# Pacific Herring preliminary data summary for West Coast of Vancouver Island 2019

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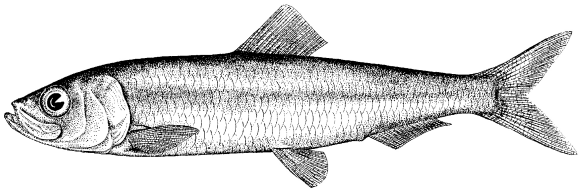

Pacific Herring (*Clupea pallasii*). Image credit: Fisheries and Oceans Canada.

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**Disclaimer** This report contains preliminary data collected for Pacific Herring in 2019 in the West Coast of Vancouver Island major stock assessment regions (SAR). These data may differ from data used and presented in the final stock assessment.

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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 2019. 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 Pacific 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 2019 in the West Coast of Vancouver Island major SAR (Figure 2). Data collected outside the SAR boundary are not included in this summary, and are not used for the purposes of stock assessment. Although we summarise data at the scale of the SAR for stock assessments, we summarise data at finer spatial scales in this report: locations are nested within sections, sections are nested within statistical areas, and statistical areas are nested within SARs (Table 2). Note that we refer to 'year' instead of 'herring season' in this report; therefore 2019 refers to the 2018/2019 Pacific Herring season.

# 2 Data collection programs

Biological samples were collected by the seine charter vessel "Proud Canadian" for 20 days from February 20$^{th}$ to March 11$^{th}$. The primary purpose of the test charter vessel was to collect biological samples from main bodies of herring from Statistical Areas 23, 24, and 25. Nearshore herring samples were collected by the Nuu-chah-nulth staff as part of a pilot sampling program and on-going collaboration between WCVI First Nations and DFO. These nearshore biological samples were collected from spawning aggregations using cast nets. WCVI First Nations spawn reconnaissance charters reported spawn activity in all 3 areas, and conducted spawn surveys using surface survey methods in Hesquiat Harbour (Statistical Area 24).

Herring spawn locations were primarily identified with fixed-wing overflights conducted by DFO Resource Management Area staff. Ten flights were conducted this season from February through March. Satellite imagery was purchased for five weeks from end of February to the end of March. These images were analyzed for the presence of spawn that may not have been seen by the flight program. Two dive charter vessels operated on the WCVI:

- The "Pachena No.1" surveyed 17 days from March 2$^{nd}$ to March 18$^{th}$, mainly in Statistical Areas 24 and 25, and
- The "Seaveyor" surveyed 13 days from March 11$^{th}$ to April 11$^{th}$.

The seine test charter vessel and the dive survey vessels were funded by DFO, through a contract to the Herring Conservation Research Society.

# 3 Catch and biological samples

In the 1950s and 1960s, the reduction fishery dominated Pacific Herring catch; starting in the 1970s, catch has been predominantly from roe seine and gillnet fisheries. The reduction fishery is different from current fisheries in several ways. First, the reduction fishery caught Pacific Herring of all ages, whereas current fisheries target spawning (i.e., mature) fish. Thus, reduction fisheries included age-1 fish which are not typically caught in current fisheries. Second, the reduction fishery has some uncertainty regarding the quantity and location of catch; in some cases this may affect our ability to allocate catch to a specific SAR. For the roe gillnet fishery, all Pacific Herring catch has been validated

by a dockside monitoring program since 1998; the catch validation program started in 1999 for the roe seine fishery. Finally, the reduction fishery operated during the winter months, whereas roe fisheries typically target spawning fish between February and April.

Landed commercial catch of Pacific Herring by year and fishery is shown in Table 3 and Figure 3. Total harvested spawn on kelp (SOK) in 2019 in the West Coast of Vancouver Island major SAR is shown in Table 4; we also calculate the estimated spawning biomass associated with SOK harvest. See the draft spawn index techincal report for calculations to convert SOK harvest to spawning biomass.

In 2019, 25 Pacific Herring biological samples were collected and processed for the West Coast of Vancouver Island major SAR (Table 5, Table 6), and a total of 1,140 Pacific Herring were aged in 2019. Differences between biological data collected from two sampling protocols regarding the number-, proportion-, weight-, and length-at-age for Pacific Herring in 2019 in the West Coast of Vancouver Island major SAR are shown in Table 7, Table 8, Table 9, and Table 10, respectively. The nearshore sampling program is a multi-year pilot study (using cast nets), therefore only biological data from the seine samples were used for the purposes of stock assessment. The locations in which the biological samples were collected are presented in Figure 4. Included herein are biological summaries of observed proportion-, number-, weight-, and length-at-age (Figure 5, Table 11, and Figure 6, respectively). Biological summaries only include samples collected using seine nets (commercial and test) due to size-selectivity of other gear types such as gillnet. Only representative biological samples are included, where 'representative' indicates whether the Pacific Herring sample in the set accurately reflects the larger Pacific Herring school.

# 4 Spawn survey data

Pacific Herring spawn surveys were conducted at 23 individual locations in 2019 in the West Coast of Vancouver Island major SAR (Table 12, and Figure 7). A summary of spawn from the last decade (2009 to 2018) is shown in Figure 8. Figure 9 shows spawn start date by decade and Statistical Area. 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, Table 13, and Figure 13). We describe the calculations used to estimate the spawn index in the draft spawn index techincal report. The 'spawn index' 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 to 1987), and dive surveys (1988 to 2019).

Some Pacific Herring Sections contribute more than others to the total spawn index, and the percentage contributed by Section varies yearly (Figure 12b, Figure 14). For example, in 2019, Section 253 contributed the most to the spawn index (34%). As with Sections, some Statistical Areas contribute more than others to the total spawn index (Figure 12c, Figure 15). An animation shows the spawn index by spawn survey location

from 1951 to 2019 (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:

- Compared to last year, the spatial extent of reported spawn was about the same.
- In Statistical Area 23, spawning activity was reported in the usual areas from Salmon Beach to Toquart Bay, with spawn also along the south side of Ucluelet.
- In Statistical Area 24, multiple spawns occurred from January to March, with the majority occurring in Hesquiaht Harbour.
- As with last year in Statistical Area 25, there was a noticeable increase in spawning activity in Nootka Sound, and multiple spawns around the Nuchatlitz islands.

# 6 Tables

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. Statistical Areas and Sections for Pacific Herring in the West Coast of Vancouver Island major stock assessment region (SAR).

| Region | Statistical Area | Section |
|---|---|---|
| West Coast of Vancouver Island | 23 | 230 |
| West Coast of Vancouver Island | 23 | 231 |
| West Coast of Vancouver Island | 23 | 232 |
| West Coast of Vancouver Island | 23 | 233 |
| West Coast of Vancouver Island | 23 | 239 |
| West Coast of Vancouver Island | 24 | 240 |
| West Coast of Vancouver Island | 24 | 241 |
| West Coast of Vancouver Island | 24 | 242 |
| West Coast of Vancouver Island | 24 | 243 |
| West Coast of Vancouver Island | 24 | 244 |
| West Coast of Vancouver Island | 24 | 245 |
| West Coast of Vancouver Island | 24 | 249 |
| West Coast of Vancouver Island | 25 | 250 |
| West Coast of Vancouver Island | 25 | 251 |
| West Coast of Vancouver Island | 25 | 252 |
| West Coast of Vancouver Island | 25 | 253 |
| West Coast of Vancouver Island | 25 | 259 |

Table 3. Total landed commercial catch of Pacific Herring in metric tonnes (t) by gear type in 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). Legend: 'Other' represents the reduction, the food and bait, as well as the special use fishery; 'RoeSN' represents the roe seine fishery; and 'RoeGN' 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.

| Gear | Catch (t) |
|---|---|
| Other | 0 |
| RoeSN | 0 |
| RoeGN | 0 |

Table 4. Total harvested Pacific Herring spawn on kelp (SOK) in pounds (lb), and the associated estimate of spawning biomass in metric tonnes (t) from 2009 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). See the draft spawn index techincal report for calculations to convert SOK harvest to spawning biomass. Note: 'WP' indicates that data are withheld due to privacy concerns.

| Year | Harvest (lb) | Spawning biomass (t) |
|---|---|---|
| 2009 | 0 | 0 |
| 2010 | 0 | 0 |
| 2011 | 0 | 0 |
| 2012 | 0 | 0 |
| 2013 | 0 | 0 |
| 2014 | 0 | 0 |
| 2015 | 0 | 0 |
| 2016 | 0 | 0 |
| 2017 | 0 | 0 |
| 2018 | 0 | 0 |
| 2019 | 0 | 0 |

Table 5. Number of Pacific Herring biological samples processed from 2009 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). Each sample is approximately 100 fish.

| | Number of samples | | |
|---|---|---|---|
| Year | Commercial | Test | Total |
| 2009 | 0 | 29 | 29 |
| 2010 | 0 | 27 | 27 |
| 2011 | 0 | 28 | 28 |
| 2012 | 0 | 10 | 10 |
| 2013 | 0 | 5 | 5 |
| 2014 | 0 | 4 | 4 |
| 2015 | 0 | 20 | 20 |
| 2016 | 0 | 25 | 25 |
| 2017 | 0 | 19 | 19 |
| 2018 | 0 | 42 | 42 |
| 2019 | 0 | 25 | 25 |

Table 6. Number and type of Pacific Herring biological samples processed in 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). Each sample is approximately 100 fish.

| Type | Gear | Use | Number of samples |
|---|---|---|---|
| Test | Other | Nearshore | 11 |
| Test | Seine | Test fishery | 14 |

Table 7. Observed number-at-age of Pacific Herring by sample type in 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The age-10 class is a 'plus group' which includes fish ages 10 and older. Legend: 'Nearshore' refers to samples collected using cast nets as part of a pilot study with First Nations.

| | Number-at-age | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample type | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Nearshore | 101 | 616 | 82 | 37 | 106 | 15 | 6 | 0 | 0 |
| Seine test | 63 | 575 | 111 | 56 | 265 | 46 | 21 | 3 | 0 |
| Total | 164 | 1191 | 193 | 93 | 371 | 61 | 27 | 3 | 0 |

Table 8. Observed proportion-at-age of Pacific Herring by sample type in 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The age-10 class is a 'plus group' which includes fish ages 10 and older. Legend: 'Nearshore' refers to samples collected using cast nets as part of a pilot study with First Nations.

| | Proportion-at-age | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample type | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Nearshore | 0.105 | 0.640 | 0.085 | 0.038 | 0.110 | 0.016 | 0.006 | 0.000 | 0.000 |
| Seine test | 0.055 | 0.504 | 0.097 | 0.049 | 0.232 | 0.040 | 0.018 | 0.003 | 0.000 |
| Total | 0.078 | 0.566 | 0.092 | 0.044 | 0.176 | 0.029 | 0.013 | 0.001 | 0.000 |

Table 9. Observed mean weight-at-age in grams (g) of Pacific Herring by sample type in 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The age-10 class is a 'plus group' which includes fish ages 10 and older. Legend: 'Nearshore' refers to samples collected using cast nets as part of a pilot study with First Nations.

| | Mean weight-at-age (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample type | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Nearshore | 54 | 70 | 81 | 100 | 111 | 116 | 118 | NA | NA |
| Seine test | 61 | 81 | 97 | 115 | 131 | 135 | 140 | 141 | NA |
| Total | 57 | 76 | 91 | 109 | 126 | 130 | 135 | 141 | NA |

Table 10. Observed mean length-at-age in millimetres (mm) of Pacific Herring by sample type in 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The age-10 class is a 'plus group' which includes fish ages 10 and older. Legend: 'Nearshore' refers to samples collected using cast nets as part of a pilot study with First Nations.

| | Mean length-at-age (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample type | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Nearshore | 155 | 170 | 179 | 191 | 198 | 203 | 201 | NA | NA |
| Seine test | 158 | 172 | 182 | 194 | 200 | 202 | 205 | 208 | NA |
| Total | 156 | 171 | 181 | 193 | 200 | 202 | 204 | 208 | NA |

Table 11. Observed proportion-at-age for Pacific Herring from 2009 to 2019 in the West Coast of Vancouver Island 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 |
| 2009 | 0.024 | 0.664 | 0.157 | 0.127 | 0.023 | 0.006 | 0.000 | 0.000 | 0.000 |
| 2010 | 0.176 | 0.295 | 0.424 | 0.052 | 0.045 | 0.007 | 0.001 | 0.000 | 0.000 |
| 2011 | 0.048 | 0.630 | 0.211 | 0.096 | 0.009 | 0.005 | 0.000 | 0.000 | 0.000 |
| 2012 | 0.021 | 0.186 | 0.621 | 0.103 | 0.059 | 0.007 | 0.003 | 0.000 | 0.000 |
| 2013 | 0.034 | 0.241 | 0.150 | 0.475 | 0.050 | 0.045 | 0.005 | 0.000 | 0.000 |
| 2014 | 0.029 | 0.752 | 0.147 | 0.029 | 0.032 | 0.007 | 0.000 | 0.004 | 0.000 |
| 2015 | 0.140 | 0.238 | 0.505 | 0.068 | 0.017 | 0.028 | 0.004 | 0.000 | 0.001 |
| 2016 | 0.040 | 0.648 | 0.168 | 0.124 | 0.014 | 0.003 | 0.004 | 0.001 | 0.000 |
| 2017 | 0.025 | 0.076 | 0.664 | 0.132 | 0.082 | 0.016 | 0.002 | 0.002 | 0.000 |
| 2018 | 0.053 | 0.133 | 0.109 | 0.566 | 0.096 | 0.035 | 0.005 | 0.002 | 0.000 |
| 2019 | 0.055 | 0.504 | 0.097 | 0.049 | 0.232 | 0.040 | 0.018 | 0.003 | 0.000 |

Table 12. Pacific Herring spawn survey locations, start date, and spawn index in metric tonnes (t) in 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The 'spawn index' is not scaled by the spawn survey scaling parameter, $q$. Missing spawn index values (NAs) indicate incomplete spawn surveys.

| Statistical Area | Section | Location name | Start date | Spawn index (t) |
|---|---|---|---|---|
| 23 | 232 | Food Islets | April 01 | 237 |
| 23 | 232 | Macoah Pass | March 14 | 185 |
| 23 | 232 | Maggie Rvr | March 01 | 127 |
| 23 | 232 | Newcombe Chnl | April 01 | 2,113 |
| 23 | 232 | Port Albion | March 05 | 187 |
| 23 | 232 | Stuart Bay | March 07 | 364 |
| 23 | 232 | Toquart Bay | March 01 | 6 |
| 23 | 232 | Two Rivers + | March 09 | 655 |
| 23 | 232 | Ucluelet Head | March 05 | 2 |
| 24 | 242 | Antons Spit | January 24 | 2,130 |
| 24 | 242 | Hesquiat Hrbr | January 24 | 470 |
| 24 | 242 | Hesquiat Pen | March 13 | 70 |
| 24 | 242 | Leclaire Pt | February 26 | NA |
| 24 | 242 | Rondeault Pt | March 21 | 37 |
| 24 | 245 | Clifford Pt | March 06 | 67 |
| 25 | 252 | Plumper Harbour | March 13 | 1,584 |
| 25 | 252 | Strange Is | March 08 | 2,749 |
| 25 | 252 | Villaverde Islands | March 13 | 207 |
| 25 | 253 | Inner Nuchatlitz | March 27 | 2,329 |
| 25 | 253 | Outer Nuchatlitz | February 18 | 1,309 |
| 25 | 253 | Port Langford | March 02 | 2,152 |
| 25 | 253 | Rosa Hrbr | March 27 | 13 |
| 25 | 253 | Rosa Is | March 27 | 38 |

Table 13. Summary of Pacific Herring spawn survey data from 2009 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2019). The 'spawn index' 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) |
|---|---|---|---|---|
| 2009 | 32,340 | 152 | 1 | 10,607 |
| 2010 | 17,055 | 65 | 2 | 2,464 |
| 2011 | 54,735 | 65 | 2 | 9,663 |
| 2012 | 14,953 | 221 | 2 | 5,407 |
| 2013 | 33,775 | 103 | 1 | 12,258 |
| 2014 | 35,825 | 144 | 1 | 13,937 |
| 2015 | 20,450 | 276 | 1 | 11,323 |
| 2016 | 60,575 | 122 | 1 | 20,528 |
| 2017 | 44,200 | 181 | 1 | 15,734 |
| 2018 | 61,825 | 137 | 1 | 28,107 |
| 2019 | 49,325 | 131 | 1 | 17,030 |

# 7 Figures

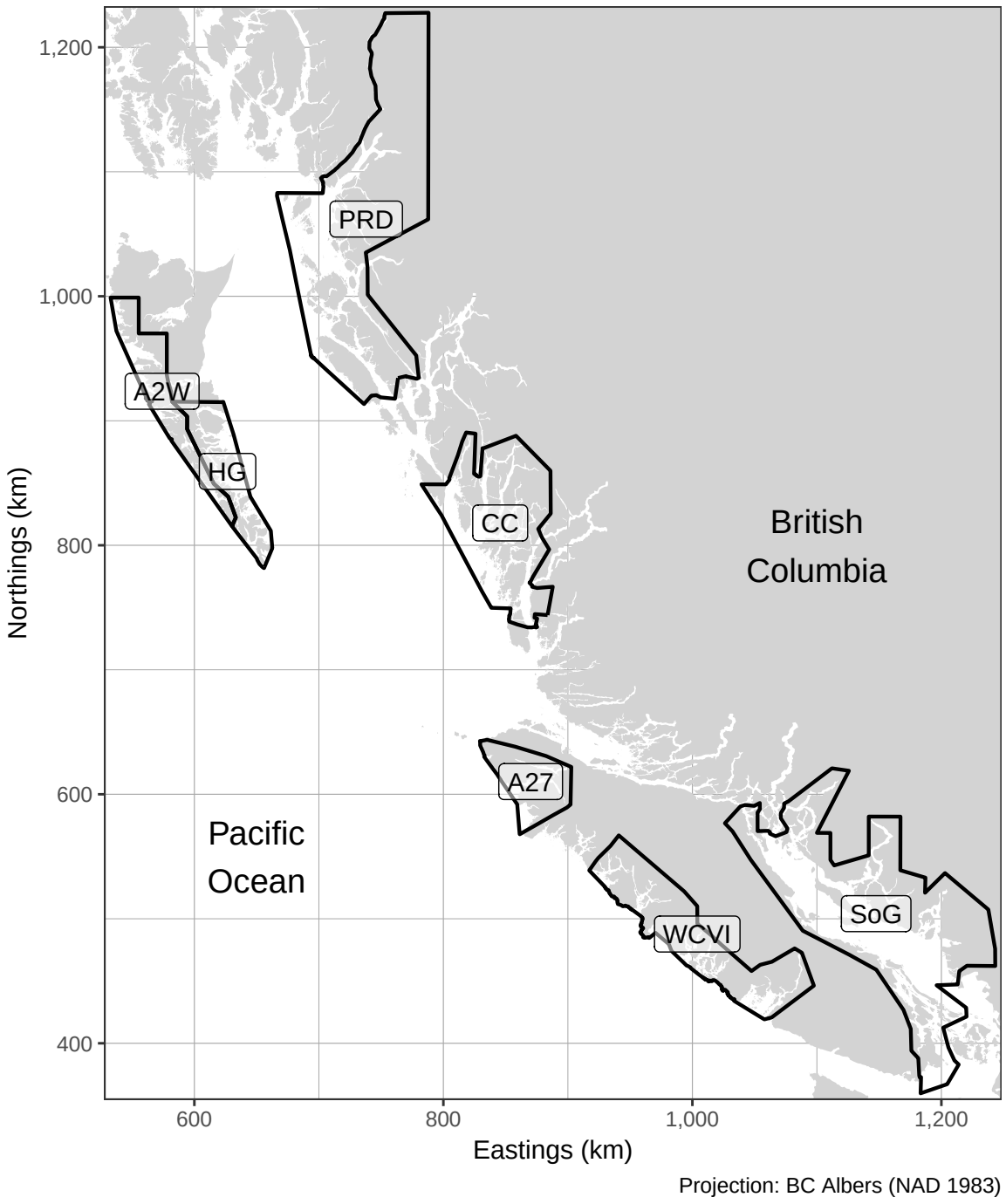


Figure 1. Boundaries for the Pacific Herring stock assessment regions (SARs) in British Columbia: there are 5 major SARs (HG, PRD, CC, SoG, and WCVI), and 2 minor SARs (A27 and A2W; Table 1). Units: kilometres (km).

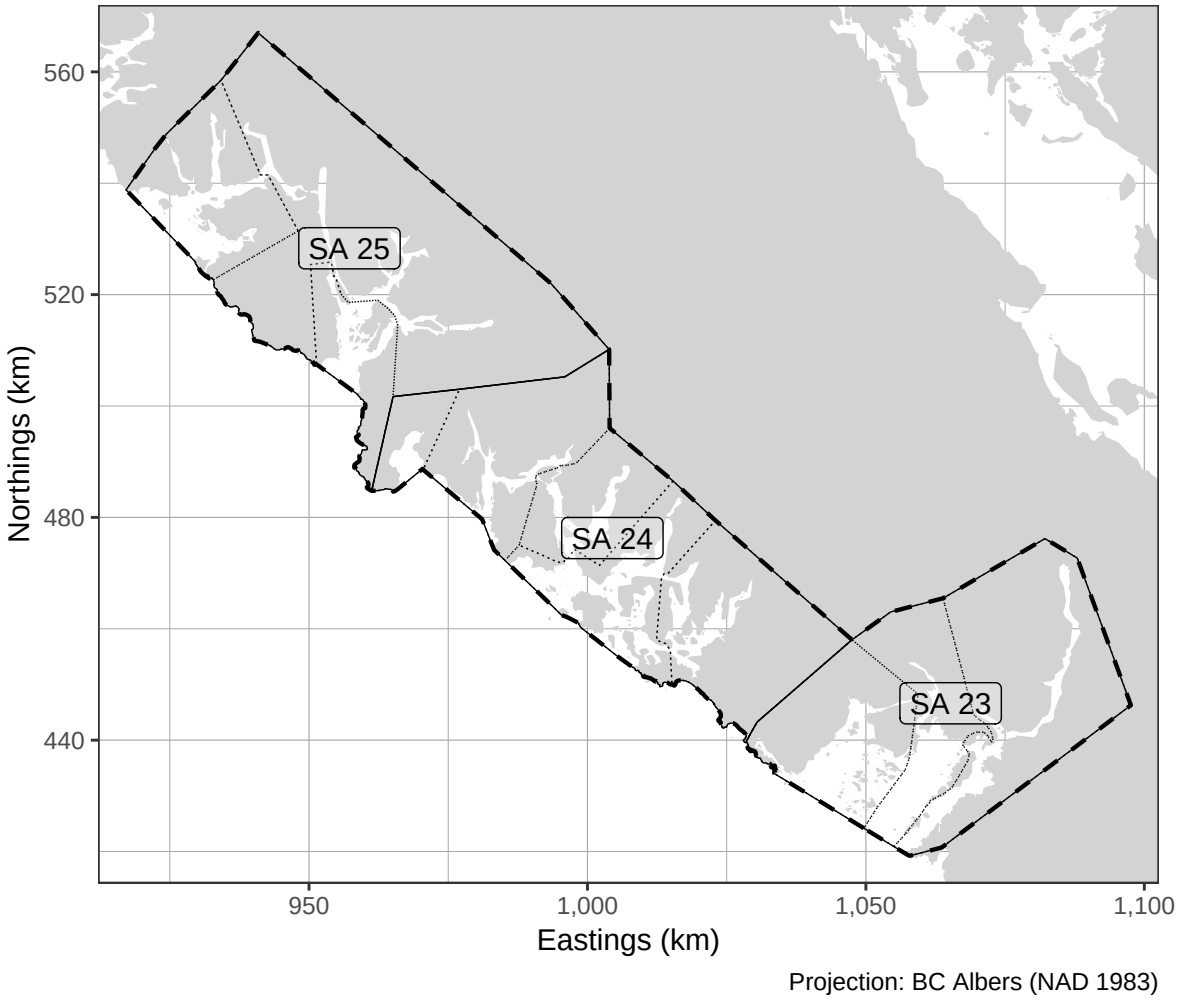


Figure 2. Boundaries for the West Coast of Vancouver Island major stock assessment region (SAR; thick dashed lines), associated Statistical Areas (SA; thin solid lines), and associated Sections (thin dotted lines). Units: kilometres (km).

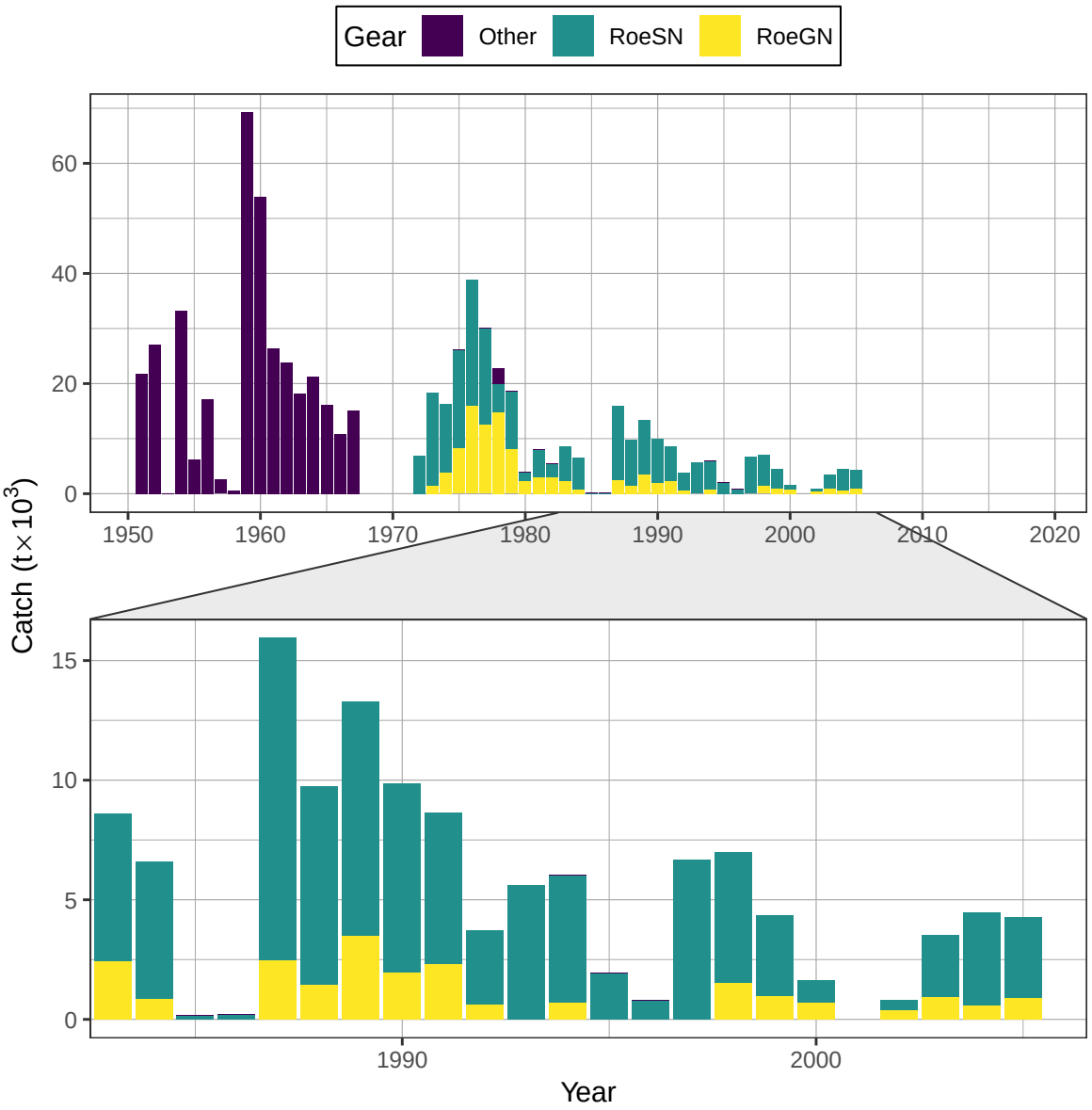


Figure 3. Time series of total landed catch in thousands of metric tonnes ($t \times 10^3$) of Pacific Herring by gear type from 1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). Legend: 'Other' represents the reduction, the food and bait, as well as the special use fishery; 'RoeSN' represents the roe seine fishery; and 'RoeGN' represents the roe gillnet fishery. Data from the spawn-on-kelp (SOK) fishery is not included.

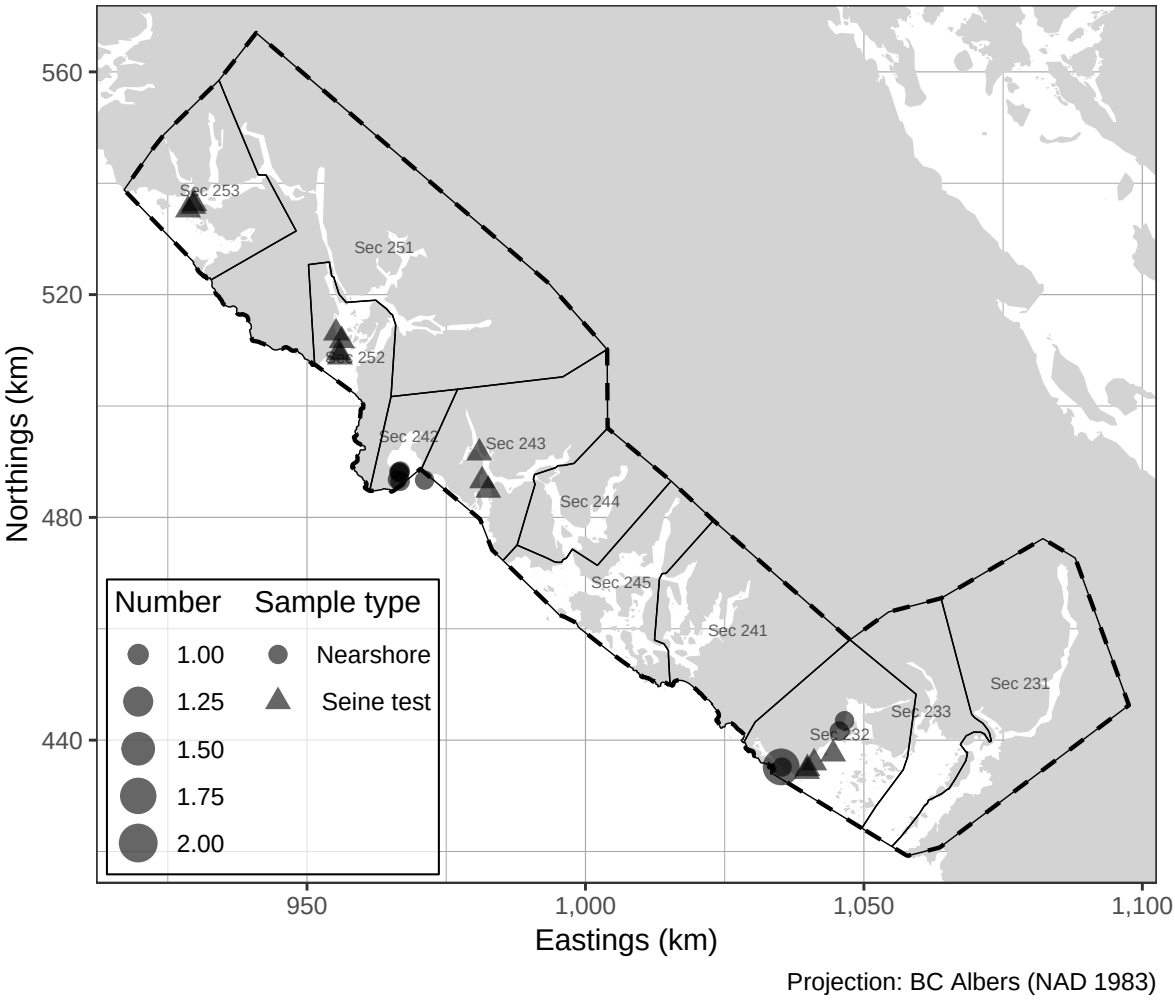


Figure 4. Location and type of Pacific Herring biological samples collected in 2019 in the West Coast of Vancouver Island major stock assessment region (SAR; thick dashed lines), and associated Sections (Sec; thin solid lines). Units: kilometres (km).

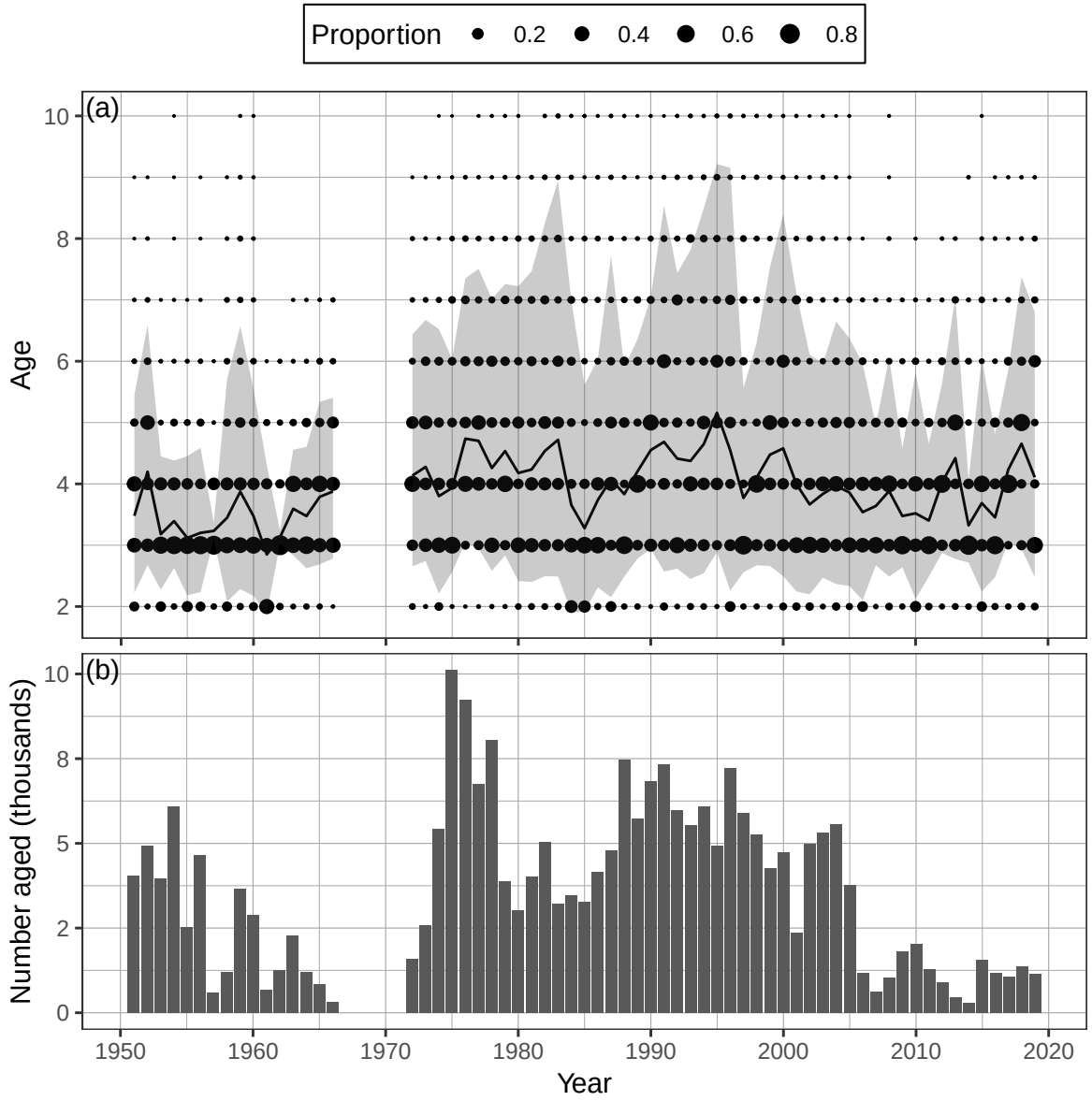


Figure 5. Time series of observed proportion-at-age (a) and number aged in thousands (c) of Pacific Herring from 1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The black line is the mean age, and the shaded area is the approximate 90% distribution. Biological 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.

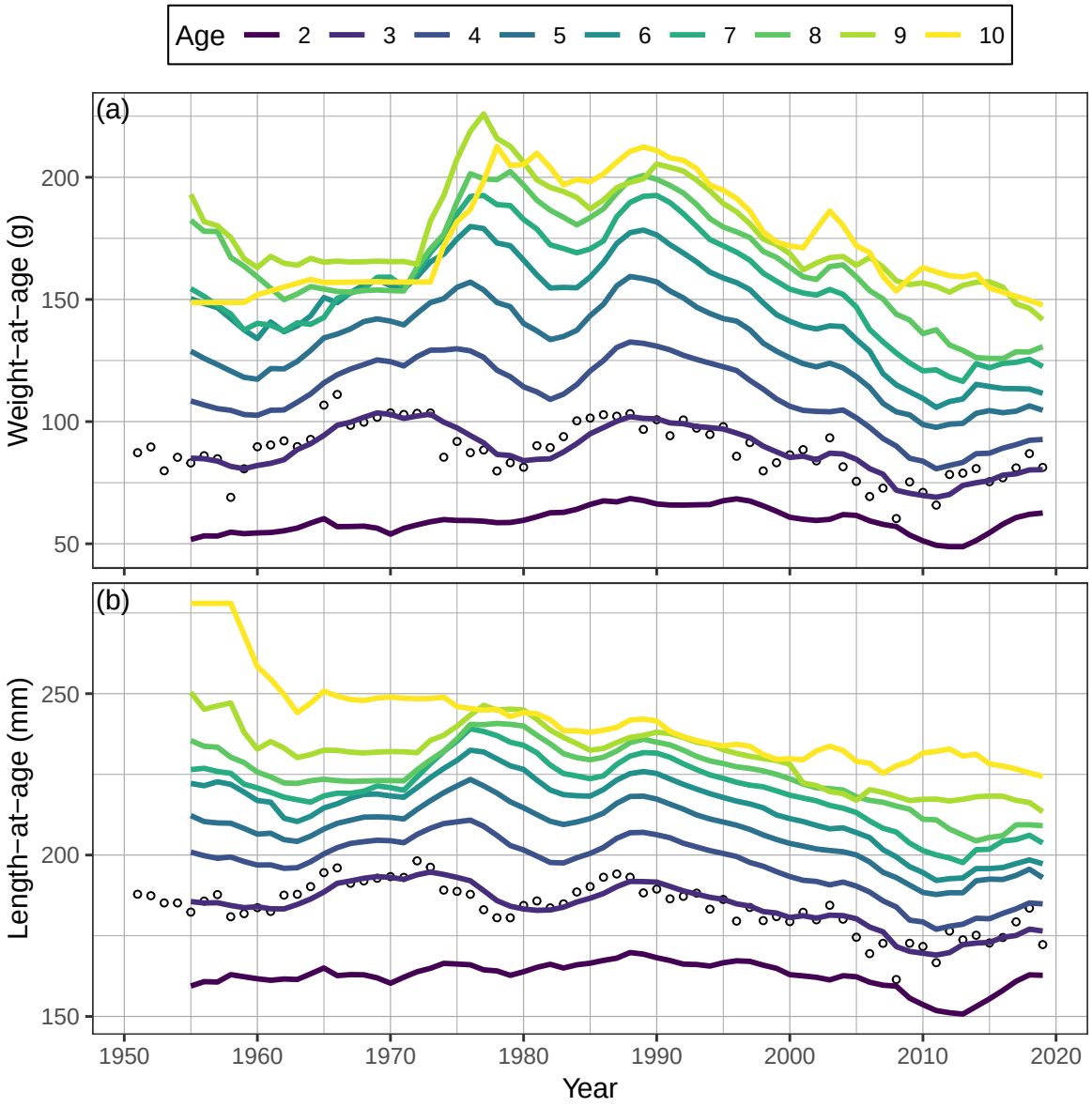


Figure 6. Time series of weight-at-age in grams (g; panel a) and length-at-age in milimetres (mm; panel b) for age-3 (circles) and 5-year running mean weight- and length-at-age (lines) for Pacific Herring from 1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). Missing weight- and length-at-age values (i.e., years with 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.

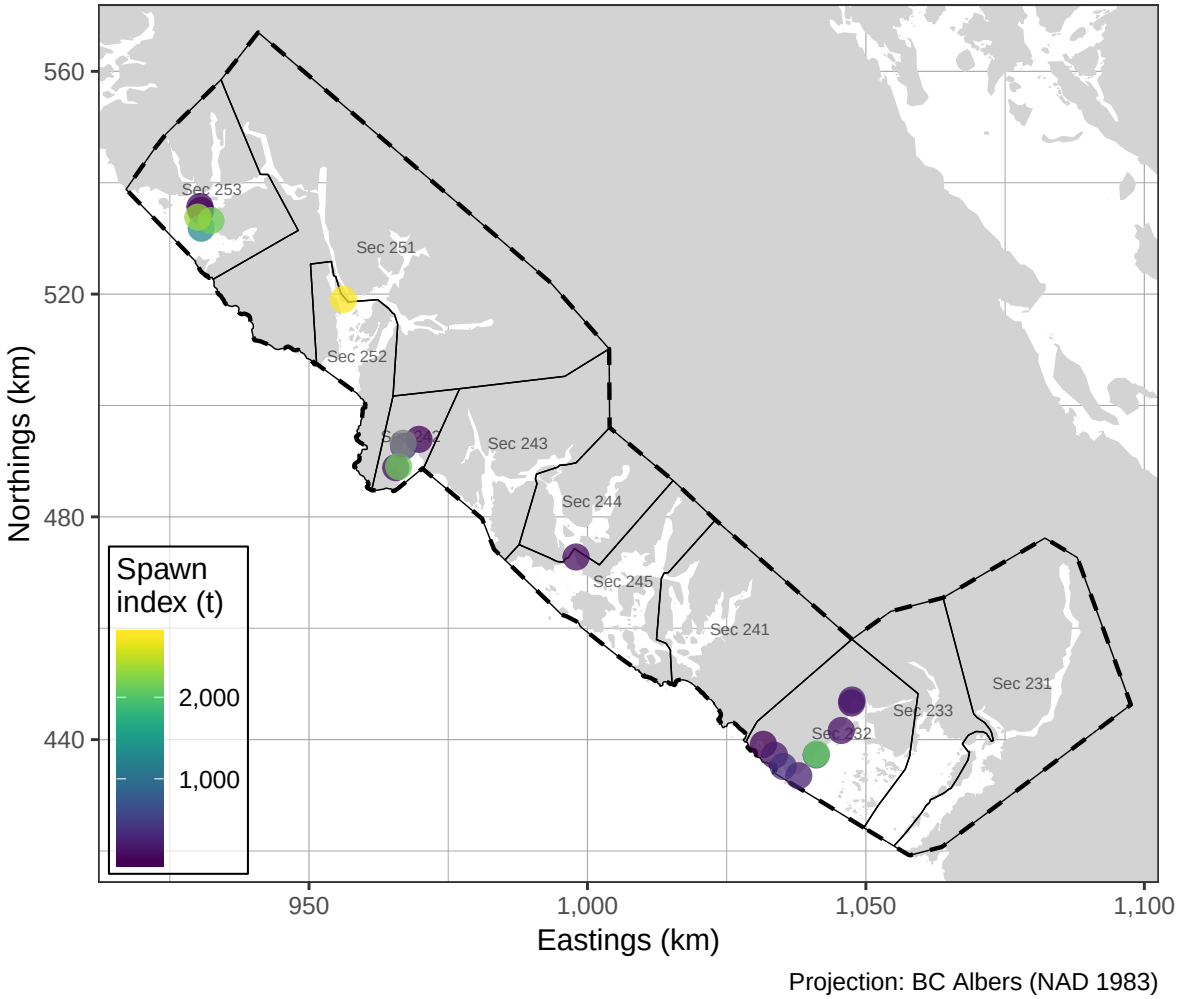


Figure 7. Pacific Herring spawn survey locations, and spawn index in metric tonnes (t) in 2019 in the West Coast of Vancouver Island major stock assessment region (SAR; thick dashed lines), and associated Sections (Sec; thin solid lines). The 'spawn index' is not scaled by the spawn survey scaling parameter, $q$. Missing spawn index values (grey circles) indicate incomplete spawn surveys. Units: kilometres (km).

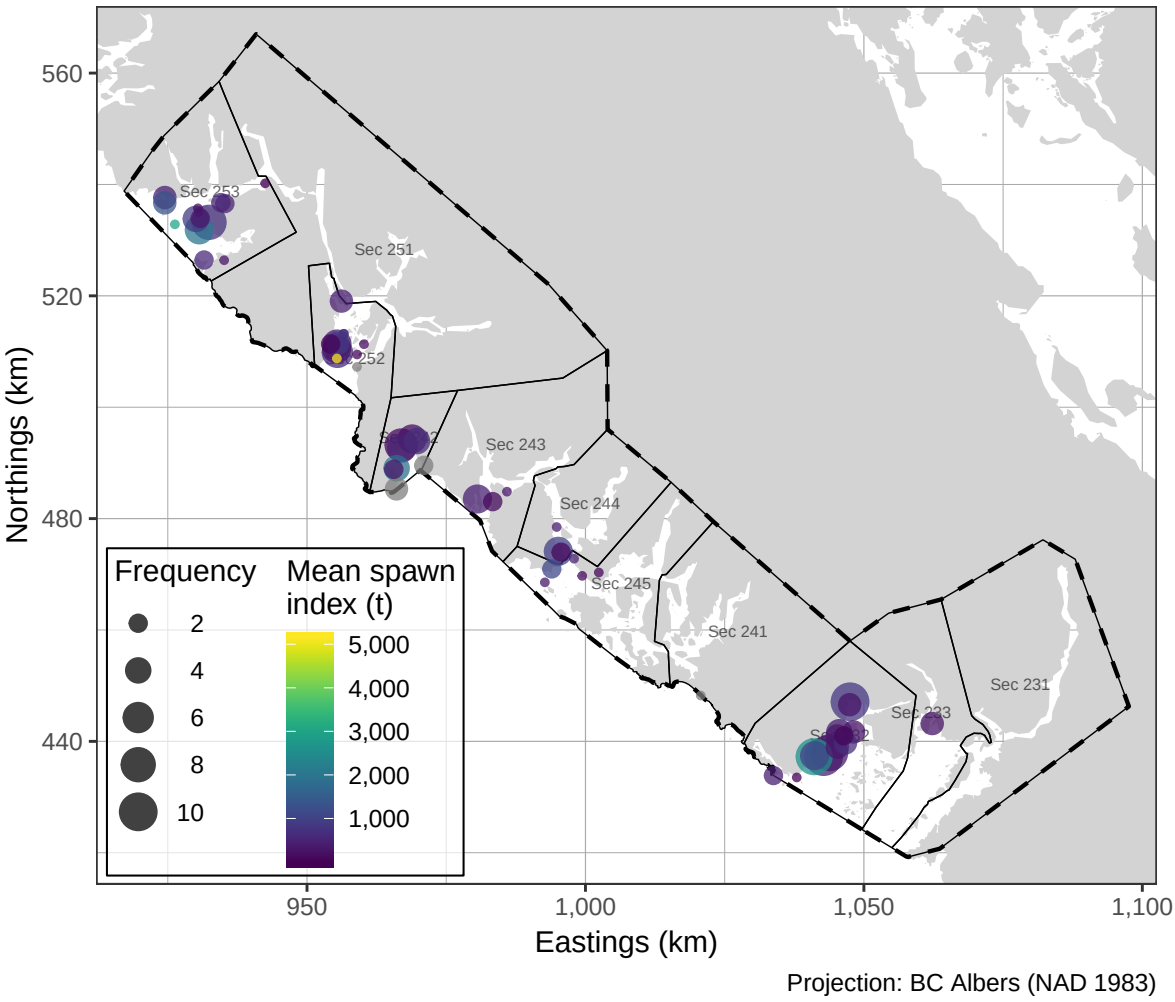


Figure 8. Pacific Herring spawn survey locations, mean spawn index in metric tonnes (t), and spawn frequency from 2009 to 2018 in the West Coast of Vancouver Island major stock assessment region (SAR; thick dashed lines), and associated Sections (Sec; thin solid lines). The 'spawn index' is not scaled by the spawn survey scaling parameter, $q$. Missing spawn index values (grey circles) indicate incomplete spawn surveys. Units: kilometres (km).

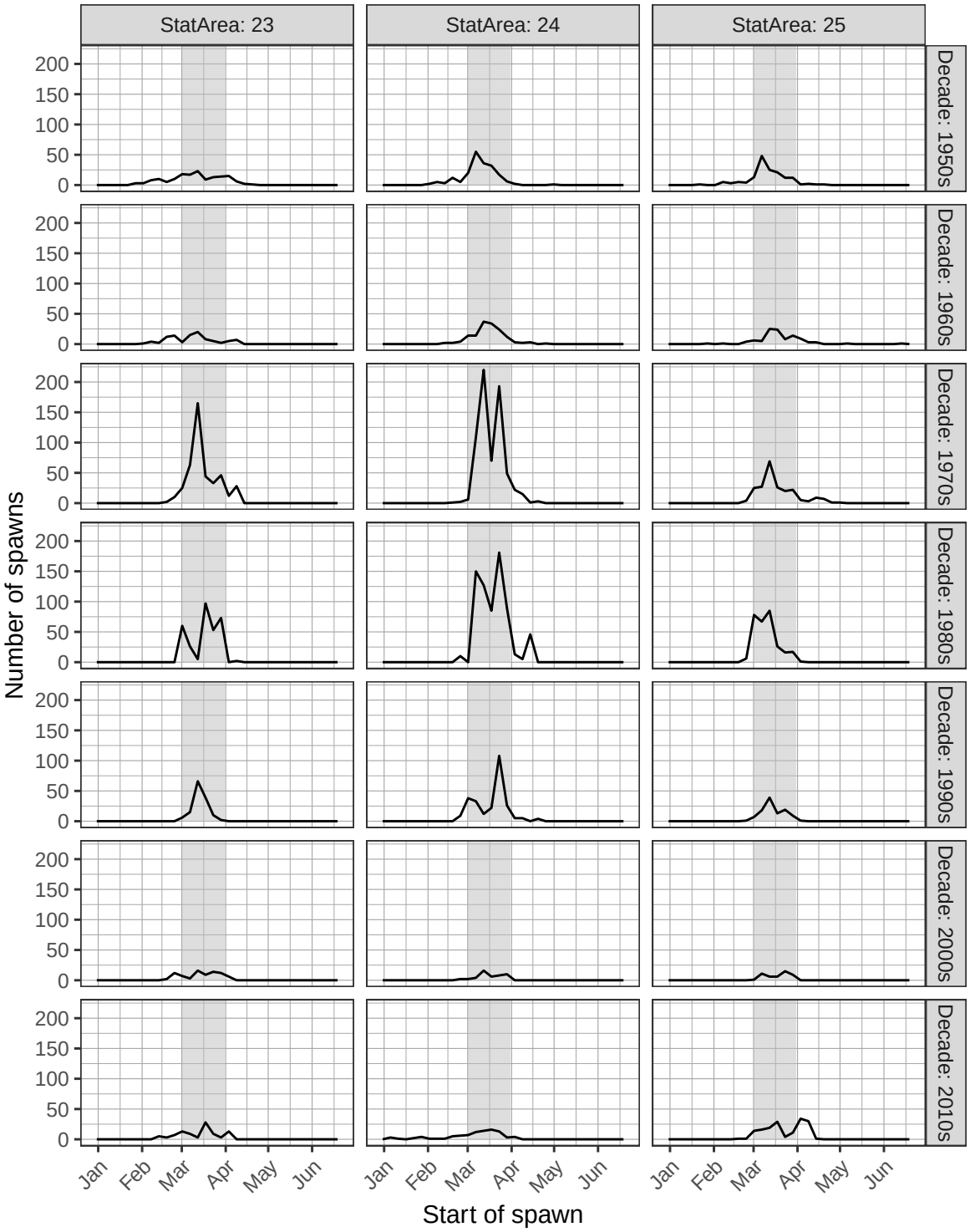


Figure 9. Pacific Herring spawn start date by decade and Statistical Area. Grey shaded regions indicate March 1st to 31st. Note that spawn size and intensity varies; therefore the number of spawns is not directly proportional to spawn extent or biomass.

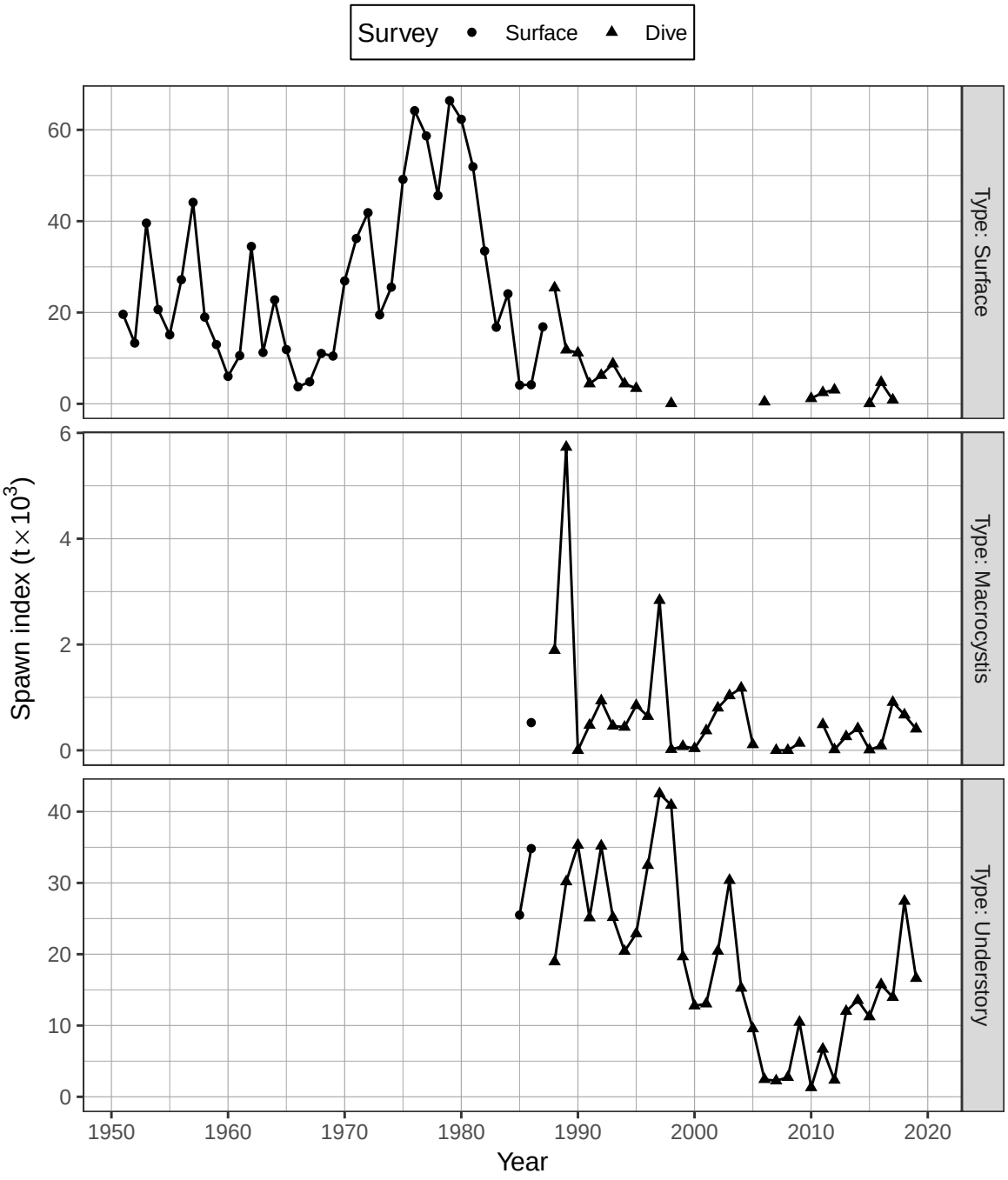


Figure 10. Time series of spawn index in thousands of metric tonnes ($t \times 10^3$) by type for Pacific Herring from 1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). There are three types of spawn survey observations: observations of spawn taken from the surface usually at low tide, underwater observations of spawn on giant kelp, Macrocystis (*Macrocystis* spp.), and underwater observations of spawn on other types of algae and the substrate, which we refer to as 'understory.' The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2019).

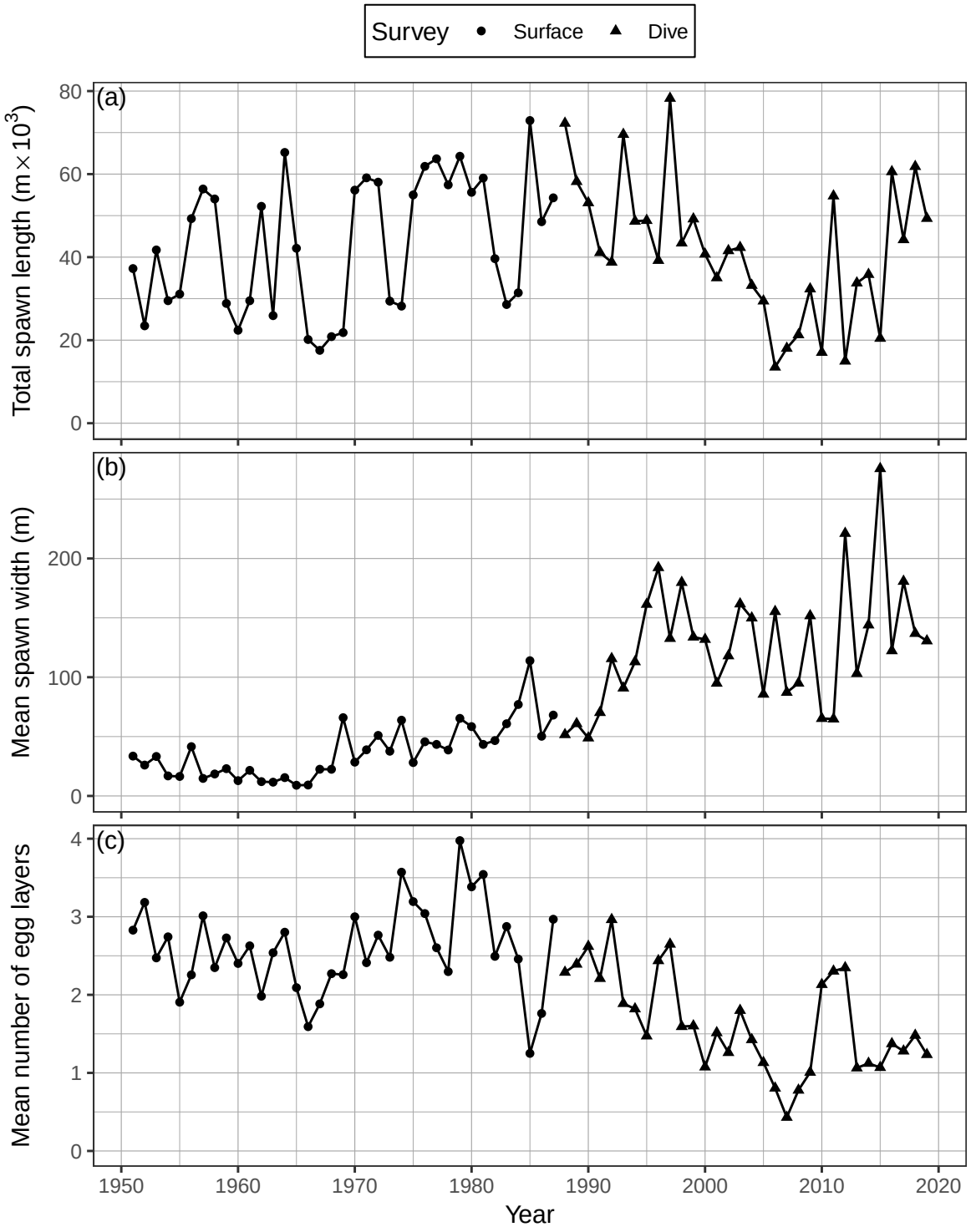


Figure 11. Time series of total spawn length in thousands of metres (m $\times$ $10^3$; panel a), mean spawn width in metres (b), and mean number of egg layers (c) for Pacific Herring from 1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2019).

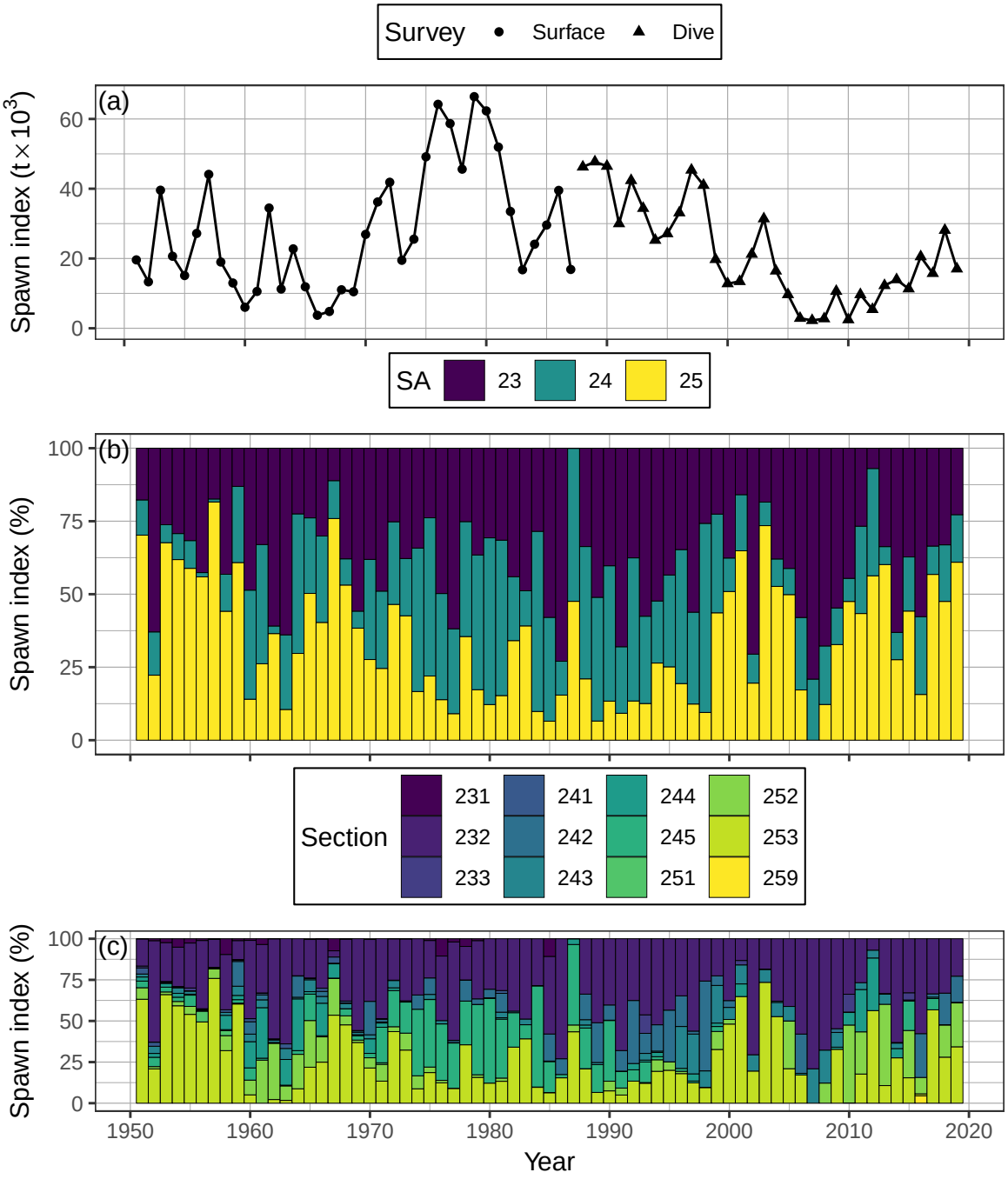


Figure 12. Time series of spawn index in thousands of metric tonnes ($t \times 10^3$) for Pacific Herring from 1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR; panel a), as well as percent contributed by Statistical Area (SA), and Section (b, & c, respectively). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2019). The 'spawn index' is not scaled by the spawn survey scaling parameter, $q$.

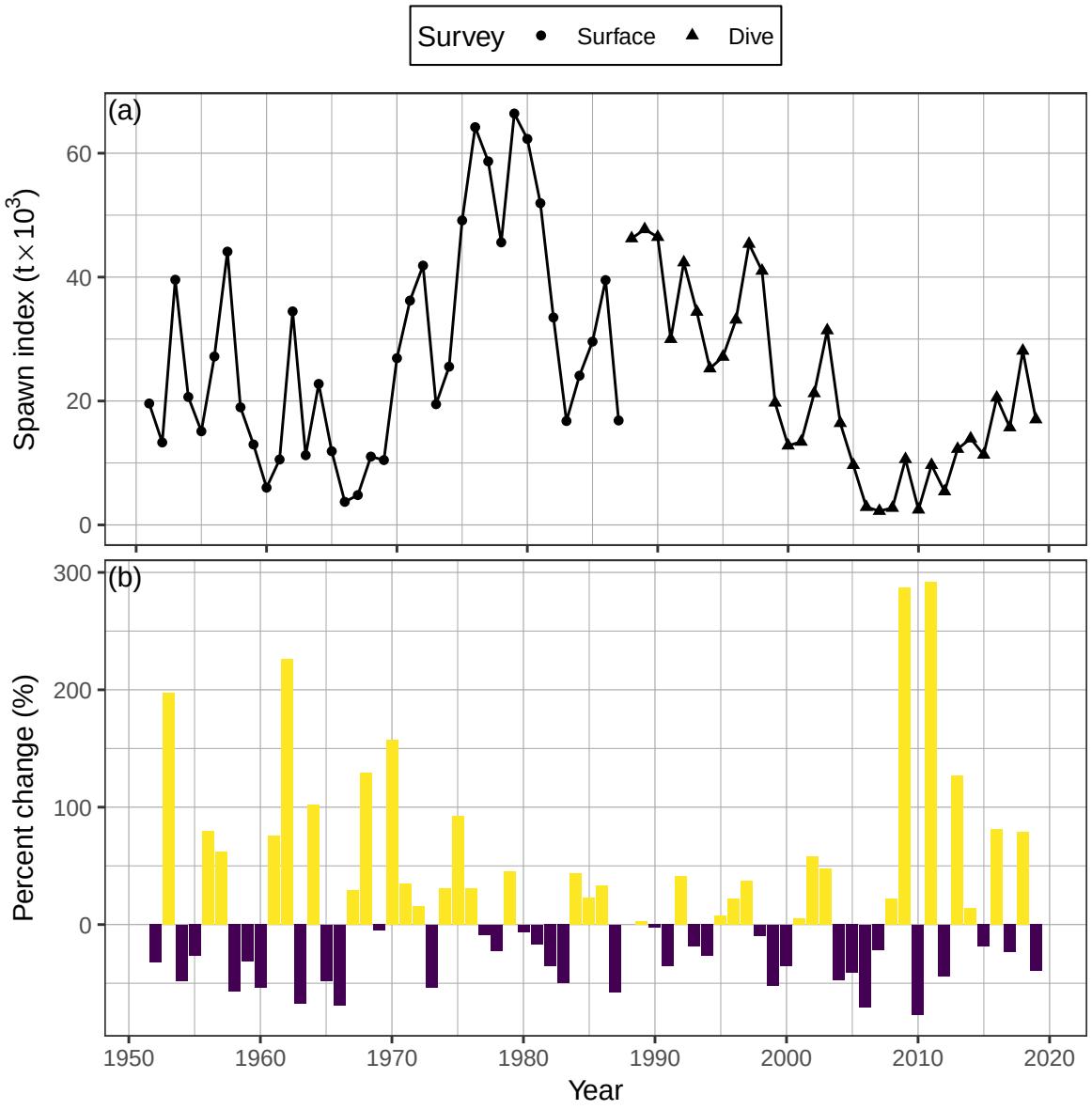


Figure 13. Time series of spawn index in thousands of metric tonnes (t $\times$ $10^3$) for Pacific Herring from1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR; panel a), and percent change (b). We calculate percent change as $\delta_t = \frac{I_t - I_{t-1}}{I_{t-1}}$ where $I_t$ is the spawn index in year $t$. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2019). The 'spawn index' is not scaled by the spawn survey scaling parameter, $q$.

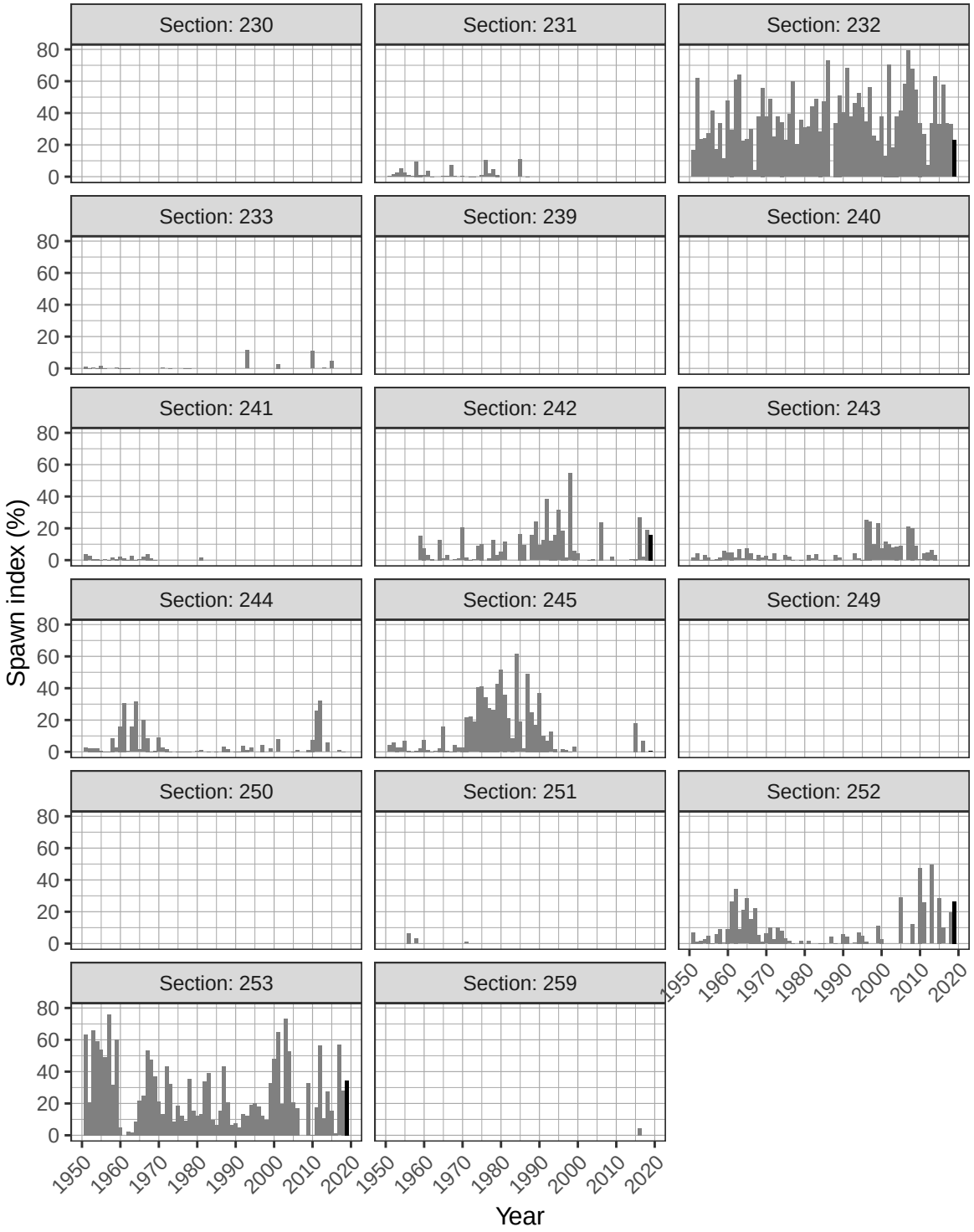


Figure 14. Time series of percent of spawn index by Section for Pacific Herring from 1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The year 2019 has a darker bar to facilitate interpretation. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2019). The 'spawn index' is not scaled by the spawn survey scaling parameter, $q$.

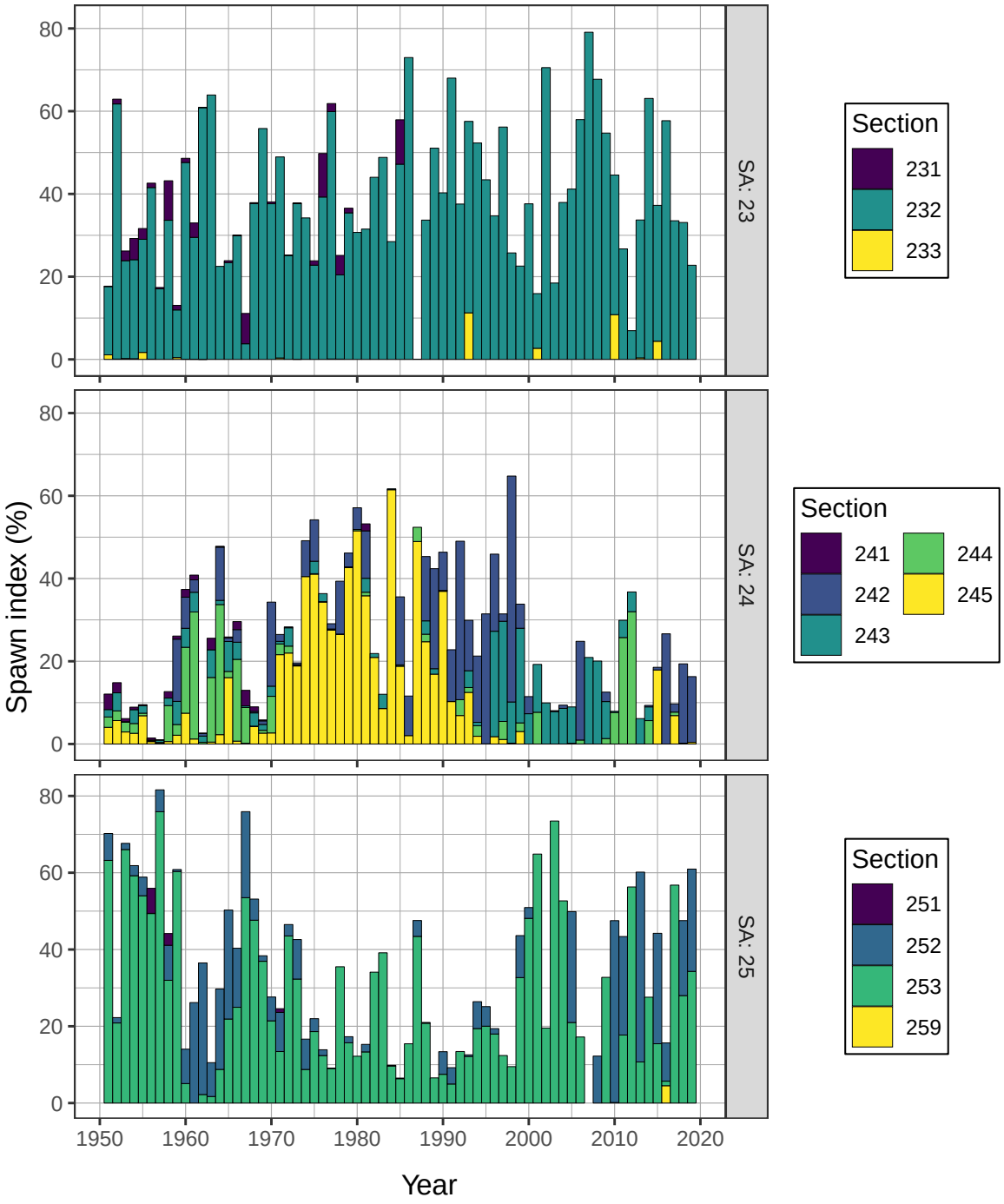


Figure 15. Time series of percent of spawn index by Statistical Area (SA) and Section for Pacific Herring from 1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2019). The 'spawn index' is not scaled by the spawn survey scaling parameter, $q$.

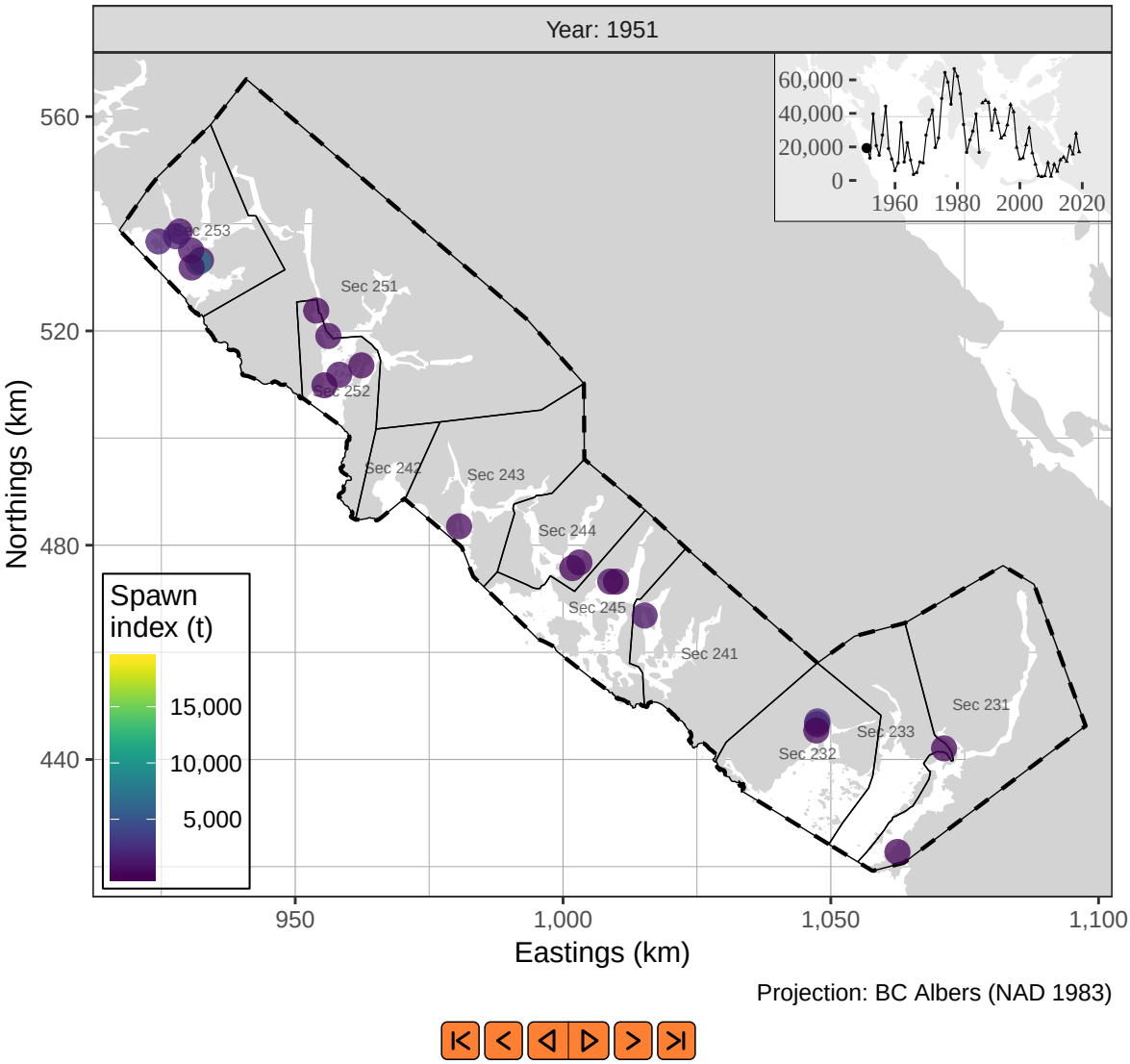


Figure 16. Animation of Pacific Herring spawn survey locations and spawn index in metric tonnes (t) from 1951 to 2019 in the West Coast of Vancouver Island major stock assessment region (SAR; thick dashed lines), and associated Sections (Sec; thin solid lines). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2019). The 'spawn index' is not scaled by the spawn survey scaling parameter, $q$. Missing spawn index values (grey circles) indicate incomplete spawn surveys. The inset shows the total spawn index by year. Units: kilometres (km).