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STOCK STATUS UPDATE WITH APPLICATION OF MANAGEMENT PROCEDURES FOR PACIFIC HERRING (*CLUPEA PALLASII*) IN BRITISH COLUMBIA: STATUS IN 2024 AND FORECAST FOR 2025

CONTEXT

Pacific Herring (*Clupea pallasii*) abundance in British Columbia (BC) is assessed using a statistical catch-age (SCA) model (Martell et al. 2011). In 2017, the Pacific Herring stock assessment included updates to the SCA model, a bridging analysis to support these changes (Cleary et al. 2019), and estimation of stock productivity and current stock status relative to the new limit reference point (LRP) of $0.3SB_0$ (Kronlund et al. 2017), where SB_0 is estimated unfished spawning biomass. In 2022, upper stock reference (USR) point options were introduced for the major stock assessment regions (SARs) and this assessment includes estimates of stock status relative to productive period USRs (DFO 2023a). The overall structure of the SCA model has not changed since 2017.

In 2016, Fisheries and Oceans Canada (DFO) committed to renewing the current management framework to address a range of challenges facing Pacific Herring stocks and fisheries in BC. Renewal of the management framework included engaging in a management strategy evaluation (MSE) process to evaluate the performance of candidate management procedures against a range of hypotheses about future stock and fishery dynamics. As part of the MSE process, a Canadian Science Advisory Secretariat (CSAS) regional peer review occurred in 2018, where performance of Pacific Herring management procedures (MPs) were assessed against conservation objectives for the Strait of Georgia (SoG) and West Coast of Vancouver Island (WCVI) SARs (DFO 2019). Steps included operating model (OM) development (Benson et al. 2022), fitting the OM to Pacific Herring stock and fishery monitoring data (OM conditioning), and closed-loop simulations of MP performance for alternative future natural mortality scenarios. In 2019, DFO initiated the MSE process for the Haida Gwaii (HG), Prince Rupert District (PRD), and Central Coast (CC) SARs (DFO 2020a). Updates to MP evaluations were then conducted for SoG and WCVI SARs in 2020 (DFO 2021a) and for PRD, CC, SoG, and WCVI in 2023 (DFO 2022, 2023a).

This assessment includes new science advice on choice of USR points for four of the five major Pacific Herring SARs: HG, PRD, CC, and WCVI. Note that the SoG SAR is assessed in DFO (2025) using a new modelling framework (Johnson et al. 2024). An analysis of USR options for PRD, CC, SoG, and WCVI was completed in 2022 (DFO 2023a) and provisional USRs based on productive periods identified for each SAR was implemented in the 2022/23 Integrated Fisheries Management Plan (IFMP).

Since initiation of the Pacific Herring MSE process, MP evaluations have been included in the annual stock assessment as follows:

1. The 2018 stock assessment included MP recommendations for the SoG and WCVI SARs (DFO 2019).

2. The 2019 stock assessment included MP recommendations for the HG, PRD, and CC SARs, and implemented MP recommendations from previous years for the SoG and WCVI SARs (DFO 2020b).
3. The 2020 stock assessment included updated MP recommendations for the SoG and WCVI SARs, and implemented MP recommendations from previous years for the HG, PRD, and CC SARs (DFO 2021a).
4. The 2021 stock assessment included updated MP recommendations for the PRD and CC SARs, and implemented MP recommendations from previous years for the SoG and WCVI SARs (DFO 2021b).
5. The 2022 stock assessment included updated MP recommendations for the PRD, CC, SoG, and WCVI SARs (DFO 2022).
6. The 2023 stock assessment implemented MPs from previous years for the PRD, CC, SoG, and WCVI SARs (DFO 2024). Note that MPs for HG and SoG are not currently updated through this process. Management measures to support long-term recovery of HG herring are being developed through the HG rebuilding plan process.[1] MPs for SoG are updated in DFO (2025) using methods from Johnson et al. (2024).

This 2024 stock assessment includes MP recommendations for PRD, CC, and WCVI, derived in 2022 by updating herring OM conditioning (Benson et al. 2022) using the historic stock and fishery data from 1951 to 2021 (DFO 2022). There are no new MP evaluations for 2024 (all probability metrics reflect the MP evaluations presented in 2022).

Fisheries and Oceans Canada (DFO) Pacific Fisheries Management Branch requested that DFO Pacific Science Branch assess the status of British Columbia (BC) Pacific Herring stocks in 2024 and recommend harvest advice for 2025 using simulation-tested MPs to inform the development of the 2024/2025 IFMP, where appropriate. Estimated stock trajectories, current status of stocks for 2024, management procedure options, and harvest advice recommendations from those MPs for 2025 reflect methods of Cleary et al. (2019) and Benson et al. (2022) and, where applicable, recommendations from the aforementioned 2018, 2019, 2020, 2021, 2022, and 2023 MSE analyses (Section “Application of MPs and harvest options for 2025”).

This Science Response results from the regional peer review of September 23, 2024 on the 2024/2025 Pacific Herring Stock Assessment, Forecast of Mature Stock Biomass, and Harvest Options for 2025 (HG, PRD, CC, WCVI).

BACKGROUND

Pacific Herring in BC are managed as five major and two minor SARs (Figure 1). The major SARs are Haida Gwaii (HG), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SoG), and West Coast of Vancouver Island (WCVI). The minor SARs are Area 27 (A27) and Area 2 West (A2W). We conduct formal analyses of stock trend information for the major SARs annually. Although SoG is assessed in DFO (2025) some tables and figures in this document include SoG data for completeness.

[1] Haida Gwaii ’íináang | iinang Pacific Herring: An ecosystem overview and ecosystem-based rebuilding plan. Approved by the Minister of Fisheries and Oceans, the Council of Haida Nation and Parks Canada. April 2024. In Press.

For the minor SARs, we present available catch data, biological data, and spawn survey data (Section "Minor stock assessment regions"). Beginning in 2021 we include similar data for the special area, Area 10 (Section "Special areas"). Note that Area 10 is a subset of the Central Coast and is outside the SAR boundary. Formal analyses of stock trends are not included for minor SARs or special areas.

Description of the fishery

There are several Pacific Herring fisheries in BC. After conservation, First Nations have priority access to fish for food, social, and ceremonial (FSC) purposes. Commercial fishing opportunities consist of four directed fisheries: food and bait (FB), special use (SU), spawn-on-kelp (SOK), and roe herring. There is also a small recreational fishery.

First Nations fish for whole herring, herring roe, and herring eggs for FSC purposes. Whole herring are fished by seine, gillnet, rake, dip net, and jig. Herring eggs are collected as spawn on seaweed such as kelp (i.e., SOK), or spawn on tree boughs placed in spawning locations. Indigenous harvest of herring for FSC purposes may occur coast wide where authorized by a communal licence.

In addition, treaty and Aboriginal commercial fisheries may occur in some specific management regions. Four modern treaties (Nisga'a, Tsawwassen, Maa-nulth, and Tla'amin) have been ratified in BC and articulate a treaty right to FSC harvest of fish. Five Nuu-chah-nulth First Nations located on the West Coast of Vancouver Island – Ahousaht, Ehattesaht, Hesquiaht, Mowachaht/Muchalaht, and Tla-o-qui-aht (the Five Nations) – have Aboriginal rights to fish for any species of fish, with the exception of Geoduck, within their Fishing Territories and to sell that fish. DFO developed a 2022/2023 Five Nations Multi-Species Fishery Management Plan (FMP). The FMP includes specific details about the fishery, such as allocation/access, licensing and designations, fishing area, harvesting opportunities, and fishery monitoring and catch reporting. Feedback provided by the Five Nations during consultations was considered and incorporated into the 2023/2024 FMP by DFO where possible. For further information see the 2023/2024 FMP.

On the Central Coast, Heiltsuk Nation have an Aboriginal right to commercially harvest Pacific Herring SOK. The Heiltsuk currently hold nine SOK licences in this area, and SOK is harvested using the preferred means of the Heiltsuk, which is open ponding. The DFO and Heiltsuk are also committed to annual development of a Joint Fisheries Management Plan for Pacific Herring in the Central Coast.

In 2023/2024, the primary Pacific Herring fisheries were seine roe and gillnet roe fisheries, with a combined coast wide catch of 5,711 tonnes (t). The FB seine fishery had a coast wide catch of 1,289 t. Roe fisheries operated in SoG and PRD this season, and FB and SU fisheries operated in SoG only. Commercial SOK fisheries operated only in the CC in 2023/2024.

A complete dockside monitoring program exists for all Pacific Herring commercial fisheries and the resulting validated catch data are included in the annual stock assessment process for all fisheries, except SOK. The exclusion of SOK fishery data from the annual stock assessment process was identified as a key uncertainty in the most recent CSAS review of the stock assessment framework (Cleary et al. 2019). Recommendations for addressing this uncertainty will require quantifying ponding mortality and removals (i.e., eggs) associated with SOK fisheries. Progress has been made in quantifying SOK mortality sources within the new modelling framework (DFO 2023b), however those approaches are not transferable to the SCA model (Martell et al. 2011) used here.

Description of the stock assessment process

The SCA model is fitted to commercial catch data, fishery and survey proportion-at-age data, and a fishery-independent spawning biomass index to estimate total and spawning biomass, natural mortality, and recruitment. Observed annual weight-at-age is estimated external to the model, and maturity-at-age is a fixed input parameter. In 2017, an updated version of the SCA model was applied to assess each of the five major Pacific Herring SARs (Cleary et al. 2019). The main change from the SCA model used from 2011 to 2016 was partitioning variance between observation and process error to improve variance structure estimates (Cleary et al. 2019). A bridging analysis was used to validate the updated model which showed nearly identical parameter estimates and biomass trajectories from the new model compared to previous versions of the model, which supported adopting the updated model (Cleary et al. 2019).

A Bayesian framework is used to estimate time series of spawning biomass, instantaneous natural mortality, and age-2 recruitment from 1951 to 2024. Advice to managers for the major SARs includes posterior estimates of current stock status SB_{2024}, stock status relative to the LRP $0.3SB_0$, and spawning biomass in 2025, SB_{2025}, assuming no catch. Projected pre-fishery spawning biomass is based on the current year's recruitment deviations from average as predicted by the Beverton-Holt stock-recruit model, and estimated natural mortality and weight-at-age, both averaged over the last five years. The Markov chain Monte Carlo (MCMC) sampling procedure follows the same method implemented by Cleary et al. (2019).

Cleary et al. (2019) reported results from two SCA model fits with different assumptions about dive survey catchability q_2 (from 1988 to 2024): assessment model 1 (AM1) which estimates q_2 with a prior distribution; and assessment model 2 (AM2) where $q_2 = 1$. The assumptions that the dive survey spawn index represents all the spawn deposited and that no eggs are lost to predation are strong. However, there is little information in the stock assessment data to inform an estimate of q_2; examination of Bayes posteriors show that priors are not updated for the HG, CC, SoG, and WCVI SARs, and estimated values reflect prior means (Cleary et al. 2019, Appendix D). Assuming $q_2 = 1$ produces a "minimum" biomass estimate buffering any other assessment and management implementation errors (Martell et al. 2011; DFO 2012). Application of AM1 would remove such safeguards despite recent simulation evaluation showing that large (positive) assessment errors are produced by the current assessment model even with $q_2 = 1$ (DFO 2019). Scaling the assessment with values of $q_2 < 1$ is likely to result in larger absolute assessment errors than those estimated when $q_2 = 1$ (DFO 2019). For these reasons, advice presented here is based on the AM2 parameterization, supported also by comparisons presented in DFO (2016, Table A1), and Cleary et al. (2019, Appendix D).

ANALYSIS AND RESPONSE

Management strategy evaluation

Fisheries and Oceans Canada (DFO) has committed to renewing the current management framework to address a range of challenges facing Pacific Herring stocks and fisheries in BC. Renewal of the management framework for Pacific Herring uses MSE to evaluate the performance of candidate MPs against hypotheses about past and future stock and fishery dynamics. The purpose of the MSE process is to identify and eliminate MPs that incur unacceptable risks to a stock and identify MPs that provide acceptable outcomes related to conservation and fishery management objectives. Identifying preferred MPs requires measurable objectives that include reference points (typically categorized as limits and targets) and those related to catch, catch variability, and socio-cultural goals. MSE is an iterative and ongoing process conducted with the participation of First Nations, the fishing industry, as well as government and non-government organizations.

The first MSE cycles for the SoG and WCVI SARs were completed in 2018 (DFO 2019). Steps included OM development (Benson et al. 2022), fitting OMs and simulations of MP performance for various hypothesized natural mortality scenarios (DFO 2019). In 2019, the MSE process was extended to HG, PRD, and CC SARs and performance evaluation of SAR specific MPs (DFO 2020a), with subsequent updates outlined in Section “CONTEXT”. Management procedure evaluation tables were updated in 2022 (DFO 2022).

Currently, a core set of fisheries management objectives (DFO 2020a) have been drafted for each major SAR, however only the conservation objective (1) has been used in the selection of MPs:

1. Maintain spawning biomass at or above the LRP with at least 75% probability over three Pacific Herring generations (i.e., avoid a biomass limit; $P(SB_t \geq 0.3SB_0) \geq 0.75$), where generation time is estimated to be about five years (Cleary et al. 2010).
2. Maintain spawning biomass at or above the USR with at least 50% probability over three Pacific Herring generations (i.e., achieve a target biomass; $P(SB_t \geq SB_{targ}) \geq 0.50$).
3. Maintain average annual variability (AAV) in catch below 25% over three Pacific Herring generations (i.e., minimize catch variability; AAV < 0.25).
4. Maximize average annual catch over three Pacific Herring generations (i.e., maximize average catch).

A fully specified set of objectives has not yet been developed for each SAR. DFO will continue to collaborate with coastal First Nations to develop area-specific objectives specific for FSC and SOK fisheries. In addition, DFO will continue to engage with the herring industry, government, and non-government organizations to describe broader objectives related to conservation, economics, and access.

MPs for each SAR differ in the form of the harvest control rule (HCR) and choice of catch cap, but use the same type of monitoring data and assessment model (e.g., Cleary et al. 2019). The current stock assessment model assumes natural mortality M is time-varying and this is reflected in the MSE as two hypotheses about future Pacific Herring natural mortality:

1. M is a time-varying, density-dependent process (DDM), and
2. M is a time-varying, density-independent process (DIM).

These two hypotheses are captured as operating model (OM) scenarios in Benson et al. (2022). The DDM scenario was identified as the reference OM scenario based on discussion at the 2018 CSAS review process (DFO 2020a), while the DIM scenario was identified as a robustness OM scenario.

On June 26 to 28, 2023, a regional peer review occurred for “Application of a new modelling framework for the assessment of Pacific Herring (*Clupea pallasii*) major stocks and implementation in the MSE process.” The details of the review process are summarized in DFO (2023b), and there were two key recommendations for implementation:

1. A process to implement the new assessment and operating model, update the MSE, and identify exceptional circumstances should be developed in a phased approach in consultation with managers, First Nations and other stakeholders.

2. A minimum three year cycle for MSE updates is recommended, unless new evidence reveals exceptional circumstances.

DFO has advanced these recommendations and has implemented the spatially integrated statistical catch at age herring (SISCAH) modelling framework for the SoG SAR (DFO 2025). For the remaining four SARs, we implement MPs from the previously approved operating model (as per 2024).

Input data

There are three types of input data used for the Pacific Herring stock assessment: catch data, biological data, and abundance data. These data are described in the following sections, and summarized in Table 1. Relative to the previous assessment, the only change to input data was to extend all the time series to include the 2023/2024 herring season (July 1 to June 30). Note that we refer to 'year' instead of 'herring season' in this report; therefore 2024 refers to the 2023/2024 Pacific Herring season.

Catch data

For the purposes of stock assessment, catch data are summarized by gear type as described in Table 1 and presented in Figure 2. As in previous years, catch data for the stock assessment model does not include mortality from the commercial SOK fishery, nor any recreational fisheries or food, social, and ceremonial (FSC) harvest. Recreational fisheries and FSC harvest are considered minor relative to commercial harvest. The commercial SOK fishery is licensed based on pounds of validated SOK product (i.e., eggs adhered to kelp), not tonnes of fish used or spawned. Currently there is no basis to validate mortality imposed on the population by this fishery, however methods for estimating SOK mortality have been developed within the SISCAH modelling framework (DFO 2023b).

Combined commercial removals from 2015 to 2024 from the roe, food and bait, and special use fisheries appear in Table 2. Total SOK harvest (i.e., pounds of validated product) for the major SARs from 2015 to 2024 is presented in the Pacific Herring data summaries.

Biological data

Biological samples are collected as described in Cleary et al. (2019) and Table 1. Biological data inputs to the stock assessment are annual weight-at-age (Figure 3) and annual number-at-age, shown as proportion-at-age (Figure 4).

Declines in weight-at-age are evident for all major SARs from the mid-1980s to 2010. Declining weight-at-age may be due to a number of factors, including fishing effects (i.e., gear selectivity), environmental effects (e.g., changes in ocean productivity), or changes in sampling protocols (e.g., shorter time frame over which samples are collected). Declines in weight-at-age appear to have ceased since 2010.

Abundance data

The spawn index survey collects information on spatial extent of the spawn, number of egg layers, substrate type, and other data. There are two spawn survey periods defined by the predominant survey method: surface survey period from 1951 to 1987 and dive survey period from 1988 to 2024. Data from these surveys are used to calculate egg density in each spawn. Ultimately, we calculate the 'spawn index', the estimated biomass of mature spawners required to produce those eggs. The 2024 spawn survey followed standard dive survey protocols for the HG, PRD, CC, SoG, and WCVI SARs as described in Cleary et al. (2019). Time series of spawn index by major SAR from 1951 to 2024 are summarized in Figure 5 and Tables 3 to 6.

The surface survey methodology has been used on occasion from 1988 to 2024. Generally this occurs when spawns are observed in locations where a dive survey team is not available, or when spawns are early (e.g., January or February) or late (e.g., May) in the season. In these instances, spawning biomass estimates obtained from surface surveys for a given SAR and year are added to biomass estimates from dive surveys, and $q_2 = 1$ is assumed for the combined index. The Pacific Herring data summaries show the proportion of spawn survey data (i.e., spawn index) from the surface and dive survey methods by SAR and year. Due to the COVID-19 pandemic, only surface surveys were conducted for HG in 2020 and 2021, and for PRD in 2020. These surface survey observations are treated as dive survey observations and are assumed to be continuous with the dive survey time series. Methods for combining surface and dive survey observations are presented for the SISCAH modelling framework in DFO (2023b), but are not implemented here.

Spatial spawn distribution

Tables 3 through 6 summarize the spatial distribution of survey spawn biomass (i.e., the spawn index) by proportion over the last 10 years for the major SARs. For each SAR, spawn is summarized either by Group, or Statistical Area; the choice of spatial grouping reflects spawning behaviour and biology for each SAR based on the survey data and working group discussions with local First Nations.

Incidental mortality

Incidental mortality is described in DFO (2024) and updated time series for each SAR can be found in Pacific Herring data summaries. These data are not currently included as removals in Herring stock assessments.

First Nations observations

Data and observations for the 2024 herring spawning season were contributed by representatives of First Nations communities for each SAR and can be found in the Pacific Herring data summaries. These observations include contributions from the Haida Nation in Haida Gwaii; the Heiltsuk Nation in the Central Coast; the Homalko, Qualicum, and Tla'amin Nations in Strait of Georgia; and the Nuu-chah-nulth Nation on the West Coast of Vancouver Island. Observations include: Spawn distribution and abundance, access, FSC successes and challenges, fish behaviour, and comparison with previous seasons.

Stock status update

Analyses of stock trend information is presented following methods of Cleary et al. (2019) for the Pacific Herring major SARs. Markov chain Monte Carlo (MCMC) runs have a chain length of five million with a sample taken every one thousand iterations (i.e., thinning). Then the first one thousand samples are discarded (i.e., burn-in), leaving four thousand samples as posteriors. Perceptions of stock status based on outputs (i.e., posteriors) from SCA models are summarized for each SAR in a six-panel figure (e.g., Figure 8). The panels show:

a. Model fit to scaled spawn survey data,

b. Instantaneous natural mortality rate M estimates,

c. Number of age-2 recruits,

d. Spawning biomass SB_t and total catch C_t, with reference lines at model estimates of $0.3SB_0$,

e. Recruitment deviations (log scale) from the Beverton-Holt recruitment function, and

f. Spawning biomass production $P_t = SB_{t+1} - SB_t + C_{t+1}$ for the dive survey period, with reference lines at model estimates of $0.3SB_0$.

Note that spawn survey data (i.e., spawn index) is scaled to abundance in panel (a) by the spawn survey scaling parameter q. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987) and dive surveys (1988 to 2024). Thus, two q parameters are implemented in the estimation procedure: q_1 (1951 to 1987) with a weakly informative prior, and q_2 (1988 to 2024) with a strongly informative prior approximating 1.0.

Reference points

A biological LRP is defined for the major Pacific Herring SARs at $0.3SB_0$ (Kronlund et al. 2017). Candidate USRs were introduced in Cleary et al. (2019) and implemented as biomass objectives in simulation analyses for WCVI and SoG in 2018 (DFO 2019), and then for HG, PRD, and CC in 2019 (DFO 2020a). An analysis of USR options was undertaken in 2022 with results presented in DFO (2023a). In total, five USR options were evaluated:

1. Average spawning biomass during a productive period $\overline{SB}_{Prod}$ (i.e., a B_{MSY} proxy; Table 23),
2. $0.4SB_0$,
3. $0.5SB_0$,
4. $0.6SB_0$, and
5. Average spawning biomass from 1951 to 2024 $\overline{SB}$.

Implementing USRs as target biomass objectives within the simulation-evaluation process allows evaluation of MPs with respect to achieving USRs, including whether a given USR option can be achieved in the absence of commercial fisheries. In 2023, DFO Resource Management selected and implemented a provisional USR of $\overline{SB}_{Prod}$ through the 2022/2023 IFMP process. Stock status relative to assessment model estimates of $0.3SB_0$ (i.e., LRP) and USR options are presented in Tables 20 through 22.

LRPs and USRs relate stock status to the DFO PA Policy (DFO 2009), and the same calculations are used for each Pacific Herring SAR. There is an important distinction between reference points (e.g., LRP, USR) and operational control points (OCPs) of the HCR used to set catch limits. Specifically, OCPs define the inflection points of a HCR and identify biomass levels where management action is taken, whereas LRPs and USRs are management objectives.

Coast wide trends

Coast wide trends in Pacific Herring biomass show an average increasing trend in estimated spawning biomass from mid-to-late 2000's to present. Catches have been stable since 1980 and declining over the last decade (Figure 6). Comparisons of total estimated biomass and spawning biomass are also included for each SAR (Figure 7); these trends are presented using median posterior estimates.

Haida Gwaii

Estimated spawning biomass historic lows occurred in the late 1960s predicated by high catches, low estimated recruitment and high estimated natural mortality (Figure 8). Under variable estimated recruitment, estimated spawning biomass recovered from that point through the early 1980s supported by declining rates of estimated natural mortality. As estimated natural mortality began increasing again in the mid 1990s, estimated biomass declined. A reprieve in estimated low biomass occurred following several years with above average estimated recruitment through the late 1990s, before biomass declined to persistent historic lows from 2000 to present, with a couple of low biomass peaks in 2013 and 2019 (Figure 8d). The increasing trend in the estimated natural mortality rate starting in 1980 (Figure 8b) largely absorbed any surplus production attributed to above average recruitment events (e.g., 1997, 2012, 2018; Figure 8c, d). Estimated natural mortality has been on a slow decline since the early 2000s but low estimated recruitment has failed to lead to a positive estimated productivity.

The HG stock persists in a low biomass state, with many years also showing low productivity which has largely precluded stock growth (Figure 8f). Above-average recruitment of age-2 fish in 2018, leading to increases in survey biomass in 2019 and 2020 were positive signs but average to below-average recruitment since then, which estimates negative productivity, has brought biomass back down to the LRP. The effective harvest rate U_t has been at or near zero since 2000 (Figure 13), with the last commercial roe fishery in 2002, and the last commercial SOK fishery in 2004.

Estimated unfished spawning biomass SB_0 is 21,508 t, and the LRP of $0.3SB_0$ is 6,452 t (posterior medians). Compared to last year, estimated spawning biomass decreased from 7,442 (SB_{2023}) to 6,415 t (SB_{2024}, posterior median), and is equivalent to 29.5% of SB_0 (Tables 15 & 19). Spawning biomass in 2024 is estimated to be above the LRP with a 48.3% probability (Table 19). Management measures to support long-term recovery of herring stocks in Haida Gwaii are being developed through the rebuilding plan process.[1]

Prince Rupert District

Estimated spawning biomass reached historic highs in the early 1960s due to low estimated mortality rate and high estimated recruitment (Figure 9). This was followed immediately by below average recruitment and a rise to the highest estimated mortality rate, more than doubling within 10 years. In response, the stock collapsed by the mid-1960s to the lowest estimated spawning biomass. Spawning biomass recovered by the mid-1980s estimated to be about 50% of the historic high, but began a steady decline in the late-1980s, amid slowly rising mortality rates and variable recruitment, before stabilizing at a relatively low level (but above historic lows) between 2005 and 2018 (Figure 9b, d, e).

Since 2018 estimated spawning biomass has shown modest increases in biomass with above average age-2 recruitment in 2014, 2018 and, 2022 and stable natural mortality rates (Figure 9c, d, f). Productivity in recent years is relatively high compared to the last 30 years, with the highest estimated productivity in 2022 (Figure 9f) and with natural mortality decreasing in the last handful of years. This combination has led to an abundance estimate that is steeply increasing, and is the highest since the mid-1960s.

Fluctuations in spawning biomass trends appear to be less than in other SARs in the last 30 years, possibly because they are smaller in magnitude and offset each other as shown in Figure 9a.

Estimated unfished spawning biomass SB_0 is 57,822 t, and the LRP of $0.3SB_0$ is 17,347 t (posterior medians). Compared to last year, estimated spawning biomass increased from 41,971 (SB_{2023}) to 49,837 t (SB_{2024}, posterior median), and is equivalent to 85.0% of SB_0 (Tables 16 & 20). Spawning biomass in 2024 is estimated to be above the LRP with a 99.7% probability (Table 20). Commercial fisheries have occurred annually in PRD from the mid-1980s through 2018, during which the effective harvest rate U_t was estimated to be at or below 20% in all years except 1989 (Figure 13).

Central Coast

Estimated spawning biomass reached a historic high around 1980 preceded by low estimated natural mortality rates and the highest estimated recruitment on record (1979, Figure 10). From there a decline in estimated spawning biomass appears to be influenced initially by higher estimated natural mortality rates and highly variable estimated recruitment. Spawning biomass trend declined during the 1985-2008 period and an increase in estimated natural mortality led to historically low estimated biomass levels from 2006 to 2012. Decreasing estimated natural mortality lead to moderate increases in biomass through 2020. From 2021 to 2023, increasing estimated natural mortality caused a decrease in estimated biomass, which was mitigated in part by higher than average estimated recruitment in 2022 (Figure 10a, b, e). Model estimates show decreasing spawning biomass since 2020 (Table 17), and the analysis of surplus production shows an estimated production close to neutral for 2021 and 2022, and negative for 2023 (Figure 10f).

An examination of spawn biomass by herring section shows the recent decline in herring spawn to have largely occurred in Upper Spiller Channel (Section 078), Section 086, Kitasu Bay/East Higgins (Section 067), and Thompson/Stryker (Section 074; Figure 11). The occurrence of spawn in Thompson/Stryker from 2020 to 2022 represented the first significant spawns in this section in many years. The mechanisms driving spawn fluctuations in these smaller areas in the Central Coast occur throughout the time series and are not well understood.

From 1990 to 2006 the effective harvest rate U_t is estimated to fluctuate above and below the reference harvest rate of 20%, with median estimates exceeding 20% in some of these years (Figure 13). Occurrences of U_t exceeding 20% are due in part to positive assessment model errors and lags in detecting a directional change in the trend.

Following a commercial fishery closure from 2007 to 2013, the CC SAR was reopened to commercial fisheries: commercial roe fisheries occurred in 2014, 2015, and 2016. Commercial SOK fisheries have operated at some level most years from 2014 to 2024 (see the Pacific Herring data summaries). SOK removals are not included in the estimation of U_t.

Estimated unfished spawning biomass SB_0 is 48,873 t, and the LRP of $0.3SB_0$ is 14,662 t (posterior medians). Compared to last year, estimated spawning biomass decreased from 24,536 (SB_{2023}) to 20,720 t (SB_{2024}, posterior median), and is equivalent to 41.8% of SB_0 (Tables 17 & 21). Spawning biomass in 2024 is estimated to be above the LRP with a 83.6% probability (Table 21).

West Coast of Vancouver Island

The time series of estimated spawning biomass reached an estimated peak in the mid to late 1970s during a time period of lowest observed model estimates of natural mortality and variable estimated recruitment (Figure 12). From the late 1980s through to around 2008 an increase in estimated mortality and a generally variable but low estimated recruitment led to a declining trend, down from the peaks observed in the late 1970s to a slump in the mid 2000s to mid 2010s (Figure 12a, b, c).

In the last 5 years productivity has increased with mostly higher than average recruitment and declining natural mortality estimates resulting in increasing spawning biomass estimates not seen since the 1970s (Figure 12a, b, f). Biomass estimates are nearing the highest since 1951.

The absence of a commercial fishery since 2005 means the realized harvest rate has been zero for the last 15 years (Figure 13).

Previous years WCVI MCMC diagnostics showed parameter autocorrelation especially in the estimation of fishery selectivity-at-50% ($\hat{a}_1$) and its standard deviation ($\hat{\gamma}_1$) for the "other" fisheries category (i.e., reduction, food and bait, special use). These results were largely ameliorated this year by changing parameter priors.

Estimated unfished spawning biomass SB_0 is 46,443 t, and the LRP of $0.3SB_0$ is 13,933 t (posterior medians). Compared to last year, estimated spawning biomass increased from 49,100 (SB_{2023}) to 65,496 t (SB_{2024}, posterior median), and is equivalent to 139.3% of SB_0 (Tables 18 & 22). Spawning biomass in 2024 is estimated to be above the LRP with a 100.0% probability (Table 22).

Management performance

Historic management procedure performance can be assessed using the time series of effective harvest rate U. Estimated effective harvest rate U in each year t is $U_t = C_t/(C_t + SB_t)$, where C_t is catch in year t, and SB_t is estimated spawning biomass in year t. Time series of U_t are presented in Figure 13, where U_t of 20% is used as a reference line only and is not indicative of annual management decisions on TAC for each SAR.

Application of MPs and harvest options for 2025

Harvest options for PRD, CC, and WCVI for 2025 reflect application of simulation-tested MPs using the Herring OM (Benson et al. 2022). OM conditioning was updated in 2022 using historic stock and fishery data from 1951 to 2021; no MP updates were conducted for 2023 or 2024. MPs are not provided for HG because this is now conducted within the HG rebuilding plan process[1] and MPs for SoG are provided in (DFO 2025).

Haida Gwaii

The HG stock persisted in a low biomass state from approximately 2000-2018 (Figure 8). The stock was below the LRP for much of that period and shows little evidence of sustained stock growth despite the absence of commercial fisheries since 2002 (and since 2004 for the SOK fishery). Survey biomass increased from 2019 to 2020, remained stable in 2021, and declined from 2021 to 2023, with a slight increase in 2024. Results of the simulation-evaluations found that none of the proposed MPs, including the historical and no fishing MPs, maintained spawning biomass above the LRP with high probability (i.e., at least 75%, DFO 2009).[2]

In the absence of fishing, spawning biomass in 2025 SB_{2025} is forecast to be 7,556 t (posterior median; Table 19). Spawning biomass in 2025 is forecast to be below the LRP of $0.3SB_0$ (6,452 t) with a 37.8% probability, in the absence of fishing (Table 19 and Figure 14).

[2]"High" probability is defined as 75 to 95% by the DFO decision-making framework (DFO 2009).

Given it's prolonged low biomass state, a rebuilding plan was required for Haida Gwaii Pacific Herring. A comprehensive plan was co-developed by the Council of Haida Nation, Fisheries and Oceans Canada and Parks Canada and was finalized in April 2024.[1]

Guidance for developing rebuilding plans (DFO 2013) states that the primary objective of any rebuilding plan is to promote stock growth out of the Critical Zone (i.e., to grow the stock above the status-based LRP) by ensuring removals from all fishing sources are kept to the lowest possible level until the stock has cleared this zone with high probability. However, stock rebuilding does not end having met this goal, and one of the goals of the rebuilding plan will be to identify candidate threshold biomass levels greater than the LRP that are consistent with a rebuilt state.

Based on MP evaluations and the ongoing rebuilding plan process, the harvest recommendation for the Haida Gwaii stock in 2025 is 0 t. All future MP evaluations will occur through the rebuilding plan process.

Prince Rupert District

The PRD estimated stock biomass showed little trend from 2005 to 2018, fluctuating at or near the LRP of $0.3SB_0$ (Figure 9d). Spawning biomass increased above $0.3SB_0$ in 2019 and has remained above since.

In the summer of 2022, we updated the conditioning of the OM for PRD with 2021 spawn, catch, and biological data. We re-ran MSE simulations to generate updated probability values for MPs presented in 2019 (DFO 2020b) and 2020 (DFO 2021c). These latest MP evaluations also appear in DFO (2023a). No new MPs were included, however probability metrics for the five USRs options (DFO 2023a) were estimated and have been added to the harvest options tables. Updated closed-loop feedback simulations for PRD show that MPs with harvest rates at 5, 10, and 20% maintain spawning biomass above the LRP with 85 to 97% probability, over both OM scenarios (Table 24). The mean effective harvest rate U_t for the past 10 years with non-zero catches (from 2010 to 2023) is 9% (Figure 13).

While MPs with harvest rates ranging from 5% to 20% were able to meet the core conservation objective of maintaining spawning biomass above the LRP with high probability (i.e., at least 75%)[2], they also imply different trade-offs among biomass and yield objectives. Since multiple MPs meet the conservation objective, other socio-economic reasons may drive the choice for a particular MP.

In the absence of fishing, spawning biomass in 2025 SB_{2025} is forecast to be 47,883 t (posterior median; Table 20). Spawning biomass in 2025 is forecast to be below the LRP of $0.3SB_0$ (17,347 t) with a 0.5% probability, in the absence of fishing (Table 20 and Figure 14).

Harvest options for 2025, resulting from simulation-tested MPs are presented in Table 24 and include probability values for the LRP and provisional USR which reflect updated OM conditioning. Options reflect application of MPs to the 2025 forecast biomass for PRD, whereby each MP meets the conservation objective with a minimum 75% probability under both DDM and DIM OM scenarios. For ease of comparison with MP performance evaluation, harvest options are presented along side MP performance metrics for both OM scenarios (Table 24).

Central Coast

The CC stock persisted in a low biomass, low productivity state from approximately 2005 to 2014. An increasing trend was observed from 2015 to 2020, followed by a decline from 2021 to 2024 (Figure 10a).

In the summer of 2022, we updated the conditioning of the MSE operating model for CC with 2021 spawn, catch, and biological data. These latest MP evaluations also appear in DFO (2023a). No new MPs were included, however probability metrics for the five USRs options (DFO 2023a) were estimated and have been added to the harvest options tables. The updated simulations show that MPs with harvest rates at 5% and 10% maintain spawning biomass above the LRP with 81 to 91% probability over both OM scenarios (Table 25). The mean effective harvest rate U_t for the past 10 years with non-zero catches (from 2001 to 2016) is 12% (Figure 13).

Harvest options listed in Table 25 reflect application of MPs to the 2025 forecast biomass for CC, whereby each MP meets the conservation objective with a minimum 75% probability under both DDM and DIM OM scenarios.

Since multiple MPs meet the conservation objective of maintaining spawning biomass above the LRP with at least 75% probability, other socio-economic objectives may drive the choice for a particular MP. Additionally, the current CC OM is unable to directly address Heilstuk Nation conservation objectives related to herring age and size, nor objectives on a finer spatial scale or those specific to SOK fisheries. These limitations exist for all five major SARs.

In the absence of fishing, spawning biomass in 2025 SB_{2025} is forecast to be 17,462 t (posterior median; Table 21). Spawning biomass in 2025 is forecast to be below the LRP of $0.3SB_0$ (14,662 t) with a 32.6% probability, in the absence of fishing (Table 21 and Figure 14).

Finally, DFO acknowledges commitment to the Heiltsuk Nation for the development of a Joint Fisheries Management Plan for Pacific Herring in the Central Coast in 2025. Results presented here may inform this ongoing commitment.

West Coast of Vancouver Island

The WCVI stock persisted in a low biomass, low productivity state from approximately 2004 to 2014. In recent years, biomass has increased above the LRP of $0.3SB_0$ and is approaching historic levels.

In 2022, with updated 2021 data, closed-loop feedback simulations for WCVI show the conservation objective is met under the DDM OM scenario with between 80 and 84% probability, and the same MPs failed to meet the conservation objective under the DIM OM scenario, where natural mortality rates are most similar to the last 10 years (p between 61 to 65%).

In the absence of fishing, spawning biomass in 2025 SB_{2025} is forecast to be 59,778 t (posterior median; Table 22). Spawning biomass in 2025 is forecast to be below the LRP of $0.3SB_0$ (13,933 t) with a 0.0% probability, in the absence of fishing (Table 22 and Figure 14).

Harvest options for 2025, resulting from simulation-tested MPs, are presented in Table 26. These options reflect application of MPs to the 2025 forecast biomass for WCVI, under the two OM scenarios. All MPs and scenarios listed in Table 26 include updated performance metrics under both scenarios (DFO 2023a).

Ecosystem considerations

Ecosystem considerations are taken into account in the model in a number of ways. First, Pacific Herring in BC are managed as 5 major SARs, taking into account stock-specific life history, abundance, and pressures that feed into the models. Second, the biological LRP is set to a higher value compared to those recommended in the DFO sustainable fisheries policy (DFO 2009) and above the recommendation of 0.5B_{MSY} which is implemented in New Zealand fisheries (Shelton and Sinclair 2008). This herring LRP accounts for the mid-trophic level (i.e., middle-of-the-food-chain) nature of herring which likely drives the observed highly variable herring productivity.

Boldt et al. (2022) identified possible environmental and biological pressures that link to herring distribution, growth, and production. Environmental pressures include the timing, duration, and magnitude of upwelling, which can affect the amount of prey available to herring (Mackas et al. 2001; Boldt et al. 2018; Hourston and Thomson 2019), as well as predation and competition (Godefroid et al. 2019). Other physical environmental pressures include sea surface temperature (SST), salinity, sea level, river discharge, and Ekman transport (Tester 1948; Alderdice and Hourston 1985; Stocker et al. 1985; Stocker and Noakes 1985; Schweigert and Noakes 1990; Ware 1991; Zebdi and Collie 1995).

Third, while these ecosystem indicators are not directly incorporated into the assessment model, they are modelled implicitly via time varying natural mortality and recruitment. Fourth, candidate USRs (DFO 2023a) incorporate area-specific ecosystem considerations and have been introduced to the MSE process and the IFMP to evaluate the lower boundary of the Healthy status.

Incorporating spatial and ecosystem indicators is an area of ongoing research for Pacific Herring. DFO is committed to an ecosystem approach to fisheries management and provides further summary of recent research in (DFO 2024).

CONCLUSIONS

The 2024 Science Response includes formal analyses of stock trend information for Pacific Herring major SARs using the stock assessment framework reviewed in Cleary et al. (2019) with data updated to include 2024.

DFO has committed to developing and implementing a rebuilding plan for Haida Gwaii Pacific Herring. Based on MP evaluations, the harvest recommendation for the HG SAR is 0 t.

The MSE process identifies a range of MPs that meet the conservation objective with at least 75% probability for the PRD, CC, and WCVI SARs for the DDM reference OM scenario (DFO 2020a, 2021a). Harvest options and MP calculations for 2025 for these three SARs are combined with MP evaluations (probabilities) from the latest MSE update. Tables also include MP performance and harvest options for the DIM robustness OM scenario (Tables 24 to 26).

Science advice for the minor SARs is limited to presentation of catch data, biological data, and spawn survey data (Section “Minor stock assessment regions”). Similarly, science advice for the special area, Area 10 is limited to presentation of catch data, biological data, and spawn survey data (Section “Special areas”).

TABLES

Table 1. Input data for the 2024 Pacific Herring statistical catch-age model for the major SARs. The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987) and dive surveys (1988 to 2024). Note: the 'spawn index' is not scaled by the spawn survey scaling parameter q.

Source	Data	Years
Roe gillnet fishery	Catch	1972 to 2024
Roe seine fishery	Catch	1972 to 2024
Other fisheries	Catch	1951 to 2024
Test fishery (seine)	Biological: number-at-age	1975 to 2024
Test fishery (seine)	Biological: weight-at-age	1975 to 2024
Roe seine fishery	Biological: number-at-age	1972 to 2024
Roe seine fishery	Biological: weight-at-age	1972 to 2024
Roe gillnet fishery	Biological: number-at-age	1972 to 2024
Other fisheries	Biological: number-at-age	1951 to 2024
Other fisheries	Biological: weight-at-age	1951 to 2024
Surface survey	Abundance: spawn index	1951 to 1987
Dive survey	Abundance: spawn index	1988 to 2024

Table 2. Total landed Pacific Herring catch in tonnes from 2015 to 2024 in the major stock assessment regions (SARs). Note that the SoG stock is assessed in DFO (2025) but SoG data is included in this table for completeness. Legend: Haida Gwaii (HG), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SoG), and West Coast of Vancouver Island (WCVI). Note: 'WP' indicates that data are withheld due to privacy concerns.

	SAR				
Year	**HG**	**PRD**	**CC**	**SoG**	**WCVI**
2015	0	2,163	626	19,968	0
2016	0	2,425	213	21,310	0
2017	0	2,849	0	25,279	0
2018	0	417	0	19,067	0
2019	0	0	0	21,419	0
2020	0	0	0	10,439	0
2021	0	0	0	14,396	0
2022	0	0	0	4,672	0
2023	0	168	0	6,002	0
2024	0	0	0	7,000	0

Table 3. Haida Gwaii SAR: spawn index in tonnes for Pacific Herring and proportion of spawn index by Group from 2015 to 2024. Legend: 'Cumshewa/Selwyn' is Section 023 and 024; 'Juan Perez/Skincuttle' is Sections 021 and 025; and 'Louscoone' is Section 006. Note: the 'spawn index' is not scaled by the spawn survey scaling parameter q, and 'NA' indicates that data are not available.

		Proportion		
Year	**Spawn index**	**Cumshewa/Selwyn**	**Juan Perez/Skincuttle**	**Louscoone**
2015	13,102	0.060	0.940	0.000
2016	6,888	0.053	0.947	0.000
2017	3,016	0.018	0.982	0.000
2018	4,588	0.234	0.766	0.000
2019	11,624	0.065	0.919	0.016
2020	20,423	0.077	0.923	0.000
2021	18,234	0.025	0.975	0.000
2022	5,281	0.150	0.850	0.000
2023	1,584	0.038	0.962	0.000
2024	11,732	0.087	0.906	0.007

Table 4. Prince Rupert District SAR: spawn index in tonnes for Pacific Herring and proportion of spawn index by Statistical Area from 2015 to 2024. Note: the 'spawn index' is not scaled by the spawn survey scaling parameter q, and 'NA' indicates that data are not available.

		Proportion		
Year	**Spawn index**	**03**	**04**	**05**
2015	17,407	0.056	0.756	0.188
2016	18,985	0.007	0.808	0.185
2017	19,235	0.052	0.632	0.317
2018	14,155	0.057	0.667	0.277
2019	27,190	0.010	0.452	0.538
2020	25,845	0.026	0.542	0.432
2021	33,062	0.068	0.717	0.214
2022	35,220	0.001	0.793	0.207
2023	42,202	0.000	0.720	0.280
2024	50,054	0.000	0.913	0.086

Table 5. Central Coast SAR: spawn index in tonnes for Pacific Herring and proportion of spawn index by Statistical Area from 2015 to 2024. Note: the ‘spawn index’ is not scaled by the spawn survey scaling parameter q, and ‘NA’ indicates that data are not available.

		Proportion		
Year	**Spawn index**	**06**	**07**	**08**
2015	32,146	0.223	0.706	0.072
2016	32,508	0.245	0.726	0.028
2017	23,517	0.359	0.584	0.057
2018	12,264	0.322	0.626	0.052
2019	46,255	0.323	0.641	0.036
2020	42,713	0.417	0.550	0.033
2021	28,674	0.257	0.697	0.045
2022	22,711	0.259	0.703	0.038
2023	17,551	0.152	0.766	0.081
2024	26,803	0.276	0.585	0.139

Table 6. West Coast of Vancouver Island SAR: spawn index in tonnes for Pacific Herring and proportion of spawn index by Statistical Area from 2015 to 2024. Note: the ‘spawn index’ is not scaled by the spawn survey scaling parameter q, and ‘NA’ indicates that data are not available.

		Proportion		
Year	**Spawn index**	**23**	**24**	**25**
2015	11,323	0.372	0.185	0.442
2016	20,528	0.577	0.266	0.157
2017	16,476	0.320	0.138	0.542
2018	28,107	0.331	0.194	0.475
2019	17,030	0.228	0.163	0.610
2020	18,761	0.562	0.288	0.150
2021	29,339	0.150	0.728	0.122
2022	23,707	0.243	0.503	0.254
2023	77,005	0.163	0.754	0.083
2024	86,308	0.361	0.460	0.179

Table 7. Haida Gwaii SAR: key parameters in the Pacific Herring statistical catch-age model. Parameters are summarised by posterior (5th, 50th, and 95th percentile) and maximum posterior density (MPD) estimates. Legend: R_0 is unfished age-2 recruitment; h is steepness of the stock-recruitment relationship; M is instantaneous natural mortality rate; $\overline{R}$ is average age-2 recruitment from 1951 to 2024; $\overline{R}_{init}$ is average age-2 recruitment in 1950; ρ is the fraction of total variance associated with observation error; ϑ is the precision of total error; q is catchability for surface (1951 to 1987; q_1) and dive (1988 to 2024; q_2) survey periods; τ is the standard deviation of process error (i.e., recruitment); and σ is the standard deviation of observation error (i.e., survey index). Note: τ and σ are calculated values.

Parameter	5%	50%	95%	MPD
R_0	163.099	208.183	275.560	207.873
h	0.676	0.799	0.899	0.817
M	0.258	0.450	0.710	0.416
$\overline{R}$	112.211	128.646	148.678	134.505
$\overline{R}_{init}$	10.816	35.144	155.298	38.652
ρ	0.257	0.321	0.391	0.314
ϑ	0.730	0.879	1.053	0.948
q_1	0.452	0.528	0.608	0.520
q_2	0.983	0.999	1.016	0.999
τ	0.785	0.877	0.984	0.851
σ	0.531	0.603	0.684	0.575

Table 8. Prince Rupert District SAR: key parameters in the Pacific Herring statistical catch-age model. See Table 7 for description.

Parameter	5%	50%	95%	MPD
R_0	278.828	358.584	506.584	344.298
h	0.527	0.689	0.844	0.720
M	0.340	0.557	0.881	0.519
$\overline{R}$	194.662	220.942	252.464	225.267
$\overline{R}_{init}$	102.422	358.065	1,906.856	405.325
ρ	0.205	0.270	0.345	0.264
ϑ	0.979	1.183	1.416	1.253
q_1	0.453	0.525	0.599	0.521
q_2	0.984	1.001	1.017	1.000
τ	0.701	0.783	0.880	0.766
σ	0.411	0.476	0.550	0.459

Table 9. Central Coast SAR: key parameters in the Pacific Herring statistical catch-age model. Parameters are summarised by posterior (5th, 50th, and 95th percentile) and maximum posterior density (MPD) estimates. Legend: R_0 is unfished age-2 recruitment; h is steepness of the stock-recruitment relationship; M is instantaneous natural mortality rate; $\overline{R}$ is average age-2 recruitment from 1951 to 2024; $\overline{R}_{init}$ is average age-2 recruitment in 1950; ρ is the fraction of total variance associated with observation error; ϑ is the precision of total error; q is catchability for surface (1951 to 1987; q_1) and dive (1988 to 2024; q_2) survey periods; τ is the standard deviation of process error (i.e., recruitment); and σ is the standard deviation of observation error (i.e., survey index). Note: τ and σ are calculated values.

Parameter	5%	50%	95%	MPD
R_0	330.830	409.500	530.773	399.320
h	0.664	0.794	0.901	0.817
M	0.309	0.534	0.862	0.490
$\overline{R}$	247.440	277.039	310.933	277.905
$\overline{R}_{init}$	70.755	266.162	1,399.998	328.943
ρ	0.180	0.239	0.310	0.217
ϑ	1.030	1.252	1.491	1.325
q_1	0.277	0.320	0.365	0.324
q_2	0.982	0.999	1.016	0.999
τ	0.698	0.779	0.877	0.769
σ	0.379	0.437	0.505	0.405

Table 10. West Coast of Vancouver Island SAR: key parameters in the Pacific Herring statistical catch-age model. See Table 7 for description.

Parameter	5%	50%	95%	MPD
R_0	455.442	575.362	760.145	561.618
h	0.610	0.736	0.857	0.748
M	0.426	0.669	0.976	0.633
$\overline{R}$	337.850	384.152	440.272	386.675
$\overline{R}_{init}$	53.966	205.507	871.480	315.061
ρ	0.234	0.302	0.385	0.293
ϑ	1.109	1.354	1.619	1.454
q_1	0.712	0.843	0.983	0.854
q_2	0.984	1.000	1.016	0.999
τ	0.637	0.716	0.811	0.697
σ	0.415	0.473	0.540	0.449

Table 11. Haida Gwaii SAR: age-2 recruitment from 2015 to 2024 for the Pacific Herring statistical catch-age model. Recruitment in millions is summarised by posterior (5th, 50th, and 95th percentile) and maximum posterior density (MPD) estimates.

Year	5%	50%	95%	MPD
2015	47.650	71.742	105.767	73.208
2016	100.395	147.769	213.349	151.894
2017	164.467	235.060	343.546	244.117
2018	316.369	449.387	651.493	467.234
2019	41.365	63.406	97.102	65.134
2020	23.007	35.311	55.248	36.816
2021	77.809	119.896	184.675	124.243
2022	79.410	124.230	193.241	127.317
2023	58.642	94.932	154.696	96.096
2024	43.622	85.619	163.874	83.725

Table 12. Prince Rupert District SAR: age-2 recruitment from 2015 to 2024 for the Pacific Herring statistical catch-age model. See Table 11 for description.

Year	5%	50%	95%	MPD
2015	142.225	201.298	280.416	205.052
2016	75.854	113.480	167.198	116.407
2017	240.539	345.898	491.217	352.319
2018	684.714	956.346	1,322.787	984.445
2019	64.779	93.384	133.816	95.225
2020	141.779	210.135	305.033	214.391
2021	109.099	172.106	270.589	173.194
2022	526.325	823.510	1,246.552	841.838
2023	366.961	678.730	1,214.137	680.455
2024	170.349	318.946	597.379	317.595

Table 13. Central Coast SAR: age-2 recruitment from 2015 to 2024 for the Pacific Herring statistical catch-age model. Recruitment in millions is summarised by posterior (5th, 50th, and 95th percentile) and maximum posterior density (MPD) estimates.

Year	5%	50%	95%	MPD
2015	128.309	170.387	225.712	172.274
2016	146.279	194.125	256.873	196.746
2017	207.607	275.312	369.396	280.442
2018	821.400	1,084.850	1,428.632	1,109.210
2019	90.762	123.663	167.979	125.670
2020	341.563	464.181	619.176	473.451
2021	183.032	258.413	363.130	261.677
2022	692.803	976.010	1,372.723	992.928
2023	192.233	296.538	450.338	298.734
2024	85.049	271.571	722.879	279.486

Table 14. West Coast of Vancouver Island SAR: age-2 recruitment from 2015 to 2024 for the Pacific Herring statistical catch-age model. See Table 11 for description.

Year	5%	50%	95%	MPD
2015	674.414	884.760	1,168.990	898.643
2016	99.116	134.998	183.148	137.013
2017	101.434	139.350	191.871	141.801
2018	311.440	429.406	590.066	439.614
2019	214.969	298.742	409.239	303.626
2020	617.458	834.133	1,129.520	852.793
2021	499.726	695.953	966.394	705.738
2022	689.350	964.554	1,367.137	972.510
2023	462.248	689.087	1,024.017	692.295
2024	131.353	366.126	1,005.182	373.597

Table 15. Haida Gwaii SAR: spawning biomass and depletion from 2015 to 2024 for the Pacific Herring statistical catch-age model. Spawning biomass and depletion are summarised by the posterior (5th, 50th, and 95th percentile) and maximum posterior density (MPD) estimates in thousands of tonnes. Note: depletion is relative spawning biomass SB_t/SB_0, where SB_t is spawning biomass in year t, and SB_0 is estimated unfished spawning biomass.

	Spawning biomass				Depletion			
Year	5%	50%	95%	MPD	5%	50%	95%	MPD
2015	5.139	6.858	9.251	6.850	0.218	0.319	0.463	0.335
2016	4.148	5.598	7.619	5.605	0.176	0.260	0.382	0.274
2017	5.317	7.168	9.856	7.257	0.223	0.331	0.492	0.354
2018	7.735	10.461	14.182	10.659	0.323	0.485	0.722	0.521
2019	9.107	12.486	17.116	12.749	0.379	0.579	0.865	0.623
2020	6.950	9.592	13.313	9.708	0.289	0.446	0.665	0.474
2021	4.807	6.724	9.442	6.680	0.202	0.311	0.465	0.326
2022	4.683	6.691	9.553	6.520	0.201	0.312	0.466	0.318
2023	4.872	7.442	11.550	7.117	0.212	0.345	0.553	0.348
2024	3.211	6.415	12.477	5.923	0.145	0.295	0.585	0.289

Table 16. Prince Rupert District SAR: spawning biomass and depletion from 2015 to 2024 for the Pacific Herring statistical catch-age model. See Table 15 for description.

	Spawning biomass				Depletion			
Year	5%	50%	95%	MPD	5%	50%	95%	MPD
2015	15.657	19.192	23.628	19.259	0.222	0.331	0.459	0.353
2016	13.172	16.426	20.576	16.503	0.189	0.284	0.395	0.302
2017	11.299	14.657	18.937	14.764	0.167	0.252	0.359	0.271
2018	14.721	19.131	24.494	19.293	0.218	0.328	0.468	0.354
2019	23.242	30.272	39.251	30.551	0.345	0.520	0.743	0.560
2020	19.853	25.842	33.554	25.920	0.295	0.444	0.631	0.475
2021	17.073	22.503	29.699	22.226	0.258	0.387	0.544	0.407
2022	20.501	27.134	35.918	26.362	0.311	0.467	0.653	0.483
2023	29.421	41.971	59.189	40.410	0.461	0.718	1.062	0.741
2024	28.862	49.837	79.105	47.084	0.471	0.850	1.411	0.863

Table 17. Central Coast SAR: spawning biomass and depletion from 2015 to 2024 for the Pacific Herring statistical catch-age model. Spawning biomass and depletion are summarised by the posterior (5th, 50th, and 95th percentile) and maximum posterior density (MPD) estimates in thousands of tonnes. Note: depletion is relative spawning biomass SB_t/SB_0, where SB_t is spawning biomass in year t, and SB_0 is estimated unfished spawning biomass.

	Spawning biomass				Depletion			
Year	5%	50%	95%	MPD	5%	50%	95%	MPD
2015	16.953	21.060	26.326	21.327	0.311	0.429	0.580	0.450
2016	16.749	21.148	26.551	21.423	0.309	0.430	0.583	0.452
2017	16.496	20.912	26.357	21.273	0.306	0.424	0.580	0.449
2018	18.361	23.041	28.959	23.494	0.339	0.469	0.636	0.495
2019	25.173	32.033	40.461	32.735	0.470	0.652	0.889	0.690
2020	20.868	26.812	34.376	27.312	0.388	0.548	0.752	0.576
2021	15.981	21.137	27.899	21.303	0.301	0.430	0.600	0.449
2022	16.898	22.669	29.857	22.450	0.322	0.461	0.638	0.473
2023	17.351	24.536	33.978	24.114	0.336	0.499	0.714	0.509
2024	12.138	20.720	34.300	19.938	0.237	0.418	0.704	0.420

Table 18. West Coast of Vancouver Island SAR: spawning biomass and depletion from 2015 to 2024 for the Pacific Herring statistical catch-age model. See Table 15 for description.

	Spawning biomass				Depletion			
Year	5%	50%	95%	MPD	5%	50%	95%	MPD
2015	13.222	17.043	21.639	17.227	0.254	0.365	0.499	0.379
2016	17.609	22.913	29.495	23.273	0.341	0.490	0.675	0.513
2017	13.596	17.576	22.769	17.834	0.265	0.376	0.516	0.393
2018	11.970	15.360	19.543	15.499	0.236	0.327	0.446	0.341
2019	11.937	15.517	20.002	15.580	0.236	0.331	0.451	0.343
2020	14.140	18.393	24.132	18.407	0.279	0.394	0.541	0.405
2021	19.044	25.094	33.388	24.983	0.376	0.536	0.741	0.550
2022	28.806	38.661	51.251	38.069	0.580	0.823	1.137	0.838
2023	34.315	49.100	69.528	48.213	0.702	1.050	1.517	1.062
2024	39.613	65.496	102.477	63.722	0.824	1.393	2.227	1.403

Table 19. Haida Gwaii SAR: proposed reference points for the Pacific Herring statistical catch-age model. Reference points are summarised by posterior (5th, 50th, and 95th percentile) estimates. All biomass numbers are in thousands of tonnes. Legend: SB_0 is estimated unfished spawning biomass; $\overline{SB}_{Prod}$ is average spawning biomass during a productive period (Table 23); SB_t is spawning biomass in year t; P is probability; and SB_{2025} is projected spawning biomass in 2025 assuming no fishing. Note that the age-10 class is a 'plus group' which includes fish ages 10 and older.

Reference point	5%	50%	95%
SB_0	17.161	21.508	28.041
$0.3SB_0$	5.148	6.452	8.412
$0.75\overline{SB}_{Prod}$	15.106	19.107	25.312
SB_{2024}	3.211	6.415	12.477
SB_{2024}/SB_0	0.145	0.295	0.585
$P\ (SB_{2024} < 0.3SB_0)$	–	0.517	–
$P\ (SB_{2024} < 0.75\overline{SB}_{Prod})$	–	0.997	–
SB_{2025}	3.336	7.556	18.466
SB_{2025}/SB_0	0.155	0.351	0.854
$P\ (SB_{2025} < 0.3SB_0)$	–	0.378	–
$P\ (SB_{2025} < 0.75\overline{SB}_{Prod})$	–	0.950	–
Proportion aged 3	0.09	0.33	0.71
Proportion aged 4 to 10	0.20	0.47	0.75

Table 20. Prince Rupert District SAR: proposed reference points for the Pacific Herring statistical catch-age model. See Table 19 for description.

Reference point	5%	50%	95%
SB_0	45.124	57.822	81.796
$0.3SB_0$	13.537	17.347	24.539
$\overline{SB}_{Prod}$	28.602	34.547	42.573
SB_{2024}	28.862	49.837	79.105
SB_{2024}/SB_0	0.471	0.850	1.411
$P\ (SB_{2024} < 0.3SB_0)$	–	0.003	–
$P\ (SB_{2024} < \overline{SB}_{Prod})$	–	0.151	–
SB_{2025}	25.641	47.883	83.812
SB_{2025}/SB_0	0.421	0.813	1.471
$P\ (SB_{2025} < 0.3SB_0)$	–	0.005	–
$P\ (SB_{2025} < \overline{SB}_{Prod})$	–	0.211	–
Proportion aged 3	0.04	0.13	0.36
Proportion aged 4 to 10	0.57	0.81	0.93

Table 21. Central Coast SAR: proposed reference points for the Pacific Herring statistical catch-age model. Reference points are summarised by posterior (5th, 50th, and 95th percentile) estimates. All biomass numbers are in thousands of tonnes. Legend: SB_0 is estimated unfished spawning biomass; $\overline{SB}_{Prod}$ is average spawning biomass during a productive period (Table 23); SB_t is spawning biomass in year t; P is probability; and SB_{2025} is projected spawning biomass in 2025 assuming no fishing. Note that the age-10 class is a 'plus group' which includes fish ages 10 and older.

Reference point	5%	50%	95%
SB_0	40.126	48.873	62.821
$0.3SB_0$	12.038	14.662	18.846
$\overline{SB}_{Prod}$	26.908	31.795	38.085
SB_{2024}	12.138	20.720	34.300
SB_{2024}/SB_0	0.237	0.418	0.704
$P\ (SB_{2024} < 0.3SB_0)$	–	0.164	–
$P\ (SB_{2024} < \overline{SB}_{Prod})$	–	0.913	–
SB_{2025}	8.970	17.462	35.002
SB_{2025}/SB_0	0.184	0.357	0.713
$P\ (SB_{2025} < 0.3SB_0)$	–	0.326	–
$P\ (SB_{2025} < \overline{SB}_{Prod})$	–	0.919	–
Proportion aged 3	0.08	0.26	0.58
Proportion aged 4 to 10	0.33	0.60	0.81

Table 22. West Coast of Vancouver Island SAR: proposed reference points for the Pacific Herring statistical catch-age model. See Table 19 for description.

Reference point	5%	50%	95%
SB_0	38.242	46.443	59.783
$0.3SB_0$	11.472	13.933	17.935
$\overline{SB}_{Prod}$	27.674	33.905	41.721
SB_{2024}	39.613	65.496	102.477
SB_{2024}/SB_0	0.824	1.393	2.227
$P\ (SB_{2024} < 0.3SB_0)$	–	0.000	–
$P\ (SB_{2024} < \overline{SB}_{Prod})$	–	0.024	–
SB_{2025}	33.406	59.778	107.119
SB_{2025}/SB_0	0.703	1.267	2.291
$P\ (SB_{2025} < 0.3SB_0)$	–	0.000	–
$P\ (SB_{2025} < \overline{SB}_{Prod})$	–	0.068	–
Proportion aged 3	0.06	0.20	0.46
Proportion aged 4 to 10	0.48	0.73	0.88

Table 23. Year range for calculating proportion of average spawning biomass of Pacific Herring during a productive period $\overline{SB}_{Prod}$ in the major stock assessment regions (SARs). Note that the SoG stock is assessed in DFO (2025) but SoG data is included in this table for completeness.

SAR	Years	Proportion
Haida Gwaii	1975 to 1985	0.75
Prince Rupert District	1983 to 1992	1.00
Central Coast	1990 to 1999	1.00
Strait of Georgia	1988 to 2007	0.80
West Coast of Vancouver Island	1990 to 1999	1.00

Table 24. Prince Rupert District SAR: management procedure (MP) performance for the Pacific Herring statistical catch-age model. Performance metrics are given for two operating model (OM) scenarios: density-dependent natural mortality (DDM) and density-independent natural mortality (DIM). Performance criteria are calculated over three Pacific Herring generations (i.e., 15 years) from the start of the projection period for all objectives (Obj). MPs are ordered within each scenario by performance of achieving Objective 1. The recommended total allowable catch (TAC) and associated harvest rate (HR) in 2025 are calculated for each MP using posterior densities values. Legend: limit reference point (LRP); upper stock reference (USR); P is probability; maximum (Max); SB_t is spawning biomass in year t; SB_0 is estimated unfished spawning biomass; $\overline{SB}_{Prod}$ is average spawning biomass during a productive period (Table 23); average annual variability (AAV) in catch; and $\overline{C}$ is average annual catch. MPs are defined in DFO (2019) and DFO (2020a). Biomass and catch are in thousands of tonnes (t). Note: Dashes or 0.00 indicate that TAC and HR do not apply because the MP specifies no fishing. Also note that TAC and HR are median values calculated by the MP using posterior distributions of SB_{2024} and SB_0. The HR is derived according to the MP shape and is equivalent to TAC/SB_{2024}. In cases where MPs include a cap, the cap is constant regardless of estimated SB_{2024}, and higher SB_{2024} leads to lower HR.

Scenario		Conservation Obj 1 (LRP) $P \geq 75\%$	Biomass Obj 2 (USR) P	Yield Obj 3 $< 25\%$	Yield Obj 4 Max	2025	
OM	MP	$SB_t \geq 0.3SB_0$	$SB_t \geq \overline{SB}_{Prod}$	AAV	$\overline{C}$	TAC	HR
DDM	NoFish_FSC	98%	86%	0.00	0.14	–	–
DDM	HS30-60_HR05	97%	82%	45.71	2.33	2.38	0.05
DDM	HS50-60_HR20_Cap2.5	97%	80%	36.62	2.13	2.50	0.05
DDM	HS30-60_HR10_Cap2.5	96%	79%	26.53	2.25	2.50	0.05
DDM	MinE50_HR10	96%	79%	39.83	4.21	4.78	0.10
DDM	MinE30_HR10	94%	67%	30.73	4.48	4.79	0.10
DDM	MinE50_HR20	93%	55%	50.09	6.43	9.49	0.20
DIM	NoFish_FSC	94%	71%	0.00	0.14	–	–
DIM	HS30-60_HR05	93%	65%	51.69	1.82	2.38	0.05
DIM	HS50-60_HR20_Cap2.5	92%	63%	42.60	1.96	2.50	0.05
DIM	HS30-60_HR10_Cap2.5	91%	61%	35.58	2.07	2.50	0.05
DIM	MinE50_HR10	89%	56%	52.38	3.35	4.78	0.10
DIM	MinE30_HR10	87%	52%	33.96	3.77	4.79	0.10
DIM	MinE50_HR20	85%	31%	63.44	5.10	9.49	0.20

Table 25. Central Coast SAR: management procedure performance for the Pacific Herring statistical catch-age model. Performance metrics are given for two operating model (OM) scenarios: density-dependent natural mortality (DDM) and density-independent natural mortality (DIM). Performance criteria are calculated over three Pacific Herring generations (i.e., 15 years) from the start of the projection period for all objectives (Obj). MPs are ordered within each scenario by performance of achieving Objective 1. The recommended total allowable catch (TAC) and associated harvest rate (HR) in 2025 are calculated for each MP using posterior densities values. Legend: limit reference point (LRP); upper stock reference (USR); P is probability; maximum (Max); SB_t is spawning biomass in year t; SB_0 is estimated unfished spawning biomass; $\overline{SB}_{Prod}$ is average spawning biomass during a productive period (Table 23); average annual variability (AAV) in catch; and $\overline{C}$ is average annual catch. MPs are defined in DFO (2019) and DFO (2020a). Biomass and catch are in thousands of tonnes (t). Note: Dashes or 0.00 indicate that TAC and HR do not apply because the MP specifies no fishing. Also note that TAC and HR are median values calculated by the MP using posterior distributions of SB_{2024} and SB_0. The HR is derived according to the MP shape and is equivalent to TAC/SB_{2024}. In cases where MPs include a cap, the cap is constant regardless of estimated SB_{2024}, and higher SB_{2024} leads to lower HR.

Scenario		Conservation Obj 1 (LRP) $P \geq 75\%$	Biomass Obj 2 (USR) P	Yield Obj 3 $< 25\%$	Yield Obj 4 Max	2025	
OM	**MP**	$SB_t \geq 0.3SB_0$	$SB_t \geq \overline{SB}_{Prod}$	**AAV**	$\overline{C}$	**TAC**	**HR**
DDM	NoFish_FSC	92%	69%	0.00	0.14	–	–
DDM	HS30-60_HR05	91%	64%	40.76	1.74	0.16	0.01
DDM	HS30-60_HR10_Cap5	90%	58%	38.83	2.92	0.32	0.02
DDM	MinE50_HR10	90%	58%	53.22	2.92	0.00	0.00
DIM	NoFish_FSC	85%	54%	0.00	0.14	–	–
DIM	HS30-60_HR05	83%	48%	50.38	1.38	0.16	0.01
DIM	MinE50_HR10	82%	43%	70.82	2.21	0.00	0.00
DIM	HS30-60_HR10_Cap5	81%	43%	52.19	2.45	0.32	0.02

Table 26. West Coast of Vancouver Island SAR: management procedure performance for the Pacific Herring statistical catch-age model. See Table 24 for description.

Scenario		Conservation Obj 1 (LRP) $P \geq 75\%$	Biomass Obj 2 (USR) P	Yield Obj 3 $< 25\%$	Yield Obj 4 Max	2025	
OM	**MP**	$SB_t \geq 0.3SB_0$	$SB_t \geq \overline{SB}_{Prod}$	**AAV**	$\overline{C}$	**TAC**	**HR**
DDM	NoFish_FSC	84%	33%	0.00	0.14	–	–
DDM	HS30-60_HR10_Cap2	82%	27%	60.72	1.15	2.00	0.03
DDM	MinE30_HR05	82%	27%	59.45	1.01	2.99	0.05
DDM	HS50-60_HR10	82%	25%	89.73	1.28	5.98	0.10
DDM	HS30-60_HR15_Cap2	81%	27%	57.13	1.30	2.00	0.03
DDM	HS50-60_HR15	81%	23%	82.56	2.08	8.97	0.15
DDM	MinE30_HR10	80%	24%	75.21	1.87	5.98	0.10
DIM	NoFish_FSC	65%	17%	0.00	0.14	–	–
DIM	HS30-60_HR10_Cap2	63%	15%	71.81	0.79	2.00	0.03
DIM	MinE30_HR05	63%	15%	70.09	0.76	2.99	0.05
DIM	HS30-60_HR15_Cap2	62%	15%	80.94	0.83	2.00	0.03
DIM	HS50-60_HR10	62%	14%	96.54	0.72	5.98	0.10
DIM	MinE30_HR10	61%	13%	83.98	1.26	5.98	0.10
DIM	HS50-60_HR15	61%	12%	107.55	1.00	8.97	0.15

FIGURES

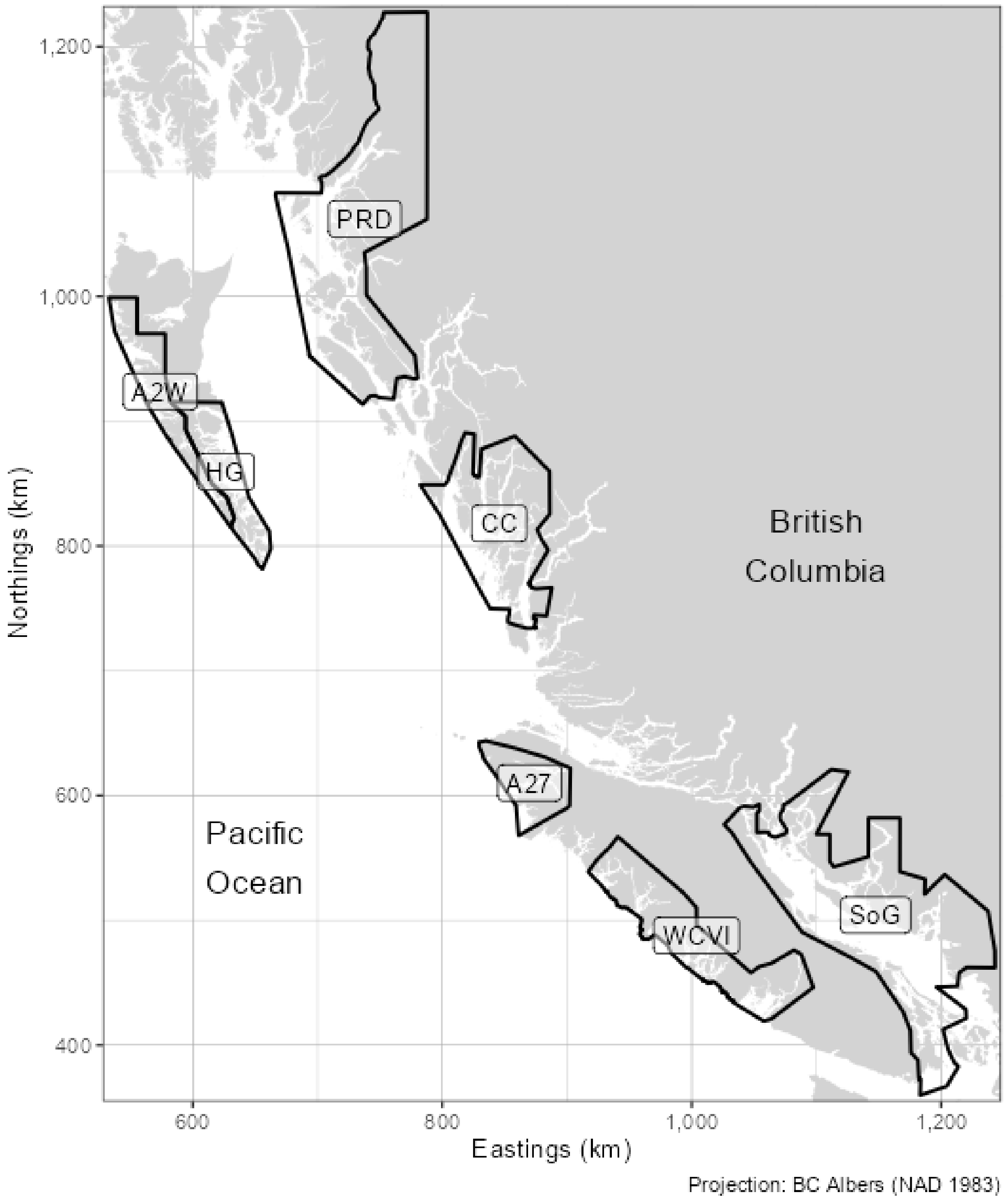

Figure 1. Boundaries for Pacific Herring SARs in British Columbia. The major SARs are Haida Gwaii (HG), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SoG), and West Coast of Vancouver Island (WCVI). The minor SARs are Area 27 (A27) and Area 2 West (A2W). Units: kilometres (km).

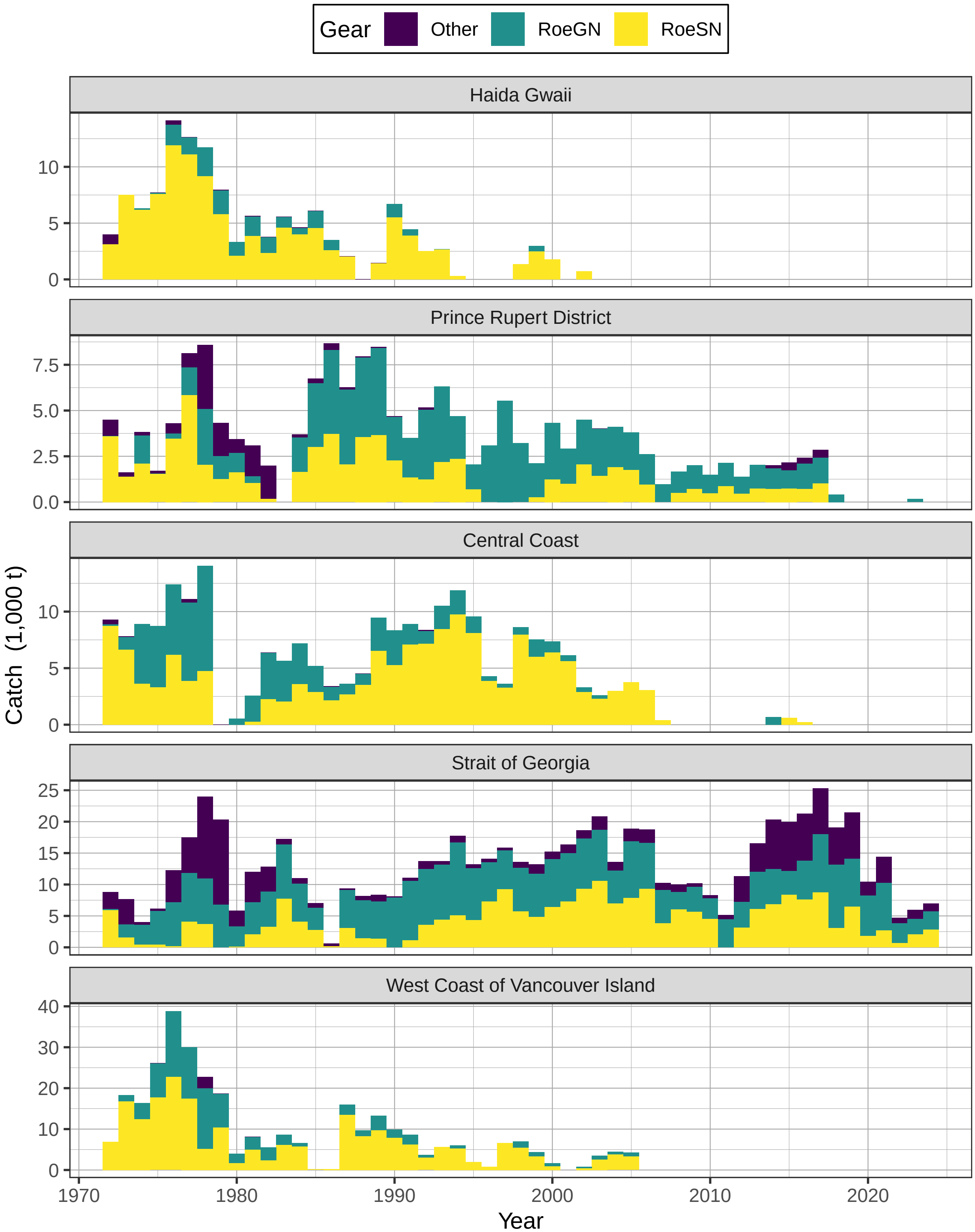

Figure 2. Total landed Pacific Herring catch in thousands of tonnes (t) from 1972 to 2024 in the major SARs. Note that the SoG stock is assessed in DFO (2025) but SoG data is included in this figure for completeness. See Figures 8 to 12 for catches during the reduction period (1951 to 1971). Legend: 'Other' represents the reduction, the food and bait, as well as the special use fishery; 'RoeGN' represents the roe gillnet fishery; and 'RoeSN' represents the roe seine fishery.

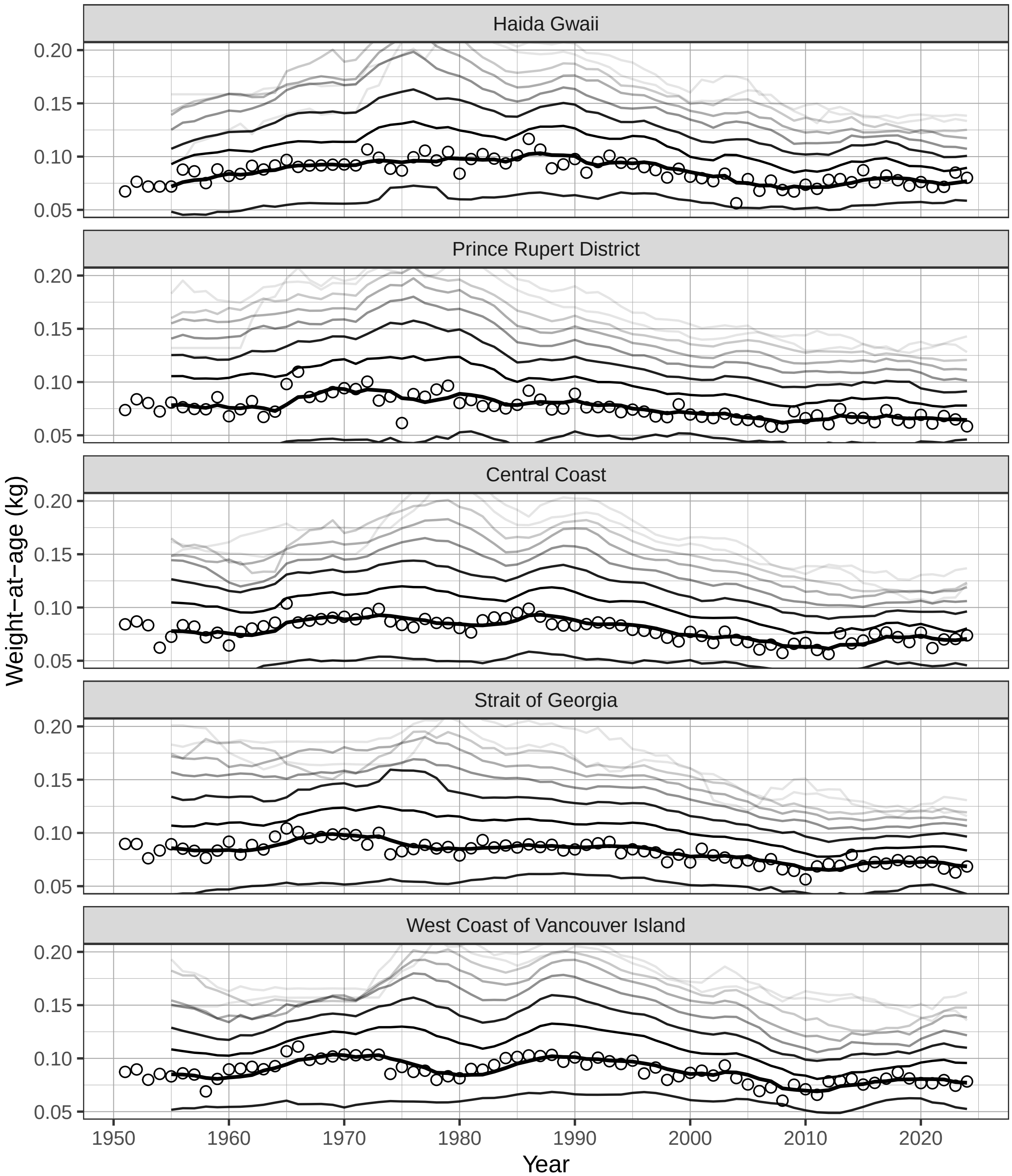

Figure 3. Mean weight-at-age for Pacific Herring in kilograms (kg) from 1951 to 2024 in the major SARs. Note that the SoG stock is assessed in DFO (2025) but SoG data is included in this figure for completeness. Lines show 5-year running means for age-2 to age-10 herring, incrementing up from bottom line and shaded from darker to lighter, except thickest line shows age-3 herring. Circles show mean for age-3 herring. In years where there are no biological samples for an age class, values are imputed as the mean of the previous 5 years, except for the beginning of the time series which are imputed by extending the first non-missing value backwards. 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 includes fish ages 10 and older. Vertical axes are cropped at 0.05 to 0.20 kg.

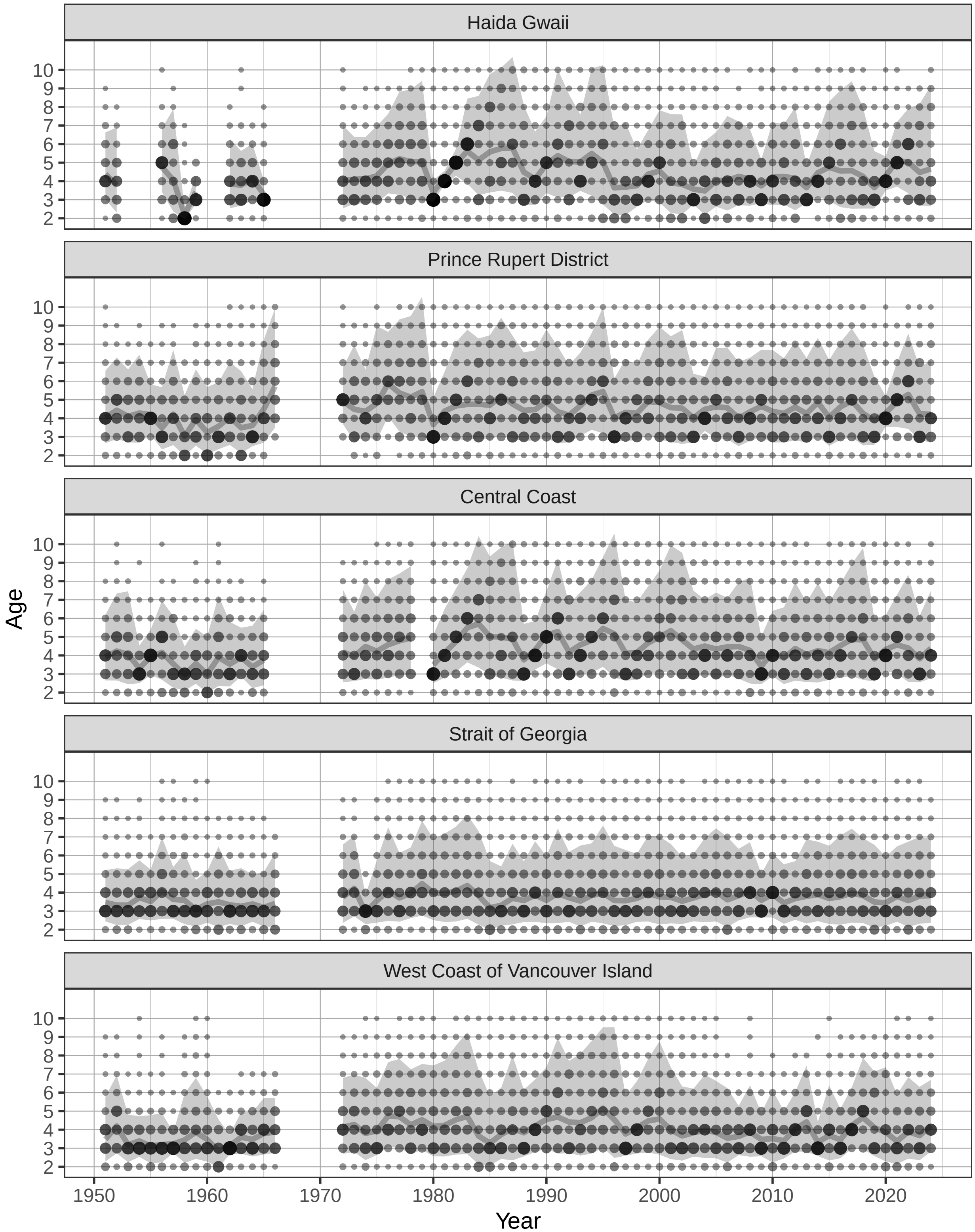

Figure 4. Proportion-at-age for Pacific Herring from 1951 to 2024 in the major SARs. Note that the SoG stock is assessed in DFO (2025) but SoG data is included in this figure for completeness. Dot size and colour indicates age class proportion for the year; each year adds up to 1.0. The gray line is 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 plus class includes fish ages 10 and older.

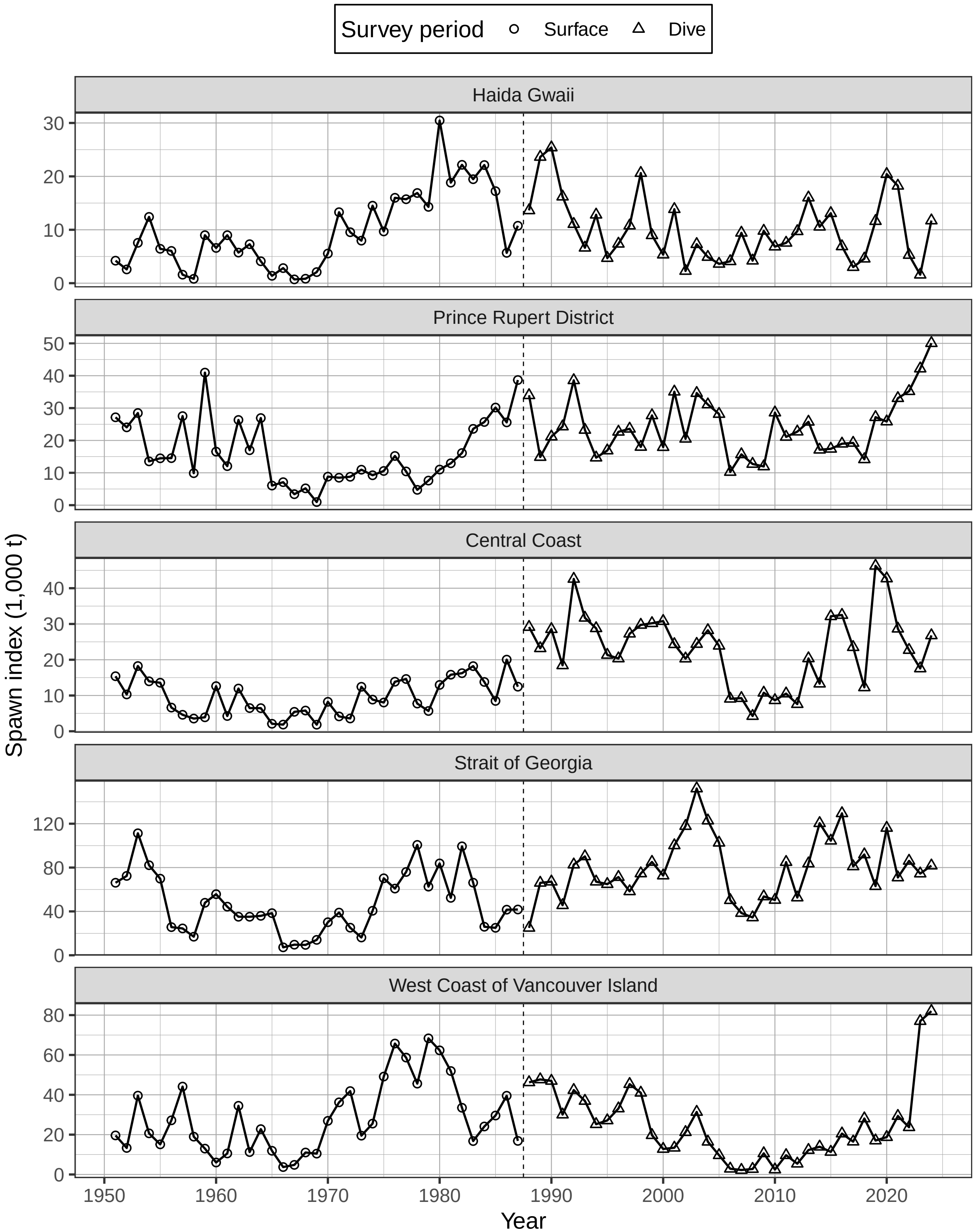

Figure 5. Spawn index in thousands of tonnes (t) for Pacific Herring from 1951 to 2024 in the major SARs. Note that the SoG stock is assessed in DFO (2025) but SoG data is included in this figure for completeness. The dashed vertical line delineates between two periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2024). Note: the 'spawn index' is not scaled by the spawn survey scaling parameter q.

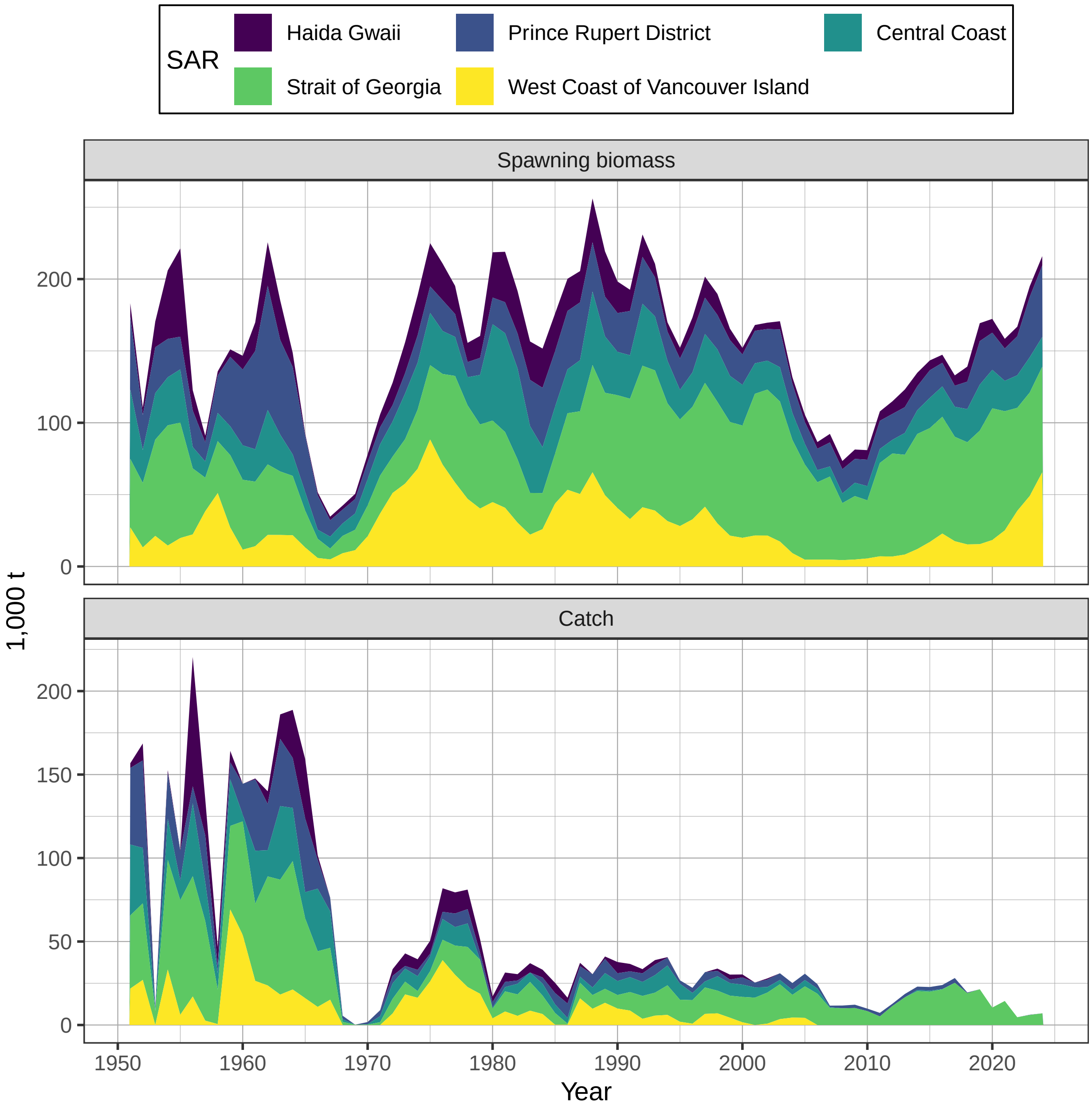

Figure 6. Spawning biomass and catch in thousands of tonnes (t) for Pacific Herring from 1951 to 2024 in the major SARs. Note that the SoG stock is assessed in DFO (2025) but SoG data is included in this figure for completeness. Spawning biomass is represented by median posterior estimates.

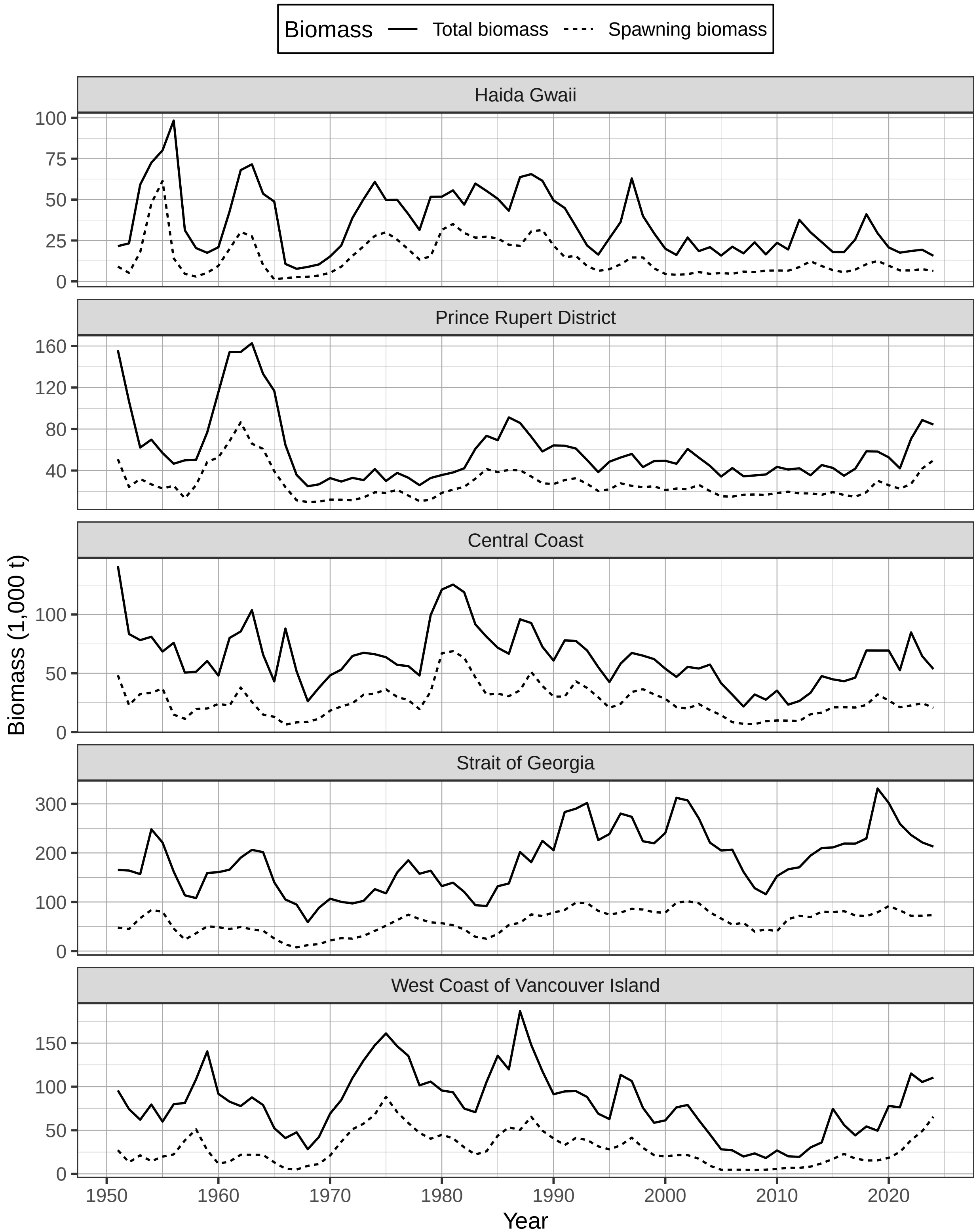

Figure 7. Total biomass and spawning biomass in thousands of tonnes (t) for Pacific Herring from 1951 to 2024 in the major SARs. Note that the SoG stock is assessed in DFO (2025) but SoG data is included in this figure for completeness. Biomass is represented by median posterior estimates.

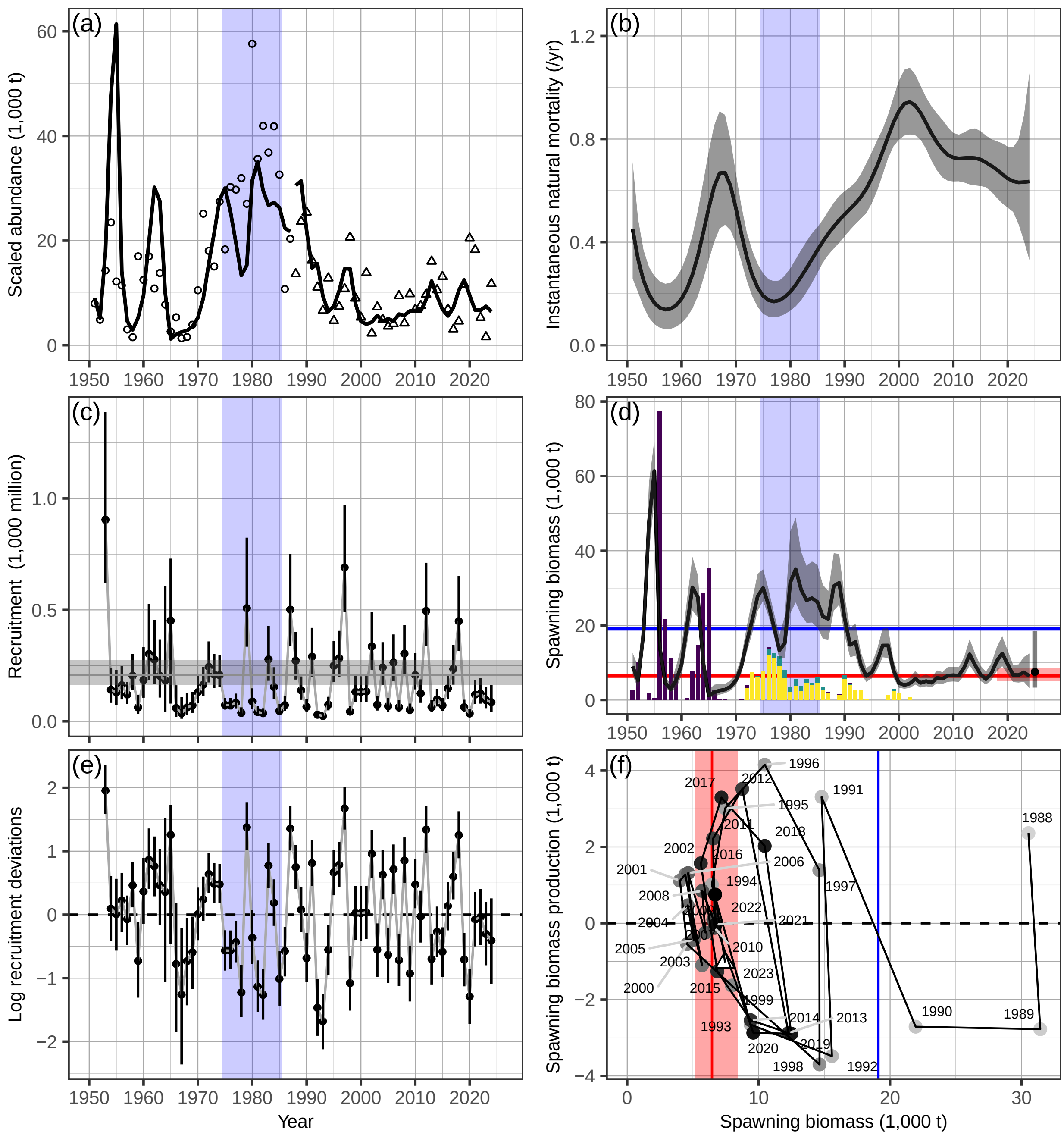

Figure 8. Haida Gwaii SAR: statistical catch-age model output for Pacific Herring from 1951 to 2024. ***Panel (a)****: Model fit (lines) to scaled abundance (points; Figure 5). Spawn index is scaled to abundance by the spawn index scaling parameter q.* ***Panel (b)****: Instantaneous natural mortality rate (year^{-1}).* ***Panel (c)****: Reconstructed number of age-2 recruits in thousands of millions from 1953 to 2024. Horizontal line indicates unfished age-2 recruitment R_0.* ***Panel (d)****: Spawning biomass (line), and forecast spawning biomass in 2025 in the absence of fishing (point). Coloured vertical bars indicate commercial catch (Figure 2).* ***Panel (e)****: Log recruitment deviations from 1953 to 2024.* ***Panel (f)****: Phase plot of spawning biomass production for the dive survey period (1988 to 2023). Points are chronologically shaded light to dark; triangle indicates 2023. Legend: biomass and catch are in thousands of tonnes (t); points and time-series lines are median posterior estimates; bands and error bars are 90% credible intervals; dashed horizontal lines indicate zero; blue circles and shaded regions indicate a productive period (Table 23); blue lines indicate proportion of spawning biomass during a productive period 0.75 $\overline{SB}_{Prod}$; and red lines indicate the median limit reference point $0.3SB_0$, where SB_0 is estimated unfished spawning biomass.*

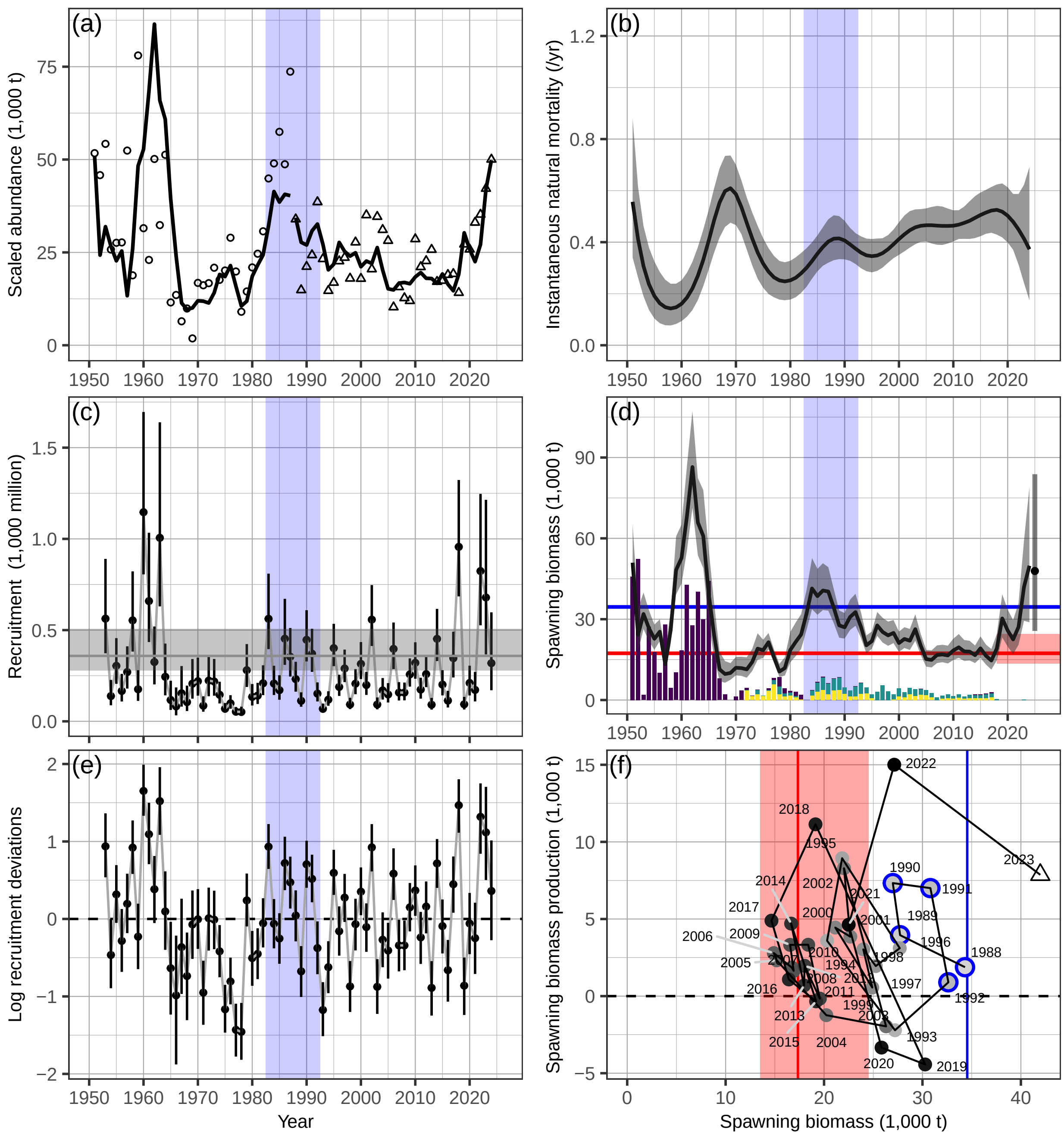

Figure 9. Prince Rupert District SAR: statistical catch-age model output for Pacific Herring from 1951 to 2024. ***Panel (a)****: Model fit (lines) to scaled abundance (points; Figure 5). Spawn index is scaled to abundance by the spawn index scaling parameter q.* ***Panel (b)****: Instantaneous natural mortality rate (year^{-1}).* ***Panel (c)****: Reconstructed number of age-2 recruits in thousands of millions from 1953 to 2024. Horizontal line indicates unfished age-2 recruitment R_0.* ***Panel (d)****: Spawning biomass (line), and forecast spawning biomass in 2025 in the absence of fishing (point). Coloured vertical bars indicate commercial catch (Figure 2).* ***Panel (e)****: Log recruitment deviations from 1953 to 2024.* ***Panel (f)****: Phase plot of spawning biomass production for the dive survey period (1988 to 2023). Points are chronologically shaded light to dark; triangle indicates 2023. Legend: biomass and catch are in thousands of tonnes (t); points and time-series lines are median posterior estimates; bands and error bars are 90% credible intervals; dashed horizontal lines indicate zero; blue circles and shaded regions indicate a productive period (Table 23); blue lines indicate proportion of spawning biomass during a productive period $\overline{SB}_{Prod}$; and red lines indicate the median limit reference point $0.3SB_0$, where SB_0 is estimated unfished spawning biomass.*

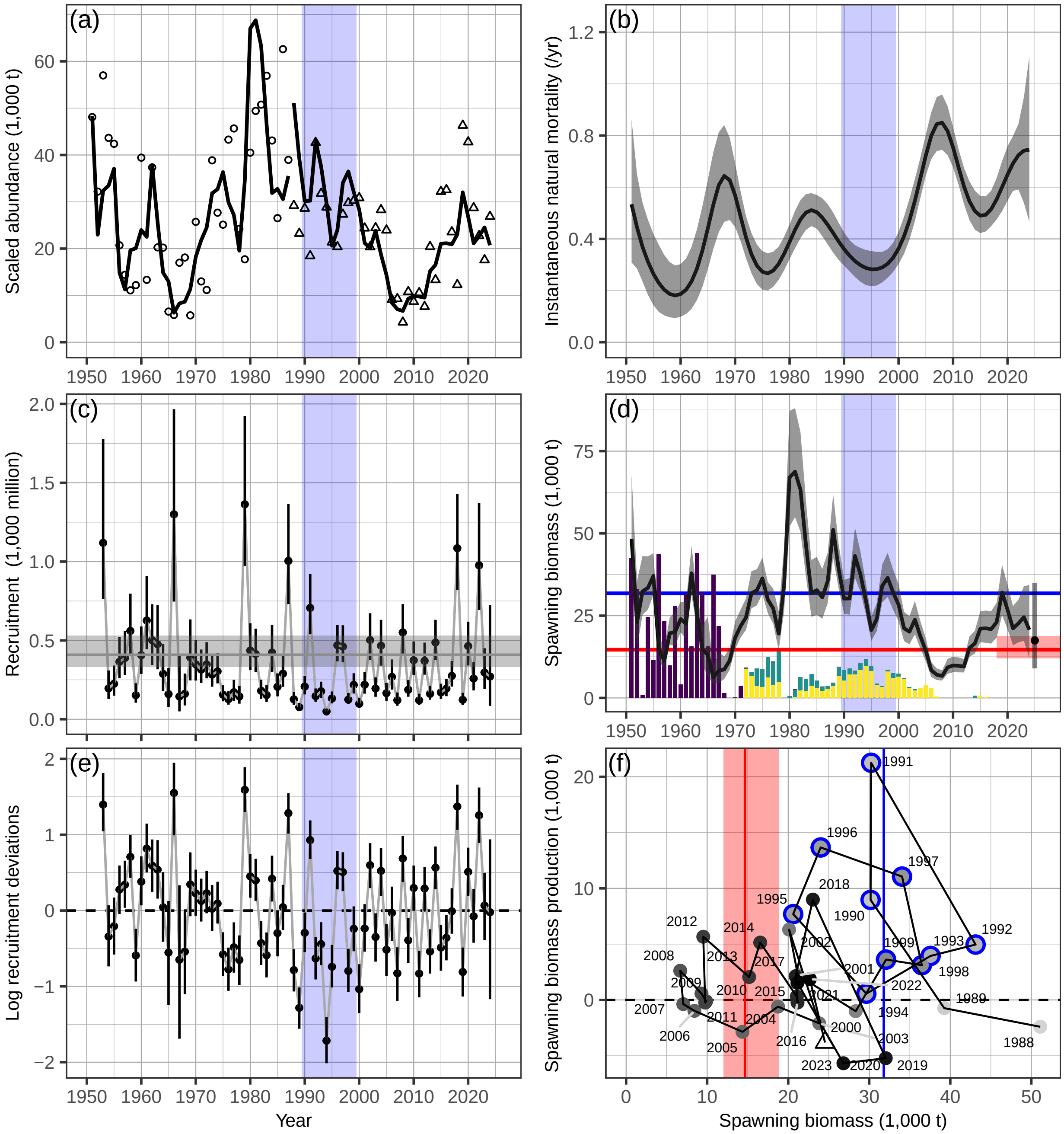

Figure 10. Central Coast SAR: statistical catch-age model output for Pacific Herring from 1951 to 2024. ***Panel (a)****: Model fit (lines) to scaled abundance (points; Figure 5). Spawn index is scaled to abundance by the spawn index scaling parameter q.* ***Panel (b)****: Instantaneous natural mortality rate (year^{-1}).* ***Panel (c)****: Reconstructed number of age-2 recruits in thousands of millions from 1953 to 2024. Horizontal line indicates unfished age-2 recruitment R_0.* ***Panel (d)****: Spawning biomass (line), and forecast spawning biomass in 2025 in the absence of fishing (point). Coloured vertical bars indicate commercial catch (Figure 2).* ***Panel (e)****: Log recruitment deviations from 1953 to 2024.* ***Panel (f)****: Phase plot of spawning biomass production for the dive survey period (1988 to 2023). Points are chronologically shaded light to dark; triangle indicates 2023. Legend: biomass and catch are in thousands of tonnes (t); points and time-series lines are median posterior estimates; bands and error bars are 90% credible intervals; dashed horizontal lines indicate zero; blue circles and shaded regions indicate a productive period (Table 23); blue lines indicate proportion of spawning biomass during a productive period $\overline{SB}_{Prod}$; and red lines indicate the median limit reference point $0.3SB_0$, where SB_0 is estimated unfished spawning biomass.*

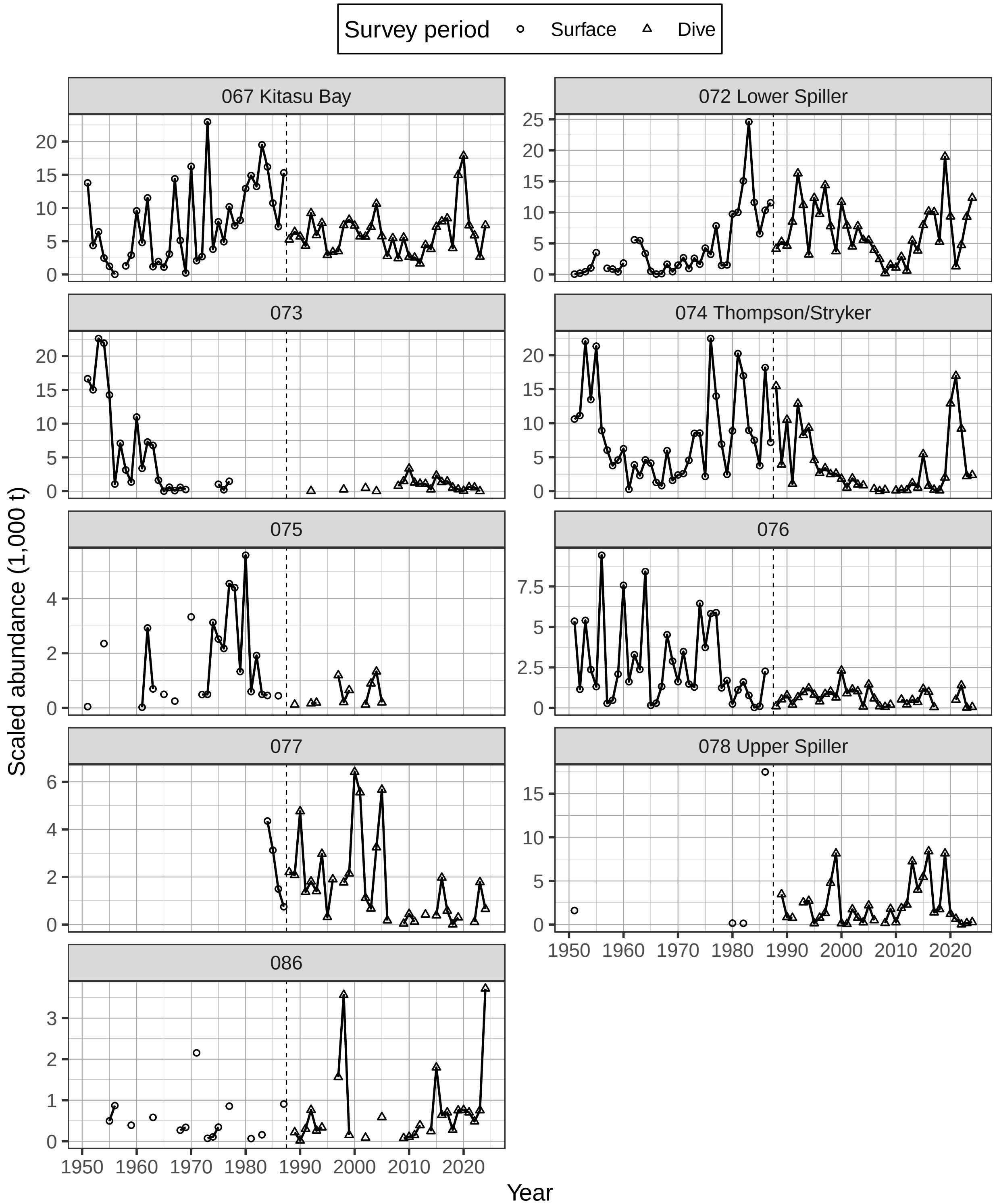

Figure 11. Central Coast SAR: scaled abundance in thousands of tonnes (t) of Pacific Herring in selected Sections from 1951 to 2024. The spawn index is scaled to abundance by the spawn survey scaling parameter q (median posterior estimate). The dashed vertical line delineates between two periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2024).

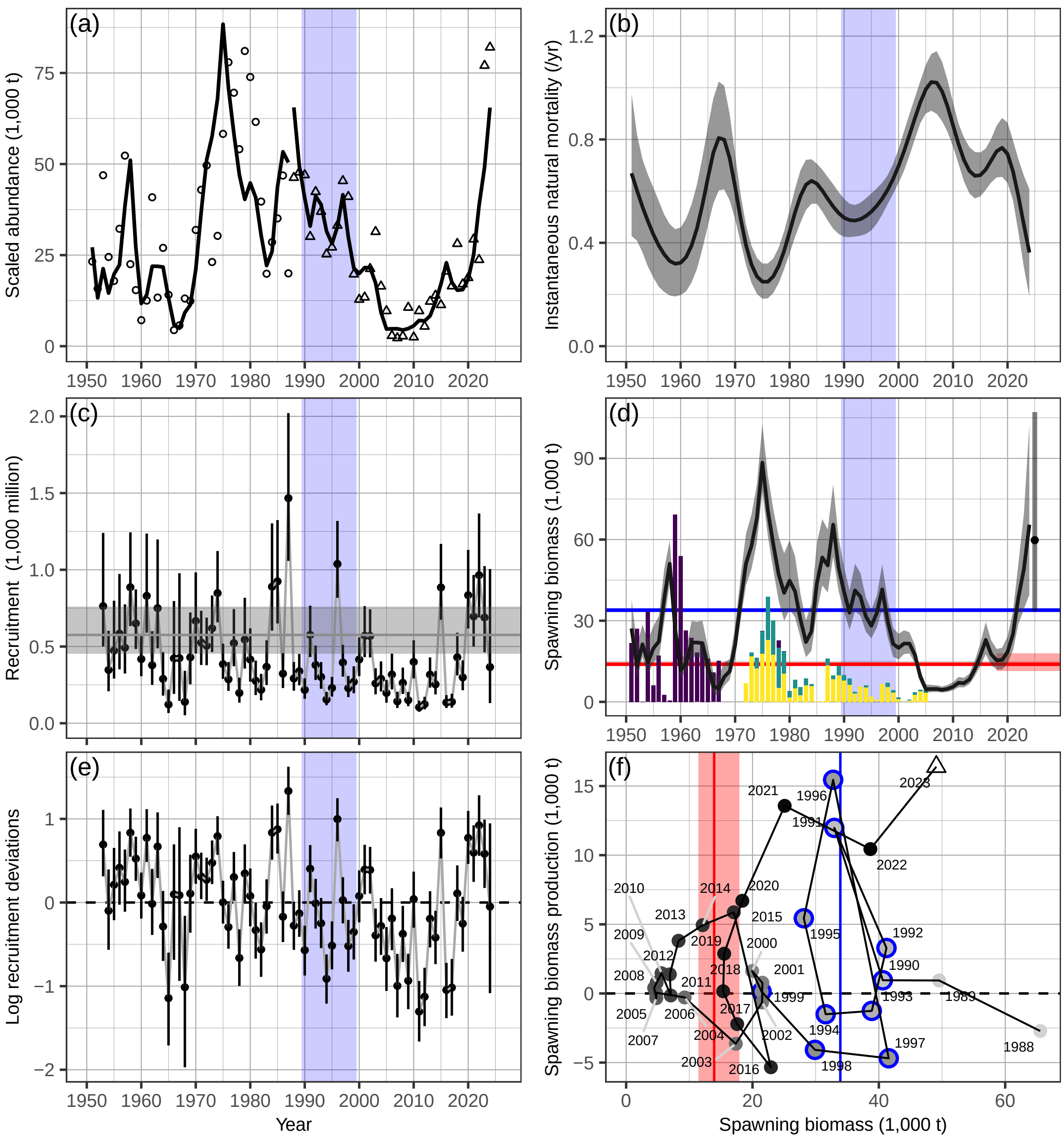

*Figure 12. West Coast of Vancouver Island SAR: statistical catch-age model output for Pacific Herring from 1951 to 2024. **Panel (a)**: Model fit (lines) to scaled abundance (points; Figure 5). Spawn index is scaled to abundance by the spawn index scaling parameter q. **Panel (b)**: Instantaneous natural mortality rate (year^{-1}). **Panel (c)**: Reconstructed number of age-2 recruits in thousands of millions from 1953 to 2024. Horizontal line indicates unfished age-2 recruitment R_0. **Panel (d)**: Spawning biomass (line), and forecast spawning biomass in 2025 in the absence of fishing (point). Coloured vertical bars indicate commercial catch (Figure 2). **Panel (e)**: Log recruitment deviations from 1953 to 2024. **Panel (f)**: Phase plot of spawning biomass production for the dive survey period (1988 to 2023). Points are chronologically shaded light to dark; triangle indicates 2023. Legend: biomass and catch are in thousands of tonnes (t); points and time-series lines are median posterior estimates; bands and error bars are 90% credible intervals; dashed horizontal lines indicate zero; blue circles and shaded regions indicate a productive period (Table 23); blue lines indicate proportion of spawning biomass during a productive period $\overline{SB}_{Prod}$; and red lines indicate the median limit reference point $0.3SB_0$, where SB_0 is estimated unfished spawning biomass.*

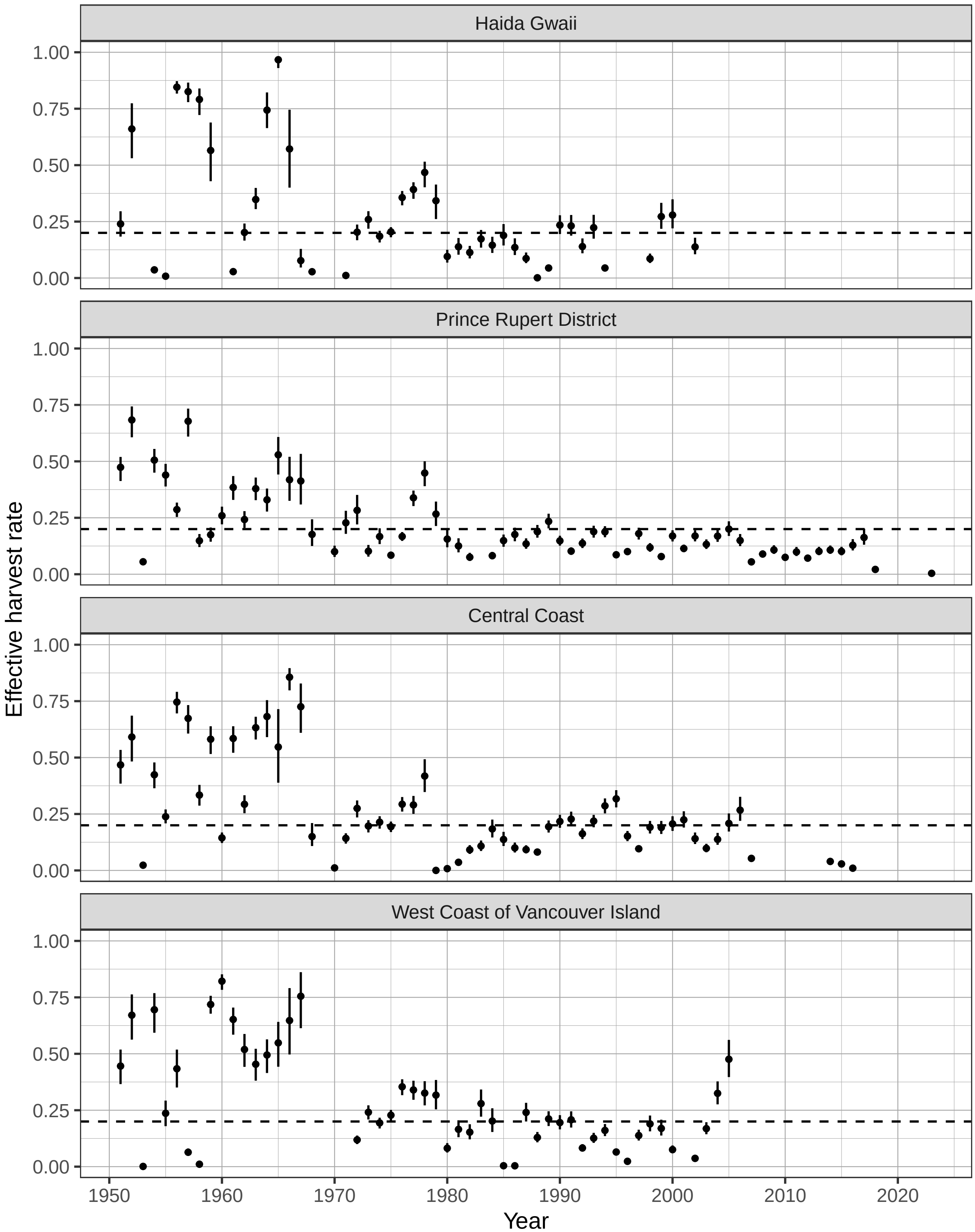

Figure 13. Effective harvest rate U_t for Pacific Herring from 1951 to 2024 in the major SARs. Effective harvest rate is $U_t = C_t/(C_t + SB_t)$ where C_t is catch in year t, and SB_t is estimated spawning biomass in year t. Points and vertical lines indicate medians and 90% credible intervals for U_t, respectively. Horizontal dashed lines indicate $U_t = 0.2$.

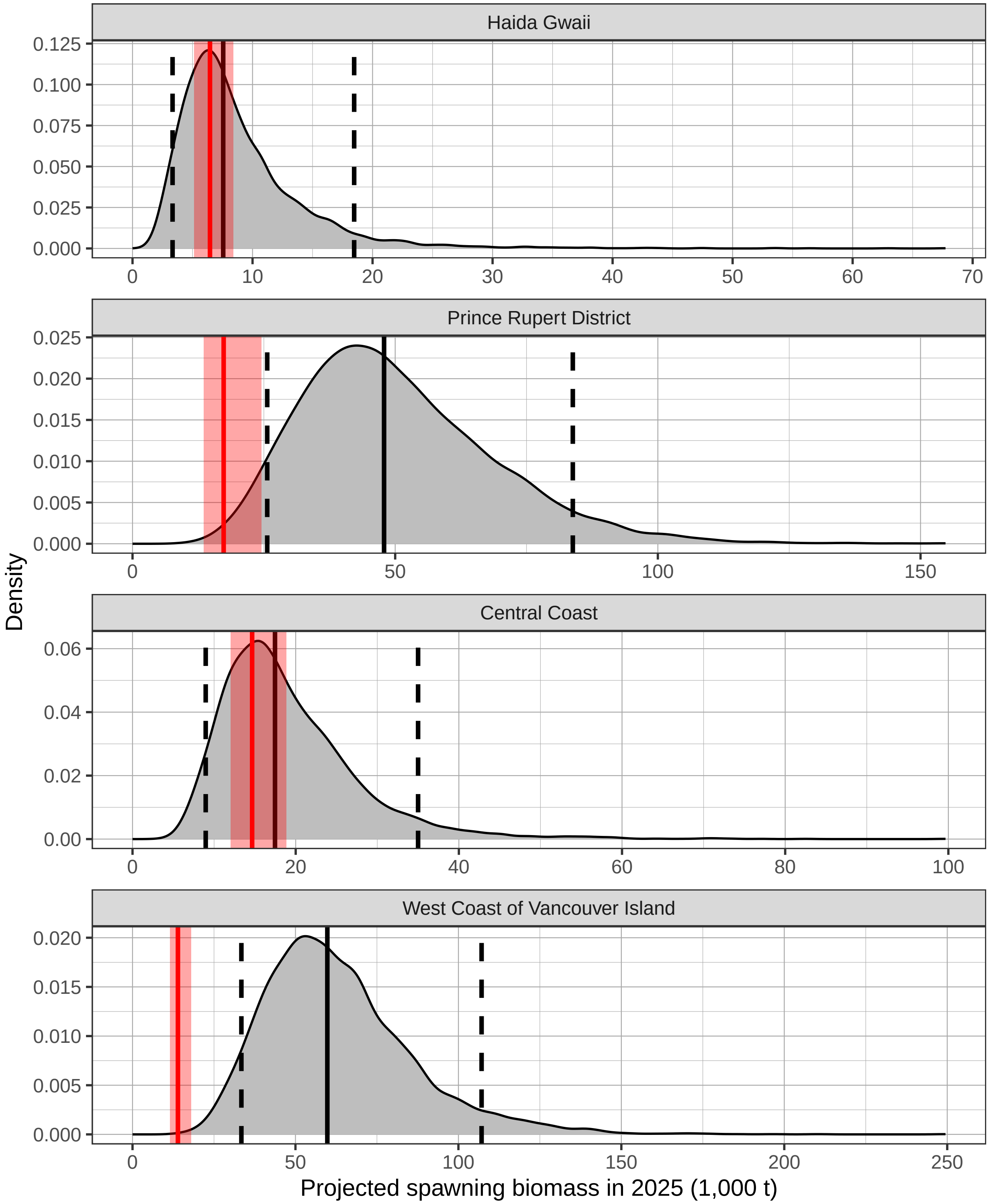

Figure 14. Projected spawning biomass of Pacific Herring assuming no fishing in 2025 SB_{2025} in thousands of tonnes (t) in the major SARs. Solid and dashed black lines indicate median posterior estimate and 90% credible intervals for SB_{2025}, respectively. Vertical red lines and shaded red areas indicate medians and 90% credible intervals for the limit reference point $0.3SB_0$, respectively, where SB_0 is estimated unfished spawning biomass.

LIST OF MEETING PARTICIPANTS

Contributor	Affiliation	Role
Jaclyn Cleary	DFO Science, Pacific	Author
Sarah Power	DFO Science, Pacific	Author
Matthew Grinnell	DFO Science, Pacific	Author
Jennifer Boldt	DFO Science, Pacific	Author (Ecosystem section)
Chris Rooper	DFO Science, Pacific	Author (Ecosystem section)
Bryan Rusch	DFO Fisheries Management, Pacific	Client
Marisa Keefe	DFO Fisheries Management, Pacific	Client
Sarah Hawkshaw	DFO Science, Pacific	Reviewer
Jessica Finney	DFO Science, Pacific	CSAS Science Advisor
Miriam O	DFO Science, Pacific	CSAS Manager

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APPENDIX

Minor stock assessment regions

DFO does not conduct formal analyses of stock trend information for the two Pacific Herring minor SARs: Area 27 (A27) and Area 2 West (A2W). However, DFO does provide landed commercial catch (Figure 15), biological data including weight-at-age (Figure 16) and proportion-at-age (Figure 17), as well as spawn index (Figure 18) from 1978 to 2024. DFO also provides the spawn index and proportion of spawn index by Section from 2015 to 2024 for A27 and A2W (Tables 27 and 28, respectively). For Area 27, spawn index by Section from 1978 to 2024 is also provided (Figure 19).

Special areas

As is the case for the minor SARs, DFO does not conduct formal analyses of stock trend information for the Pacific Herring special area, Area 10 (A10; Figure 20). However, DFO provides biological data including weight-at-age (Figure 21) and proportion-at-age (Figure 22), as well as spawn index and proportion of spawn index by Section (Figure 23 and Table 29) from 1978 to 2024, where available. Note that Area 10 is a subset of the Central Coast and is outside the SAR boundary. In addition, note that there is no landed commercial catch or incidental mortality in finfish aquaculture activities in Area 10 from 1978 to 2024.

Tables

Table 27. Area 27 SAR: spawn index in tonnes for Pacific Herring and proportion of spawn index by Section from 2015 to 2024. See Table 3 for description.

		Proportion			
Year	**Spawn index**	**271**	**272**	**273**	**274**
2015	2,169	0.000	0.000	1.000	0.000
2016	814	0.000	0.000	1.000	0.000
2017	26	0.000	0.000	1.000	0.000
2018	1,045	0.000	0.000	1.000	0.000
2019	192	0.000	0.000	1.000	0.000
2020	NA	0.000	0.000	0.000	0.000
2021	1,653	0.000	0.000	1.000	0.000
2022	NA	0.000	0.000	0.000	0.000
2023	13,511	0.000	0.000	1.000	0.000
2024	8,773	0.000	0.000	1.000	0.000

Table 28. Area 2 West SAR: spawn index in tonnes for Pacific Herring and proportion of spawn index by Section from 2015 to 2024. See Table 3 for description.

		Proportion				
Year	**Spawn index**	**001**	**002**	**003**	**004**	**005**
2015	NA	0.000	0.000	0.000	0.000	0.000
2016	3,001	0.000	1.000	0.000	0.000	0.000
2017	NA	0.000	0.000	0.000	0.000	0.000
2018	617	0.000	0.269	0.000	0.000	0.731
2019	2,884	0.000	1.000	0.000	0.000	0.000
2020	6,834	0.000	1.000	0.000	0.000	0.000
2021	1,377	0.000	1.000	0.000	0.000	0.000
2022	3,299	0.000	1.000	0.000	0.000	0.000
2023	1,192	0.000	1.000	0.000	0.000	0.000
2024	870	0.000	0.709	0.000	0.000	0.291

Table 29. Area 10 special area: spawn index in tonnes for Pacific Herring and proportion of spawn index by Section from 2015 to 2024. See Table 3 for description.

		Proportion		
Year	**Spawn index**	**101**	**102**	**103**
2015	NA	0.000	0.000	0.000
2016	588	0.000	0.967	0.033
2017	2,206	0.000	1.000	0.000
2018	477	0.000	1.000	0.000
2019	570	0.000	1.000	0.000
2020	888	0.000	1.000	0.000
2021	350	0.000	1.000	0.000
2022	34	0.000	1.000	0.000
2023	NA	0.000	0.000	0.000
2024	NA	0.000	0.000	0.000

Figures

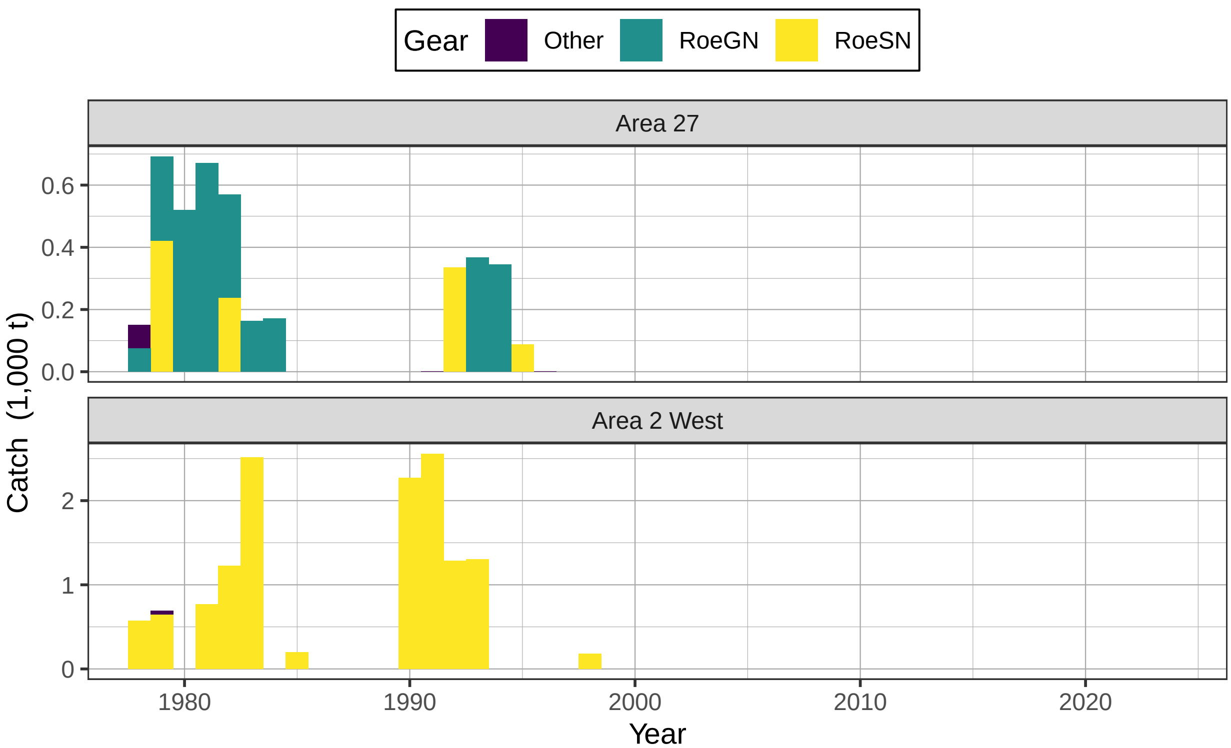

Figure 15. Total landed Pacific Herring catch in thousands of tonnes (t) from 1978 to 2024 in the minor SARs. See Figure 2 for description.

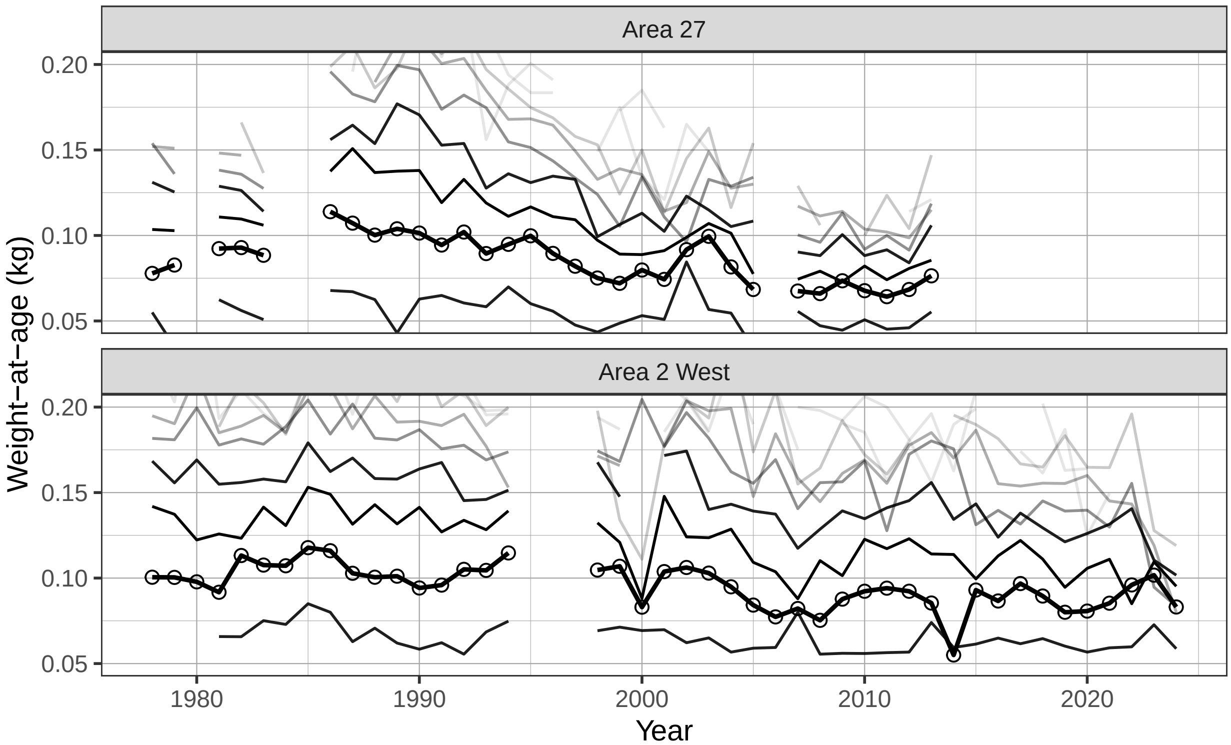

Figure 16. Mean weight-at-age for Pacific Herring in kilograms (kg) from 1978 to 2024 in the minor SARs. Circles show mean for age-3 herring. Lines show means for age-2 to age-10 herring, incrementing up from bottom line and shaded from darker to lighter. The thick line shows age-3 herring. Biological 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 includes fish ages 10 and older. Note: vertical axes are cropped at 0.05 to 0.20 kg.

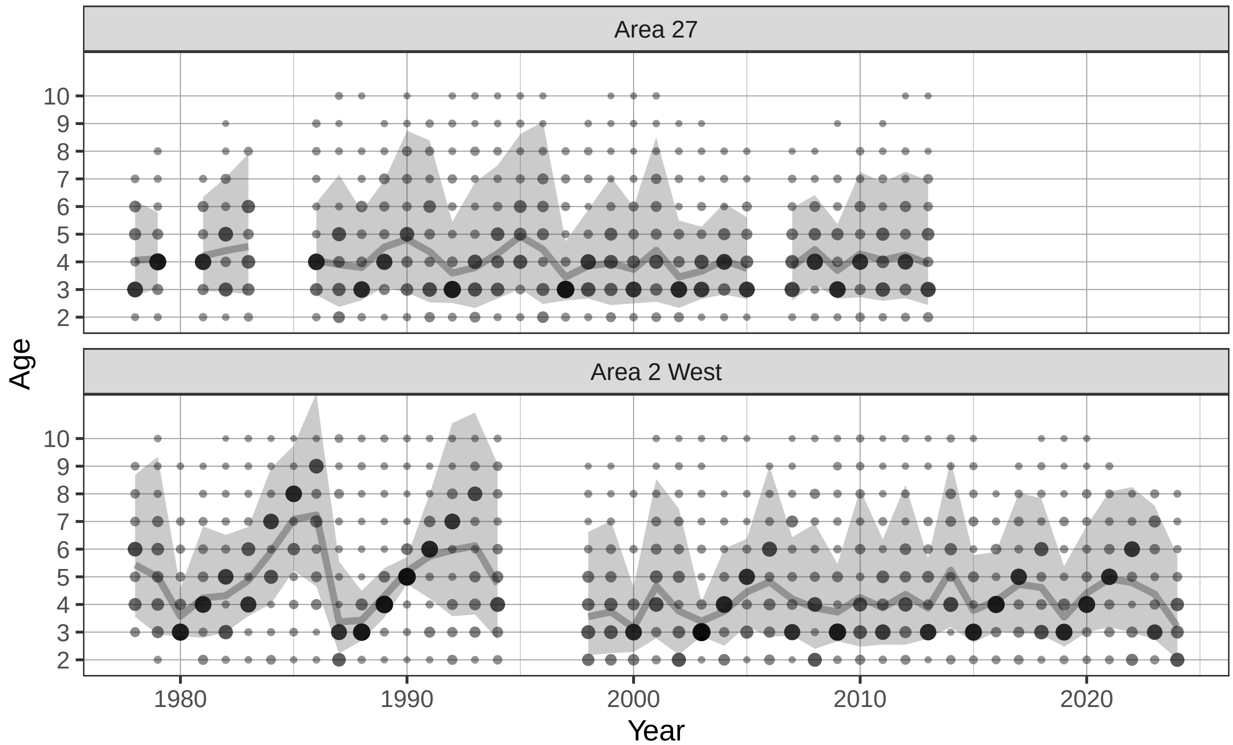

Figure 17. Proportion-at-age for Pacific Herring from 1978 to 2024 in the minor SARs. See Figure 4 for description.

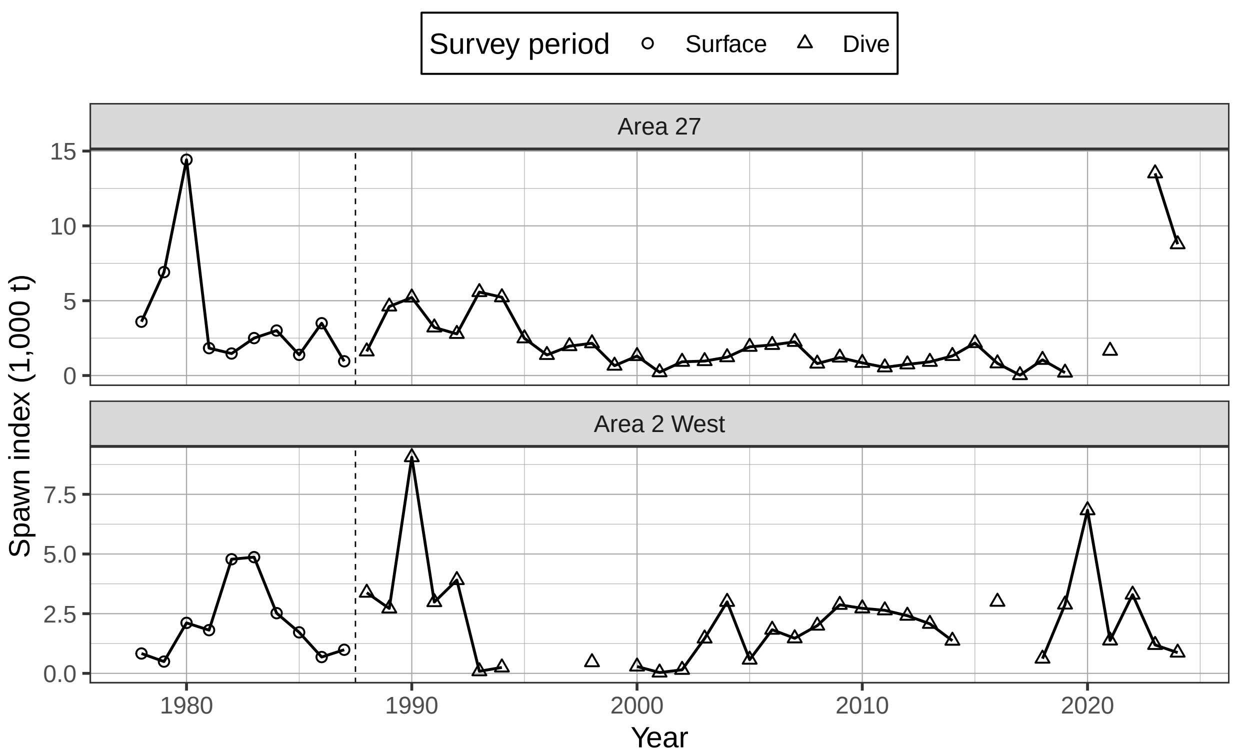

Figure 18. Spawn index in thousands of tonnes (t) for Pacific Herring from 1978 to 2024 in the minor SARs. See Figure 5 for description.

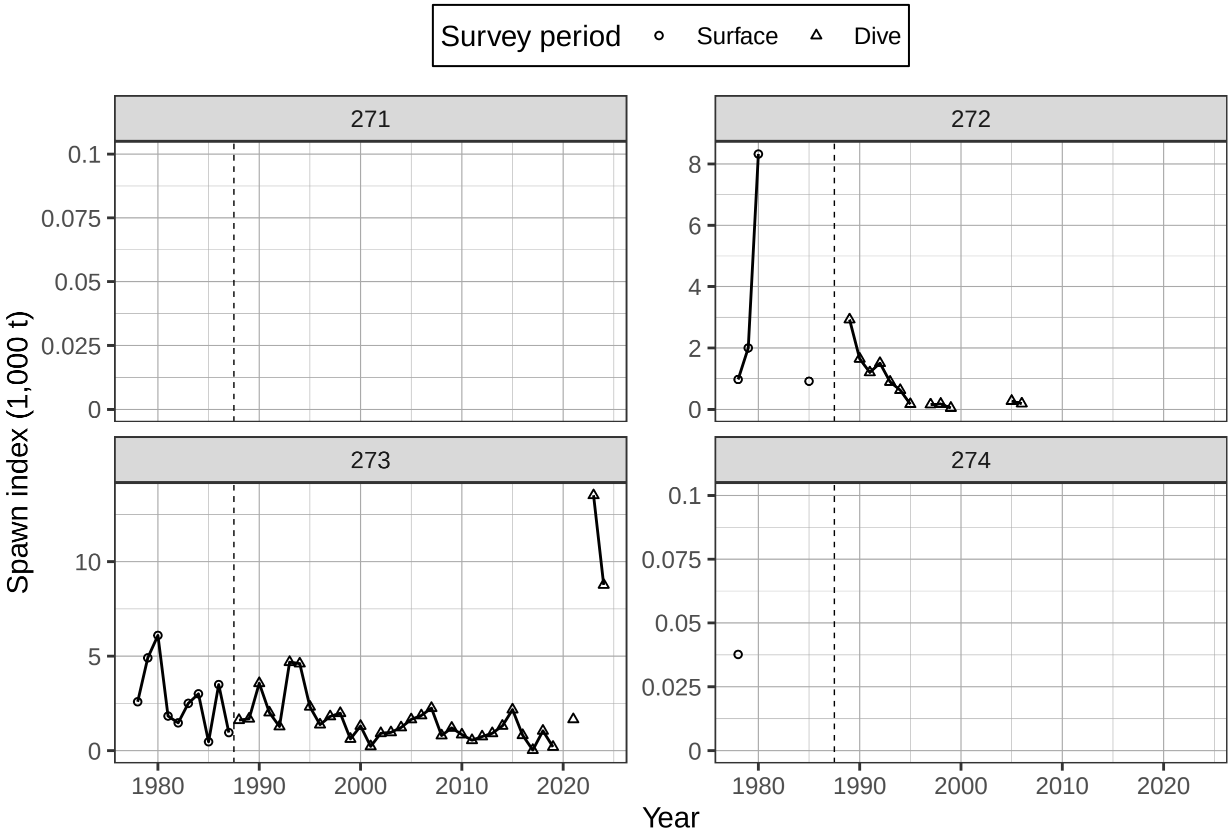

Figure 19. Area 27 SAR: spawn index in thousands of tonnes (t) of Pacific Herring by Section from 1978 to 2024. The dashed vertical line delineates between two periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2024). Note: the 'spawn index' is not scaled by the spawn survey scaling parameter q.

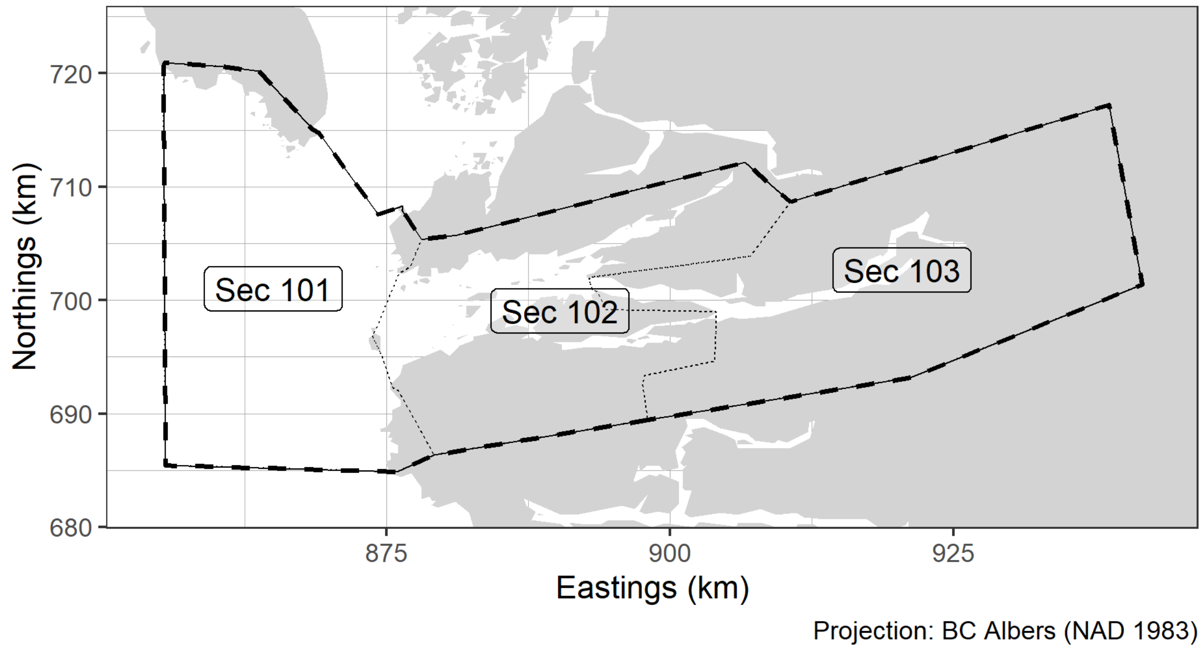

Figure 20. Sections (Sec) included in the Pacific Herring special area, Area 10 (A10). Note that special areas are not stock assessment regions (SARs); therefore they are excluded from regular monitoring and analyses. In addition, note that A10 is a subset of the Central Coast Sections that are outside the SAR boundary. Units: kilometres (km).

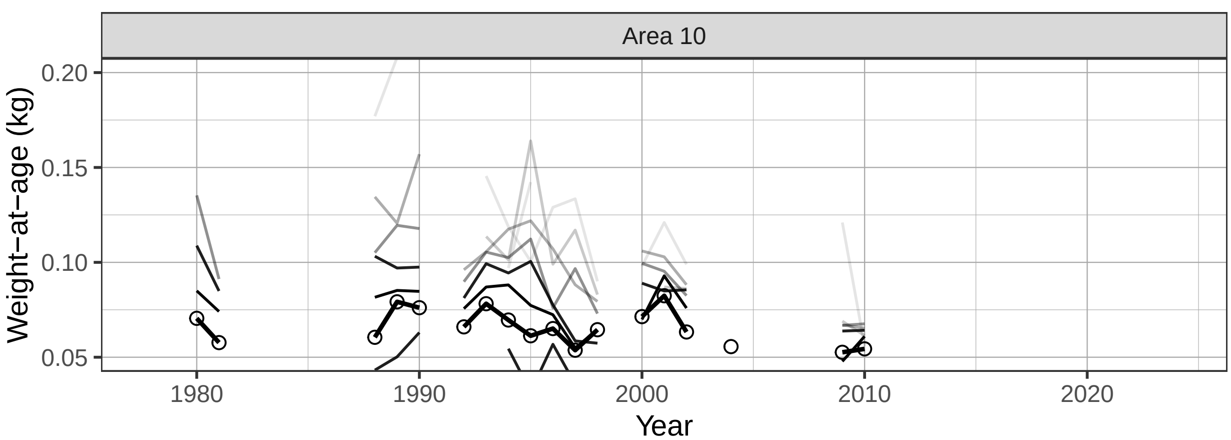

Figure 21. Mean weight-at-age for Pacific Herring in kilograms (kg) from 1978 to 2024 in the special area, Area 10. See Figure 16 for description.

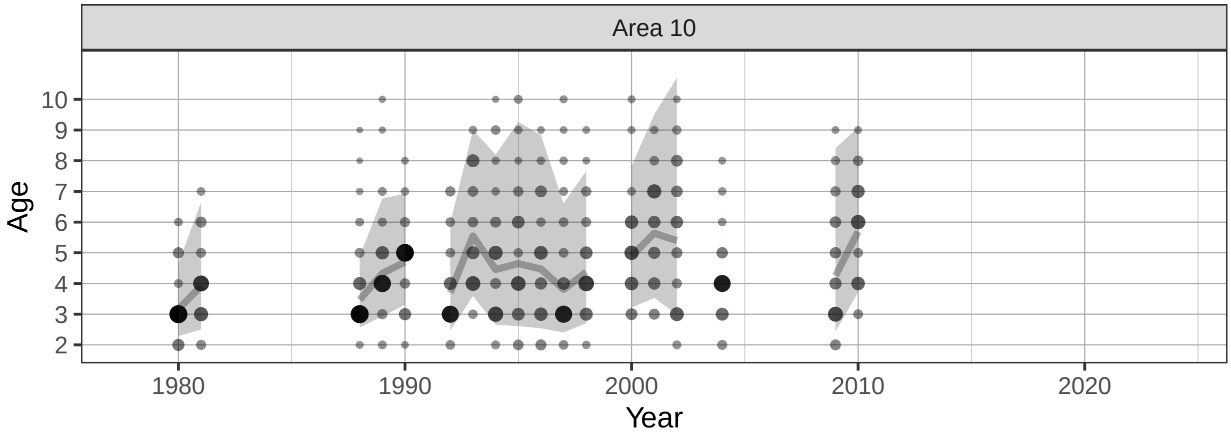

Figure 22. Proportion-at-age for Pacific Herring from 1978 to 2024 in the special area, Area 10. See Figure 4 for description.

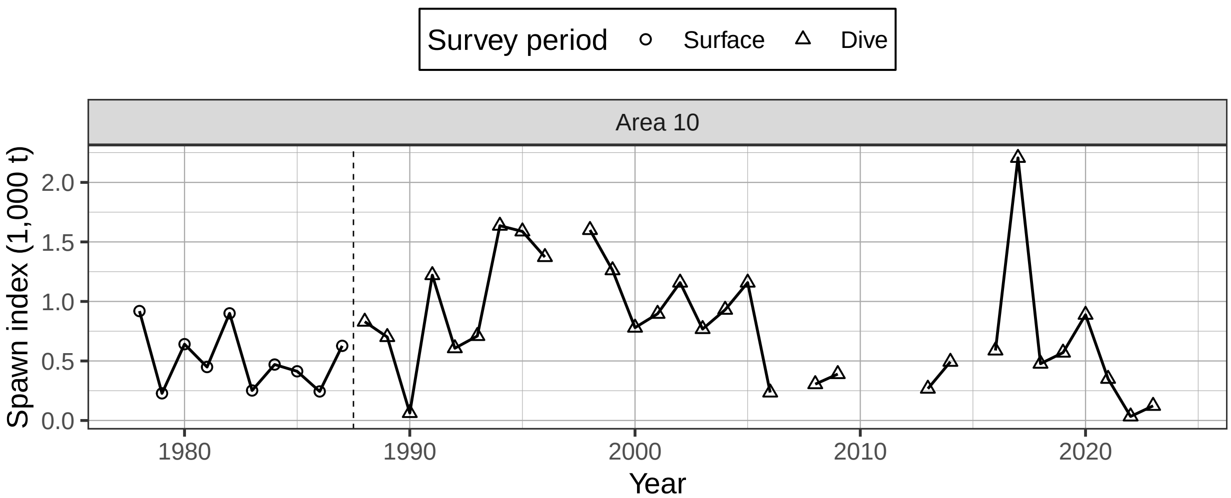

Figure 23. Spawn index in thousands of tonnes (t) for Pacific Herring from 1978 to 2024 in the special area, Area 10. See Figure 5 for description.

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Centre for Science Advice (CSA)
Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Rd.
Nanaimo, BC V9T 6N7

E-mail: DFO.PacificCSA-CASPacifique.MPO@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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