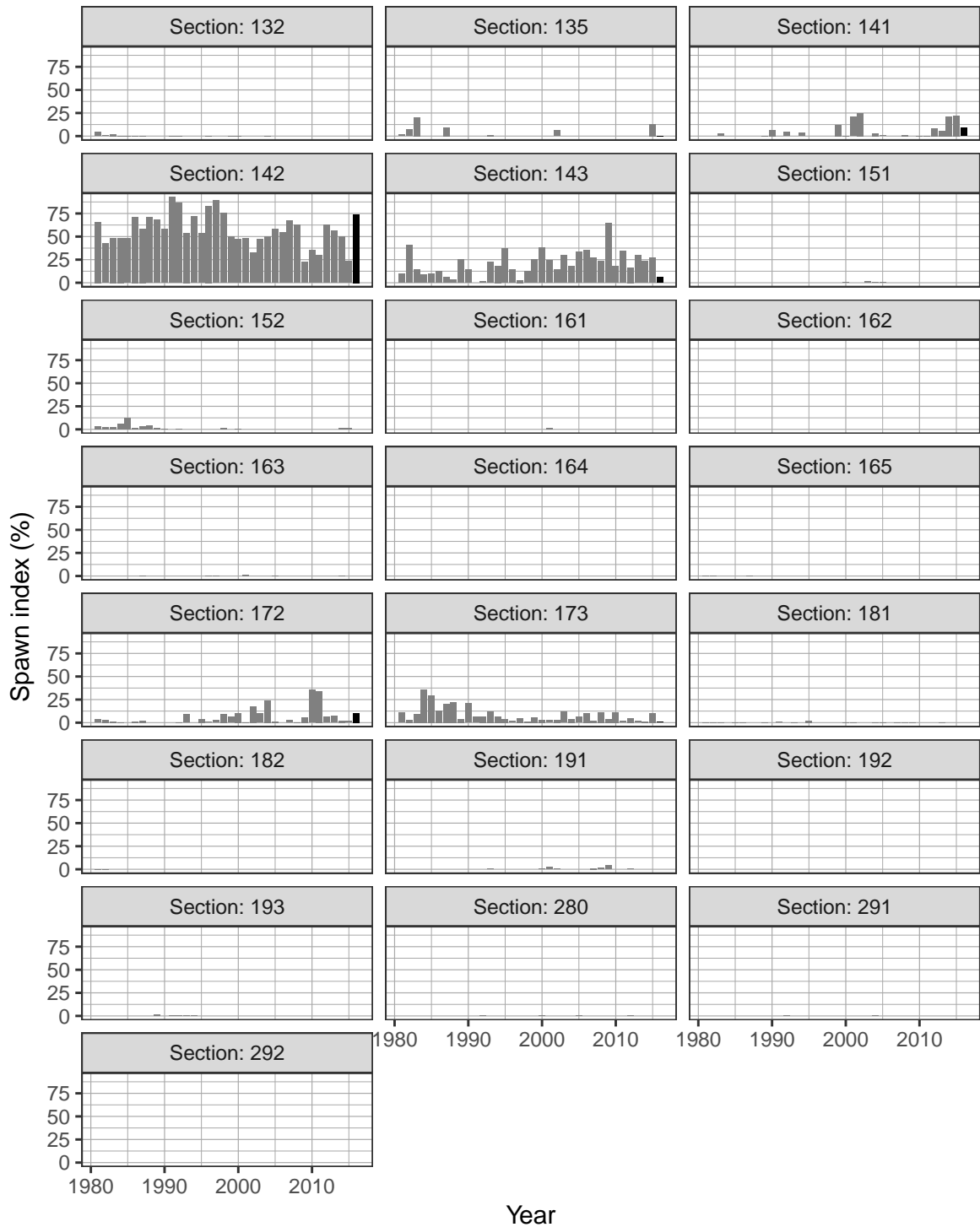


Figure 13. Time series of percent of spawn index by Section for Pacific herring from 1981 to 2016 in the Strait of Georgia major stock assessment region (SAR). The year 2016 has a darker bar to facilitate interpretation. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2016). The ‘spawn index’ represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q .

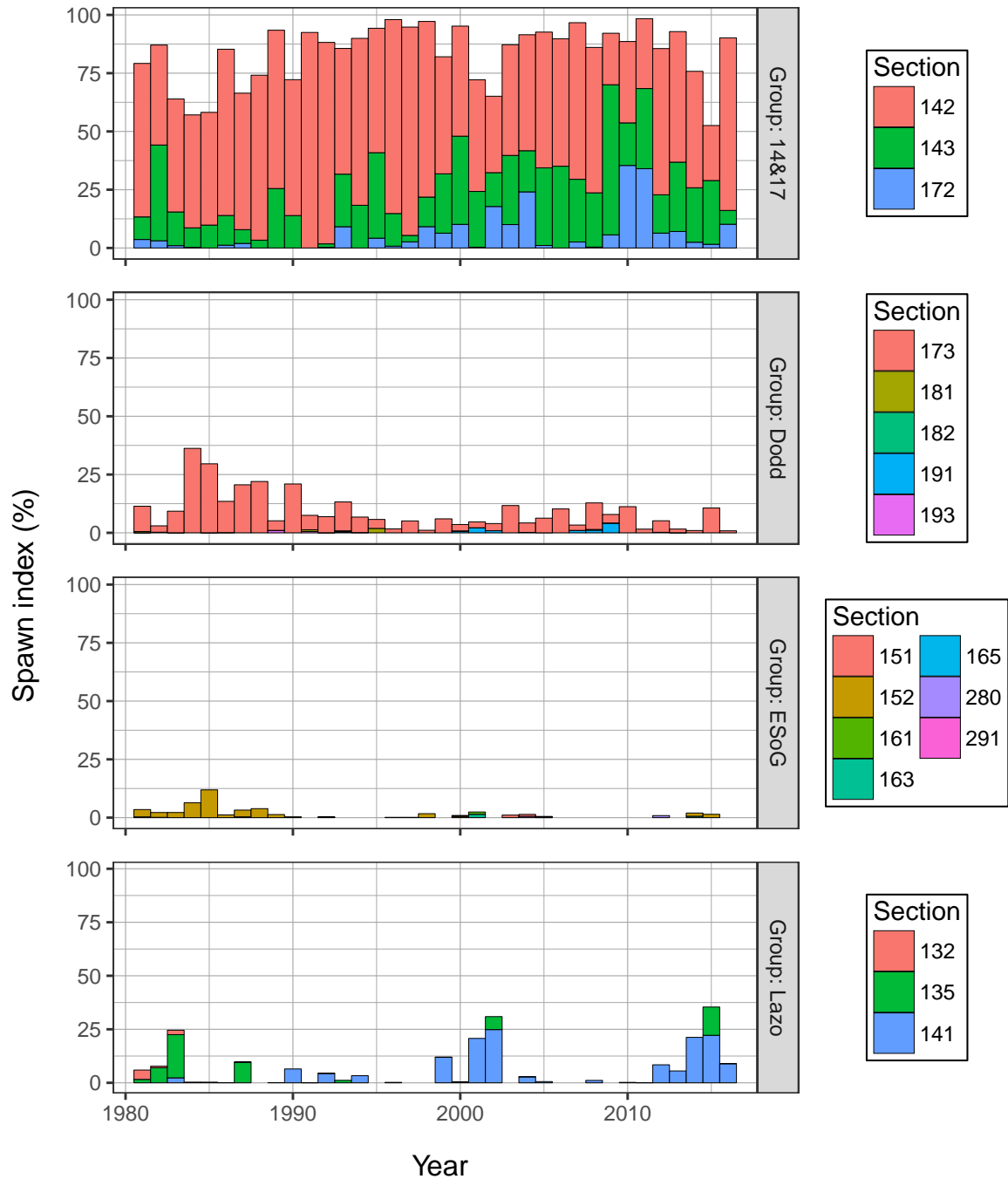


Figure 14. Time series of percent of spawn index by Group and Section for Pacific herring from 1981 to 2016 in the Strait of Georgia major stock assessment region (SAR). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2016). The ‘spawn index’ represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q . Legend: ‘14&17’ is Statistical Areas 14 and 17 (excluding Section 173); ‘Dodd’ is below Dodd Narrows; ‘ESoG’ is eastern Strait of Georgia; and ‘Lazo’ is above Cape Lazo.