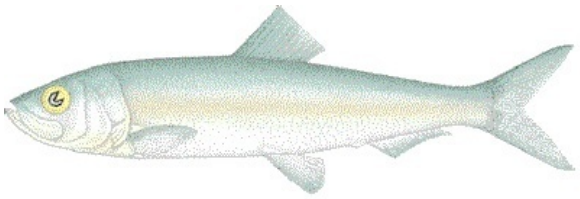
Pacific herring preliminary data summary for Central Coast 2017

DFO Science*

September 7, 2017



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

Disclaimer This report contains preliminary data, which may differ from data used and presented in the final Pacific herring stock assessment for Central Coast 2017.

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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 2017. 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.

The following is a description of data collected for Pacific herring in the Central Coast major SAR in 2017 (Figure 2). Data collected outside the SAR boundary are not

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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 2017 refers to the 2016/2017 herring season.

2 Data collection programs

The data collection program in the Central Coast reflected a number of collaborations between DFO, the Heiltsuk Nation, and the Herring Industry. Biological samples were collected by two vessels, the seine test charter "Franciscan No.1" for 10 days from March 1st to March 10th, and the seine charter vessel "Proud Canadian" for 21 days from March 15th to April 4rd. The primary purpose of the test charter vessel was to collect biological samples from main bodies of herring in Statistical Areas 06, 07, and 08, identified from soundings.

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

- The charter vessel "Pachena No.1" surveyed 21 days from April8nd to April 28th,
- The charter vessel "Ocean Cloud" surveyed 12 days from April 6th to April 17th, and
- The Kitasoo First Nations conducted 1 day of dive survey on spawn in Culpepper Lagoon (Area 06).

Three gillnet sounding vessels were operating by the Heiltsuk Nation this season: two primarily in Area 07 and one primarily in Area 08 to assist the location of fish for the spawn on kelp (SOK) operations.

2.1 Biological samples in Statistical Area 08

In the Central Coast major SAR, Pacific herring in Statistical Area (SA) 08 tend to be smaller than fish in other areas. In addition, fewer biological samples are typically collected from SA 08 compared to the other areas. For example, between 1994 and 2013, on average $\sim 7\%$ of biological samples came from SA 08. In 2014 and 2015, additional resources were available to collect biological samples in SA 08, which consequently received more sampling effort than previous years, compared to the other areas. In order to avoid using non-representative biological data in the Central Coast stock assessment model, biological samples from SA 08 in 2014 and 2015 are weighted by the average historic proportion of samples in that area (i.e., $\sim 7\%$). Biological data presented in this report (e.g., proportion-at-age, weight-at-age) reflect these weights, and are considered to be representative of the Central Coast major SAR.

3 Catch and biological samples

Landed commercial catch of Pacific herring by year and fishery is shown in Table 2 and Figure 3. Total harvested spawn on kelp (SOK) in 2017 in the Central Coast major SAR is shown in Table 3; we also calculate the estimated spawning biomass associated with SOK harvest. See calculations to convert SOK to spawning biomass in Appendix A, page 26.

In 2017, 44 Pacific herring biological samples were collected and processed for the Central Coast major SAR (Table 4, Table 5), and a total of 1,485 Pacific herring were aged in 2017. The locations in which the biological samples were collected are presented in Figure 4. Included herein are biological summaries of observed proportion-, number-, and weight-at-age (Figure 5, Table 6, and Figure 6, respectively). Some Statistical Areas tend to have larger fish at a given age (Figure 7, Table 7). 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 47 individual locations in 2017 in the Central Coast major SAR (Table 8, and Figure 8). A summary of spawn from the last decade (2007 to 2016) is shown in Figure 9. Spawn surveys are conducted to estimate the spawn length, width, number of egg layers, and substrate type, and these data are used to estimate the index of spawning biomass (i.e., the spawn index; Figure 10, Figure 11, Figure 12, Figure 13, and Table 9). In addition, spawn surveys estimate spawn depth below surface by Statistical Area, and Section (Figure 14). 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 (1988–2017).

Some herring Sections contribute more than others to the total spawn index, and the percentage contributed by Section varies yearly (Figure 13b, Figure 15). For example, in 2017, Section 072 contributed the most to the spawn index (43%). As with Sections, some Statistical Areas contribute more than others to the total spawn index (Figure 13c, Figure 16).

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:

- Similar to last year, herring schools only seemed to migrate up to 35–45 m in the dark, where they either held there or migrating back to the bottom after a couple

hours. This meant there were fewer opportunities to take seine samples.

- The soundings were around $10,000\,\mathrm{t}$ from the beginning of the first seine charter and continuing to the next charter vessel. Sounding are a measure of relative abundance, and it was unusual that soundings did not change until March 26^{th}. Soundings increased to $16,000\,\mathrm{t}$ on March 31^{st}.
- While spawn timing seemed later than normal, science confirmed that within the last 5 years that could be true. But looking back 20 years, this spawn timing was average.
- No fungus on the spawn was observed.
- Cooler water temperatures (4 to 6°C) were observed.

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 gear type in 2017 in the Central Coast 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. Data from the spawn-on-kelp (SOK) fishery is not included. Note: 'WP' indicates that data are withheld due to privacy concerns.

Period	Catch (t)
Gear1	0
Gear2	0
Gear3	0

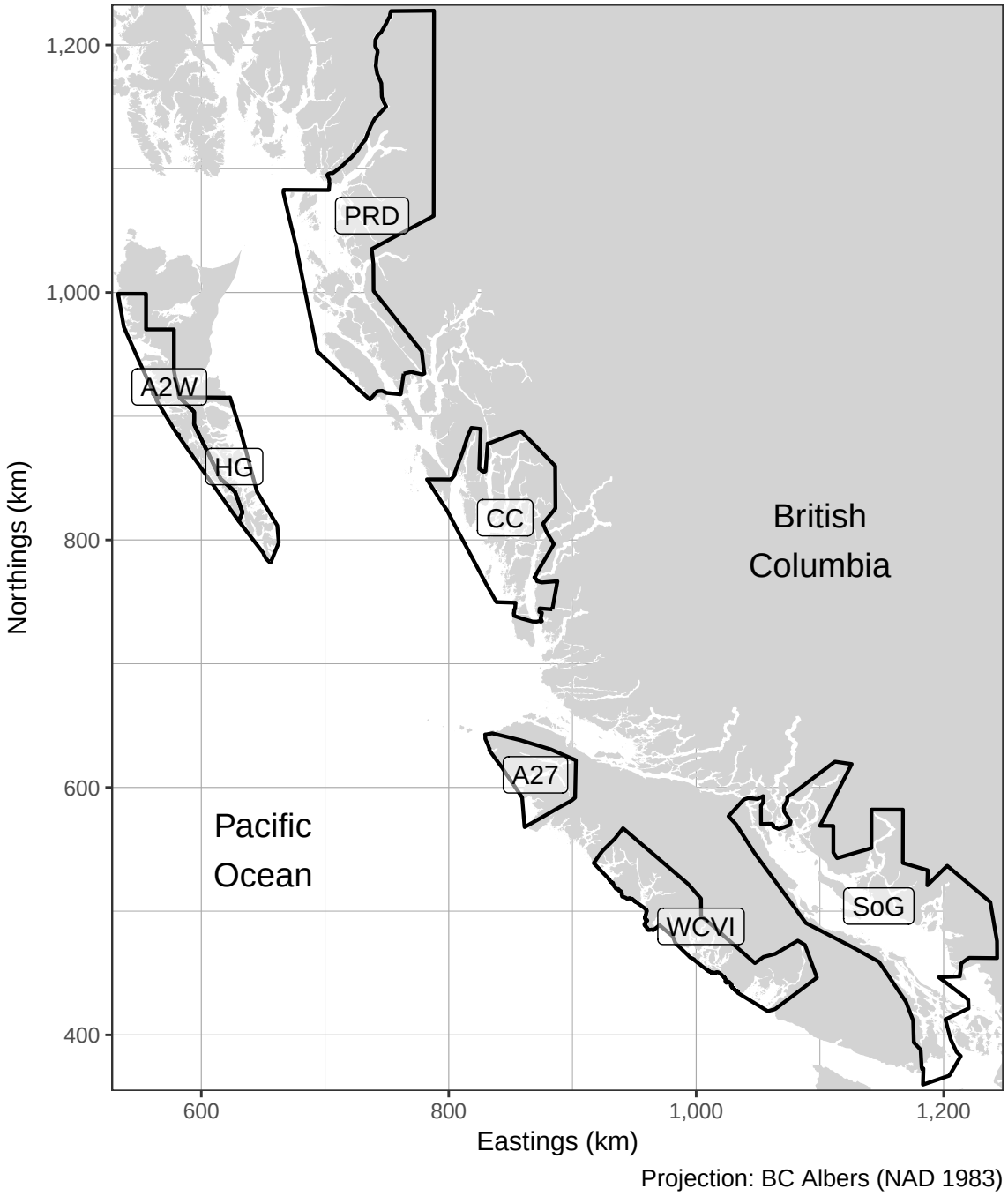

Figure 1. Boundaries for the Pacific herring stock assessment regions (SARs) in British Columbia: there are 5 major SARs (HG, PRD, CC, SoG, and WCVI), and 2 minor SARs (A27 and A2W; Table 1). Units: kilometres (km).

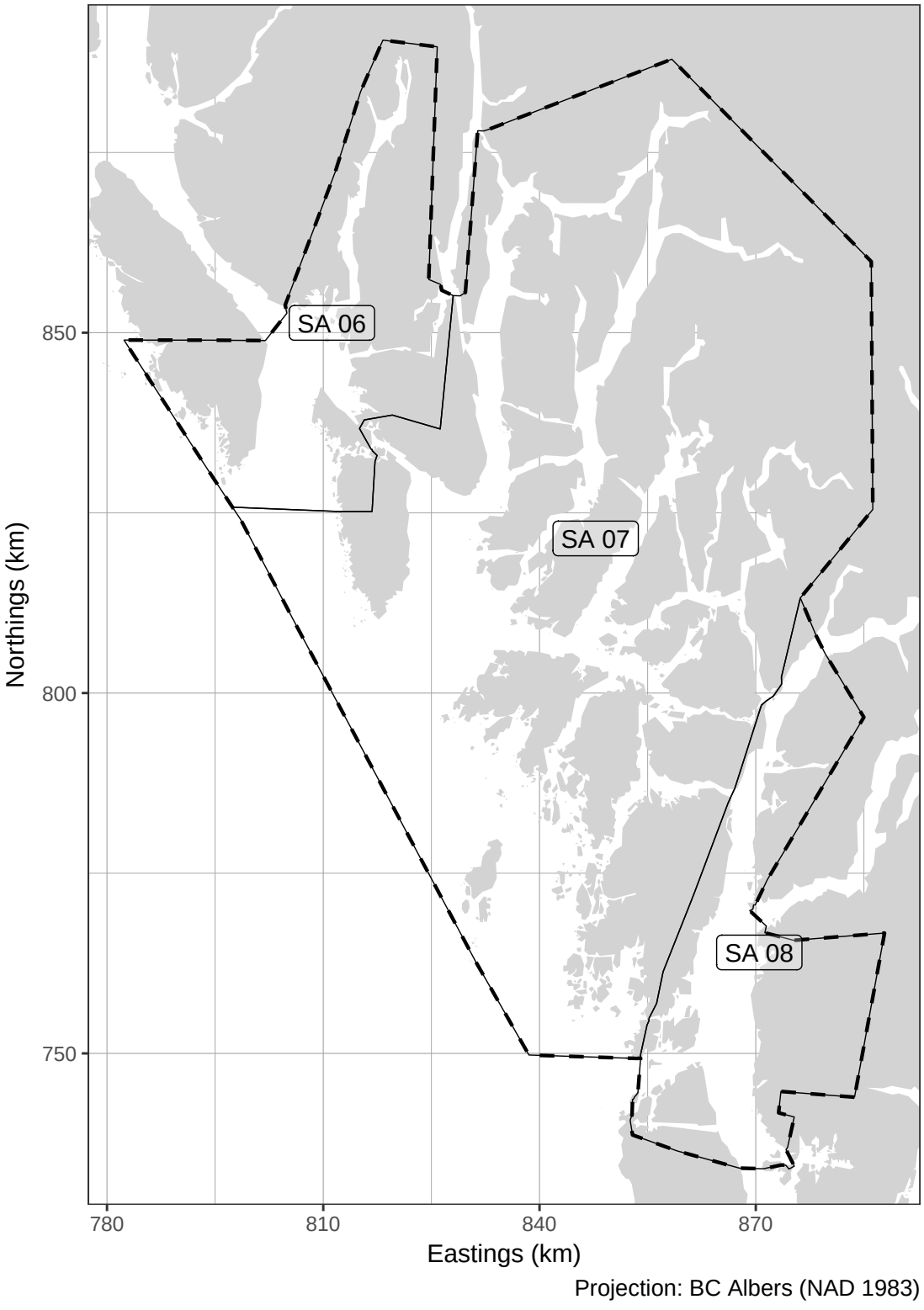

Figure 2. Boundaries for the Central Coast major stock assessment region (SAR; thick dashed lines), and associated Statistical Areas (SA; thin solid lines). Units: kilometres (km).

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 2007 to 2017 in the Central Coast major stock assessment region (SAR). See calculations to convert SOK to spawning biomass in Appendix A, page 26. Note: 'WP' indicates that data are withheld due to privacy concerns.

Year	Harvest (lb)	Spawning biomass (t)
2007	130,596	191
2008	0	0
2009	0	0
2010	0	0
2011	0	0
2012	0	0
2013	0	0
2014	239,861	350
2015	169,470	247
2016	351,953	514
2017	392,747	573

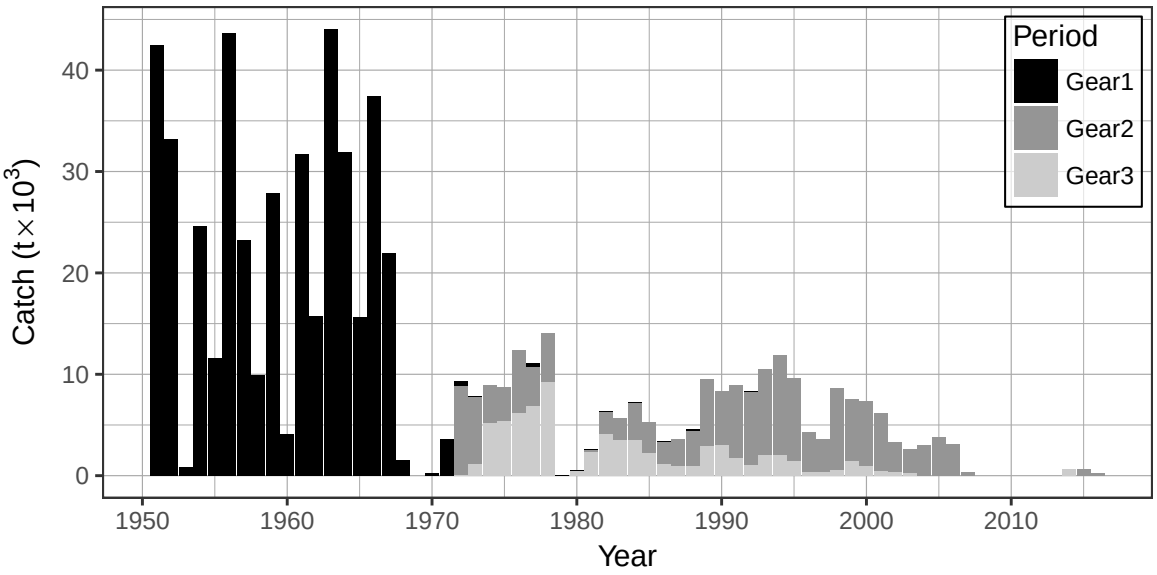

Figure 3. Time series of total landed catch in thousands of metric tonnes ($t \times 10^3$) of Pacific herring by gear type from 1951 to 2017 in the Central Coast major stock assessment region (SAR). Legend: 'Gear1' represents the reduction, the food and bait, as well as the special use fishery; 'Gear2' represents the roe seine fishery; and 'Gear3' represents the roe gillnet fishery. Data from the spawn-on-kelp (SOK) fishery is not included.

Table 4. Number of Pacific herring biological samples processed from 2007 to 2017 in the Central Coast major stock assessment region (SAR). Each sample is approximately 100 fish.

	Number of samples		
Year	Commercial	Test	Total
2007	13	13	26
2008	0	17	17
2009	0	34	34
2010	0	26	26
2011	0	30	30
2012	0	24	24
2013	0	15	15
2014	14	12	26
2015	6	14	20
2016	5	15	20
2017	4	40	44

Table 5. Number and type of Pacific herring biological samples processed in 2017 in the Central Coast major stock assessment region (SAR). Each sample is approximately 100 fish.

Type	Gear	Use	Number of samples
Commercial	Seine	Other	4
Test	Other	Nearshore	27
Test	Seine	Test Fishery	13

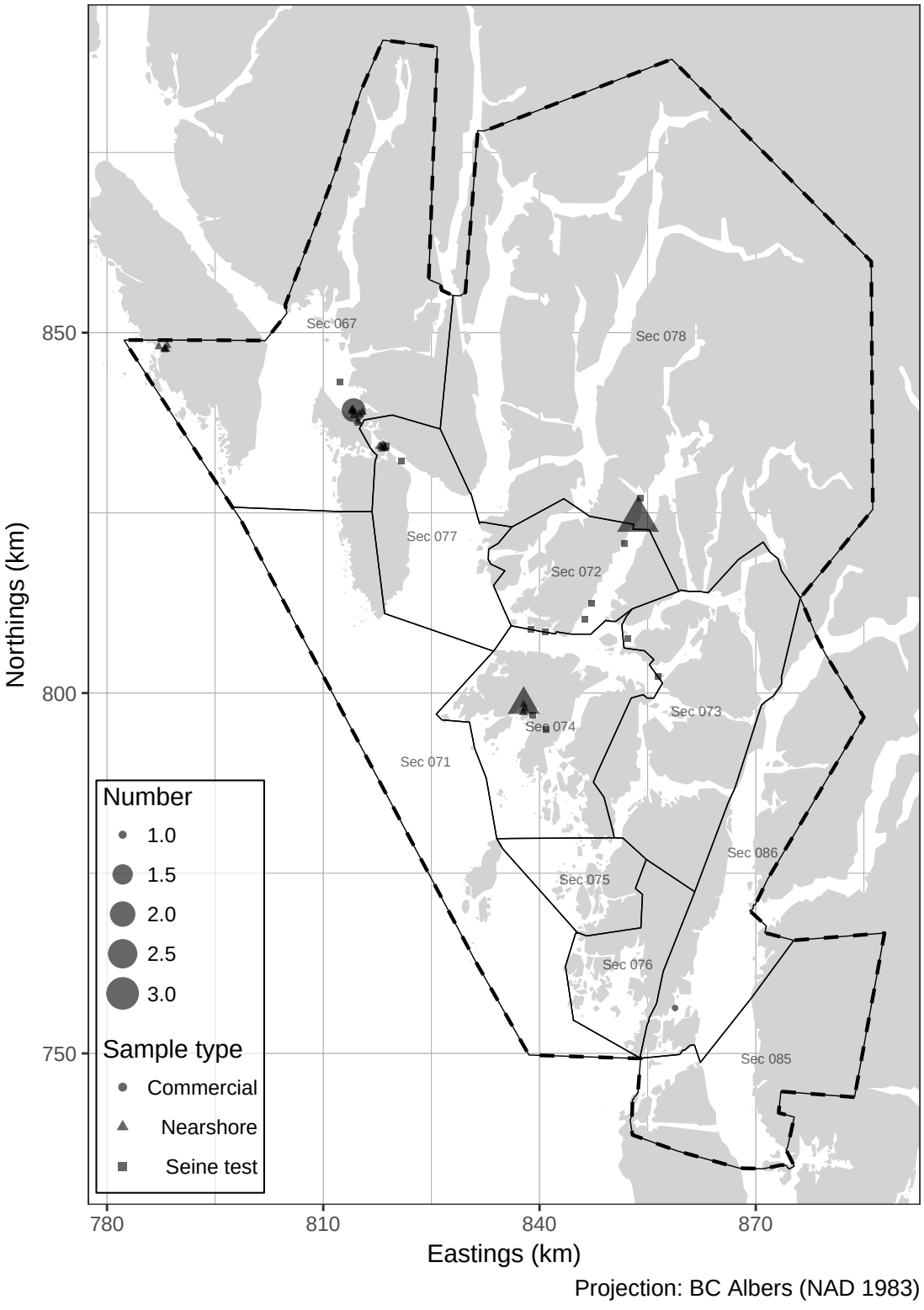

Figure 4. Location and type of Pacific herring biological samples collected in 2017 in the Central Coast major stock assessment region (SAR; thick dashed lines), and associated Sections (Sec; thin solid lines). Units: kilometres (km).

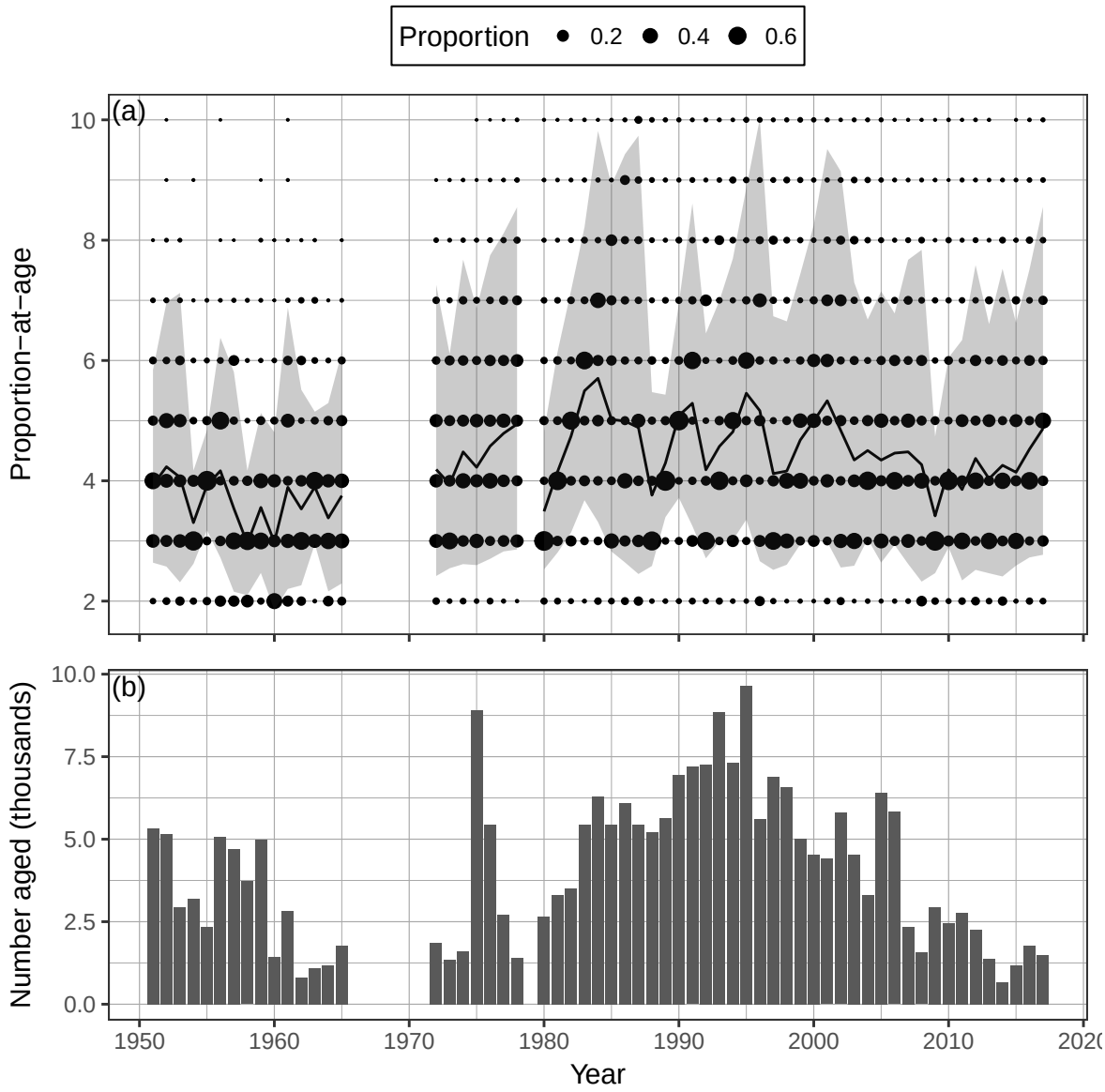

Figure 5. Time series of observed proportion-at-age (a) and number aged in thousands (b) of Pacific herring from 1951 to 2017 in the Central Coast major stock assessment region (SAR). The black line is the mean age, and the shaded area is the approximate 90% distribution. Biological summaries only include 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.

Table 6. Observed proportion-at-age for Pacific herring from 2007 to 2017 in the Central Coast major stock assessment region (SAR). The age-10 class is a 'plus group' which includes fish ages 10 and older.

	Proportion-at-age								
Year	2	3	4	5	6	7	8	9	10
2007	0.014	0.299	0.190	0.316	0.081	0.079	0.016	0.004	0.001
2008	0.142	0.103	0.419	0.117	0.156	0.028	0.027	0.005	0.001
2009	0.044	0.718	0.105	0.081	0.023	0.022	0.003	0.003	0.001
2010	0.017	0.157	0.650	0.054	0.077	0.021	0.021	0.001	0.002
2011	0.045	0.491	0.154	0.243	0.031	0.023	0.007	0.006	0.001
2012	0.077	0.106	0.484	0.119	0.167	0.024	0.016	0.005	0.003
2013	0.026	0.480	0.129	0.243	0.056	0.057	0.004	0.003	0.001
2014	0.095	0.146	0.467	0.089	0.141	0.028	0.029	0.004	0.000
2015	0.008	0.454	0.156	0.249	0.055	0.064	0.009	0.004	0.001
2016	0.040	0.091	0.549	0.094	0.146	0.028	0.039	0.011	0.003
2017	0.029	0.170	0.132	0.446	0.089	0.092	0.024	0.012	0.007

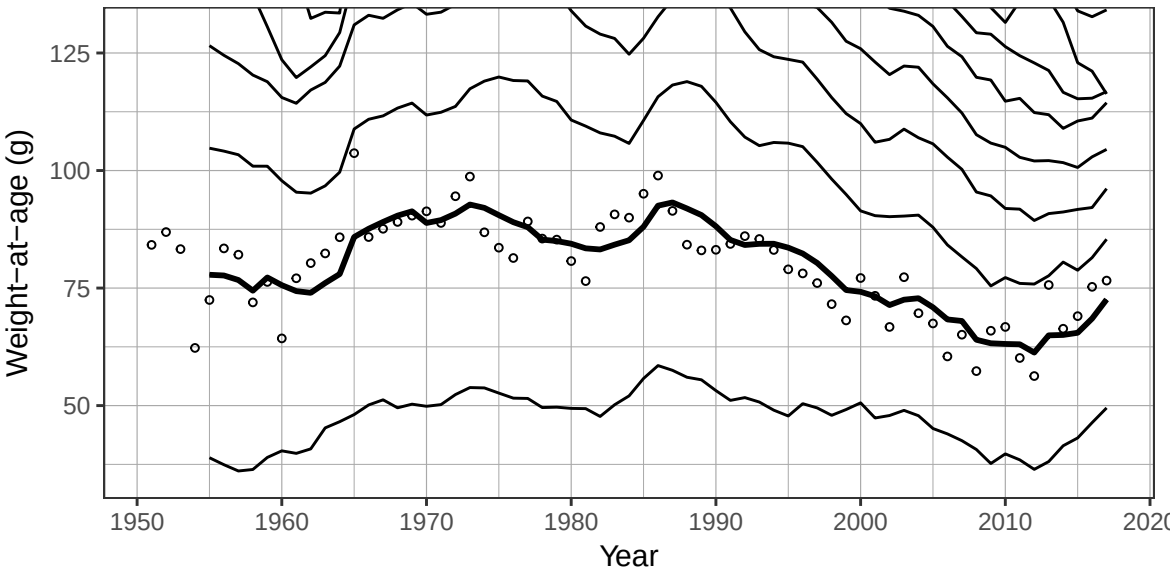

Figure 6. Time series of weight-at-age in grams (g) for age-3 (circles) and 5-year running mean weight-at-age (lines) for Pacific herring from 1951 to 2017 in the Central Coast major stock assessment region (SAR). Lines show 5-year running means for age-2 to age-10 herring (incrementing higher from the 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.

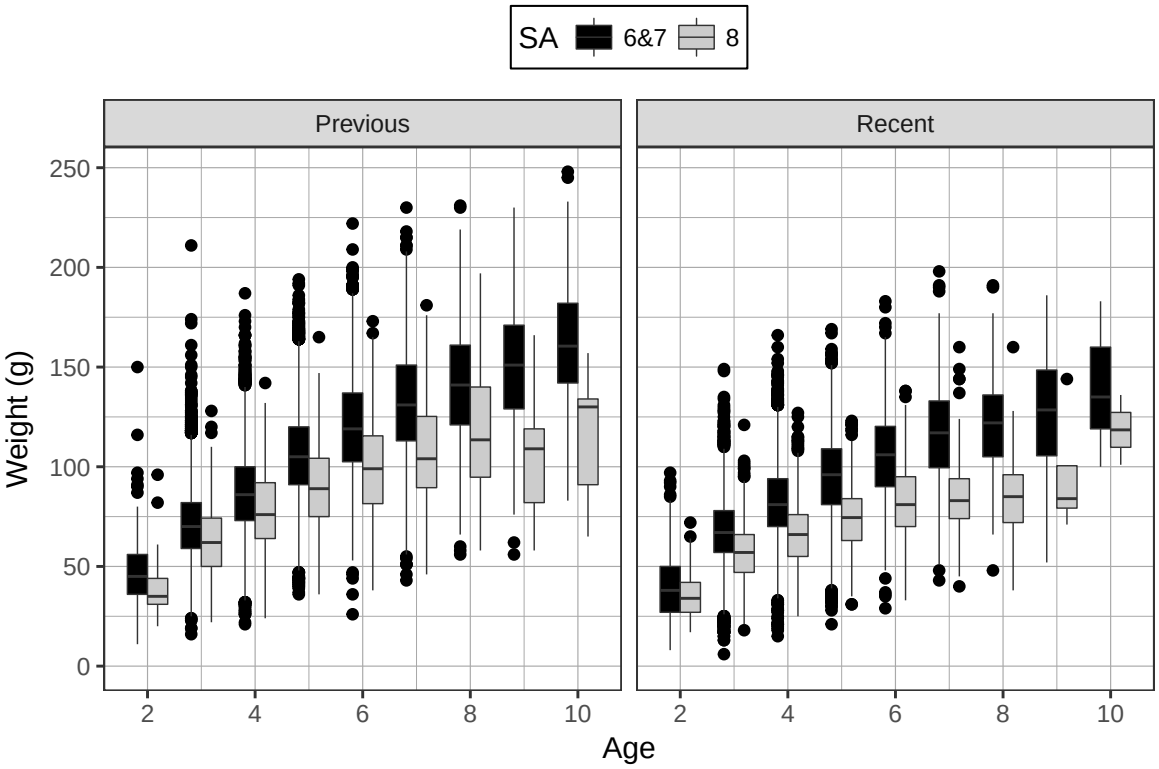

Figure 7. Weight-at-age in grams (g) of Pacific herring in the Central Coast major stock assessment region (SAR) by Statistical Area (SA) from the most recent decade (2008 to 2017), and the previous decade (1998 to 2007). The outer edges of the boxes indicate the 25th and 75th percentiles, and the middle lines indicate the 50th percentiles (i.e., medians). The whiskers extend to 1.5 $\times$ IQR, where IQR is the distance between the 25th and 75th percentiles, and dots indicate outliers. Sample sizes are given in Table 7. 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. Sample size for Pacific herring weight-at-age analysis in 2017 in the Central Coast major stock assessment region (SAR) by Statistical Area (SA) from the most recent decade (2008 to 2017), and the previous decade (1998 to 2007), as displayed in Figure 7. 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.

		Sample size	
SA	Age	Previous decade	Recent decade
6&7	2	660	744
6&7	3	11,088	5,327
6&7	4	14,129	5,311
6&7	5	9,136	2,799
6&7	6	5,143	1,472
6&7	7	3,165	599
6&7	8	1,530	286
6&7	9	724	94
6&7	10	290	37
8	2	63	275
8	3	820	1,053
8	4	960	931
8	5	484	334
8	6	255	182
8	7	172	65
8	8	68	15
8	9	13	4
8	10	5	2

Table 8. Pacific herring spawn survey locations, and spawn index in metric tonnes (t) in 2017 in the Central Coast 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)
06	067	425	Parsons Anch	1,788
06	067	430	Marvin Is	1,824
06	067	432	Osment Inlt	1,683
06	067	433	Wilby Pt	1,045
06	067	434	Kwakwa Cr	1,953
06	067	436	Wingate Pt	142
06	067	1862	Abrams Is	3
07	072	457	Spiller Chnl	1,731
07	072	467	Watch Is	484
07	072	469	Balagny Pass	11
07	072	480	Powell Anch	764
07	072	481	Shingle Rk	141
07	072	484	Ivory Is	696
07	072	490	Blair Inlt	89
07	072	491	Cecilia Is	87
07	072	494	Don Lgn +	752
07	072	496	Lambard Inlt	273
07	072	499	Lady Trutch Pass	8
07	072	529	Reid Pass	326
07	072	1537	Port Blackney	218
07	072	1688	King Cv	141
07	072	1692	Oliver Cv	439
07	072	1693	Leighton Is	532
07	072	1864	Foote Islets	90
07	072	1876	Bush Pt	463
07	072	1909	Mosquito Bay	1,438
07	072	1929	Branks It	572
07	072	1933	Cameron Pt	520
07	072	1943	Tankeeah River	165
07	072	1987	Bullen Rk	109
07	073	449	Troup Psg	1,419
07	073	454	Gunboat Pass	31
07	074	483	Idol Pt	27
07	074	538	Thompson Bay	187
07	076	564	Goodlad Bay	47
07	077	1748	E Higgins Pass	580
07	078	516	Ellerslie Bay	74
07	078	517	Spiller Chnl Hd	10

Table 8 continued

Statistical Area	Section	Location code	Location name	Spawn index (t)
07	078	518	Spiller Inlt	121
07	078	1846	Neekas Inlt	759
07	078	3005	Gerald Pt	246
07	078	3041	Culpepper Lgn	178
08	085	575	Kwakume Inlt	469
08	085	576	Illahie Inlt	119
08	085	1363	Kwakume Pt	60
08	086	497	Mustang Bay	487
08	086	570	Nalau Psg	216

Table 9. Summary of spawn survey data from 2007 to 2017 in the Central Coast 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 (1988–2017). 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 egg layers	Spawn index (t)
2007	64,500	31	1.163	9,264
2008	30,390	35	0.934	4,255
2009	70,980	31	1.390	10,771
2010	86,490	43	0.640	8,671
2011	137,530	25	0.763	10,534
2012	127,632	28	0.527	7,592
2013	158,205	34	0.913	20,369
2014	160,450	38	0.749	13,309
2015	167,060	39	1.285	32,146
2016	164,575	40	1.589	32,508
2017	125,525	39	1.511	23,517

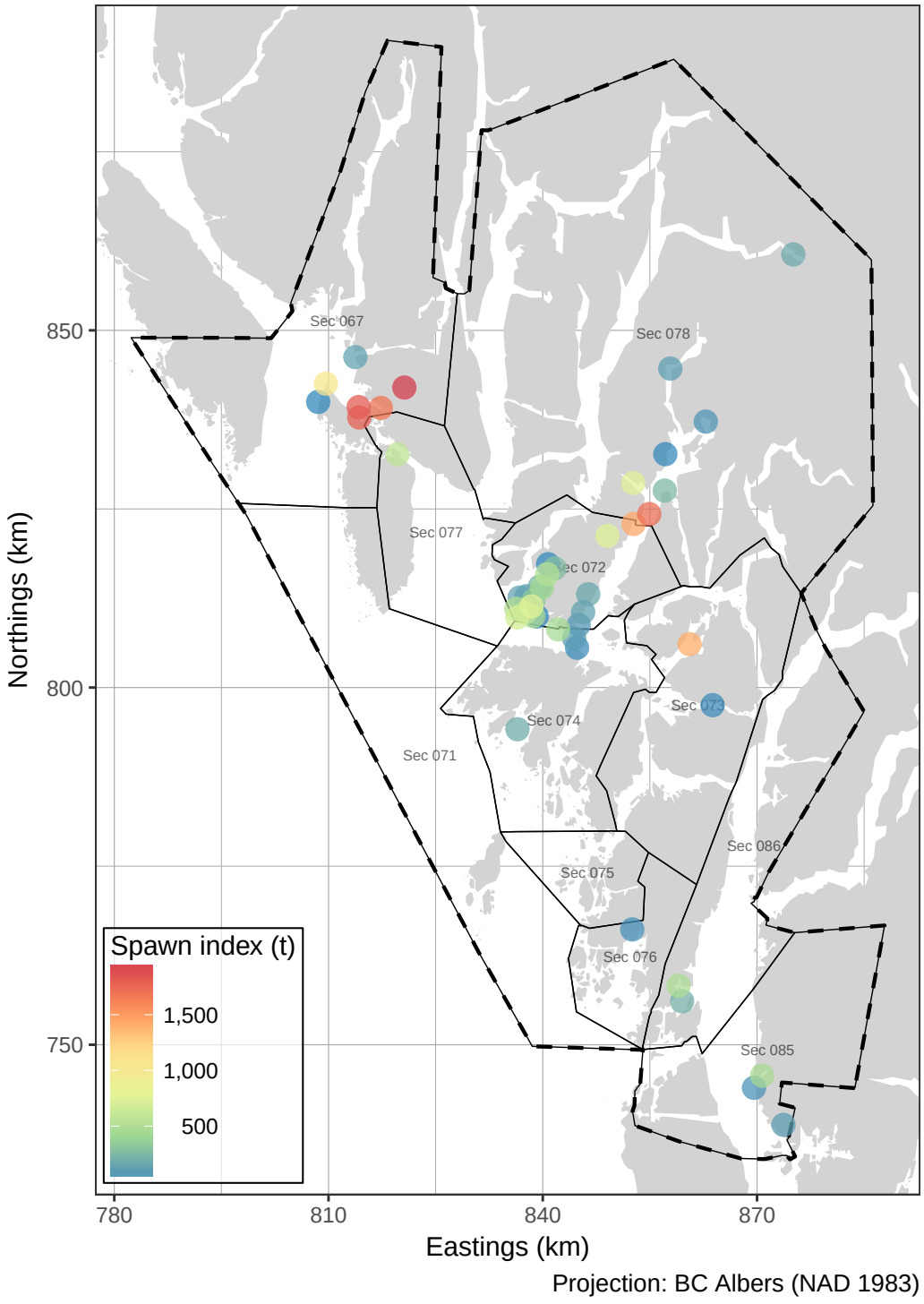

Figure 8. Pacific herring spawn survey locations, and spawn index in metric tonnes (t) in 2017 in the Central Coast major stock assessment region (SAR; thick dashed lines), and associated Sections (Sec; thin solid lines). The 'spawn index' represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q. Missing spawn index values (grey circles) indicate incomplete spawn surveys. Units: kilometres (km).

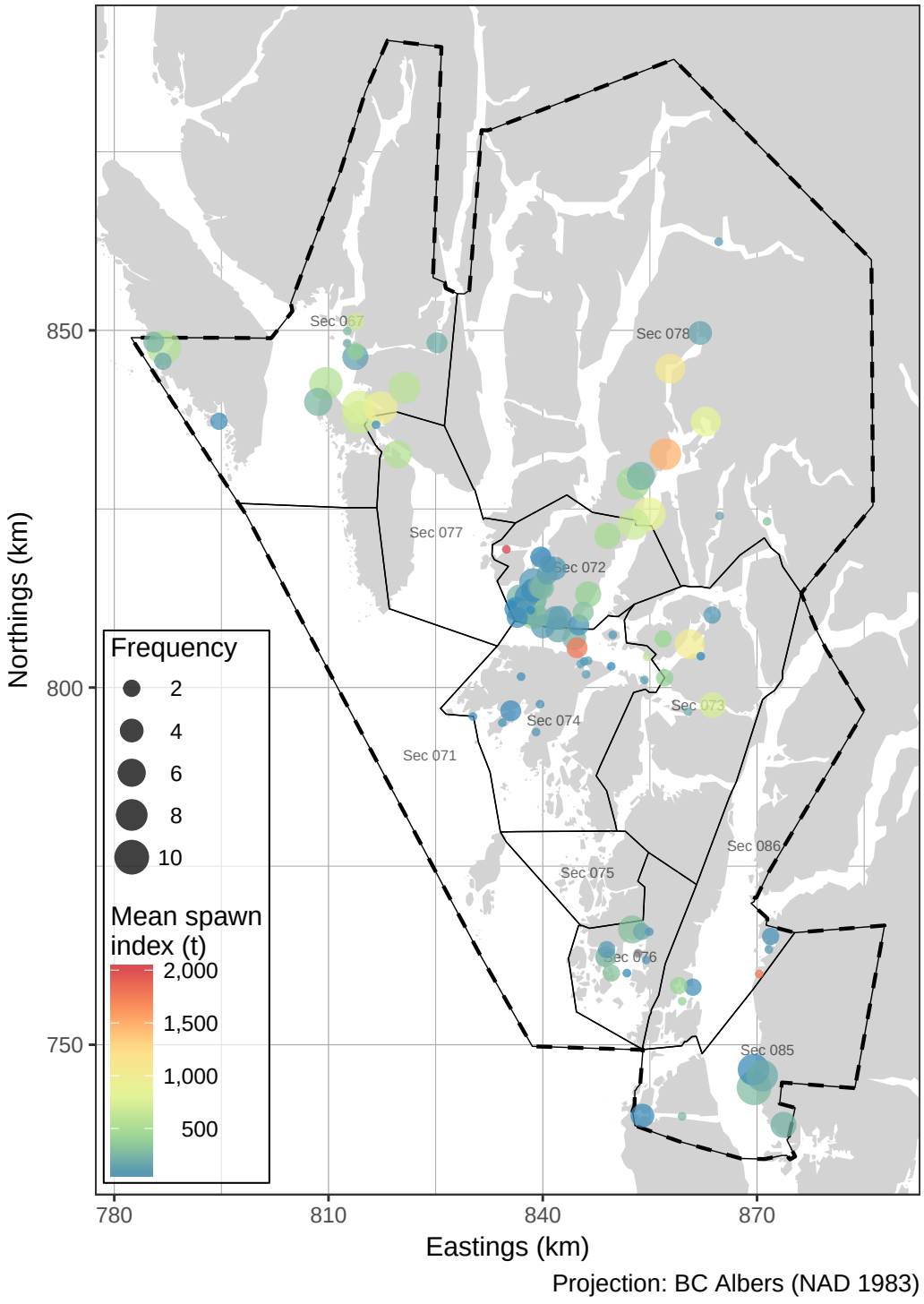

Figure 9. Pacific herring spawn survey locations, mean spawn index in metric tonnes (t), and spawn frequency from 2007 to 2016 in the Central Coast major stock assessment region (SAR; thick dashed lines), and associated Sections (Sec; thin solid lines). The 'spawn index' represents the raw survey data 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).

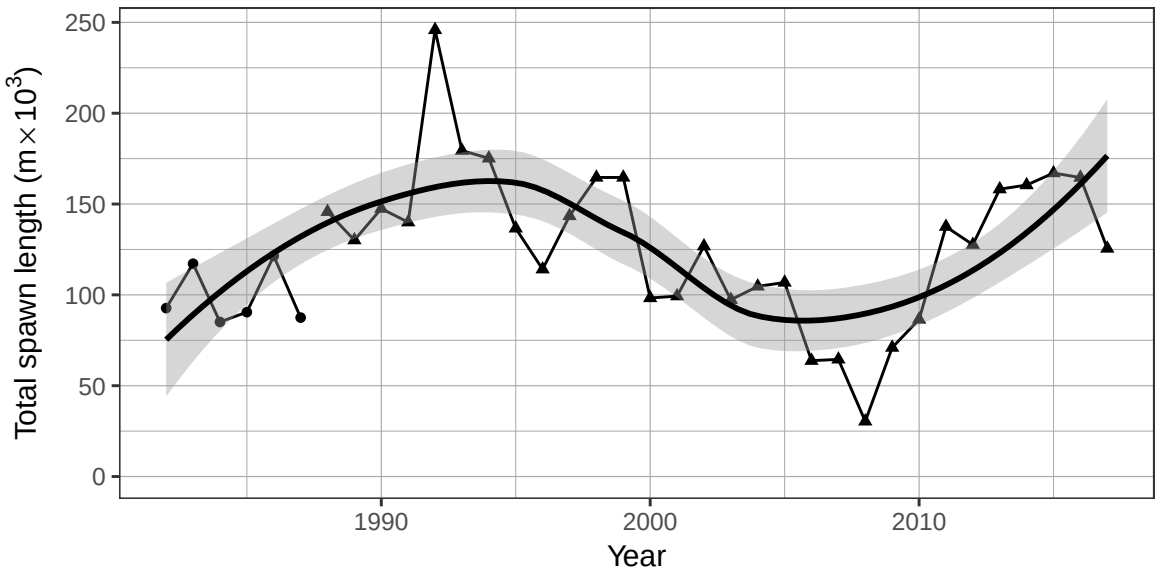

Figure 10. Time series of total spawn length in thousands of metres ($m \times 10^3$) for Pacific herring from 1982 to 2017 in the Central Coast major stock assessment region (SAR). The thick black line is a loess curve, and the shaded area is the 90% confidence interval. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2017).

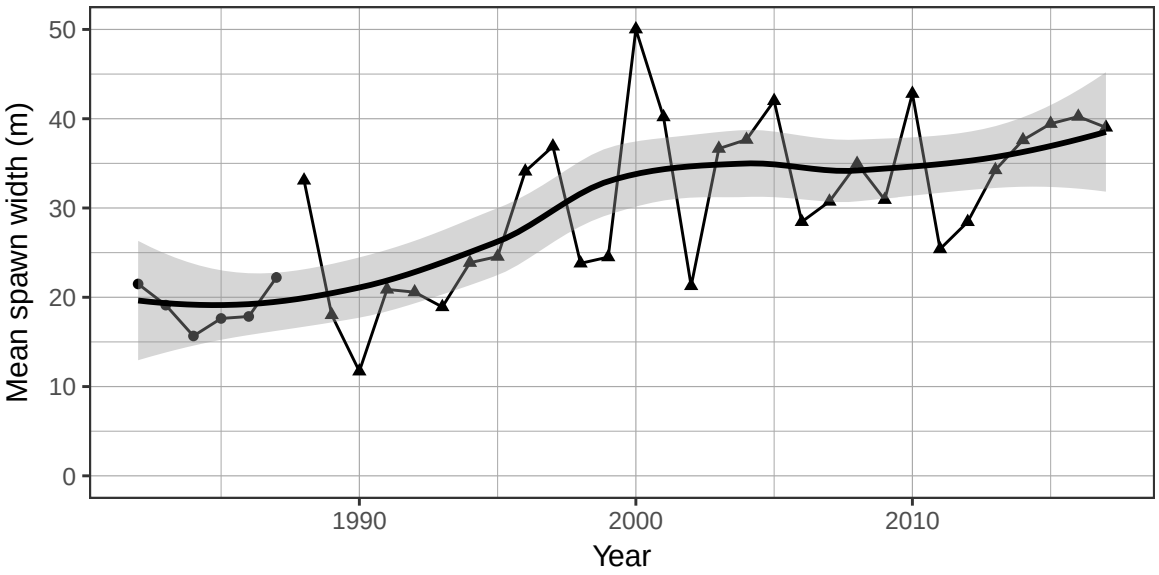

Figure 11. Time series of mean spawn width in metres (m) for Pacific herring from 1982 to 2017 in the Central Coast major stock assessment region (SAR). The thick black line is a loess curve, and the shaded area is the 90% confidence interval. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2017).

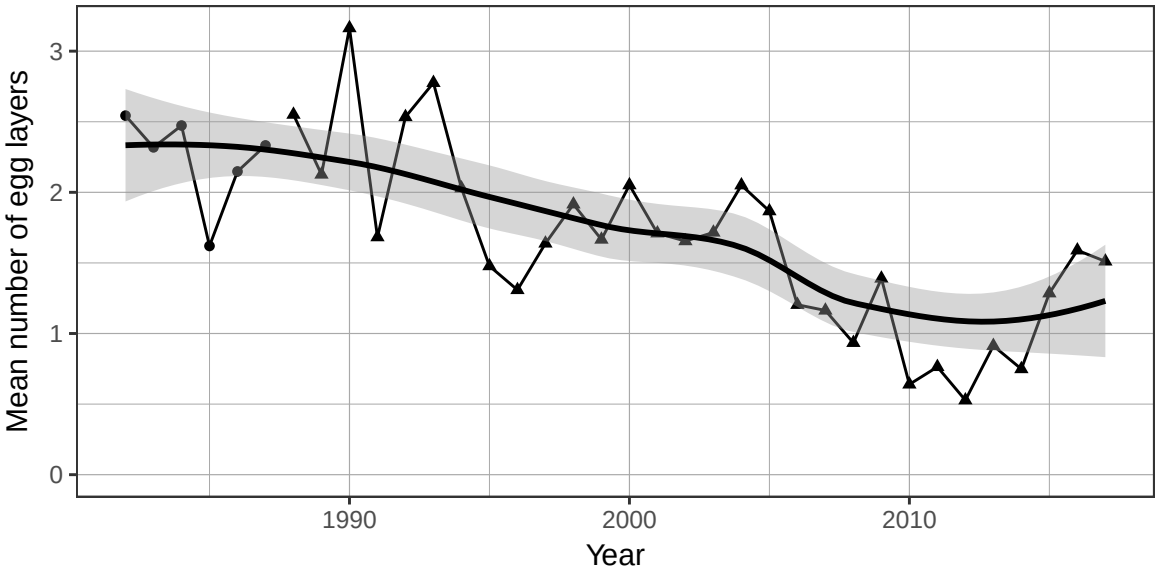

Figure 12. Time series of mean number of egg layers for Pacific herring from 1982 to 2017 in the Central Coast major stock assessment region (SAR). The thick black line is a loess curve, and the shaded area is the 90% confidence interval. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2017).

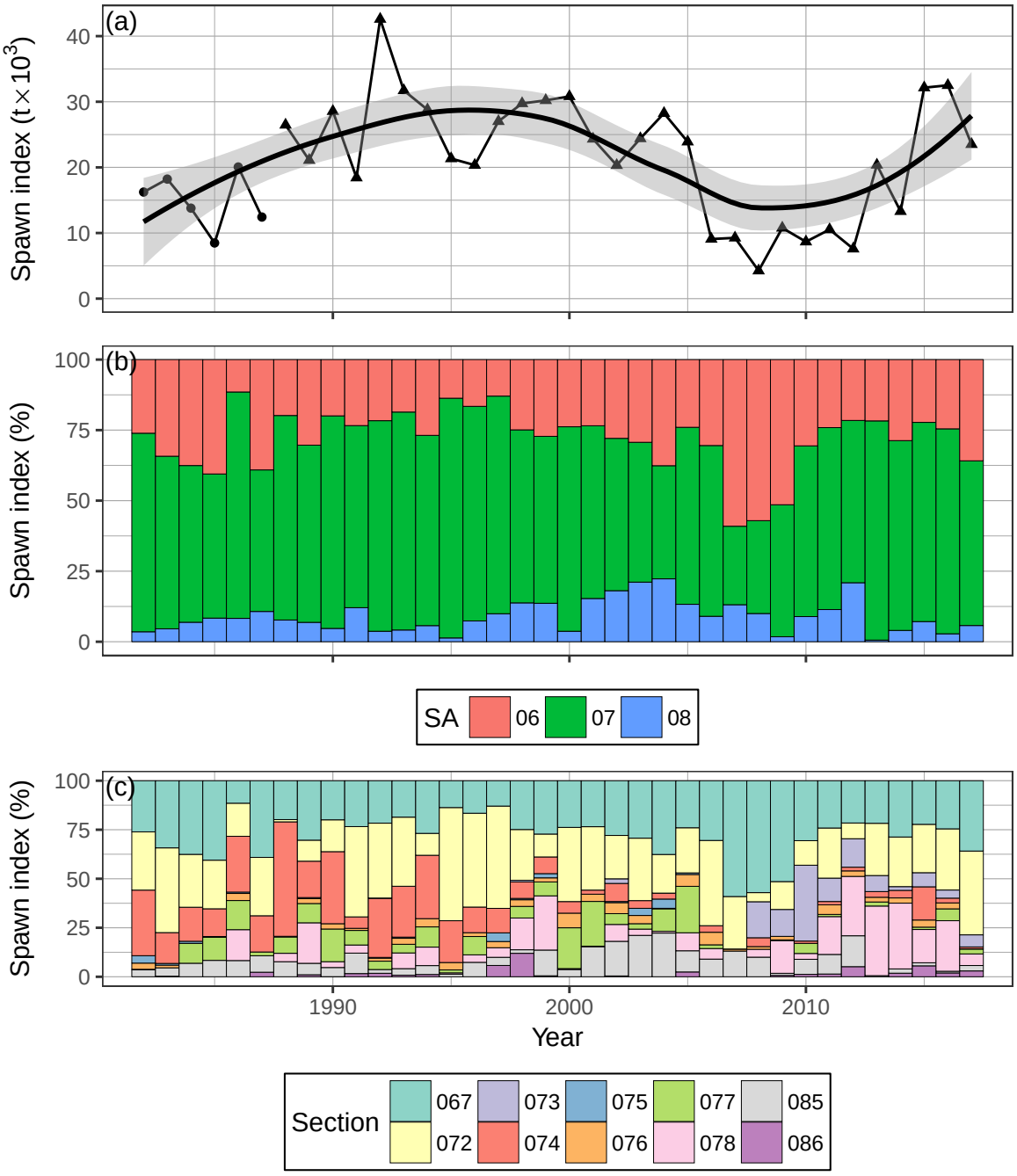

Figure 13. Time series of spawn index in thousands of metric tonnes (t $\times$ 10^3) for Pacific herring from 1982 to 2017 in the Central Coast major stock assessment region (SAR; a), as well as percent contributed by Statistical Area (SA), and Section (b, & c, respectively). The thick black line is 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 (1988–2017). The 'spawn index' represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q.

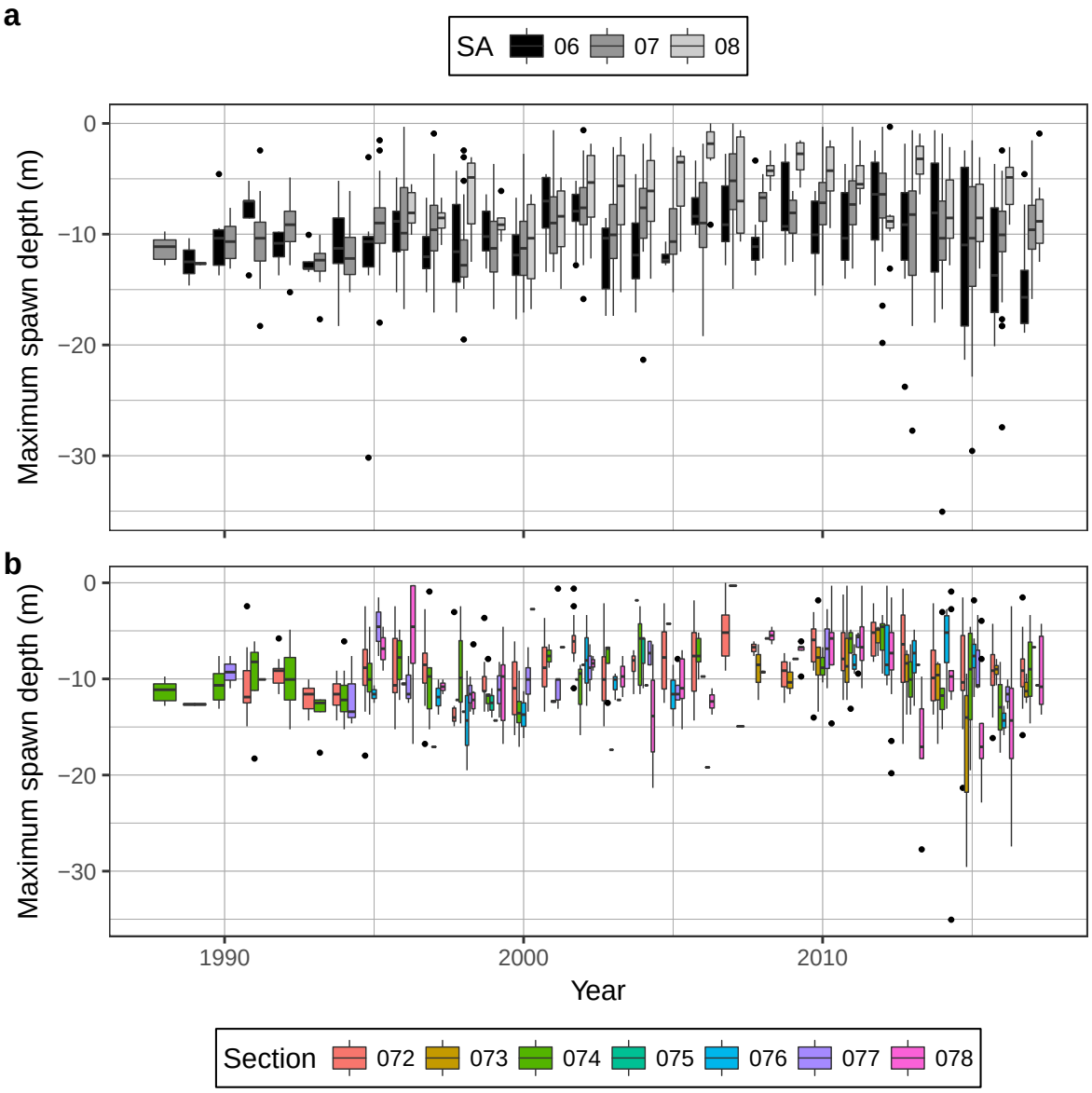

Figure 14. Time series of maximum spawn depth below surface in metres (m) for Pacific herring from 1982 to 2017 in the Central Coast major stock assessment region (SAR) by Statistical Area (SA; a), and Section (b). Note that depth is not corrected to the chart datum. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2017).

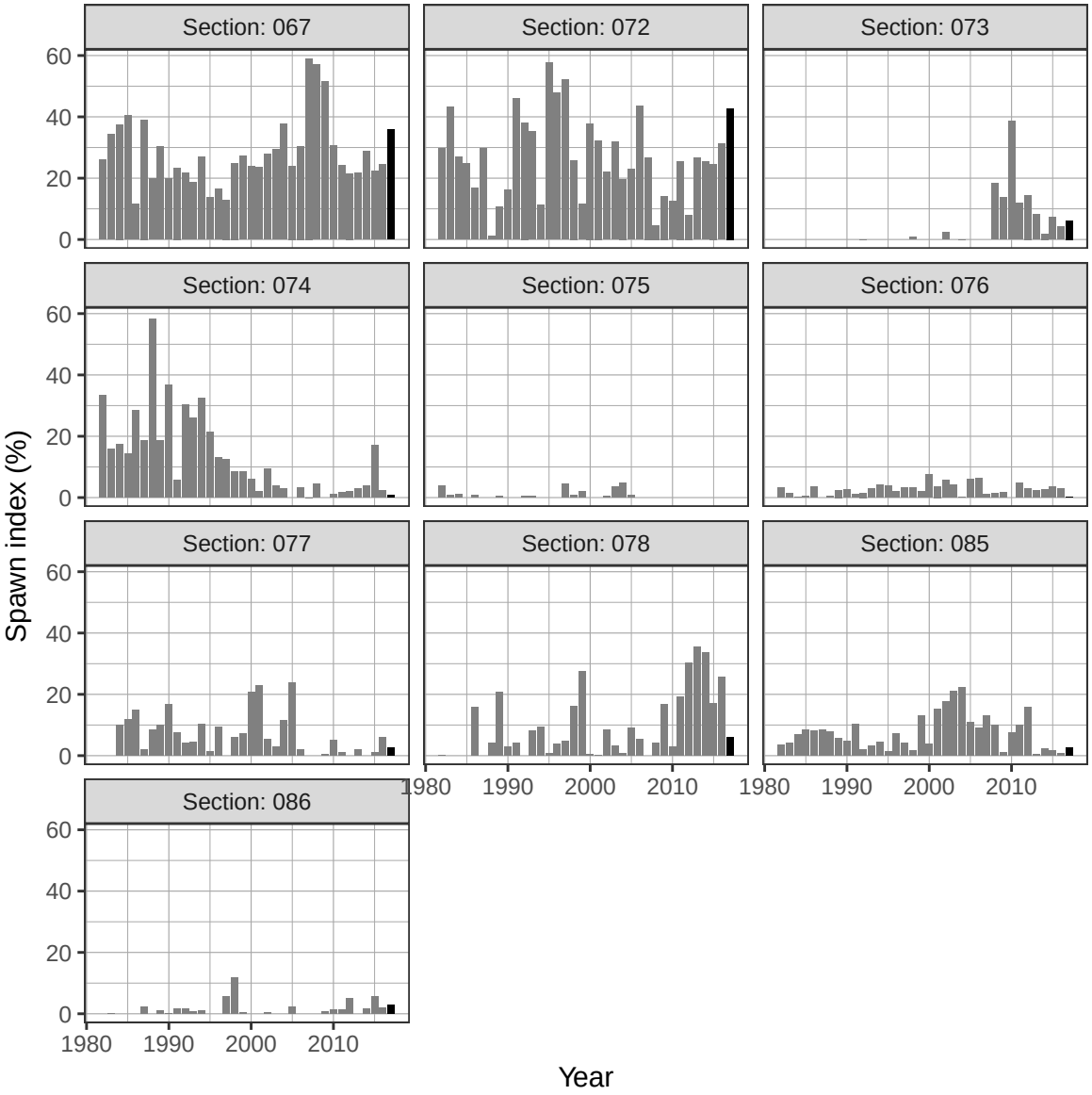

Figure 15. Time series of percent of spawn index by Section for Pacific herring from 1982 to 2017 in the Central Coast major stock assessment region (SAR). The year 2017 has a darker bar to facilitate interpretation. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2017). The 'spawn index' represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q.

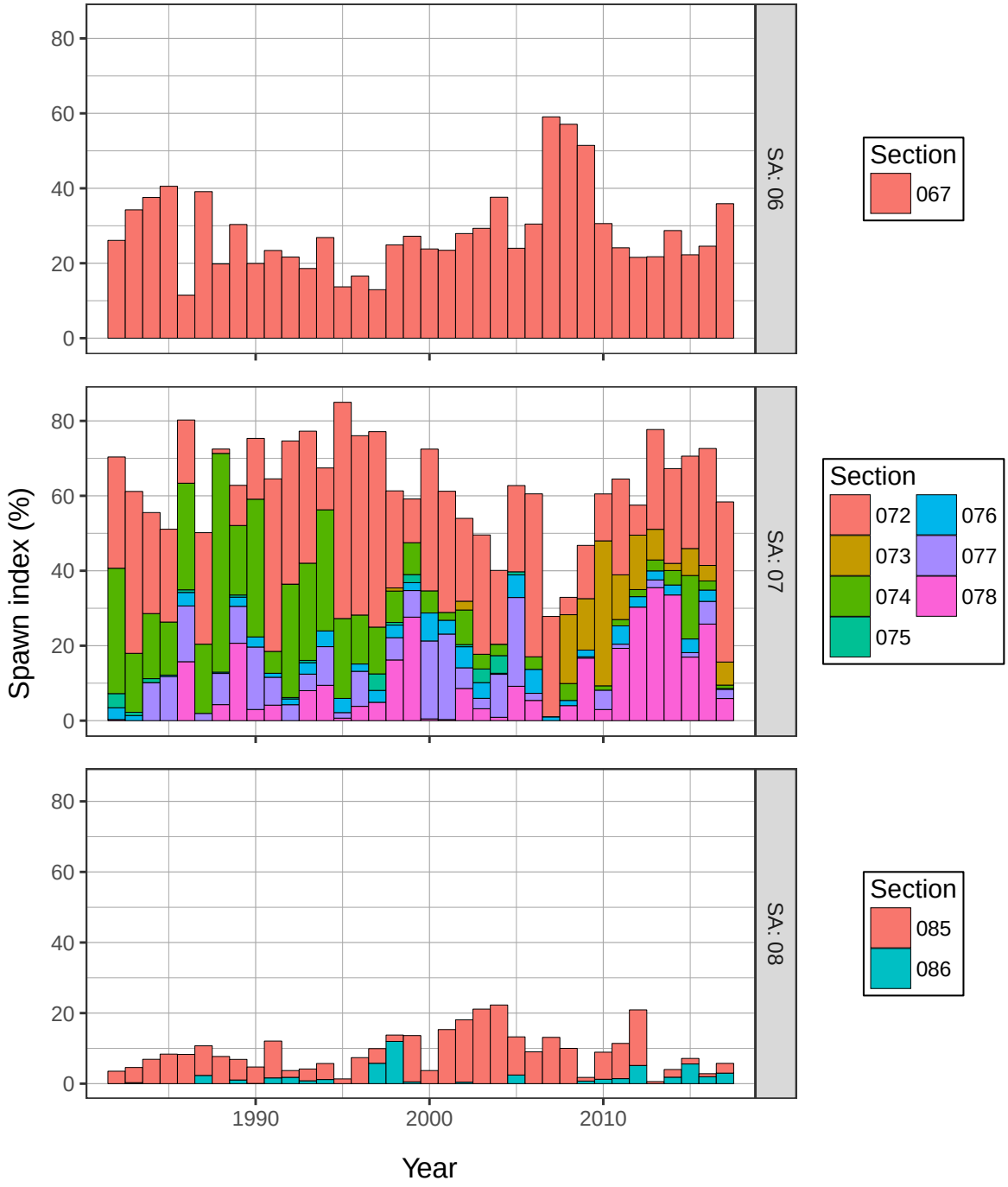

Figure 16. Time series of percent of spawn index by Statistical Area (SA) and Section for Pacific herring from 1982 to 2017 in the Central Coast major stock assessment region (SAR). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951–1987), and dive surveys (1988–2017). The 'spawn index' represents the raw survey data only, and is not scaled by the spawn survey scaling parameter, q.

Appendix A Spawn on kelp

Female Pacific herring produce an average of approximately 200,000 eggs per kilogram, kg of total body weight (Hay 1985; Hay and Brett 1988). We assume that females account for 50% of spawners, and we use the following egg conversion factor, *ECF* to convert eggs to tonnes, t of spawners

$$ECF = fecundity \cdot pFemale \cdot \frac{10^3 \text{ kg}}{\text{t}} \tag{1}$$

where *fecundity* is the number of eggs per kilogram of total female body weight in $\text{eggs} \cdot \text{kg}^{-1}$, *pFemale* is the proportion of spawners that are female, and *ECF* is in $\text{eggs} \cdot \text{t}^{-1}$. Thus, we convert eggs to spawning biomass in tonnes by dividing the number of eggs by $ECF = \text{eggs} \cdot 10^8 \cdot \text{t}^{-1}$. Although Pacific herring productivity is affected by environmental variability and other factors (Tanasichuk and Ware 1987; Hay and Brett 1988), we assume that bias from using Equation 1 is insignificant in most areas and years (Schweigert 1993).

Shields et al. (1985) collected information on the relationship between the number of egg layers in SOK product, and the proportion of the product weight that consisted of eggs and kelp. They determined that kelp represented an average of 12% of the total product weight. Since SOK product is universally brined at the time of harvest, it is necessary to also consider the uptake of salt by the eggs, which increases the overall product weight. However, there is uncertainty in the degree of brining that occurs prior to weighing the product. Nevertheless, Whyte and Englar (1977) determined that following a 24 hour brining period, the wet product weight increased about 13% due to salt uptake. However, by osmosis, the brining would also draw some water from the eggs; unfortunately this cannot be accounted for at this time. The last factor to consider is the mean fertilized egg weight, which was determined by Hay and Miller (1982) as $2.38 \cdot 10^{-6}$ kg. We estimate spawning biomass removed from the population by the SOK fishery as

$$SB = \frac{SOK \cdot eggKelpProp \cdot eggBrineProp}{eggWt \cdot ECF} \tag{2}$$

where *SOK* is the weight in kilograms of herring SOK harvest, *eggKelpProp* is the proportion of the SOK product that is eggs, not kelp (0.88), *eggBrineProp* is the proportion of SOK product that is eggs after brining (0.87), *eggWt* is the average weight in kilograms of a fertilized egg ($\text{kg} \cdot \text{egg}^{-1}$), and *SB* is the estimated spawning biomass in tonnes, based on Equation 1.

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