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A reproducible data synopsis for over 100 species of British Columbia groundfish

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The combination of fishery-dependent data, such as catch and effort, and fishery-independent survey data, such as biomass indices and age compositions, forms the backbone of most fisheries stock assessments. For British Columbia groundfish, vast quantities of such data are collected annually, with 100% at-sea observer coverage, 100% dockside monitoring of landings, and deployment of multiple trawl, trap, and hook-and-line surveys. However, there is not the capacity to conduct formal stock assessments for most stocks annually, and therefore, much of these data are not summarized to represent the nature of the data holdings. Here, we introduce a reproducible report to give a snapshot of population and fishing trends, growth and maturity patterns, as well as data availability, for 113 groundfish species in British Columbia. The report generation is fully automated — pulling data from databases, fitting models, generating visualizations, and stitching the document together to facilitate frequent publication, reproducibility, and transparency. Our goals are (1) to facilitate regular review by groundfish scientists and managers of trends in survey indices and stock composition; (2) to generate standardized datasets and visualizations that will help assessment scientists develop operating models and select candidate management procedures as part of a planned management-procedure framework for groundfish stocks; and (3) to increase data transparency between Fisheries and Oceans Canada, the fishing industry, non-governmental organizations, and the public.

1 SPECIES INDEX BY COMMON NAME

Common name	Scientific name	Section
Kelp Greenling	*Hexagrammos decagrammus*	5.79
Lingcod	*Ophiodon elongatus*	5.81
Longnose Skate	*Raja rhina*	5.15
Longspine Thornyhead	*Sebastolobus altivelis*	5.77
North Pacific Spiny Dogfish	*Squalus suckleyi*	5.8
Pacific Cod	*Gadus macrocephalus*	5.20
Pacific Flatnose	*Antimora microlepis*	5.19
Pacific Grenadier	*Coryphaenoides acrolepis*	5.30
Pacific Hake	*Merluccius productus*	5.21
Pacific Halibut	*Hippoglossus stenolepis*	5.104
Pacific Ocean Perch	*Sebastes alutus*	5.45
Pacific Sand Lance	*Ammodytes personatus*	5.42
Pacific Sanddab	*Citharichthys sordidus*	5.98
Pacific Sleeper Shark	*Somniosus pacificus*	5.7
Pacific Staghorn Sculpin	*Leptocottus armatus*	5.88
Pacific Tomcod	*Microgadus proximus*	5.22
Pearly Prickleback	*Bryozoichthys marjorius*	5.35
Petrale Sole	*Eopsetta jordani*	5.101
Prowfish	*Zaprora silenus*	5.41
Puget Sound Rockfish	*Sebastes emphaeus*	5.55
Pygmy Rockfish	*Sebastes wilsoni*	5.74
Quillback Rockfish	*Sebastes maliger*	5.60
Ragfish	*Icosteus aenigmaticus*	5.43
Red Irish Lord	*Hemilepidotus hemilepidotus*	5.84
Redbanded Rockfish	*Sebastes babcocki*	5.47
Redstripe Rockfish	*Sebastes proriger*	5.69
Rex Sole	*Glyptocephalus zachirus*	5.102
Rosethorn Rockfish	*Sebastes helvomaculatus*	5.59
Rougheye/Blackspotted Rockfish Complex	*S. aleutianus/melanostictus complex*	5.44
Roughtail Skate	*Bathyraja trachura*	5.13
Sablefish	*Anoplopoma fimbria*	5.78
Salmon Shark	*Lamna ditropis*	5.3
Sand Sole	*Psettichthys melanostictus*	5.113
Sandpaper Skate	*Bathyraja interrupta*	5.14
Sharpchin Rockfish	*Sebastes zacentrus*	5.75
Shiner Perch	*Cymatogaster aggregata*	5.34
Shortfin Eelpout	*Lycodes brevipes*	5.26
Shortraker Rockfish	*Sebastes borealis*	5.48
Shortspine Thornyhead	*Sebastolobus alascanus*	5.76
Silvergray Rockfish	*Sebastes brevispinis*	5.49
Slender Sole	*Lyopsetta exilis*	5.107
Slim Sculpin	*Radulinus asprellus*	5.93
Smootheye Poacher	*Xeneretmus leiops*	5.96
Snake Prickleback	*Lumpenus sagitta*	5.36
Southern Rock Sole	*Lepidopsetta bilineata*	5.106
Spinyhead Sculpin	*Dasycottus setiger*	5.82

Common name	Scientific name	Section
Splitnose Rockfish	*Sebastes diploproa*	5.53
Spotfin Sculpin	*Icelinus tenuis*	5.87
Spotted Ratfish	*Hydrolagus colliei*	5.17
Starry Flounder	*Platichthys stellatus*	5.110
Stripetail Rockfish	*Sebastes saxicola*	5.72
Sturgeon Poacher	*Podothecus accipenserinus*	5.95
Thornback Sculpin	*Paricelinus hopliticus*	5.91
Threadfin Grenadier	*Coryphaenoides filifer*	5.31
Threadfin Sculpin	*Icelinus filamentosus*	5.86
Tiger Rockfish	*Sebastes nigrocinctus*	5.66
Tope Shark	*Galeorhinus galeus*	5.5
Twoline Eelpout	*Bothrocara brunneum*	5.25
Vermilion Rockfish	*Sebastes miniatus*	5.63
Walleye Pollock	*Gadus chalcogrammus*	5.23
Wattled Eelpout	*Lycodes palearis*	5.28
Whitebait Smelt	*Allosmerus elongatus*	5.18
Whitebarred Prickleback	*Poroclinus rothrocki*	5.37
Whitespotted Greenling	*Hexagrammos stelleri*	5.80
Widow Rockfish	*Sebastes entomelas*	5.56
Wolf Eel	*Anarrhichthys ocellatus*	5.38
Yelloweye Rockfish	*Sebastes ruberrimus*	5.71
Yellowmouth Rockfish	*Sebastes reedi*	5.70
Yellowtail Rockfish	*Sebastes flavidus*	5.57

2 SPECIES INDEX BY SCIENTIFIC NAME

Scientific name	Common name	Section
Albatrossia pectoralis	Giant Grenadier	5.32
Allosmerus elongatus	Whitebait Smelt	5.18
Amblyraja badia	Broad Skate	5.11
Ammodytes personatus	Pacific Sand Lance	5.42
Anarrhichthys ocellatus	Wolf Eel	5.38
Anoplopoma fimbria	Sablefish	5.78
Antimora microlepis	Pacific Flatnose	5.19
Apristurus brunneus	Brown Cat Shark	5.4
Atheresthes stomias	Arrowtooth Flounder	5.99
Bathyraja abyssicola	Abyssal Skate	5.10
Bathyraja aleutica	Aleutian Skate	5.9
Bathyraja interrupta	Sandpaper Skate	5.14
Bathyraja parmifera	Alaska Skate	5.16
Bathyraja trachura	Roughtail Skate	5.13
Beringraja binoculata	Big Skate	5.12
Bothrocara brunneum	Twoline Eelpout	5.25
Bryozoichthys marjorius	Pearly Prickleback	5.35
Careproctus melanurus	Blacktail Snailfish	5.97
Cetorhinus maximus	Basking Shark	5.2
Citharichthys sordidus	Pacific Sanddab	5.98
Coryphaenoides acrolepis	Pacific Grenadier	5.30
Coryphaenoides filifer	Threadfin Grenadier	5.31
Cryptacanthodes aleutensis	Dwarf Wrymouth	5.40
Cryptacanthodes giganteus	Giant Wrymouth	5.39
Cymatogaster aggregata	Shiner Perch	5.34
Dasycottus setiger	Spinyhead Sculpin	5.82
Embassichthys bathybius	Deepsea Sole	5.100
Enophrys bison	Buffalo Sculpin	5.83
Eopsetta jordani	Petrale Sole	5.101
Gadus chalcogrammus	Walleye Pollock	5.23
Gadus macrocephalus	Pacific Cod	5.20
Galeorhinus galeus	Tope Shark	5.5
Glyptocephalus zachirus	Rex Sole	5.102
Hemilepidotus hemilepidotus	Red Irish Lord	5.84
Hemitripterus bolini	Bigmouth Sculpin	5.85
Hexagrammos decagrammus	Kelp Greenling	5.79
Hexagrammos stelleri	Whitespotted Greenling	5.80
Hexanchus griseus	Bluntnose Sixgill Shark	5.1
Hippoglossoides elassodon	Flathead Sole	5.103
Hippoglossus stenolepis	Pacific Halibut	5.104
Hydrolagus colliei	Spotted Ratfish	5.17
Icelinus filamentosus	Threadfin Sculpin	5.86
Icelinus tenuis	Spotfin Sculpin	5.87
Icosteus aenigmaticus	Ragfish	5.43

Scientific name	Common name	Section
Isopsetta isolepis	Butter Sole	5.105
Lamna ditropis	Salmon Shark	5.3
Lepidopsetta bilineata	Southern Rock Sole	5.106
Leptocottus armatus	Pacific Staghorn Sculpin	5.88
Lumpenus sagitta	Snake Prickleback	5.36
Lycodes brevipes	Shortfin Eelpout	5.26
Lycodes cortezianus	Bigfin Eelpout	5.24
Lycodes diapterus	Black Eelpout	5.27
Lycodes pacificus	Blackbelly Eelpout	5.29
Lycodes palearis	Wattled Eelpout	5.28
Lyopsetta exilis	Slender Sole	5.107
Malacocottus kincaidi	Blackfin Sculpin	5.89
Merluccius productus	Pacific Hake	5.21
Microgadus proximus	Pacific Tomcod	5.22
Microstomus pacificus	Dover Sole	5.108
Myoxocephalus polyacanthocephalus	Great Sculpin	5.90
Nezumia stelgidolepis	California Grenadier	5.33
Ophiodon elongatus	Lingcod	5.81
Paricelinus hopliticus	Thornback Sculpin	5.91
Parophrys vetulus	English Sole	5.109
Platichthys stellatus	Starry Flounder	5.110
Pleuronichthys coenosus	C-O Sole	5.111
Pleuronichthys decurrens	Curlfin Sole	5.112
Podothecus accipenserinus	Sturgeon Poacher	5.95
Poroclinus rothrocki	Whitebarred Prickleback	5.37
Prionace glauca	Blue Shark	5.6
Psettichthys melanostictus	Sand Sole	5.113
Psychrolutes phrictus	Giant Blobsculpin	5.92
Radulinus asprellus	Slim Sculpin	5.93
Raja rhina	Longnose Skate	5.15
S. aleutianus/melanostictus complex	Rougheye/Blackspotted Rockfish Complex	5.44
Scorpaenichthys marmoratus	Cabezon	5.94
Sebastes alutus	Pacific Ocean Perch	5.45
Sebastes aurora	Aurora Rockfish	5.46
Sebastes babcocki	Redbanded Rockfish	5.47
Sebastes borealis	Shortraker Rockfish	5.48
Sebastes brevispinis	Silvergray Rockfish	5.49
Sebastes caurinus	Copper Rockfish	5.50
Sebastes crameri	Darkblotched Rockfish	5.52
Sebastes diaconus	Deacon Rockfish	5.64
Sebastes diploproa	Splitnose Rockfish	5.53
Sebastes elongatus	Greenstriped Rockfish	5.54
Sebastes emphaeus	Puget Sound Rockfish	5.55
Sebastes entomelas	Widow Rockfish	5.56
Sebastes flavidus	Yellowtail Rockfish	5.57
Sebastes goodei	Chilipepper	5.58

Scientific name	Common name	Section
Sebastes helvomaculatus	Rosethorn Rockfish	5.59
Sebastes maliger	Quillback Rockfish	5.60
Sebastes melanops	Black Rockfish	5.61
Sebastes melanostomus	Blackgill Rockfish	5.62
Sebastes miniatus	Vermilion Rockfish	5.63
Sebastes nebulosus	China Rockfish	5.65
Sebastes nigrocinctus	Tiger Rockfish	5.66
Sebastes paucispinis	Bocaccio	5.67
Sebastes pinniger	Canary Rockfish	5.68
Sebastes proriger	Redstripe Rockfish	5.69
Sebastes reedi	Yellowmouth Rockfish	5.70
Sebastes ruberrimus	Yelloweye Rockfish	5.71
Sebastes saxicola	Stripetail Rockfish	5.72
Sebastes variabilis	Dusky Rockfish	5.51
Sebastes variegatus	Harlequin Rockfish	5.73
Sebastes wilsoni	Pygmy Rockfish	5.74
Sebastes zacentrus	Sharpchin Rockfish	5.75
Sebastolobus alascanus	Shortspine Thornyhead	5.76
Sebastolobus altivelis	Longspine Thornyhead	5.77
Somniosus pacificus	Pacific Sleeper Shark	5.7
Squalus suckleyi	North Pacific Spiny Dogfish	5.8
Xeneretmus leiops	Smootheye Poacher	5.96
Zaprora silenus	Prowfish	5.41

3 INTRODUCTION

The combination of fishery-dependent data, such as catch and effort, and fishery-independent survey data, such as biomass indices and age compositions, form the backbone of most fisheries stock assessment. Fisheries and Oceans Canada (DFO) at the Pacific Biological Station (PBS) in Nanaimo, British Columbia (BC), manages vast quantities of such data on groundfish species in BC. However, there is not the capacity to conduct formal stock assessments for most stocks annually, and therefore, much of these data are not summarised to represent the nature of the data holdings.

As one step to address this issue, we have created this data synopsis report to give a snapshot of long-term and recent population and fishing trends, as well as data availability, for all major BC groundfish species of commercial and conservation interest. The report is an extension of the data scorecard concept discussed at a Canadian Science Advisory Secretariat (CSAS) Regional Peer Review Meeting in May 2016 (DFO 2016a). The report is published here as a CSAS Research Document to facilitate review of the methods, and we intend to update the report annually or biennially (excluding any unchanged methods). The report generation is fully automated — pulling data from databases, fitting models, generating visualizations, and stitching the document together to facilitate rapid publication, reproducibility, and transparency.

Our goals with this report are to (1) facilitate regular review by groundfish scientists and managers of trends in survey indices and stock composition across all species to provide information for discussion on assessment priorities; (2) generate standardized datasets, biological model fits, and visualizations that will help assessment scientists develop operating models and select candidate management procedures for groundfish stocks; and (3) increase data transparency between DFO, the fishing industry, First Nations, non-governmental organizations, and the general public. We provide guidance on the limits to application of the methods and summaries in the report (Section 3.2).

3.1 REPORT STRUCTURE

The main results of this synopsis report are presented in two-page species-by-species subsections that visually synthesize most available data for each species (Section 5). The report covers 113 groundfish species that are either of commercial, recreational, conservation, or First Nations interest, or are regularly caught in our research surveys. The report focuses on the surveys and data types applicable to the widest array of these species.

Each set of pages for a single species is laid out in the same way. The page layout starts with the species common name, the species scientific name, and the DFO species code, which usually corresponds to the page number referencing the species in Hart et al. (1988). The figures themselves are laid out such that the first page has survey (Figure 1) time series trends and spatial patterns on the left and commercial time series by Pacific Marine Fisheries Commission areas (Figure 2) and spatial patterns on the right. The second page is focused on biological samples from both fishery dependent and independent sources. This page begins at the top with length and age data and their relationship with each other, then shows data on maturity, and finishes with an overview of available numbers of sampled fish across all survey and commercial samples for various biological measurements.

In terms of surveys, we have focused on the Synoptic Bottom Trawl surveys, the Outside Hard Bottom Long Line (HBLL) surveys (alternatively referred to as the Pacific Halibut Management

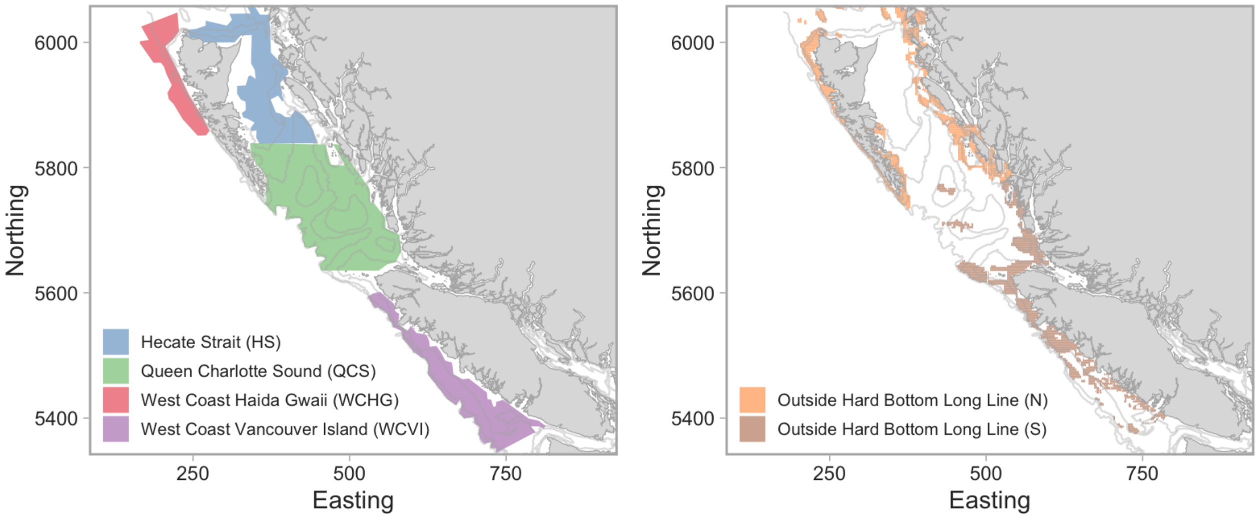


Figure 1. Synoptic bottom trawl survey boundaries (left) and Outside Hard Bottom Long Line survey boundaries (right). The colours match the colour coding through the rest of the report. The coverage of the International Pacific Halibut Commission (IPHC) survey is displayed on the IPHC survey catch rate plots as all of the individual stations fished.

Association, PHMA, surveys) (Figure 1), and the International Pacific Halibut Commission (IPHC) Fishery Independent Setline surveys, because these provide the greatest spatial and taxonomic coverage of the species in this report. Survey biomass index trends are also shown for the Hecate Strait Multispecies Assemblage (MSA HS) survey and the Inside HBLL survey. As an example, we are not showing biomass index trends or maps from the Sablefish trap surveys, since these are highly selective for Sablefish. However, we do include counts of available fish specimens from biological samples on all surveys and fit biological models such as growth models to all available data. A brief description of the included surveys is included in Appendix F along with associated references for detailed survey descriptions and designs. A table of other surveys conducted by DFO that are not included in this report but may be applicable for some species-specific analyses is also given in Appendix F.

Following the species-by-species visualizations, we include the following appendices:

1. Appendix A shows ageing precision plots for each species.
2. Appendix B shows the predicted relationships between depth and synoptic survey biomass density for each species.
3. Appendix C provides details on the data extraction from the relational databases that hold the raw data, and contact details for data requests.
4. Appendix D provides details on the catch per unit effort (CPUE) model that underlies the CPUE visualizations.
5. Appendix E provides details on the spatial modelling behind the spatial survey biomass visualizations.
6. Appendix F provides details on the survey biomass index modeling (except for the IPHC survey) including design-based and model-based estimates.
7. Appendix G provides details on the modelling for the IPHC survey time series.
8. Appendix H provides details on modelling of maturity and growth parameters.
9. Appendix I describes the computational environment and reproducibility of this report.
10. The final section contains the bibliography, including those references listed on the figure

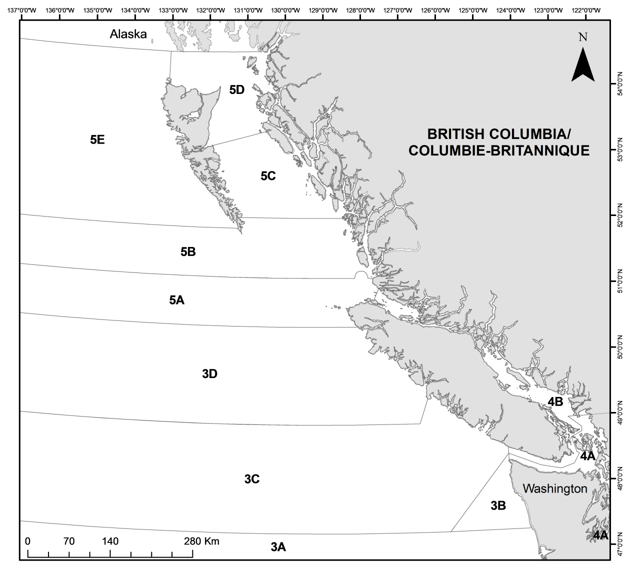


Figure 2. Map of Pacific Marine Fisheries Commission (PMFC) areas 5AB (Queen Charlotte Sound), 5CD (Hecate Strait), 5E (West Coast Haida Gwaii), 3CD (West Coast Vancouver Island), and 4B (Strait of Georgia). These are close, but not identical, to similarly named Groundfish Management Unit areas (Areas 3AB and 4A are outside of Canadian waters).

pages.

In navigating the report, we suggest that the report is best viewed in a PDF two-page view so that all the plots for a single species can be viewed at once. We also note that the Table of Contents, index pages, figures references, and citations are clickable hyperlinks to facilitate navigation.

We made a number of overarching design decisions in structuring the report:

1. Each species is displayed with the same layout to facilitate finding a type of data, comparing species, and identifying missing data via empty plots.
2. We have limited the report to two pages per species so that all plots can be laid out at once on a screen in a PDF. The data presentation is dense, but we believe there is value in being able to examine all the data for a species at once.
3. The colours representing the various surveys are held constant to facilitate tracing a single survey throughout the plots.
4. The colour scales are consistent for the survey maps and survey biological specimen number plots and for the commercial CPUE maps and commercial biological specimen number plots (the bottom plots on both pages).
5. Data on female fish are always shown in front of data on male fish and are either coloured or black whereas males are always indicated with light grey.
6. The chosen continuous colour schemes are colour-blind proof and readable when printed in grey scale.

3.2 CAVEATS

There are many caveats when interpreting this report.

1. The outputs in this report are not a substitute for stock assessment. For example, although relative biomass index trends from surveys indicate the biomass trend for a species in an area, such information is best combined with other information such as removals by commercial catches and information on the age- or length-composition of the stock to make conclusions about the status of a stock.
2. Biomass indices from trawl or longline surveys and commercial CPUE indices need careful interpretation on a stock-by-stock basis. We have attempted to flag survey index trends that may be especially suspect either because of high survey variability or because only a small fraction of trawl or longline sets contain the species, but this is not a guarantee in itself. Survey indices are not always representative of abundance for a variety of reasons, and a lack of data for a species does not necessarily indicate a small population — the surveys may simply not be suitable for sampling that species. Furthermore, changes through time, including fish behavioural changes or range shifts, could result in biases through time even for well-sampled species.
3. Survey and commercial CPUE index trends do not resolve population scale and the outputs in this report do not resolve conflicts in trends drawn from different sources for the same species.
4. The outputs in this report are not appropriate for marine spatial planning. The data as presented are resolved at a coarse spatial scale and marine spatial planning uses require specific data treatments beyond the general approaches used in this report.
5. The commercial CPUE data should not be considered to be proportional to stock abundance for a multitude of reasons (e.g., Harley et al. 2001). Nonetheless, we think there is value in transparently displaying the available data for all species.
6. The catch history reported here reflects recorded data and may not represent actual catches. The commercial catch presented here will not necessarily match reconstructed time series in stock assessments. Historical catch reconstructions require careful species-specific consideration and analysis. Furthermore, fluctuations in commercial catch, for example recent declines in species catch for Bocaccio and Yelloweye Rockfish, do not necessarily reflect declines in stock abundance and may be due to other factors including implementation of management measures (see map in Figure 3 of current fishery restriction initiatives in the Pacific Region). Reported discard weights are considered less reliable prior to 100% observer coverage of the bottom trawl fishery in 1996, and prior to fisheries integration in 2006 for the trap, hook and line, midwater trawl and Strait of Georgia (SoG) bottom trawl fisheries. The discards in the catch plot therefore only include bottom trawl discard weights from 1996 to present and trap, hook and line, midwater trawl and SoG bottom trawl discard weights from 2006 to present.
7. It is not feasible for us to individually assess the results for all species in a detailed manner. To use the results for a particular species in future assessments, or to make other inferences, we recommend that users carefully examine the data and model results. Due to the necessary automation required to construct this report, not all species-specific special cases may have been fully considered.

3.3 DATA ACCESSIBILITY

Data in this document are maintained by the Groundfish Data Unit at the Pacific Biological Station in Nanaimo, British Columbia. Data accessibility and contact details are described in Appendix C.

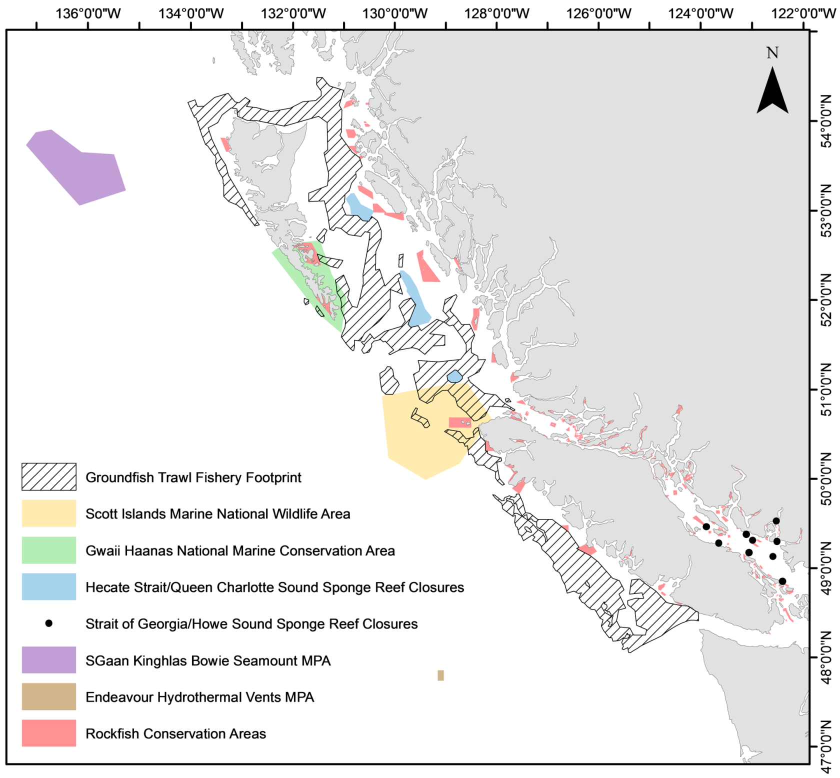


Figure 3. Map of fishery restriction initiatives in the Pacific Region (MPA = Marine Protected Area). Seasonal fishery closures are not shown.

3.4 REPRODUCIBILITY

All of the data extraction, data manipulation, model fitting, and visualization for this report is automated and reproducible. We developed the gfdata, gfplot and gfsynopsis R packages for this purpose. The gfdata package enables the data extraction. The gfplot package performs the model fitting and visualizations. It is designed to be modular so it can be used in various capacities for other groundfish analyses (Figure I.1). The gfsynopsis package calls functions from the gfplot and gfdata packages to generate this report. Appendix I provides further details on these packages and on the computational environment needed to reproduce this report.

3.5 UPDATE SCHEDULE

We intend to publish annual or biennial updates of this synopsis report — possibly as a Science Response document. These updates will include another year or two of data and any important corrections to the data, text, or visualizations. Data for each survey season will likely only be ready for publication in the report by fall of the following year. On a less frequent basis, we will consider making larger changes to the structure, methods, or content of the report within the context of a CSAS reveiw process.

4 PLOT DESCRIPTIONS

In this section we provide complete captions for each of the visualizations that form the species-by-species pages in Section 5. We use Petrale Sole as an example species for all plots except for commercial catch per unit effort maps where we use Pacific Cod.

4.1 RELATIVE BIOMASS INDEX TRENDS FROM SURVEYS

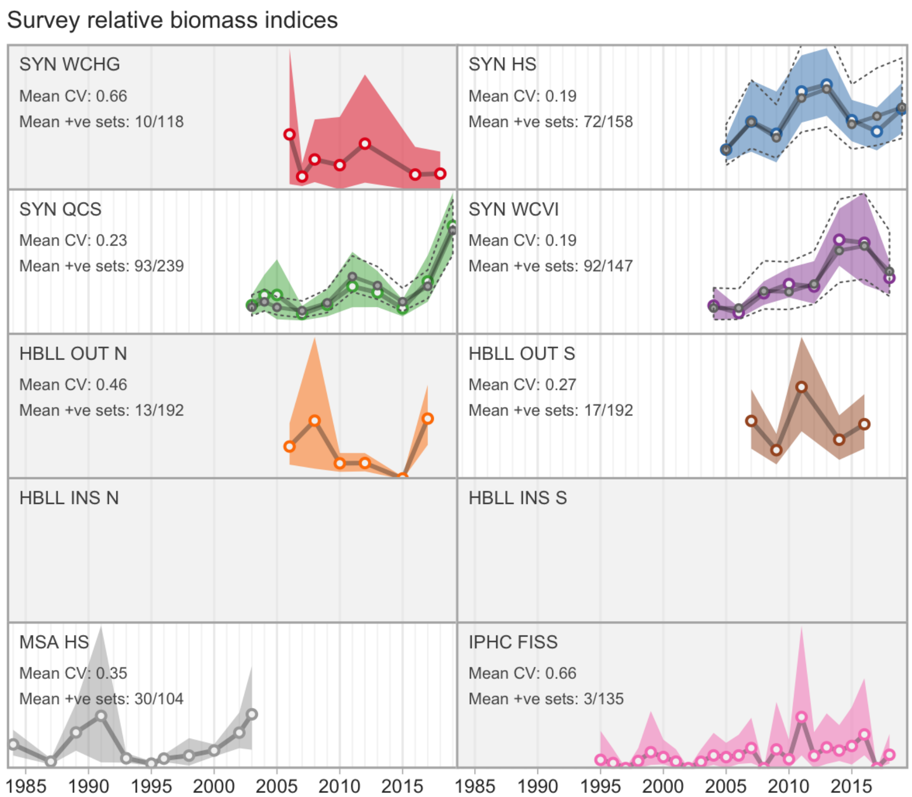


Figure 4. Example relative biomass index trends from trawl and longline surveys for Petrale Sole. Dots represent mean estimates of relative biomass and shaded ribbons around the dots and lines represent 95% bootstrap confidence intervals. 'Mean CV' is the mean of the annual coefficients of variation (CVs), and 'Mean +ve sets' indicates the ratio of the mean number (across the years) of sets that captured the species of interest to the mean number of sets. Grey shaded panels indicate survey trends with 'Mean CV' greater than 0.4 or 'Mean +ve sets' less than 5%. All vertical axes are scaled between zero and the maximum upper confidence interval value for that survey. Time series with light grey dots and dotted upper and lower lines for 95% confidence intervals represent a further index that has been standardized with a geostatistical model. SYN WCHG = West Coast Haida Gwaii Synoptic Bottom Trawl, SYN HS = Hecate Strait Synoptic Bottom Trawl, SYN QCS = Queen Charlotte Sound Synoptic Bottom Trawl, SYN WCVI = West Coast Vancouver Island Synoptic Bottom Trawl, HBLL OUT N = Hard Bottom Longline Outside North, HBLL OUT S = Hard Bottom Longline Outside South, HBLL INS N = Hard Bottom Longline Inside North, HBLL INS S = Hard Bottom Longline Inside South, MSA HS = Hecate Strait Multispecies Assemblage Bottom Trawl, IPHC FISS = International Pacific Halibut Commission Fishery-Independent Setline Survey. For the IPHC FISS, the values are relative counts per effective skate rather than biomass.

4.2 MAPS OF RELATIVE BIOMASS FROM SURVEYS

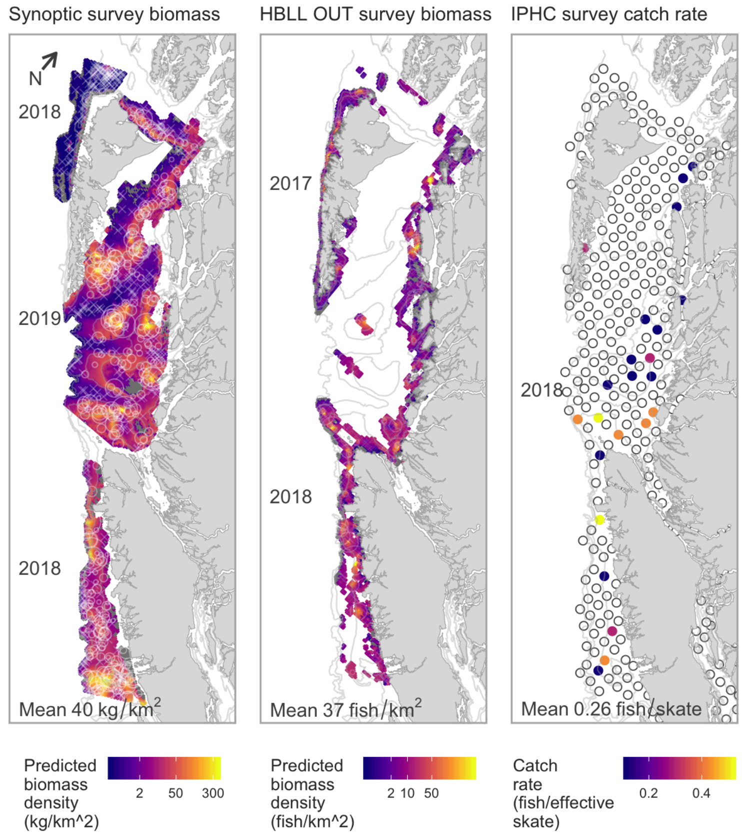


Figure 5. Example maps of relative biomass (or catch rate) from trawl and longline surveys from the latest available years of each survey for Petrale Sole. Shown are the synoptic trawl surveys (left), the outside hard bottom long line (HBLL OUT) surveys (middle), and the IPHC FISS (right). Individual sets are shown in the two left panels as faint crosses (if the species was not caught in that set), or circles with the area of the circle proportional to the species density from the set. Colour shading indicates predictions from a spatial model that includes depth and depth squared as predictors as well as spatial random effects (Appendix E). The colour scale is fourth-root transformed to render a visual pattern similar to a log transformation without overemphasizing differences close to zero. The colour scale ('Viridis plasma') is perceptually uniform, robust to colour blindness, and prints accurately in grayscale (Garnier 2018). The colour scale as shown here only represents the values for these panels — the colour scale ranges from zero to the highest value in the maps on each page. The synoptic and HBLL maps show predicted biomass density throughout the survey domain. The IPHC map shows the raw unmodelled data for fixed station locations — stations without any observations for a given species are shown as empty circles. Years on the left side of each plot indicate the year of the respective survey. Surveys (except IPHC) in which less than 2% of the sets contained the species are not modeled and are shown with raw data only. Mean values shown at the bottom are the mean fish density values from the raw data for the entire coast for the indicated years. Note that the coast has been rotated 40° to fit all the maps in the available space. Depth contours are shown at 100 m, 200 m, and 500 m.

4.3 COMMERCIAL FISHERY CATCHES

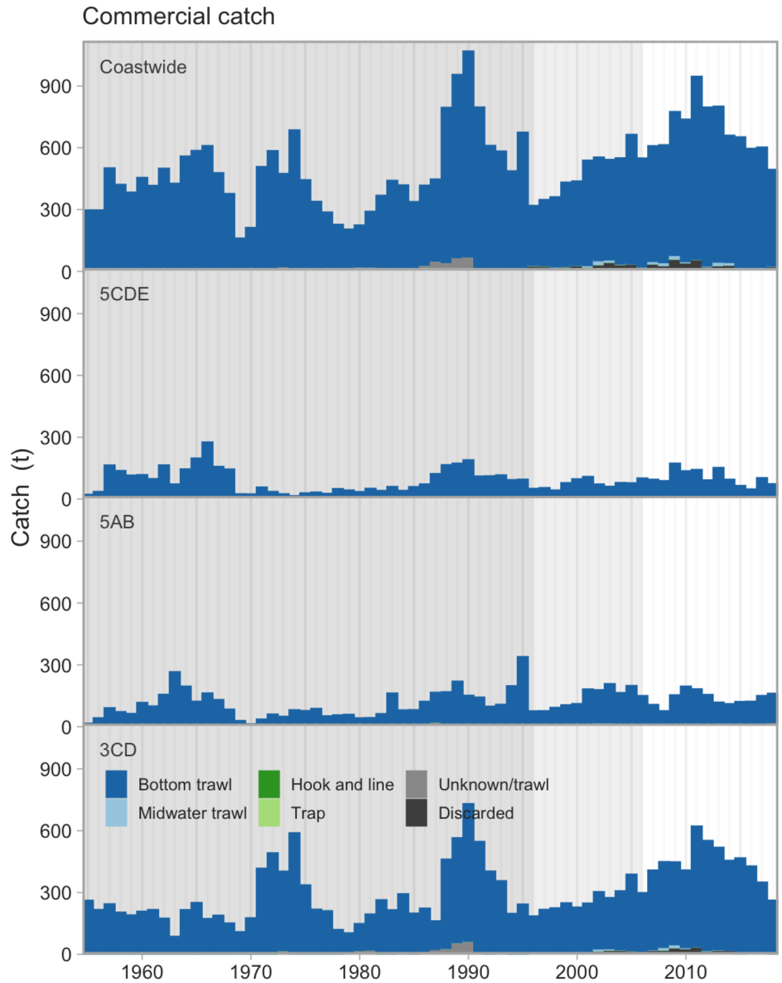


Figure 6. Example commercial fishery catch plots for Petrale Sole. Catch from various gear types is indicated by colour shading. Catch is calculated as the summed weight of landings aggregated by year. Discards include reported discard weights from all fisheries combined; however, bottom trawl discards are considered less reliable prior to 100% observer coverage in 1996 and trap, hook and line, midwater trawl and Strait of Georgia bottom trawl discards are less reliable prior to fisheries integration in 2006 and are therefore not included. Years before 1996 and 2006 are shaded grey to indicate that catches are considered less reliable than modern data: an at-sea observer program was implemented for bottom and midwater trawl fleets in outside waters in 1996 and an at-sea observer program was implemented for non-trawl sectors in 2006. Management areas, as indicated in the top left corner of each panel, are shown in Figure 2.

4.4 COMMERCIAL BOTTOM TRAWL CATCH PER UNIT EFFORT INDICES

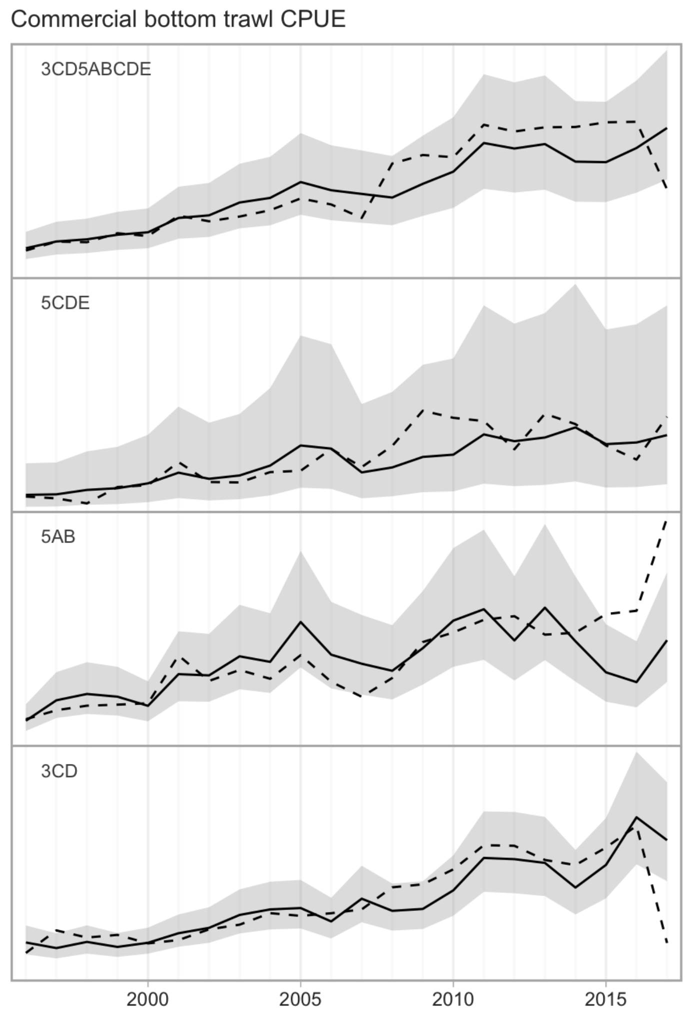


Figure 7. Example commercial bottom trawl catch per unit effort (CPUE) trends, with effort as hours trawled, for Petrale Sole. Solid lines represent CPUE trends standardized with a Tweedie GLMM (generalized linear mixed effects model) for depth, latitude, DFO locality region, vessel, and month of year (Appendix D). The line itself represents the estimate and the shaded ribbon represents a 95% confidence interval. The dashed line represents an unstandardized commercial CPUE index calculated as the sum of catch divided by the sum of effort each year. Standardized time series are scaled to have the same maximum 95% confidence interval. Unstandardized time series are scaled to have the same geometric mean as the standardized time series. These are relative index values — the absolute value of the time series is not particularly useful because it depends on arbitrary levels that the standardization variables are set to. Management areas, as indicated in the top left corner of each panel, are shown in Figure 2.

4.5 MAPS OF COMMERCIAL CATCH PER UNIT EFFORT

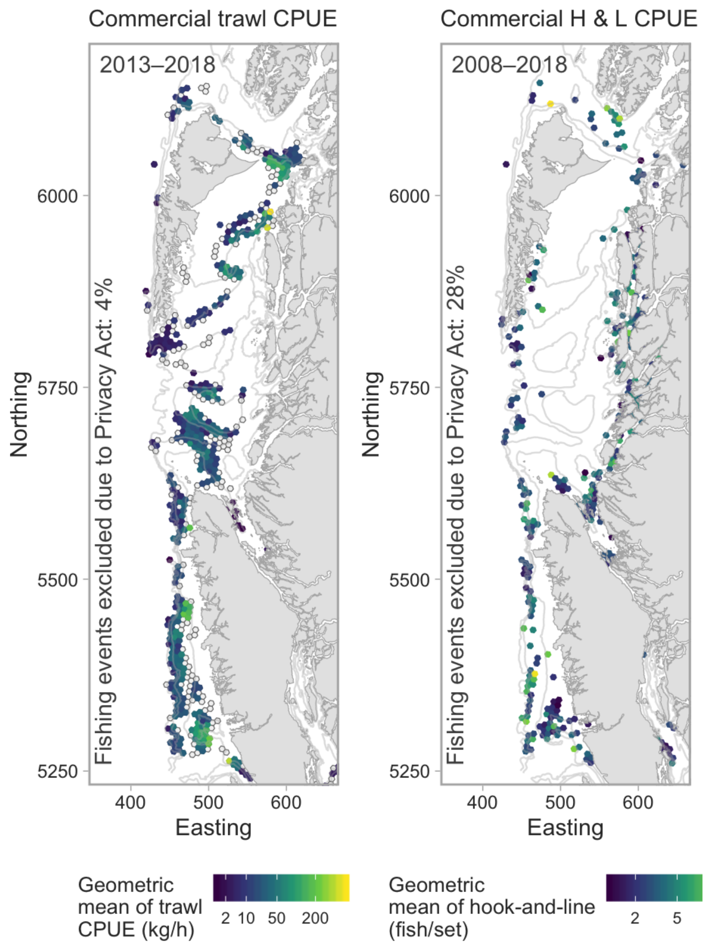


*Figure 8. Example commercial trawl and commercial hook-and-line catch-per-unit-effort maps for Pacific Cod (note this figure is **not** Petrale Sole). Lighter shading indicates higher levels of a geometric mean of catch per unit effort in a given hexagonal cell. The colour scale is fourth-root transformed to render a visual pattern similar to a log transformation without overemphasizing differences close to zero. The colour scale ('Viridis') is perceptually uniform, robust to colour blindness, and prints accurately in grayscale (Garnier 2018). Cells are 7 km wide and are only shown in cases where there are at least 3 unique vessels in a given cell to meet privacy requirements. For bottom trawl, catch per unit effort is calculated as the weight of catch (landings plus discards) divided by hours fished for all positive tows from the groundfish trawl sector. Trawl data are shown from 2013 onwards after the trawl footprint was frozen. Trawl data from 2007–2012 are indicated as outlined light grey hexagons to illustrate fishing prior to the frozen footprint. For hook and line, catch per unit effort is shown as the number of fish recorded as landed or discarded per set. Hook-and-line data are shown from 2008 onwards. Including as many years of data as possible reduces the number of discarded fishing events when implementing the 3-vessel privacy requirement. Note that the coast has been rotated 40° to fit all the maps in the available space. Depth contours are shown at 100 m, 200 m, and 500 m.*

4.6 AVAILABLE BIOLOGICAL SAMPLES

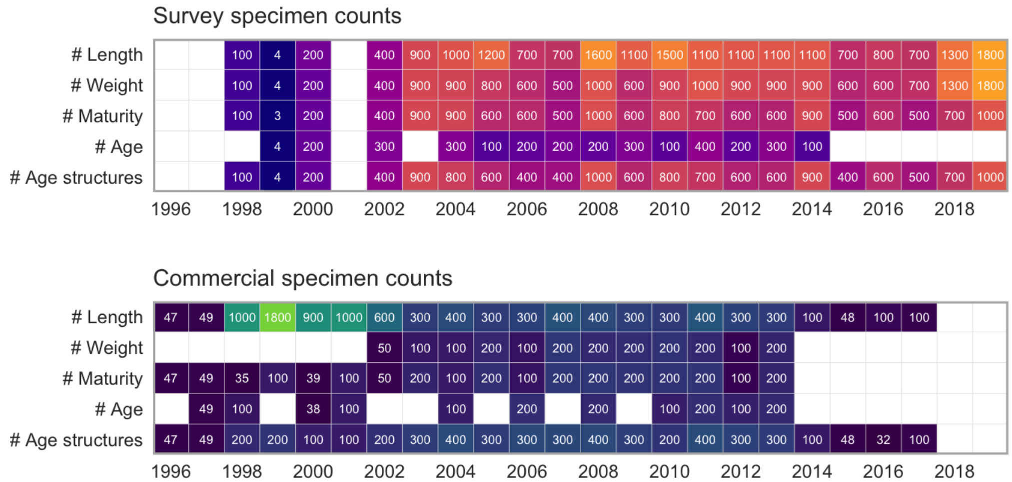


Figure 9. Example specimen-availability plot for Petrale Sole. Shown are the number of available fish specimens that have had their length measured, have been weighed, had their maturity assessed, had their age assessed, and for which ageing structures are available for ageing. Data are shown across all surveys (not just surveys shown elsewhere in the synopsis; top panel) and across all commercial fleets (bottom panel). Blank panels indicate year-measurement combinations without any data. Shading of these cells reflects the relative number of specimens available with the actual number of specimens indicated in the cells to the nearest round number.

4.7 LENGTH COMPOSITION DATA

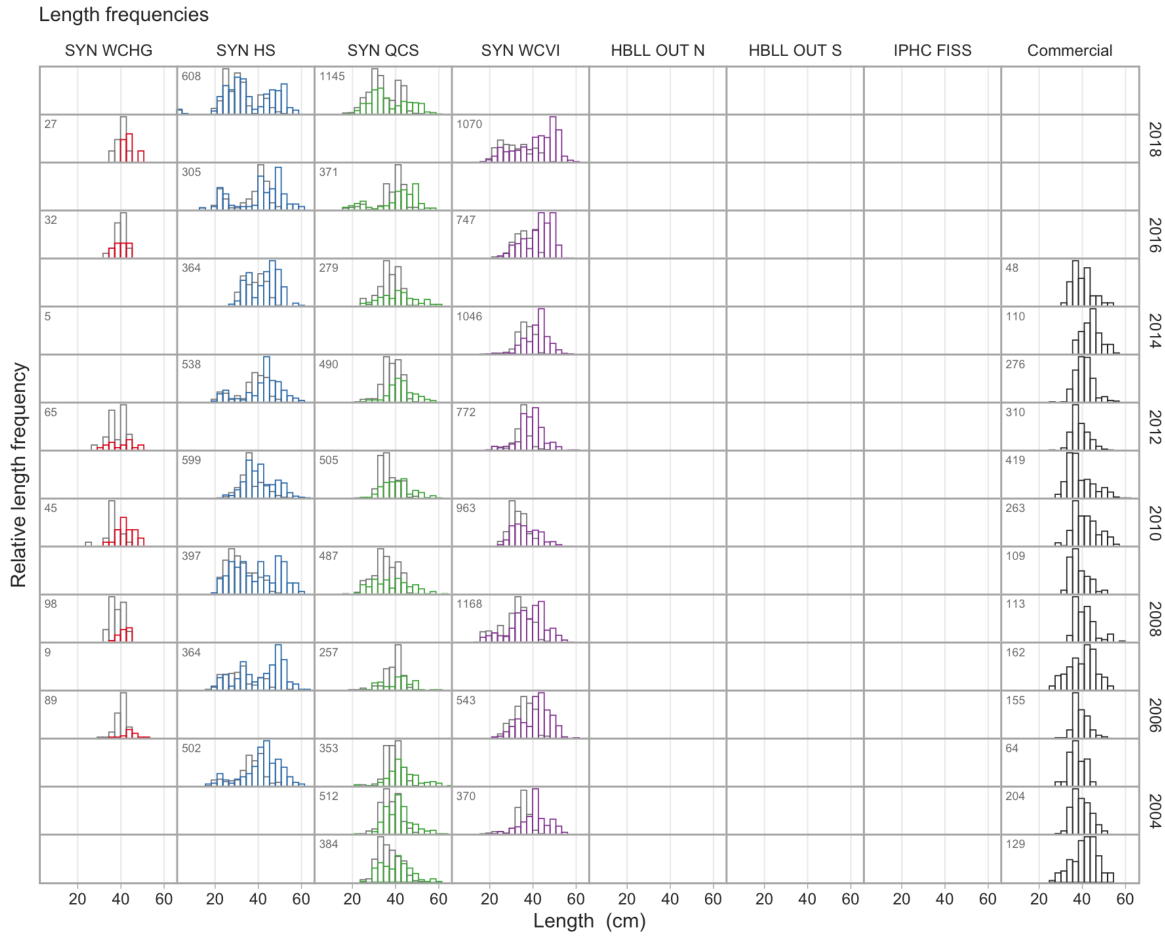


Figure 10. Example length-frequency plot for Petrale Sole. Female fish are shown as coloured (or black) bars and male fish are shown behind as light grey bars. The total number of fish measured for a given survey and year are indicated in the top left corner of each panel. Histograms are only shown if there are more than 20 fish measured for a given survey-year combination. The commercial male and female fish are combined since many are unsexed. See Figure 4 for survey abbreviations.

4.8 AGE COMPOSITION DATA

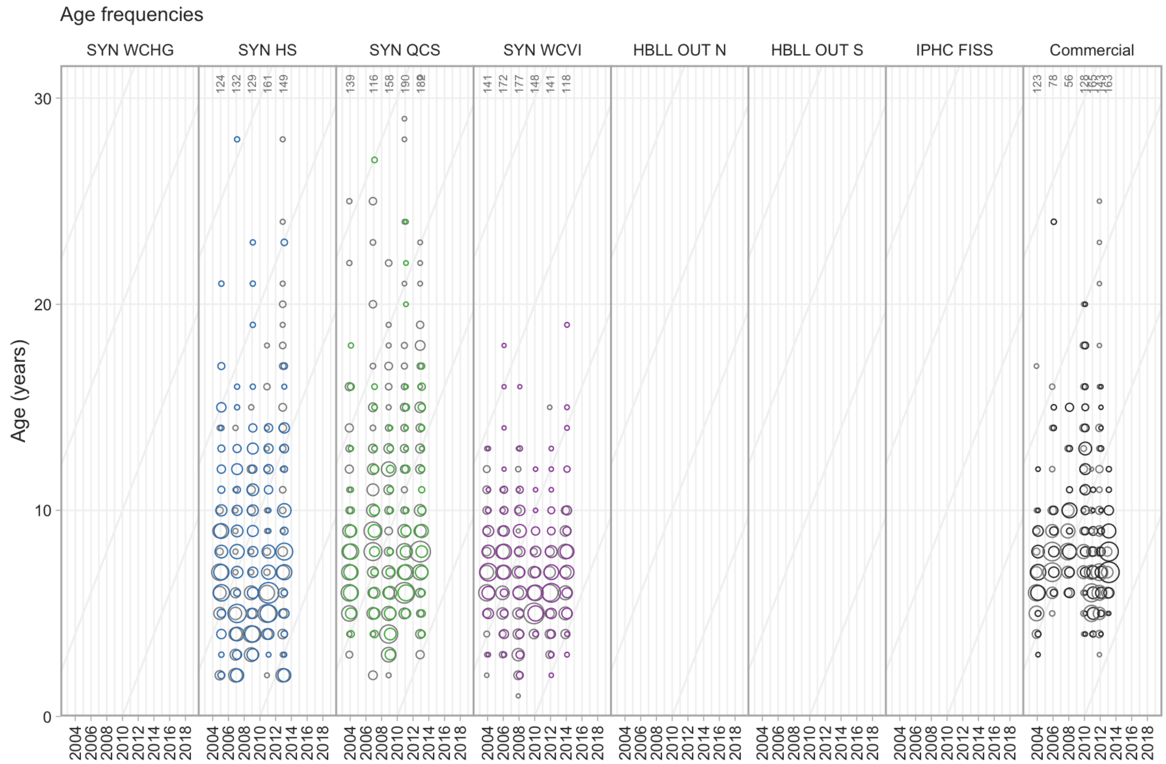


Figure 11. Example age-frequency plot for Petrale Sole. Female fish are shown as coloured (or black) circles and male fish are shown behind as light grey circles. The total number of fish aged for a given survey and year are indicated along the top of the panels. Diagonal lines are shown at five-year intervals to facilitate tracing cohorts through time. See Figure 4 for survey abbreviations. Ageing precision plots comparing precision of readings by two individuals ageing the fish are provided for all species for which age data exist in Appendix A.

4.9 LENGTH-AGE AND LENGTH-WEIGHT MODEL FITS

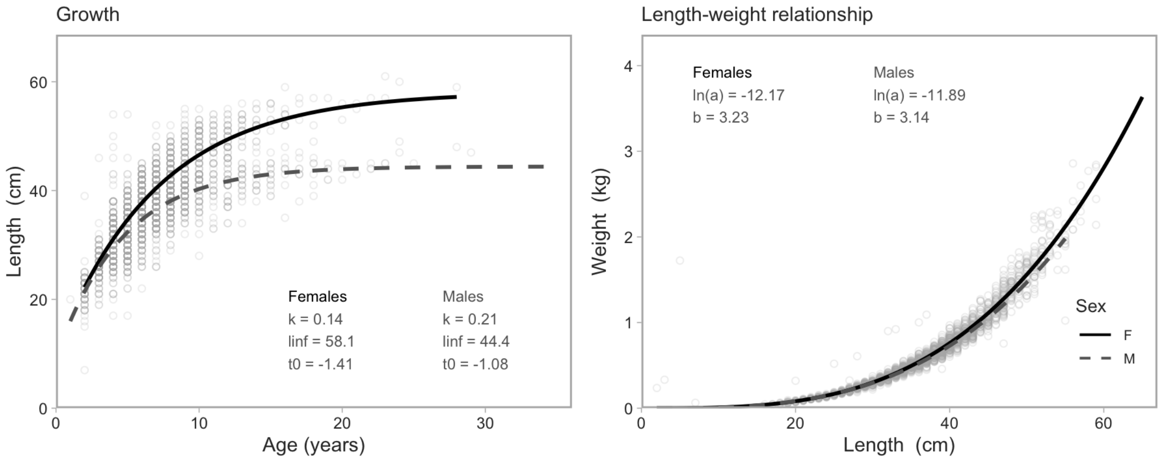


Figure 12. Example length-age and length-weight model fits and plots for Petrale Sole. The length-age growth curve is a von Bertalanffy model of the form $L_i \sim \text{Log-normal}\left(\log(l_{\text{inf}}(1 - \exp(-k(A_i - t_0)))), \sigma\right)$ *where* L_i *and* A_i *represent the length and age of fish* i, l_{inf}, k, *and* t_0 *represent the von Bertalanffy growth parameters, and* σ *represents the scale parameter. The length-weight curve is of the form* $\log(W_i) \sim$ *Student-t* $(df = 3, \log(a) + b \log(L_i), \sigma)$, *with* W_i *and* L_i *representing the weight and length for fish* i *and* σ *representing the observation error scale. We set the degrees of freedom of the Student-t distribution to 3 to be robust to outliers. The variables* a *and* b *represent the estimated length-weight parameters. Female model fits are indicated as solid black lines and male model fits are indicated as dashed grey lines. Text on the panels shows the parameter estimates and open grey circles represent individual fish that the models are fit to. These figures include all survey samples. See Appendices H.2 and H.3 for details on the models.*

4.10 MATURITY FREQUENCY BY MONTH

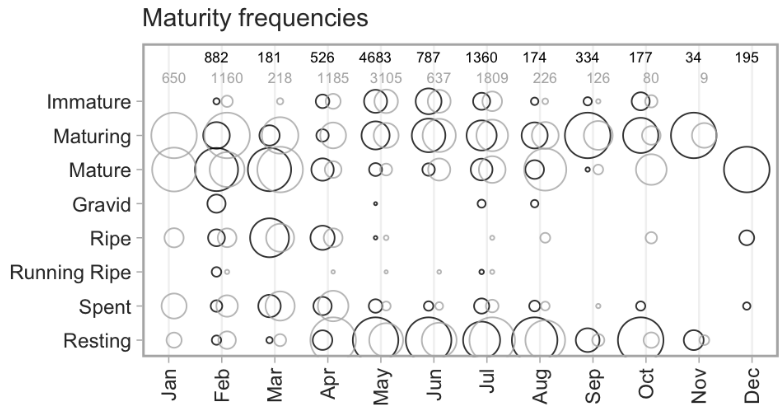


Figure 13. Example maturity-frequency-by-month plot for Petrale Sole. Categories of maturity are listed from most immature (top) to most mature (bottom); individual fish, once mature, cycle through the mature stages. The area of each circle corresponds to the number of fish specimens in a given maturity category for the given month. Female fish are indicated by black circles and male fish are indicated by light grey circles behind. The total number of fish specimens for each month are indicated by the numbers at the top of the plot. This plot includes data from both the commercial and survey samples.

4.11 MATURITY OGIVES

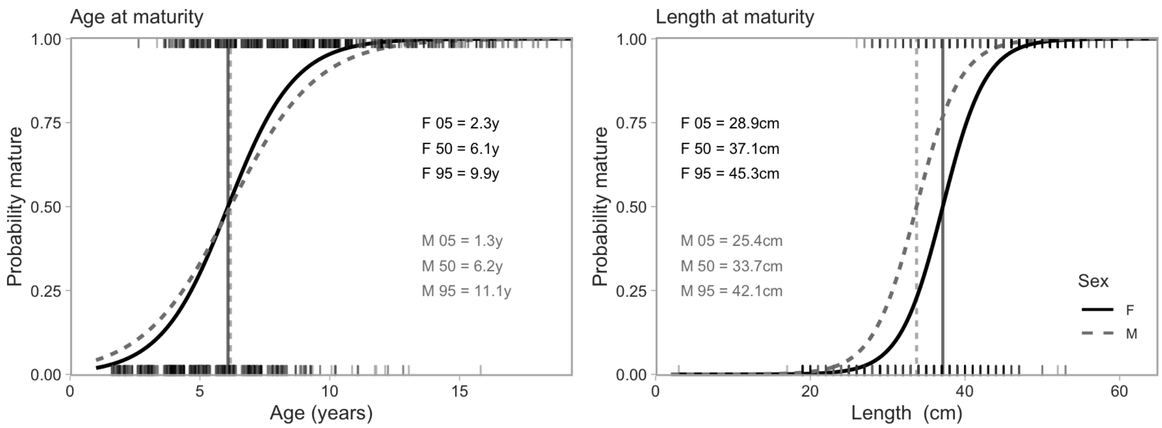


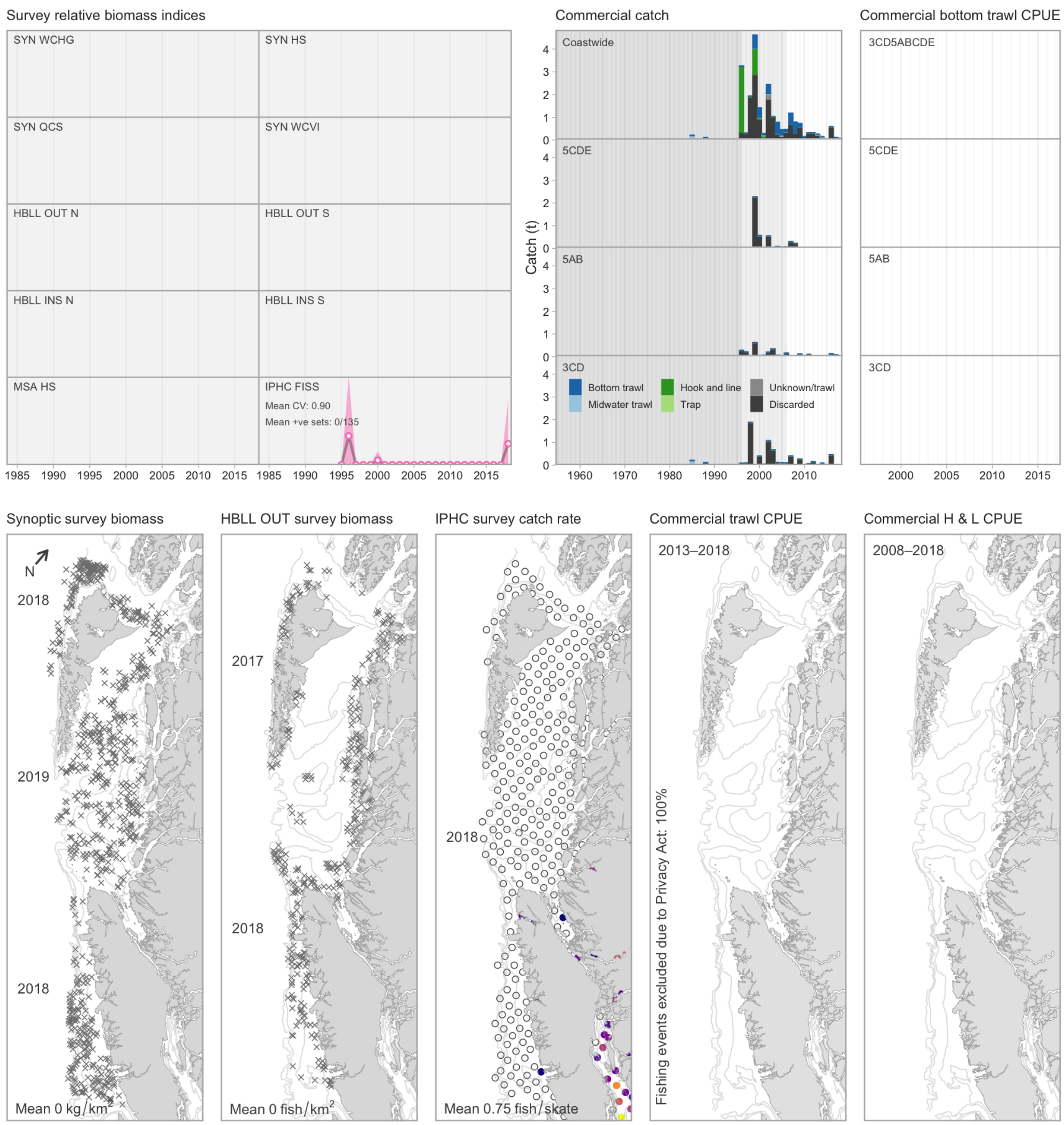
Figure 14. Example age- and length-at-maturity ogive plots for Petrale Sole. Maturity ogives are fit as logistic regressions to individual fish specimens, which are categorized as mature vs. not mature. The solid black lines represent fits to the female fish and the dashed grey lines represent fits to the male fish. The vertical lines indicate the estimated age or length at 50% maturity. Text on the panels indicates the estimated age and length at 5, 50 and 95% maturity for females (F) and males (M). Model fits are only shown for cases where there are at least 20 mature and 20 immature males and females. Short rug lines along the top and bottom of each panel represent up to 1500 randomly chosen individual fish with a small amount of random jittering in the case of ages to help differentiate individual fish. Models are fit to all available survey samples regardless of time of year. See Appendix H.1 for details.

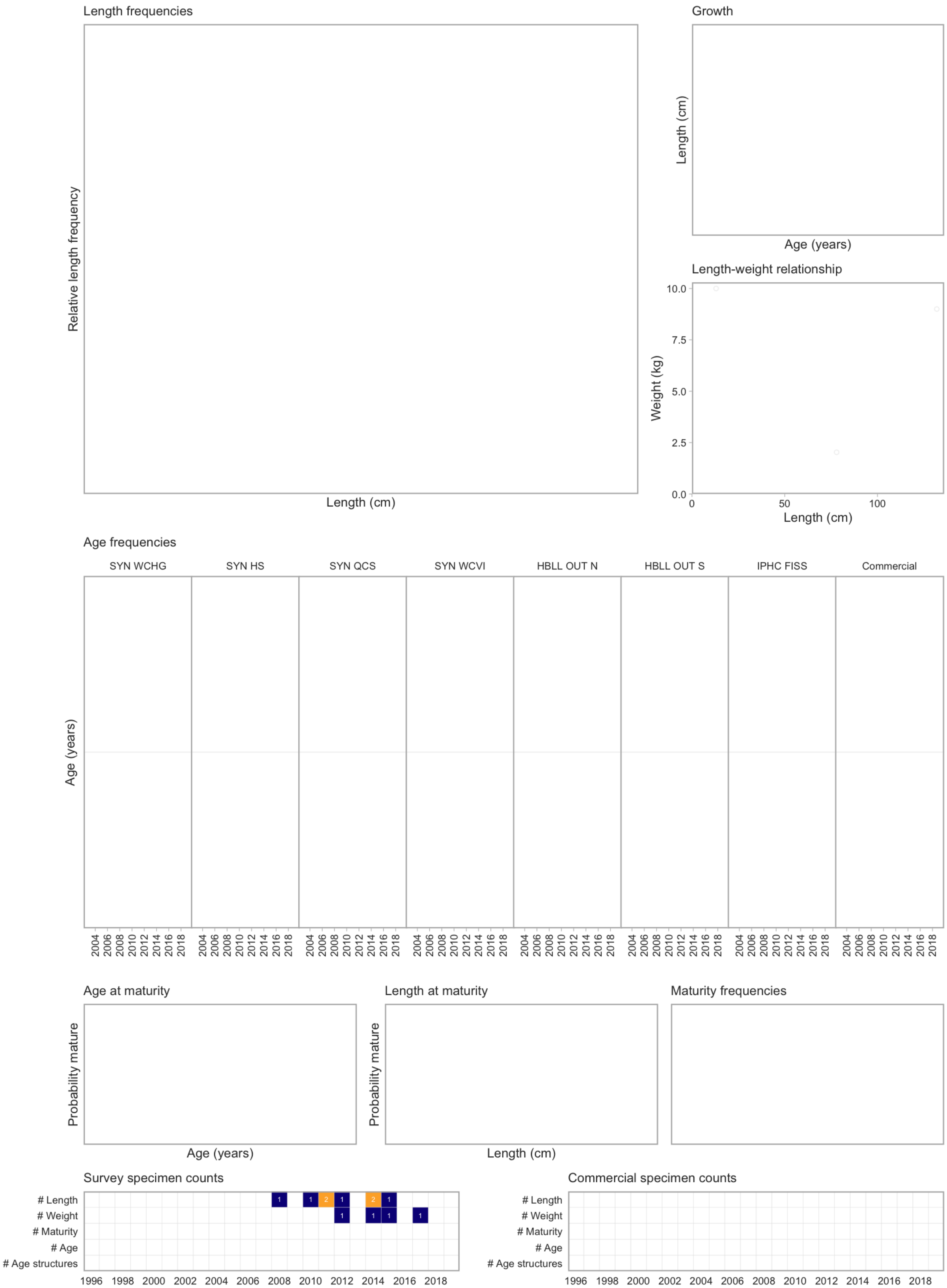
5 SYNOPSIS PLOTS

This section contains the main species-by-species data visualizations. Each species is shown on two pages with the same layout used throughout. See Section 4 for detailed figure captions. In addition to the figures, we also provide the scientific name, taxonomic details, DFO species code, a link to the FishBase and WoRMS (World Register of Marine Species) web pages, details of the most recent DFO Research Documents and Science Advisory Reports, and any information related to designations by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and to listings under the Species at Risk Act (SARA). The species are ordered according to DFO species codes. The Table of Contents at the beginning of the document includes links to the species pages in order of species codes, and Sections 1 and 2 provide links to the pages sorted alphabetically by common and scientific name, respectively.

5.1 BLUNTNOSE SIXGILL SHARK

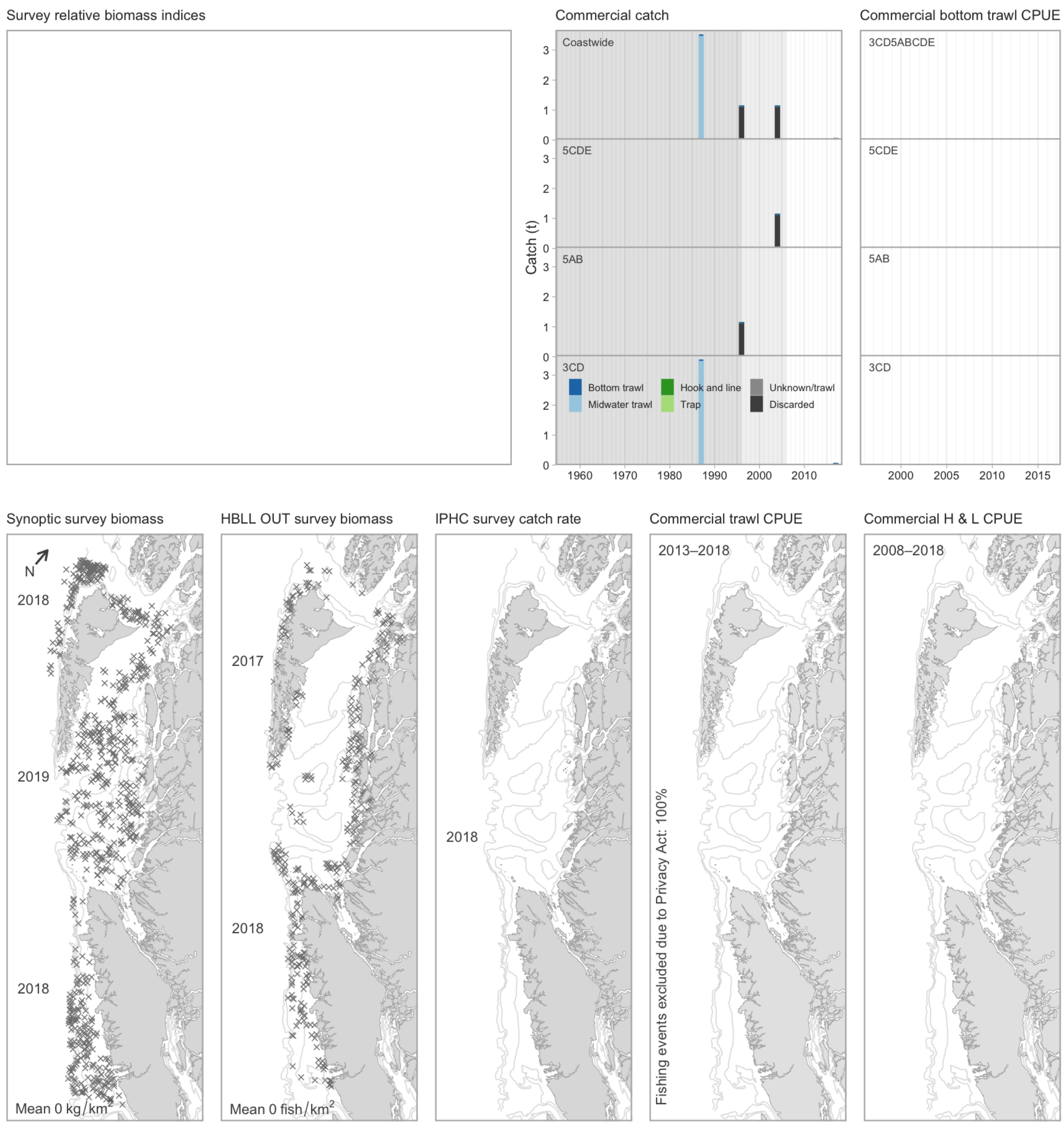
Hexanchus griseus (027)
Order: Hexanchiformes, Family: Hexanchidae, FishBase, WoRMS
COSEWIC Status Report: COSEWIC (2007a)
COSEWIC Status: Special Concern, SARA Status: Special Concern

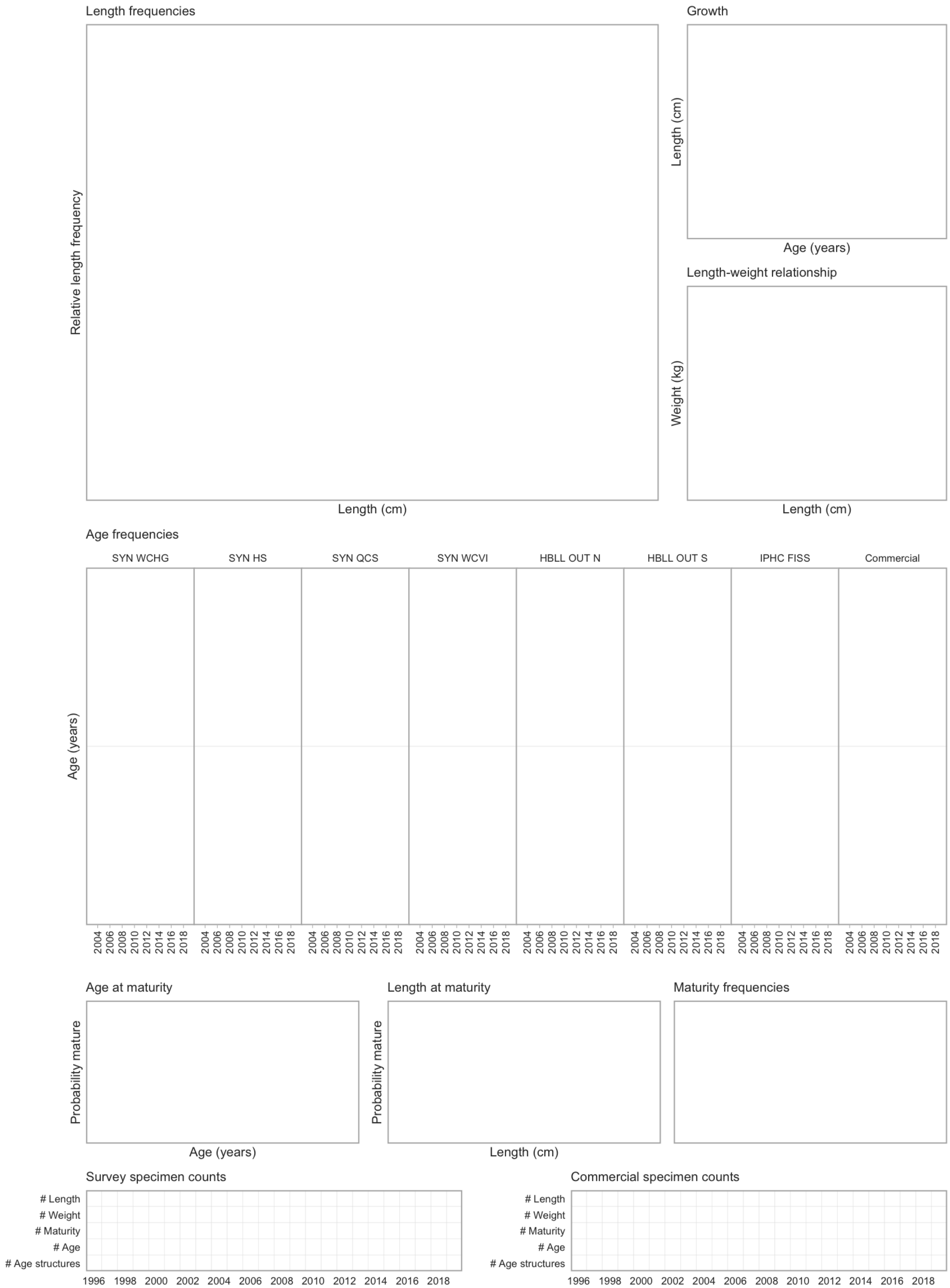



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.2 BASKING SHARK

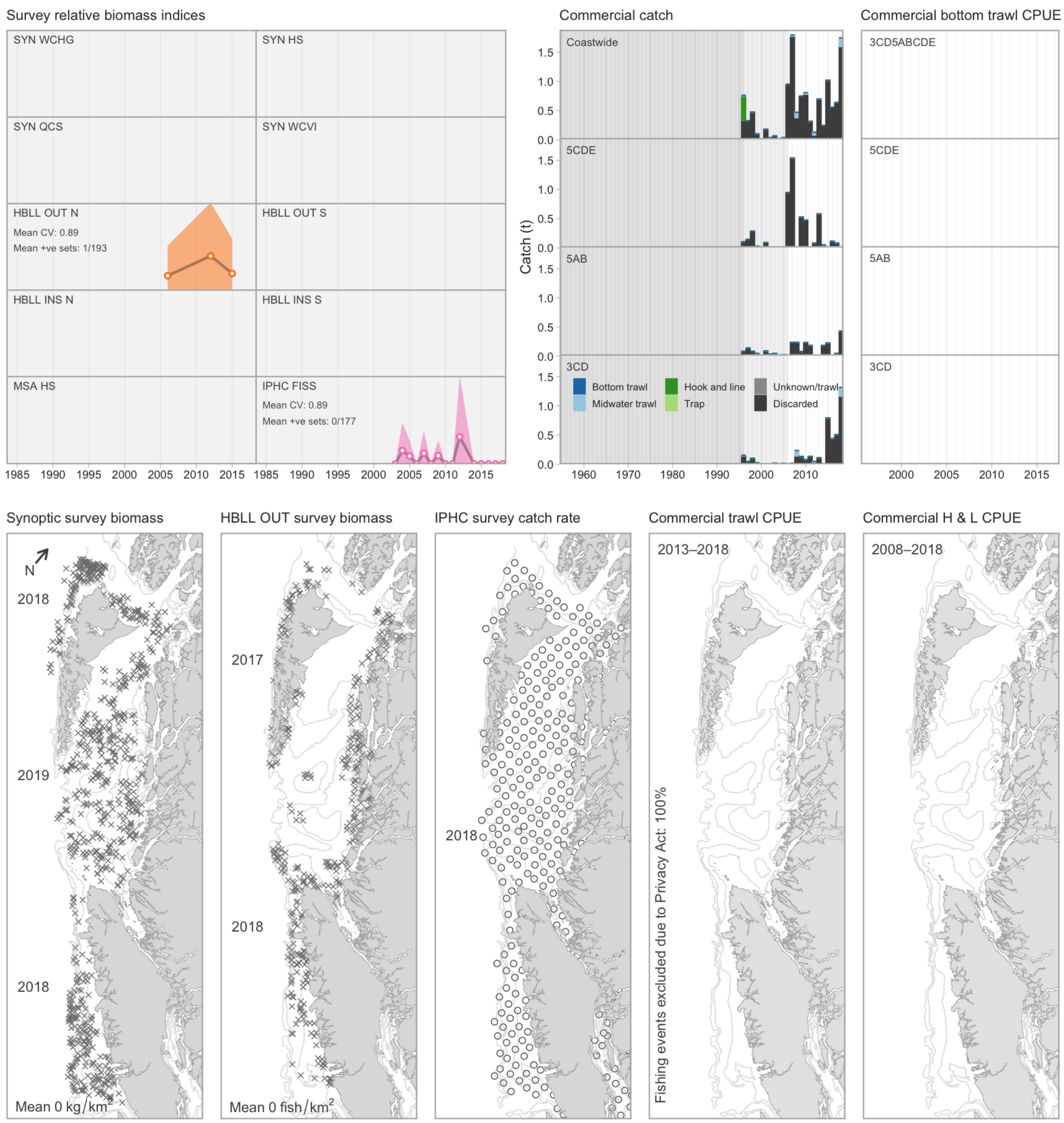
Cetorhinus maximus (034)
Order: Lamniformes, Family: Cetorhinidae, FishBase, WoRMS
Last Research Document: McFarlane et al. (2008)
Species at Risk Act Recovery Strategy: DFO (2011a)
COSEWIC Status Report: COSEWIC (2007b)
COSEWIC Status: Endangered, SARA Status: Endangered

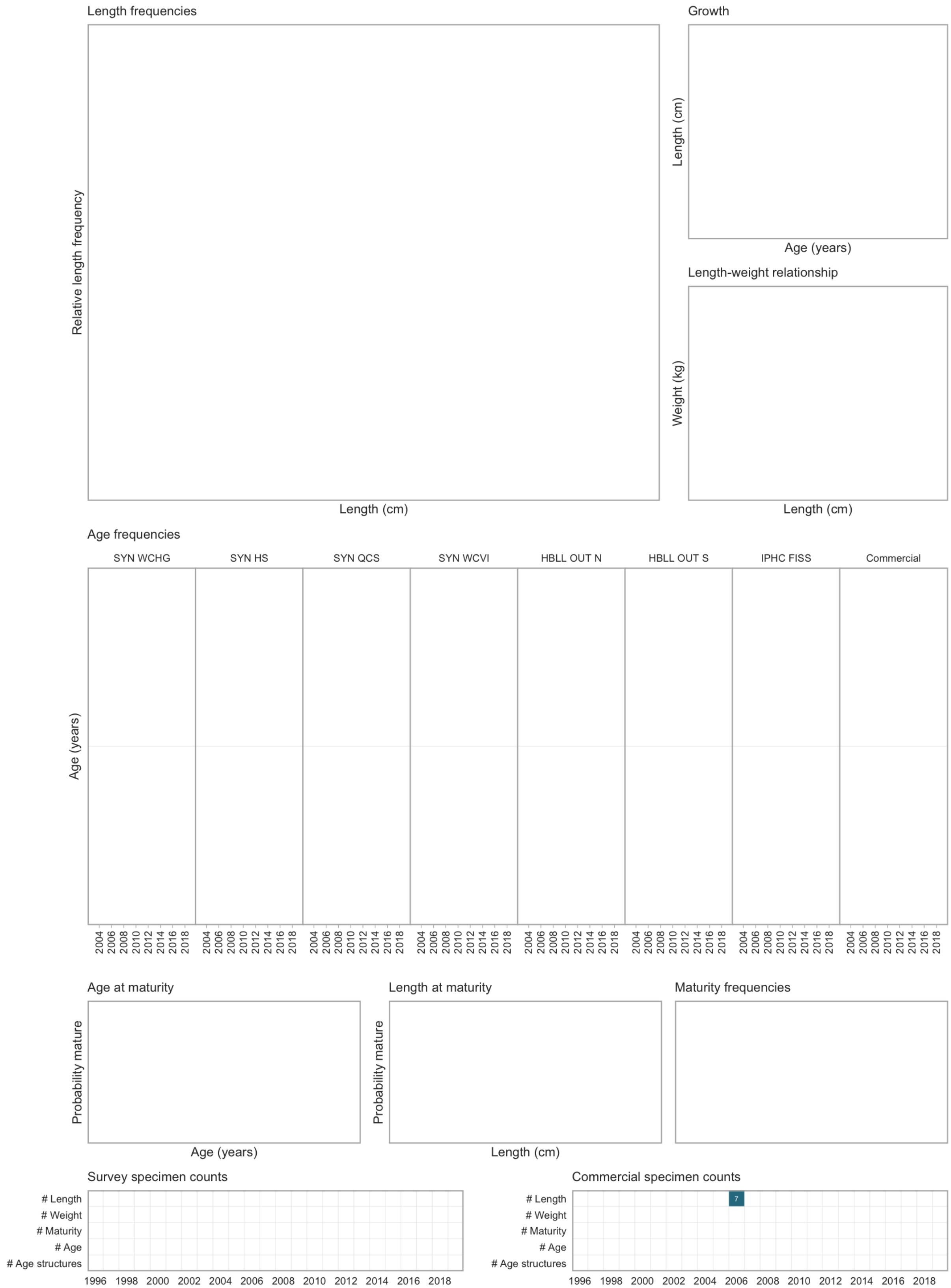



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.3 SALMON SHARK

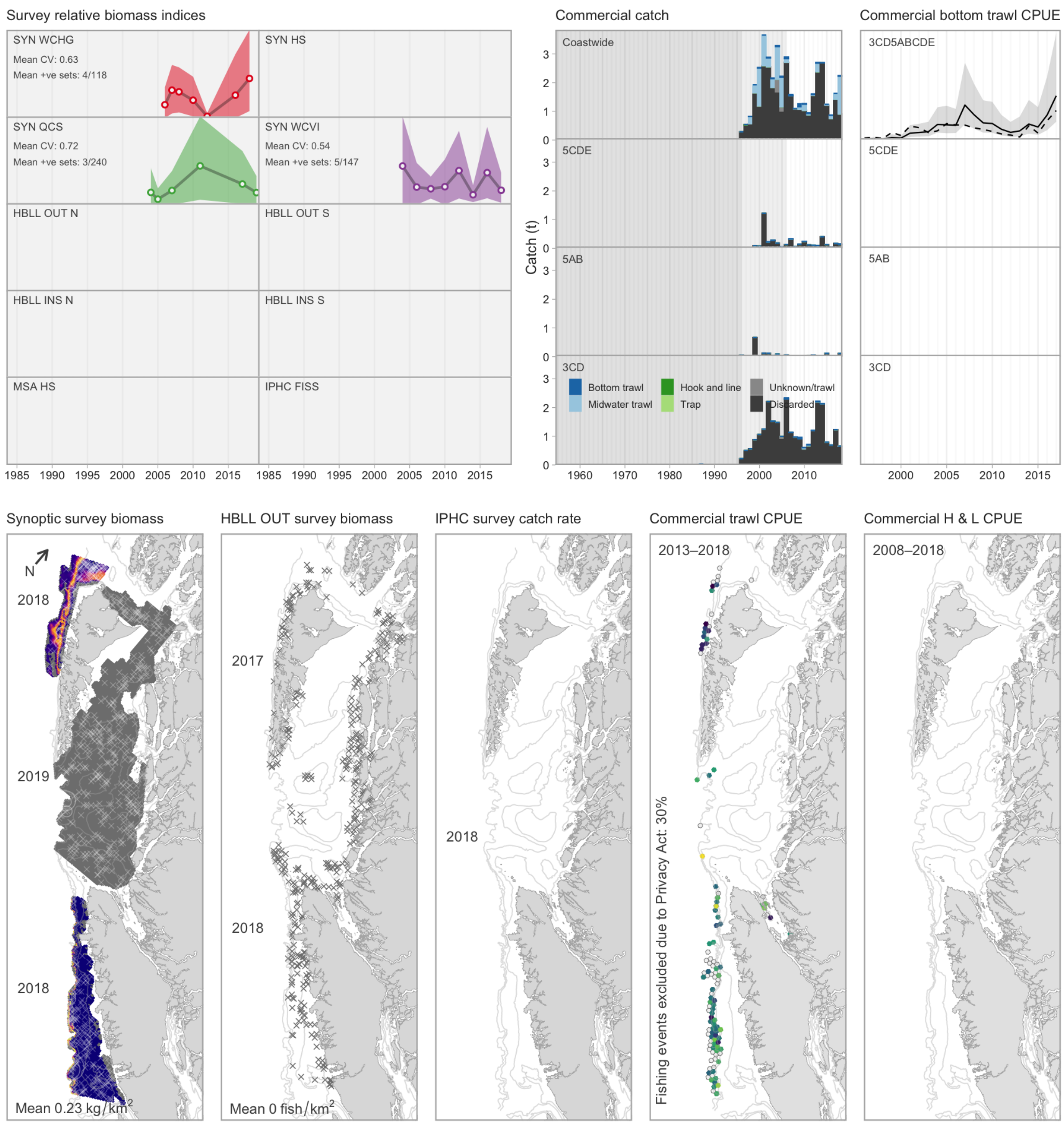
Lamna ditropis (036)
Order: Lamniformes, Family: Lamnidae, FishBase, WoRMS

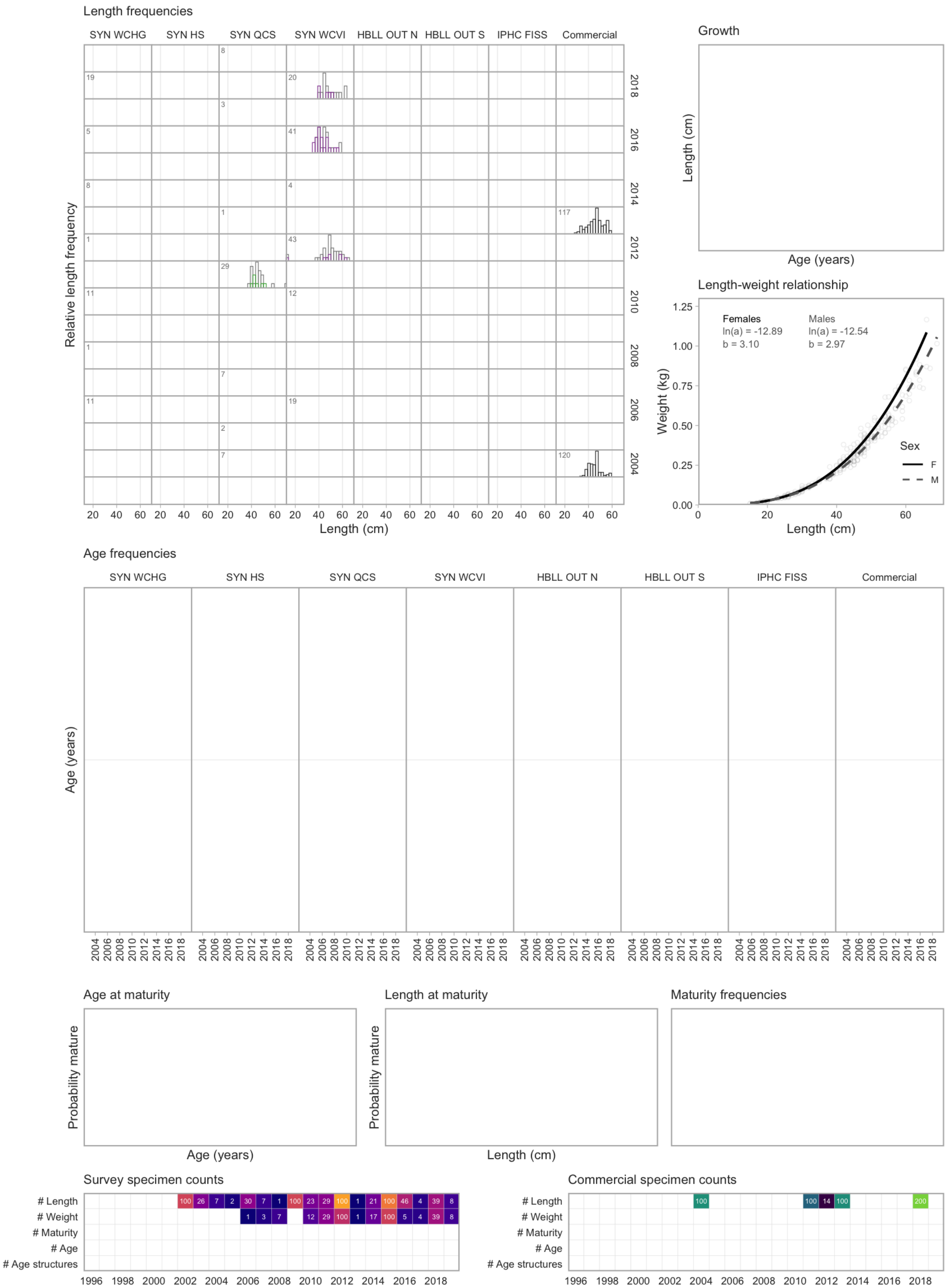



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004
2006
2008
2010
2012
2014
2016
2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
7
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

5.4 BROWN CAT SHARK

Apristurus brunneus (038)
Order: Carcharhiniformes, Family: Scyliorhinidae, FishBase, WoRMS

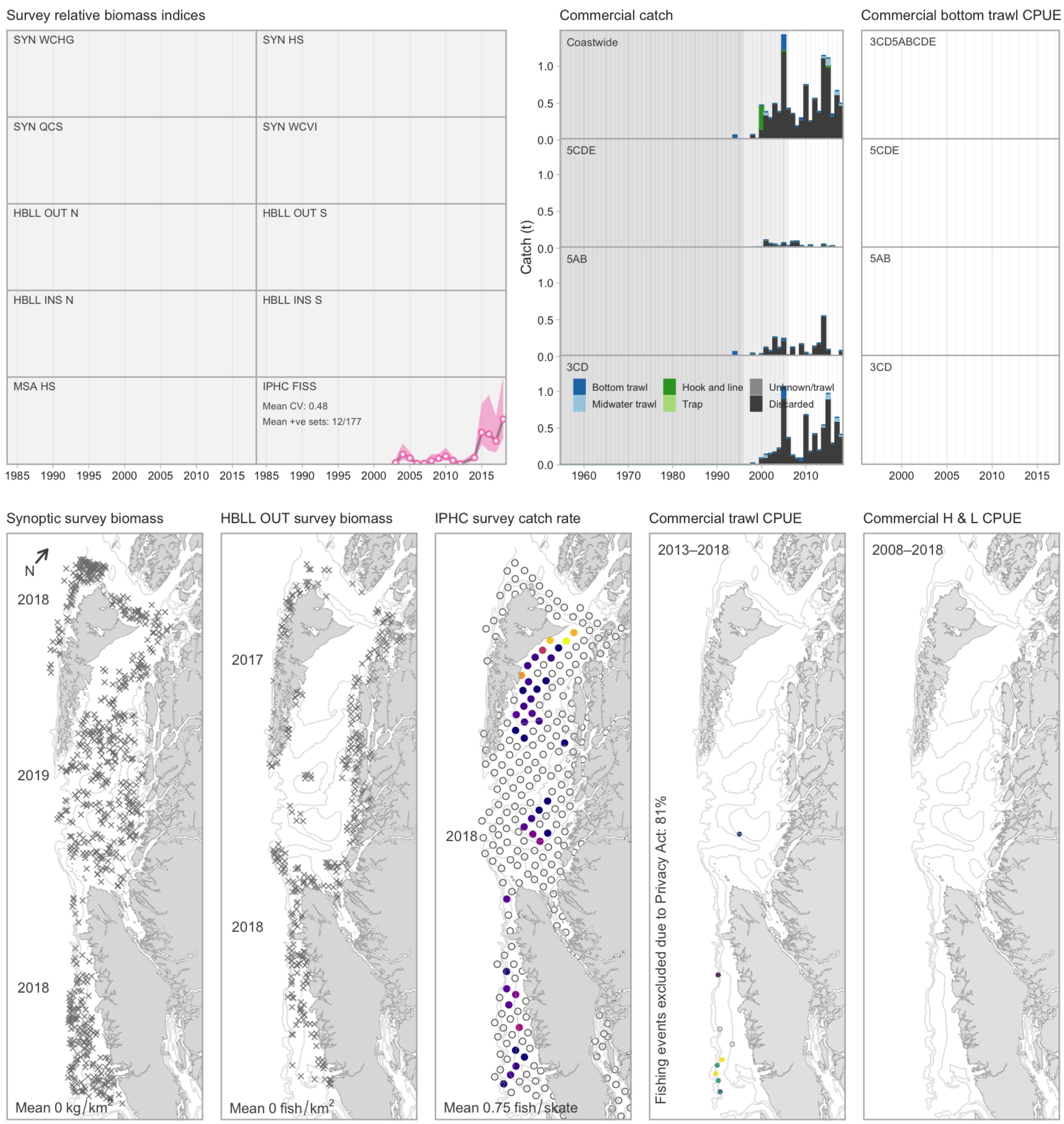


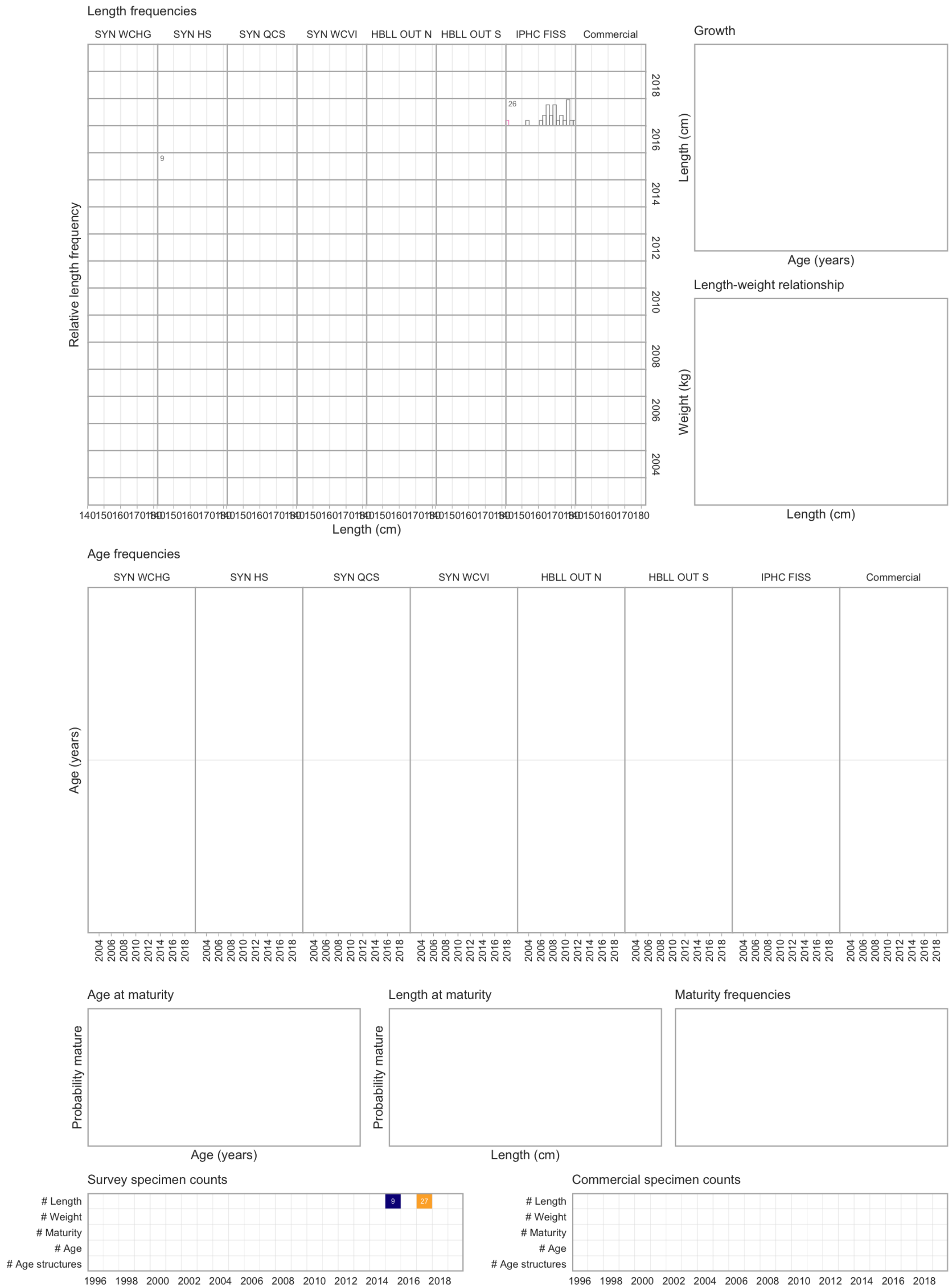


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -12.89
b = 3.10
Males
ln(a) = -12.54
b = 2.97
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.5 TOPE SHARK

Galeorhinus galeus (040)
Order: Carcharhiniformes, Family: Triakidae, FishBase, WoRMS
COSEWIC Status Report: COSEWIC (2007c)
COSEWIC Status: Special Concern, SARA Status: Special Concern

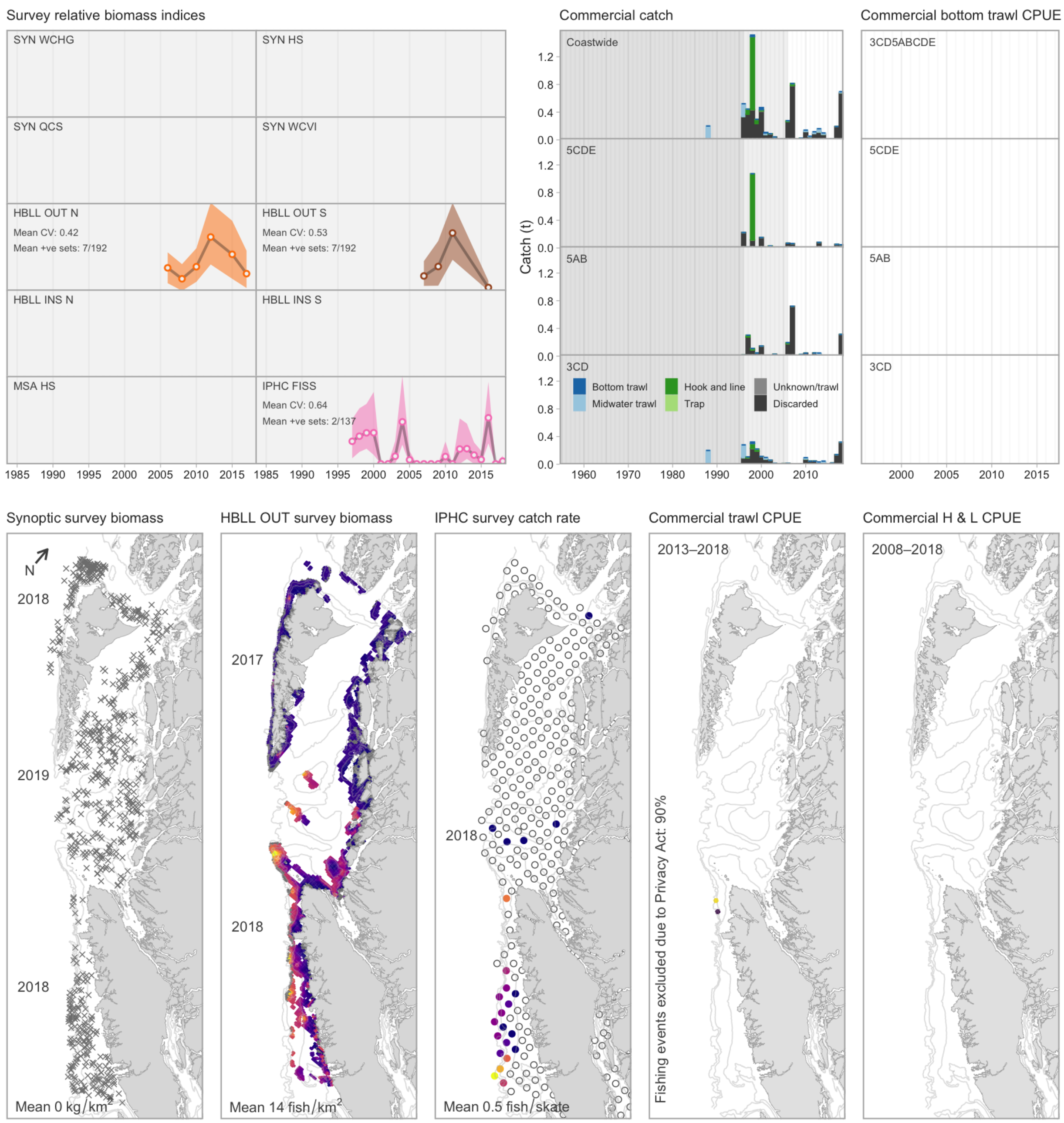


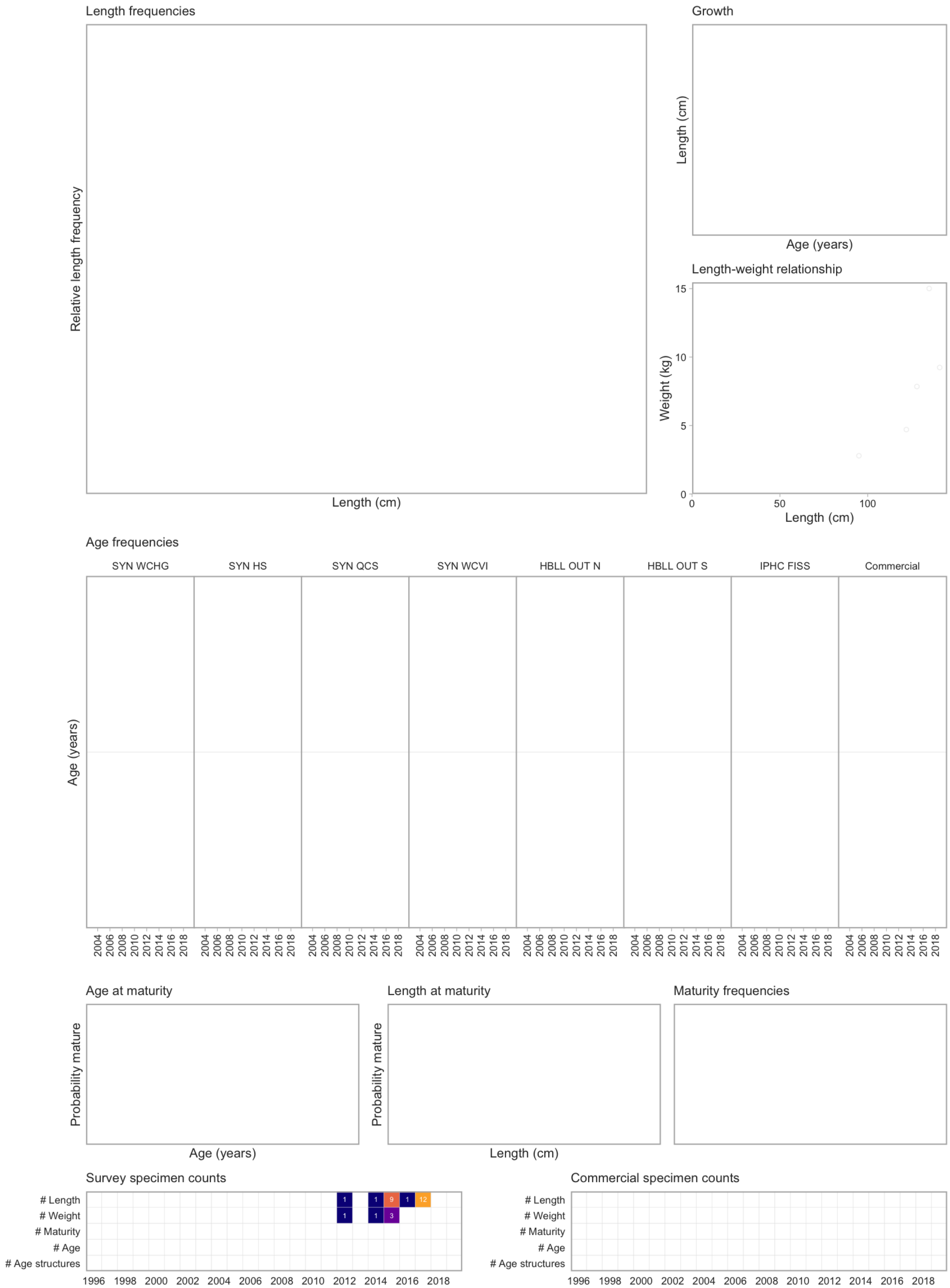


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.6 BLUE SHARK

Prionace glauca (041)
Order: Carcharhiniformes, Family: Carcharhinidae, FishBase, WoRMS
COSEWIC Status Report: COSEWIC (2016)
COSEWIC Status: Not at Risk, SARA Status: No Status

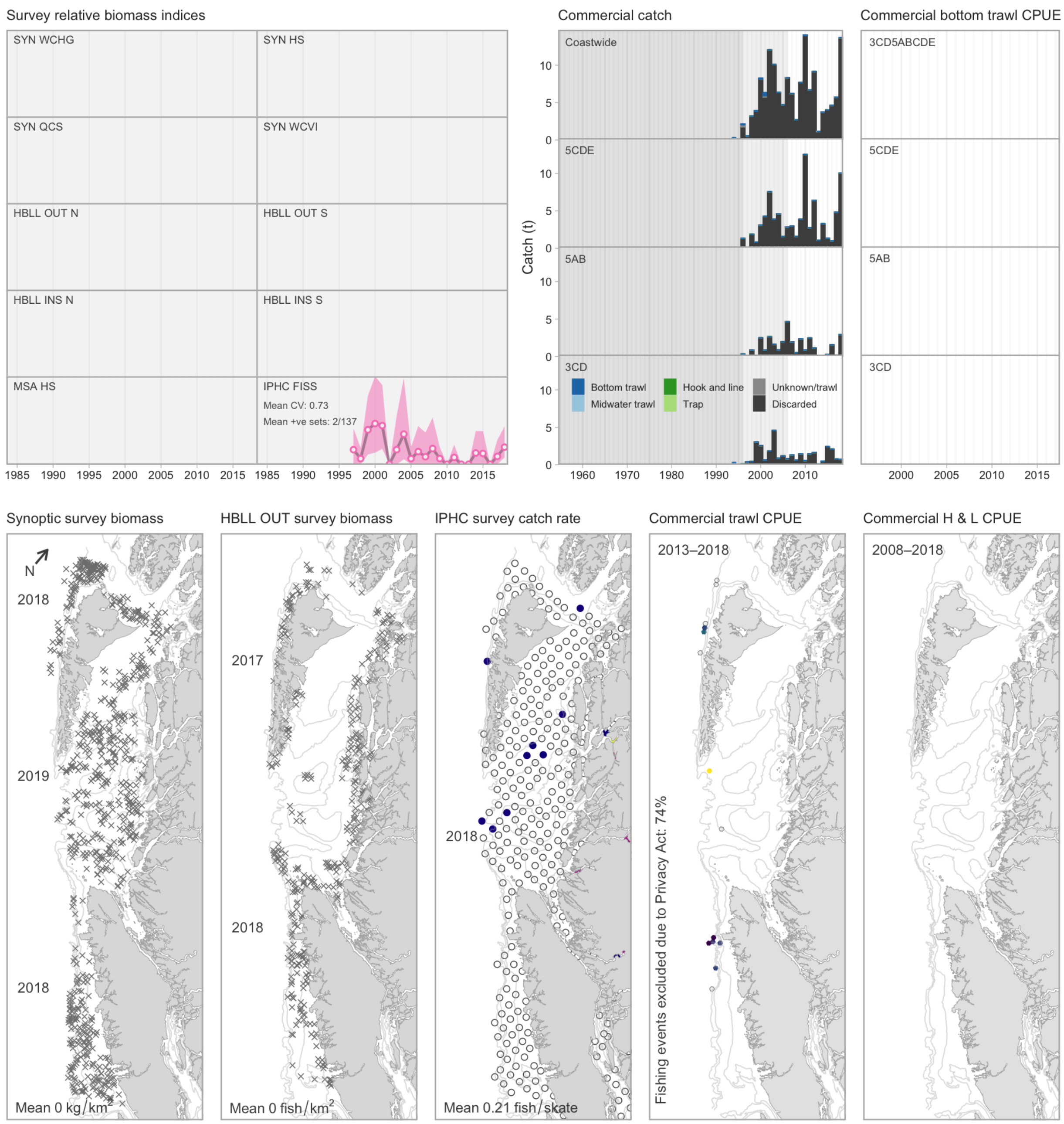


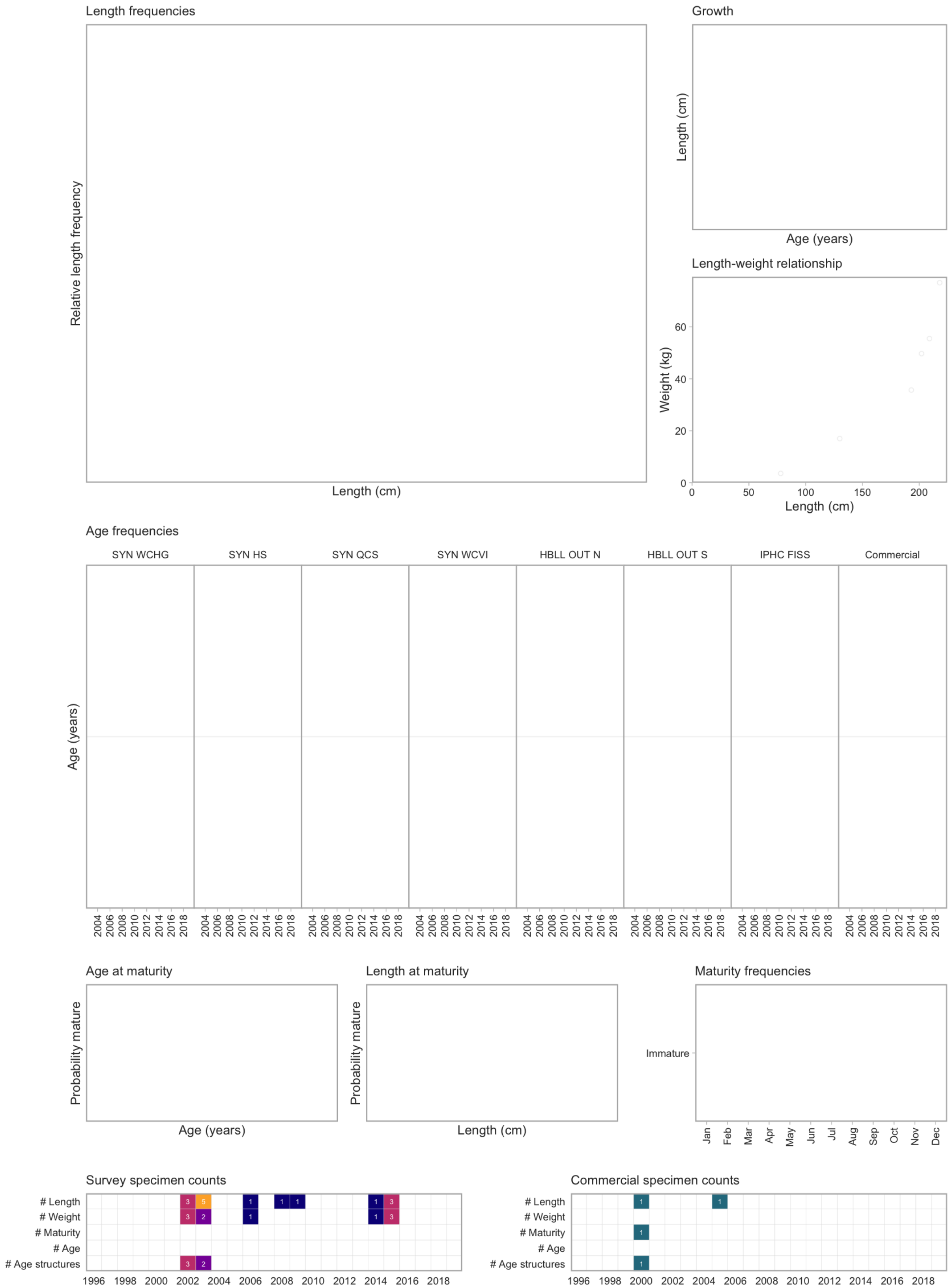


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.7 PACIFIC SLEEPER SHARK

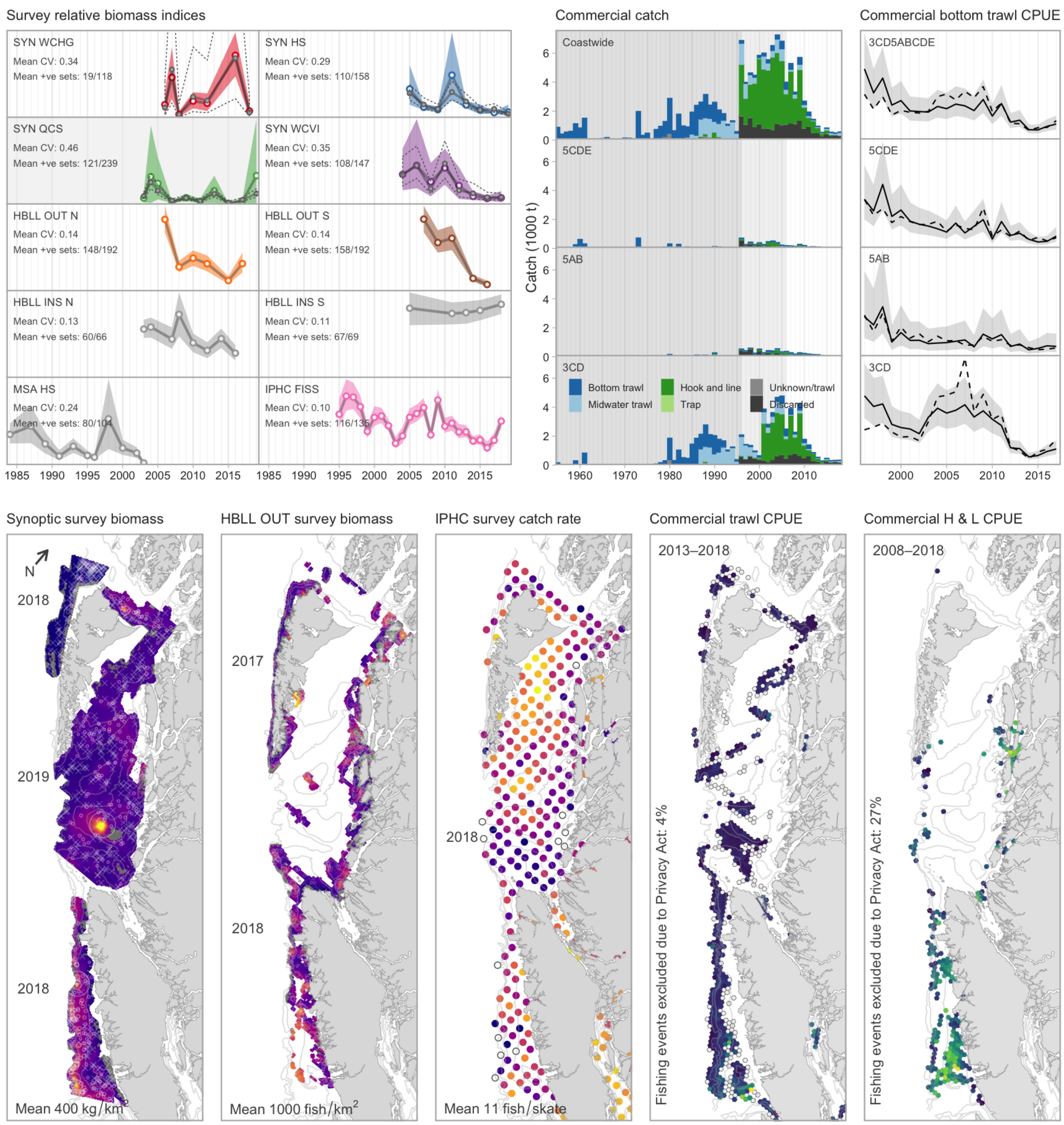
Somniosus pacificus (043)
Order: Squaliformes, Family: Somniosidae, FishBase, WoRMS

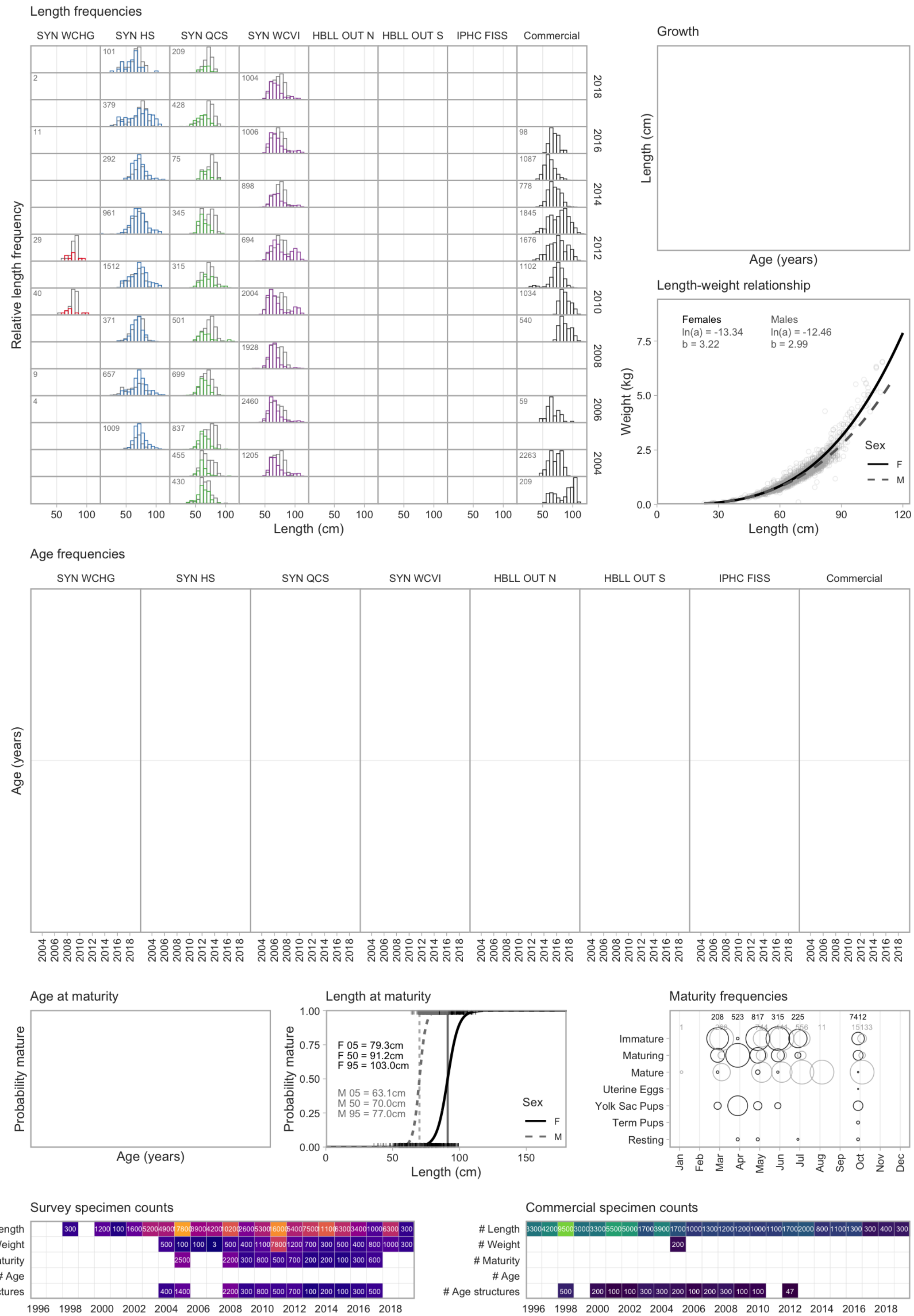



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.8 NORTH PACIFIC SPINY DOGFISH

Squalus suckleyi (044)
Order: Squaliformes, Family: Squalidae, FishBase, WoRMS
Last Research Document: Galluci et al. (2011)
Last Science Advisory Report: DFO (2010)
COSEWIC Status Report: COSEWIC (2011)
COSEWIC Status: Special Concern, SARA Status: No Status

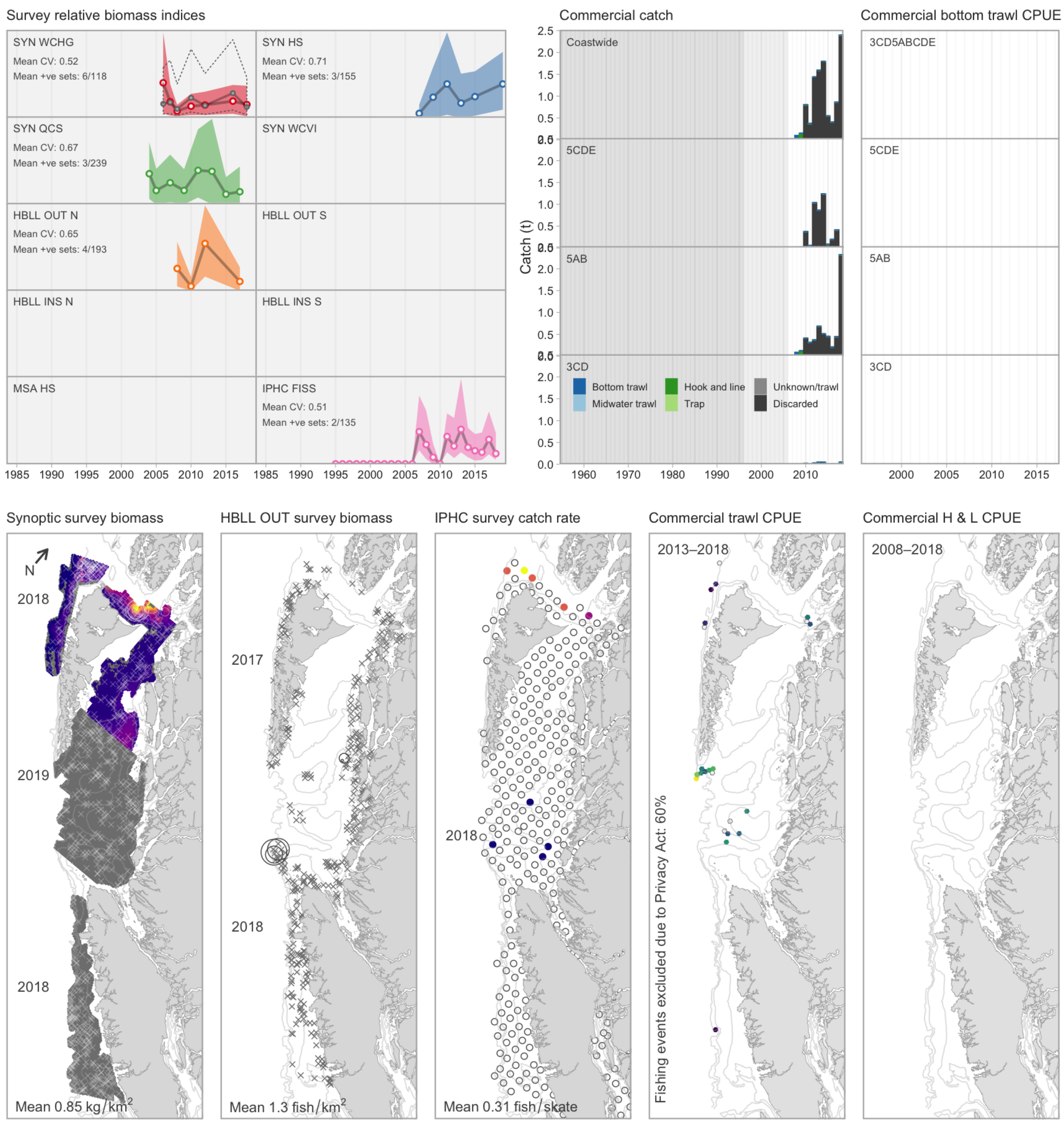


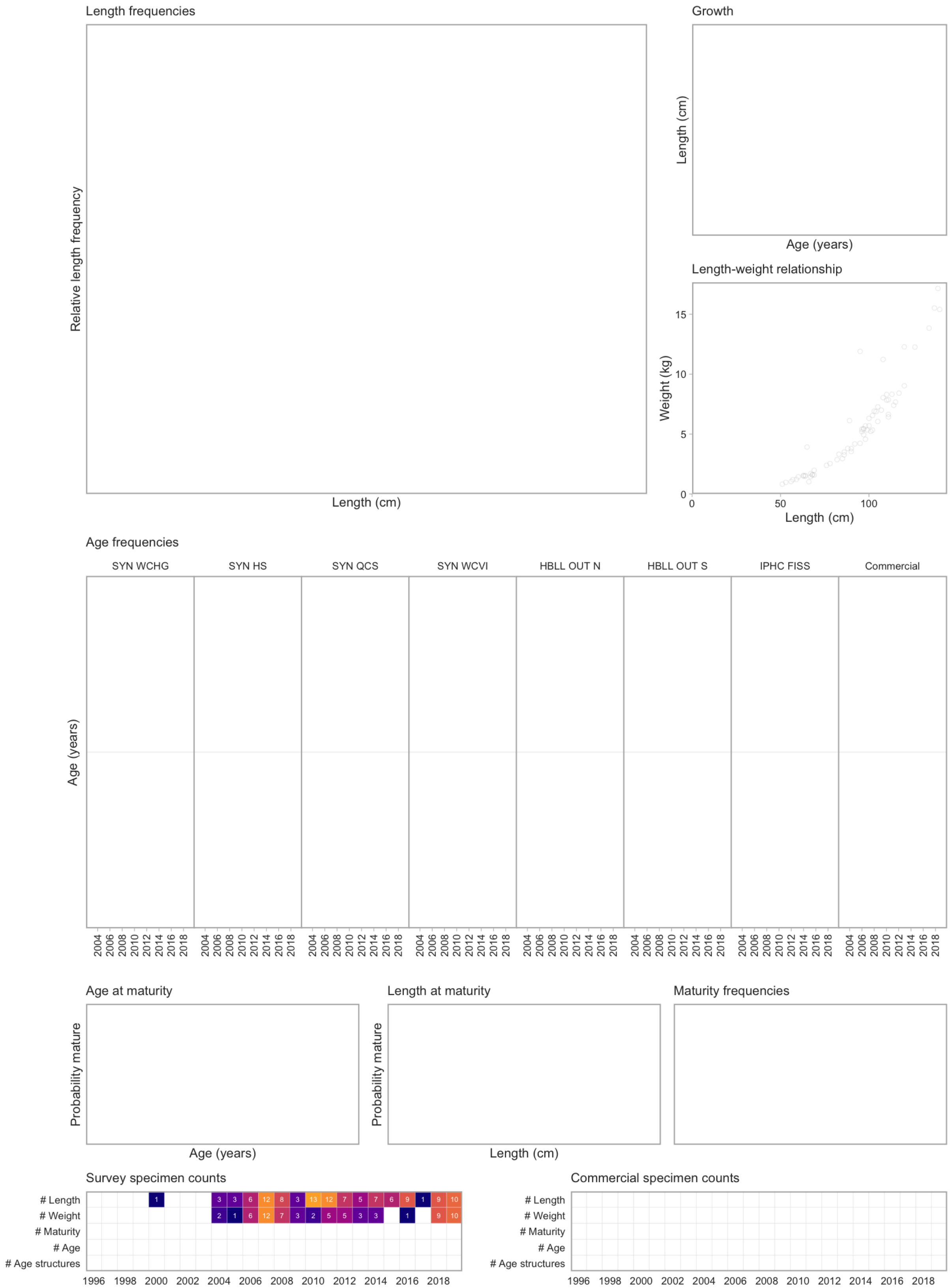


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -13.34
b = 3.22
Males
ln(a) = -12.46
b = 2.99
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 79.3cm
F 50 = 91.2cm
F 95 = 103.0cm
M 05 = 63.1cm
M 50 = 70.0cm
M 95 = 77.0cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Uterine Eggs
Yolk Sac Pups
Term Pups
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.9 ALEUTIAN SKATE

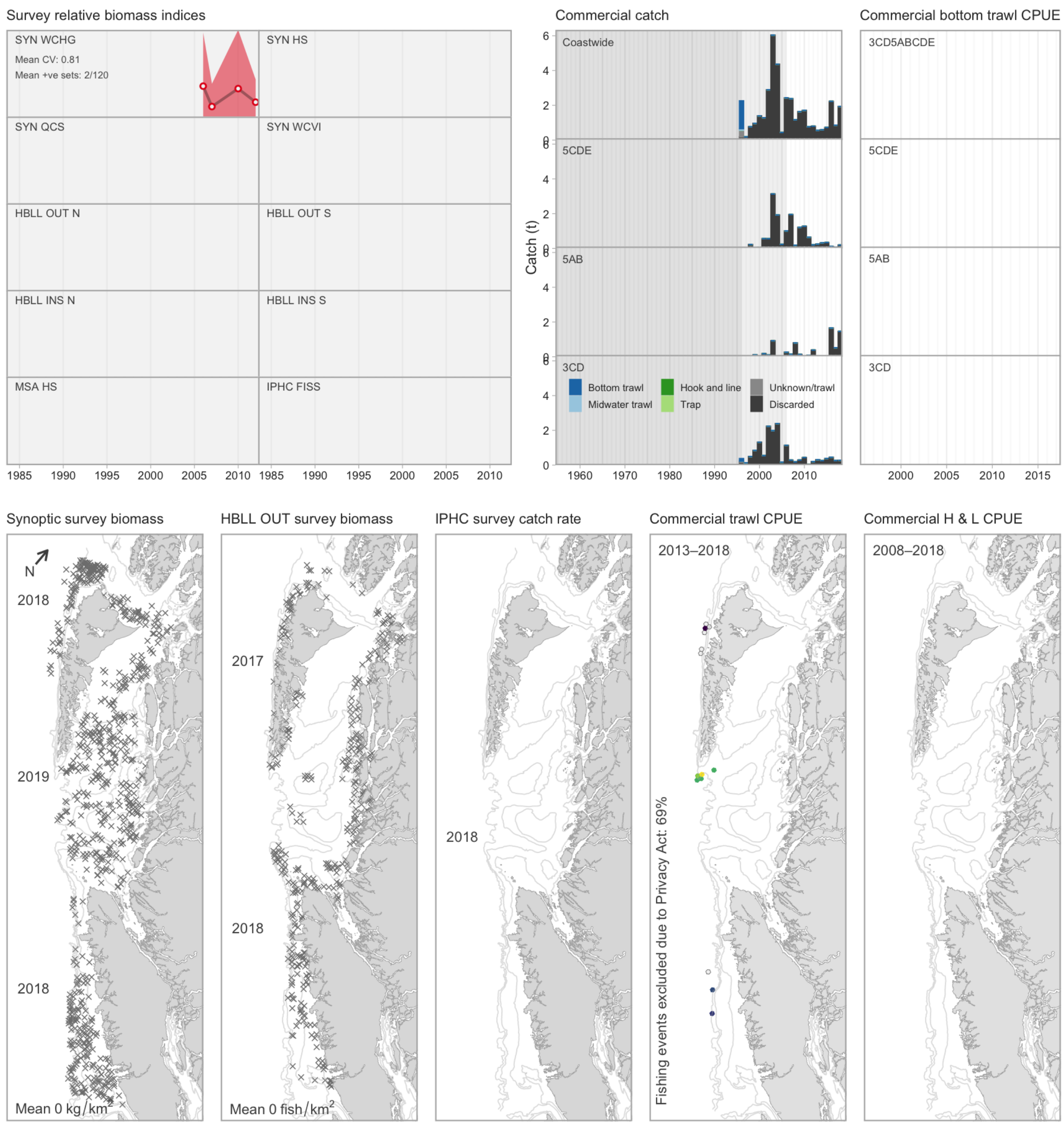
Bathyraja aleutica (052)
Order: Rajiformes, Family: Arhynchobatidae, FishBase, WoRMS

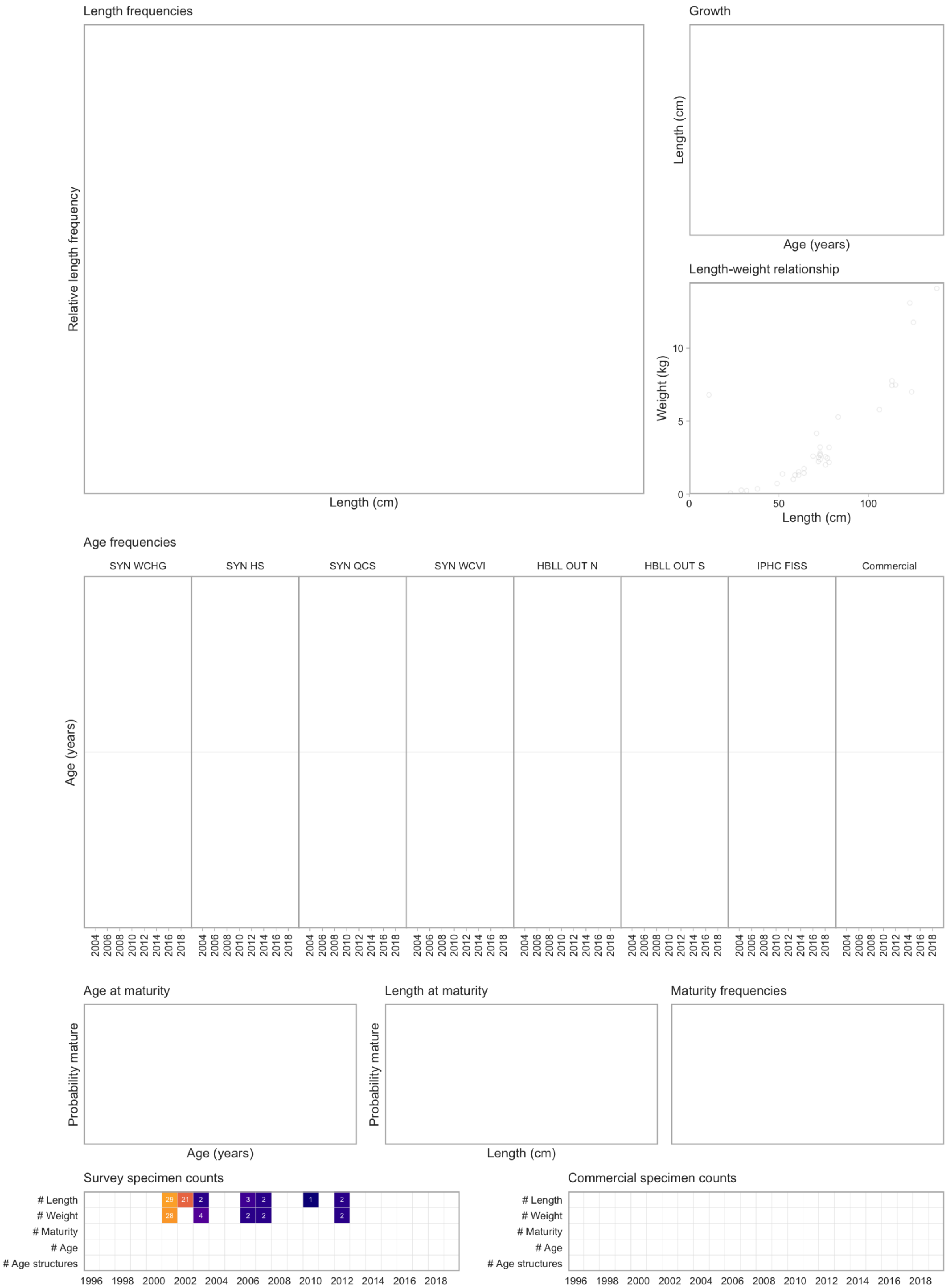



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.10 ABYSSAL SKATE

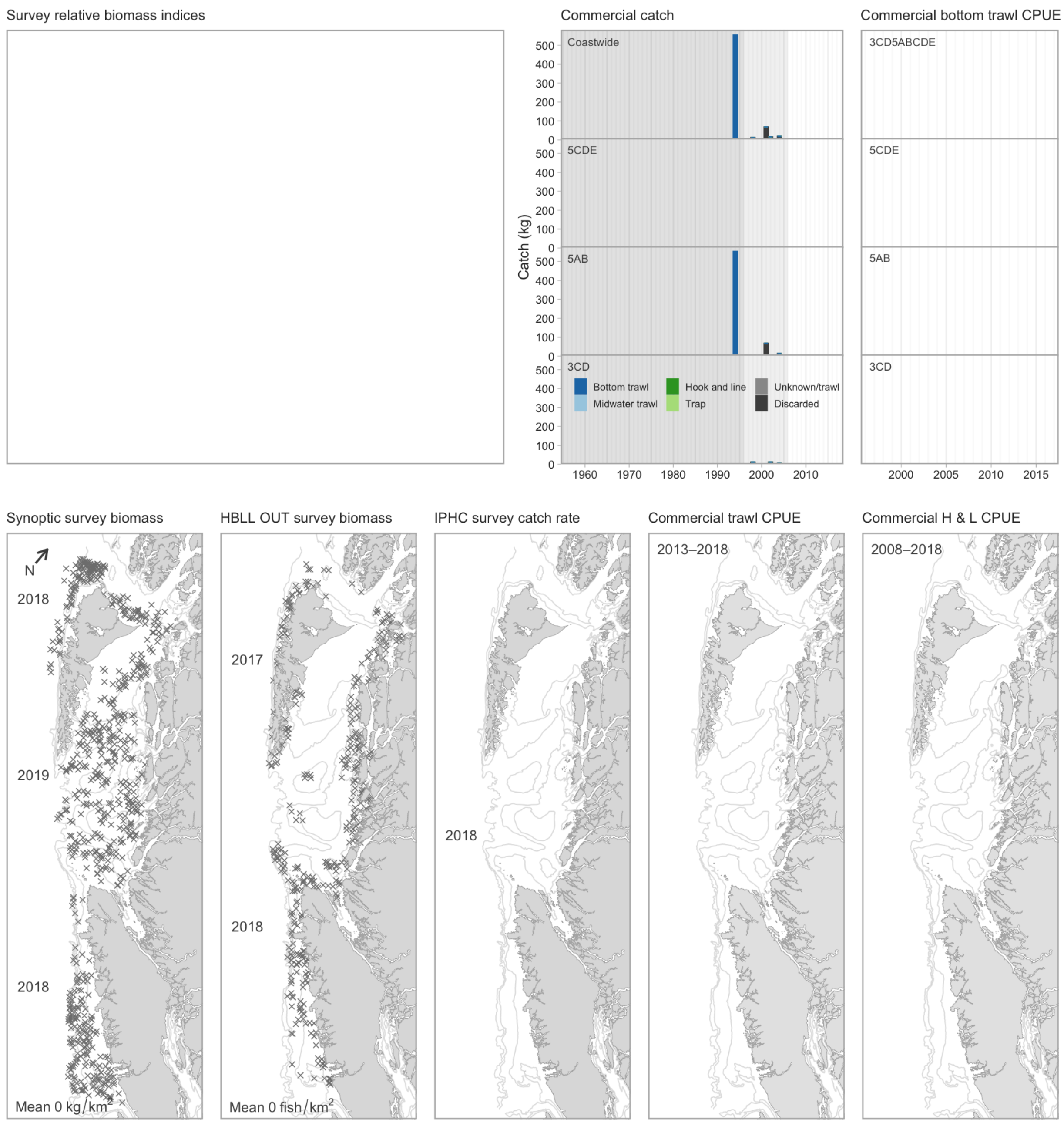
Bathyraja abyssicola (054)
Order: Rajiformes, Family: Arhynchobatidae, FishBase, WoRMS

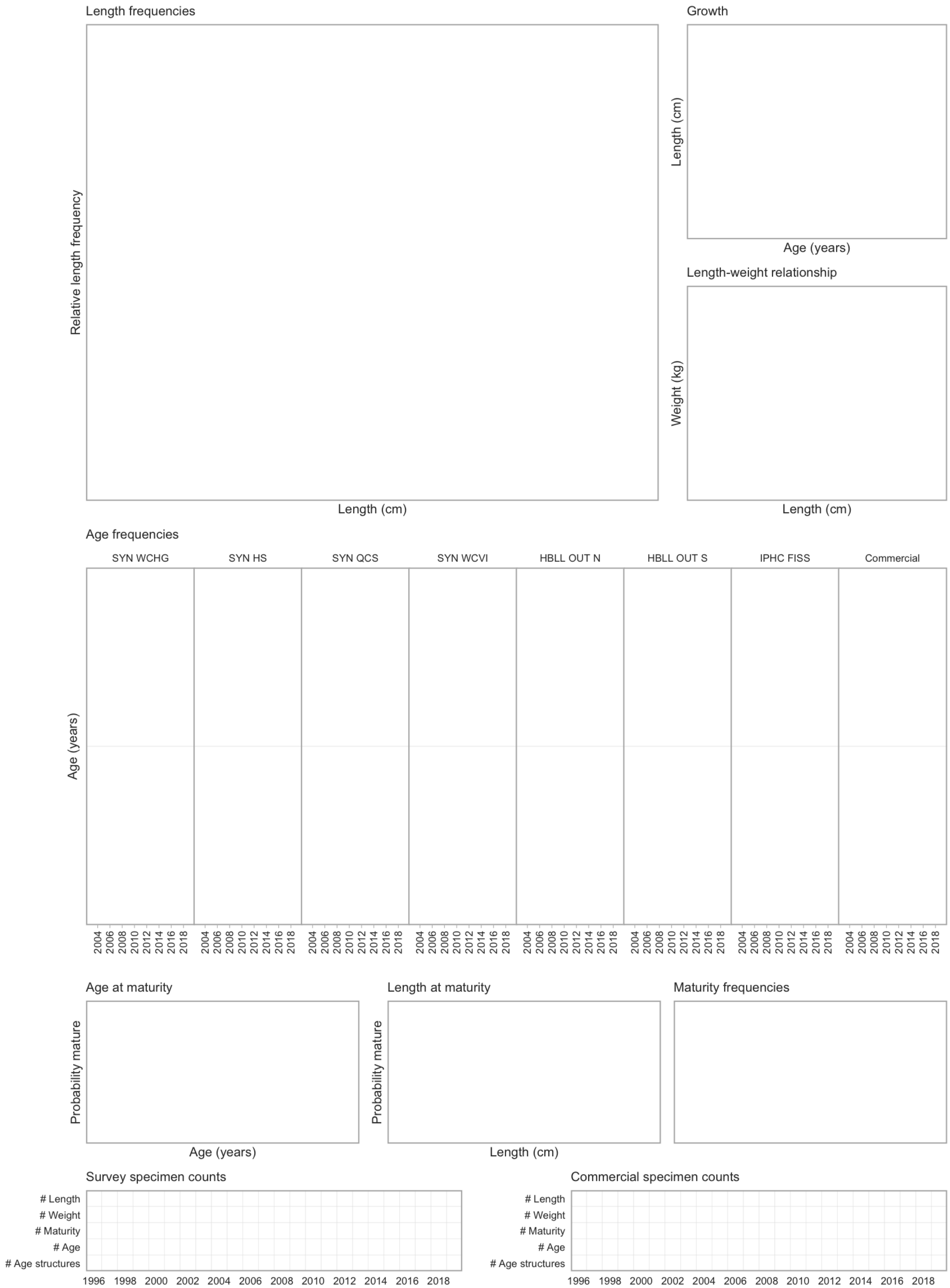



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
0
5
10
0
50
100
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004
2006
2008
2010
2012
2014
2016
2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
29
21
2
3
2
1
2
28
4
2
2
2
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

5.11 BROAD SKATE

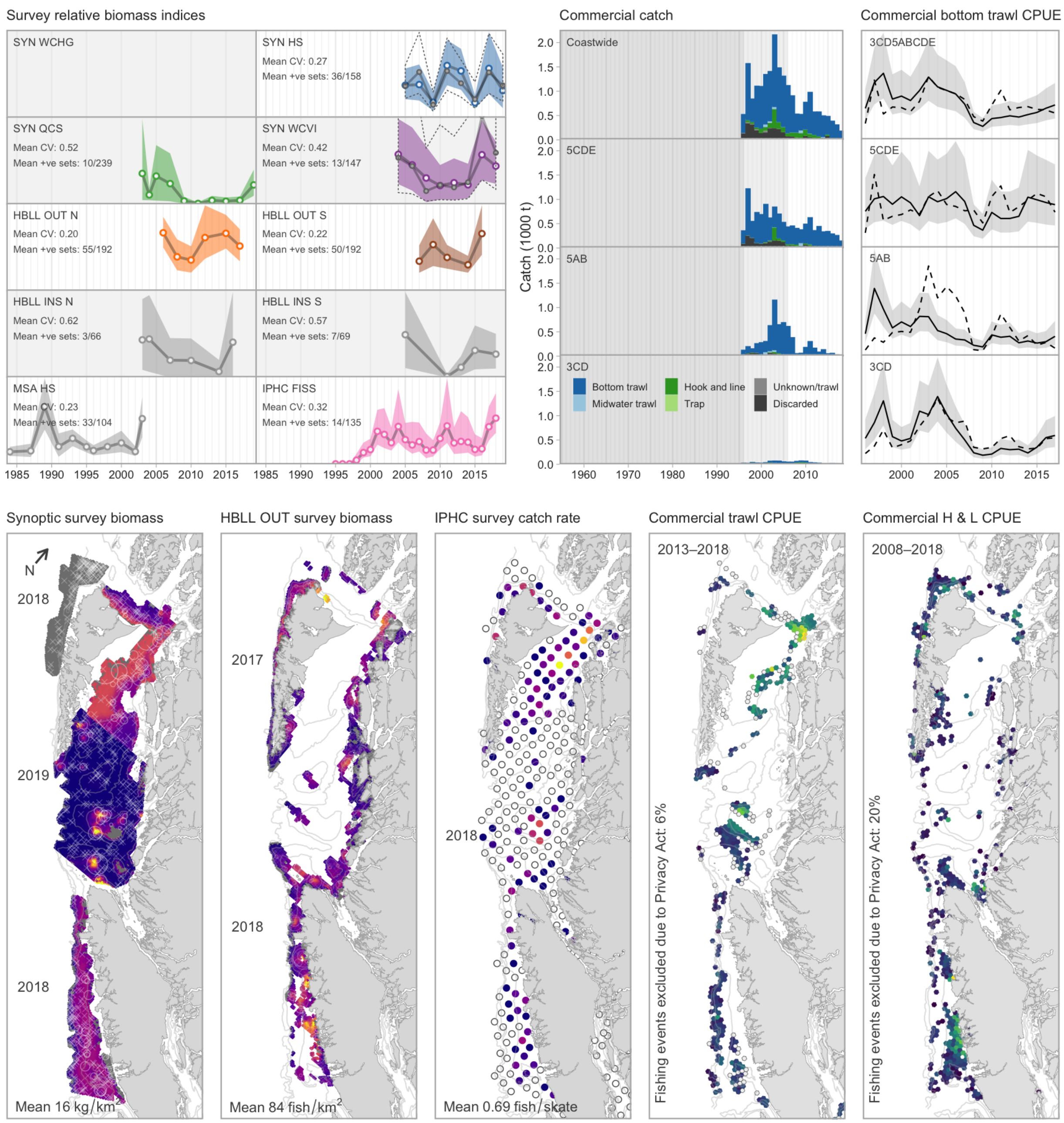
Amblyraja badia (055)
Order: Rajiformes, Family: Rajidae, FishBase, WoRMS

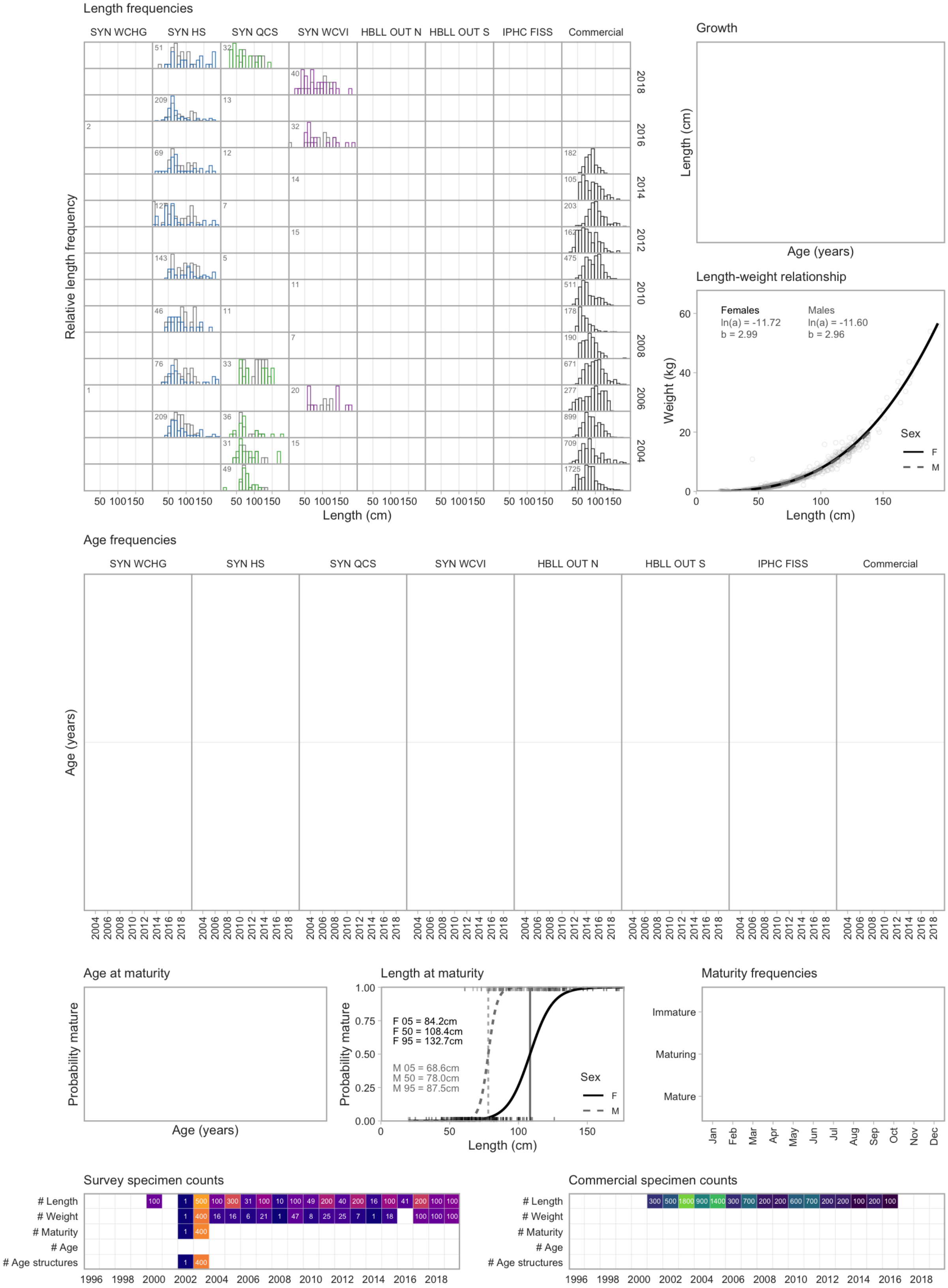



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.12 BIG SKATE

Beringraja binoculata (056)
Order: Rajiformes, Family: Rajidae, FishBase, WoRMS
Last Research Document: King et al. (2015)
Last Science Advisory Report: DFO (2014a)

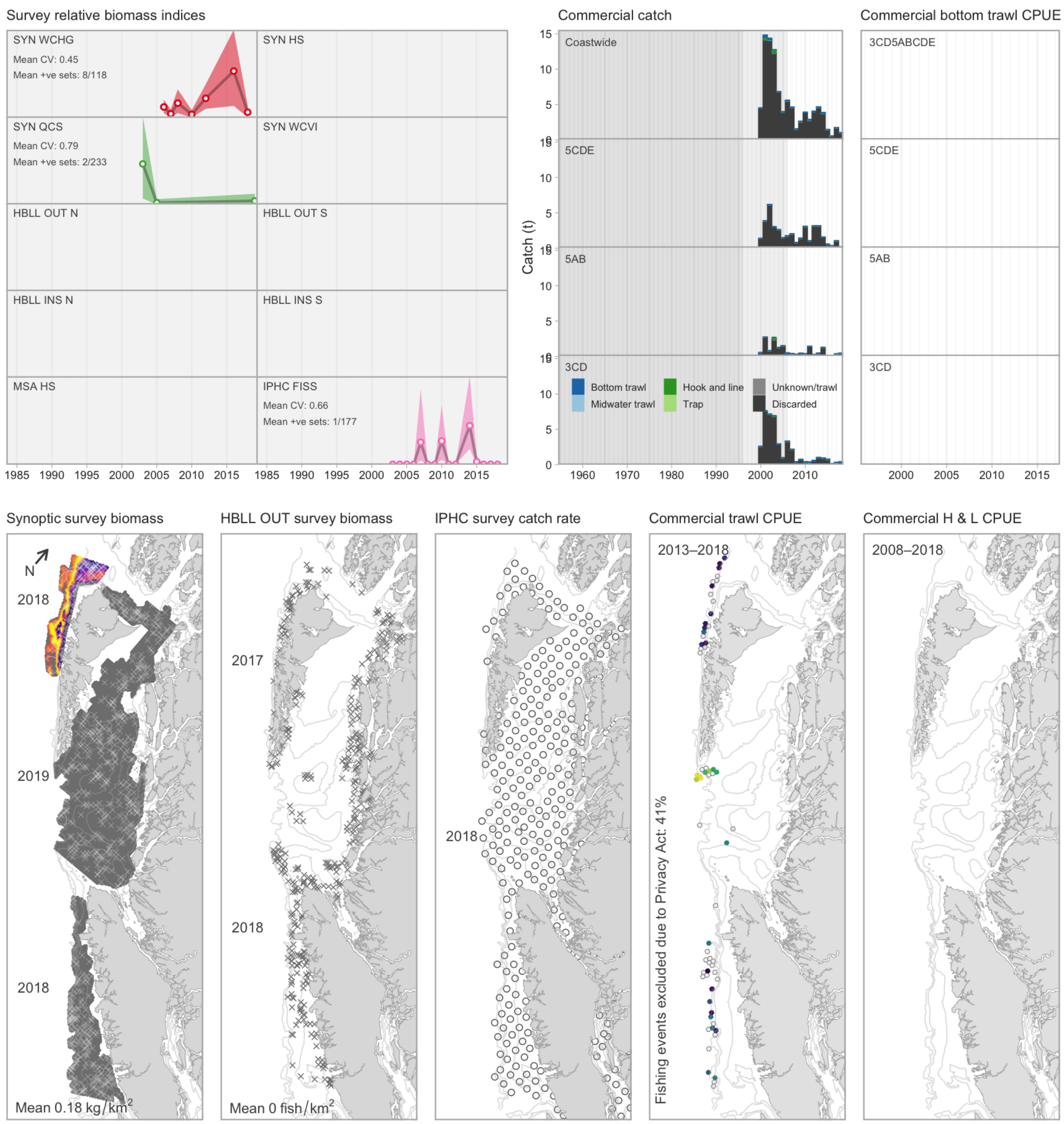


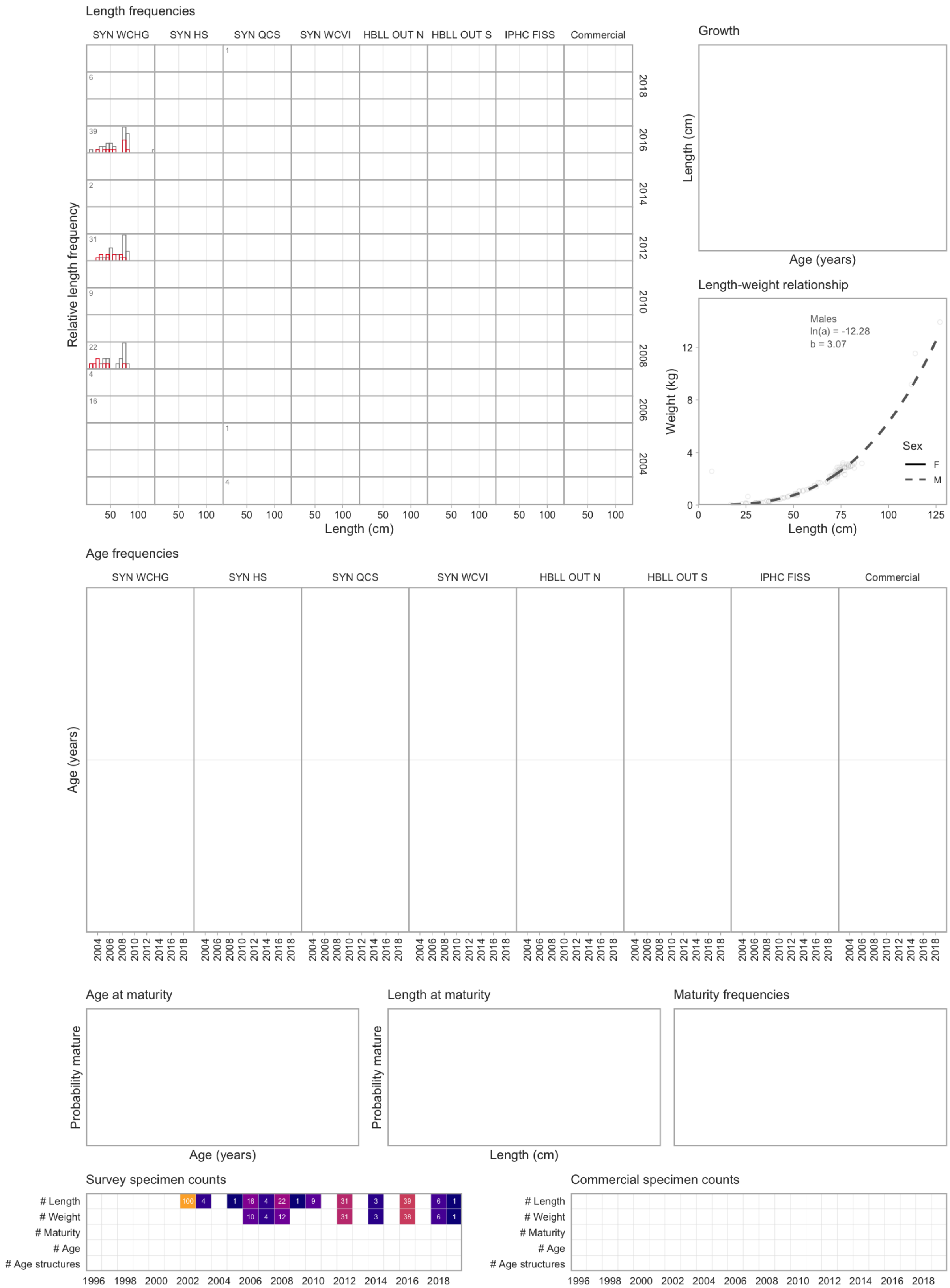


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.72
b = 2.99
Males
ln(a) = -11.60
b = 2.96
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 84.2cm
F 50 = 108.4cm
F 95 = 132.7cm
M 05 = 68.6cm
M 50 = 78.0cm
M 95 = 87.5cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.13 ROUGHTAIL SKATE

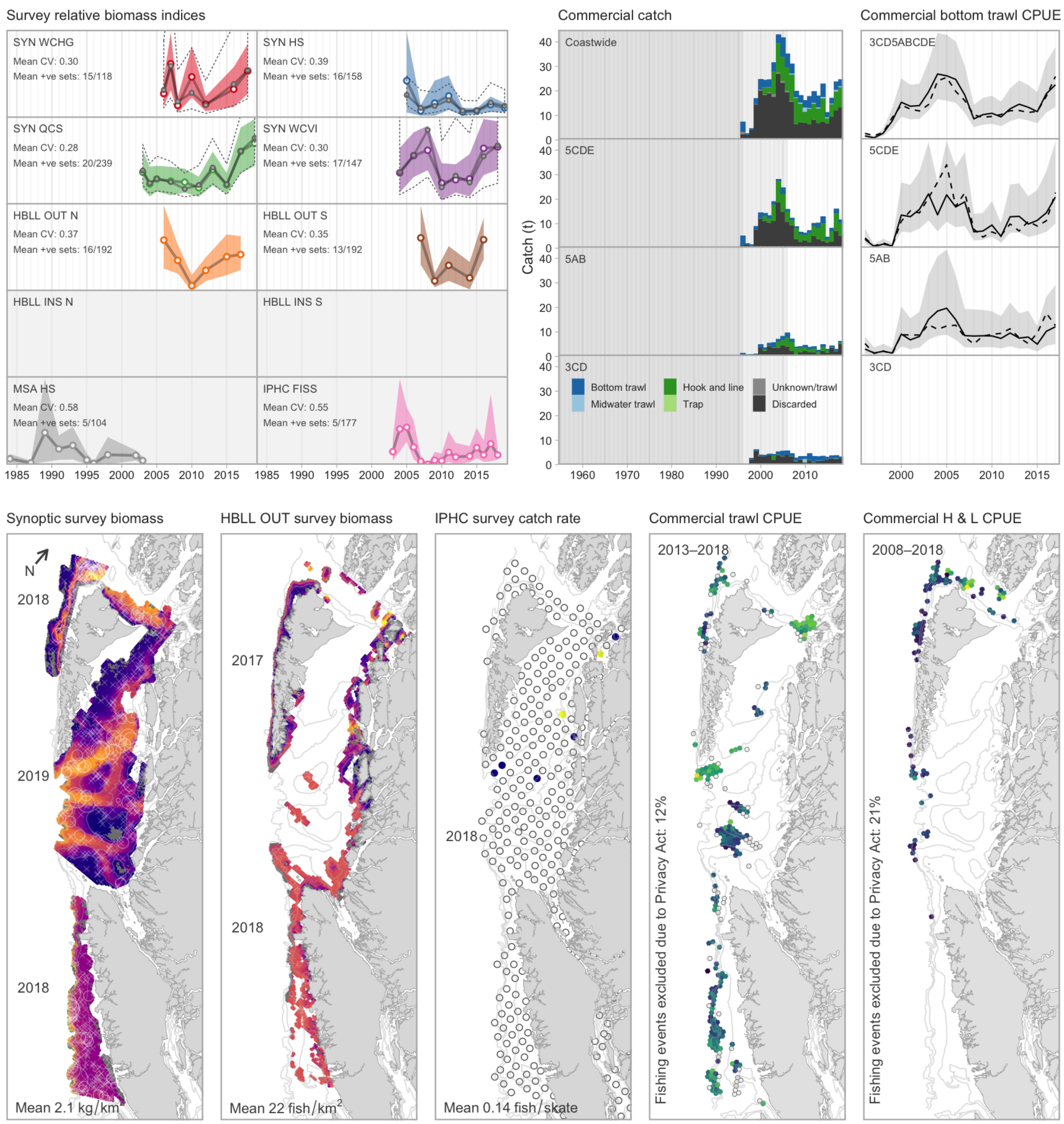
Bathyraja trachura (057)
Order: Rajiformes, Family: Arhynchobatidae, FishBase, WoRMS

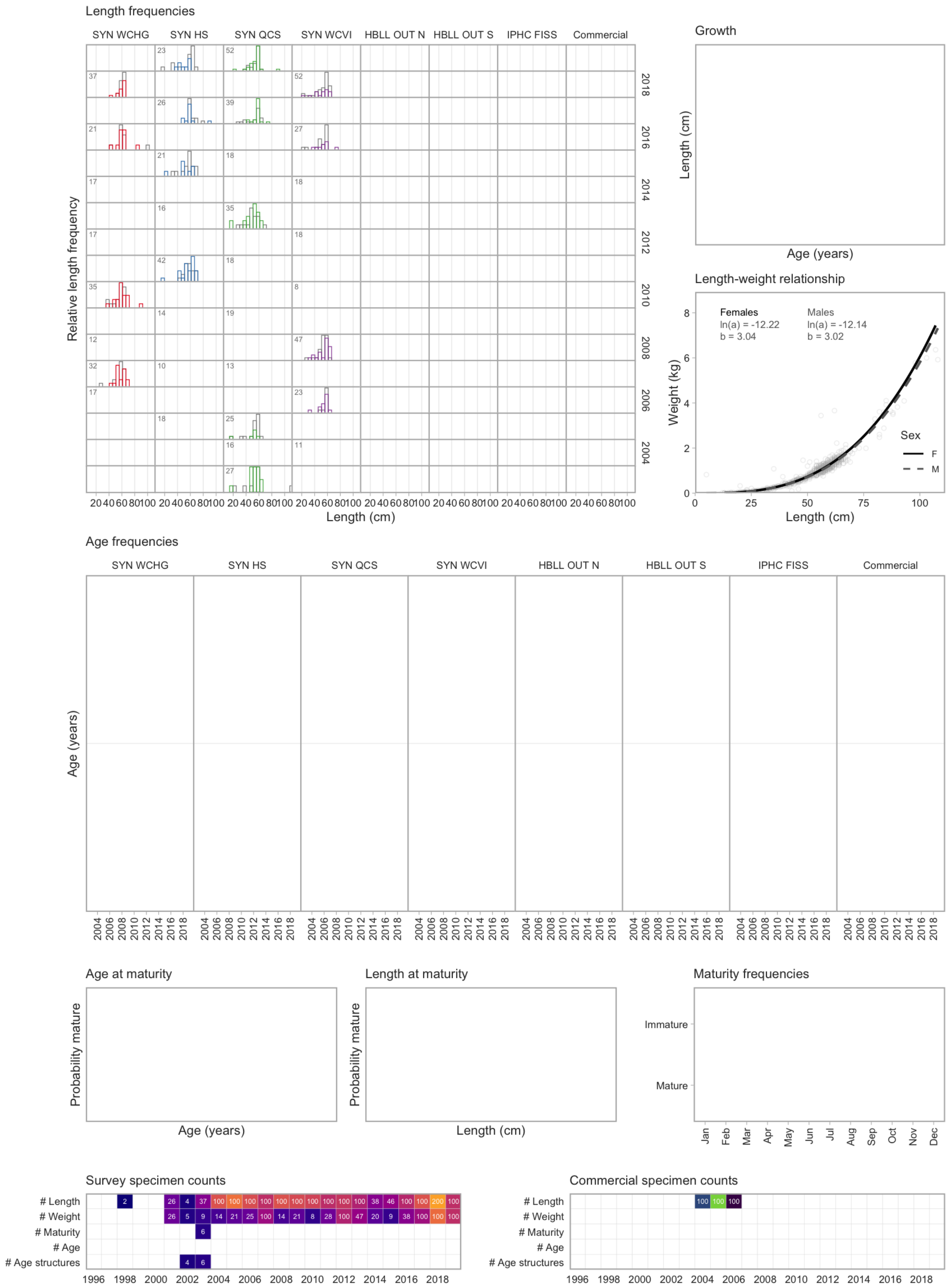



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Males
ln(a) = -12.28
b = 3.07
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.14 SANDPAPER SKATE

Bathyraja interrupta (058)
Order: Rajiformes, Family: Arhynchobatidae, FishBase, WoRMS
COSEWIC Status: Not at Risk

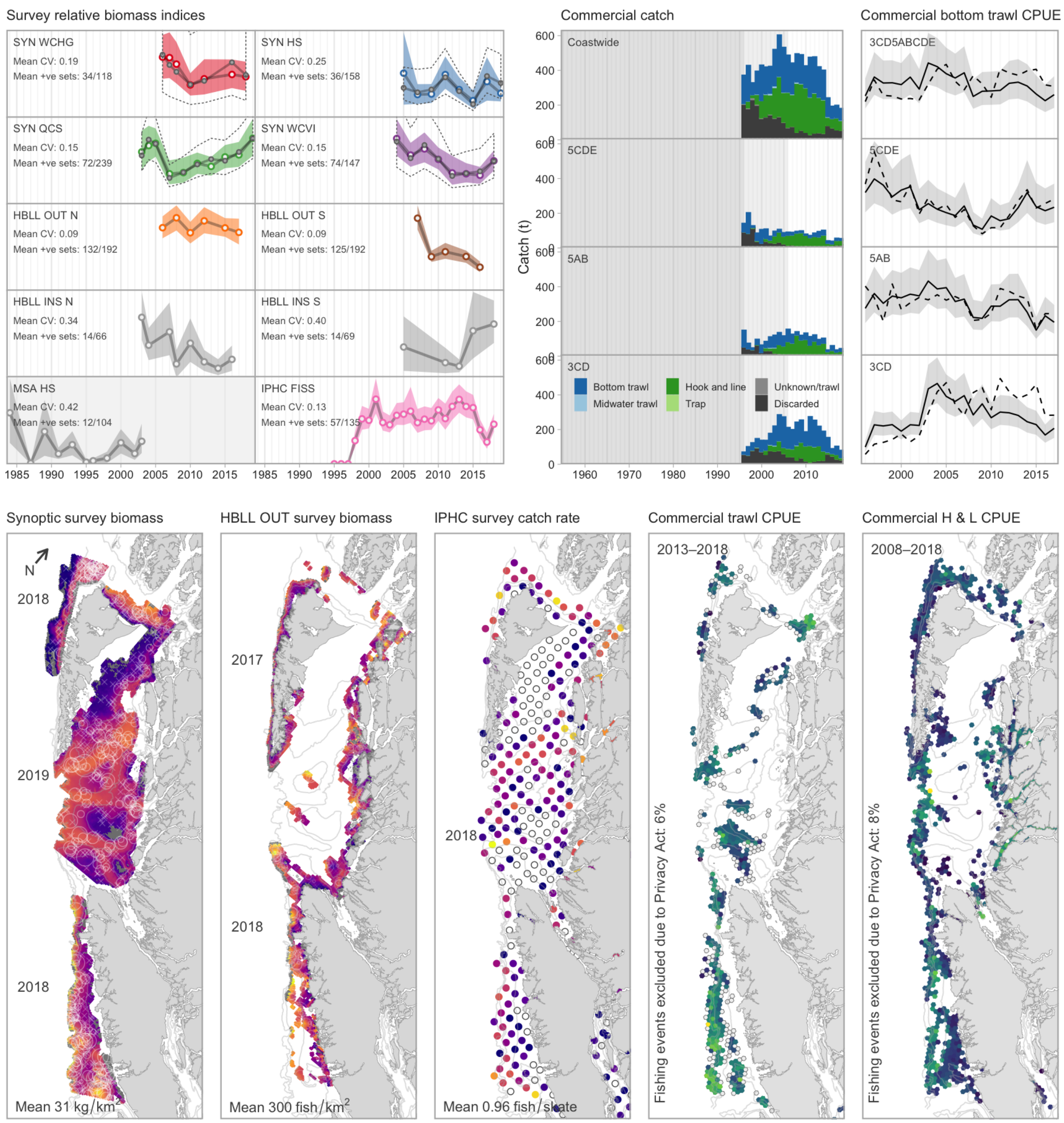


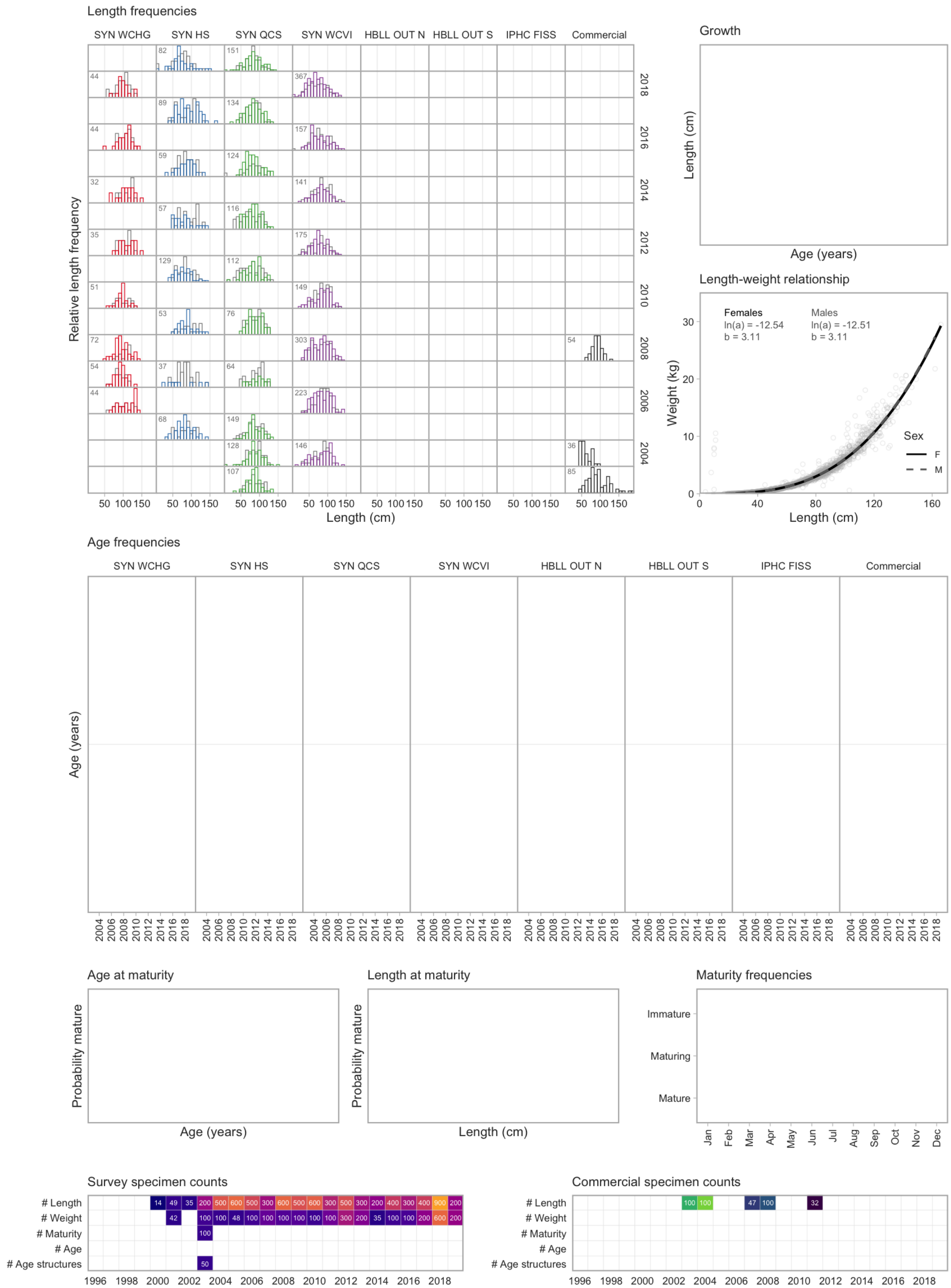


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -12.22
b = 3.04
Males
ln(a) = -12.14
b = 3.02
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Mature
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.15 LONGNOSE SKATE

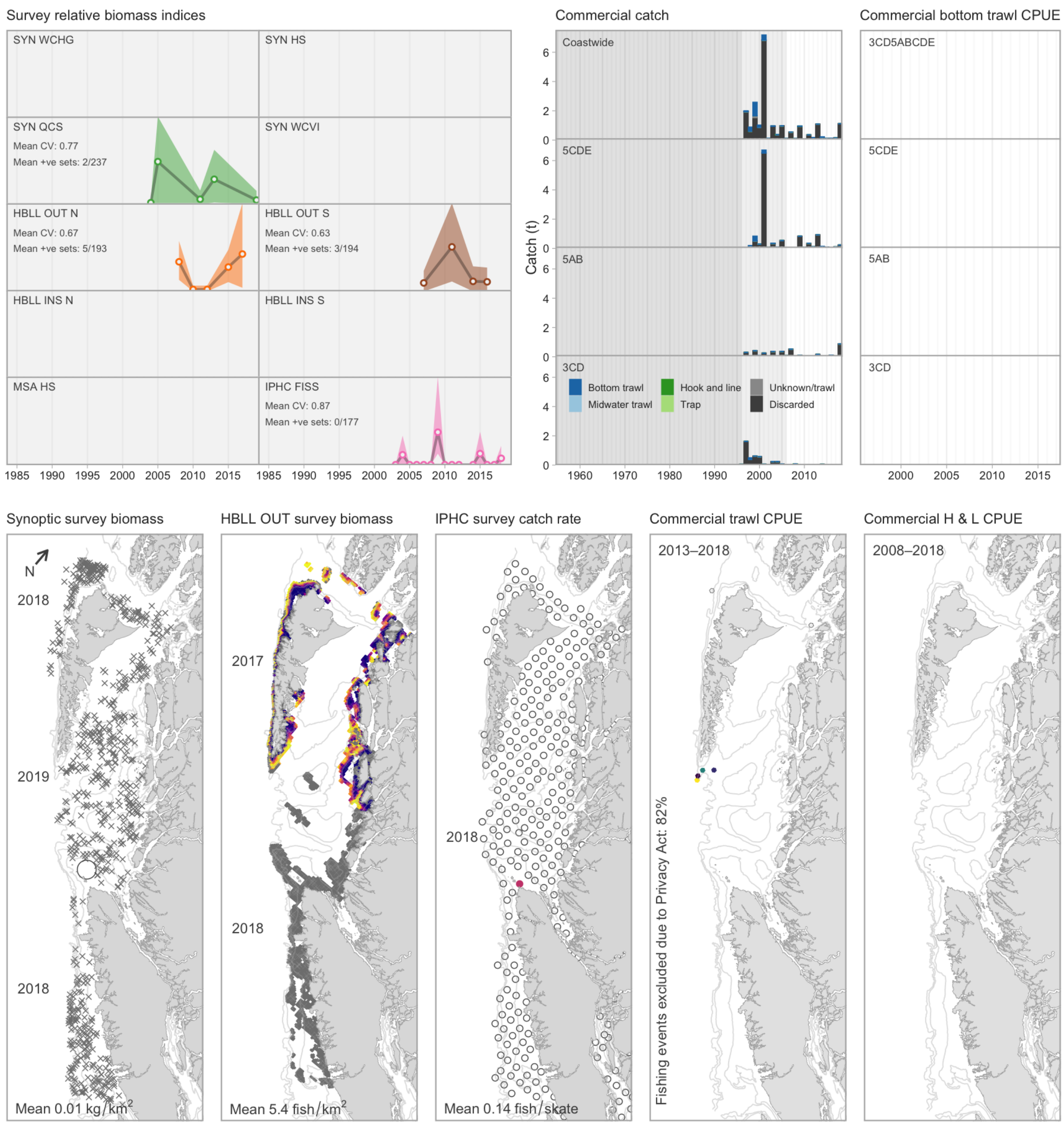
Raja rhina (059)
Order: Rajiformes, Family: Rajidae, FishBase, WoRMS
Last Research Document: King et al. (2015)
Last Science Advisory Report: DFO (2014a)
COSEWIC Status: Not at Risk

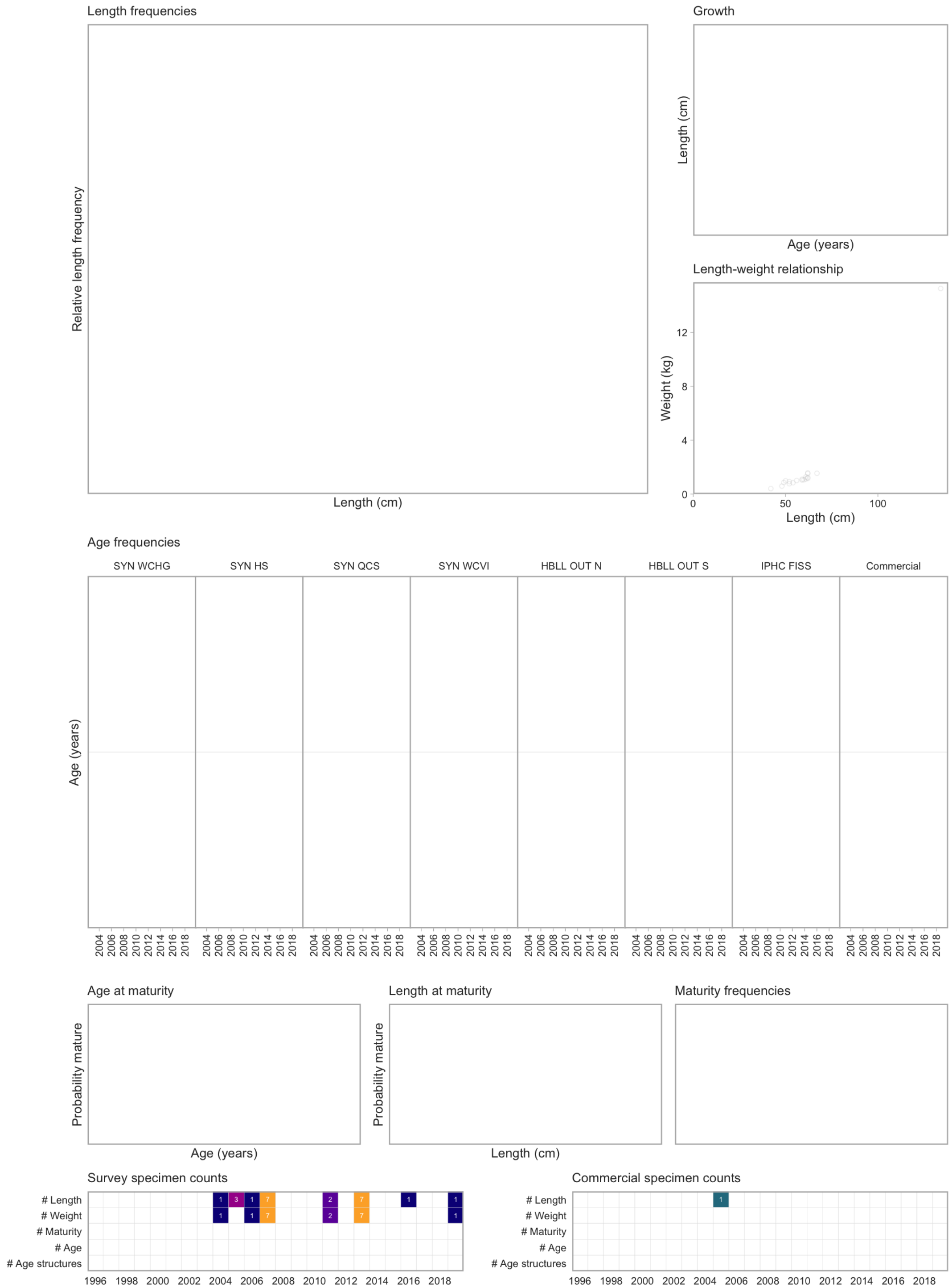



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -12.54
b = 3.11
Males
ln(a) = -12.51
b = 3.11
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.16 ALASKA SKATE

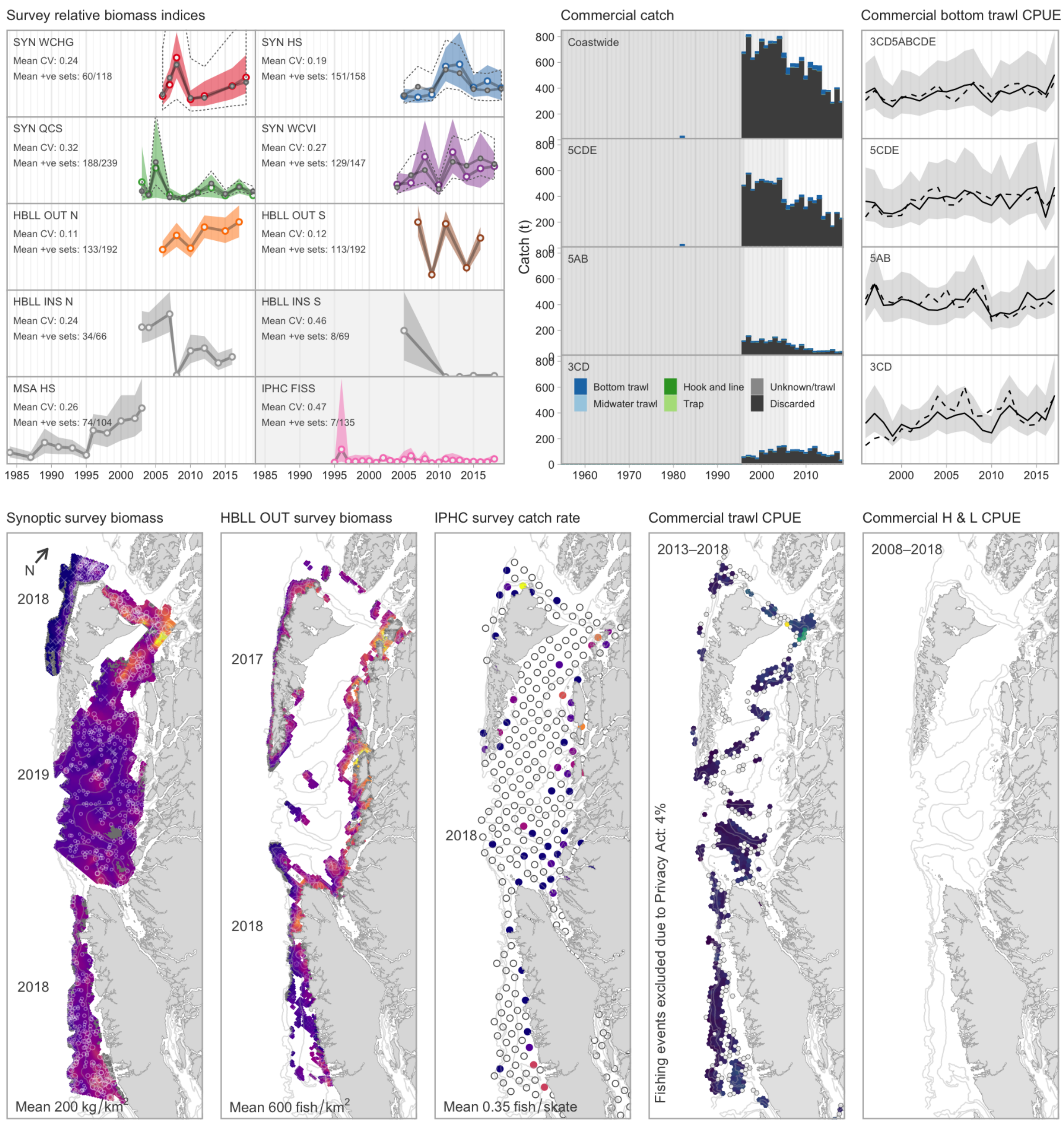
Bathyraja parmifera (061)
Order: Rajiformes, Family: Arhynchobatidae, FishBase, WoRMS




Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
0
4
8
12
0
50
100
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004
2006
2008
2010
2012
2014
2016
2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

5.17 SPOTTED RATFISH

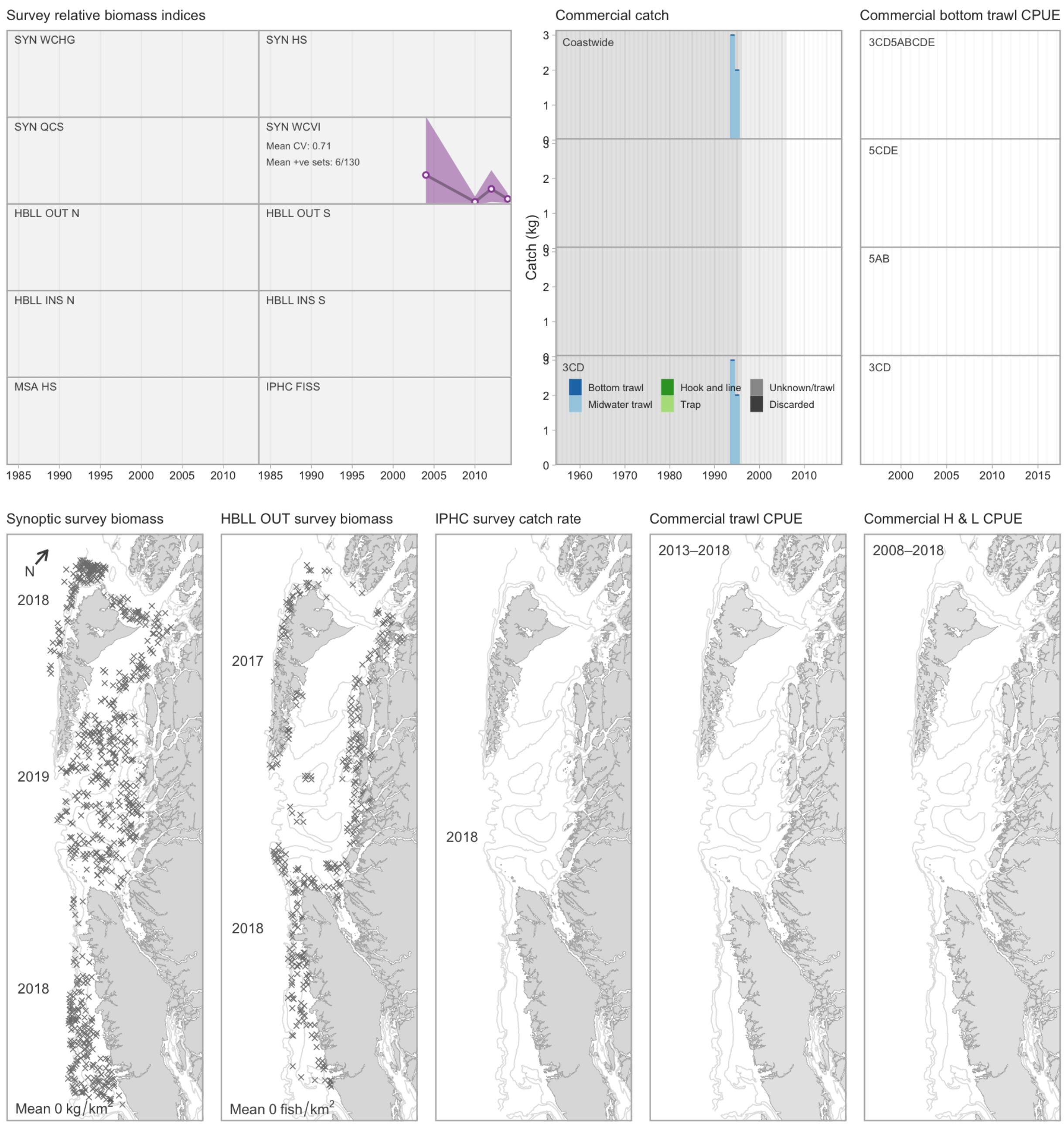
Hydrolagus colliei (066)
Order: Chimaeriformes, Family: Chimaeridae, FishBase, WoRMS

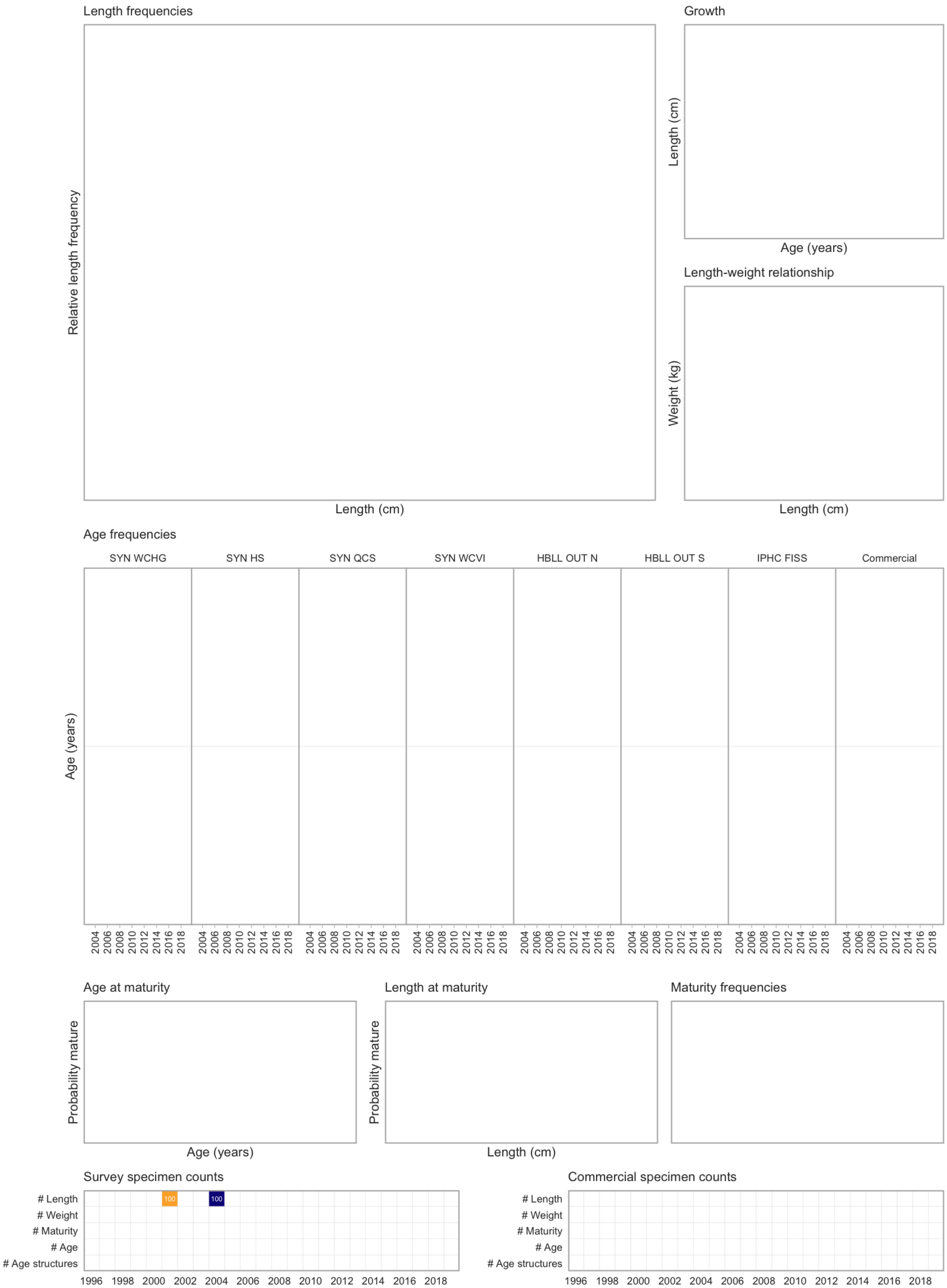



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.19
b = 2.94
Males
ln(a) = -11.25
b = 2.96
Weight (kg)
Sex
F
M
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.18 WHITEBAIT SMELT

Allosmerus elongatus (138)
Order: Osmeriformes, Family: Osmeridae, FishBase, WoRMS

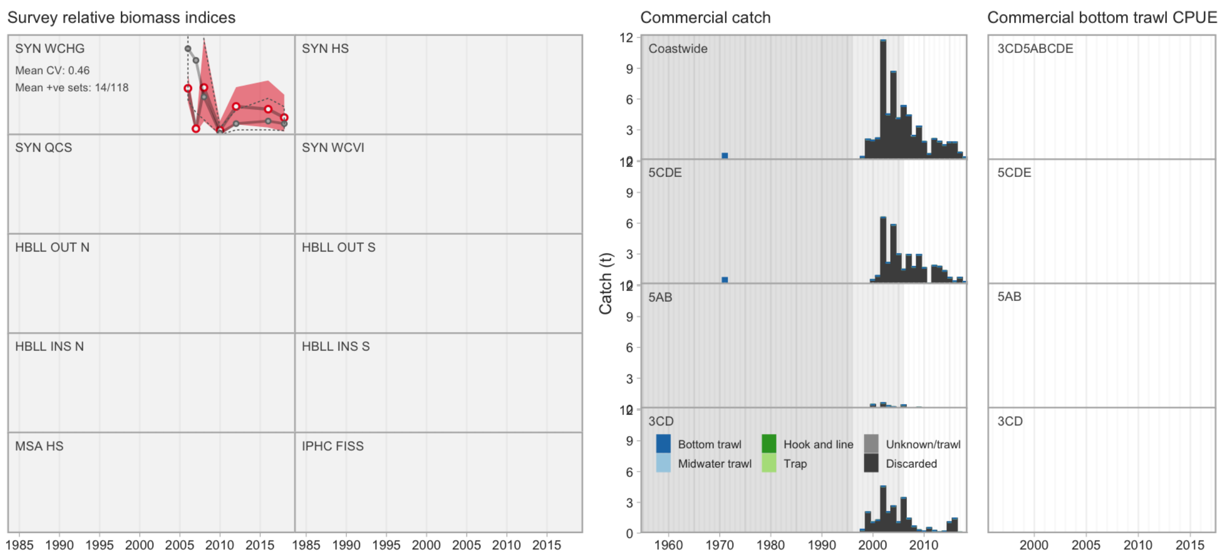


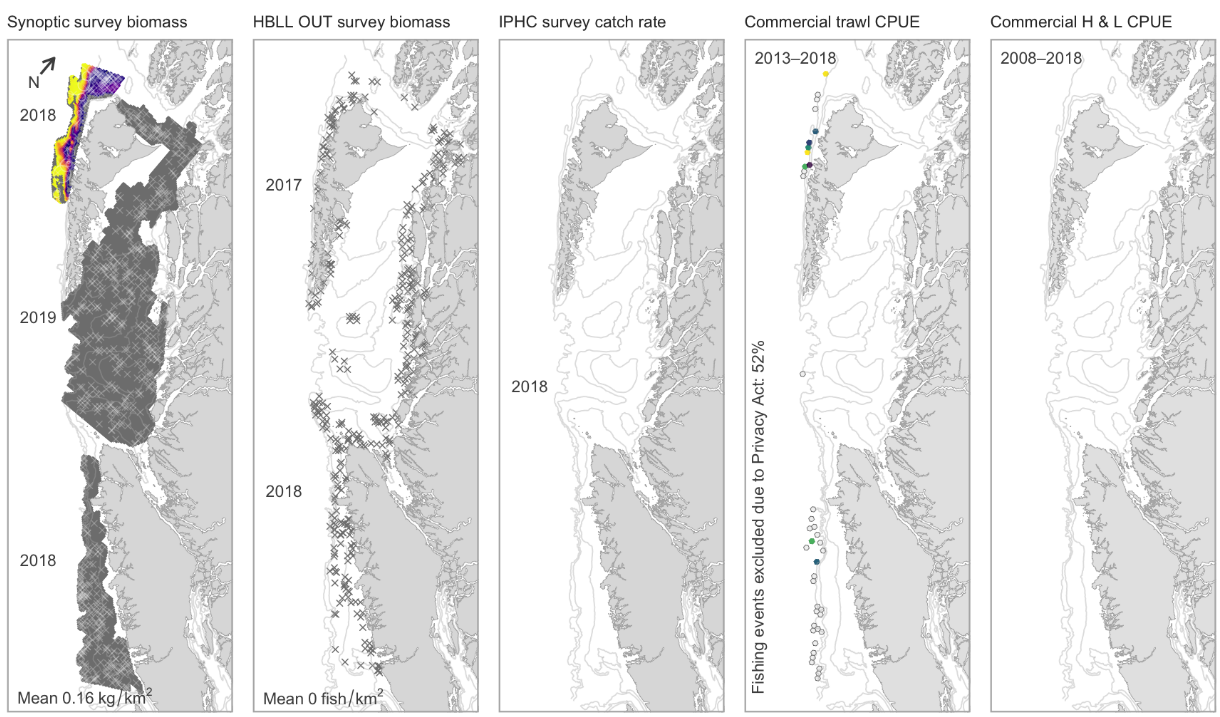


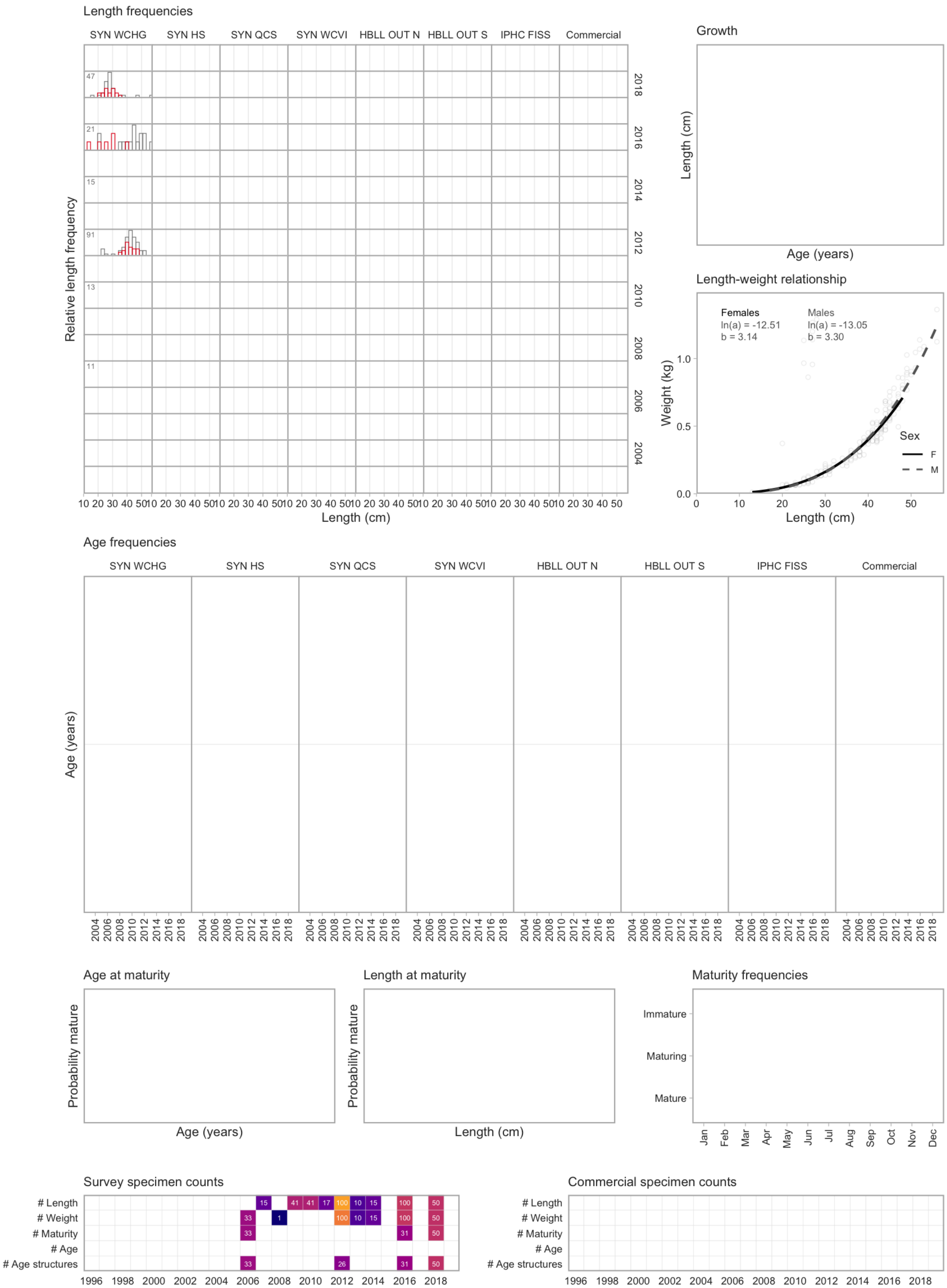
Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
100
100
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.19 PACIFIC FLATNOSE

Antimora microlepis (220)
Order: Gadiformes, Family: Moridae, FishBase, WoRMS

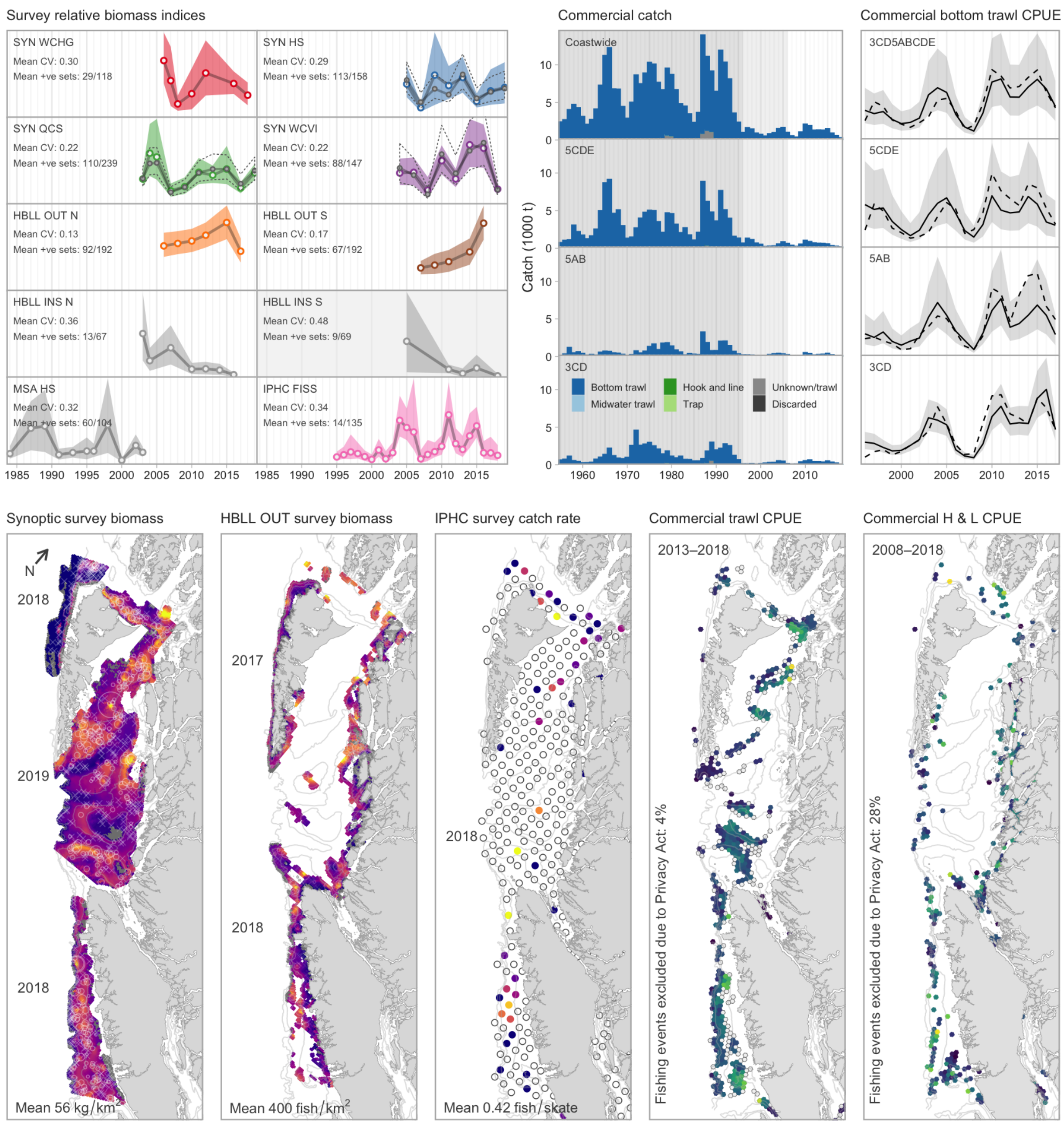


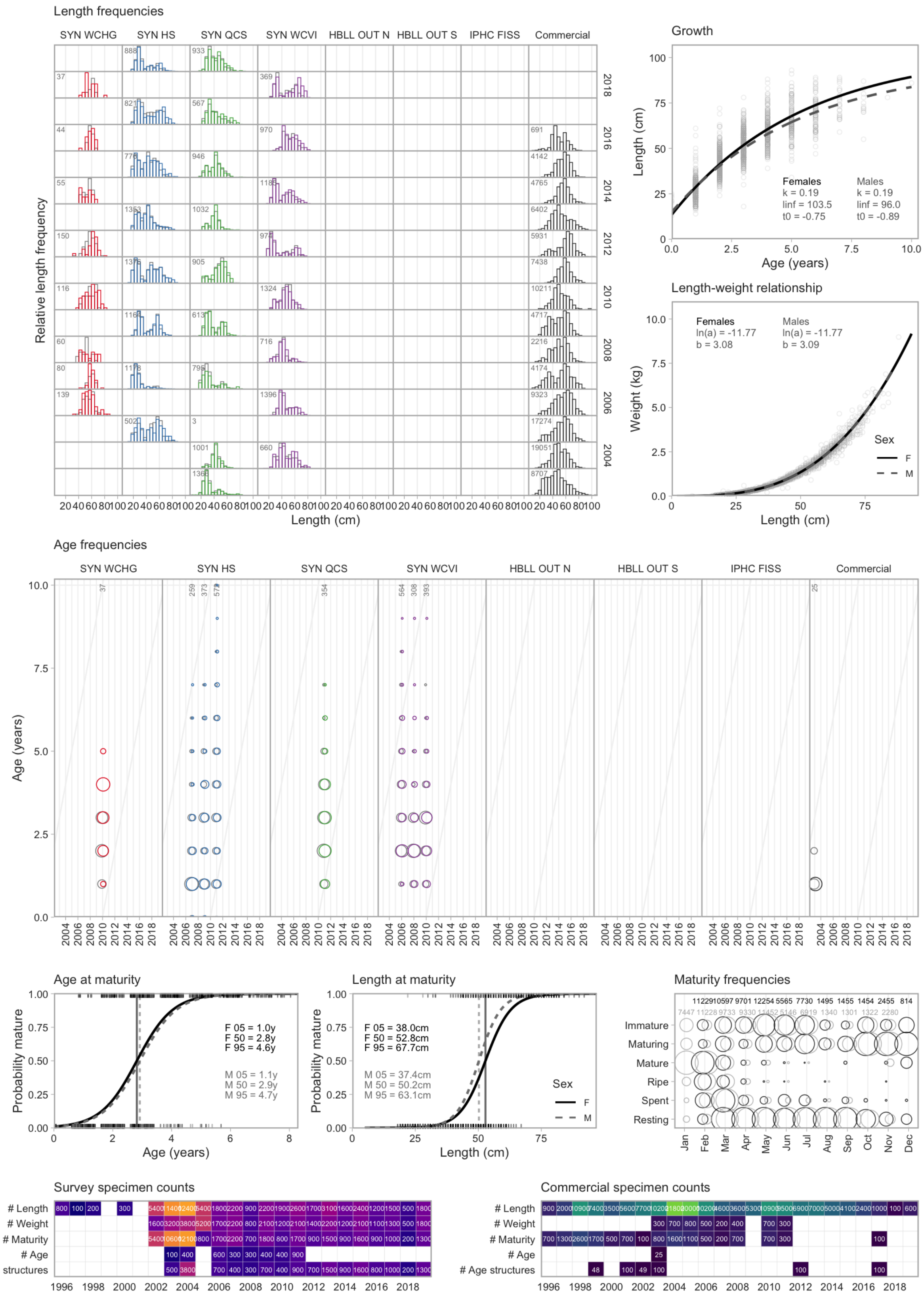



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
47
21
15
91
13
11
2018
2016
2014
2012
2010
2008
2006
2004
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -12.51
b = 3.14
Males
ln(a) = -13.05
b = 3.30
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
15
41
41
17
100
10
15
100
50
33
1
100
10
15
100
50
33
31
50
33
26
31
50
Commercial specimen counts

5.20 PACIFIC COD

Gadus macrocephalus (222)
Order: Gadiformes, Family: Gadidae, FishBase, WoRMS
Last Research Document: Forrest et al. (2019)
Last Science Advisory Report: DFO (2019a)

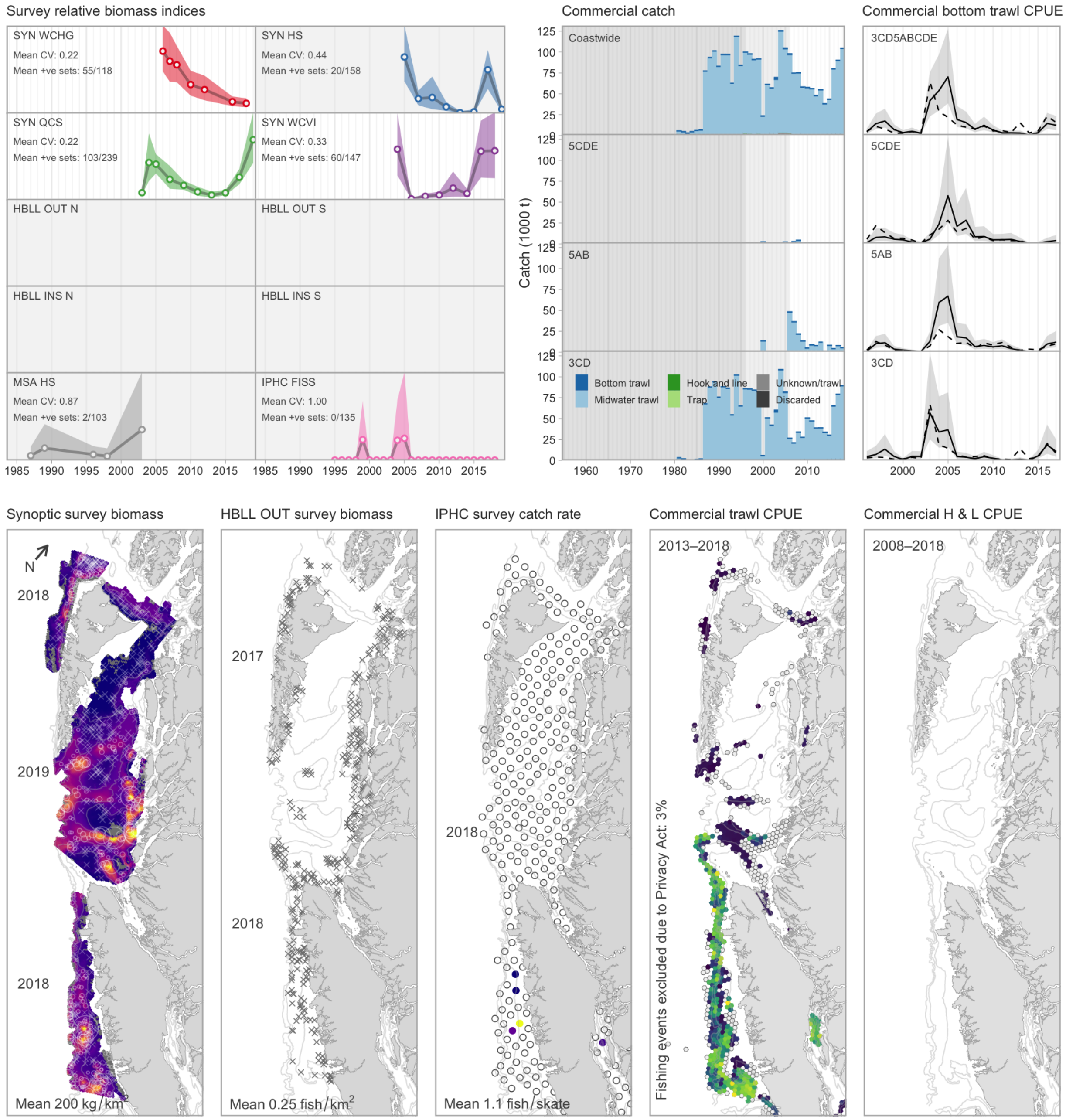


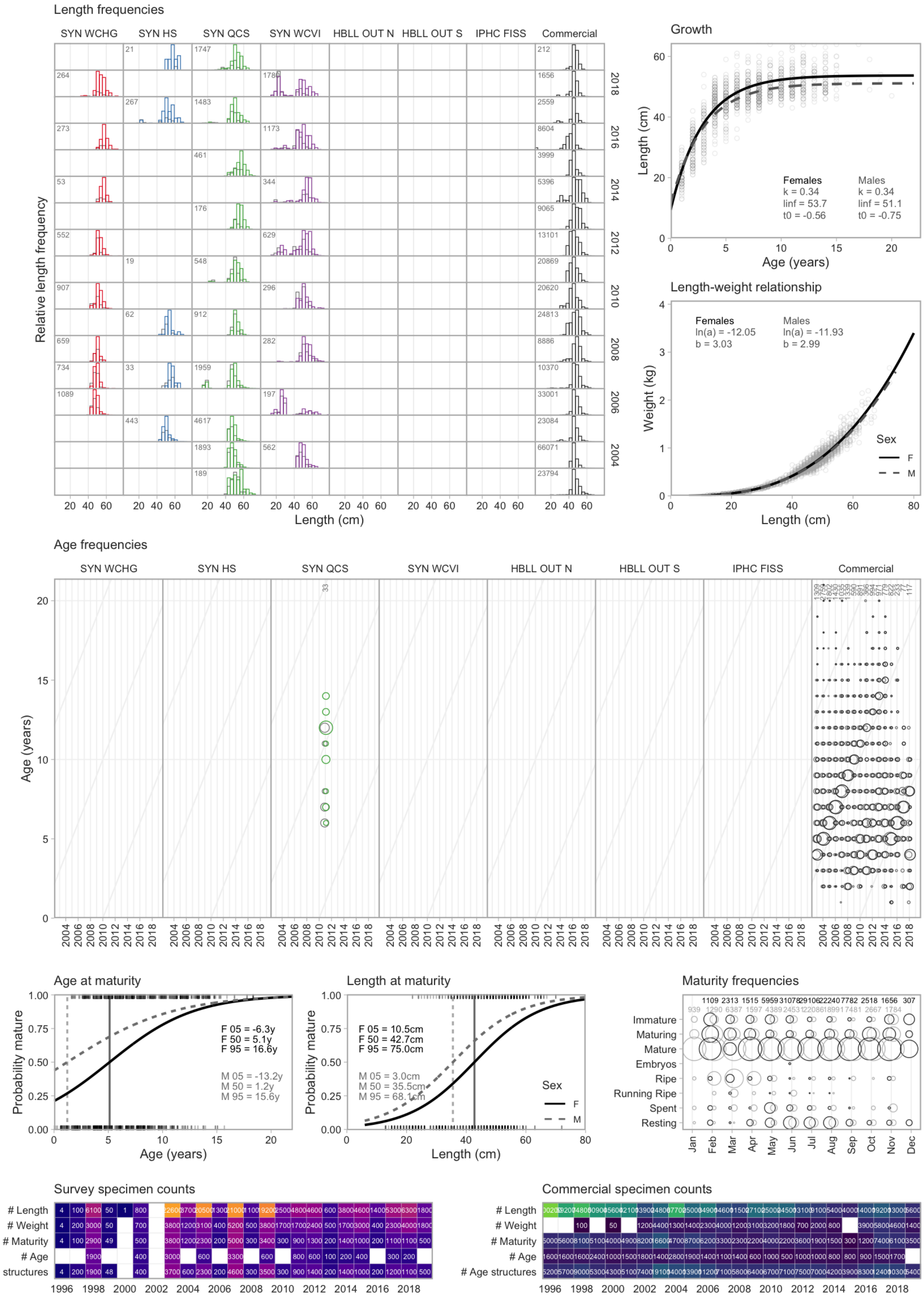


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.19
linf = 103.5
t0 = -0.75
Males
k = 0.19
linf = 96.0
t0 = -0.89
Length-weight relationship
Females
ln(a) = -11.77
b = 3.08
Males
ln(a) = -11.77
b = 3.09
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 1.0y
F 50 = 2.8y
F 95 = 4.6y
M 05 = 1.1y
M 50 = 2.9y
M 95 = 4.7y
Length at maturity
Probability mature
Length (cm)
F 05 = 38.0cm
F 50 = 52.8cm
F 95 = 67.7cm
M 05 = 37.4cm
M 50 = 50.2cm
M 95 = 63.1cm
Maturity frequencies
Immature
Maturing
Mature
Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.21 PACIFIC HAKE

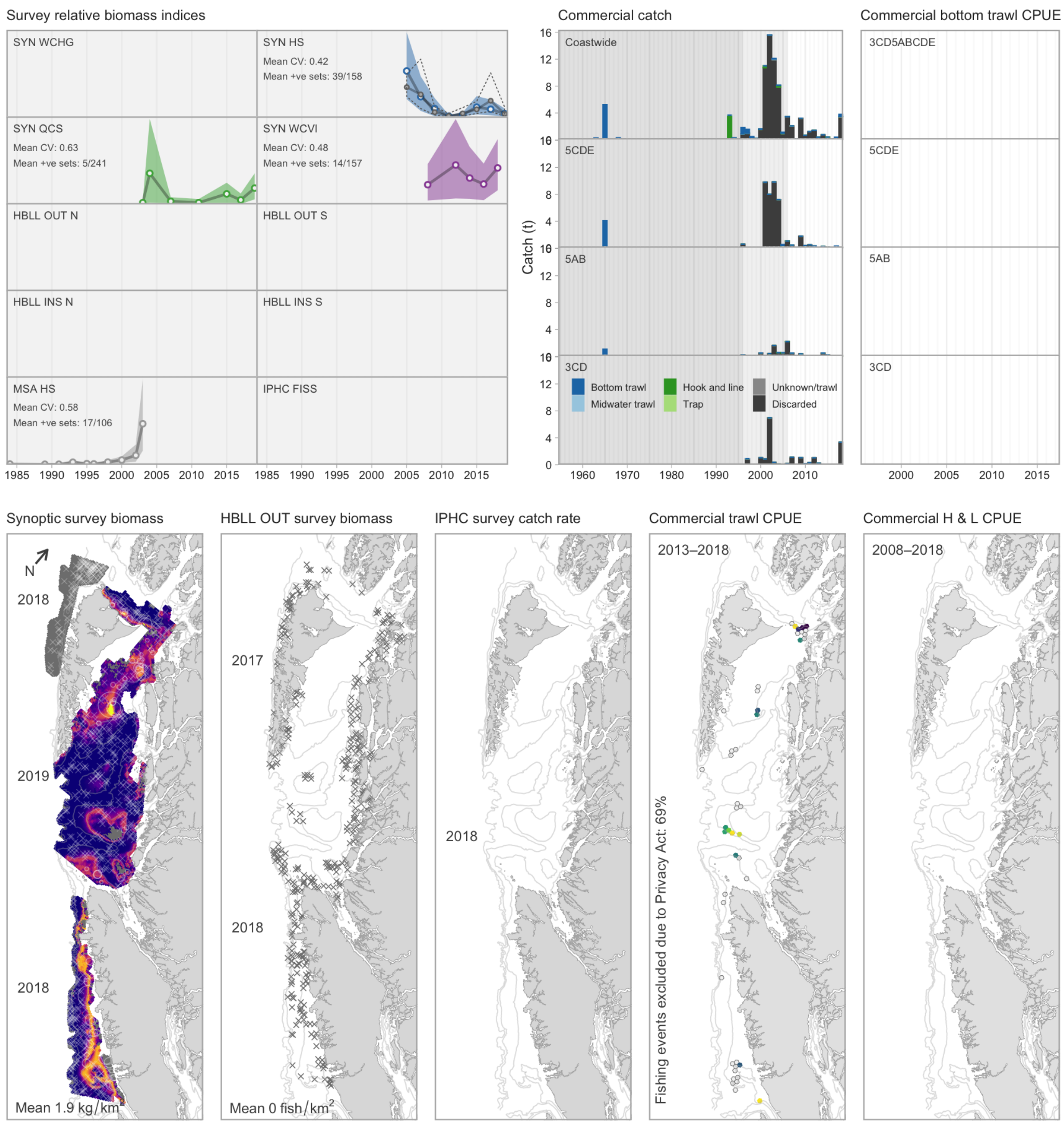
Merluccius productus (225)
Order: Gadiformes, Family: Merlucciidae, FishBase, WoRMS
Last Research Document: Edwards et al. (2018)
Note that Pacific Hake undergoes a directed joint Canada-US coastwide survey and annual assessment, which are not included in this report. The most recent stock assessment should be consulted for details on stock status.

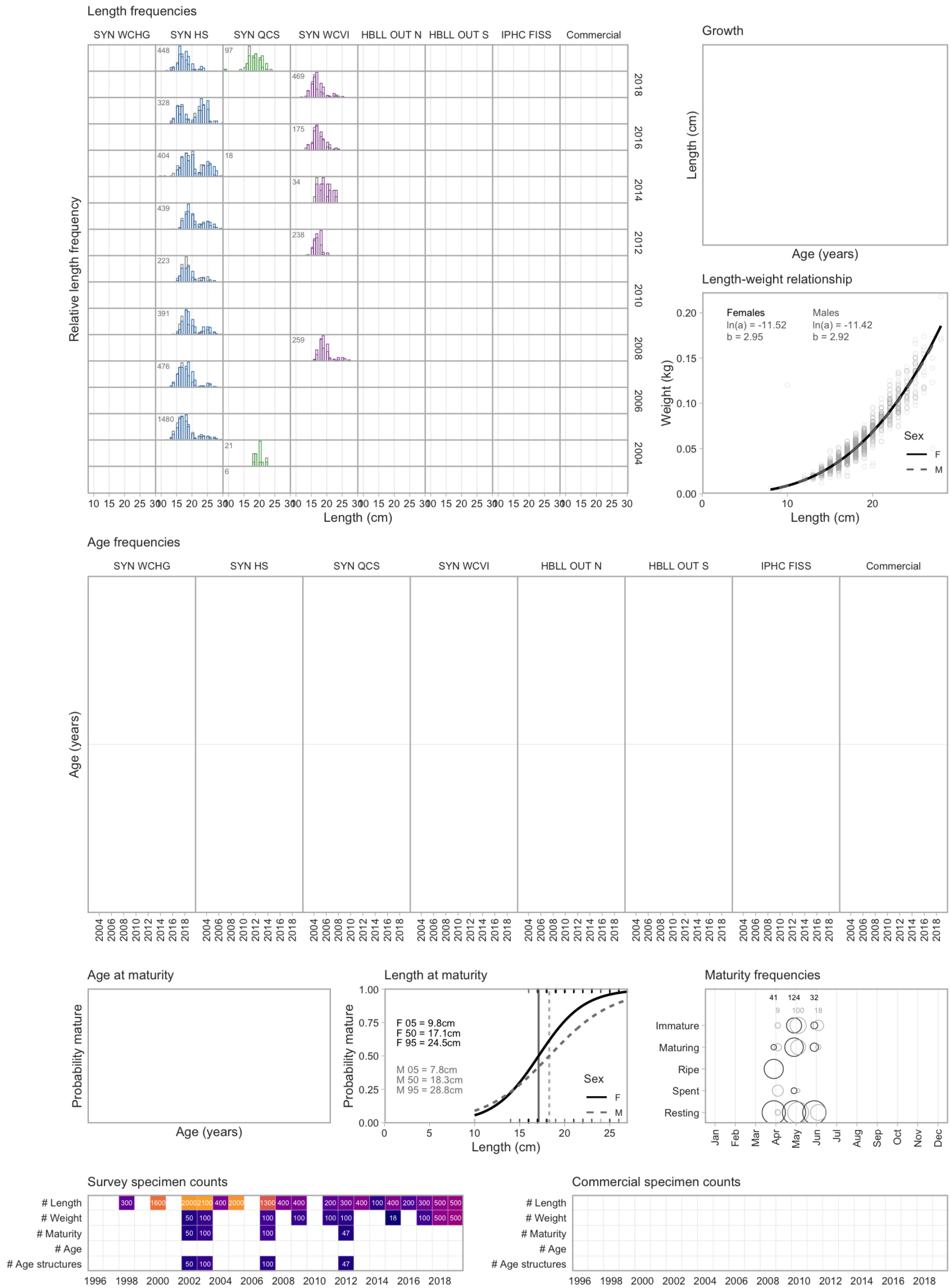



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.34
linf = 53.7
t0 = -0.56
Males
k = 0.34
linf = 51.1
t0 = -0.75
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -12.05
b = 3.03
Males
ln(a) = -11.93
b = 2.99
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = -6.3y
F 50 = 5.1y
F 95 = 16.6y
M 05 = -13.2y
M 50 = 1.2y
M 95 = 15.6y
Length at maturity
Probability mature
Length (cm)
F 05 = 10.5cm
F 50 = 42.7cm
F 95 = 75.0cm
M 05 = 3.0cm
M 50 = 35.5cm
M 95 = 68.1cm
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Survey specimen counts
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.22 PACIFIC TOMCOD

Microgadus proximus (226)
Order: Gadiformes, Family: Gadidae, FishBase, WoRMS

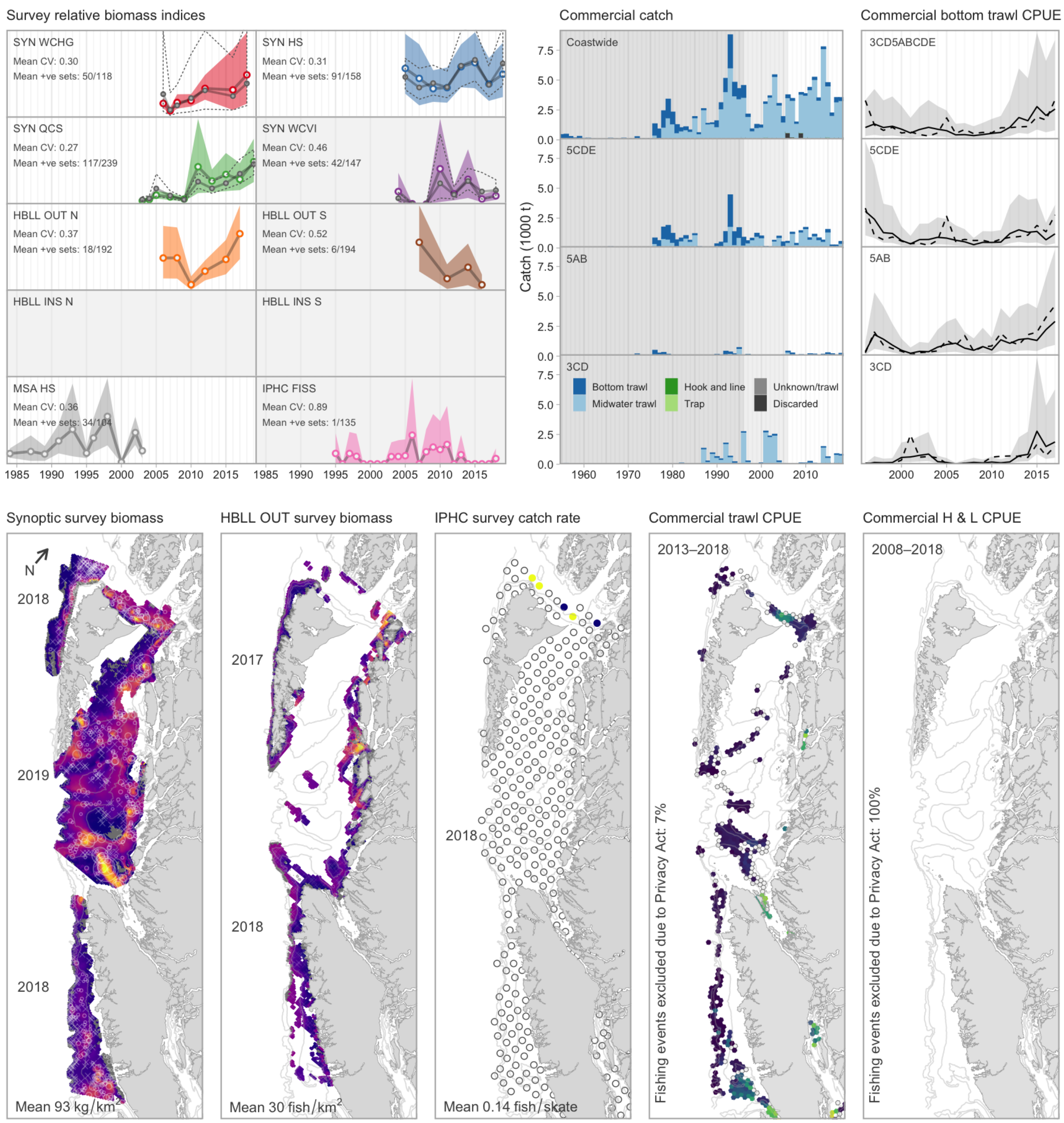


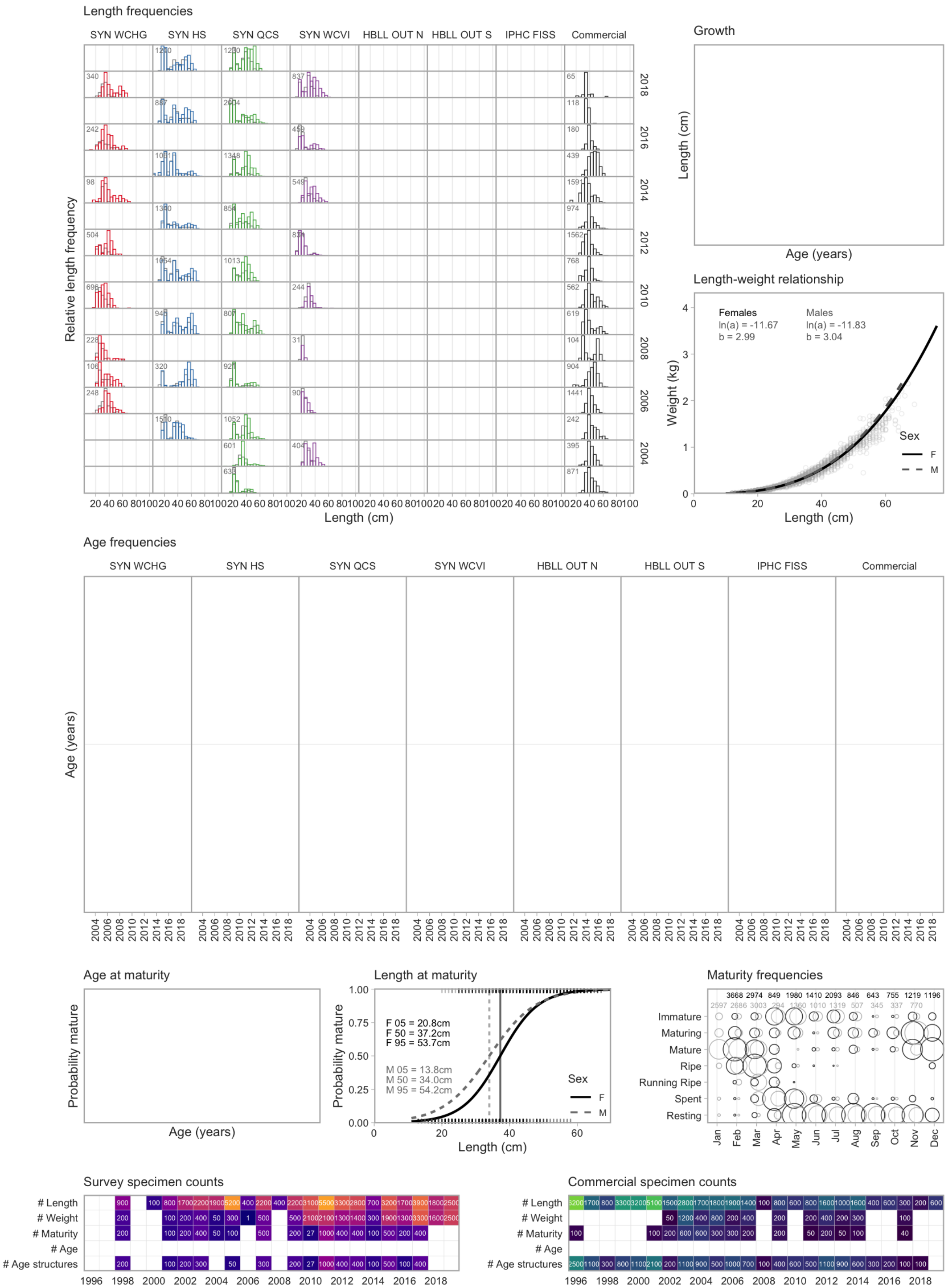


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.52
b = 2.95
Males
ln(a) = -11.42
b = 2.92
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 9.8cm
F 50 = 17.1cm
F 95 = 24.5cm
M 05 = 7.8cm
M 50 = 18.3cm
M 95 = 28.8cm
Length (cm)
Maturity frequencies
Immature
Maturing
Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.23 WALLEYE POLLOCK

Gadus chalcogrammus (228)
Order: Gadiformes, Family: Gadidae, FishBase, WoRMS
Last Research Document: Starr and Haigh (2019)
Last Science Advisory Report: DFO (2018a)
Pacific Scientific Advice Review Committee (PSARC) assessment: Saunders and Andrews (1998)

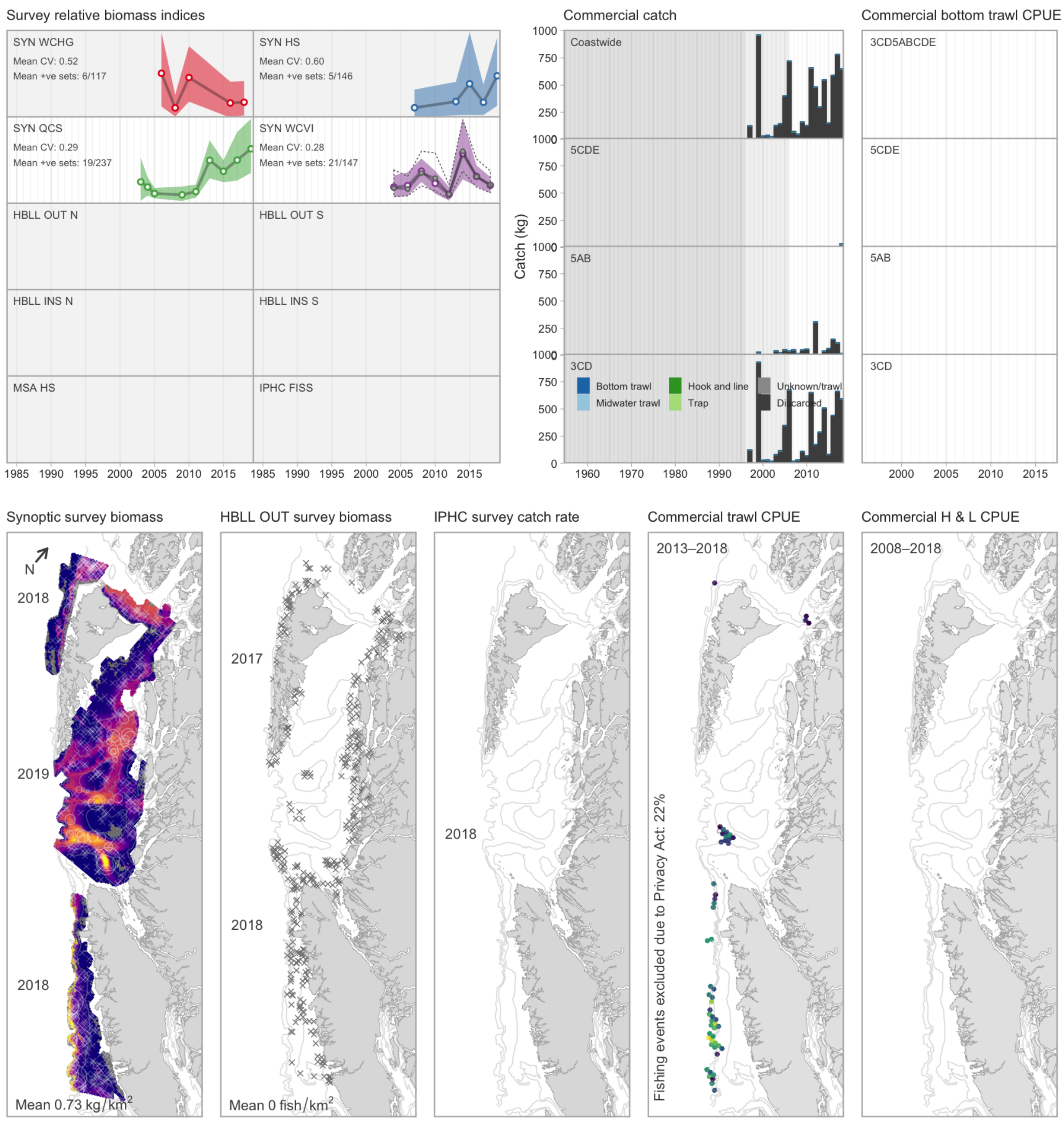


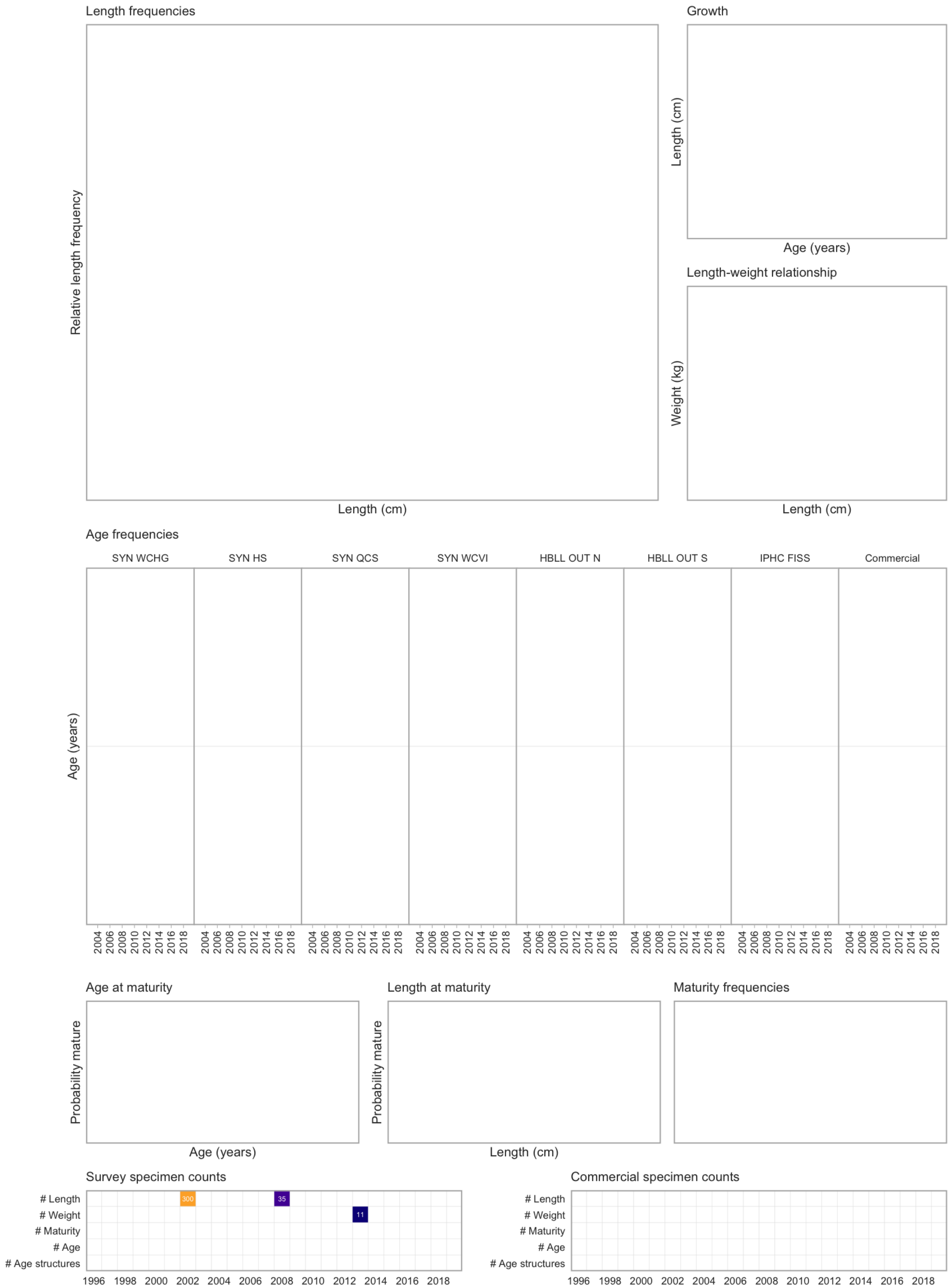


Length frequencies
Growth
Length-weight relationship
Females
ln(a) = -11.67
b = 2.99
Males
ln(a) = -11.83
b = 3.04
Age frequencies
Age at maturity
Length at maturity
F 05 = 20.8cm
F 50 = 37.2cm
F 95 = 53.7cm
M 05 = 13.8cm
M 50 = 34.0cm
M 95 = 54.2cm
Maturity frequencies
Survey specimen counts
Commercial specimen counts

5.24 BIGFIN EELPOUT

Lycodes cortezianus (233)
Order: Perciformes, Family: Zoarcidae, FishBase, WoRMS

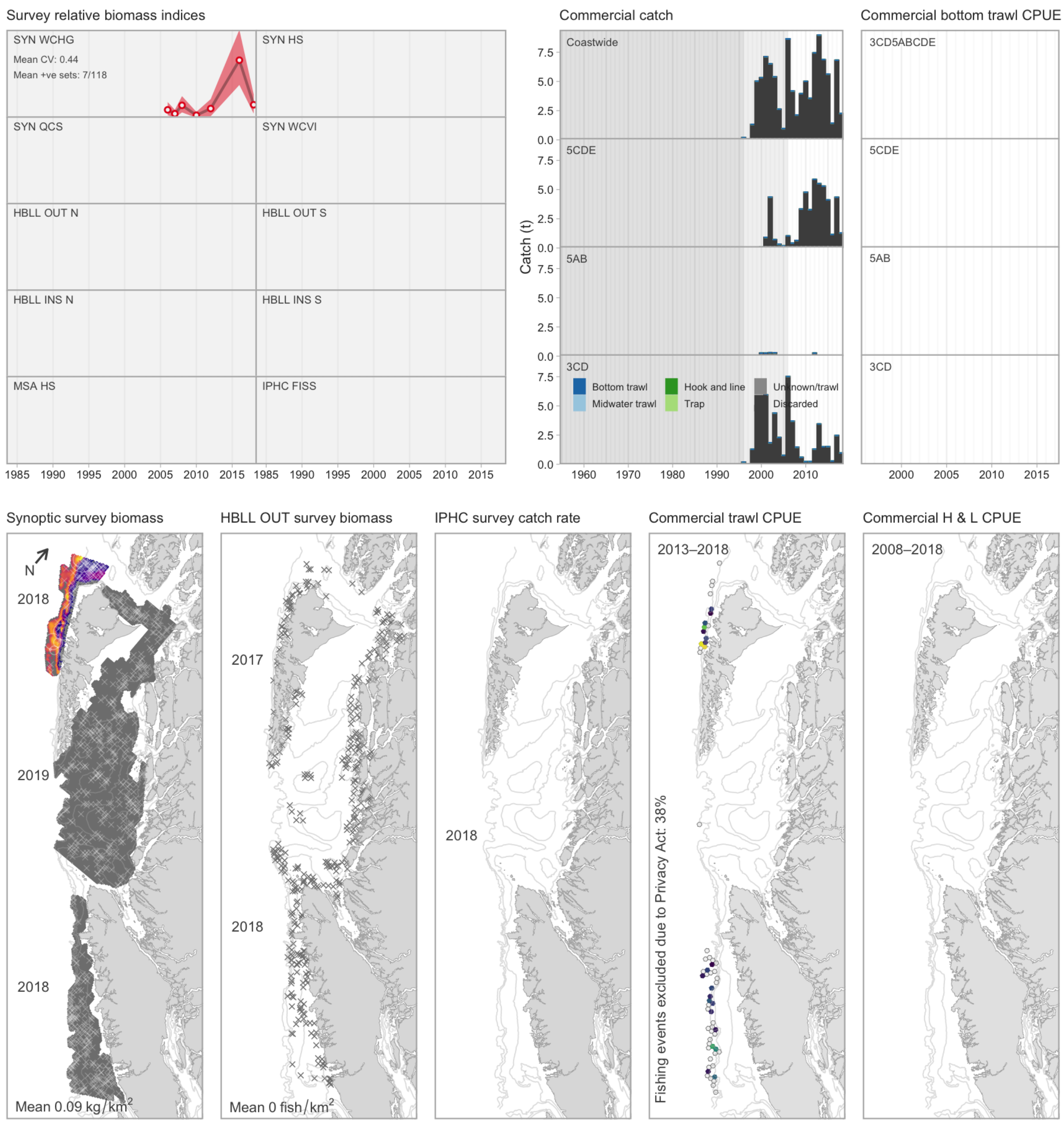


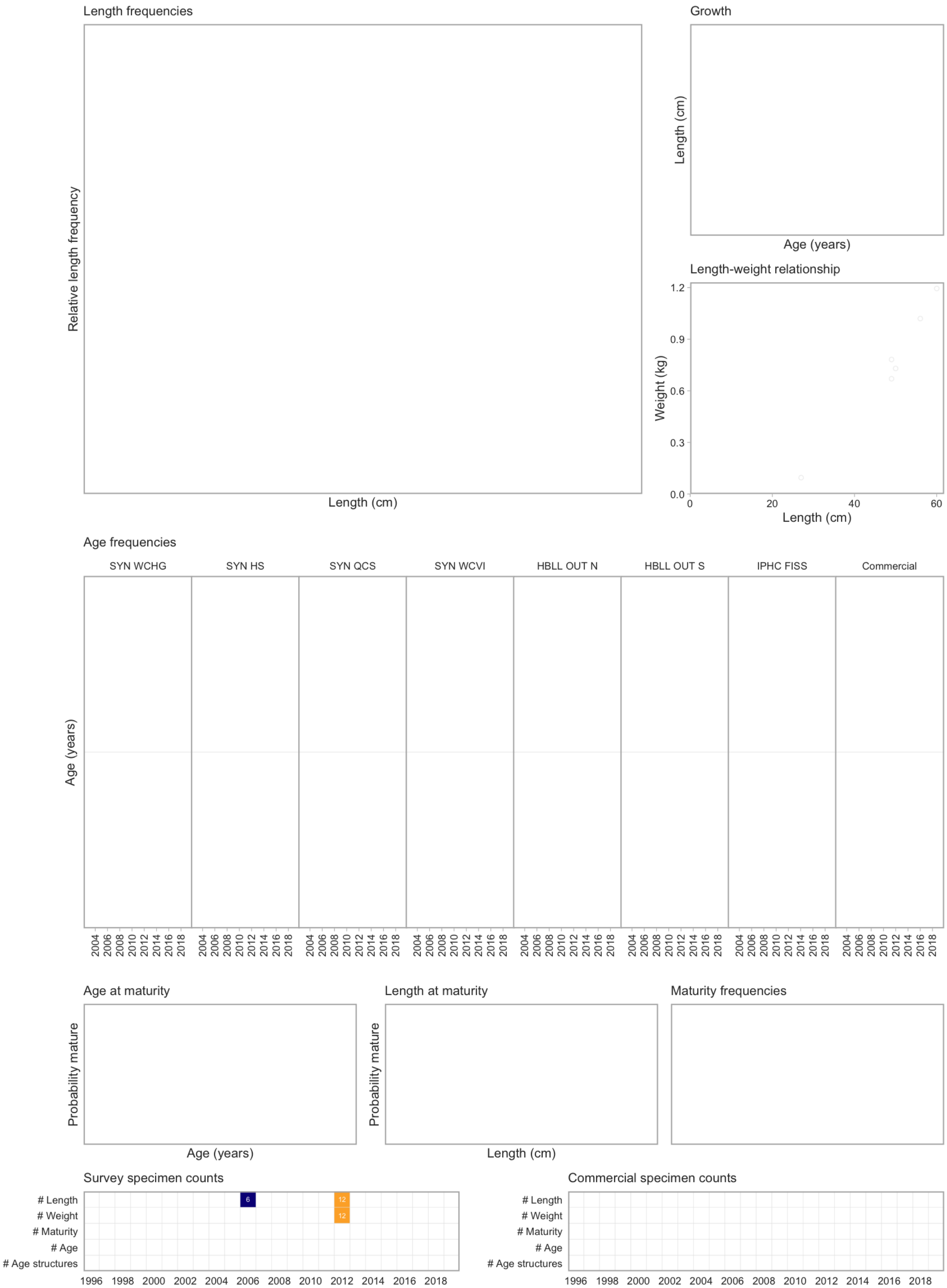


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
300
35
11
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.25 TWOLINE EELPOUT

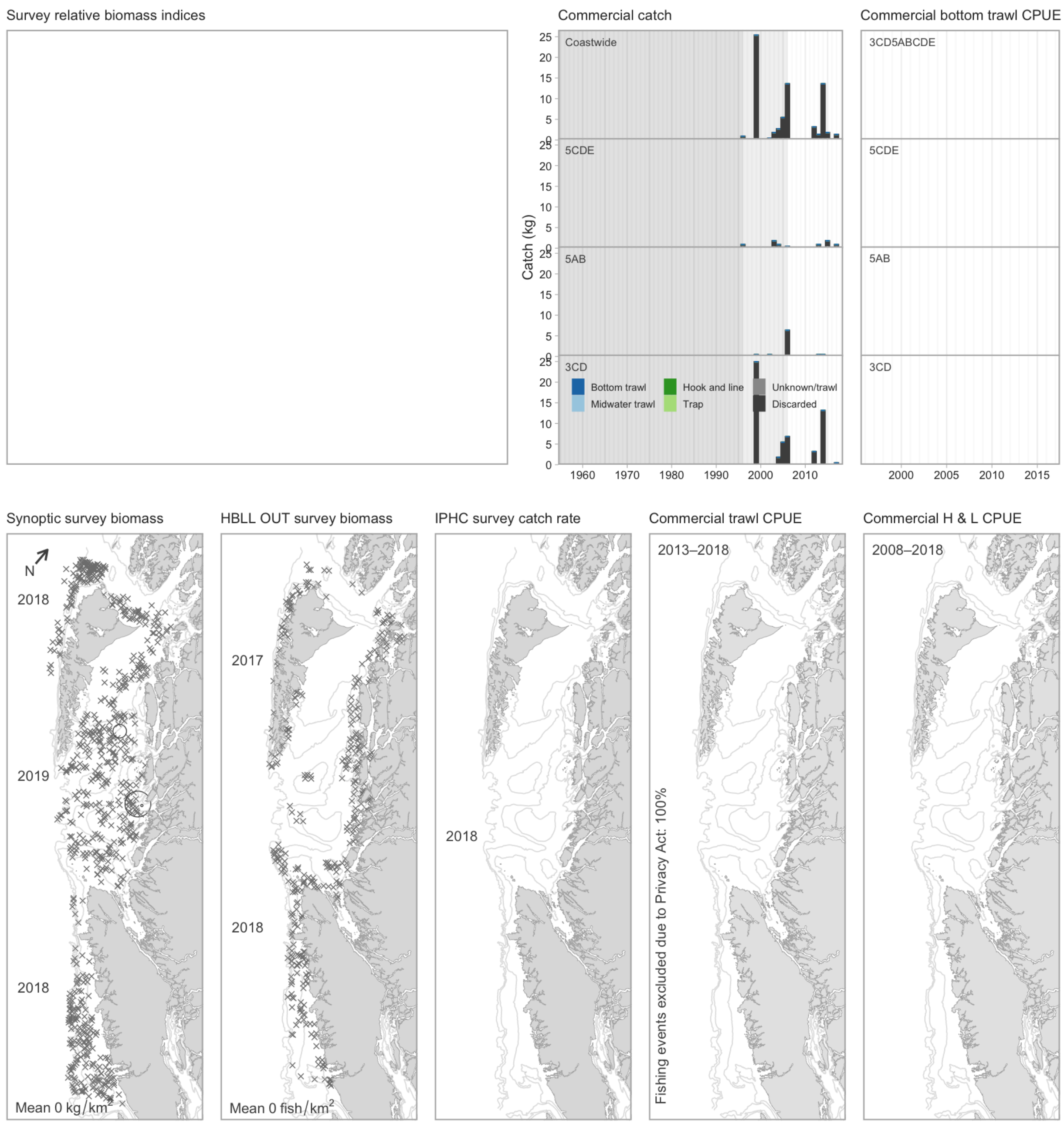
Bothrocara brunneum (235)
Order: Perciformes, Family: Zoarcidae, FishBase, WoRMS

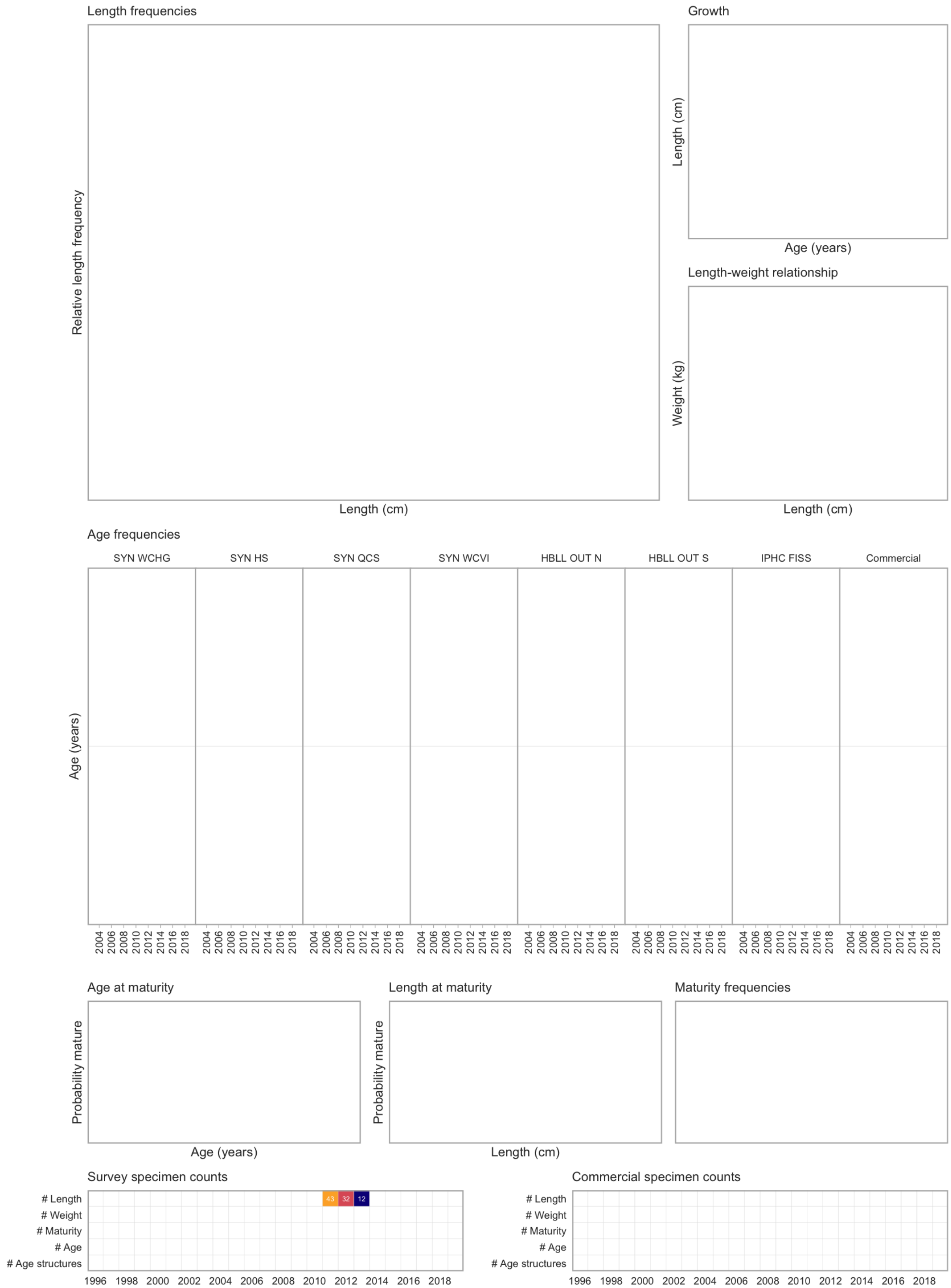



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.26 SHORTFIN EELPOUT

Lycodes brevipes (242)
Order: Perciformes, Family: Zoarcidae, FishBase, WoRMS

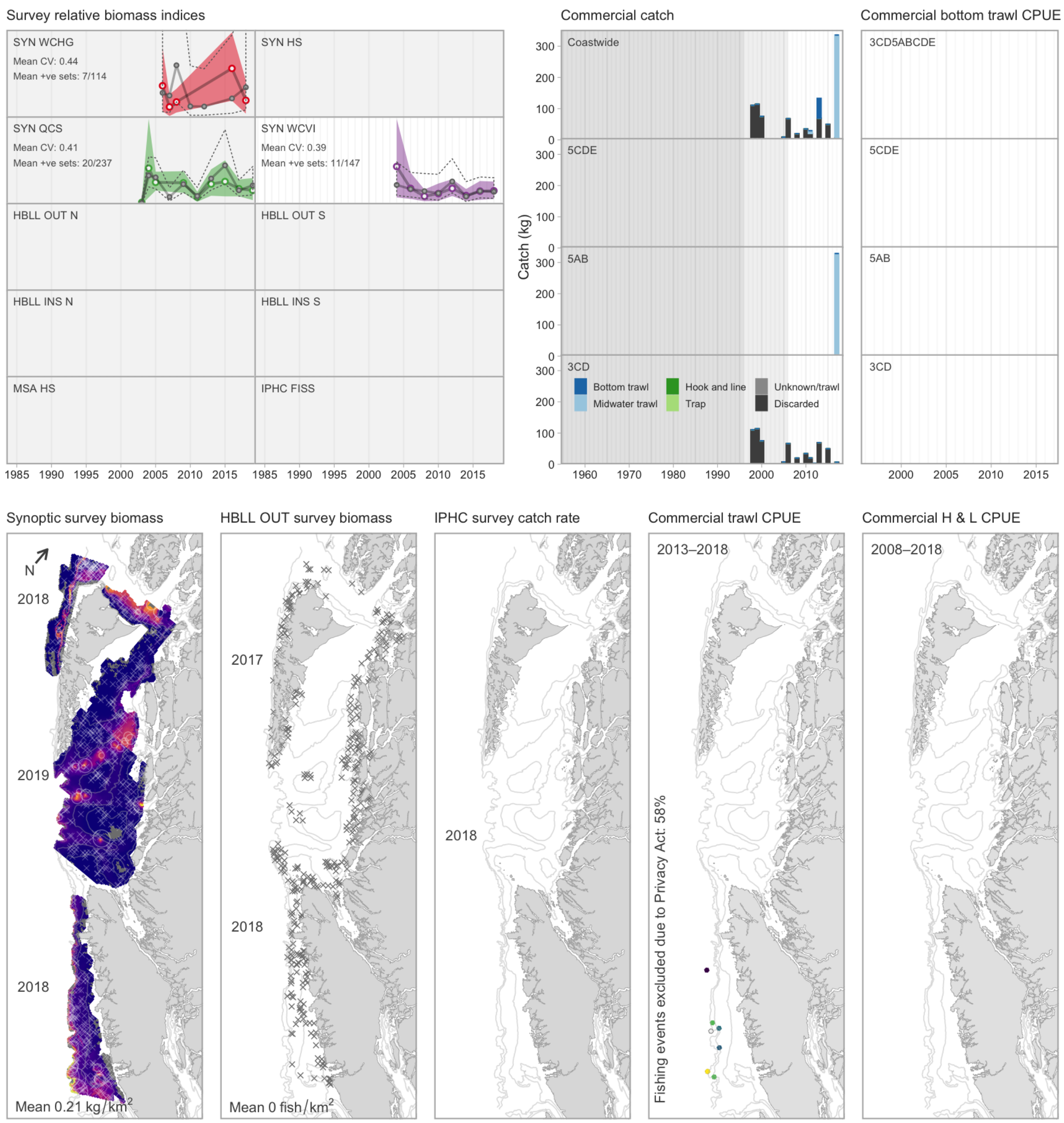


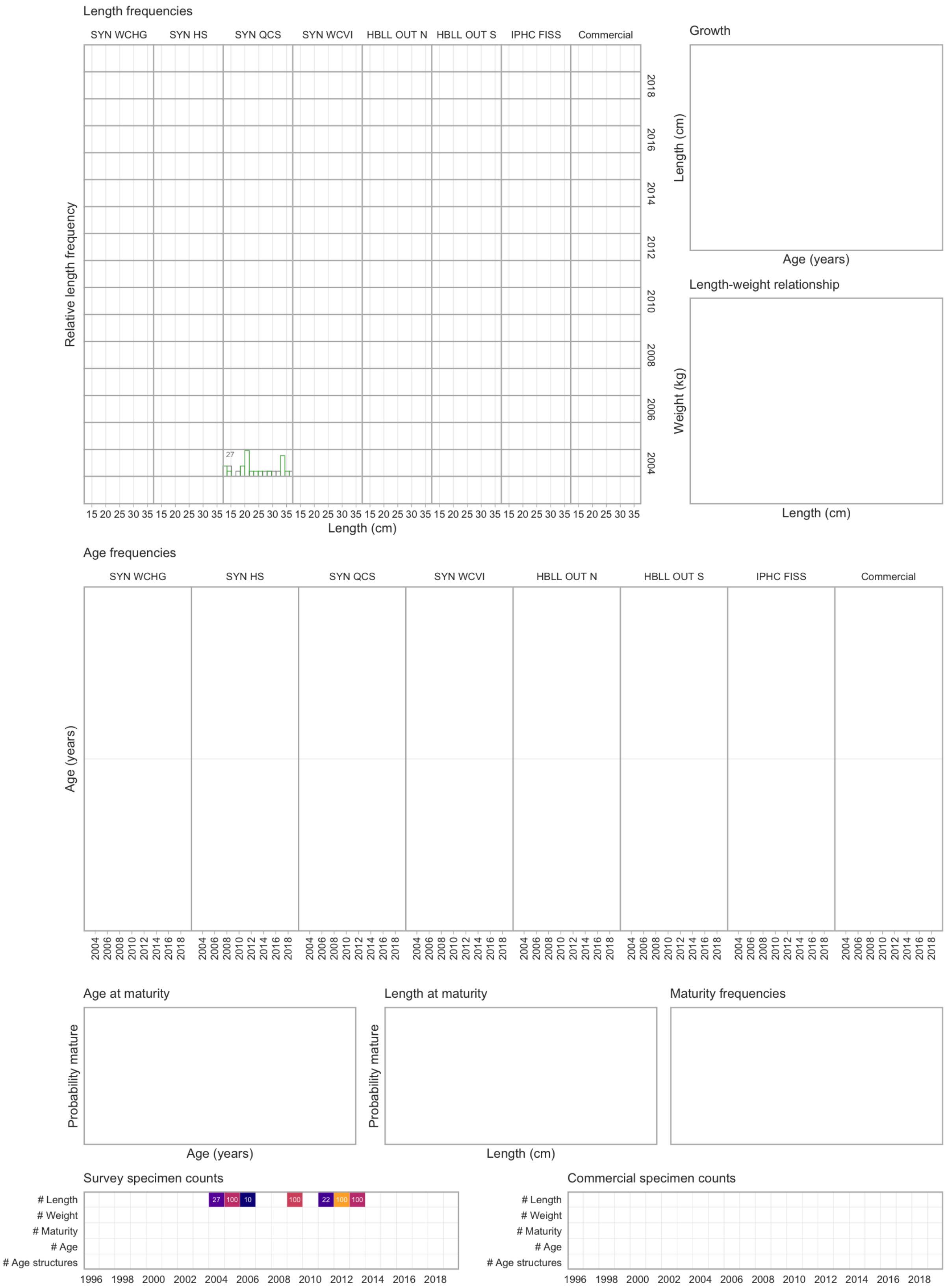


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
43
32
12
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.27 BLACK EELPOUT

Lycodes diapterus (243)
Order: Perciformes, Family: Zoarcidae, FishBase, WoRMS

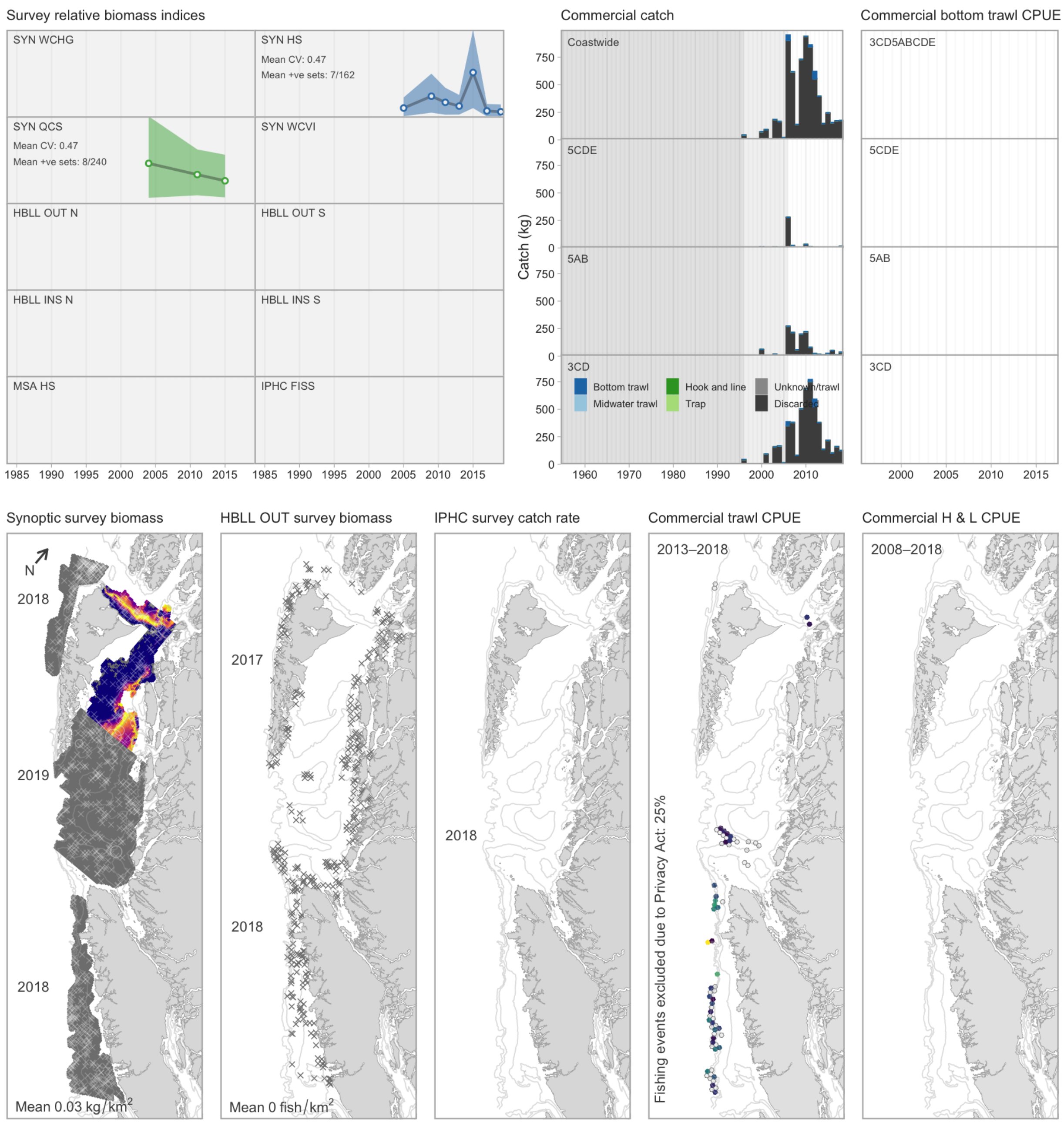


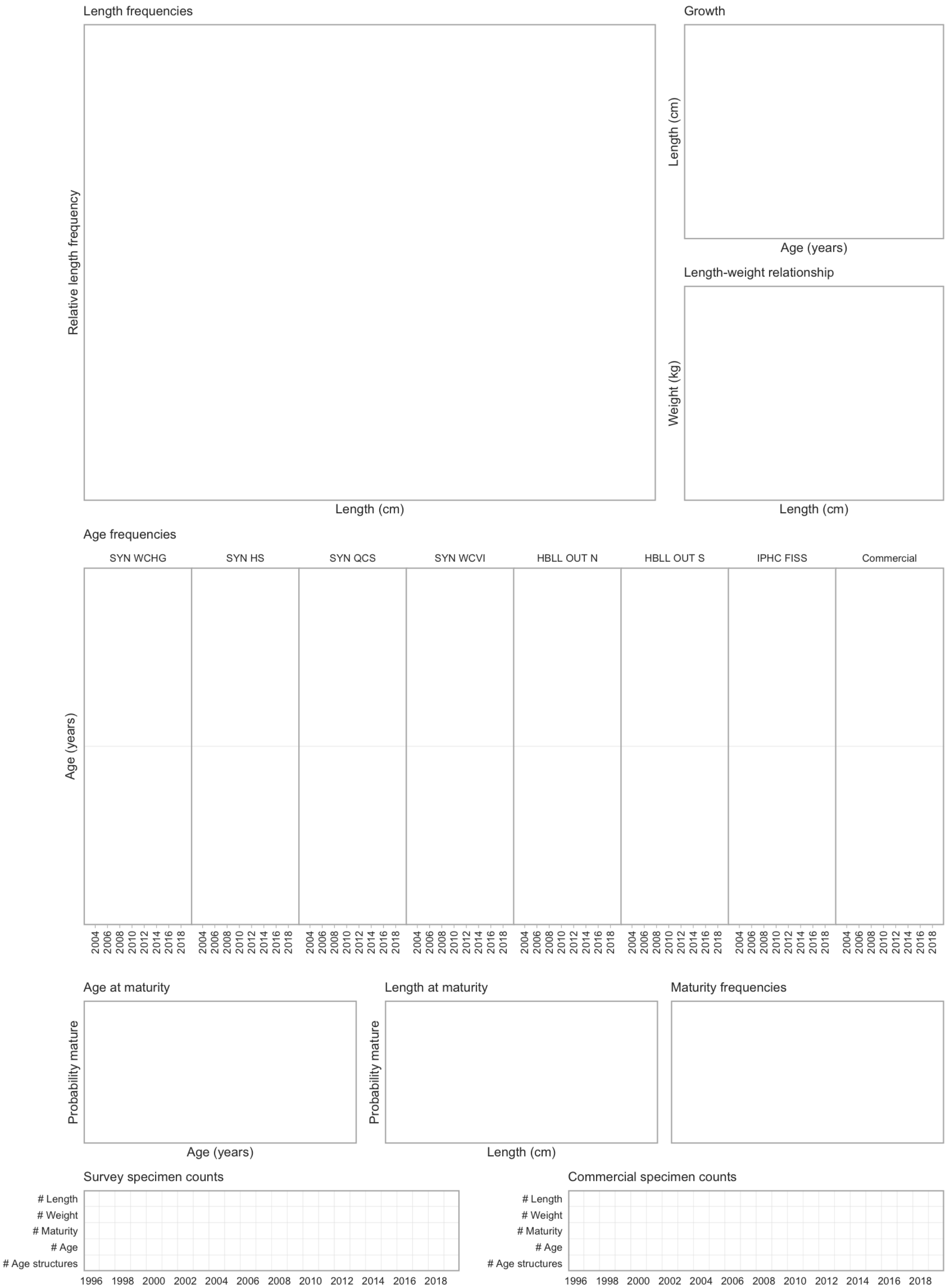


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
27
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
27
100
10
100
22
100
100
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.28 WATTLED EELPOUT

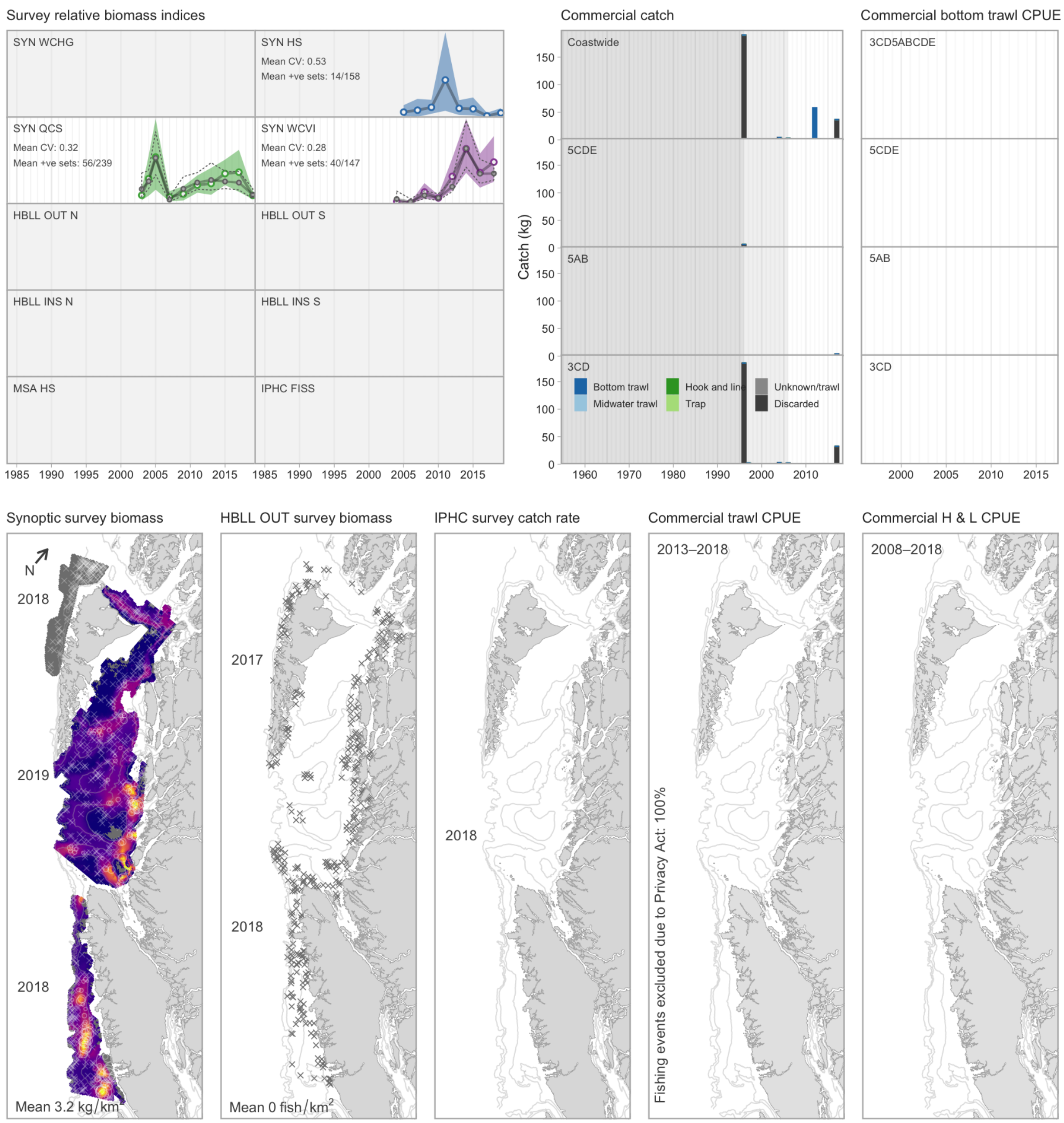
Lycodes palearis (244)
Order: Perciformes, Family: Zoarcidae, FishBase, WoRMS

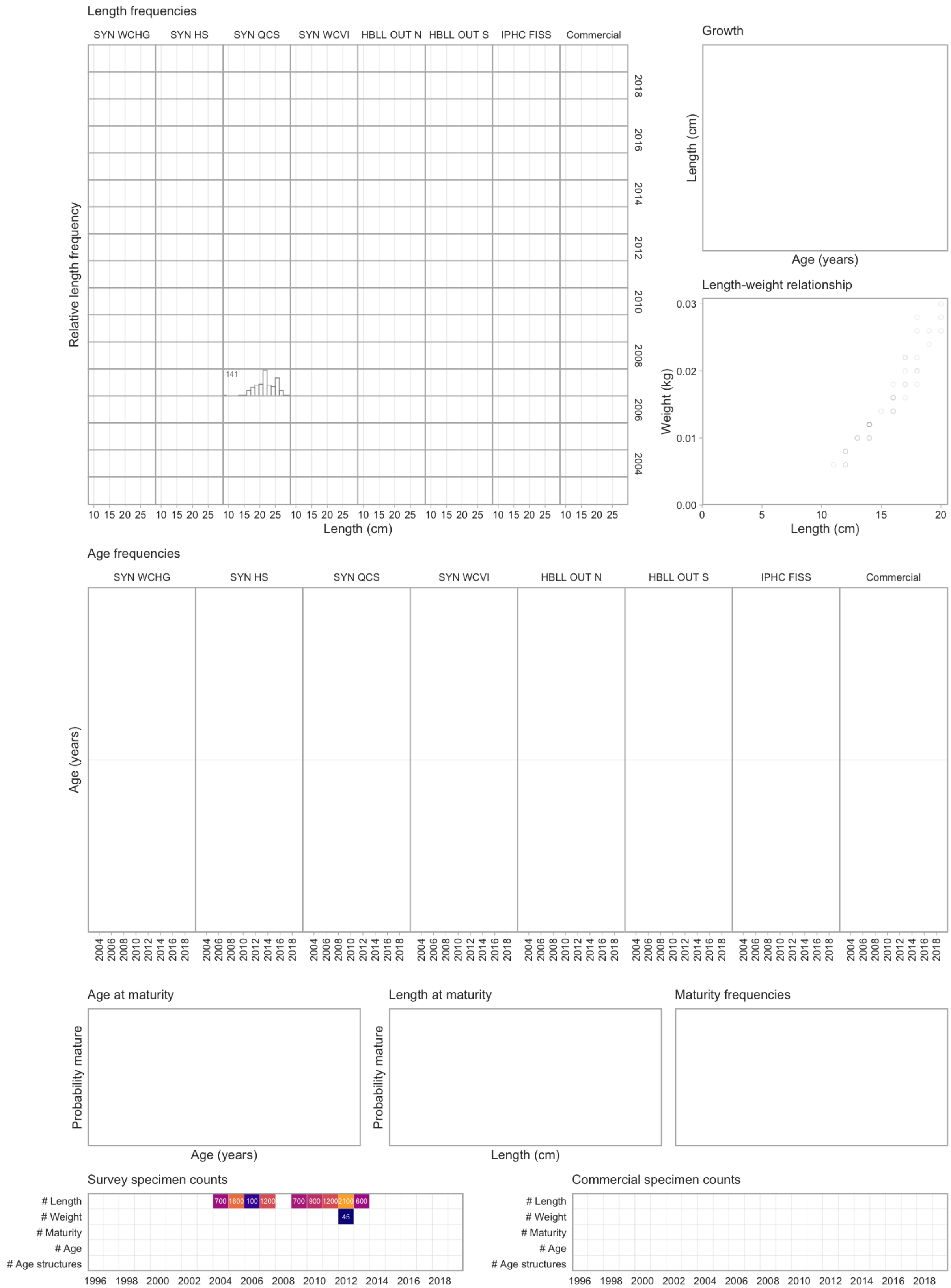



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.29 BLACKBELLY EELPOUT

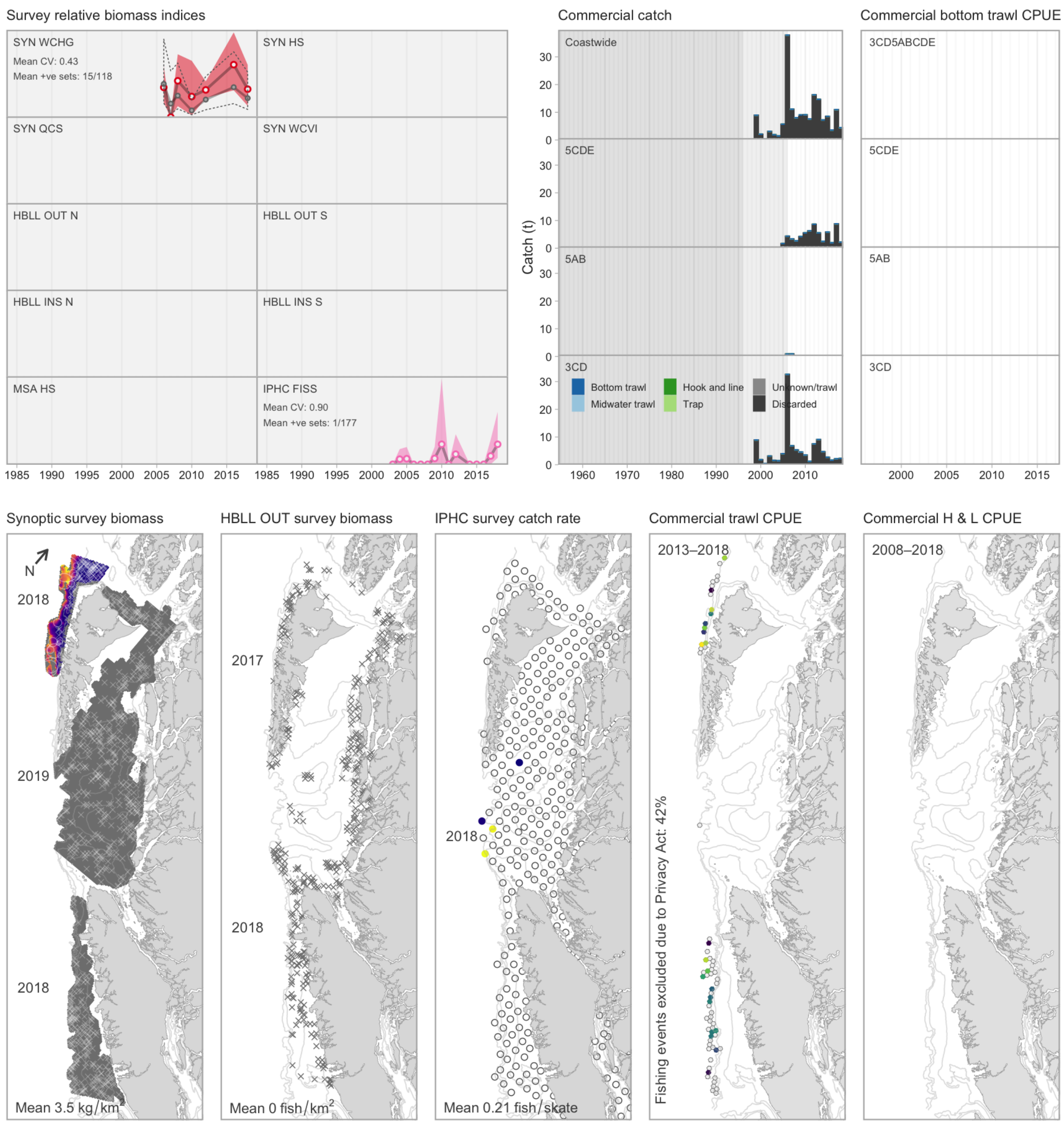
Lycodes pacificus (245)
Order: Perciformes, Family: Zoarcidae, FishBase, WoRMS

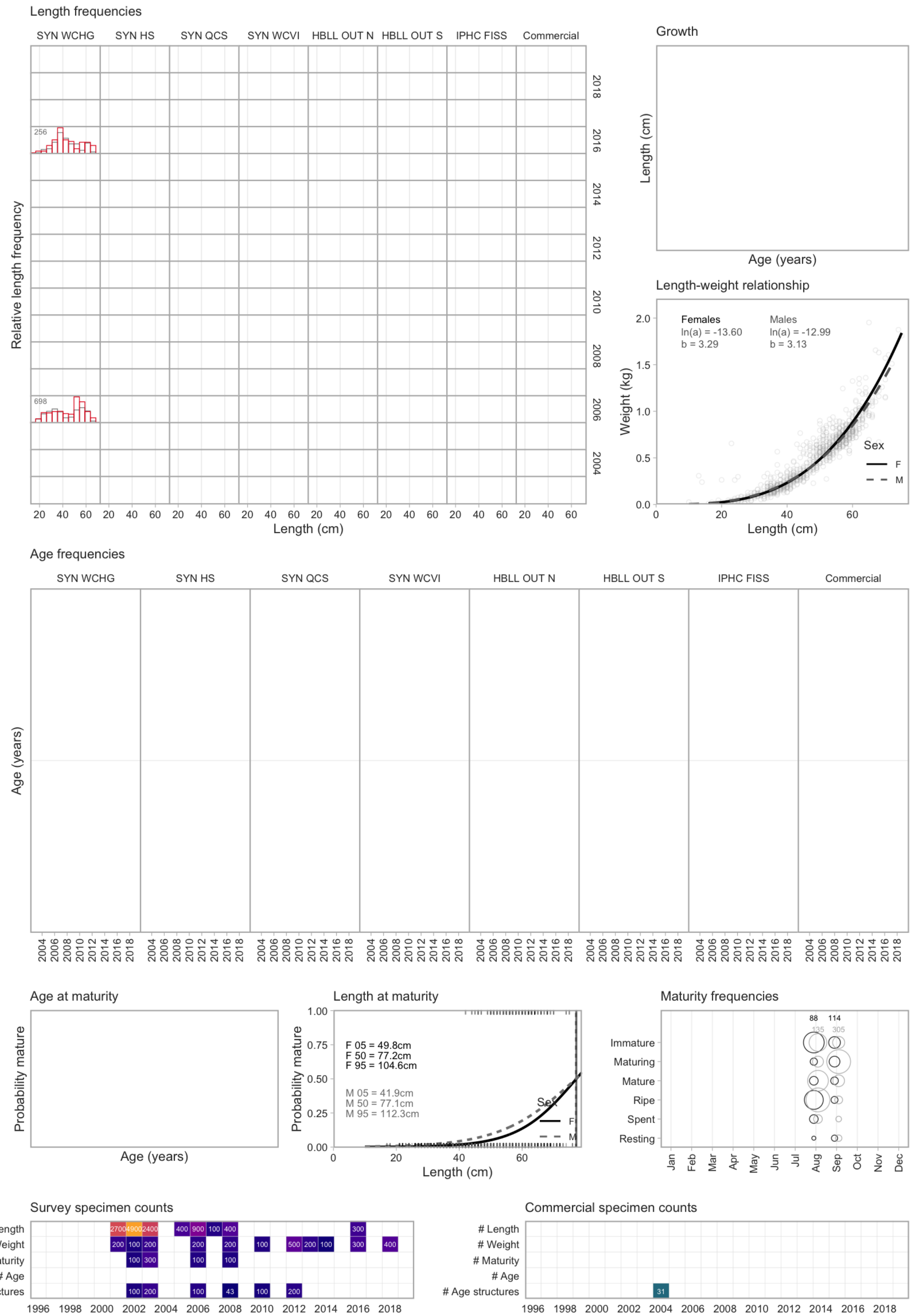



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
2018
2016
2014
2012
2010
2008
2006
2004
141
10 15 20 25
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
0.03
0.02
0.01
0.00
0 5 10 15 20
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
700 1600 100 1200 700 900 1200 2100 600
45
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.30 PACIFIC GRENADIER

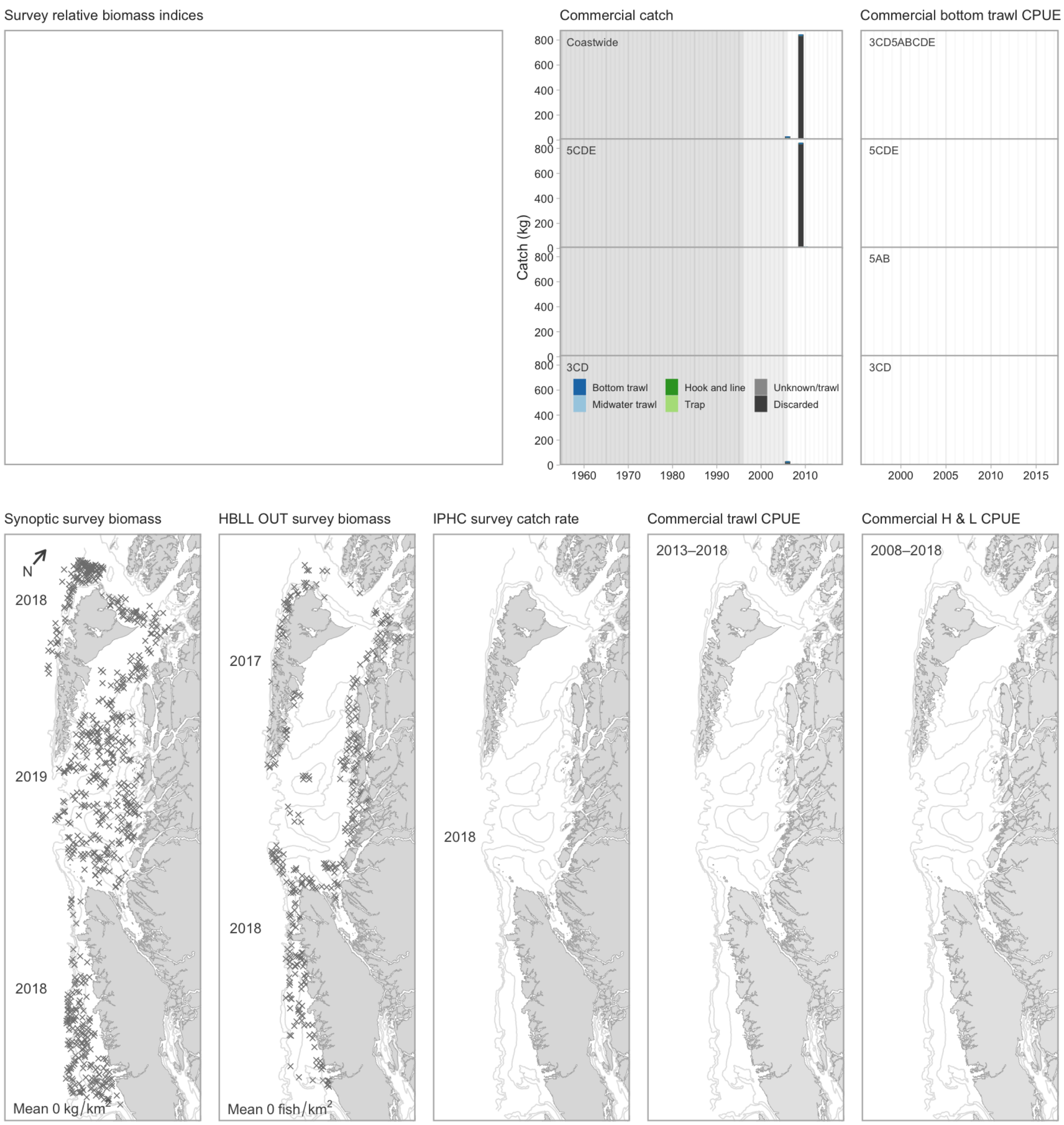
Coryphaenoides acrolepis (251)
Order: Gadiformes, Family: Macrouridae, FishBase, WoRMS

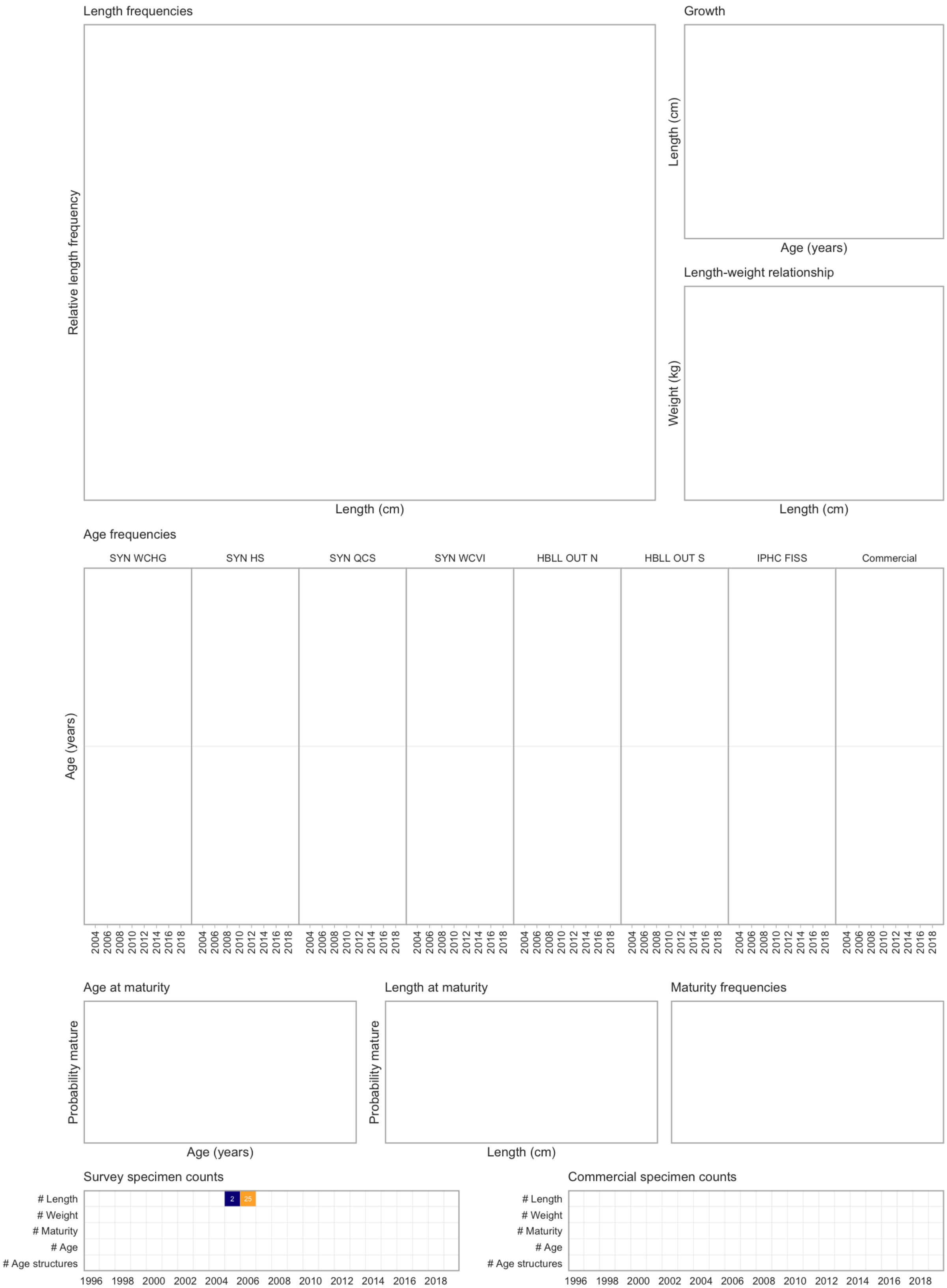



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
256
698
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -13.60
b = 3.29
Males
ln(a) = -12.99
b = 3.13
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 49.8cm
F 50 = 77.2cm
F 95 = 104.6cm
M 05 = 41.9cm
M 50 = 77.1cm
M 95 = 112.3cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Ripe
Spent
Resting
88
114
135
305
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
31

5.31 THREADFIN GRENADIER

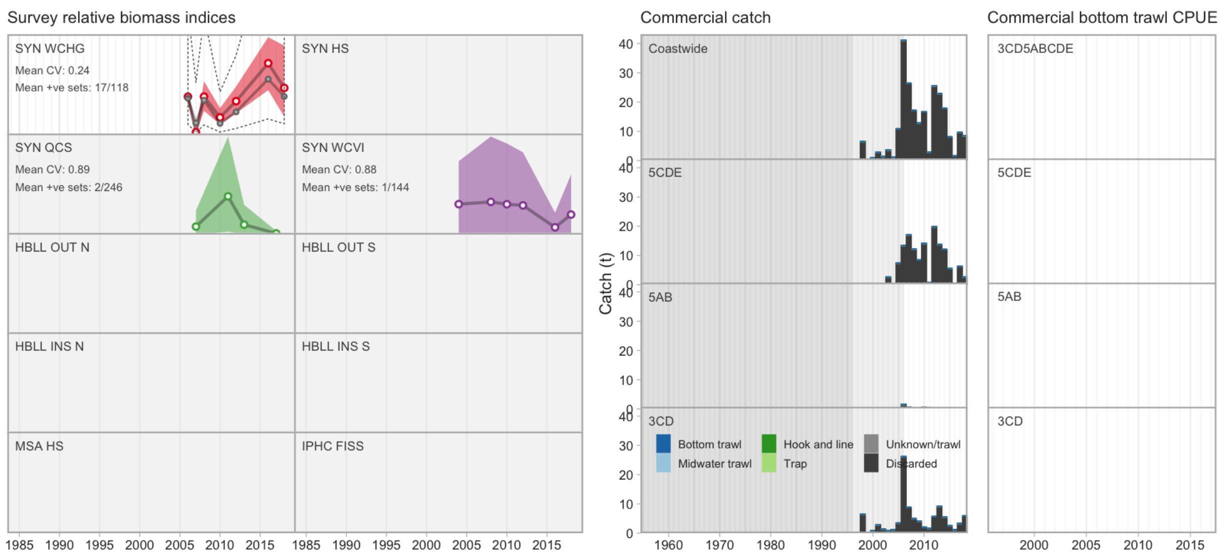
Coryphaenoides filifer (254)
Order: Gadiformes, Family: Macrouridae, FishBase, WoRMS

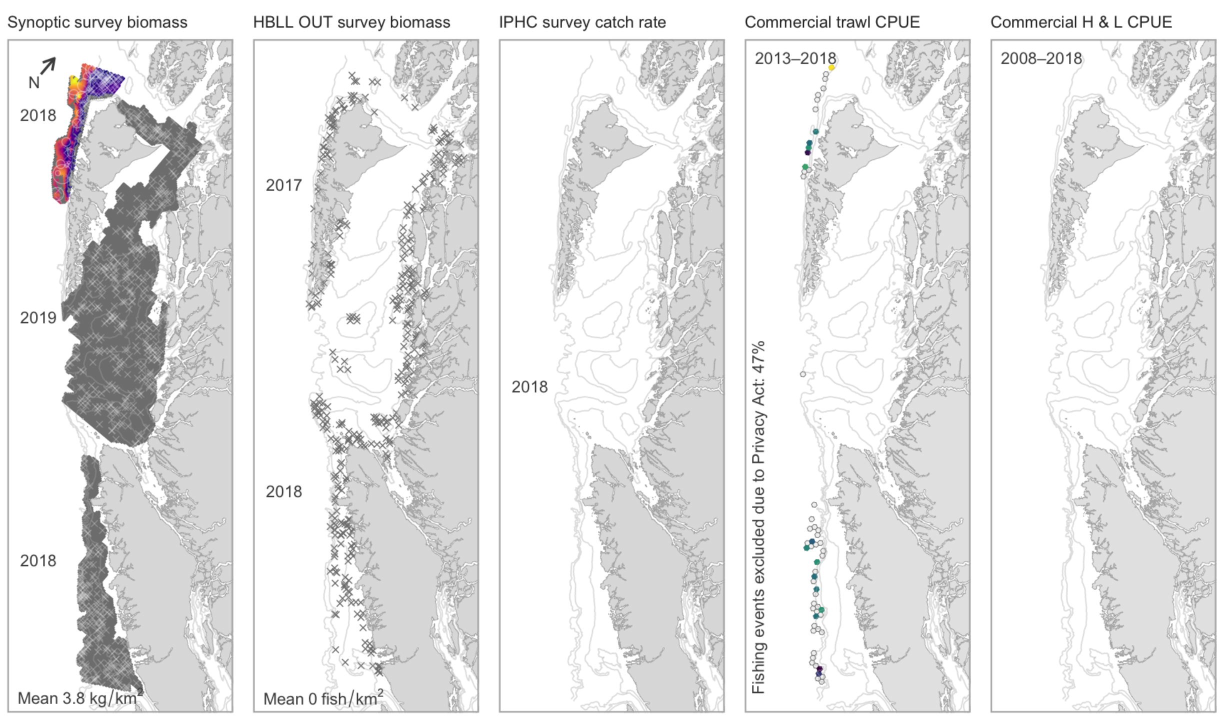


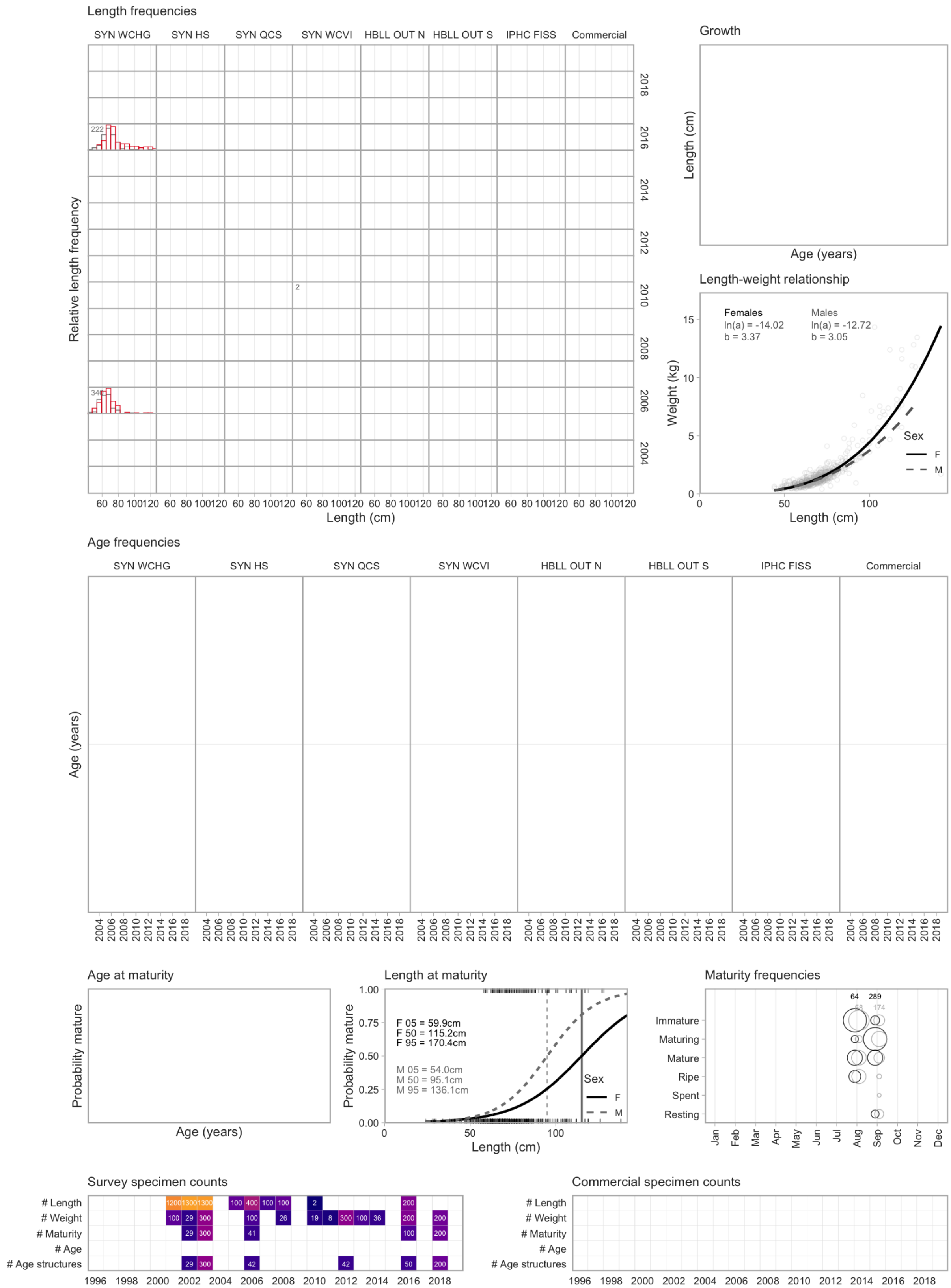

Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
2
25
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.32 GIANT GRENADIER

Albatrossia pectoralis (256)
Order: Gadiformes, Family: Macrouridae, FishBase, WoRMS

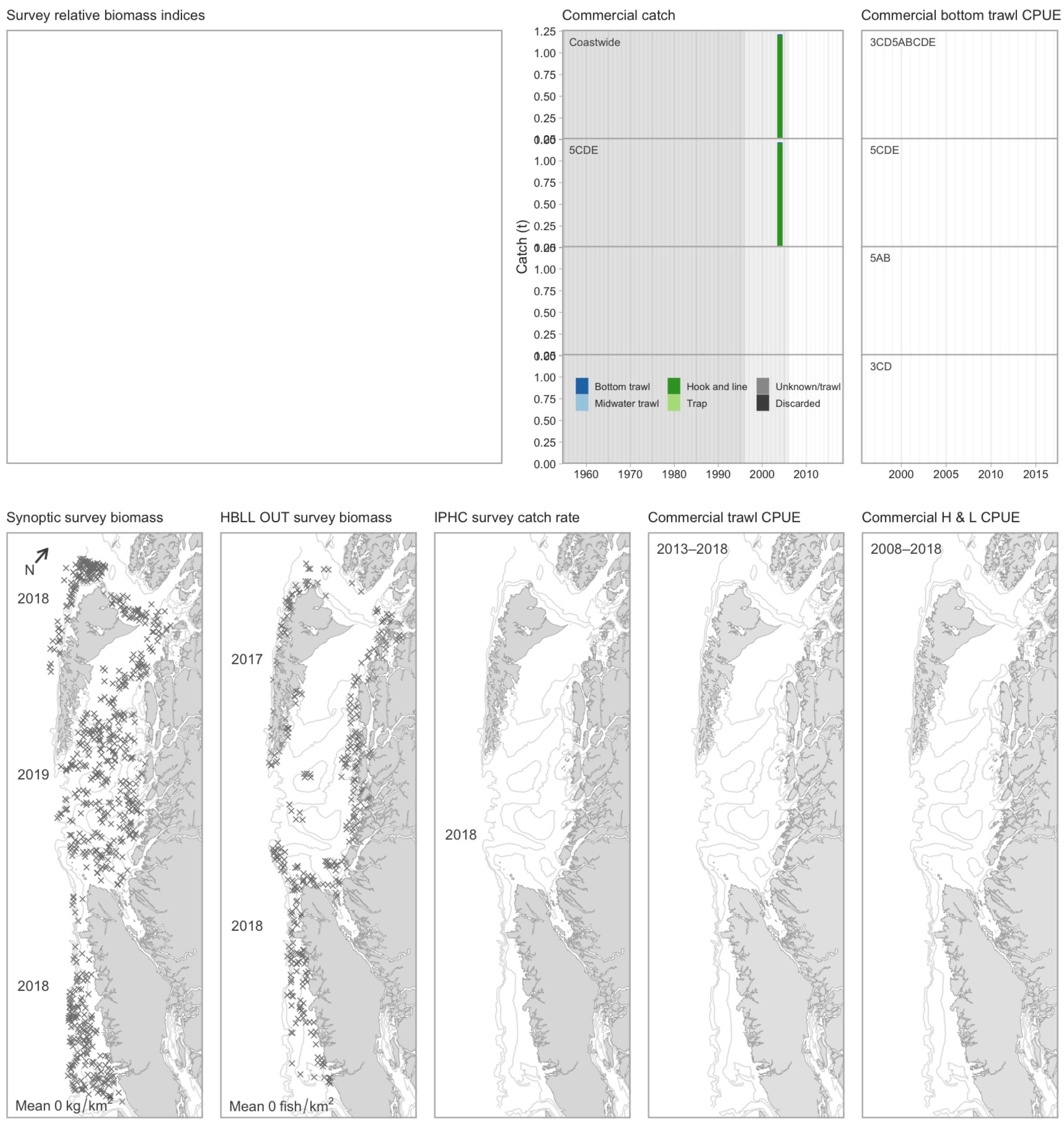


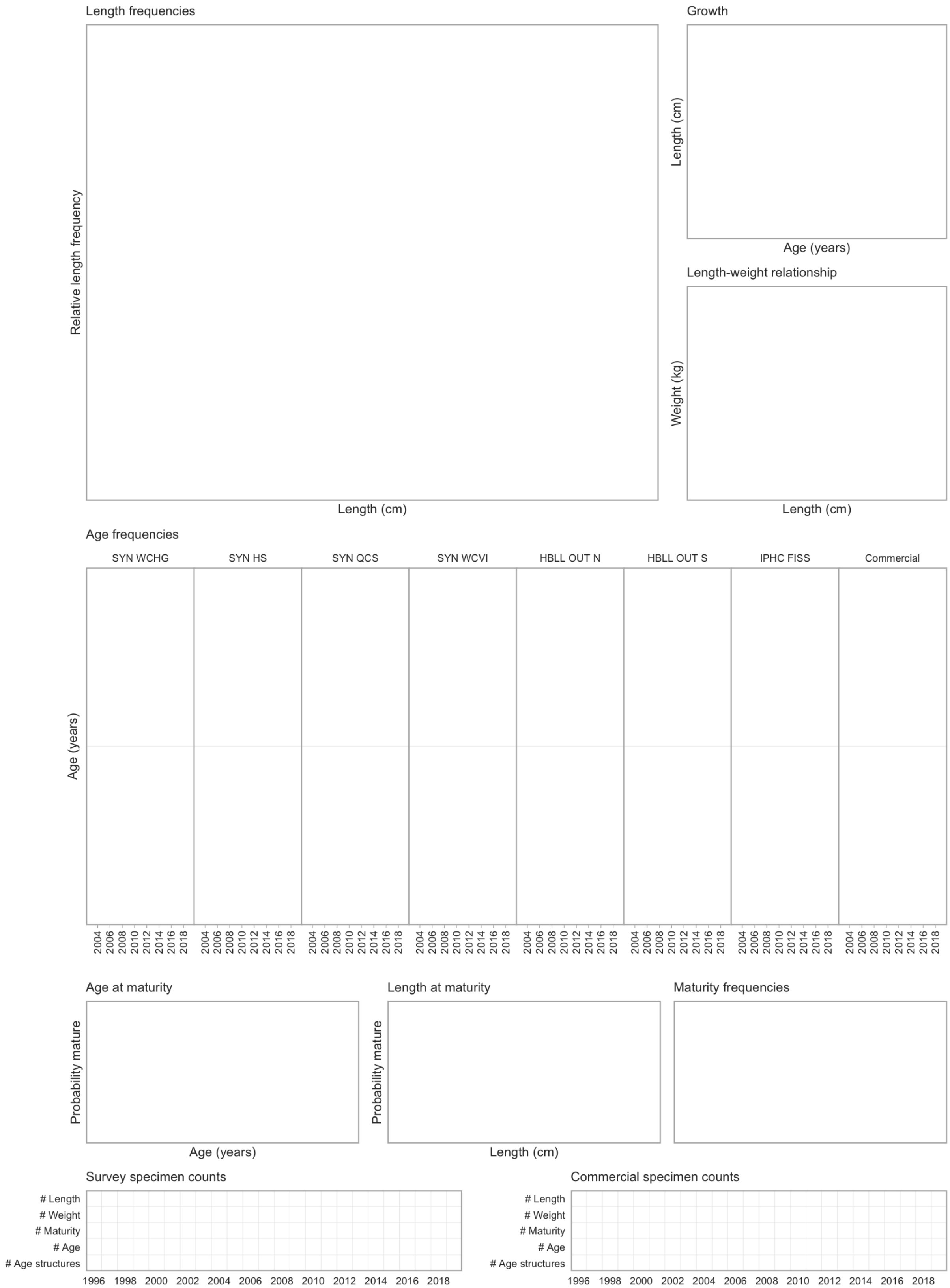



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -14.02
b = 3.37
Males
ln(a) = -12.72
b = 3.05
Weight (kg)
Length (cm)
Sex
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 59.9cm
F 50 = 115.2cm
F 95 = 170.4cm
M 05 = 54.0cm
M 50 = 95.1cm
M 95 = 136.1cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.33 CALIFORNIA GRENADIER

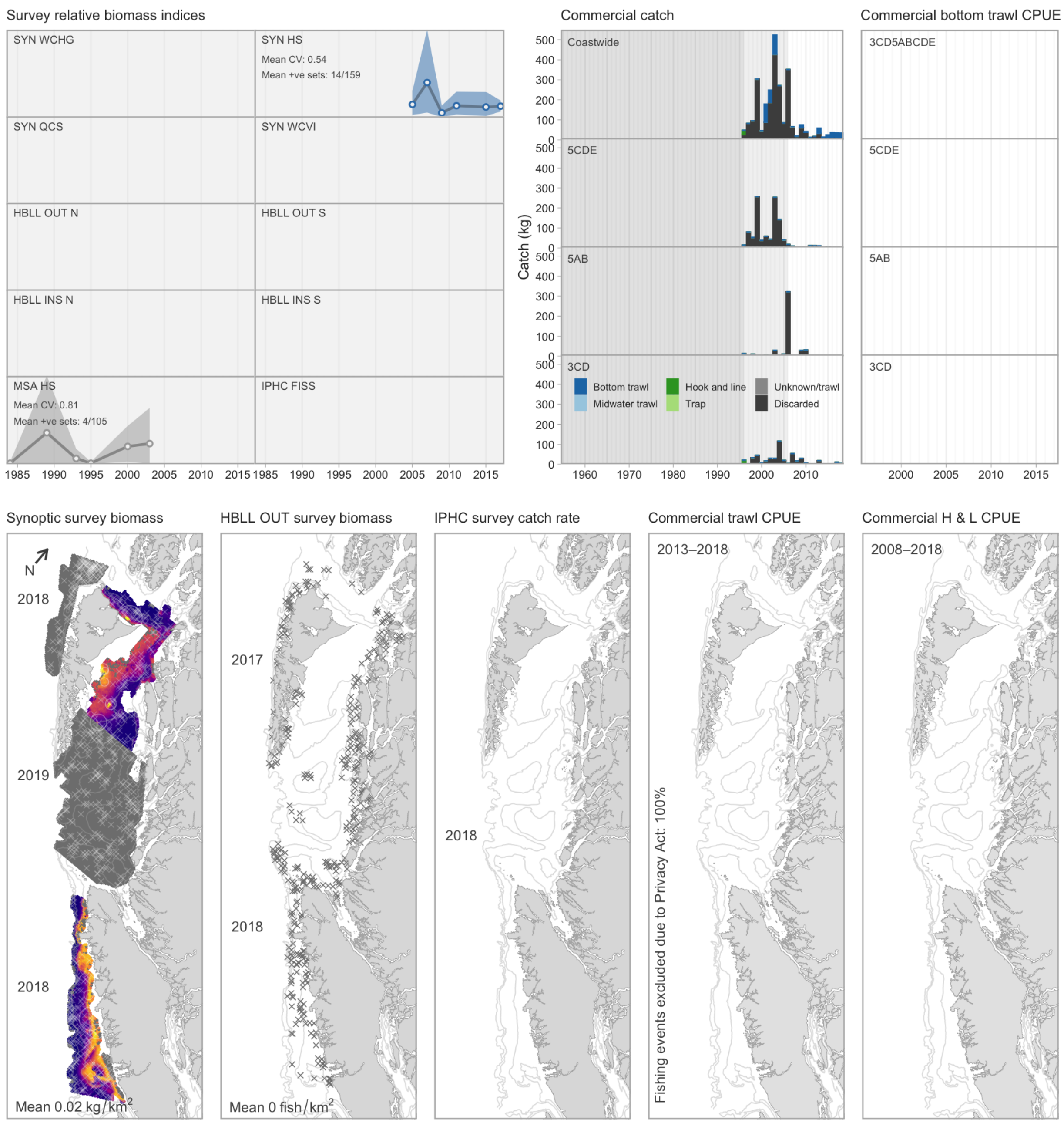
Nezumia stelgidolepis (257)
Order: Gadiformes, Family: Macrouridae, FishBase, WoRMS

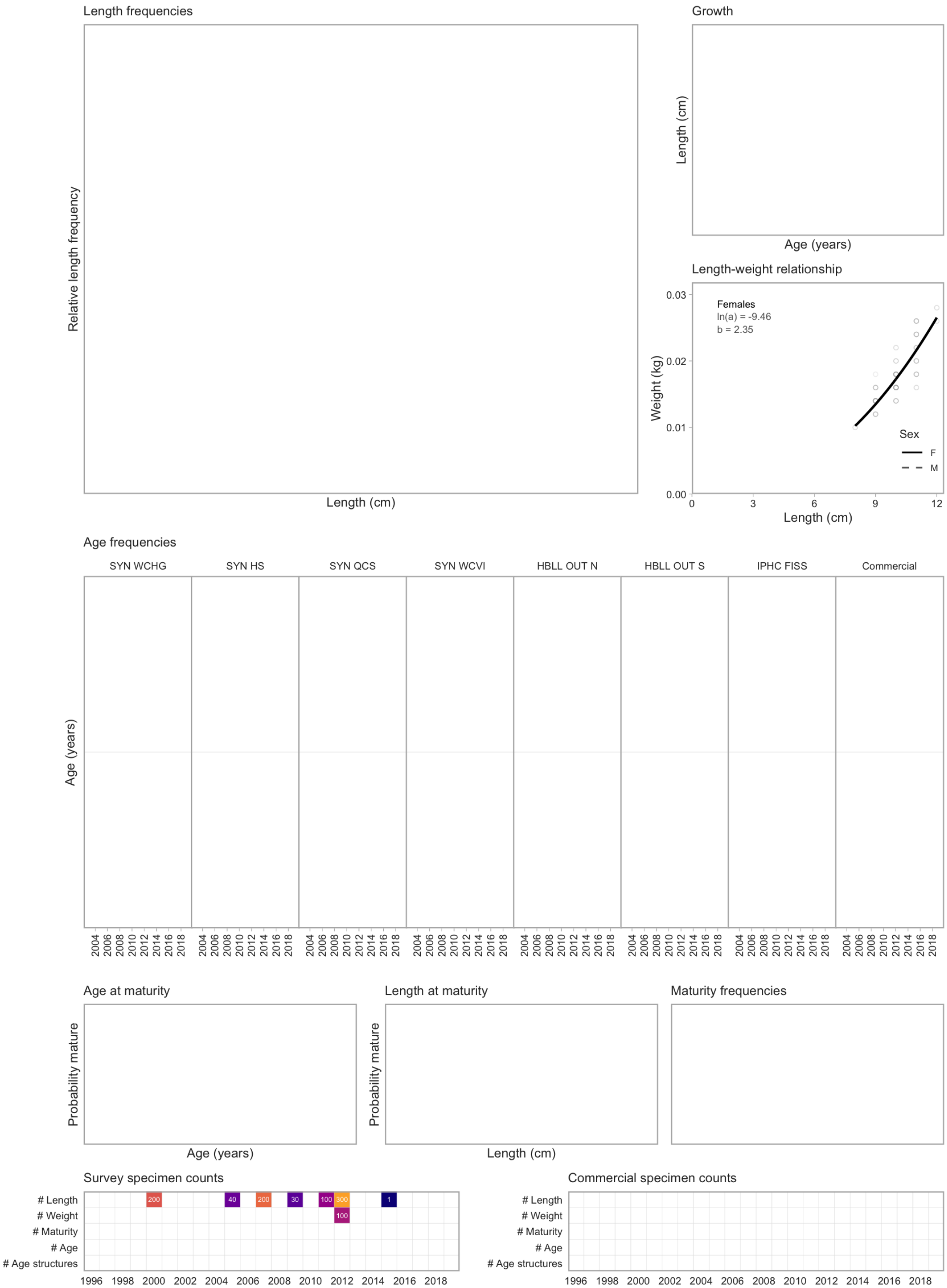



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.34 SHINER PERCH

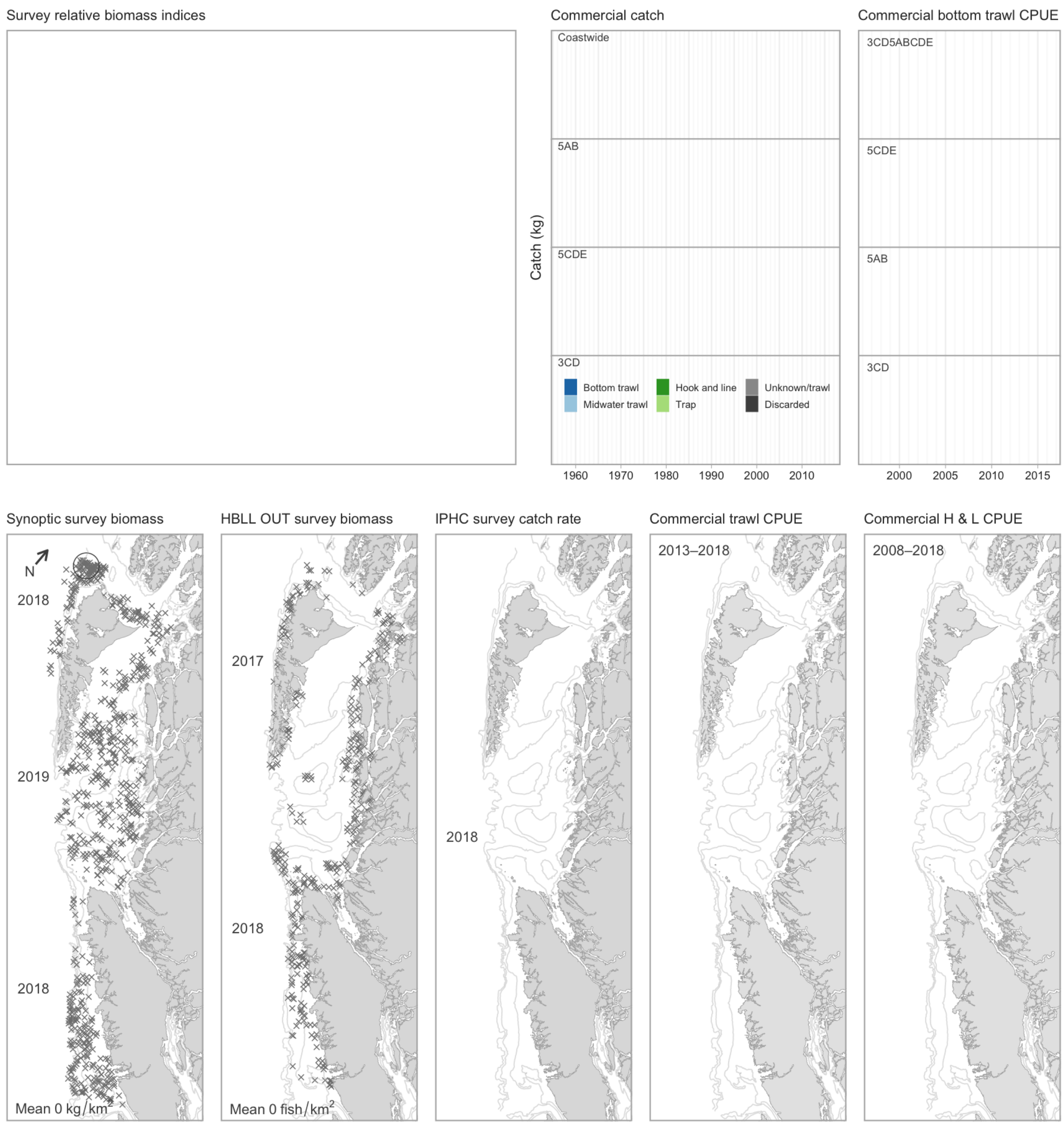
Cymatogaster aggregata (304)
Order: Perciformes, Family: Embiotocidae, FishBase, WoRMS

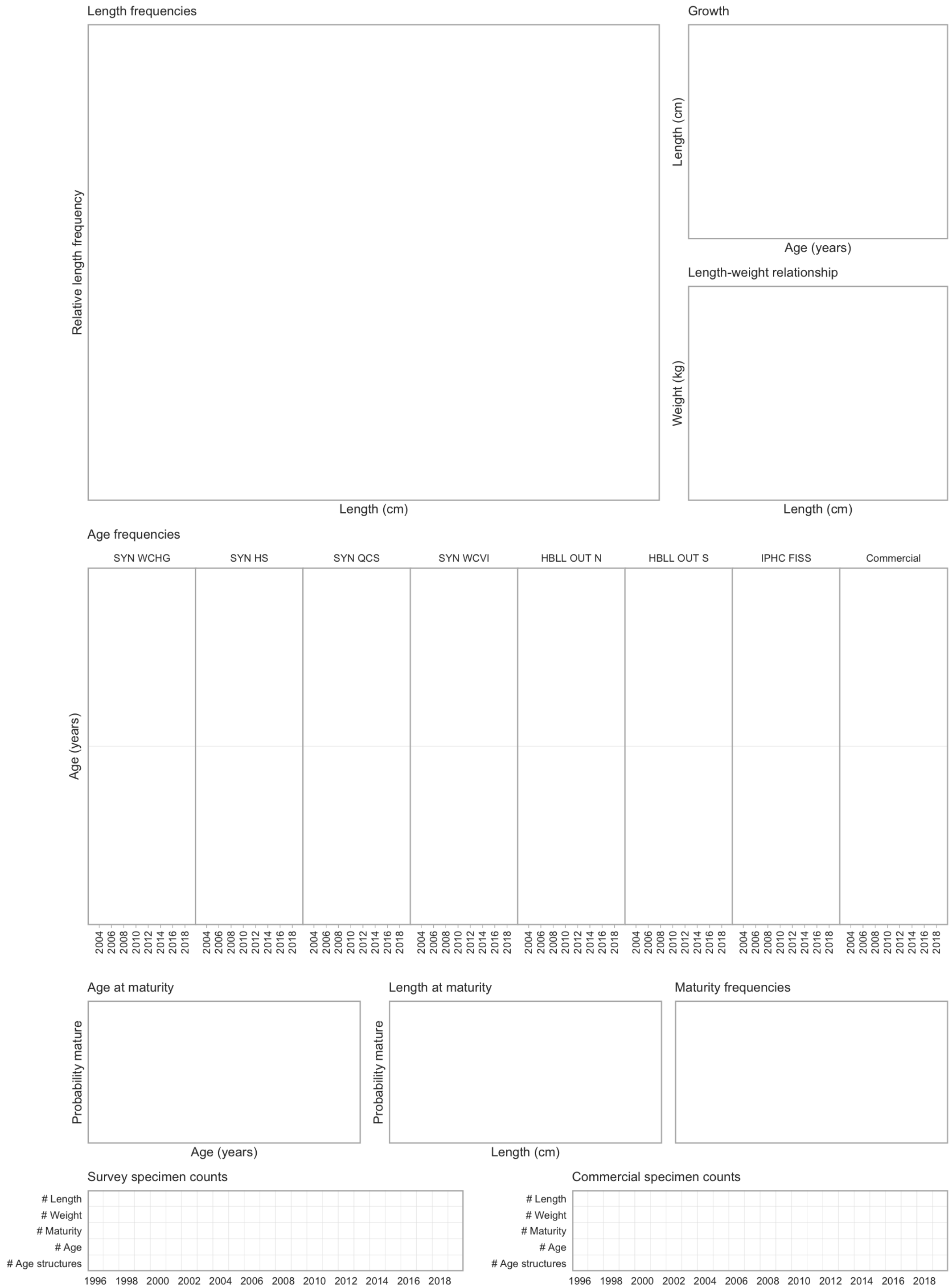



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -9.46
b = 2.35
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
200
40
200
30
100
300
1
100
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.35 PEARLY PRICKLEBACK

Bryozoichthys marjorius (331)
Order: Perciformes, Family: Stichaeidae, FishBase, WoRMS

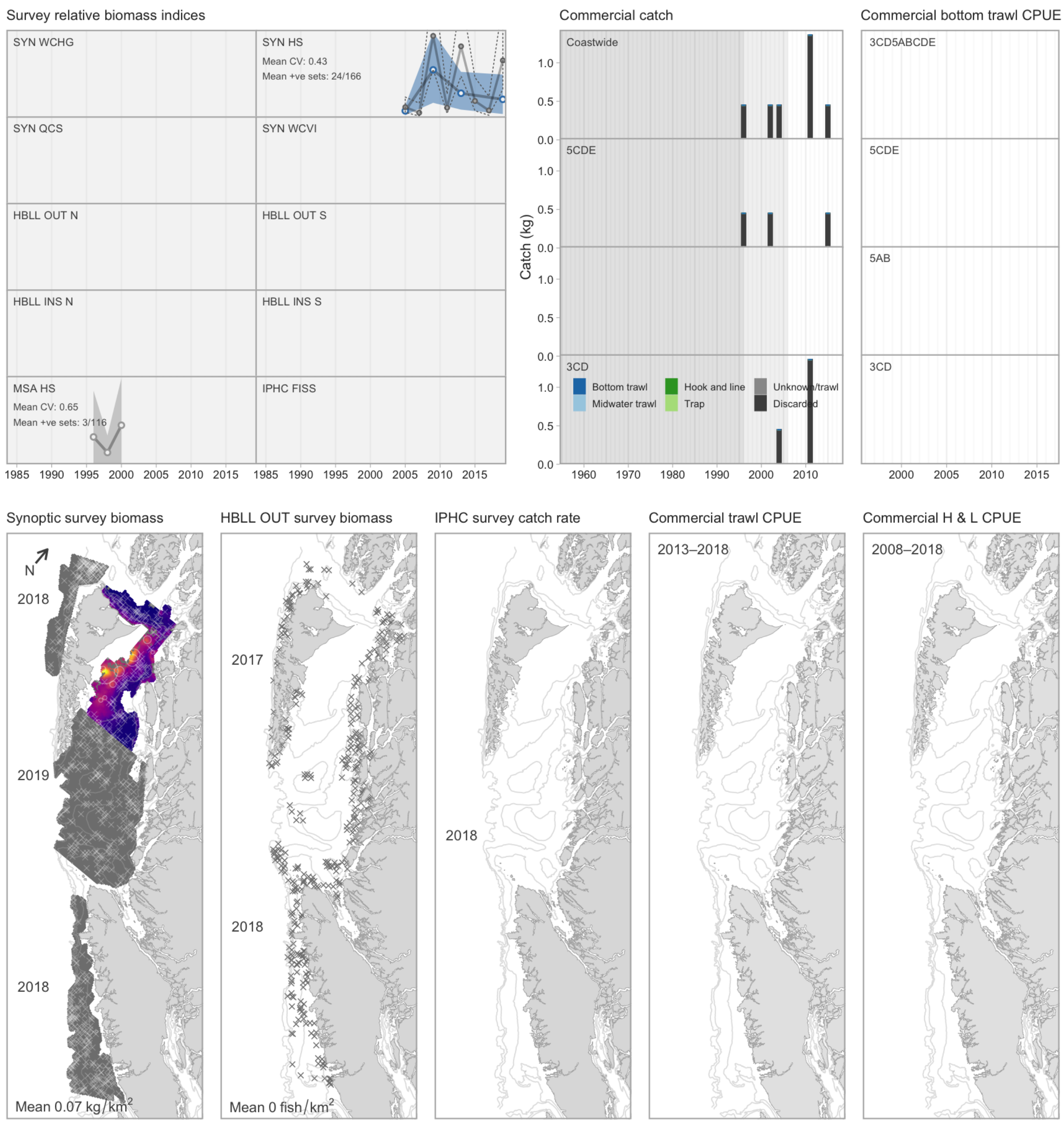


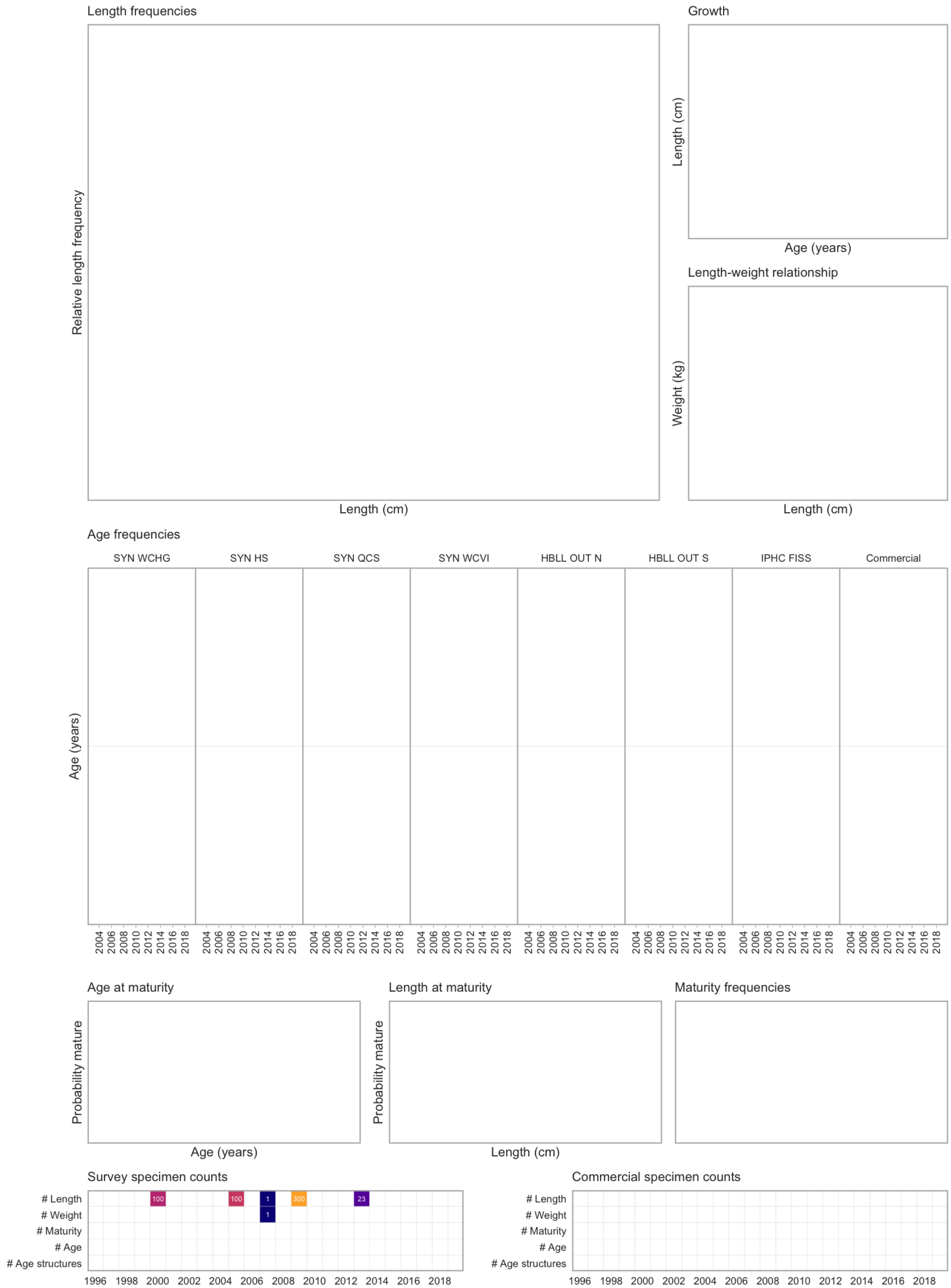


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.36 SNAKE PRICKLEBACK

Lumpenus sagitta (337)
Order: Perciformes, Family: Stichaeidae, FishBase, WoRMS

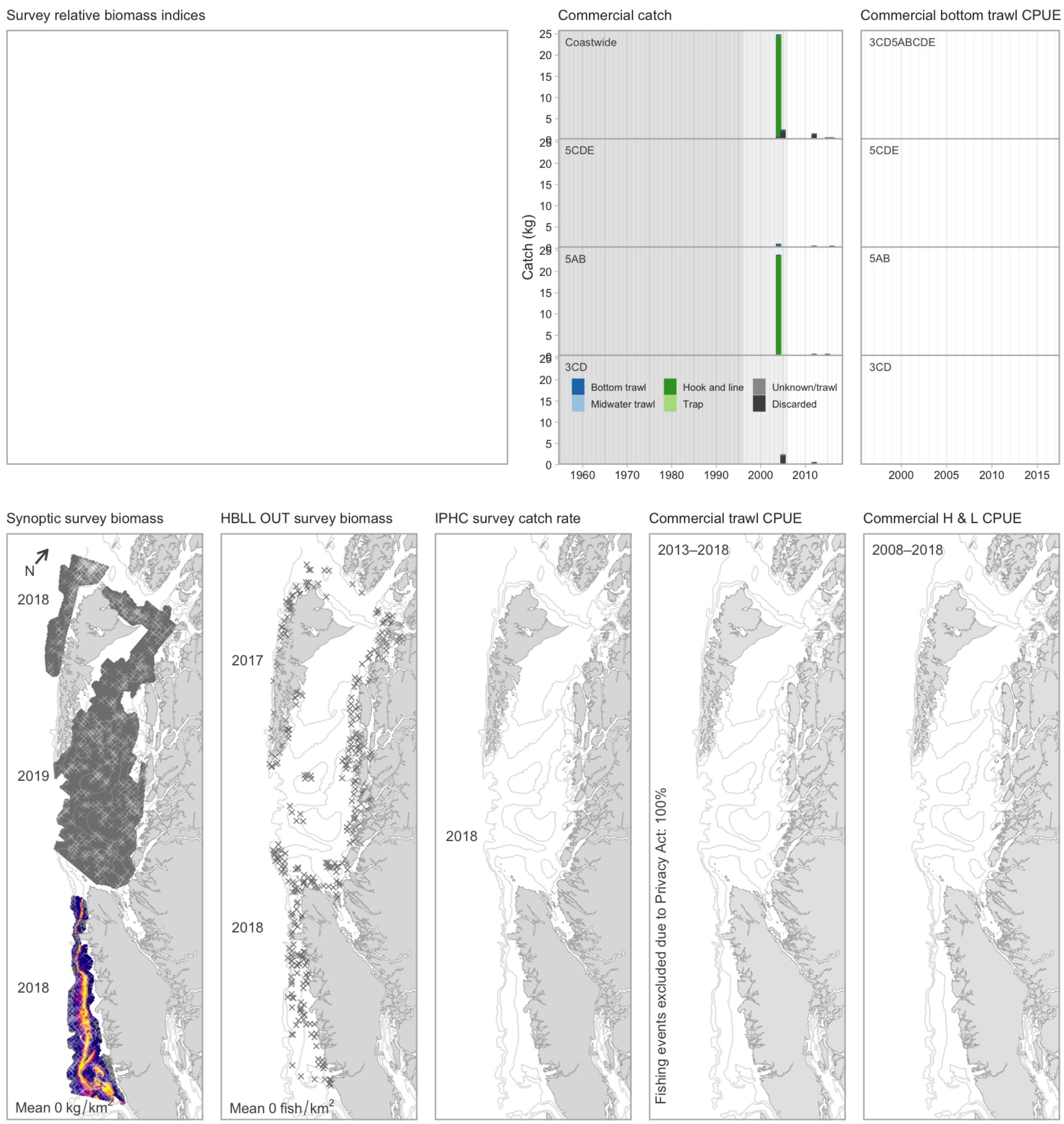


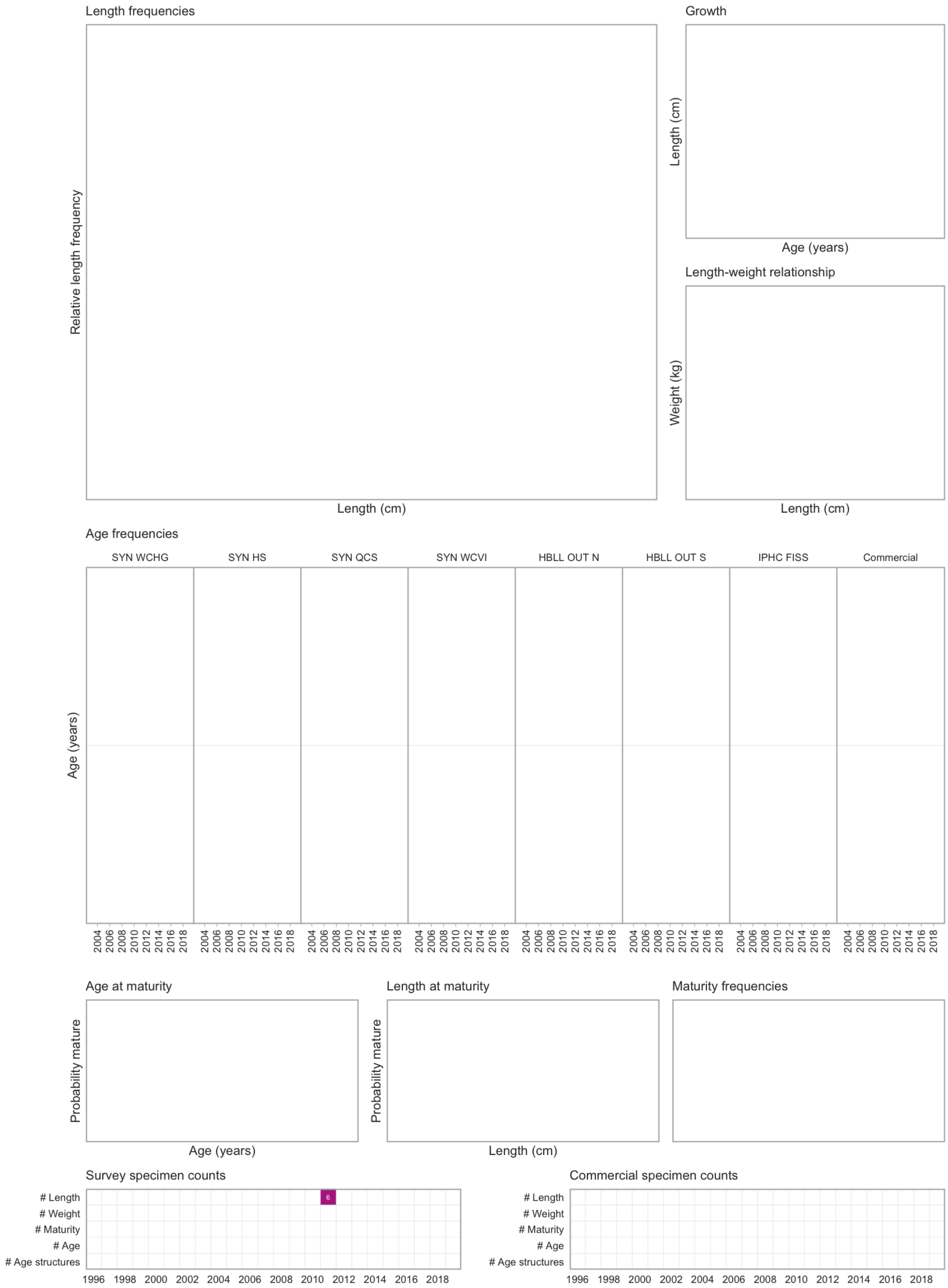


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.37 WHITEBARRED PRICKLEBACK

Poroclinus rothrocki (340)
Order: Perciformes, Family: Stichaeidae, FishBase, WoRMS

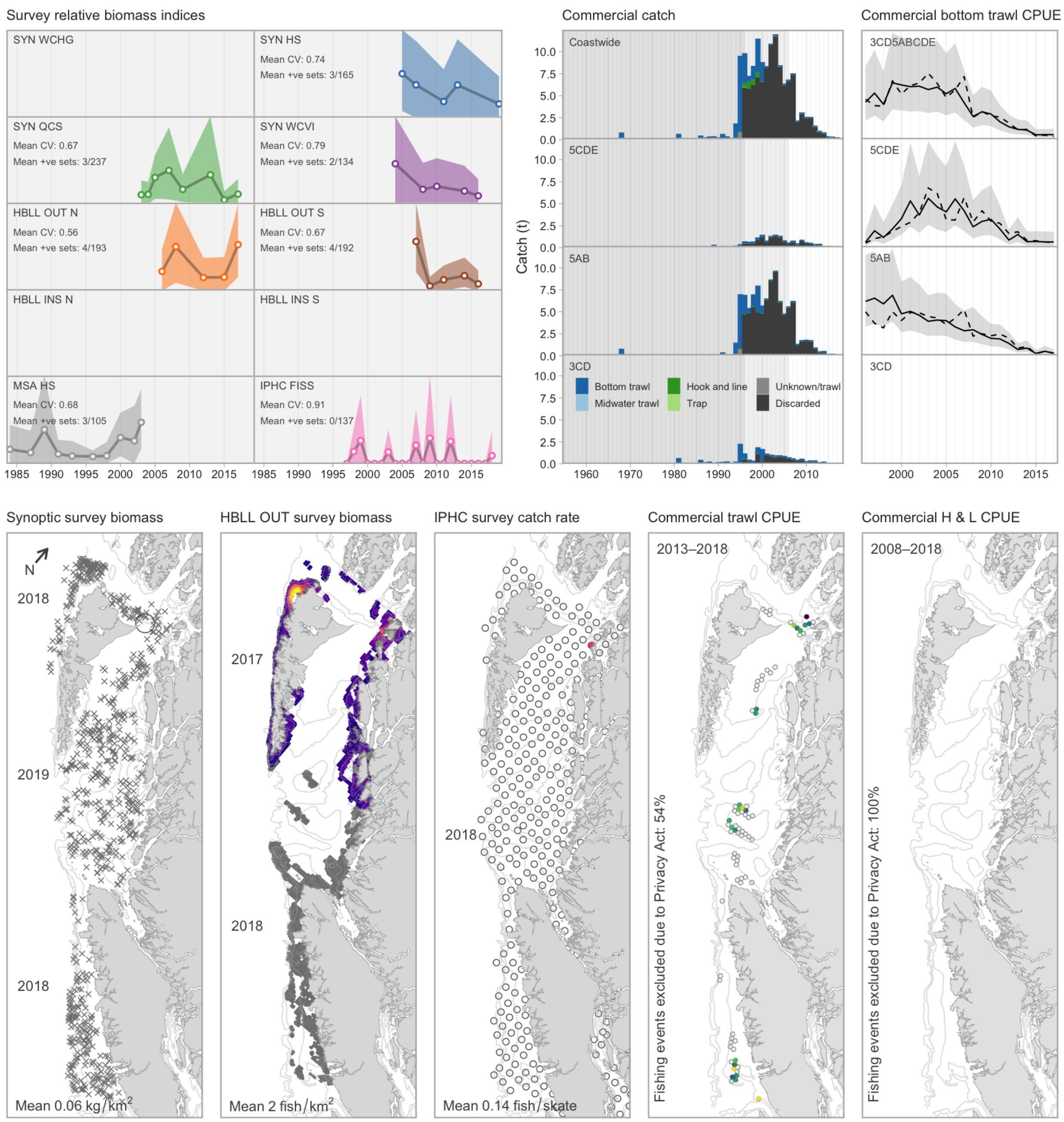


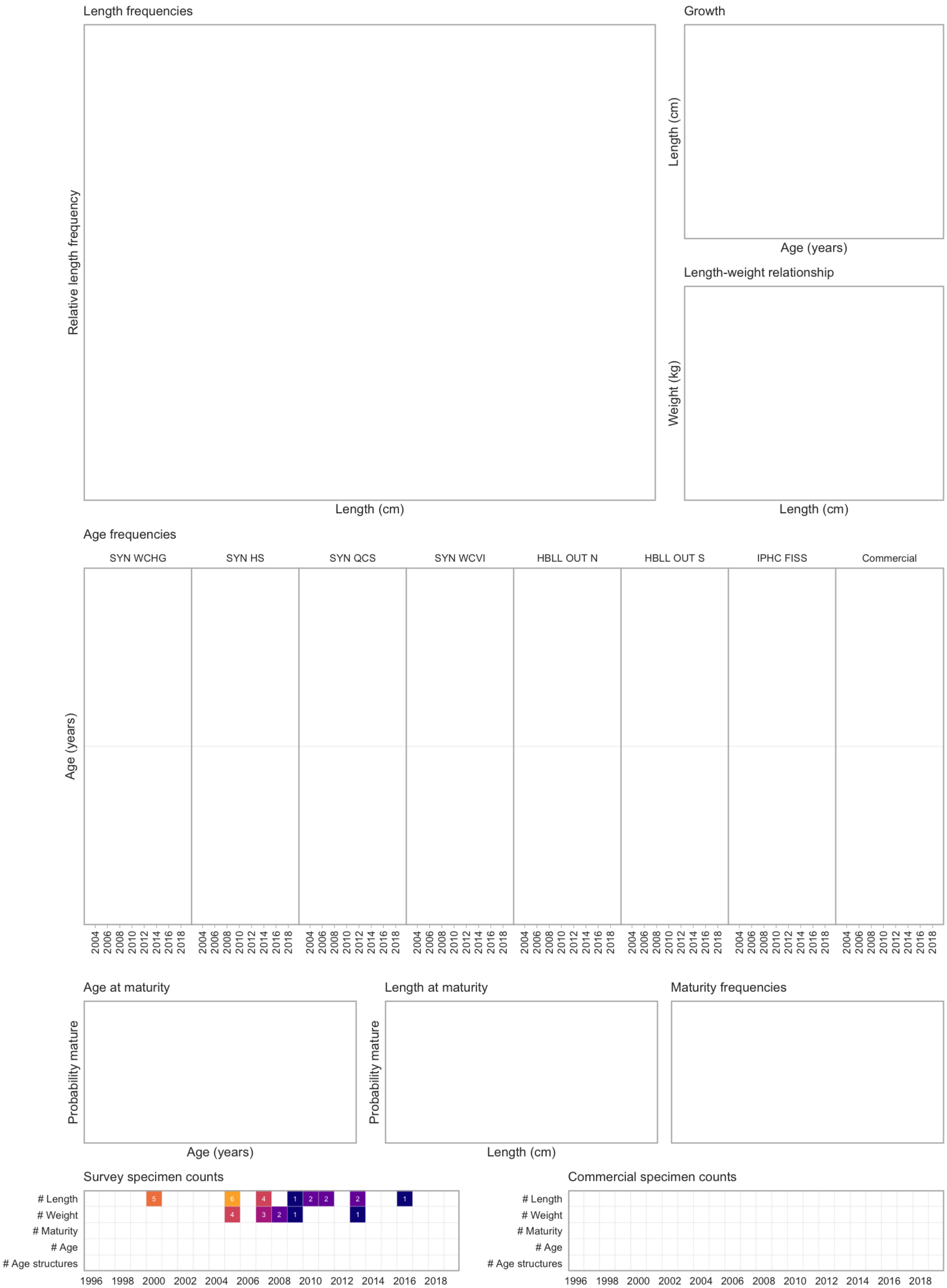


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
6
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.38 WOLF EEL

Anarrhichthys ocellatus (351)
Order: Perciformes, Family: Anarhichadidae, FishBase, WoRMS
COSEWIC Status: Not at Risk

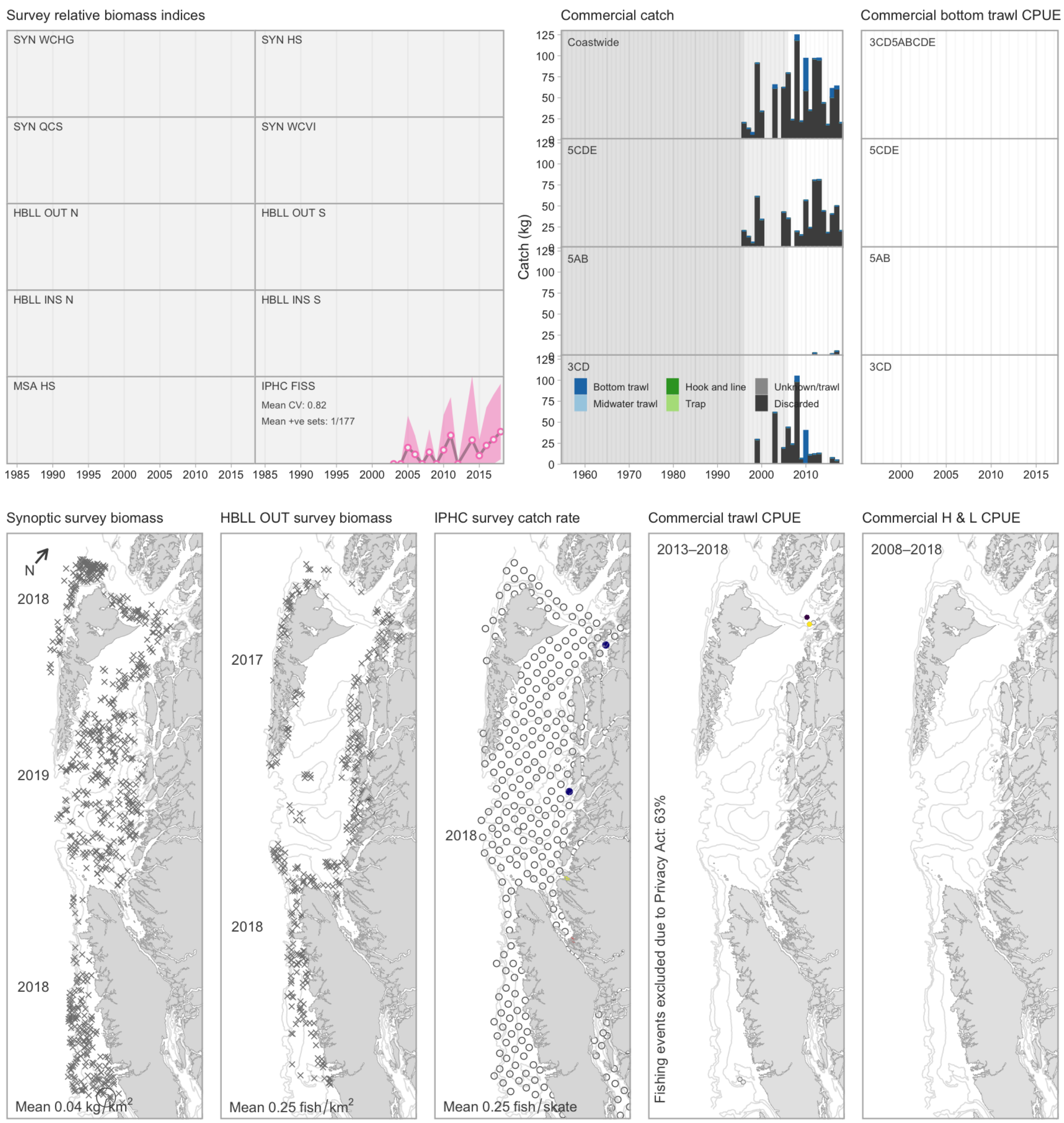


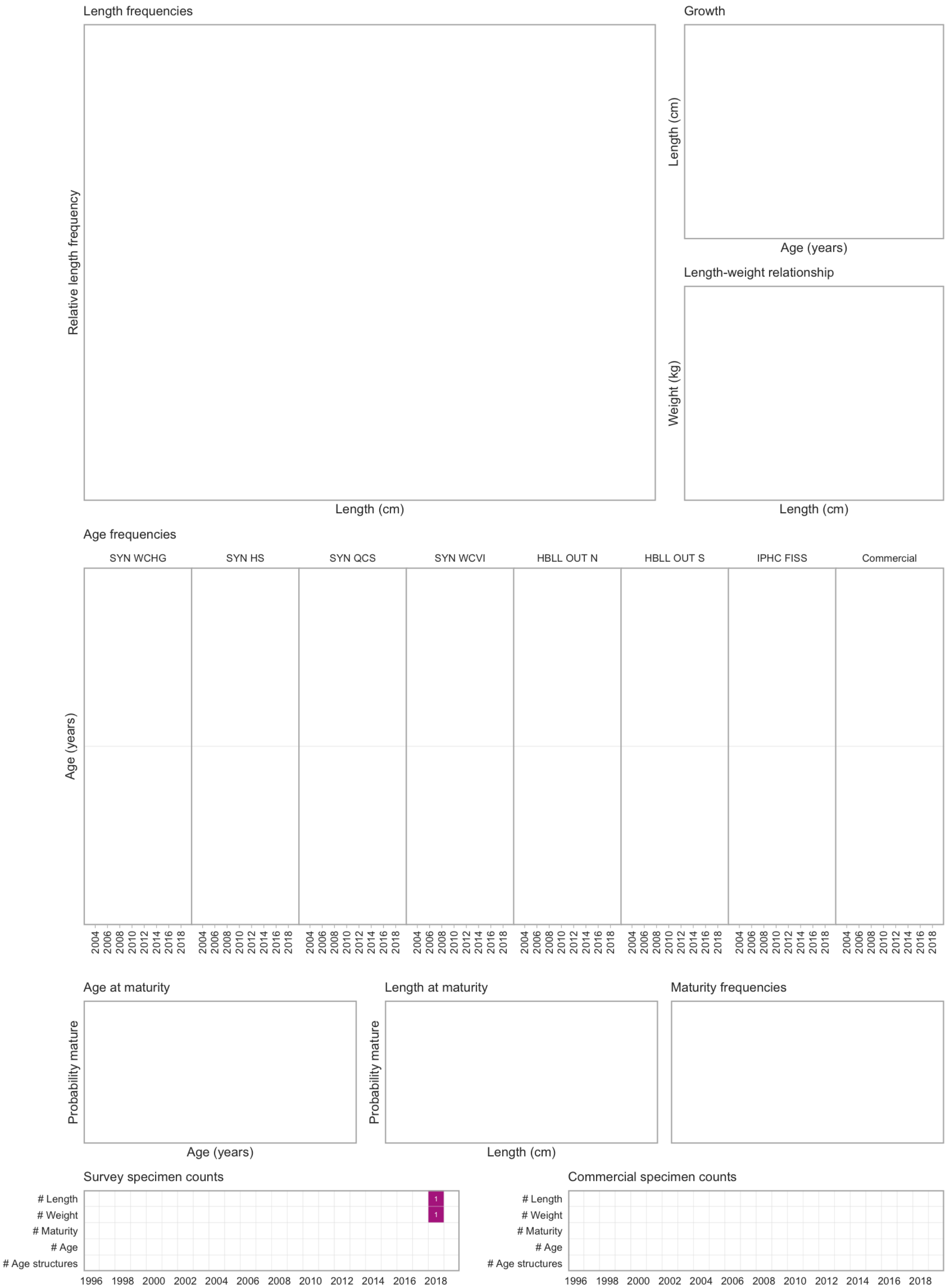


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
5 6 4 1 2 2 2 1
4 3 2 1 1
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.39 GIANT WRYMOUTH

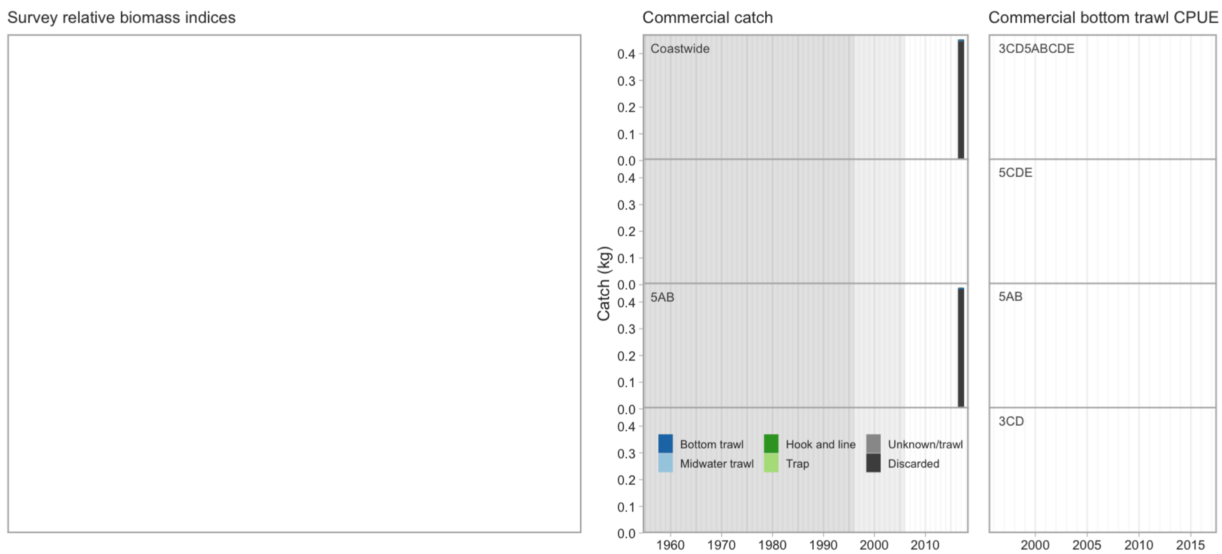
Cryptacanthodes giganteus (355)
Order: Perciformes, Family: Cryptacanthodidae, FishBase, WoRMS

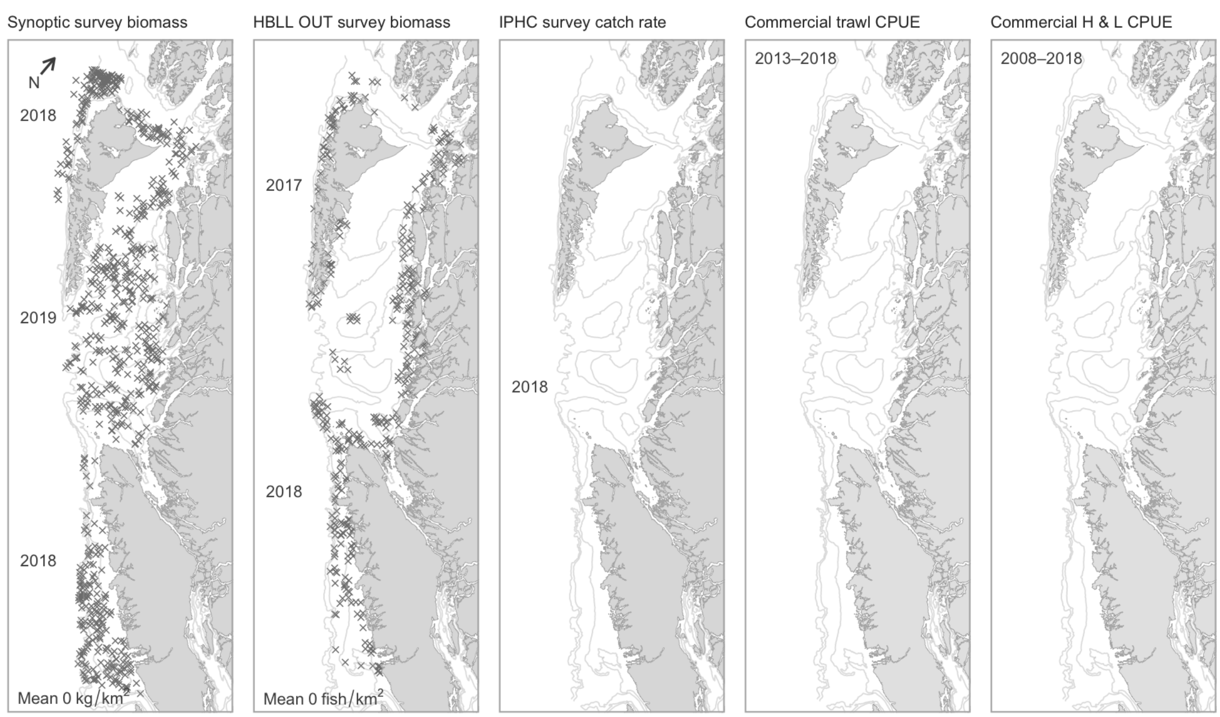


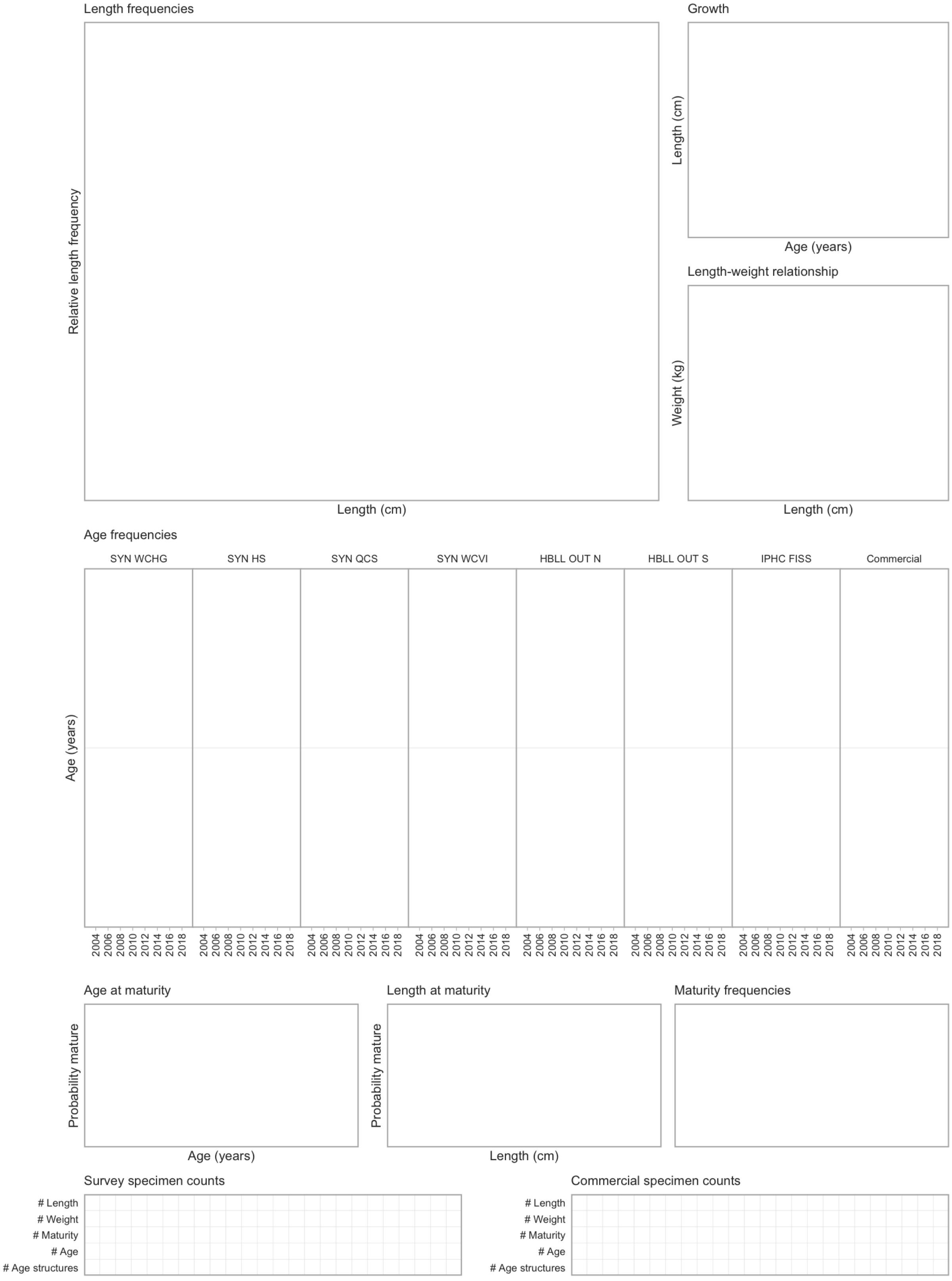

Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1
1
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.40 DWARF WRYMOUTH

Cryptacanthodes aleutensis (356)
Order: Perciformes, Family: Cryptacanthodidae, FishBase, WoRMS



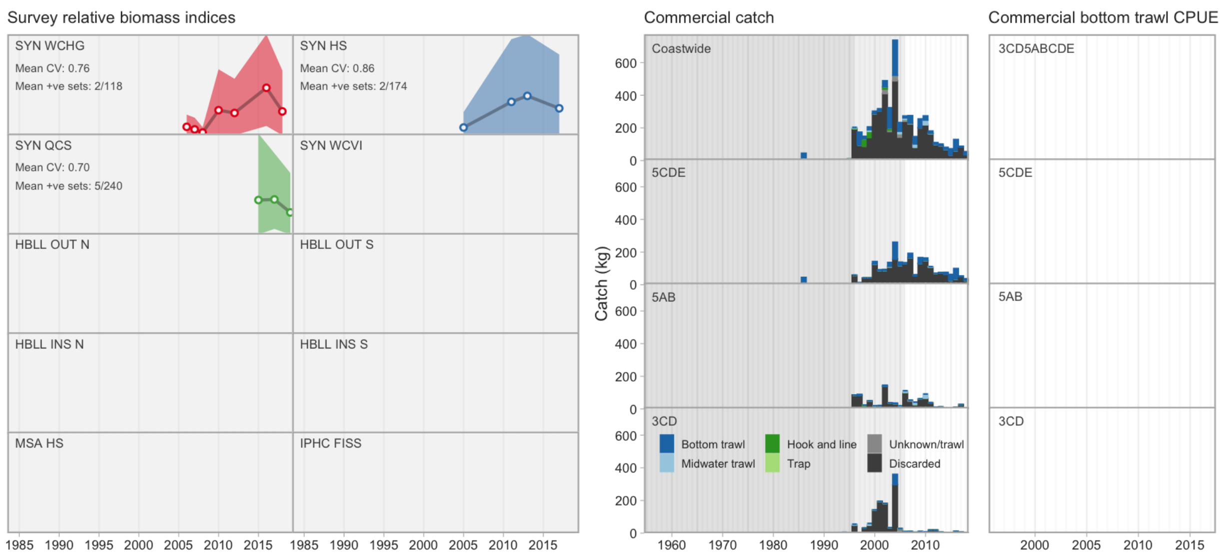


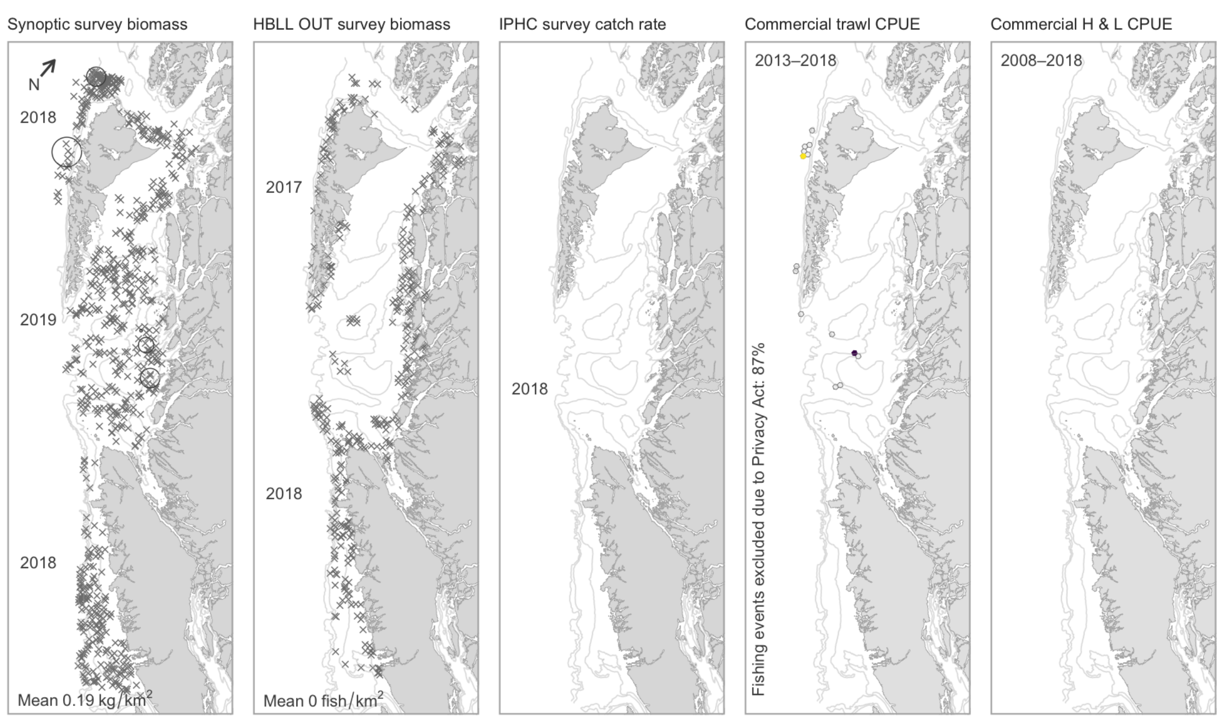


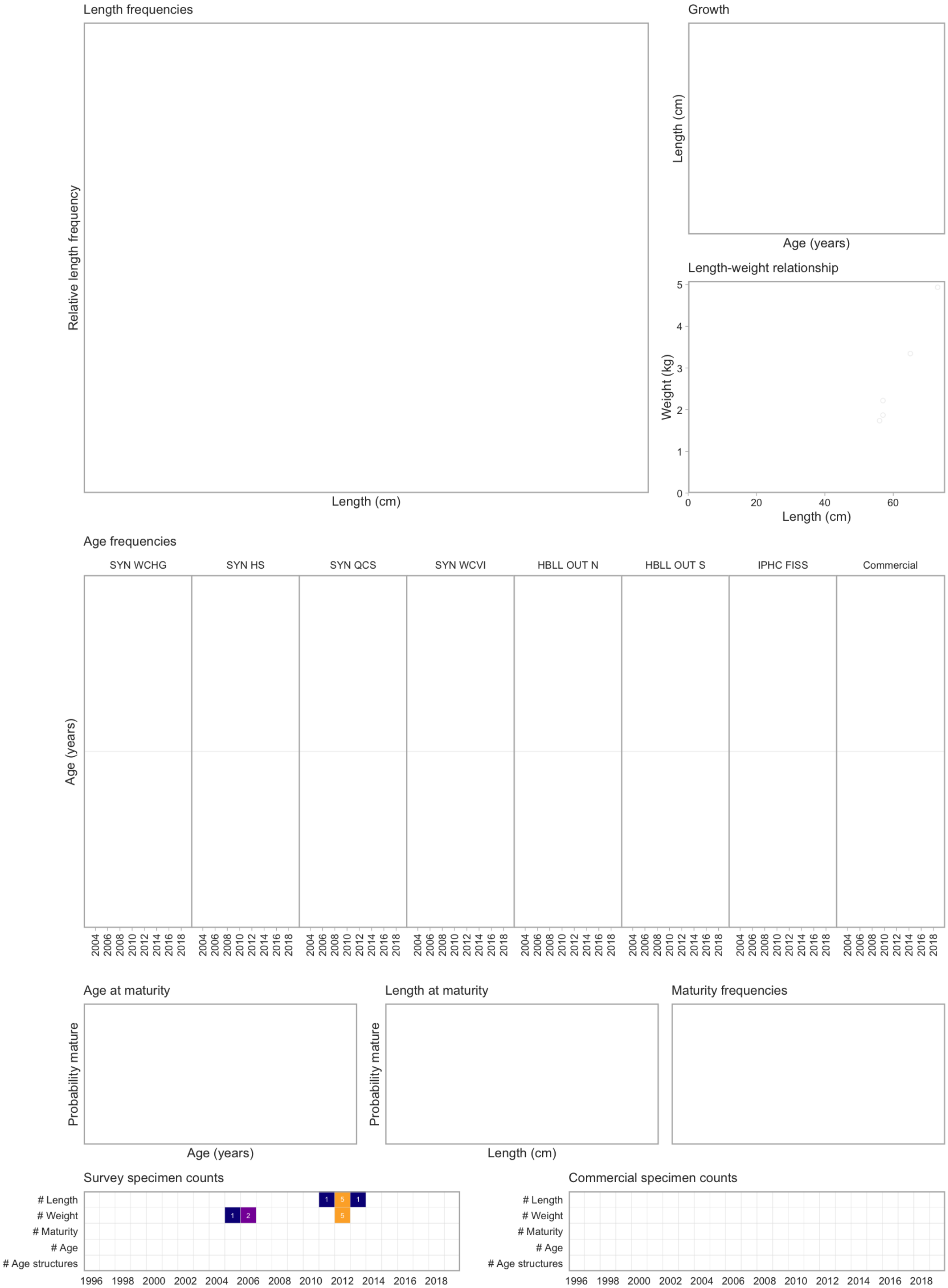
Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.41 PROWFISH

Zaprora silenus (359)
Order: Perciformes, Family: Zaproridae, FishBase, WoRMS



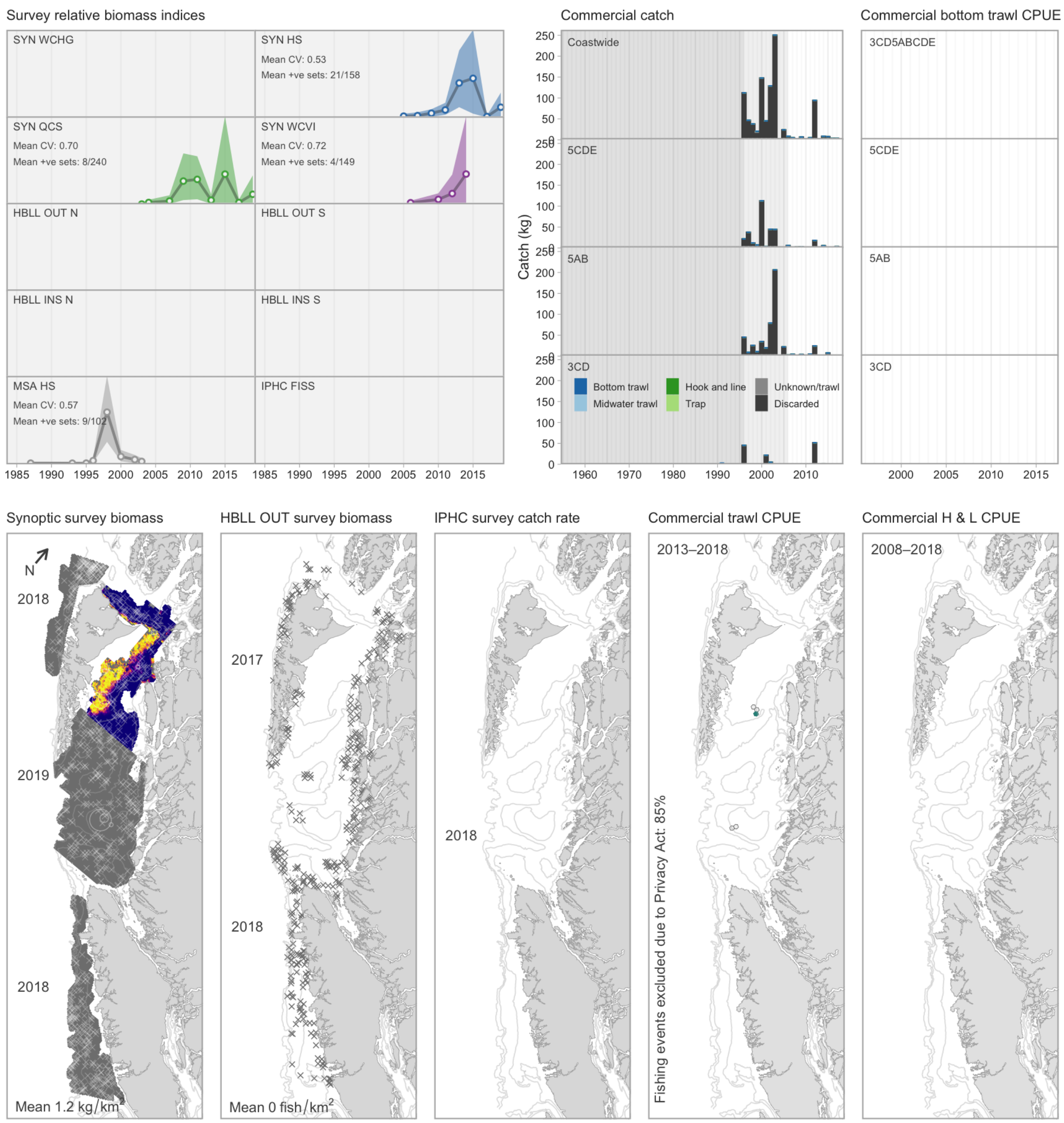


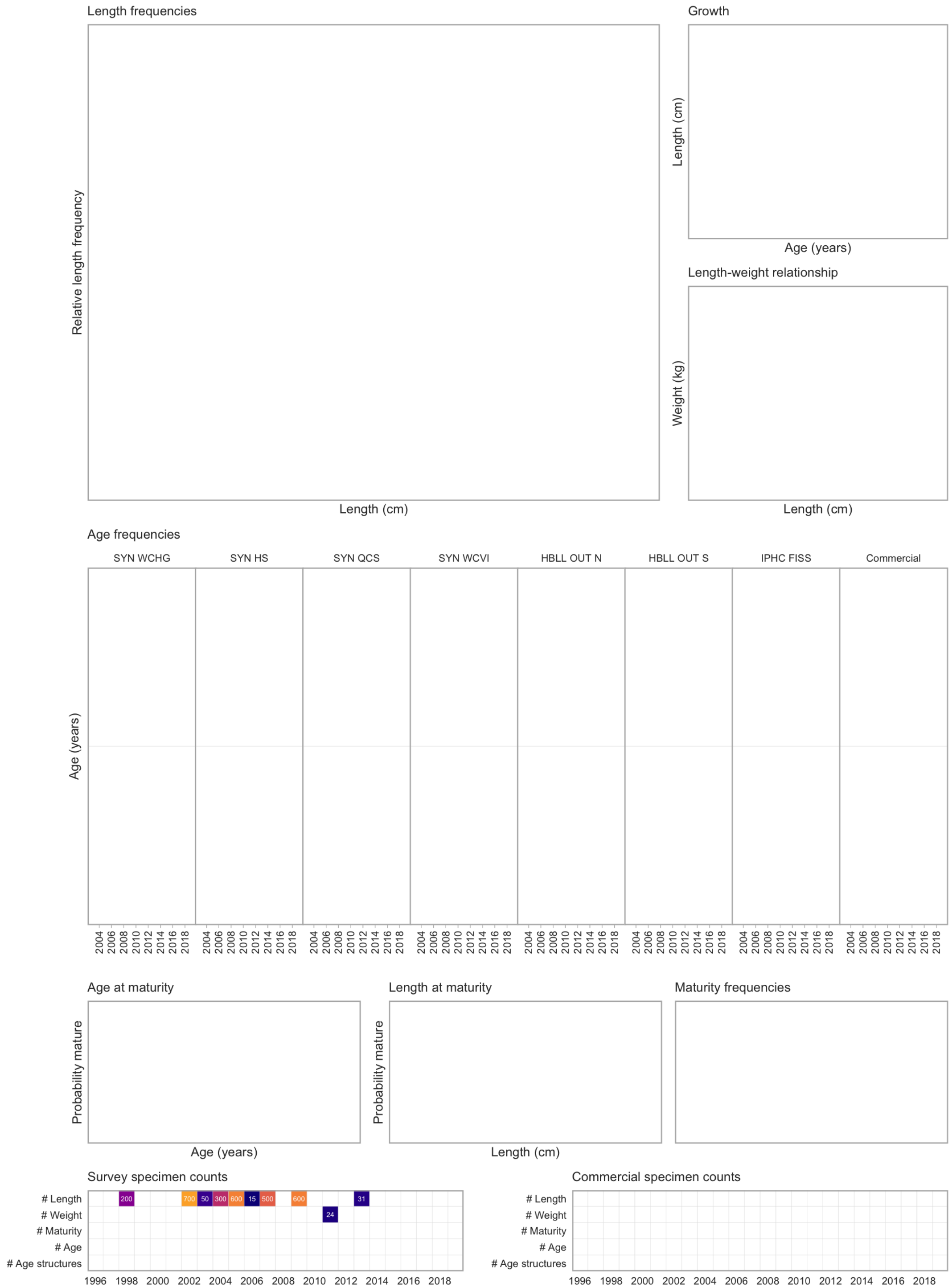


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.42 PACIFIC SAND LANCE

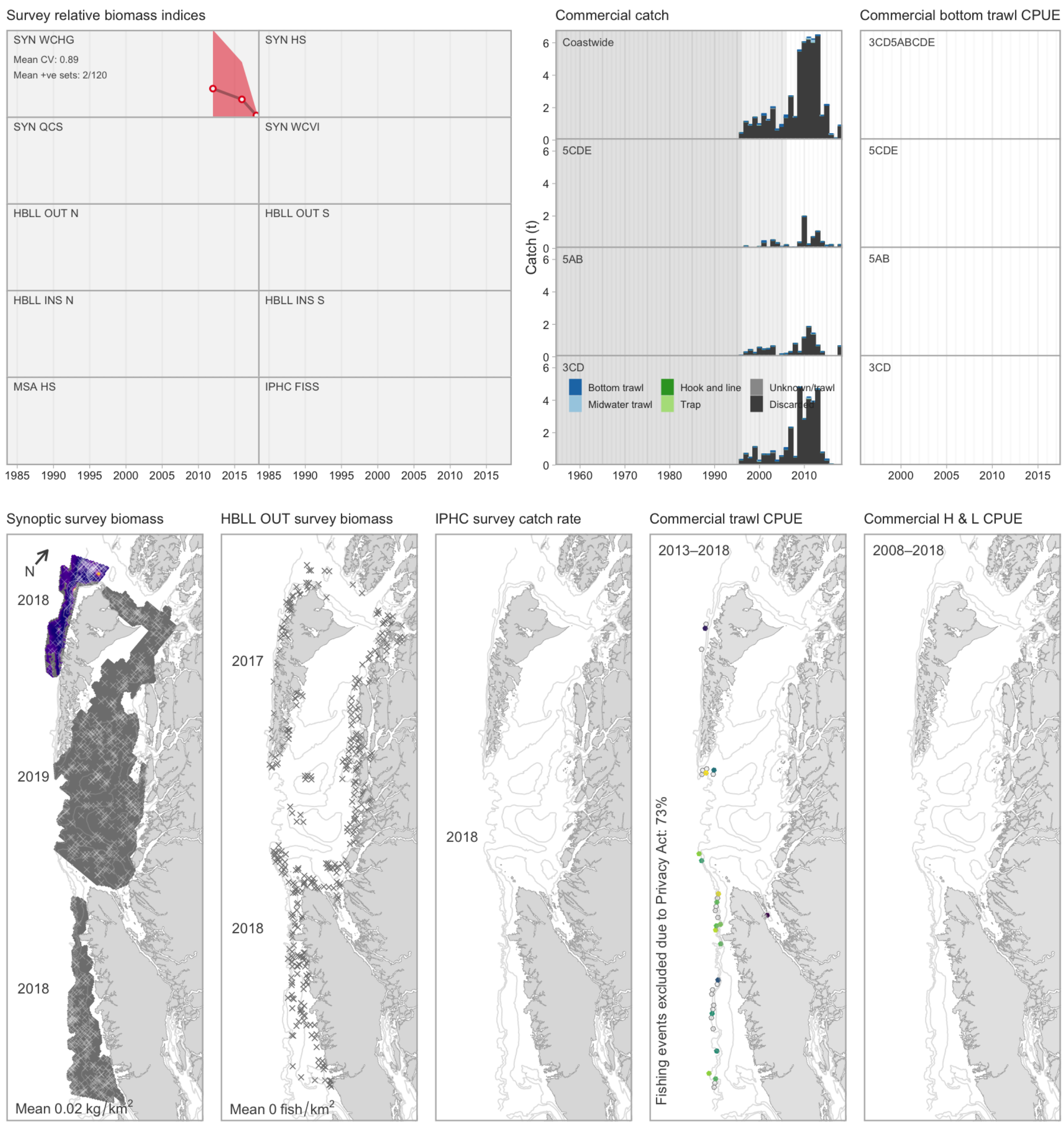
Ammodytes personatus (361)
Order: Perciformes, Family: Ammodytidae, FishBase, WoRMS

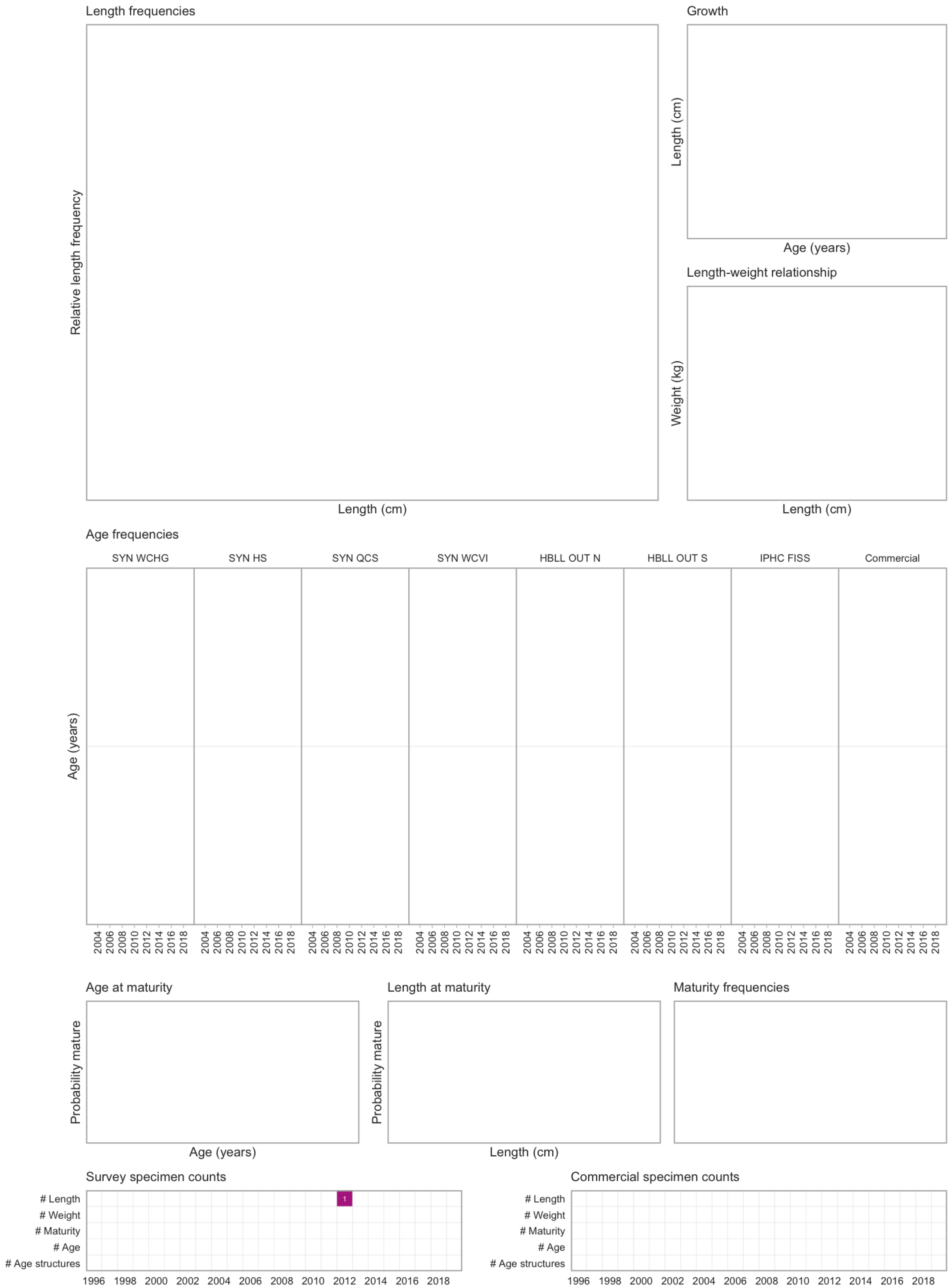



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
200 700 50 300 600 15 500 600 31
24
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.43 RAGFISH

Icosteus aenigmaticus (386)
Order: Perciformes, Family: Icosteidae, FishBase, WoRMS

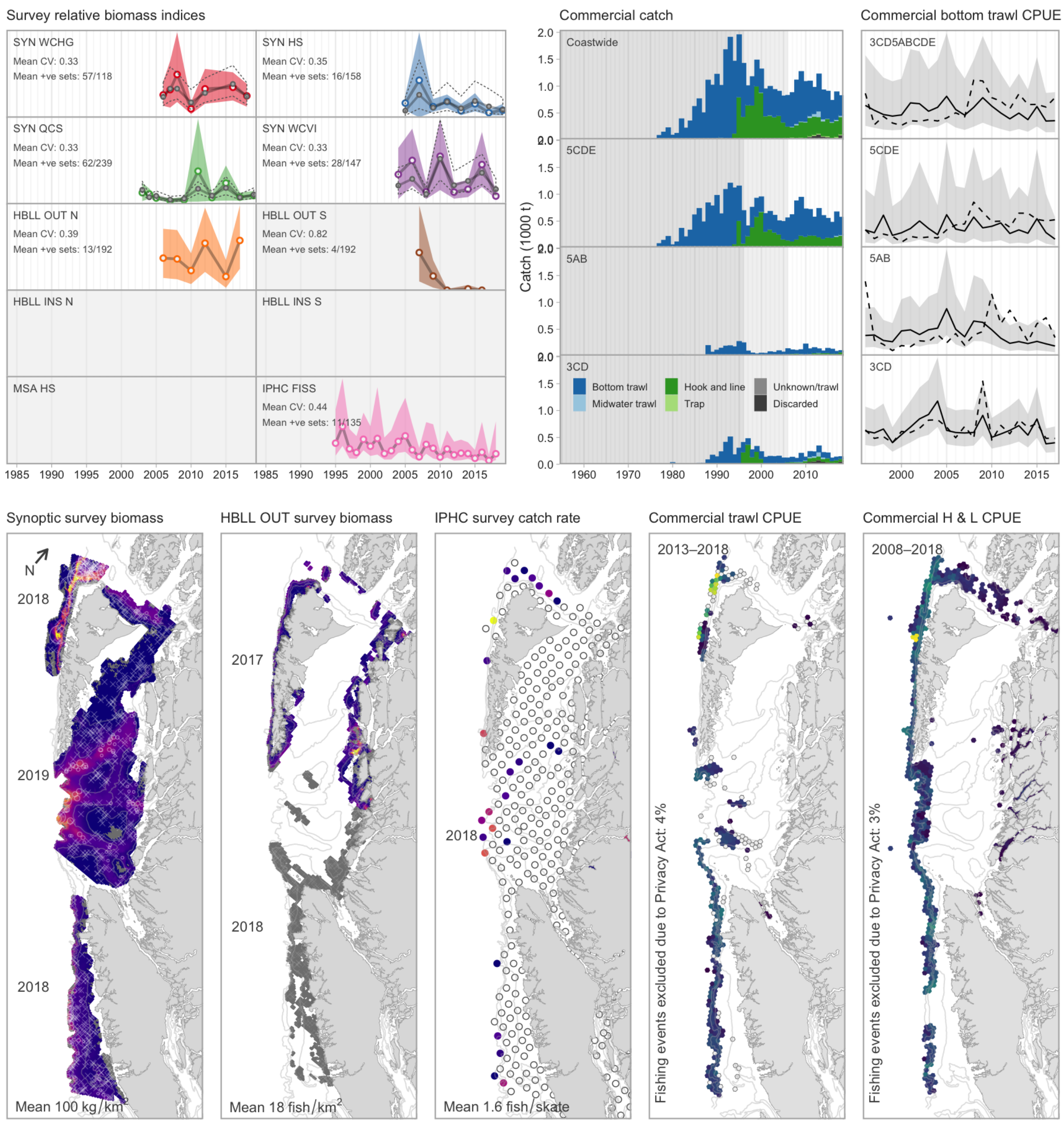


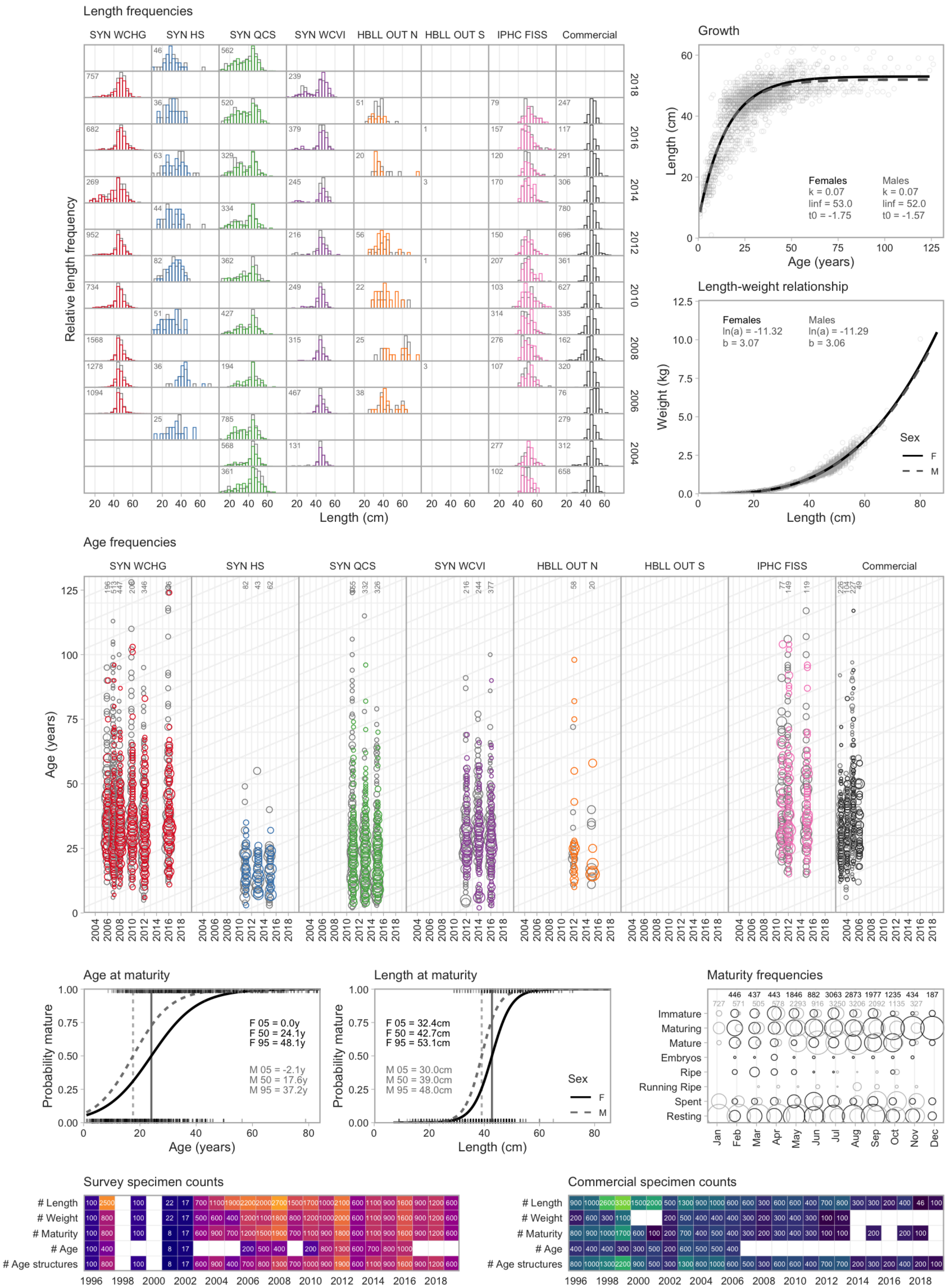


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.44 ROUGHEYE/BLACKSPOTTED ROCKFISH COMPLEX

Sebastes aleutianus/melanostictus (394)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase 1, FishBase 2
Last Research Document: Haigh et al. (2005b)
Last Science Advisory Report: DFO (1999a)
Species at Risk Act Management Plan Series: DFO (2012a)
COSEWIC Status Report: COSEWIC (2007d)
COSEWIC Status: Special Concern, SARA Status: Special Concern

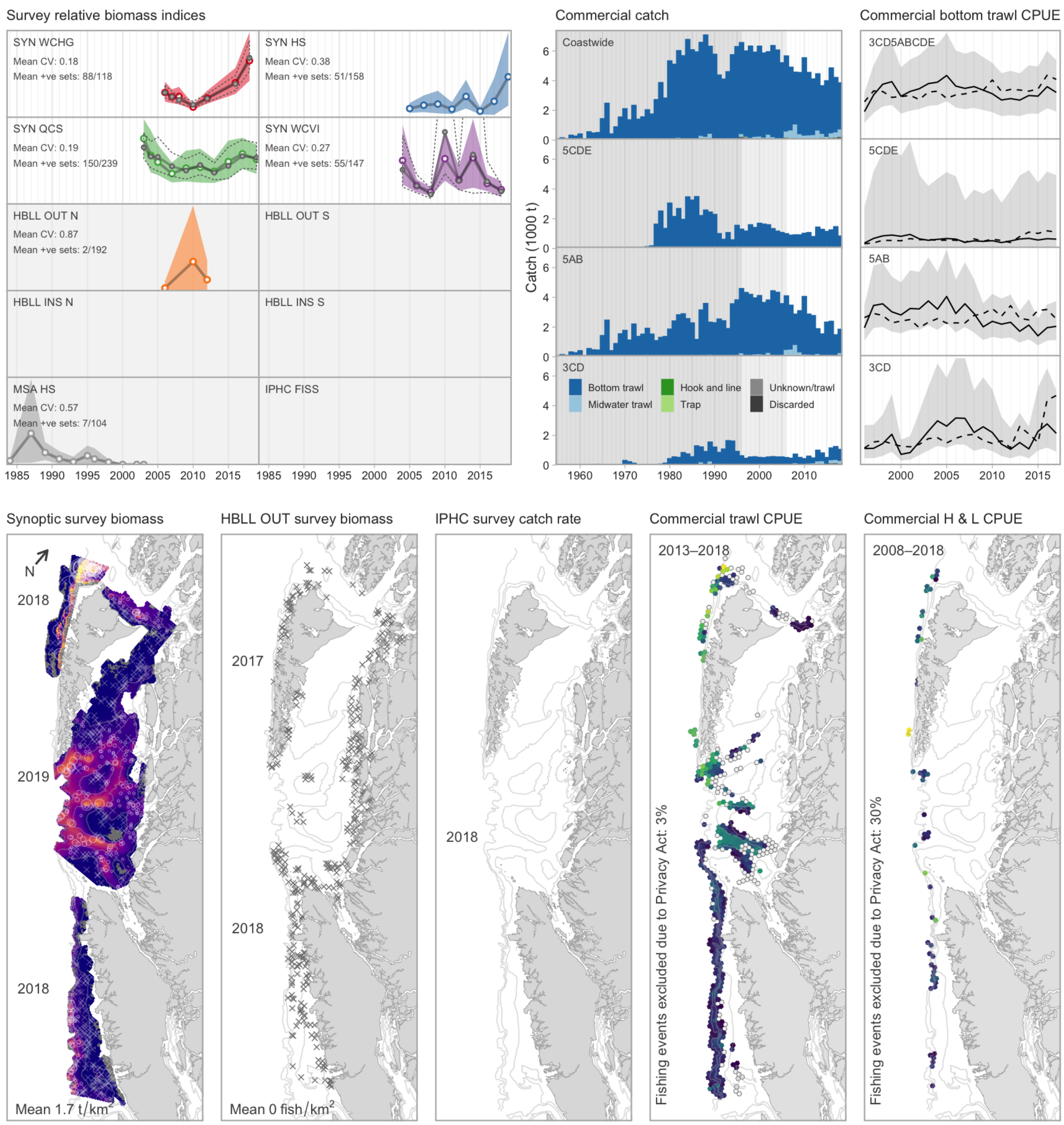


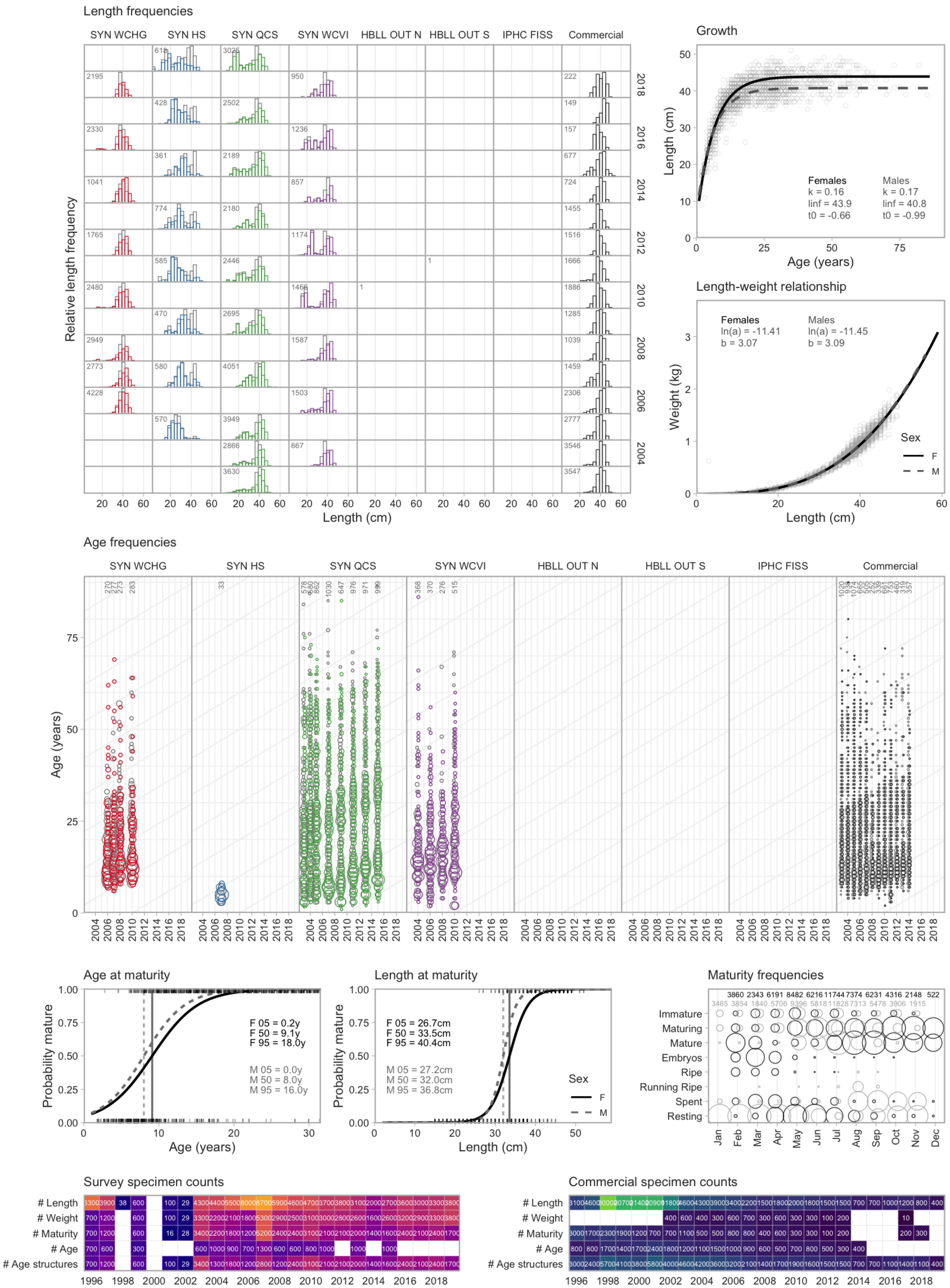


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Females
k = 0.07
linf = 53.0
t0 = -1.75
Males
k = 0.07
linf = 52.0
t0 = -1.57
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.32
b = 3.07
Males
ln(a) = -11.29
b = 3.06
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
F 05 = 0.0y
F 50 = 24.1y
F 95 = 48.1y
M 05 = -2.1y
M 50 = 17.6y
M 95 = 37.2y
Probability mature
Age (years)
Length at maturity
F 05 = 32.4cm
F 50 = 42.7cm
F 95 = 53.1cm
M 05 = 30.0cm
M 50 = 39.0cm
M 95 = 48.0cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.45 PACIFIC OCEAN PERCH

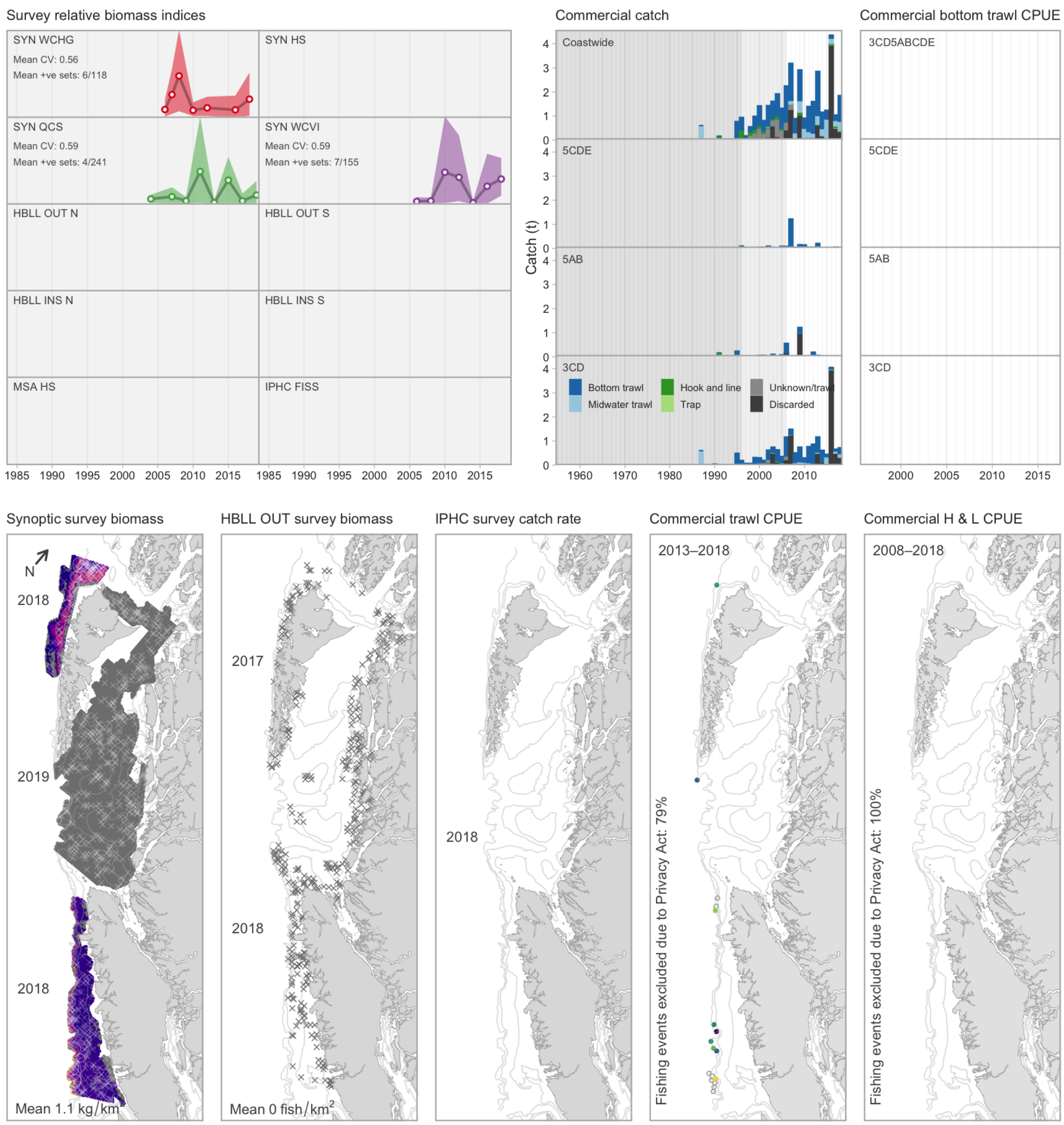
Sebastes alutus (396)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Documents: Edwards et al. (2013), Edwards et al. (2014), Haigh et al. (2018)
Last Science Advisory Reports: DFO (2013), DFO (2017a)

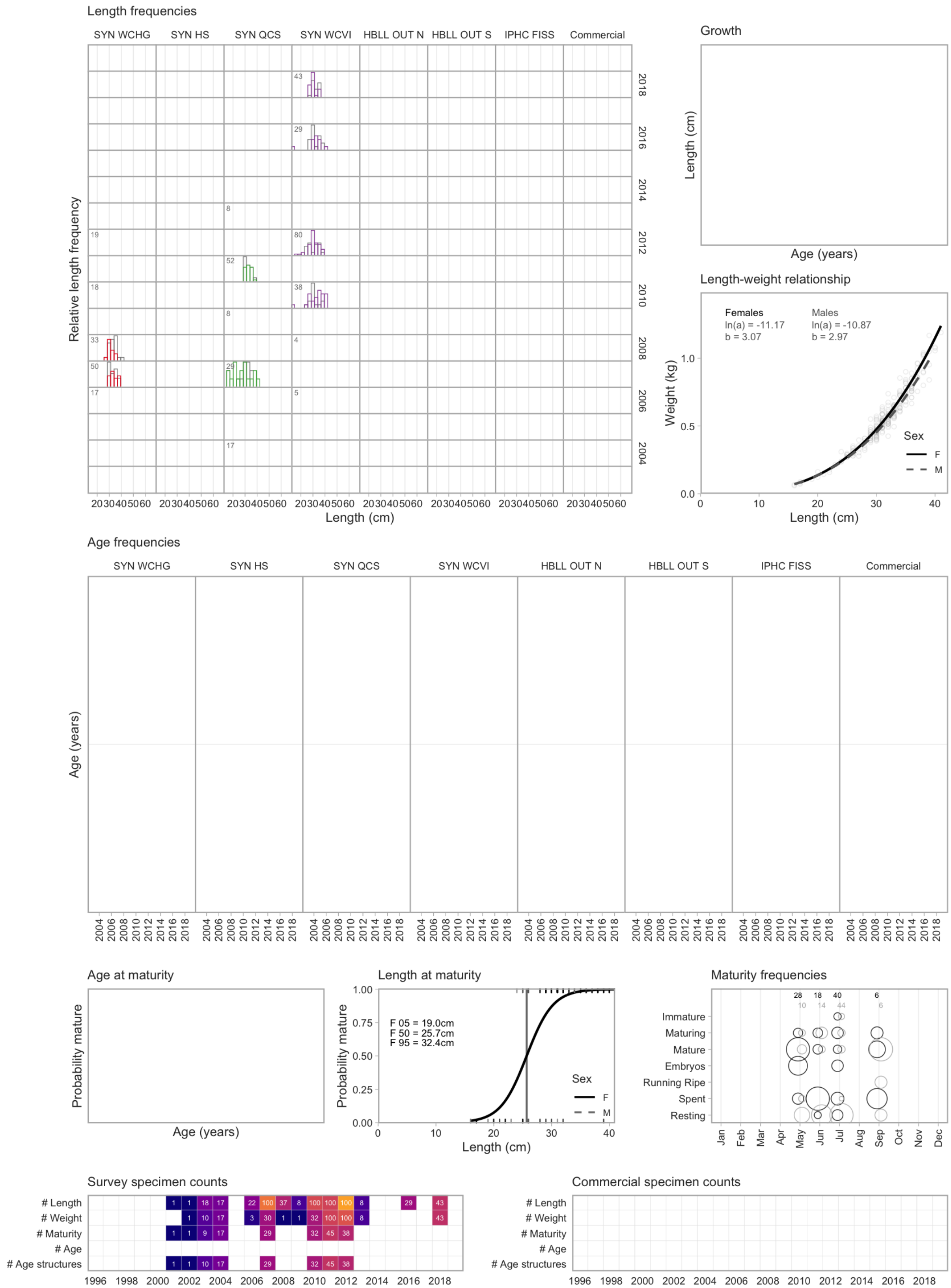



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Females
k = 0.16
linf = 43.9
t0 = -0.66
Males
k = 0.17
linf = 40.8
t0 = -0.99
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.41
b = 3.07
Males
ln(a) = -11.45
b = 3.09
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
F 05 = 0.2y
F 50 = 9.1y
F 95 = 18.0y
M 05 = 0.0y
M 50 = 8.0y
M 95 = 16.0y
Probability mature
Age (years)
Length at maturity
F 05 = 26.7cm
F 50 = 33.5cm
F 95 = 40.4cm
M 05 = 27.2cm
M 50 = 32.0cm
M 95 = 36.8cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.46 AURORA ROCKFISH

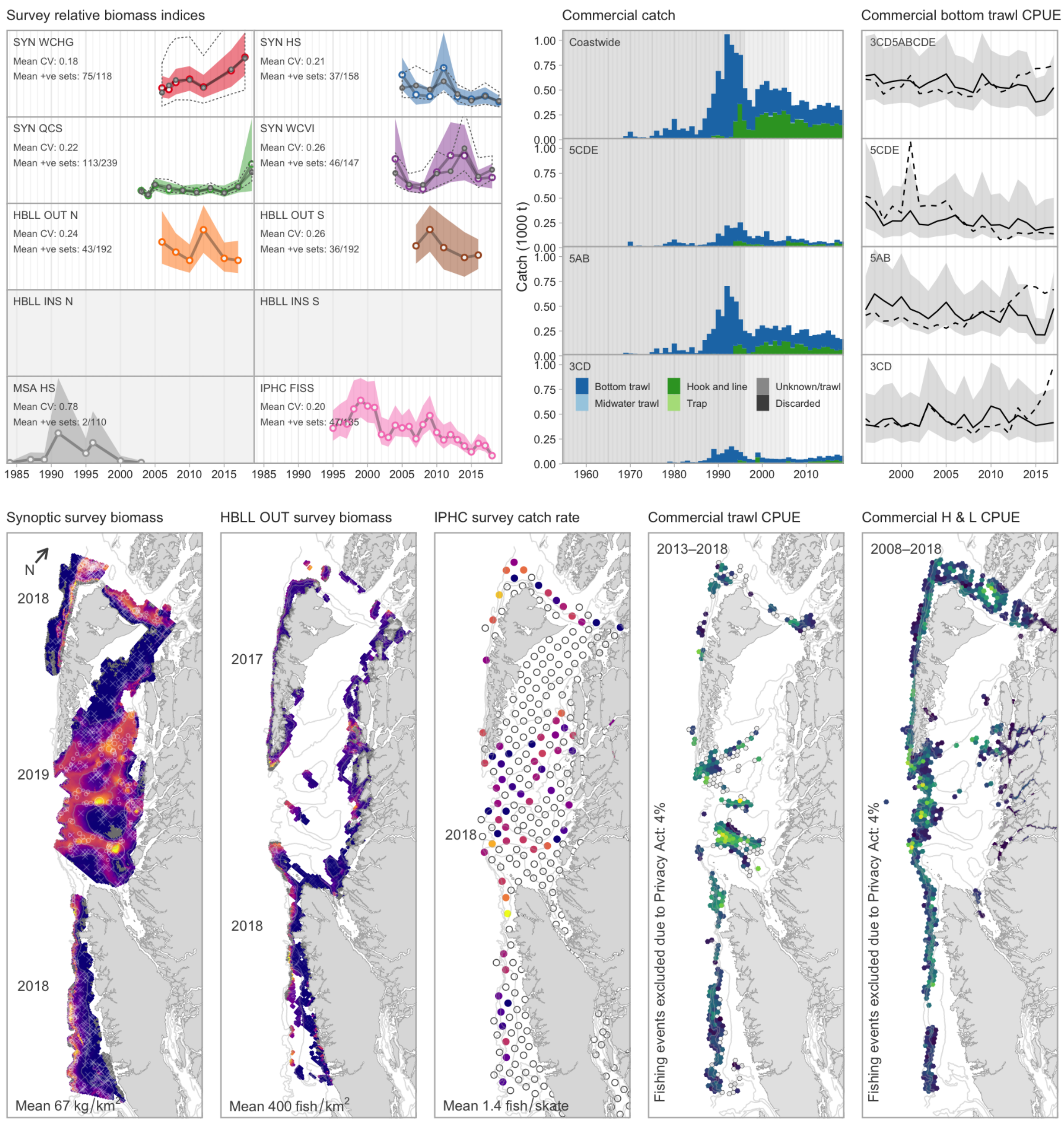
Sebastes aurora (400)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

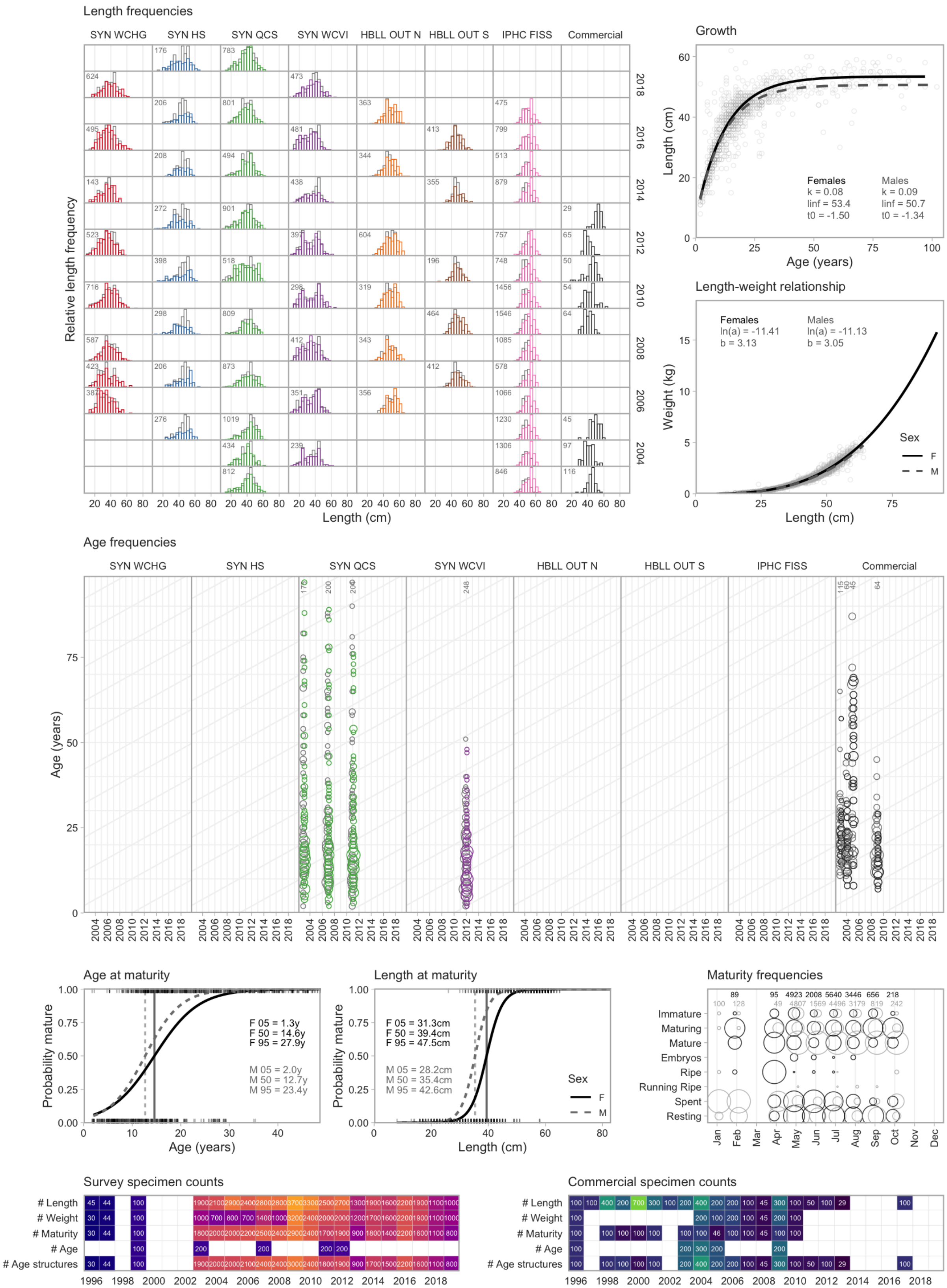



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.17
b = 3.07
Males
ln(a) = -10.87
b = 2.97
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 19.0cm
F 50 = 25.7cm
F 95 = 32.4cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Running Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.47 REDBANDED ROCKFISH

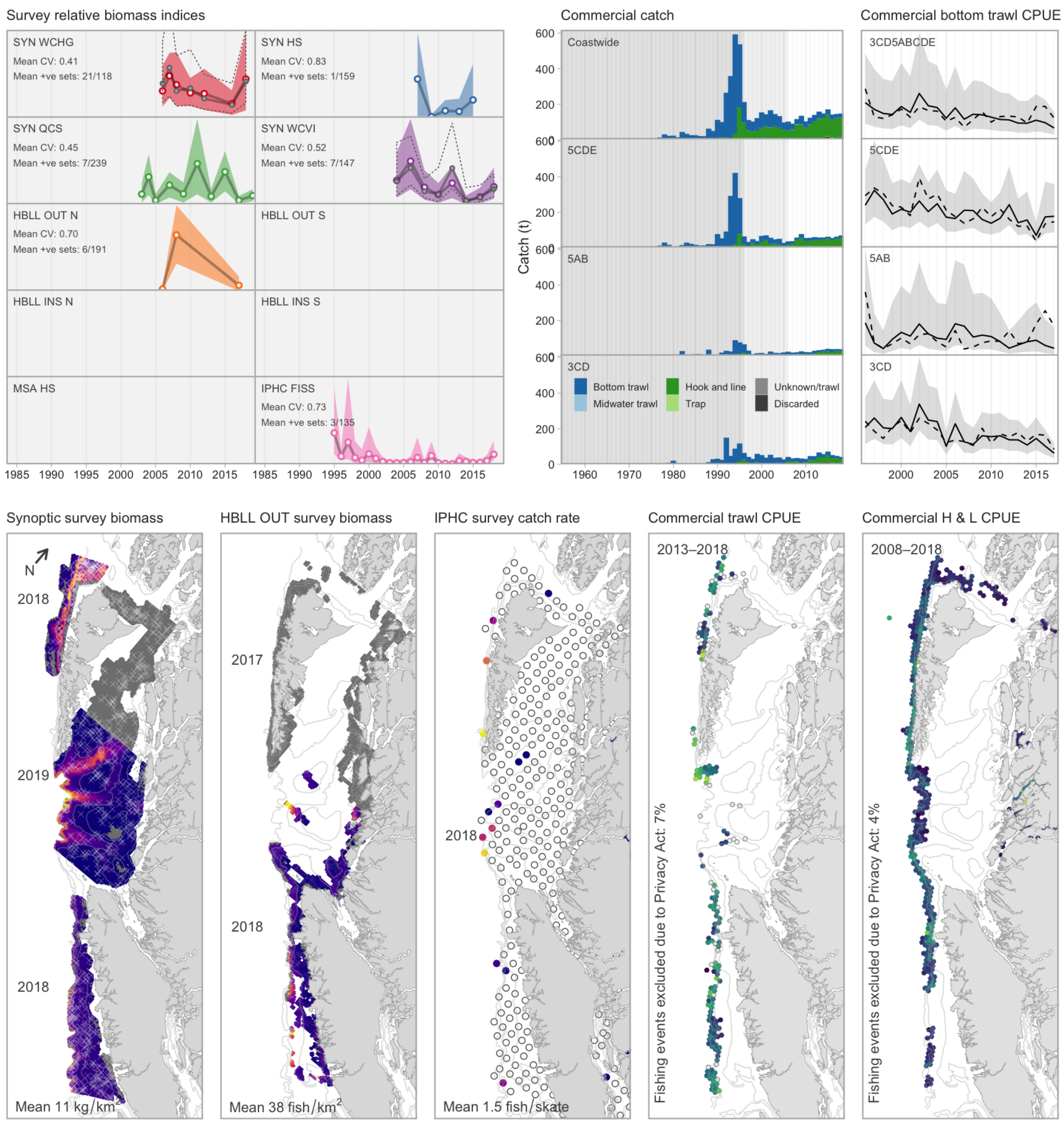
Sebastes babcocki (401)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Edwards et al. (2017)

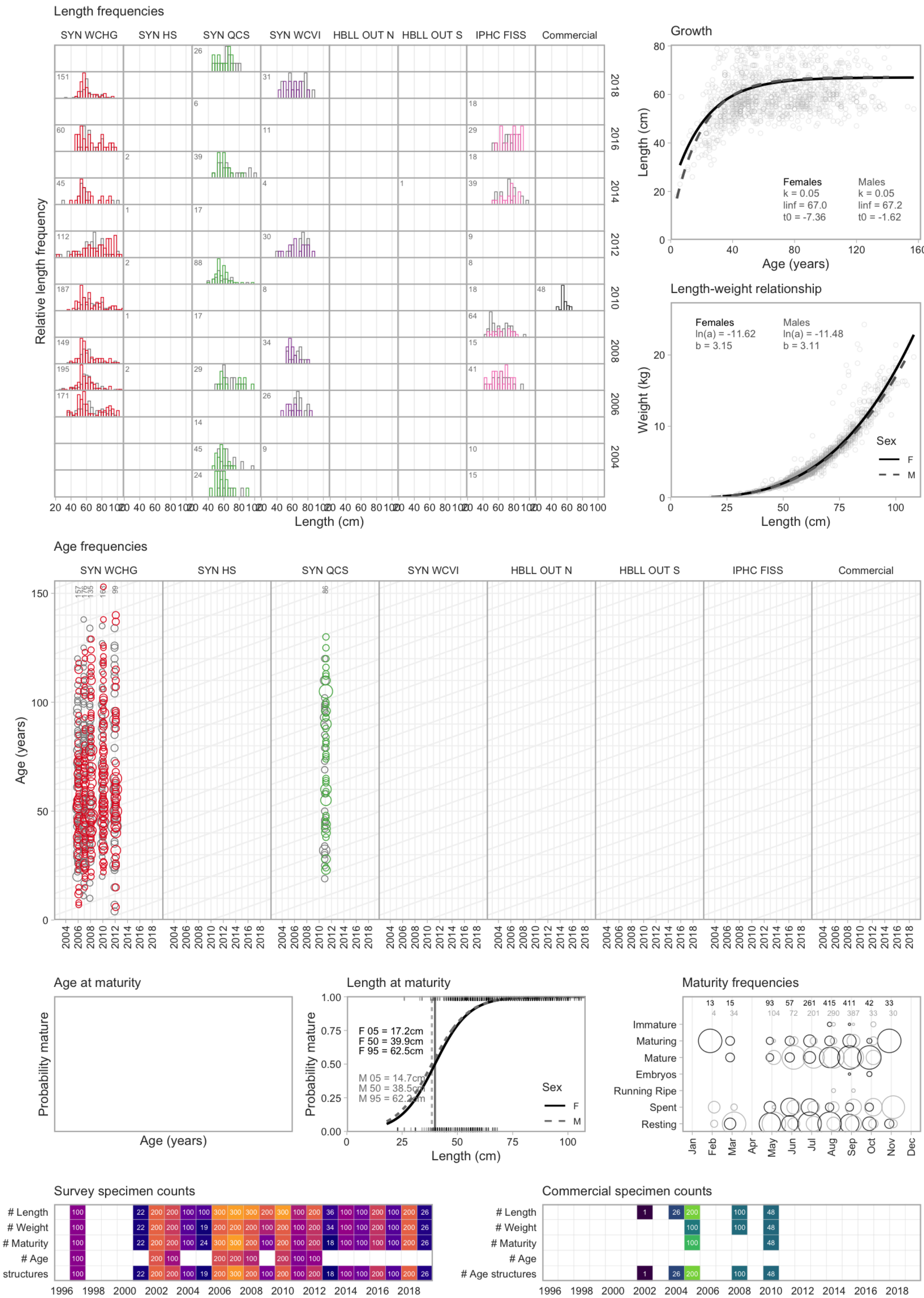



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.08
linf = 53.4
t0 = -1.50
Males
k = 0.09
linf = 50.7
t0 = -1.34
Length-weight relationship
Females
ln(a) = -11.41
b = 3.13
Males
ln(a) = -11.13
b = 3.05
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 1.3y
F 50 = 14.6y
F 95 = 27.9y
M 05 = 2.0y
M 50 = 12.7y
M 95 = 23.4y
Length at maturity
Probability mature
Length (cm)
F 05 = 31.3cm
F 50 = 39.4cm
F 95 = 47.5cm
M 05 = 28.2cm
M 50 = 35.4cm
M 95 = 42.6cm
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.48 SHORTRAKER ROCKFISH

Sebastes borealis (403)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Schnute et al. (1999a)
Last Science Advisory Report: DFO (1999b)

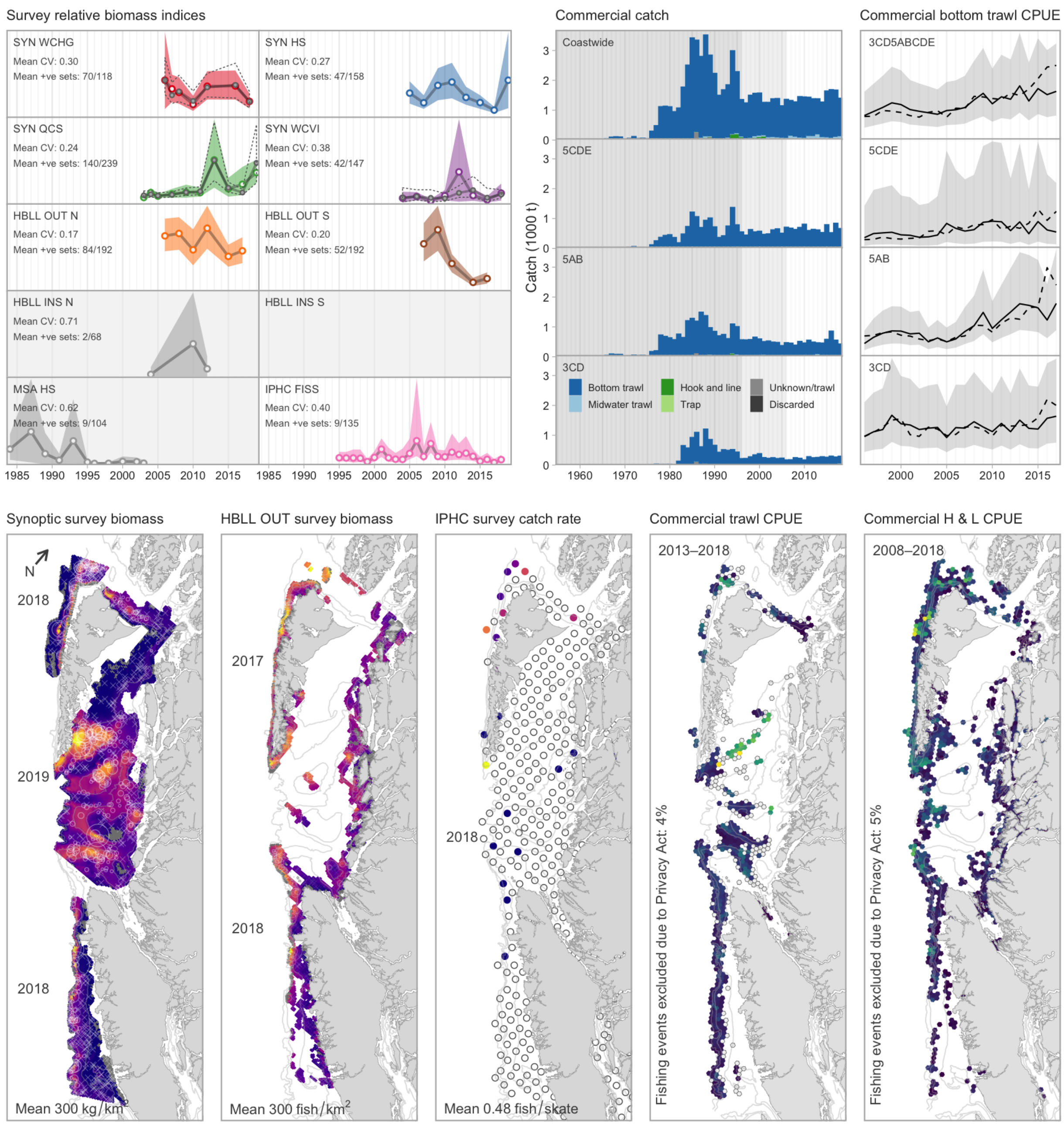


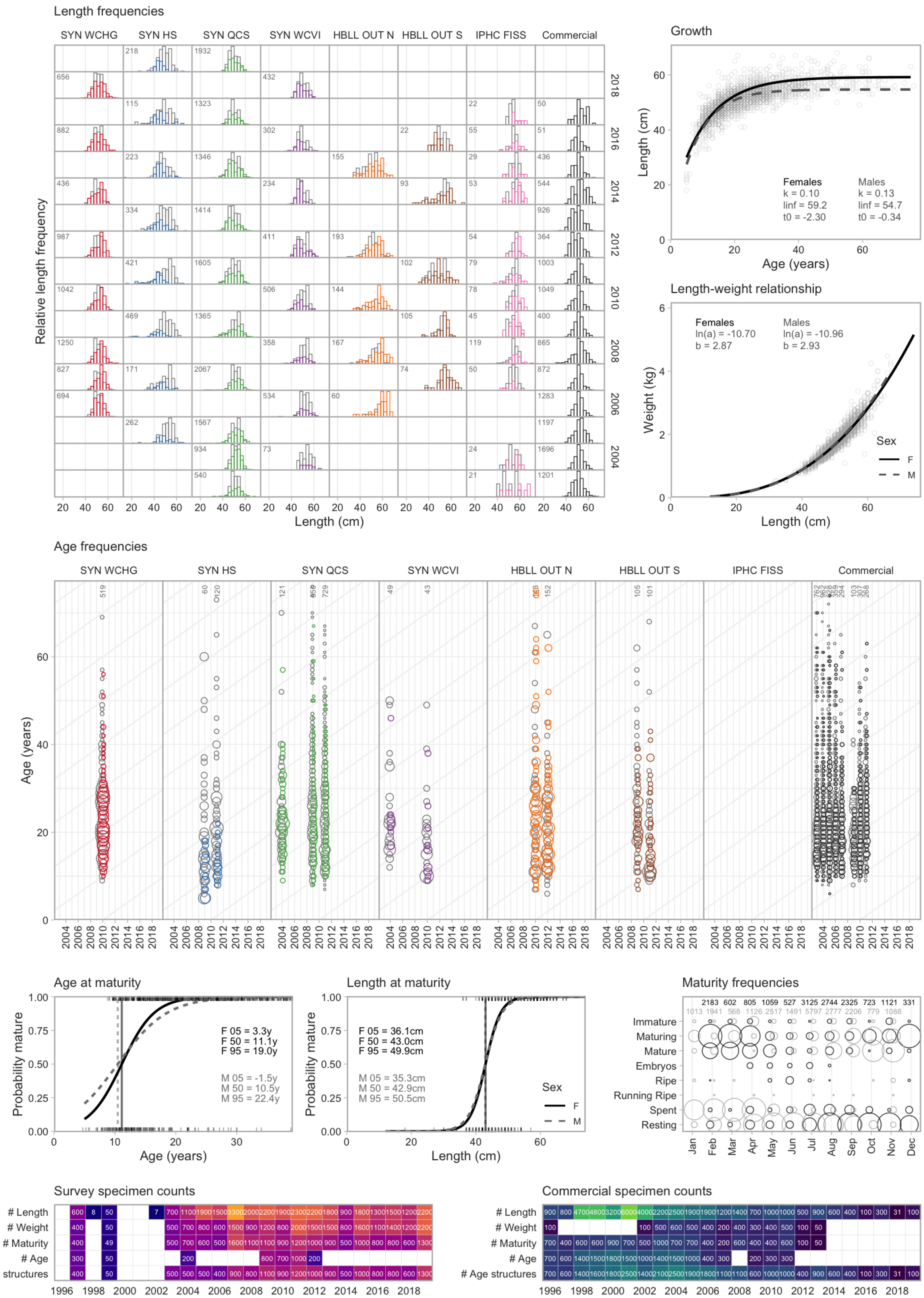


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.05
linf = 67.0
t0 = -7.36
Males
k = 0.05
linf = 67.2
t0 = -1.62
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -11.62
b = 3.15
Males
ln(a) = -11.48
b = 3.11
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 17.2cm
F 50 = 39.9cm
F 95 = 62.5cm
M 05 = 14.7cm
M 50 = 38.5cm
M 95 = 62.2cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Running Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.49 SILVERGRAY ROCKFISH

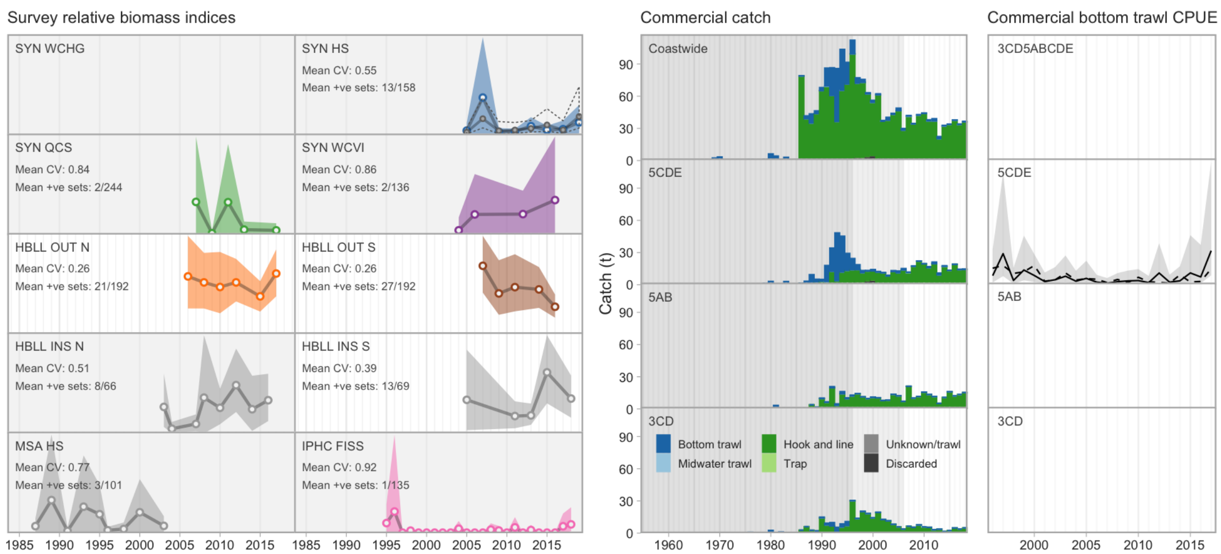
Sebastes brevispinis (405)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Starr et al. (2016)
Last Science Advisory Report: DFO (2014b)

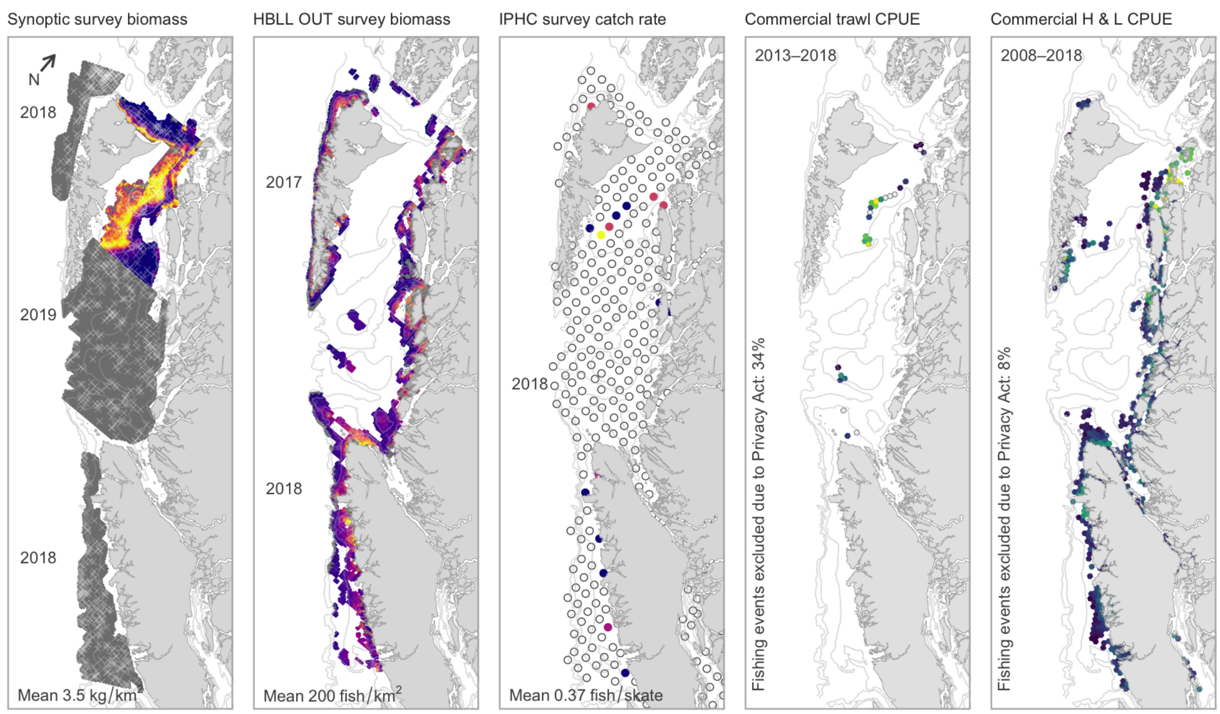


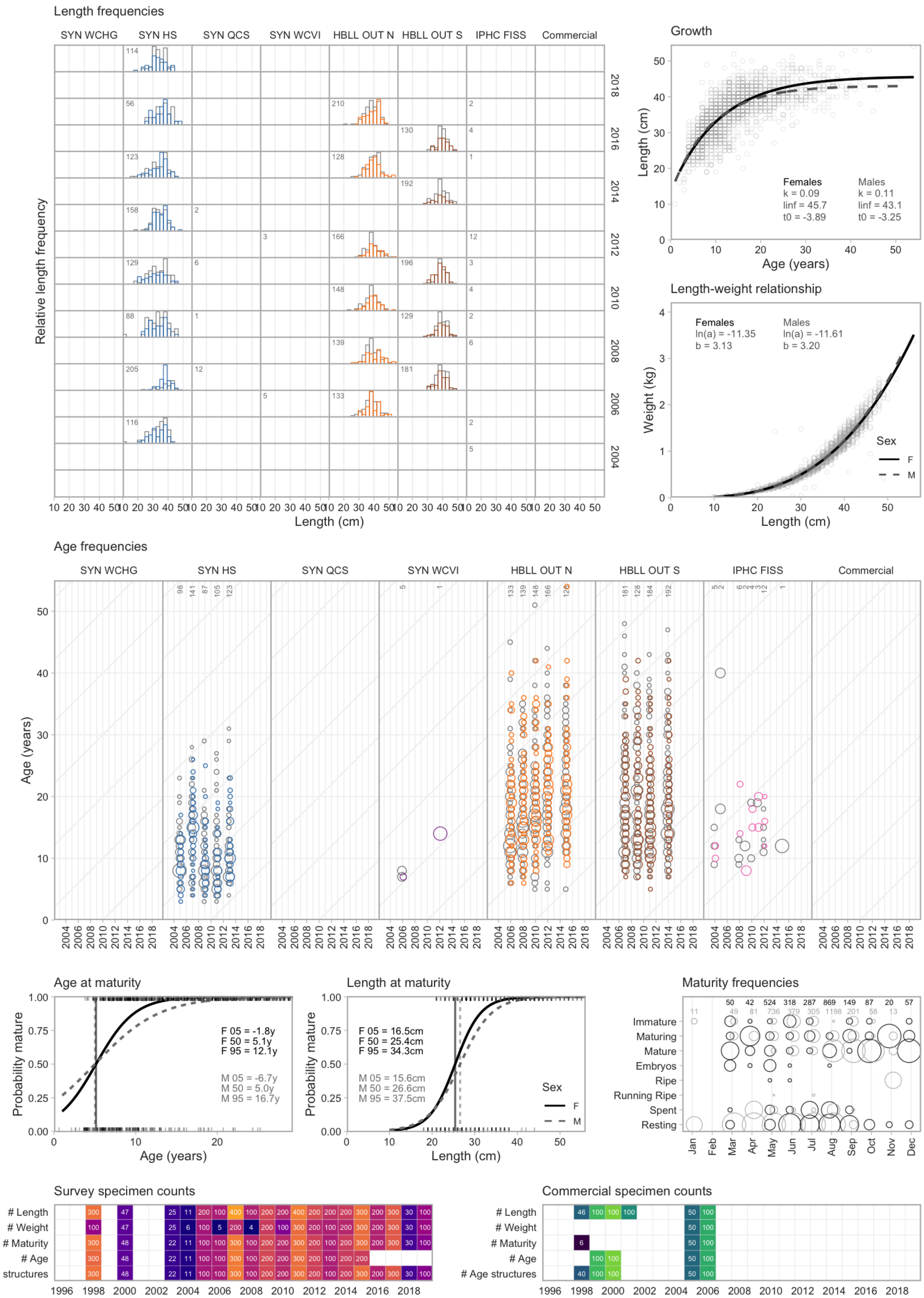

Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.10
linf = 59.2
t0 = -2.30
Males
k = 0.13
linf = 54.7
t0 = -0.34
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -10.70
b = 2.87
Males
ln(a) = -10.96
b = 2.93
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 3.3y
F 50 = 11.1y
F 95 = 19.0y
M 05 = -1.5y
M 50 = 10.5y
M 95 = 22.4y
Length at maturity
Probability mature
Length (cm)
F 05 = 36.1cm
F 50 = 43.0cm
F 95 = 49.9cm
M 05 = 35.3cm
M 50 = 42.9cm
M 95 = 50.5cm
Sex
F
M
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.50 COPPER ROCKFISH

Sebastes caurinus (407)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Technical Report: Stocker and Fargo (1995)

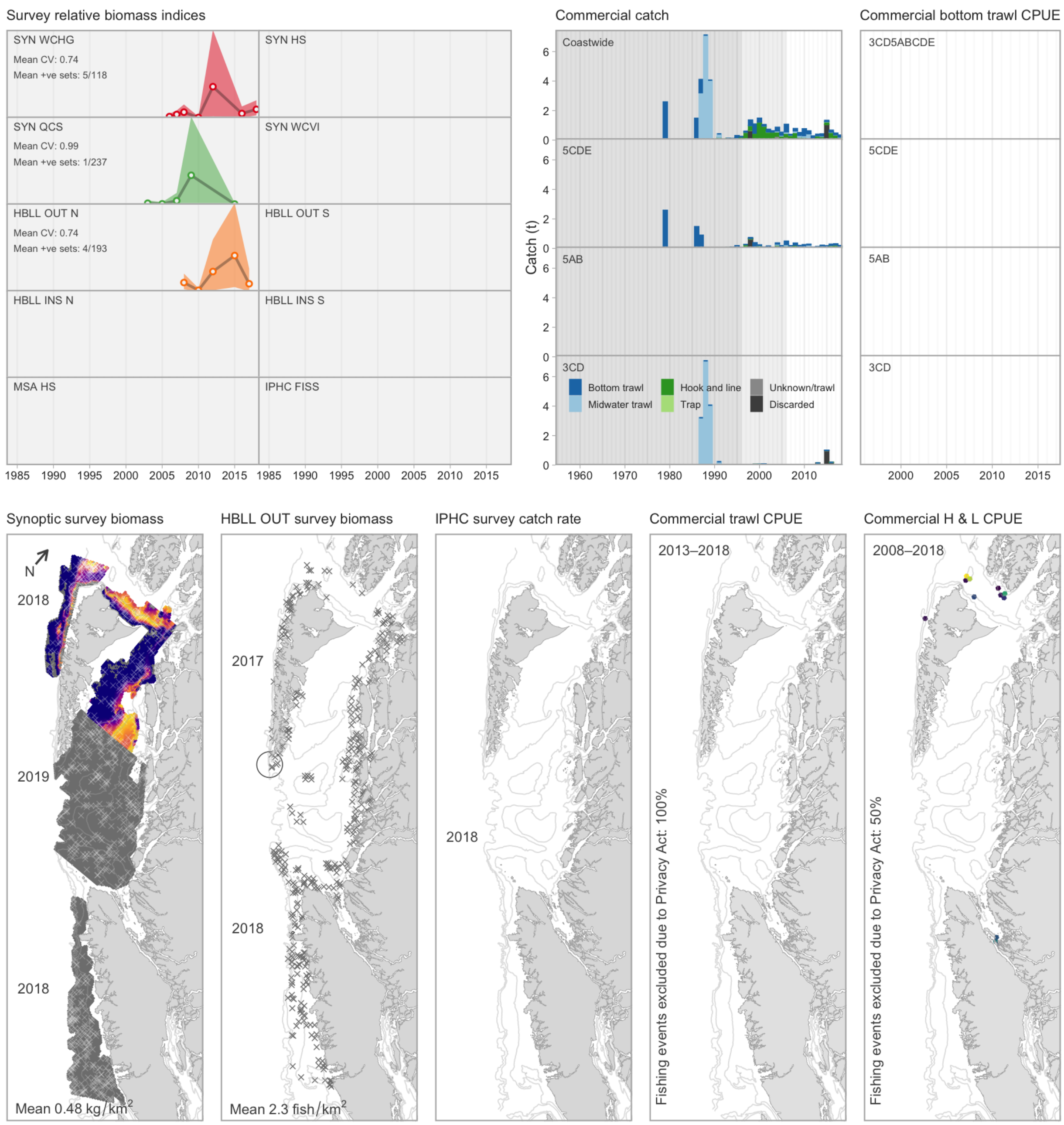


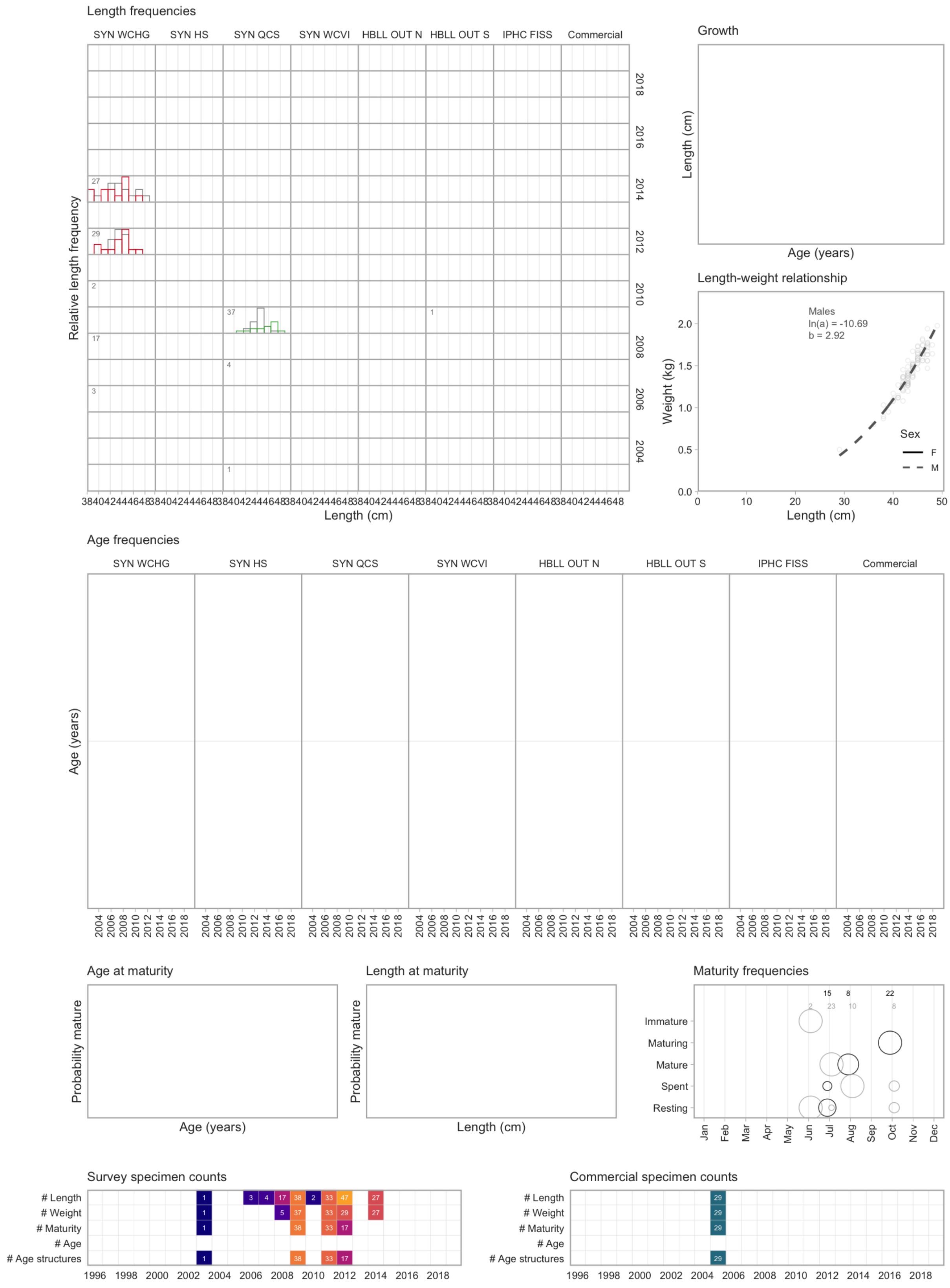



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.09
linf = 45.7
t0 = -3.89
Males
k = 0.11
linf = 43.1
t0 = -3.25
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -11.35
b = 3.13
Males
ln(a) = -11.61
b = 3.20
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = -1.8y
F 50 = 5.1y
F 95 = 12.1y
M 05 = -6.7y
M 50 = 5.0y
M 95 = 16.7y
Length at maturity
Probability mature
Length (cm)
F 05 = 16.5cm
F 50 = 25.4cm
F 95 = 34.3cm
M 05 = 15.6cm
M 50 = 26.6cm
M 95 = 37.5cm
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.51 DUSKY ROCKFISH

Sebastes variabilis (409)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

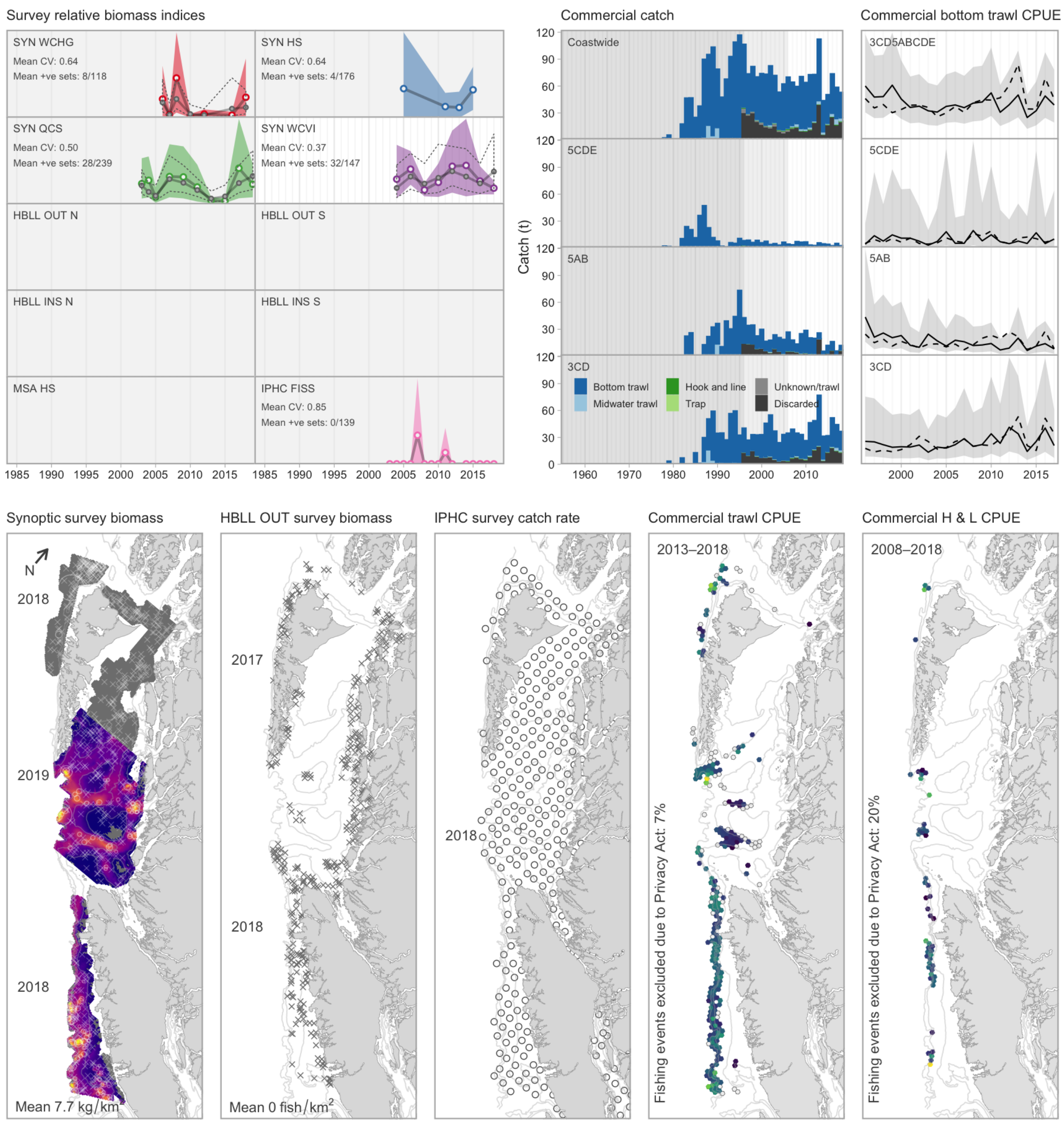


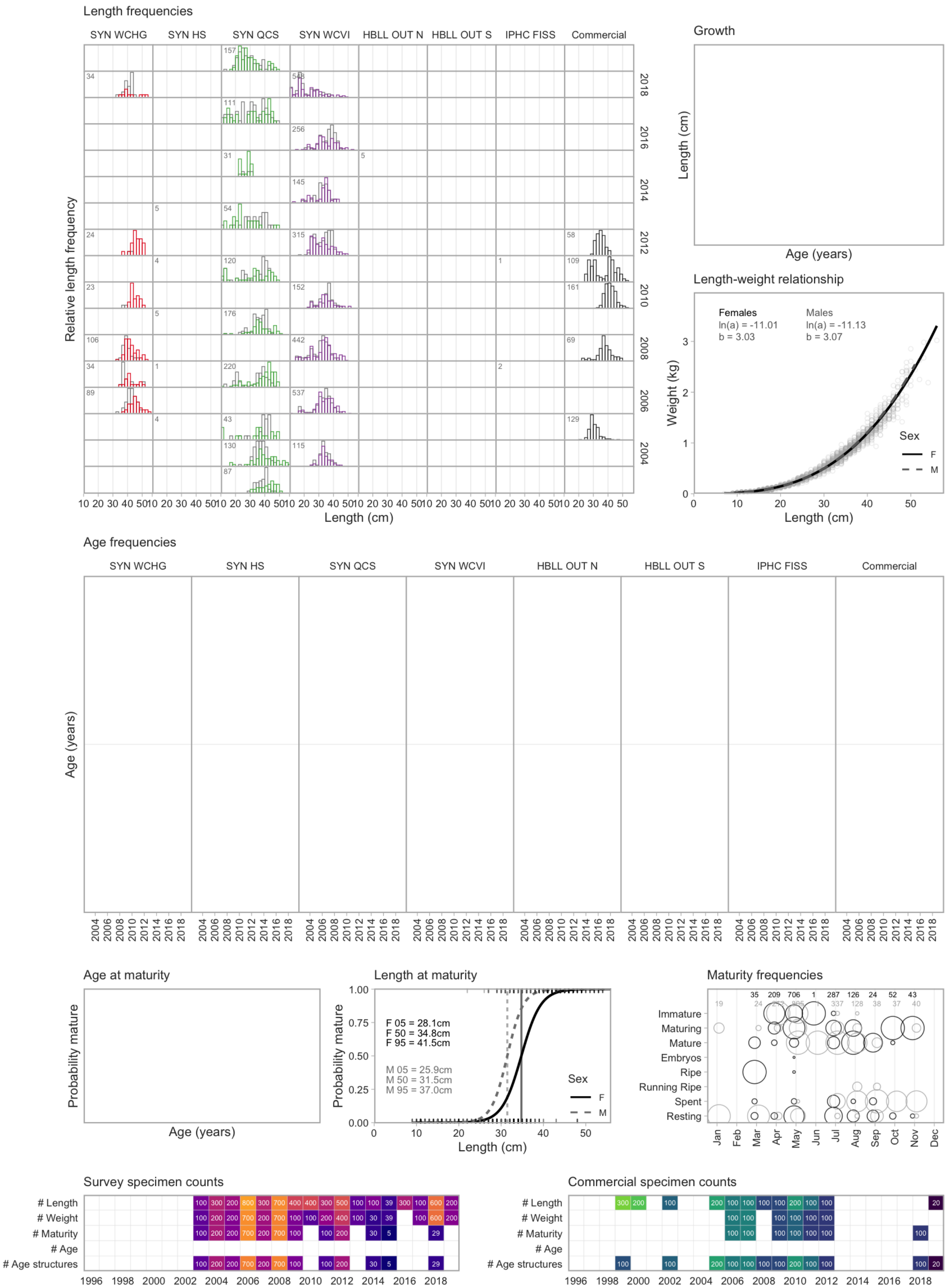


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Males
ln(a) = -10.69
b = 2.92
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.52 DARKBLOTCHED ROCKFISH

Sebastes crameri (410)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Haigh and Starr (2008)
COSEWIC Status Report: COSEWIC (2010a)
COSEWIC Status: Special Concern, SARA Status: No Status

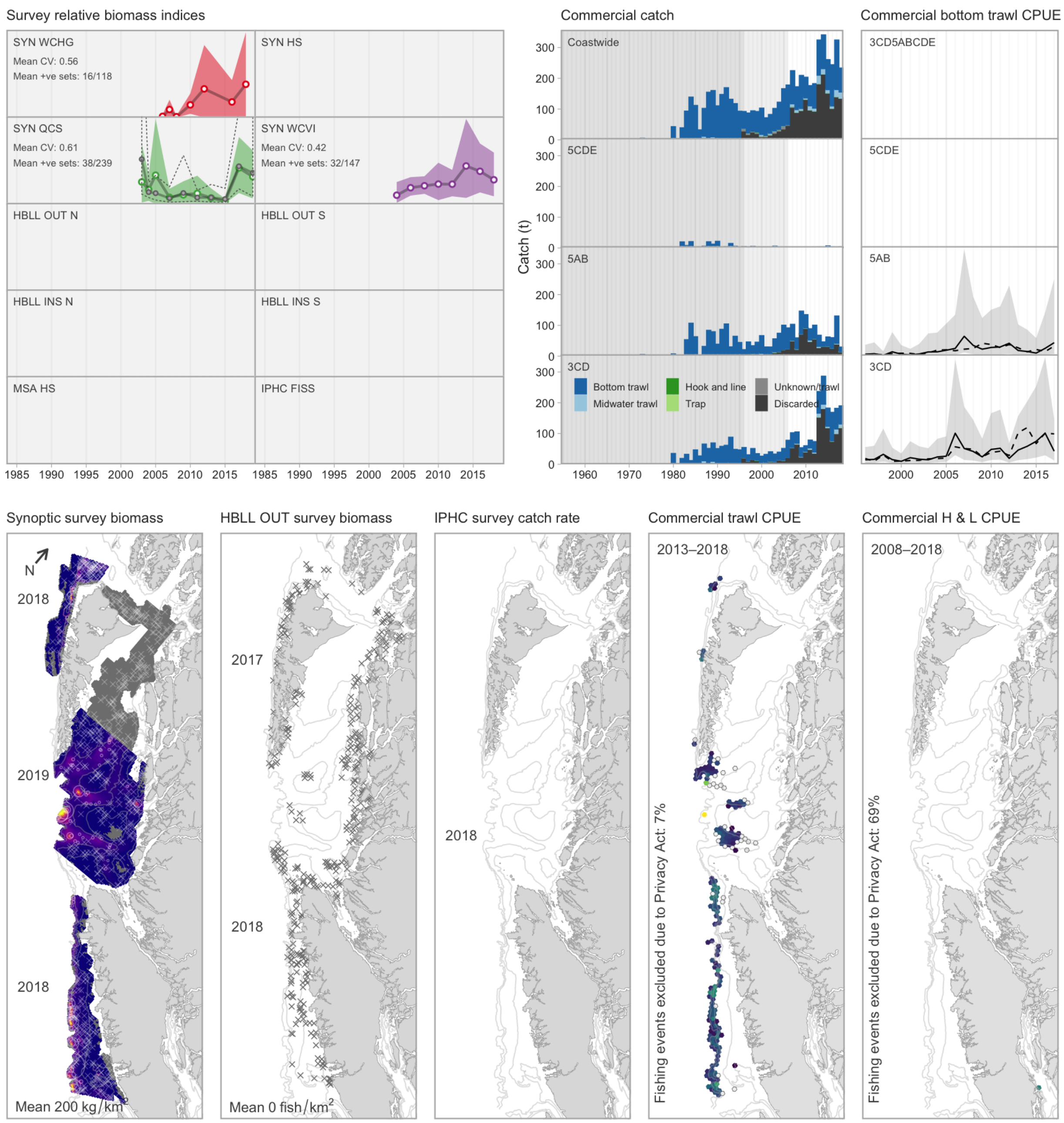


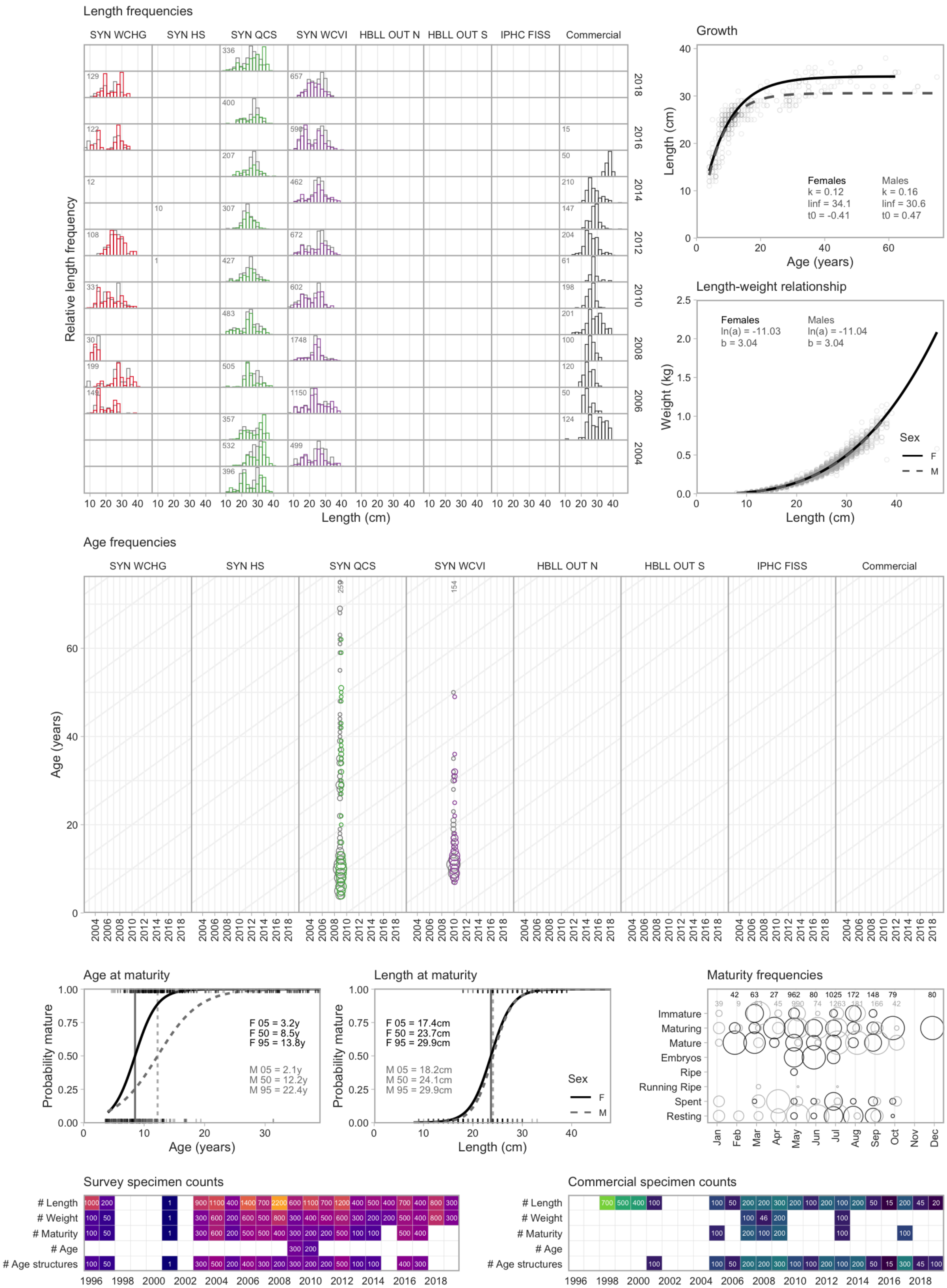


Length frequencies
Growth
Length-weight relationship
Age frequencies
Age at maturity
Length at maturity
Maturity frequencies
Survey specimen counts
Commercial specimen counts

5.53 SPLITNOSE ROCKFISH

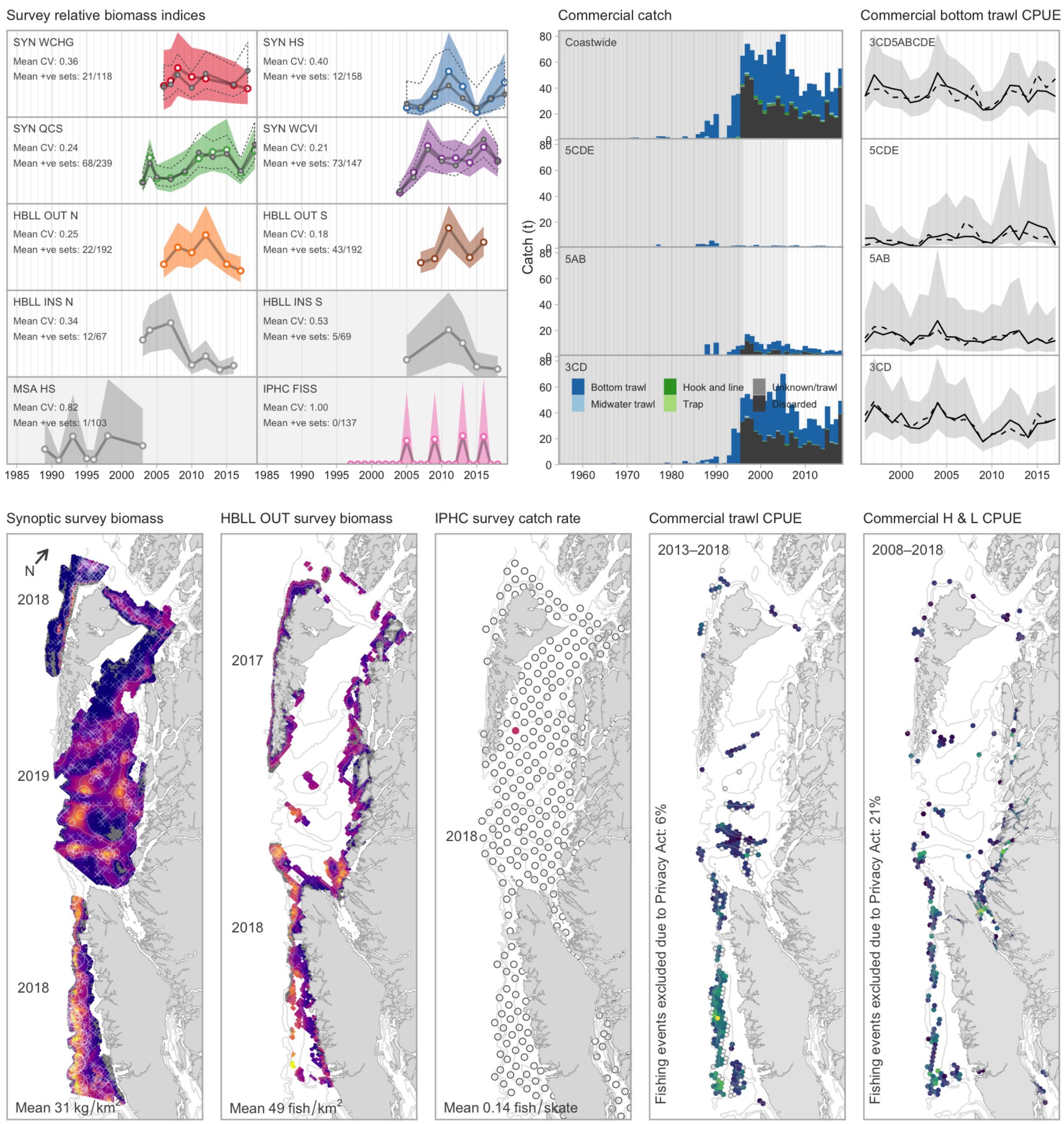
Sebastes diploproa (412)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

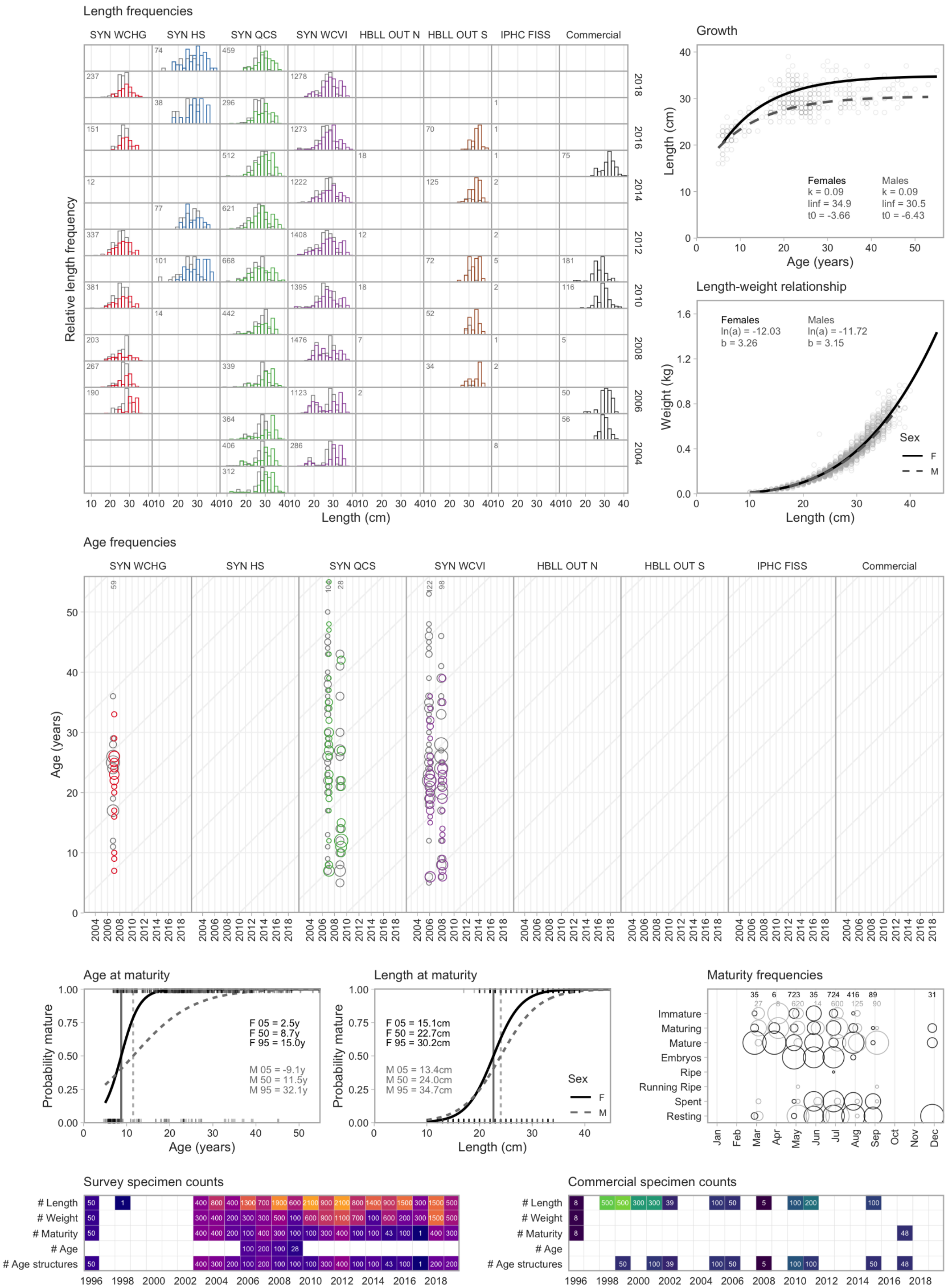



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.12
linf = 34.1
t0 = -0.41
Males
k = 0.16
linf = 30.6
t0 = 0.47
Length-weight relationship
Females
ln(a) = -11.03
b = 3.04
Males
ln(a) = -11.04
b = 3.04
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
F 05 = 3.2y
F 50 = 8.5y
F 95 = 13.8y
M 05 = 2.1y
M 50 = 12.2y
M 95 = 22.4y
Probability mature
Age (years)
Length at maturity
F 05 = 17.4cm
F 50 = 23.7cm
F 95 = 29.9cm
M 05 = 18.2cm
M 50 = 24.1cm
M 95 = 29.9cm
Probability mature
Length (cm)
Sex
F
M
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.54 GREENSTRIPED ROCKFISH

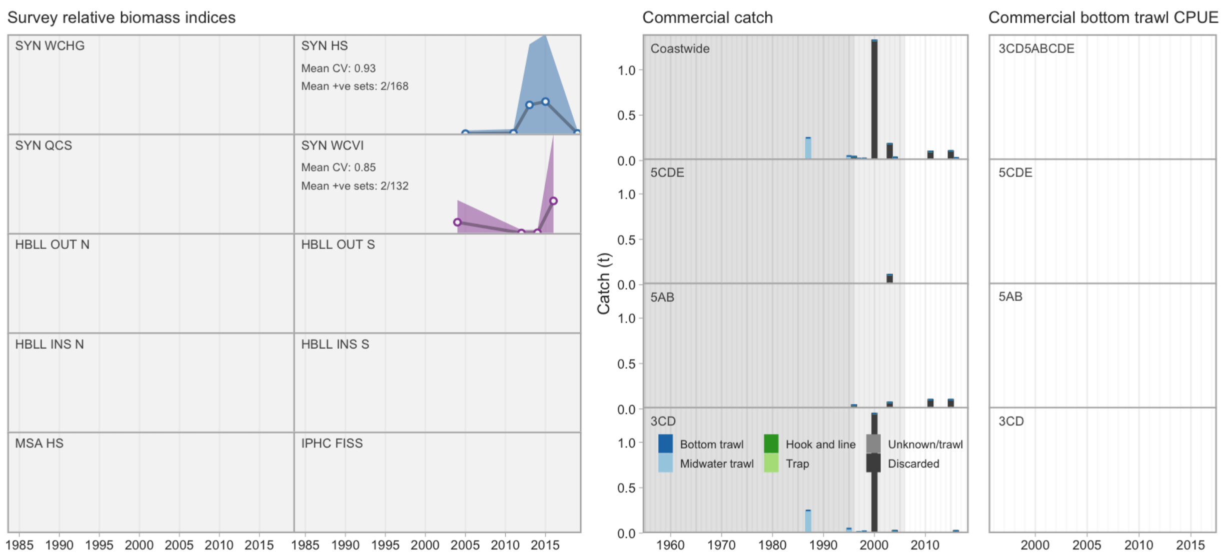
Sebastes elongatus (414)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

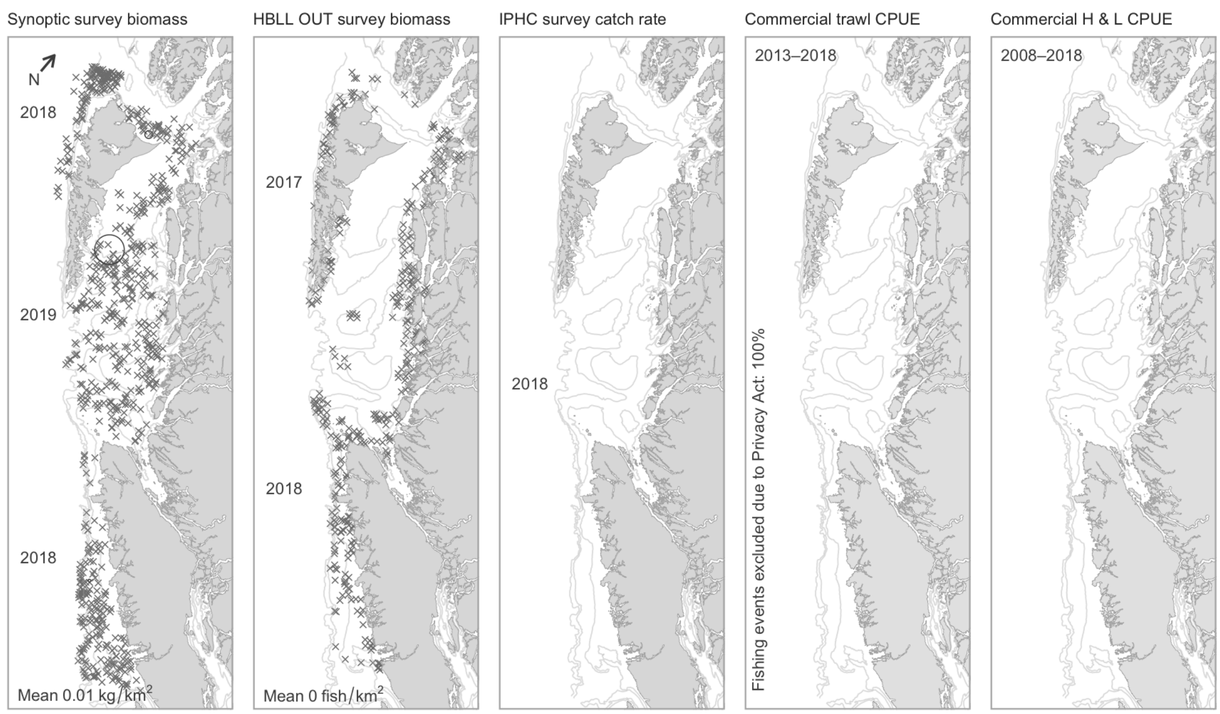


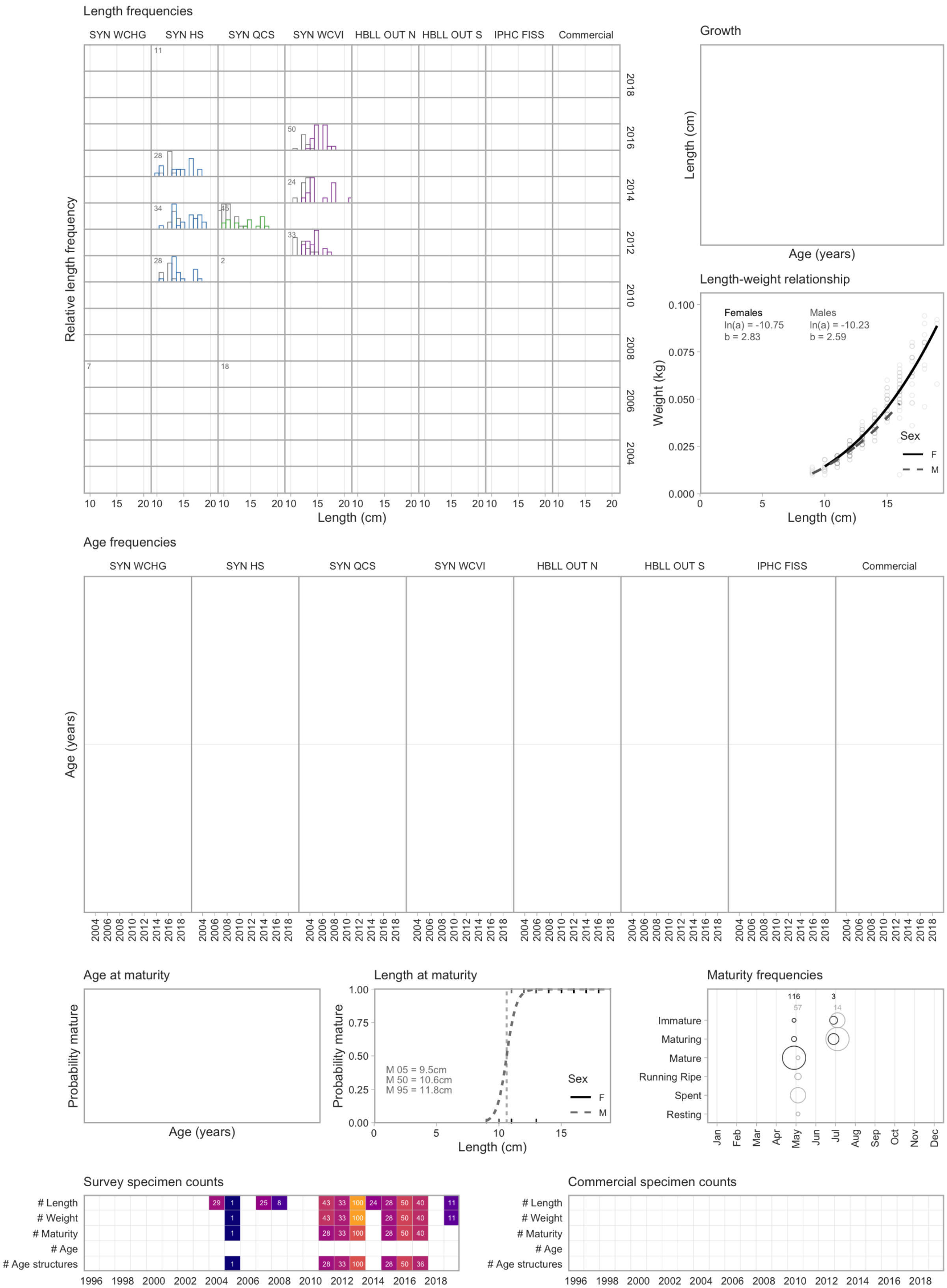

Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.09
linf = 34.9
t0 = -3.66
Males
k = 0.09
linf = 30.5
t0 = -6.43
Length-weight relationship
Females
ln(a) = -12.03
b = 3.26
Males
ln(a) = -11.72
b = 3.15
Weight (kg)
Sex
F
M
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
F 05 = 2.5y
F 50 = 8.7y
F 95 = 15.0y
M 05 = -9.1y
M 50 = 11.5y
M 95 = 32.1y
Age (years)
Length at maturity
F 05 = 15.1cm
F 50 = 22.7cm
F 95 = 30.2cm
M 05 = 13.4cm
M 50 = 24.0cm
M 95 = 34.7cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.55 PUGET SOUND ROCKFISH

Sebastes emphaeus (415)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS



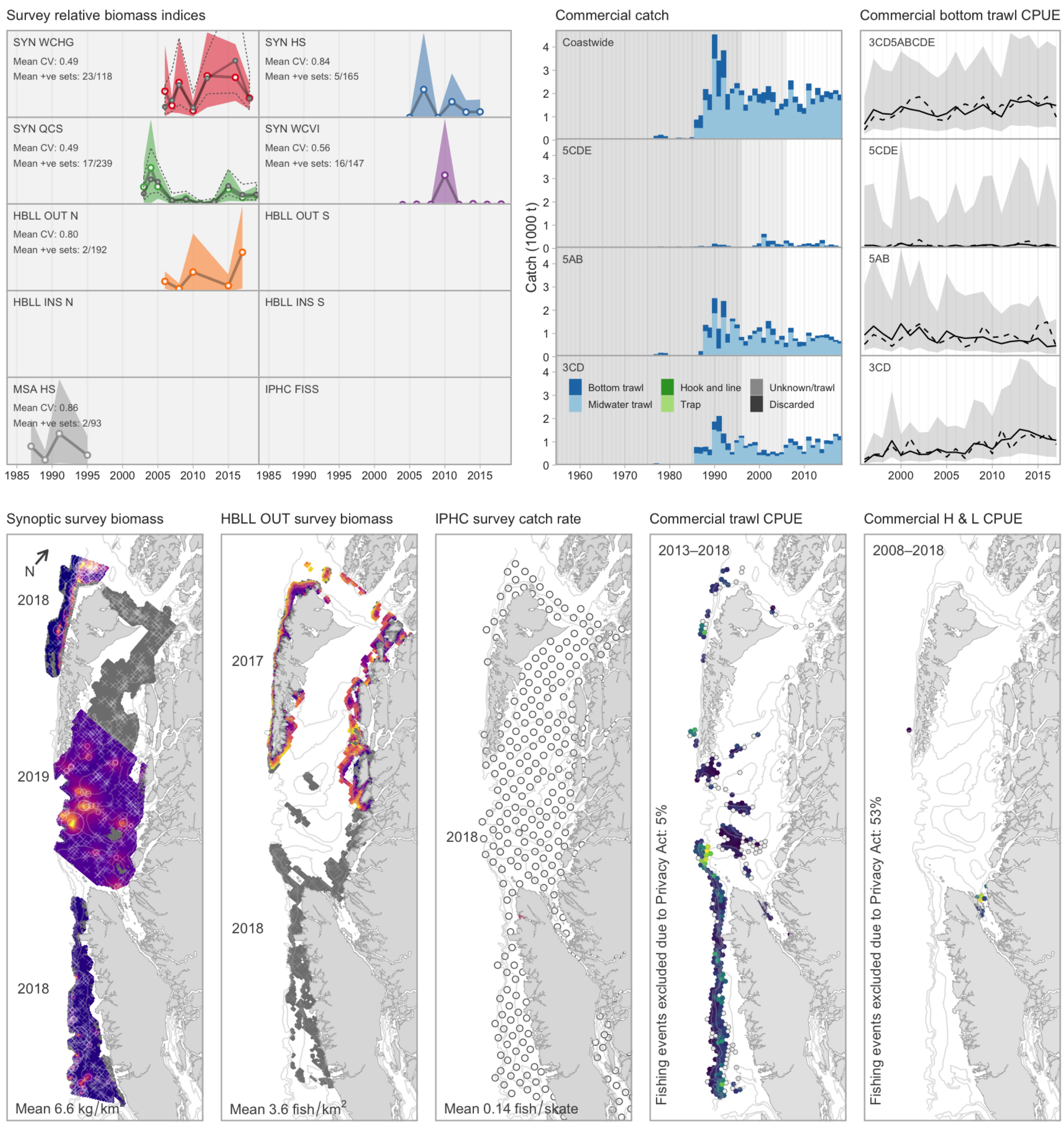


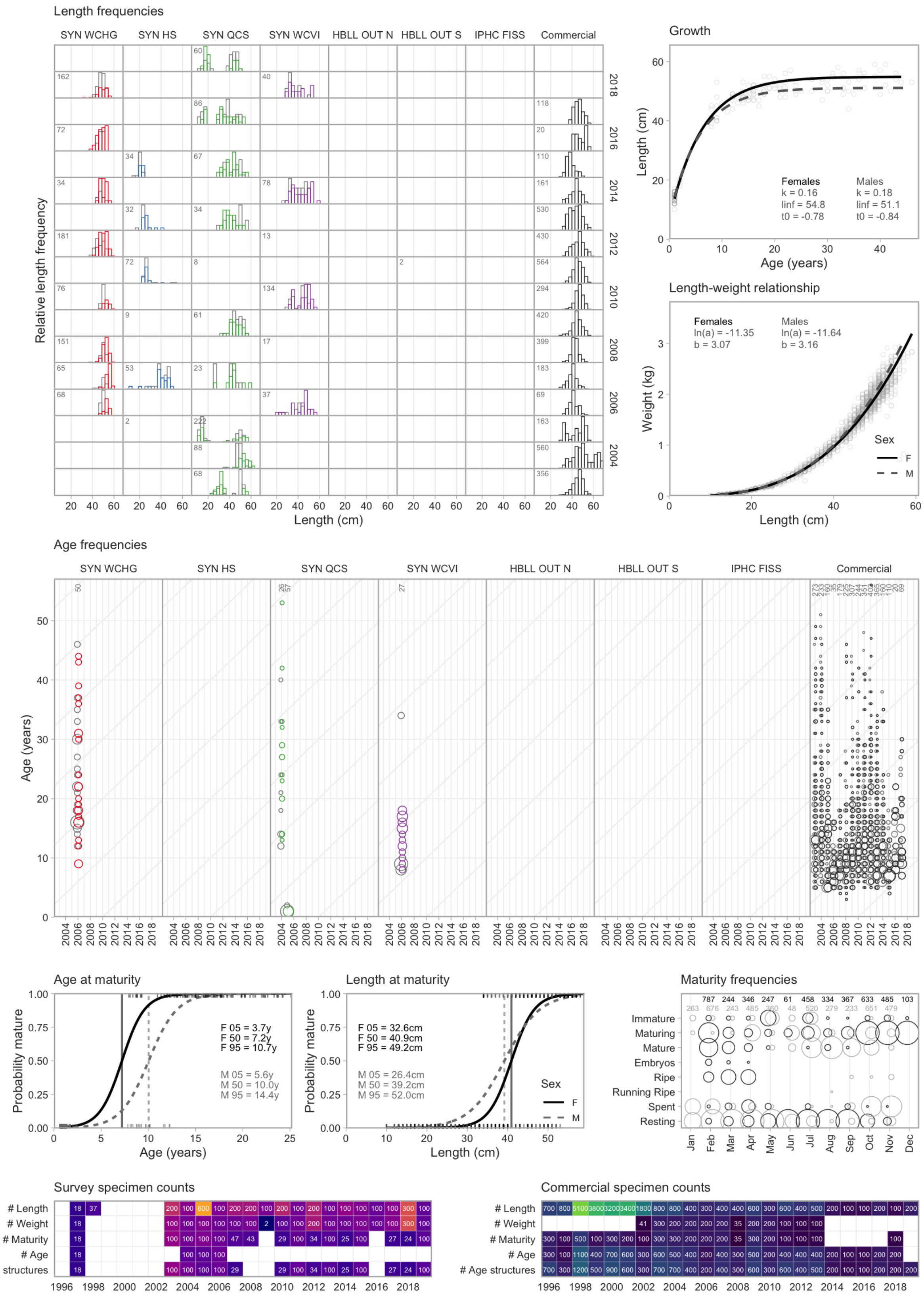


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -10.75
b = 2.83
Males
ln(a) = -10.23
b = 2.59
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
M 05 = 9.5cm
M 50 = 10.6cm
M 95 = 11.8cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.56 WIDOW ROCKFISH

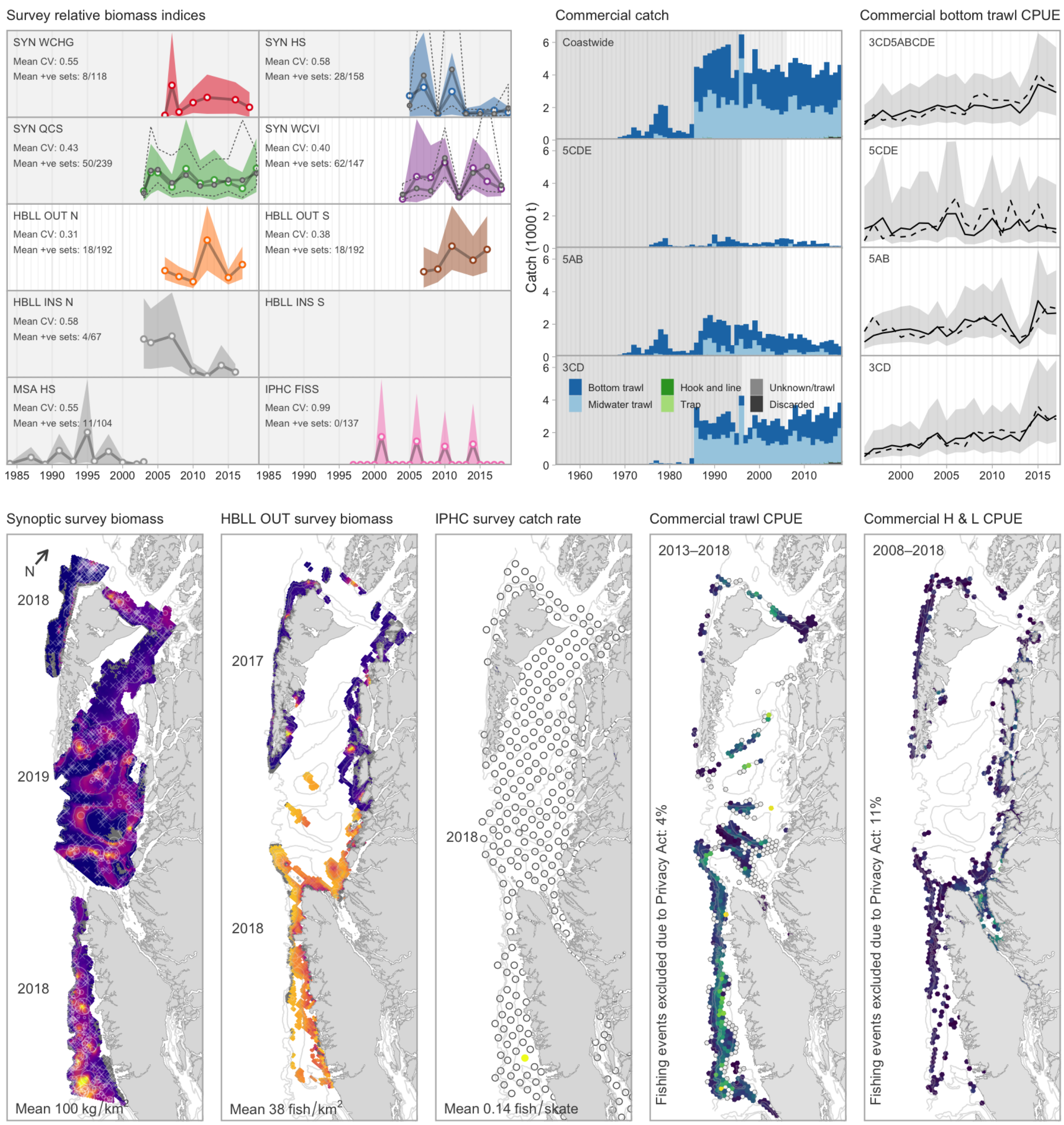
Sebastes entomelas (417)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Stanley (1999)
Last Science Advisory Report: DFO (2019b)

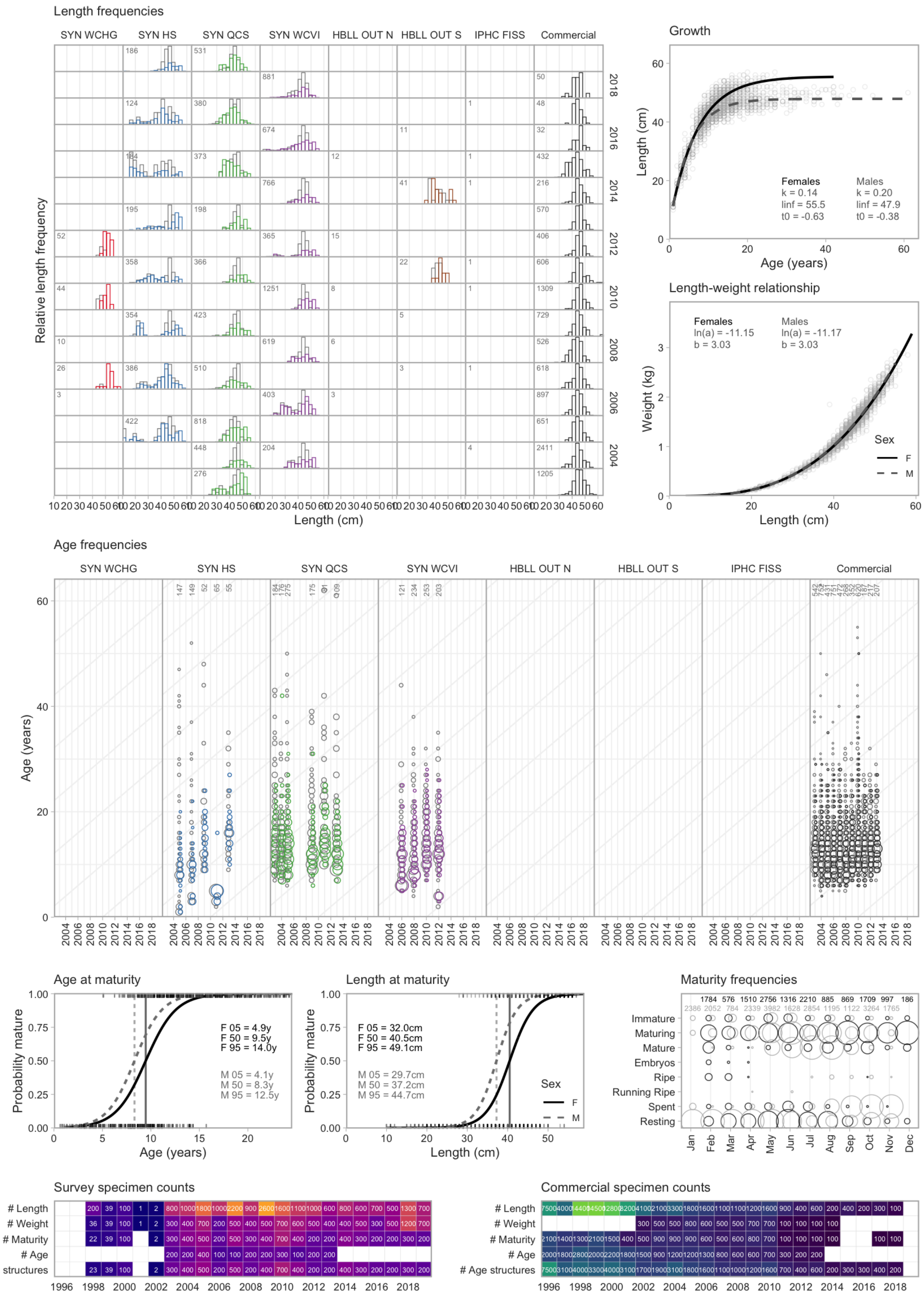



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.16
linf = 54.8
t0 = -0.78
Males
k = 0.18
linf = 51.1
t0 = -0.84
Length-weight relationship
Females
ln(a) = -11.35
b = 3.07
Males
ln(a) = -11.64
b = 3.16
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 3.7y
F 50 = 7.2y
F 95 = 10.7y
M 05 = 5.6y
M 50 = 10.0y
M 95 = 14.4y
Length at maturity
Probability mature
Length (cm)
F 05 = 32.6cm
F 50 = 40.9cm
F 95 = 49.2cm
M 05 = 26.4cm
M 50 = 39.2cm
M 95 = 52.0cm
Sex
F
M
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.57 YELLOWTAIL ROCKFISH

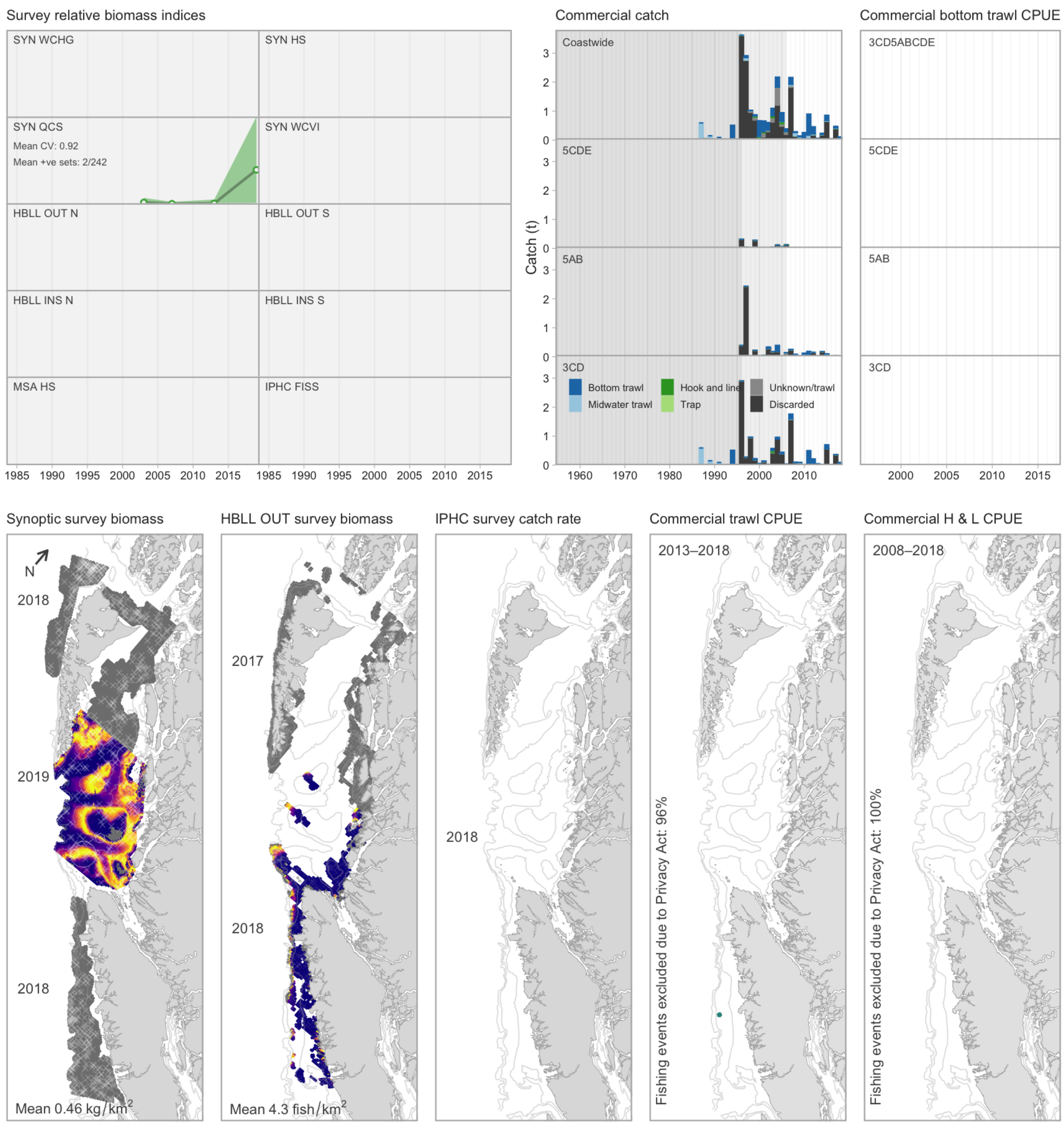
Sebastes flavidus (418)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Science Advisory Report: DFO (2015a)

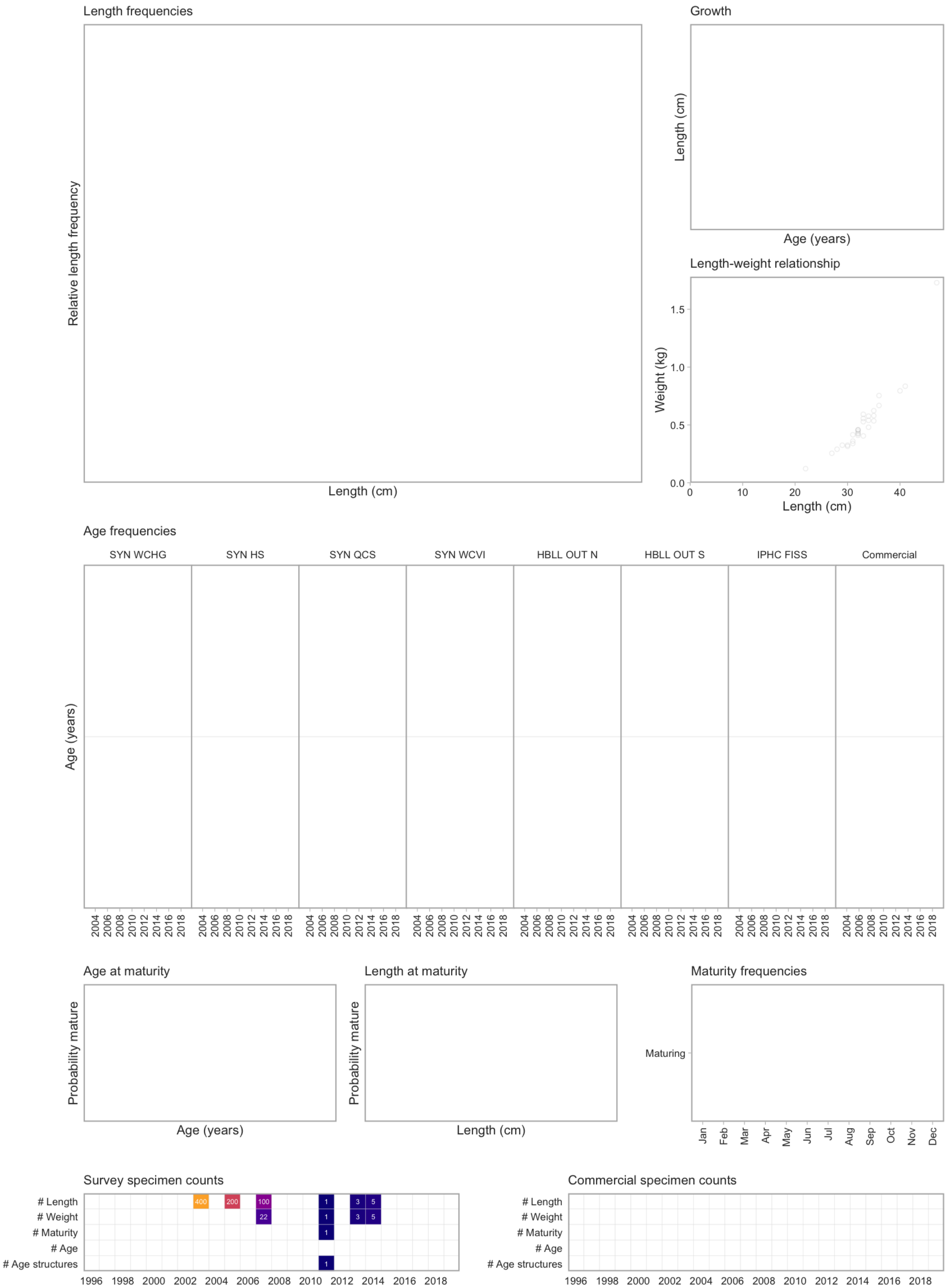



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.14
linf = 55.5
t0 = -0.63
Males
k = 0.20
linf = 47.9
t0 = -0.38
Length-weight relationship
Females
ln(a) = -11.15
b = 3.03
Males
ln(a) = -11.17
b = 3.03
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 4.9y
F 50 = 9.5y
F 95 = 14.0y
M 05 = 4.1y
M 50 = 8.3y
M 95 = 12.5y
Length at maturity
Length (cm)
F 05 = 32.0cm
F 50 = 40.5cm
F 95 = 49.1cm
M 05 = 29.7cm
M 50 = 37.2cm
M 95 = 44.7cm
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.58 CHILIPEPPER

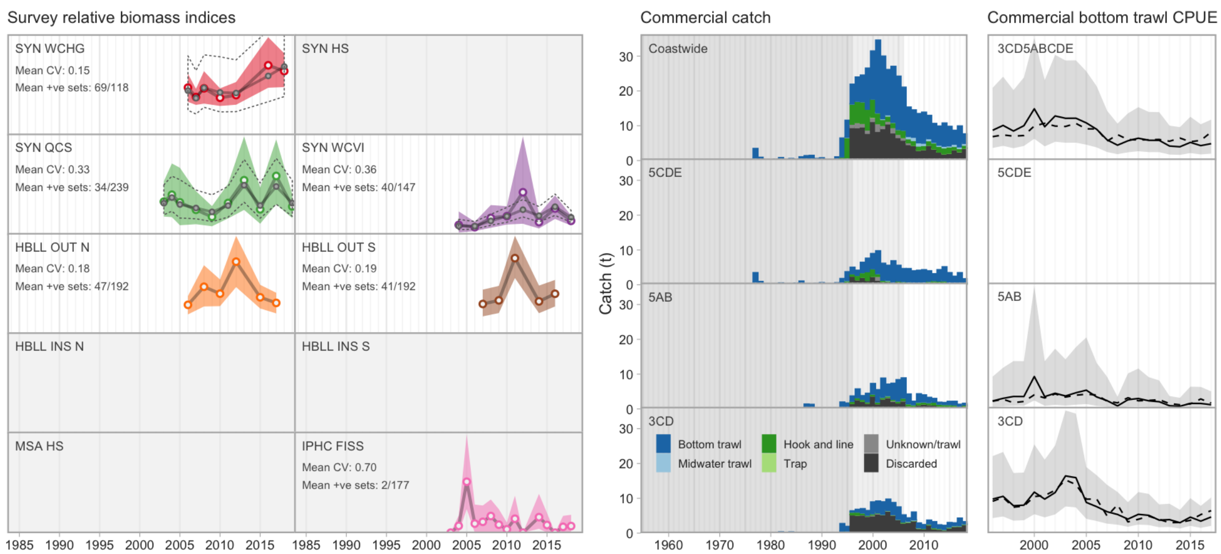
Sebastes goodei (420)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

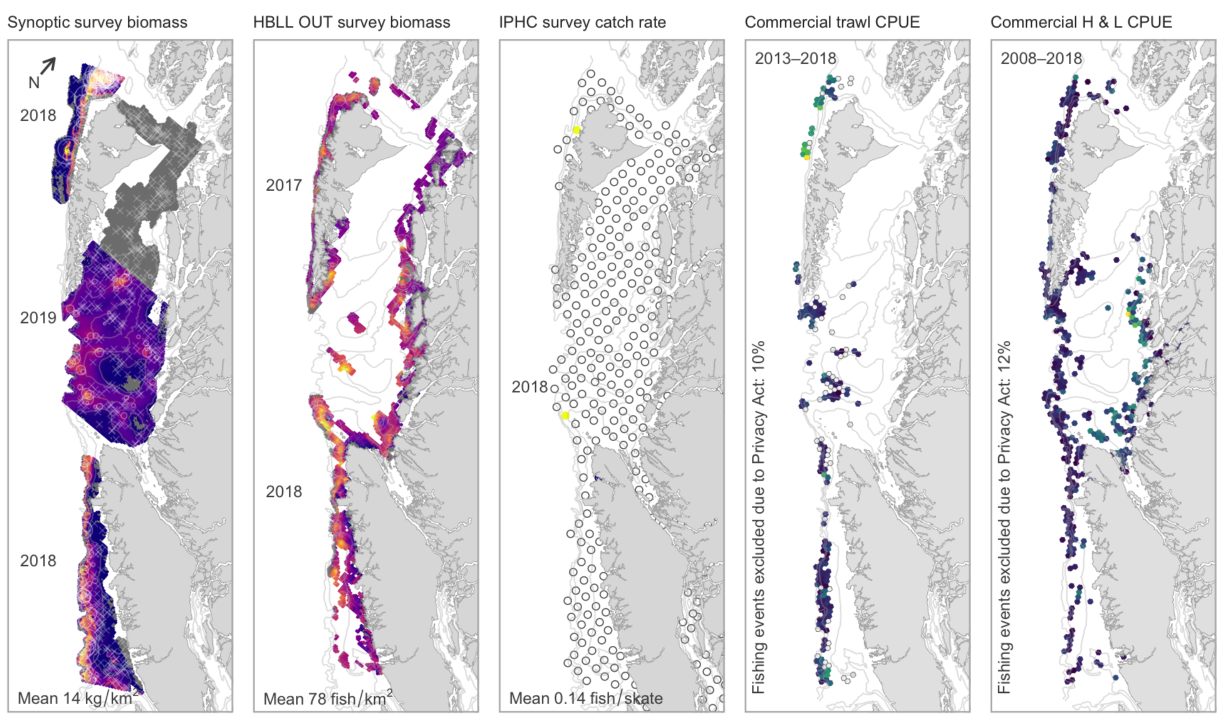


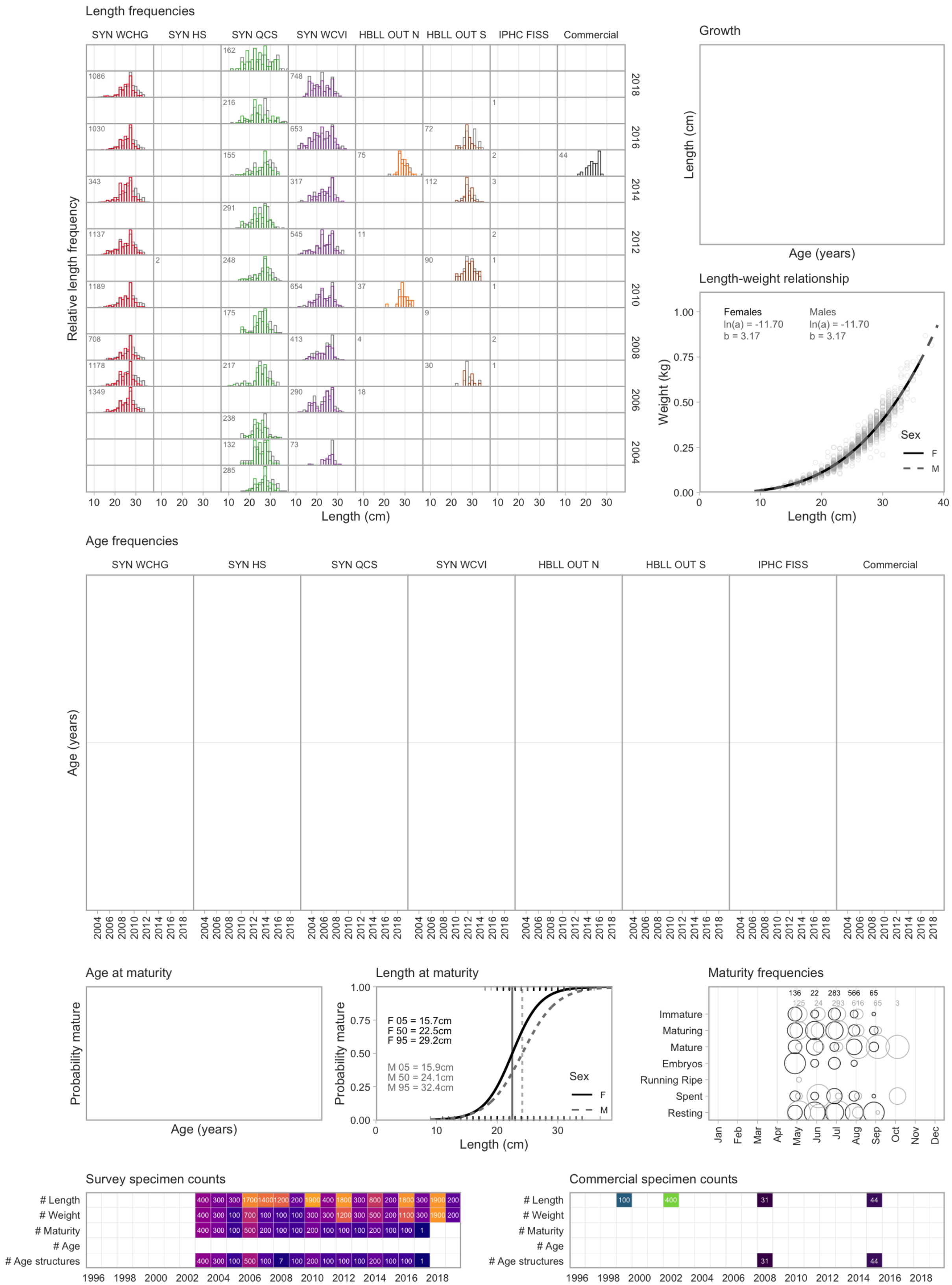

Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
1.5
1.0
0.5
0.0
0
10
20
30
40
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Maturing
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
400
200
100
22
1
3
5
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.59 ROSETHORN ROCKFISH

Sebastes helvomaculatus (421)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS



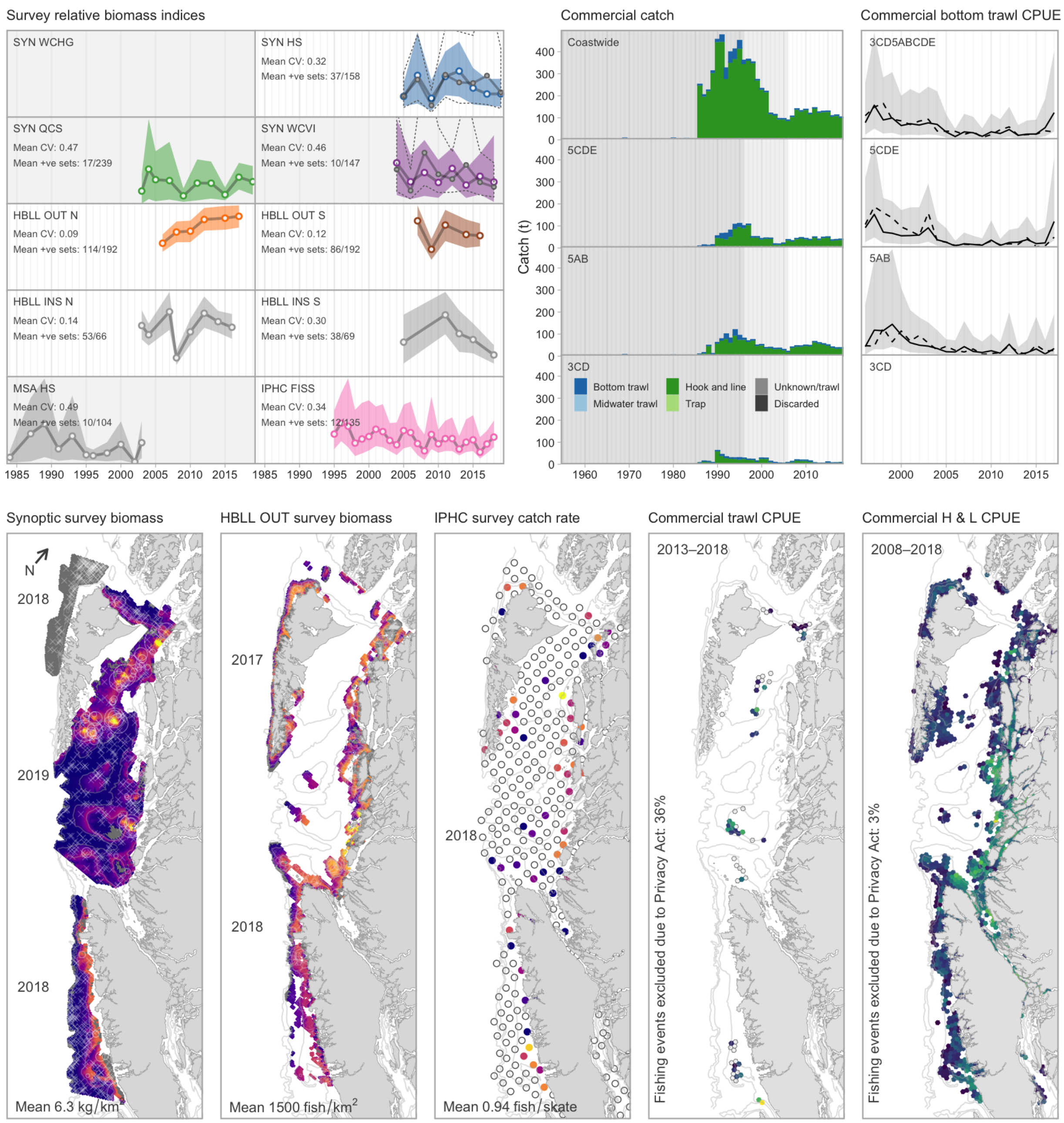


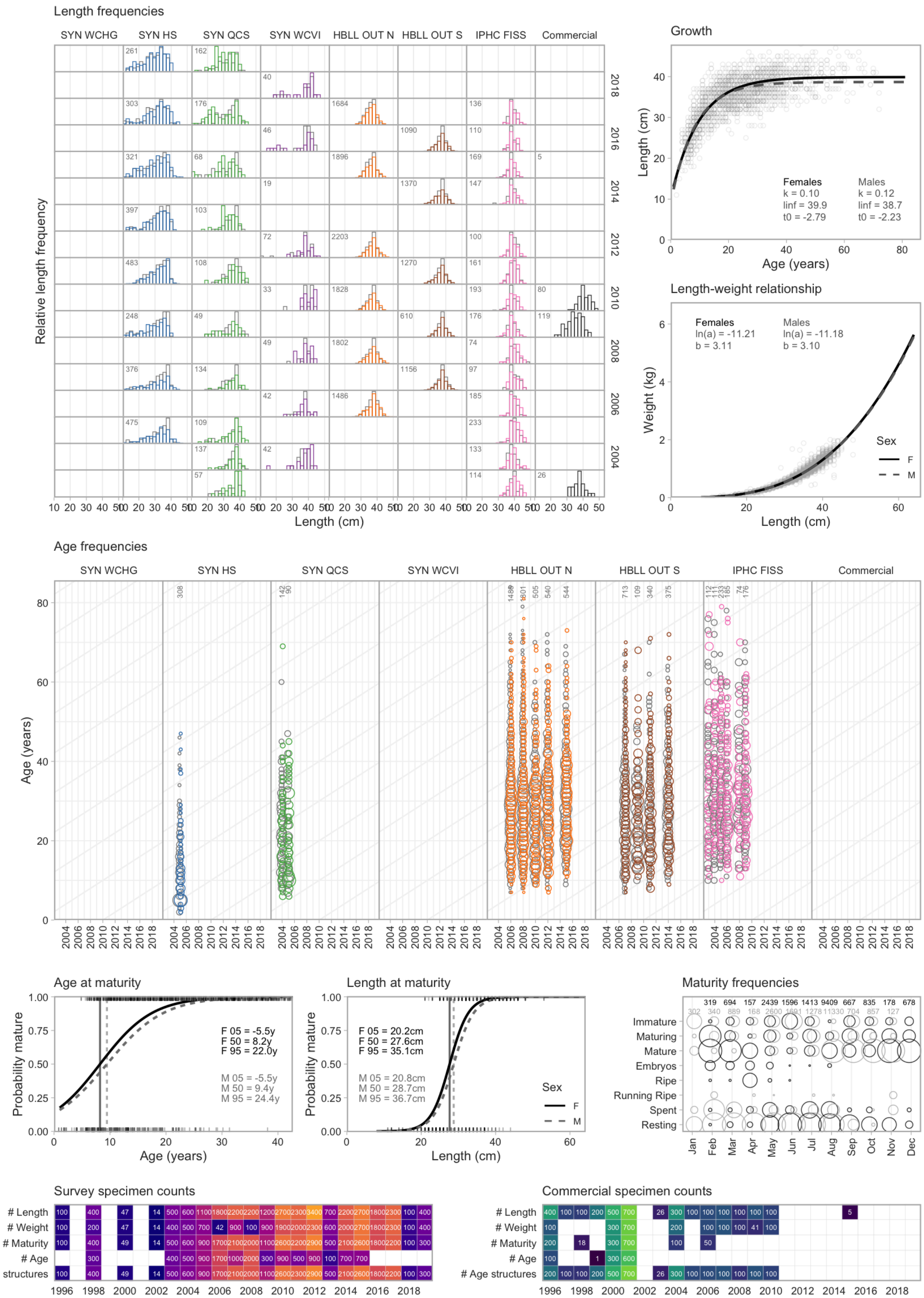


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.70
b = 3.17
Males
ln(a) = -11.70
b = 3.17
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 15.7cm
F 50 = 22.5cm
F 95 = 29.2cm
M 05 = 15.9cm
M 50 = 24.1cm
M 95 = 32.4cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.60 QUILLBACK ROCKFISH

Sebastes maliger (424)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Yamanaka et al. (2011a)
Last Science Advisory Report: DFO (2011b)
COSEWIC Status Report: COSEWIC (2009)
COSEWIC Status: Threatened, SARA Status: No Status

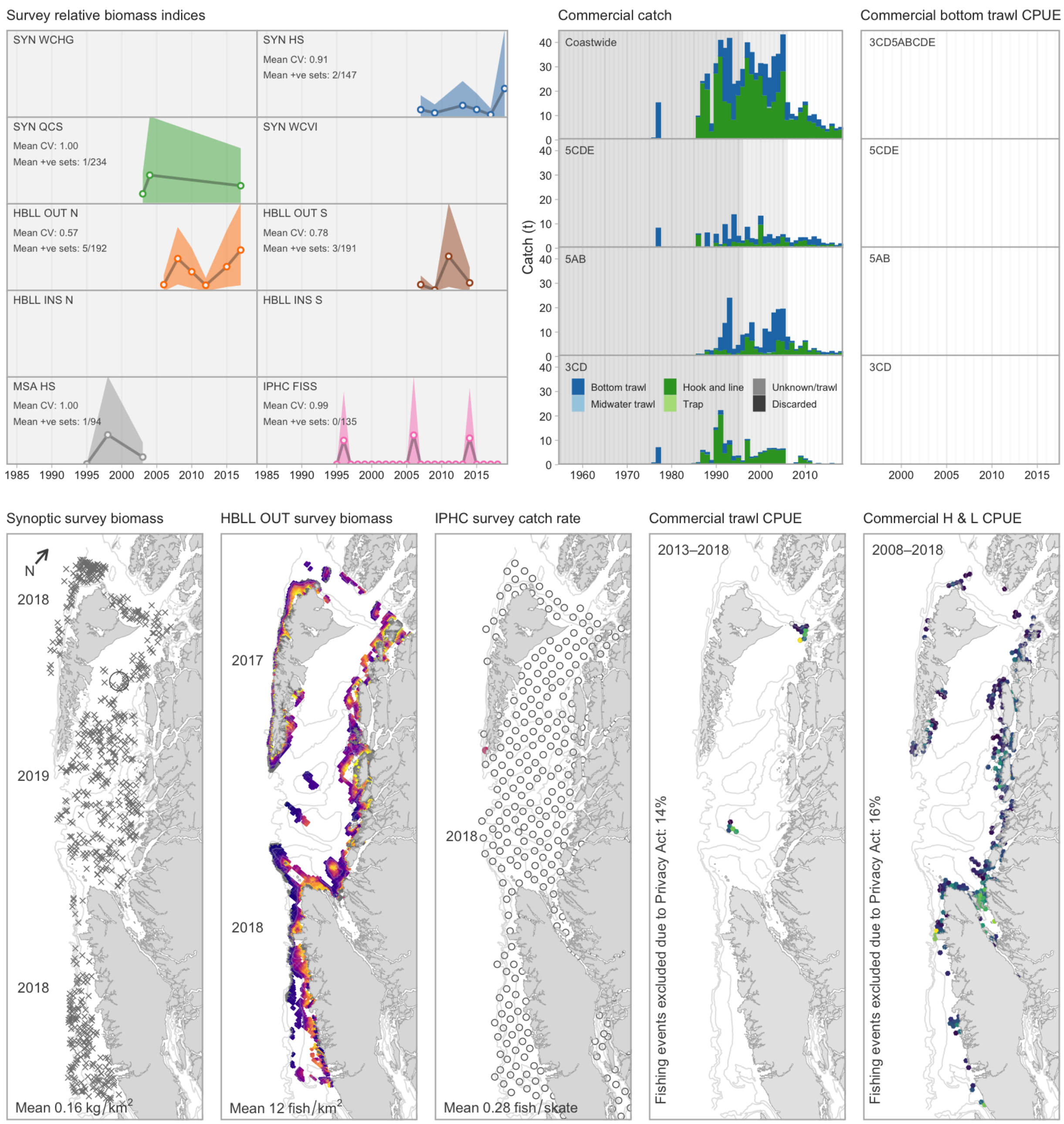


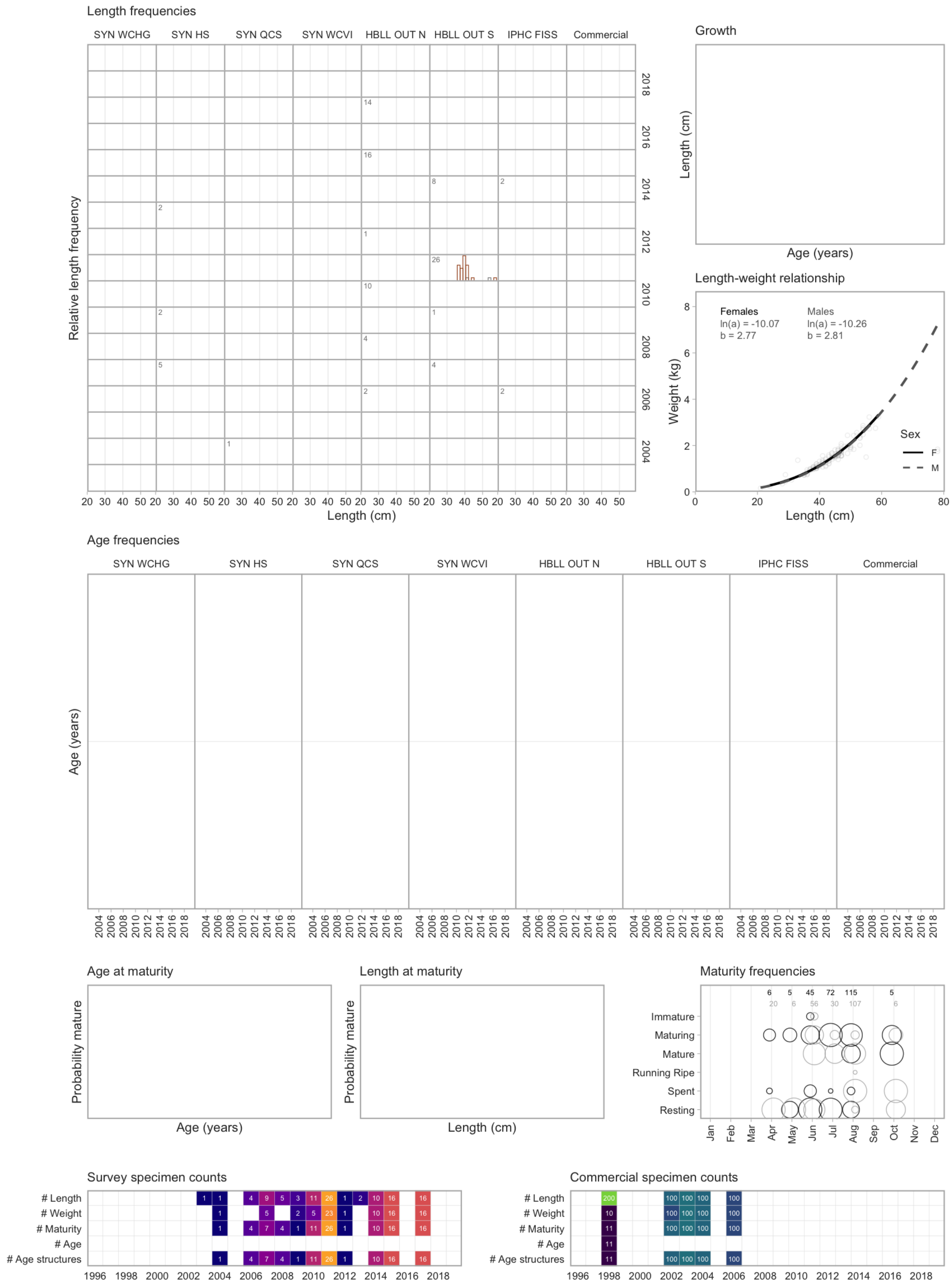


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.10
linf = 39.9
t0 = -2.79
Males
k = 0.12
linf = 38.7
t0 = -2.23
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -11.21
b = 3.11
Males
ln(a) = -11.18
b = 3.10
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = -5.5y
F 50 = 8.2y
F 95 = 22.0y
M 05 = -5.5y
M 50 = 9.4y
M 95 = 24.4y
Length at maturity
Probability mature
Length (cm)
F 05 = 20.2cm
F 50 = 27.6cm
F 95 = 35.1cm
M 05 = 20.8cm
M 50 = 28.7cm
M 95 = 36.7cm
Sex
F
M
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.61 BLACK ROCKFISH

Sebastes melanops (426)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

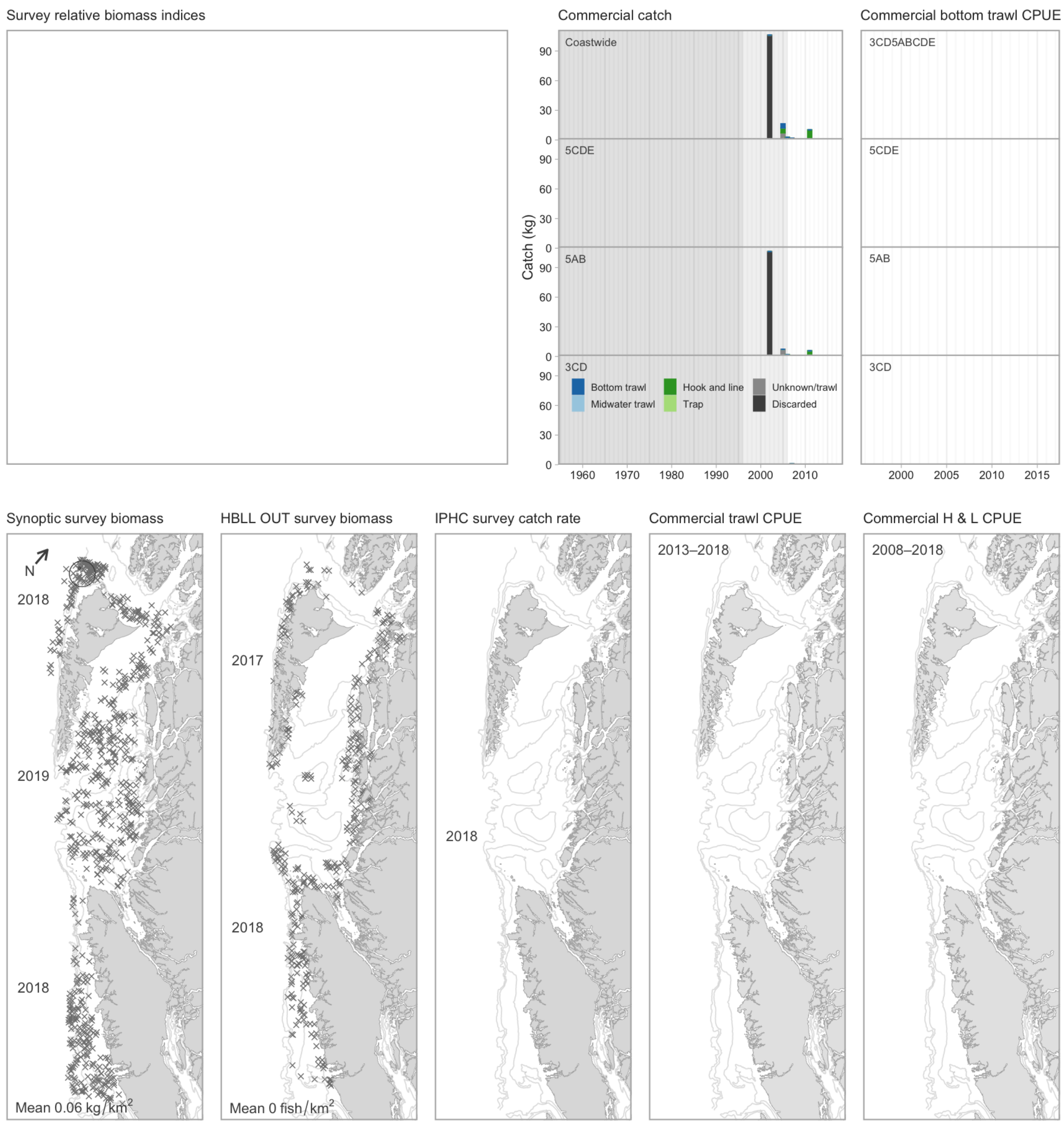


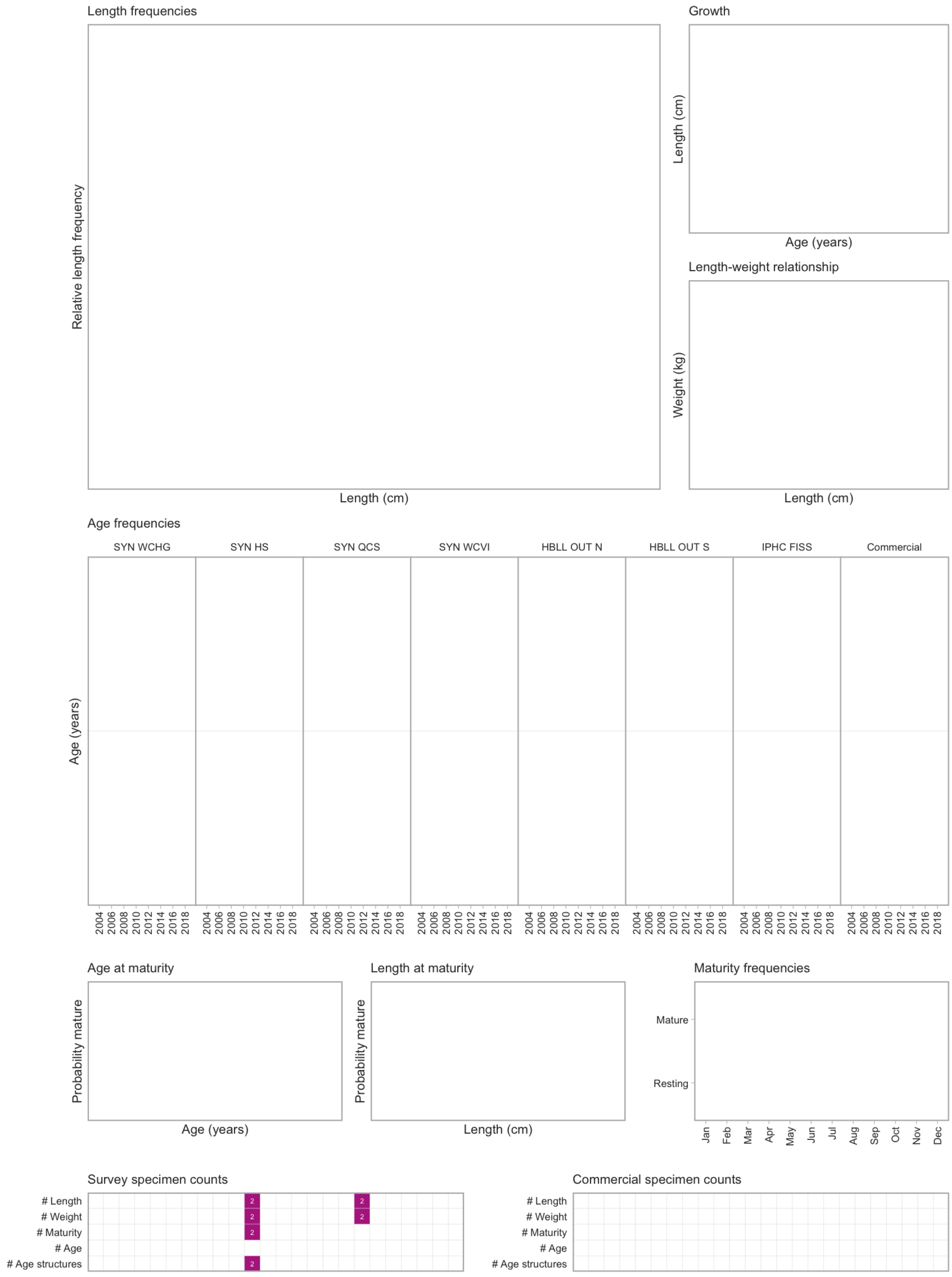


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -10.07
b = 2.77
Males
ln(a) = -10.26
b = 2.81
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.62 BLACKGILL ROCKFISH

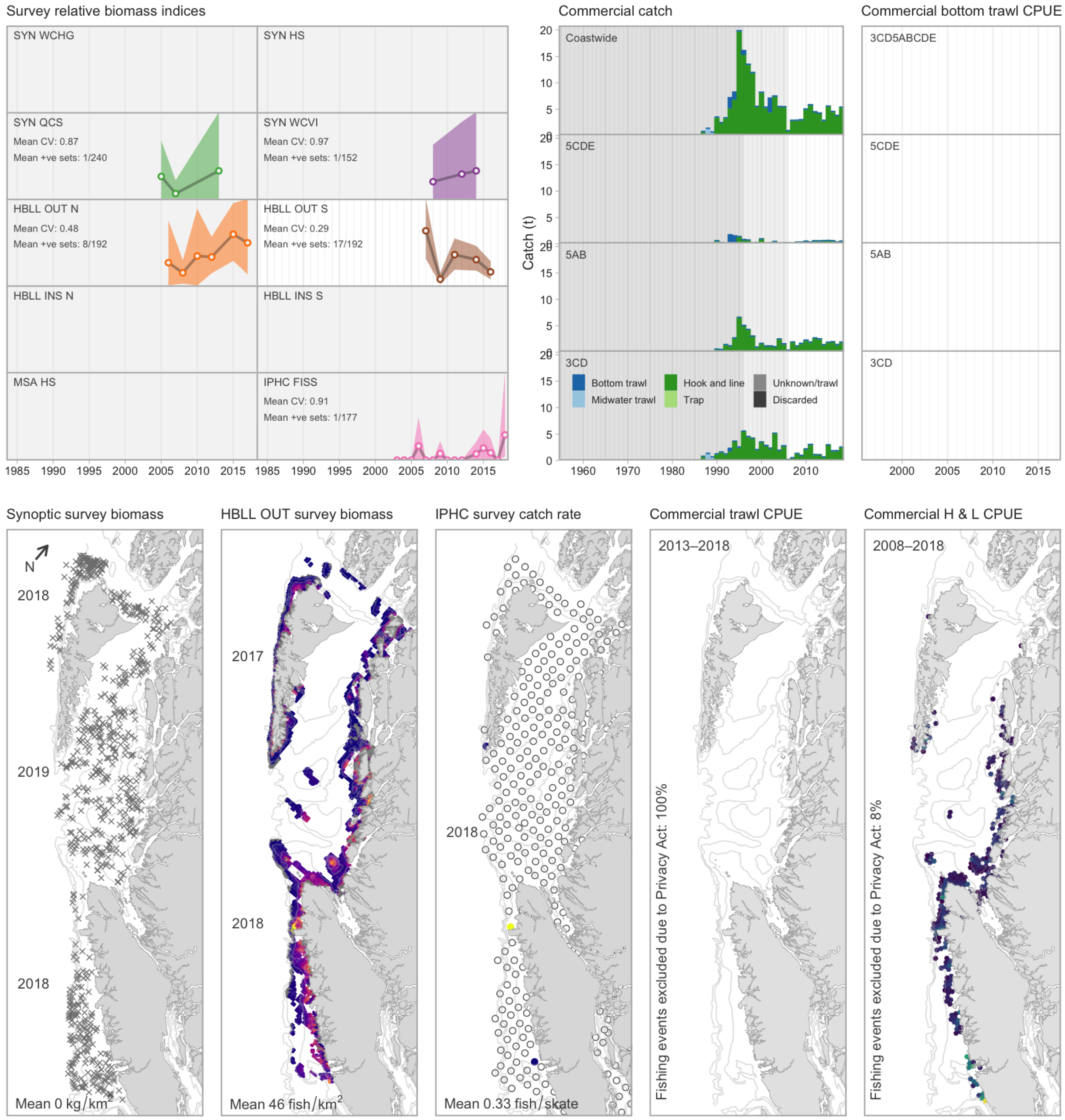
Sebastes melanostomus (427)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

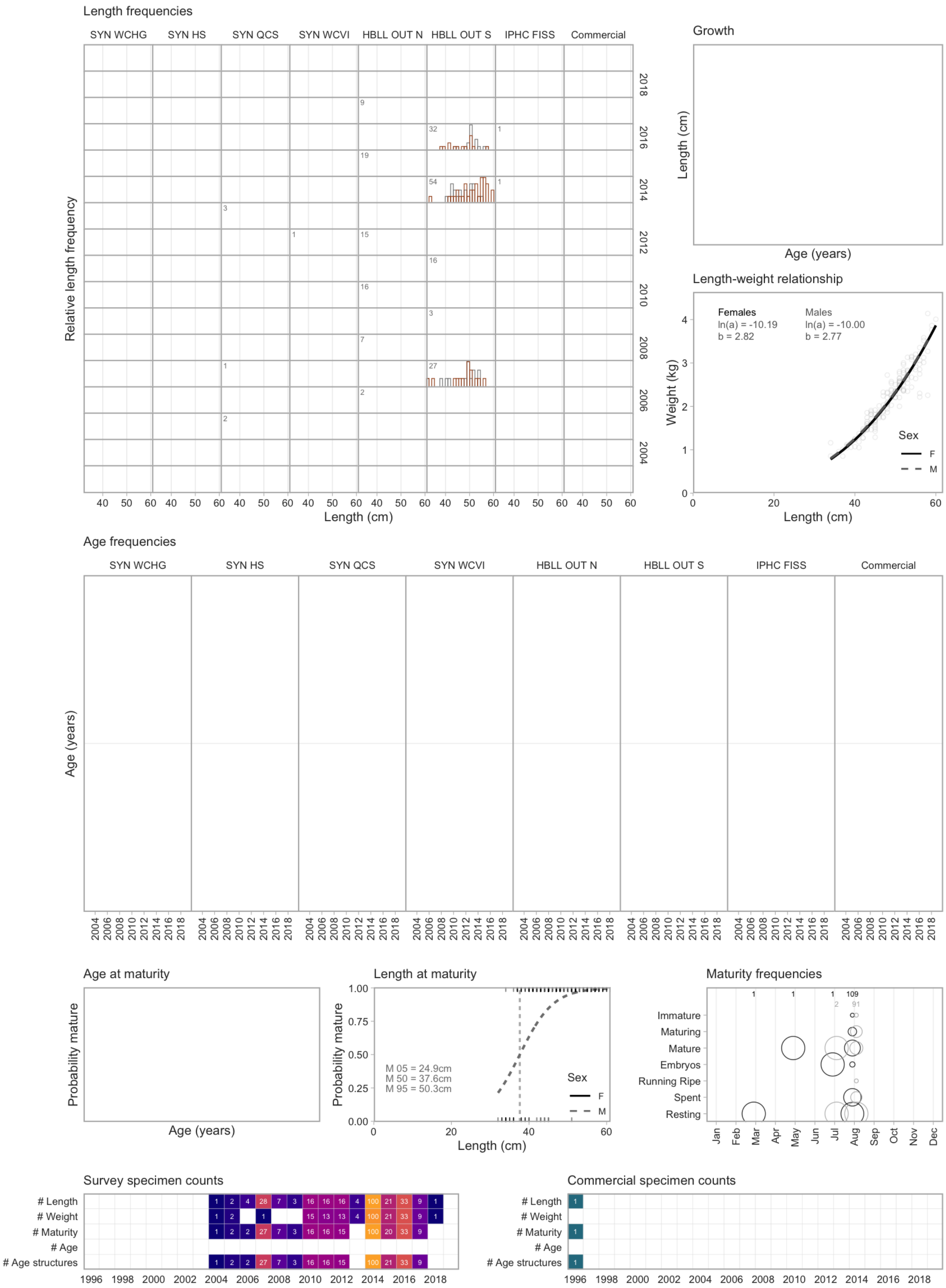



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Mature
Resting
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
2
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.63 VERMILION ROCKFISH

Sebastes miniatus (428)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

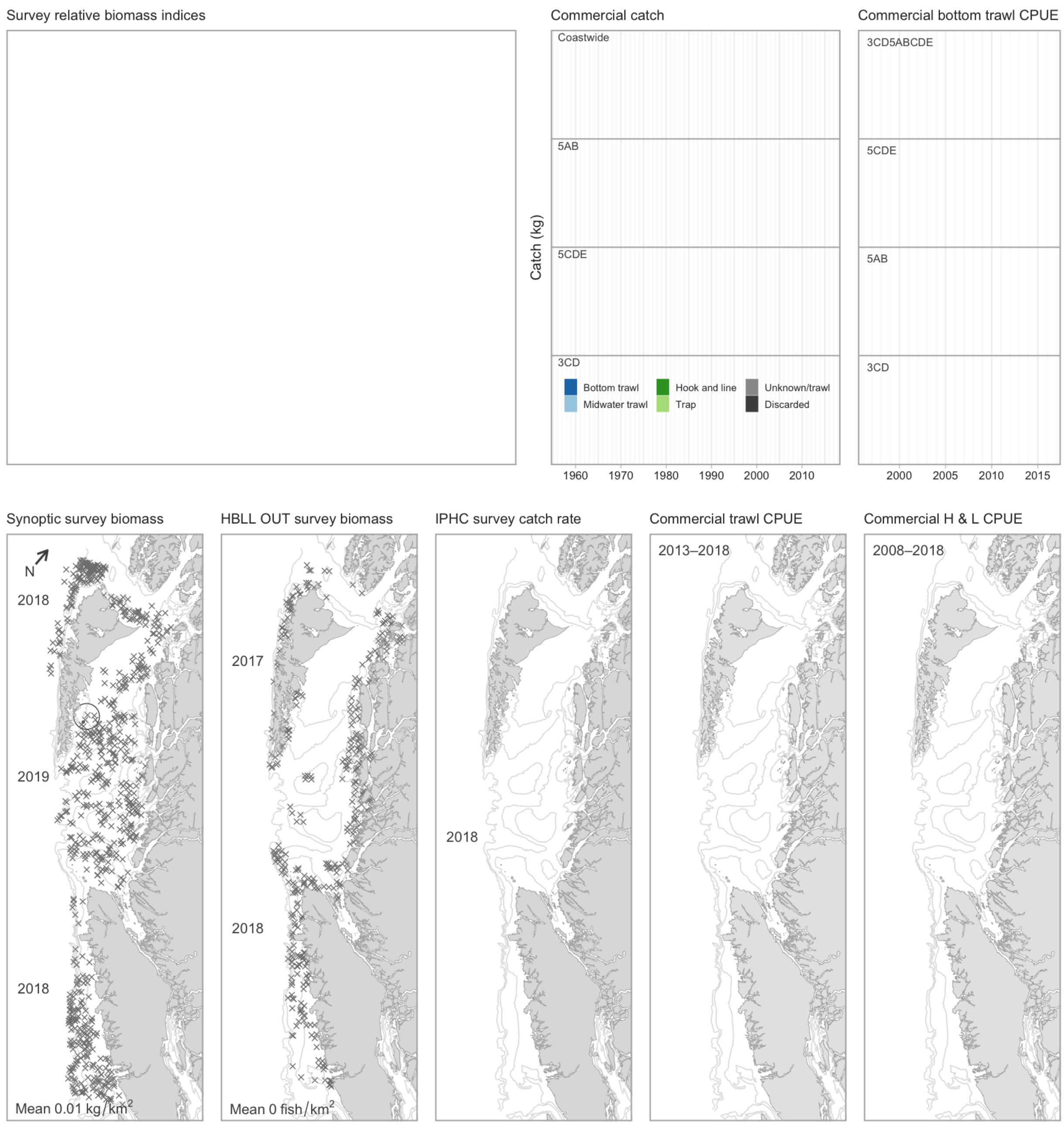


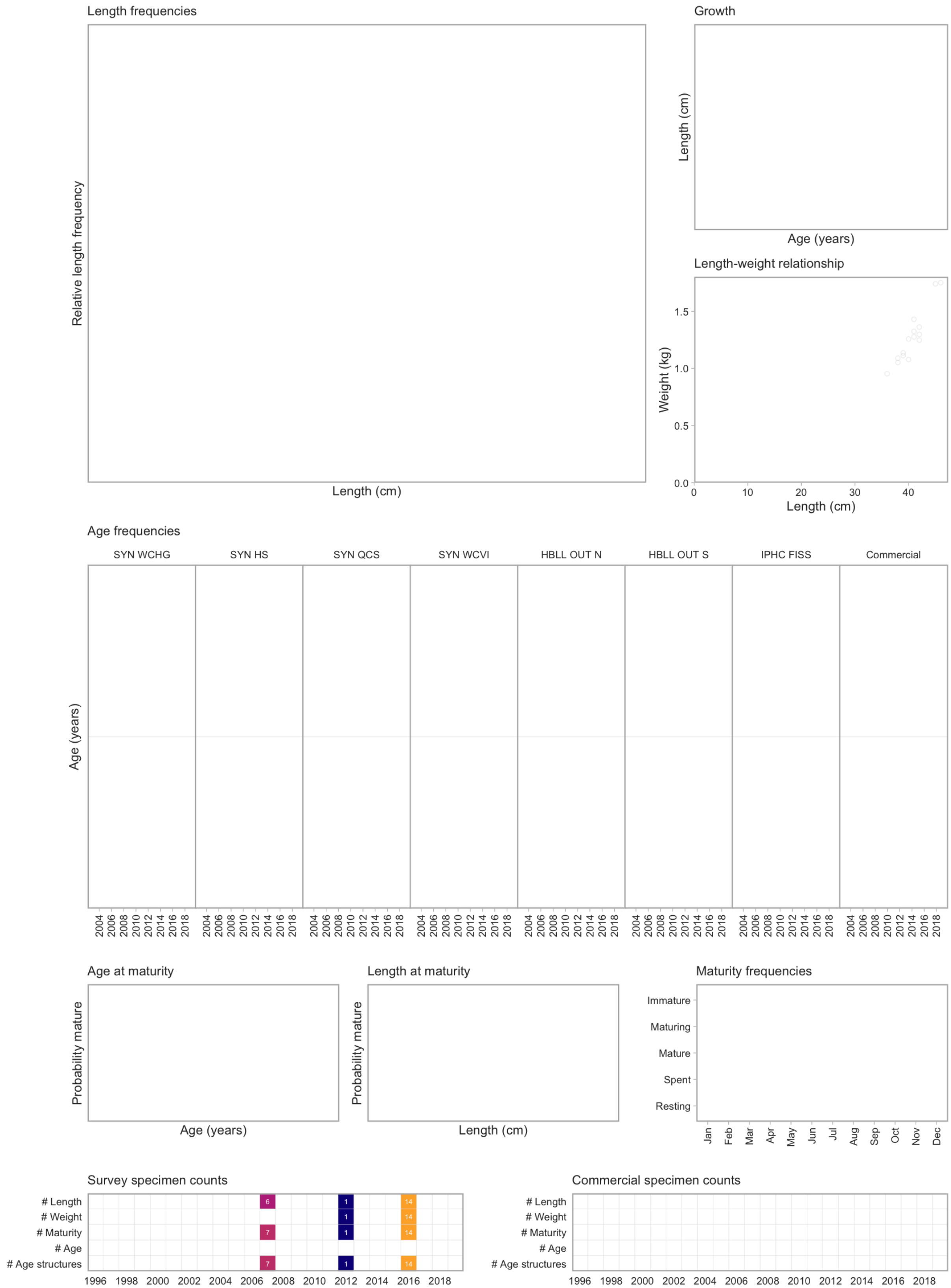


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -10.19
b = 2.82
Males
ln(a) = -10.00
b = 2.77
Weight (kg)
Sex
F
M
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
M 05 = 24.9cm
M 50 = 37.6cm
M 95 = 50.3cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.64 DEACON ROCKFISH

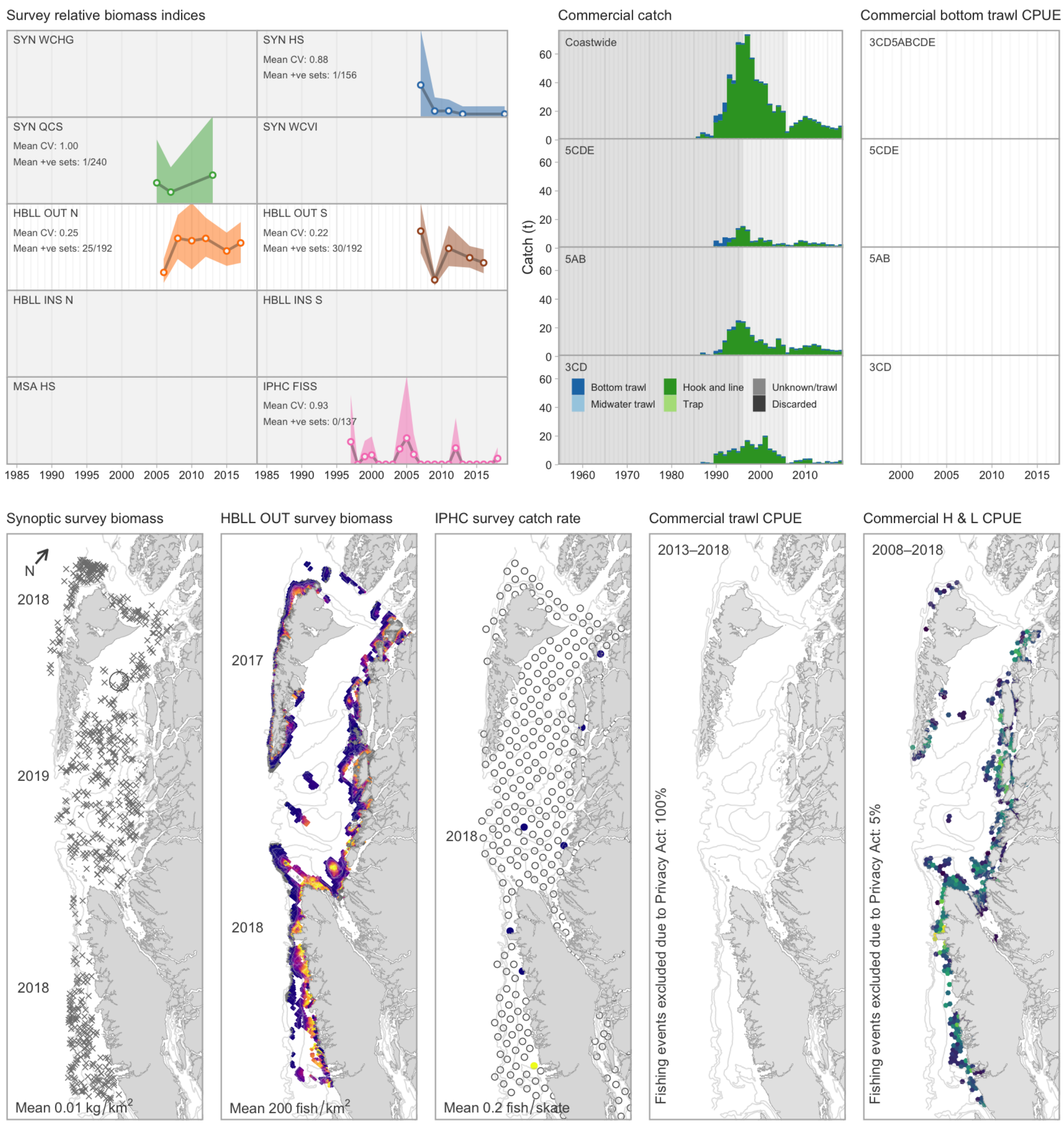
Sebastes diaconus (429)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase

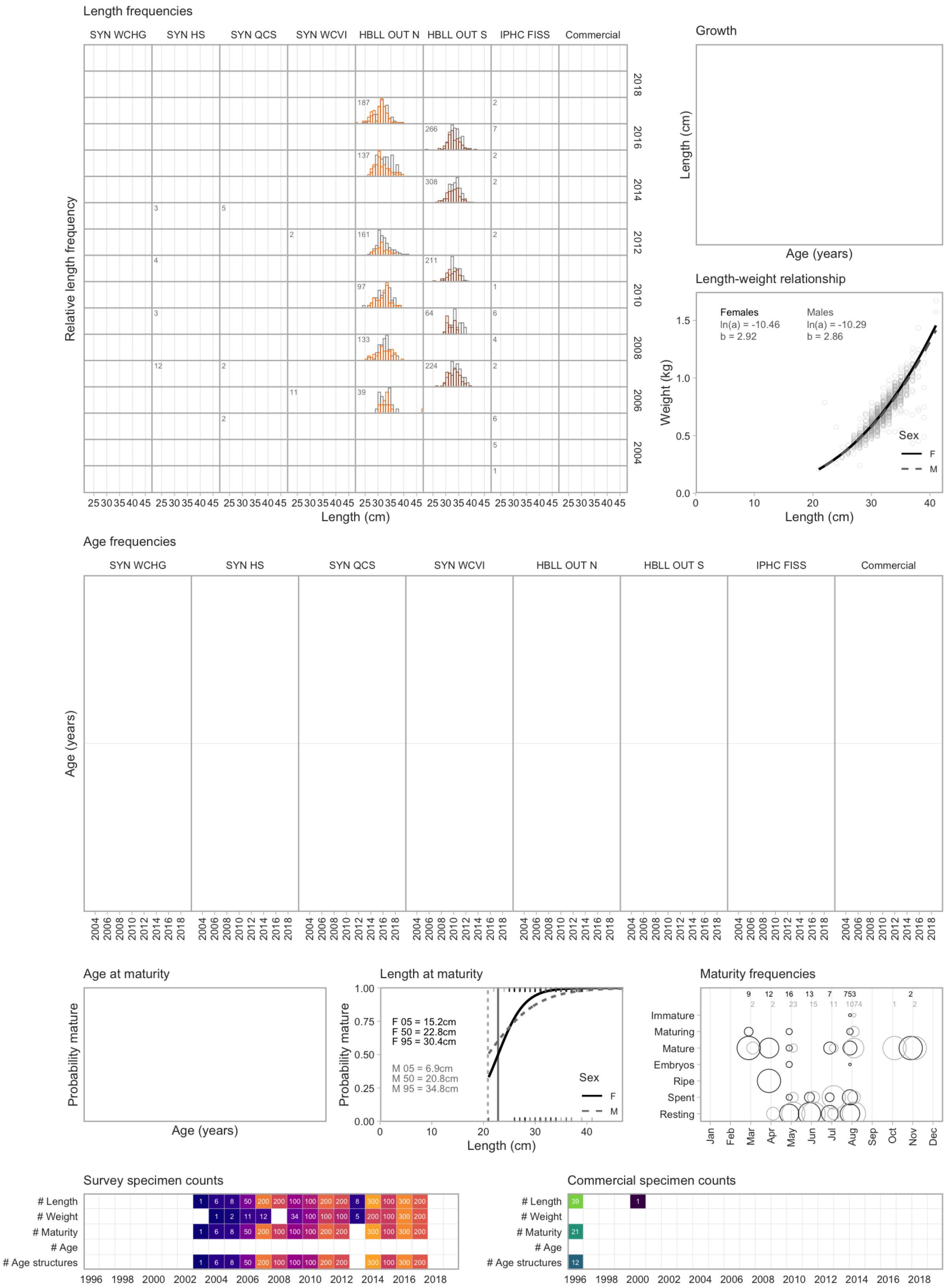



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.65 CHINA ROCKFISH

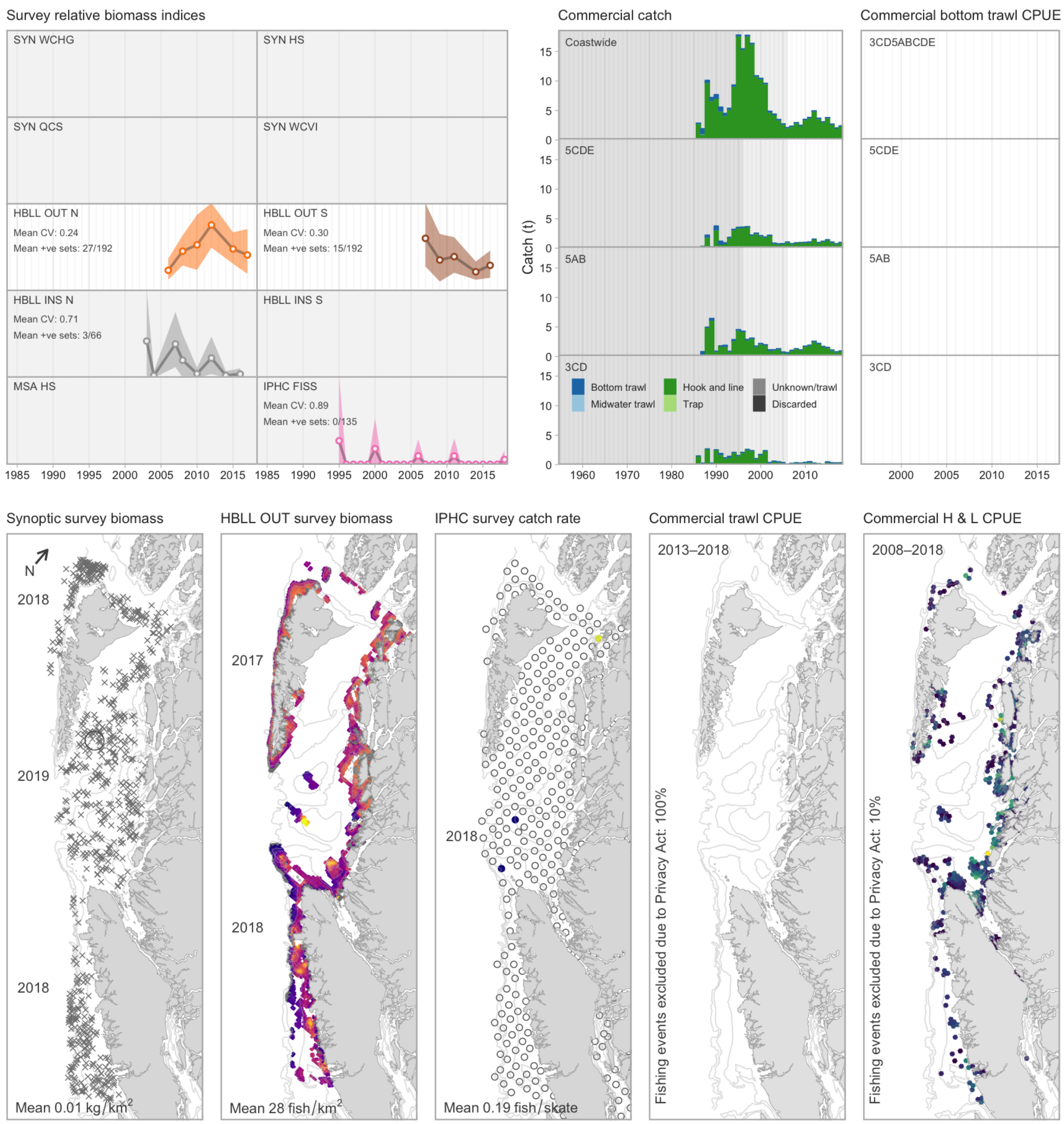
Sebastes nebulosus (431)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

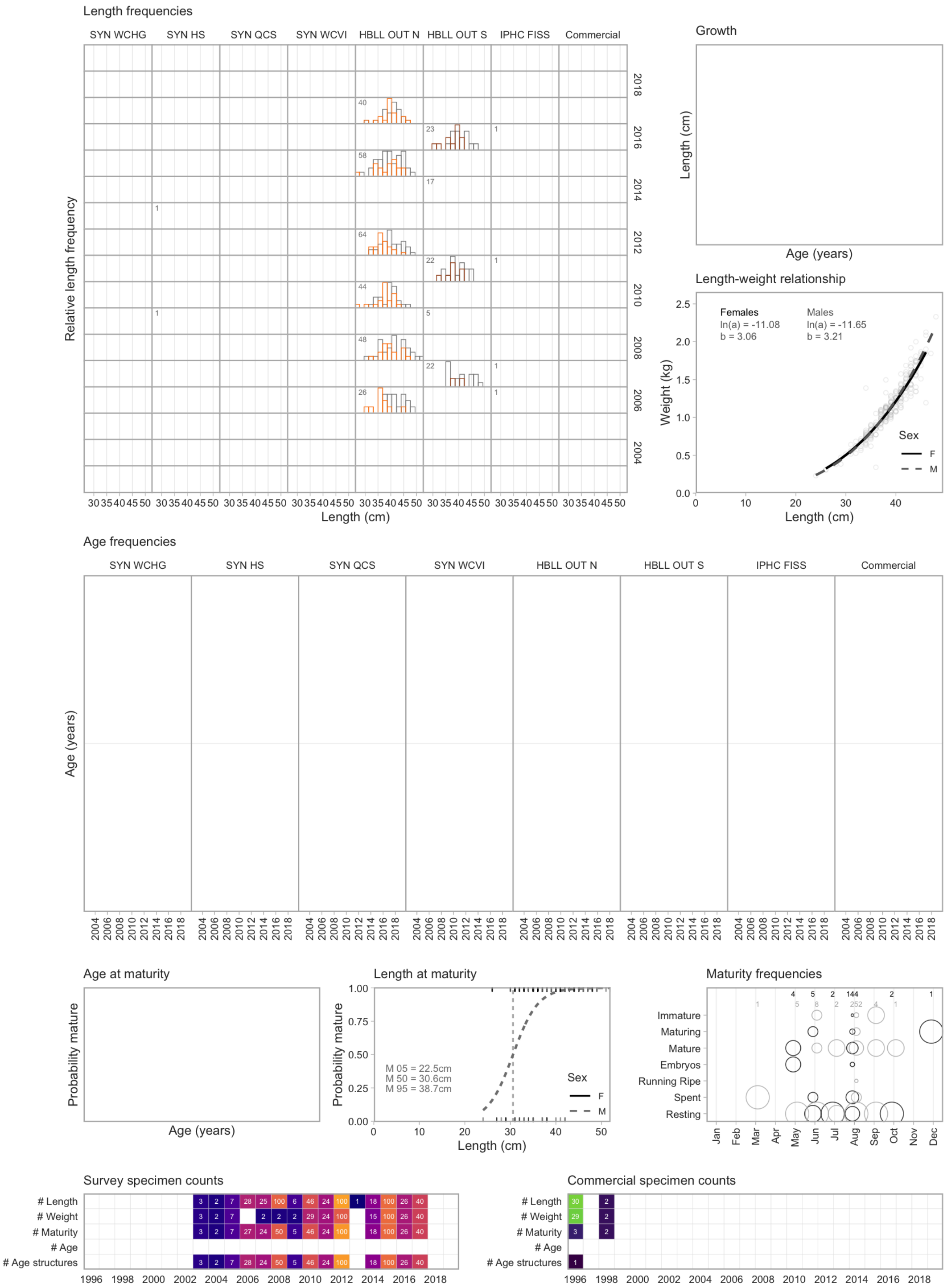



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -10.46
b = 2.92
Males
ln(a) = -10.29
b = 2.86
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 15.2cm
F 50 = 22.8cm
F 95 = 30.4cm
M 05 = 6.9cm
M 50 = 20.8cm
M 95 = 34.8cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.66 TIGER ROCKFISH

Sebastes nigrocinctus (433)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

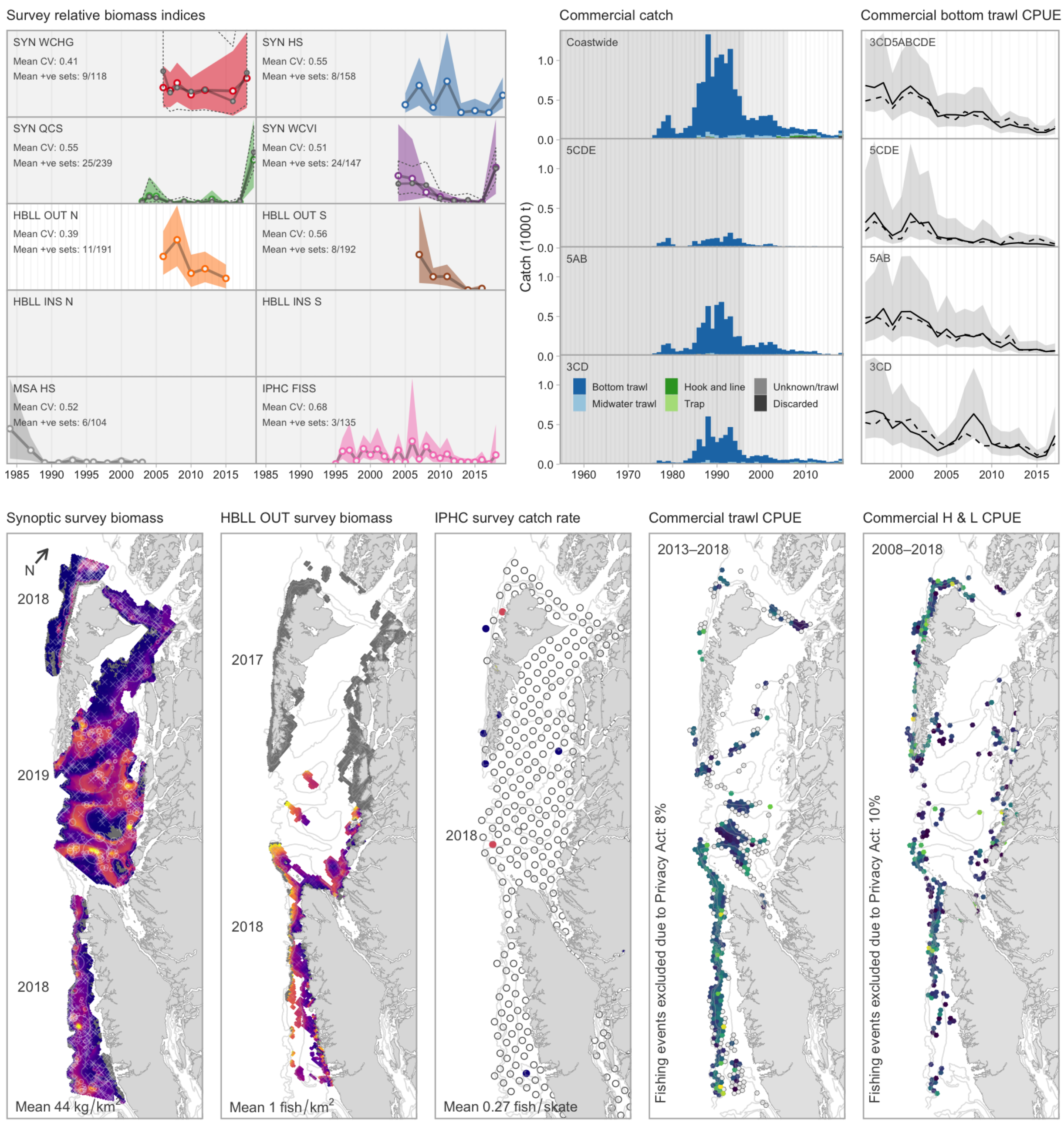


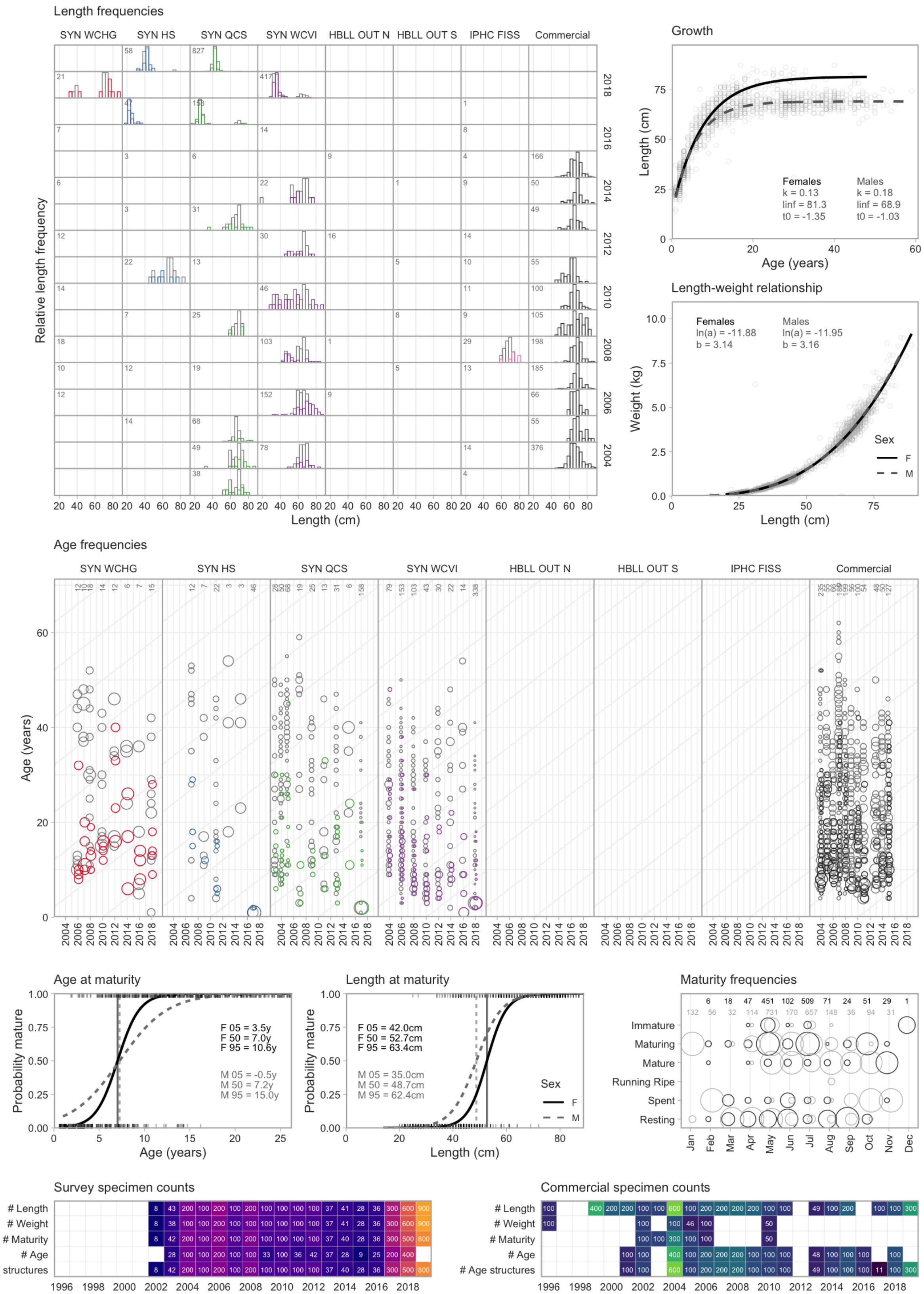


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.08
b = 3.06
Males
ln(a) = -11.65
b = 3.21
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
M 05 = 22.5cm
M 50 = 30.6cm
M 95 = 38.7cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.67 BOCACCIO

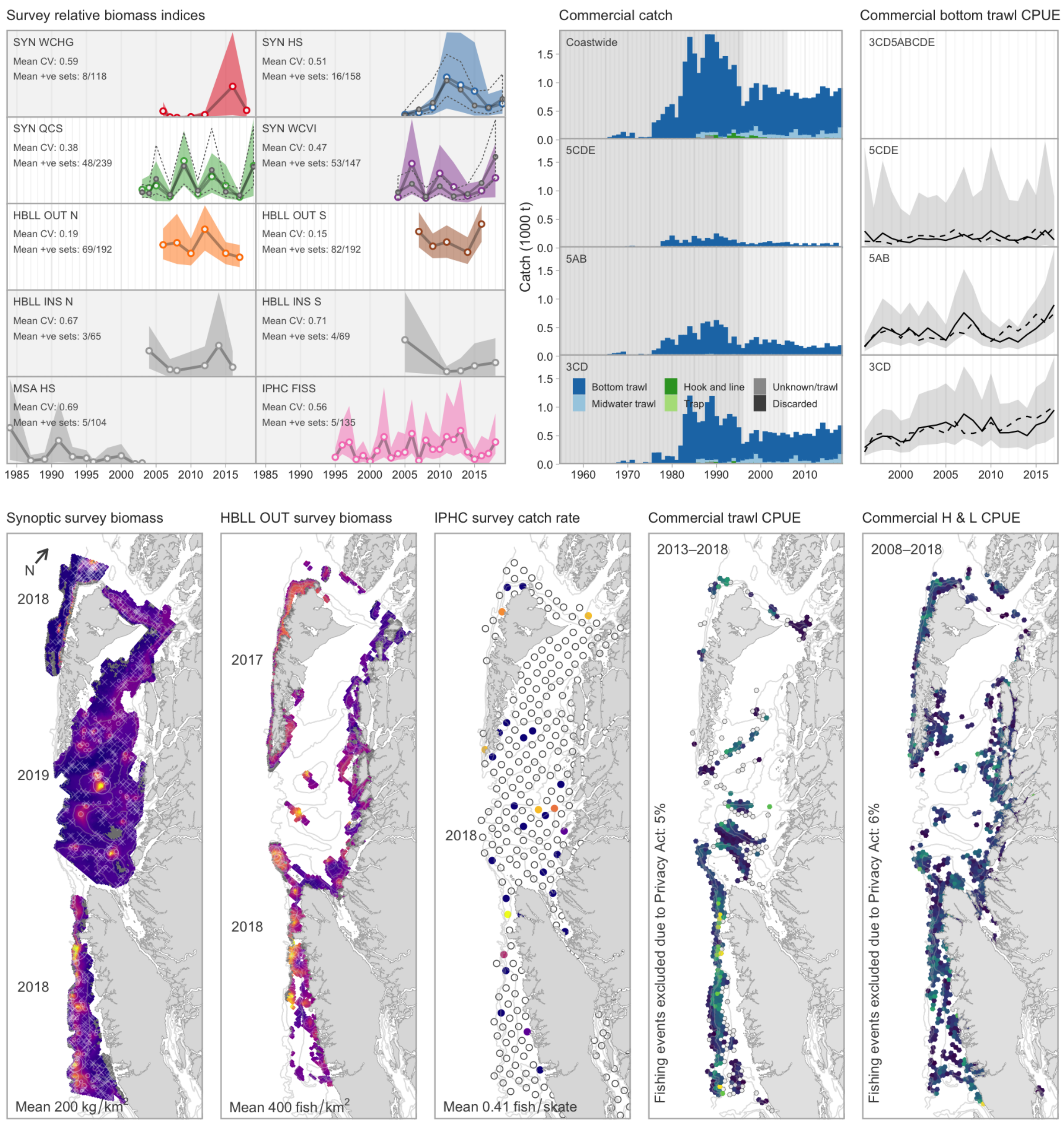
Sebastes paucispinis (435)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Stanley et al. (2012)
Last Science Advisory Report: DFO (2012b)
COSEWIC Status Report: COSEWIC (2002)
COSEWIC Status: Endangered, SARA Status: No Status

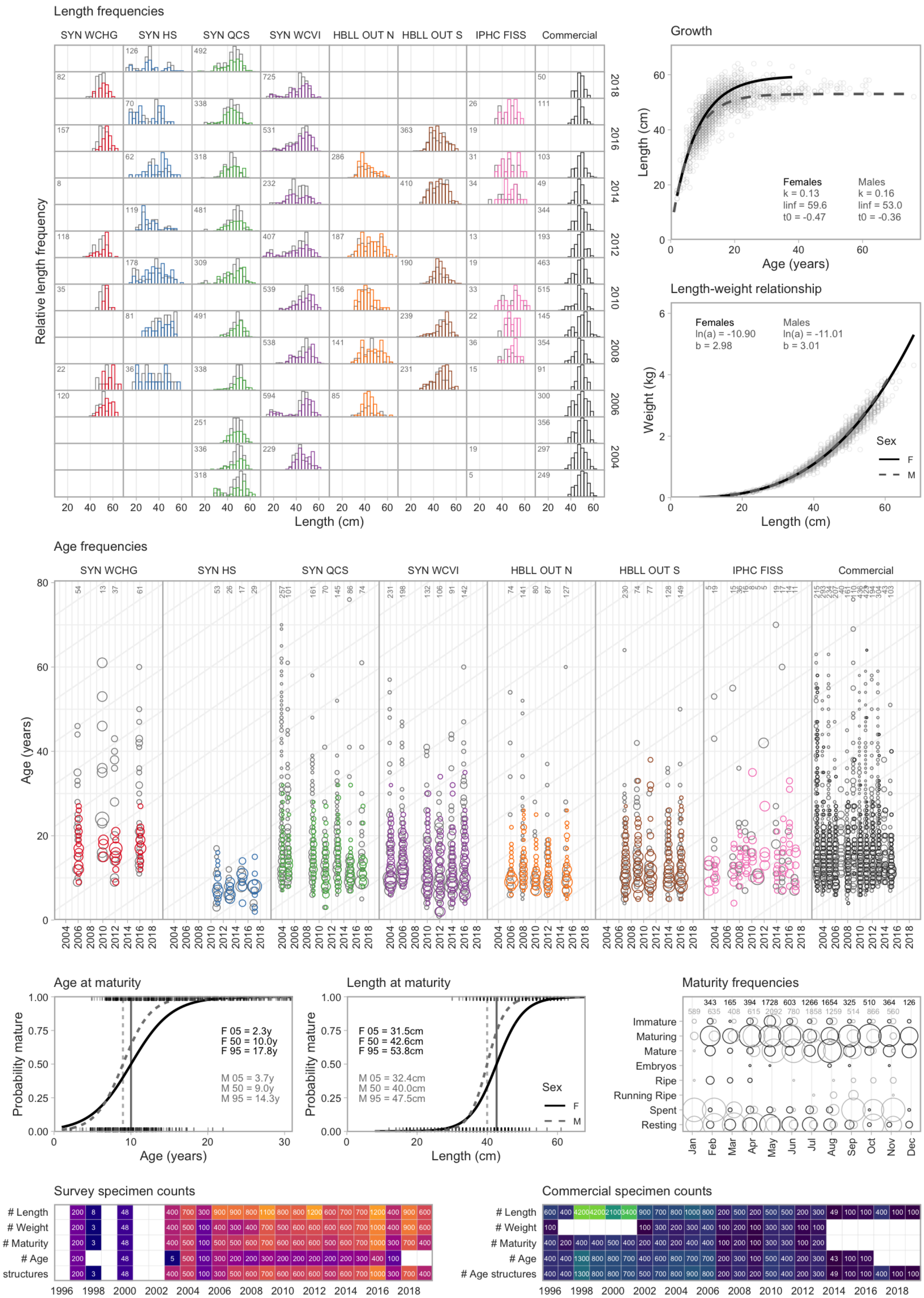



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.13
linf = 81.3
t0 = -1.35
Males
k = 0.18
linf = 68.9
t0 = -1.03
Length-weight relationship
Females
ln(a) = -11.88
b = 3.14
Males
ln(a) = -11.95
b = 3.16
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 3.5y
F 50 = 7.0y
F 95 = 10.6y
M 05 = -0.5y
M 50 = 7.2y
M 95 = 15.0y
Length at maturity
Probability mature
Length (cm)
F 05 = 42.0cm
F 50 = 52.7cm
F 95 = 63.4cm
M 05 = 35.0cm
M 50 = 48.7cm
M 95 = 62.4cm
Maturity frequencies
Immature
Maturing
Mature
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.68 CANARY ROCKFISH

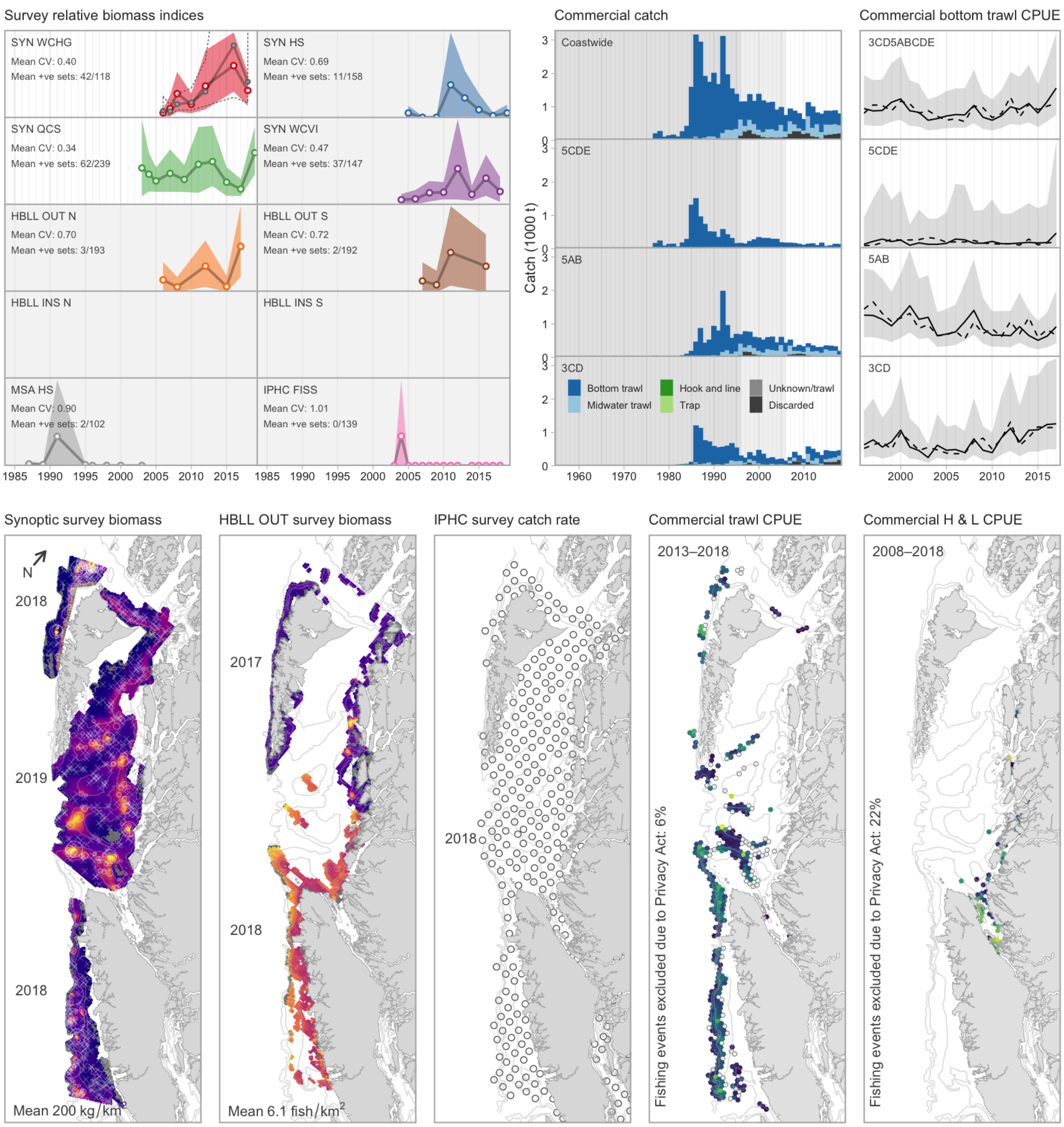
Sebastes pinniger (437)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Stanley et al. (2009)
Last Science Advisory Report: DFO (2009)
COSEWIC Status Report: COSEWIC (2007e)
COSEWIC Status: Threatened, SARA Status: No Status

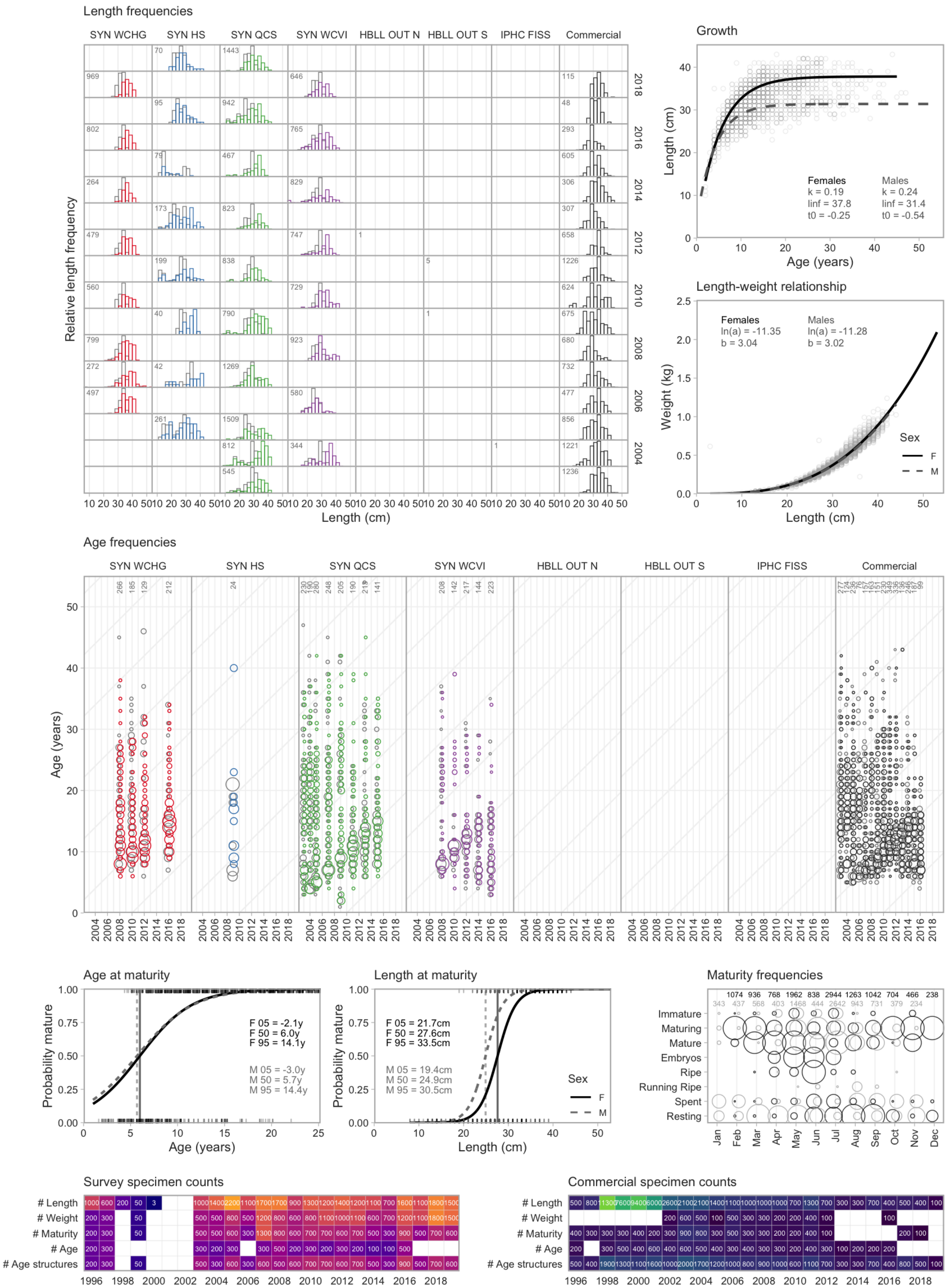



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.13
linf = 59.6
t0 = -0.47
Males
k = 0.16
linf = 53.0
t0 = -0.36
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -10.90
b = 2.98
Males
ln(a) = -11.01
b = 3.01
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 2.3y
F 50 = 10.0y
F 95 = 17.8y
M 05 = 3.7y
M 50 = 9.0y
M 95 = 14.3y
Length at maturity
Length (cm)
F 05 = 31.5cm
F 50 = 42.6cm
F 95 = 53.8cm
M 05 = 32.4cm
M 50 = 40.0cm
M 95 = 47.5cm
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.69 REDSTRIPE ROCKFISH

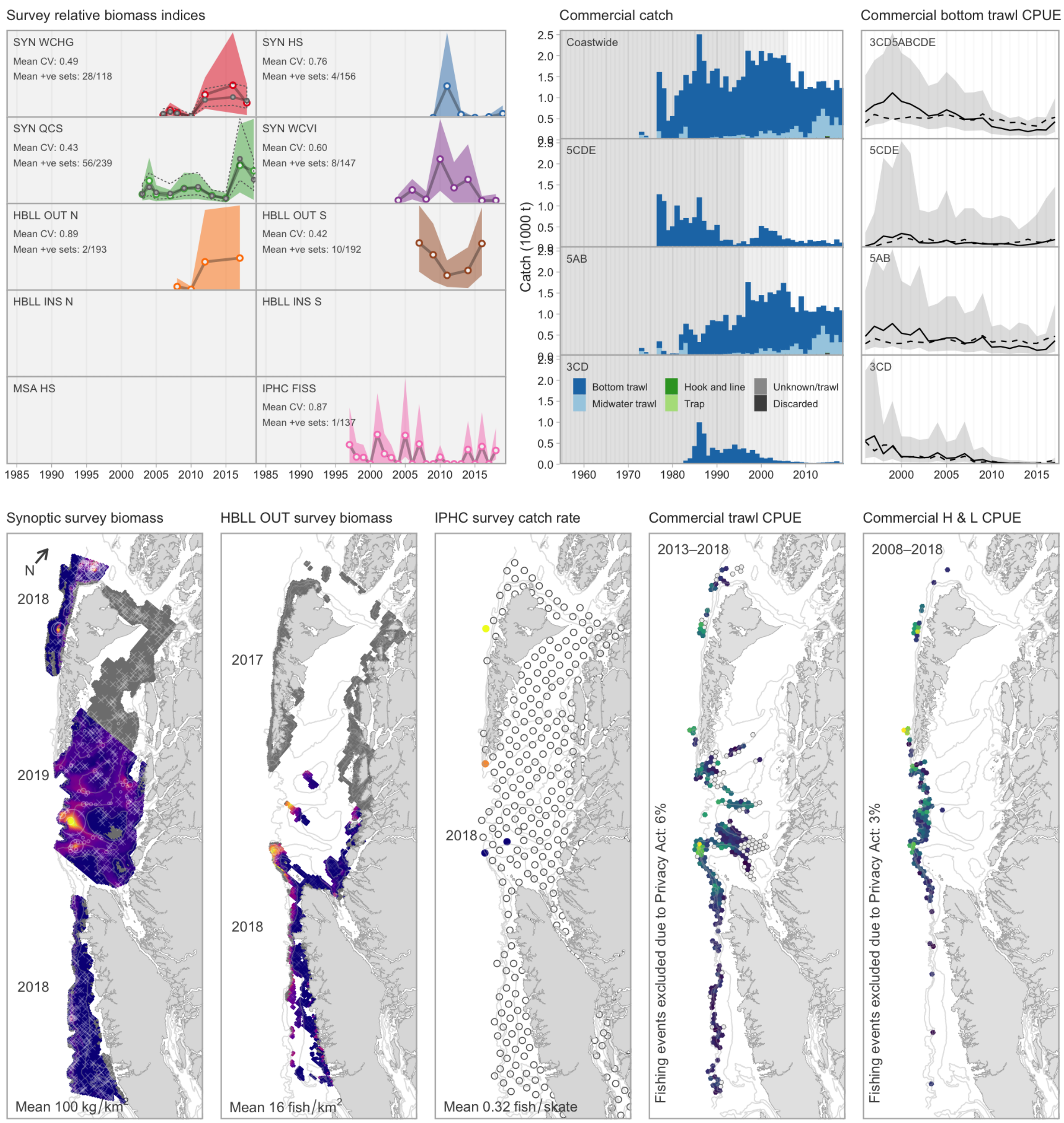
Sebastes proriger (439)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Schnute et al. (1999b)
Last Science Advisory Report: DFO (2018b)

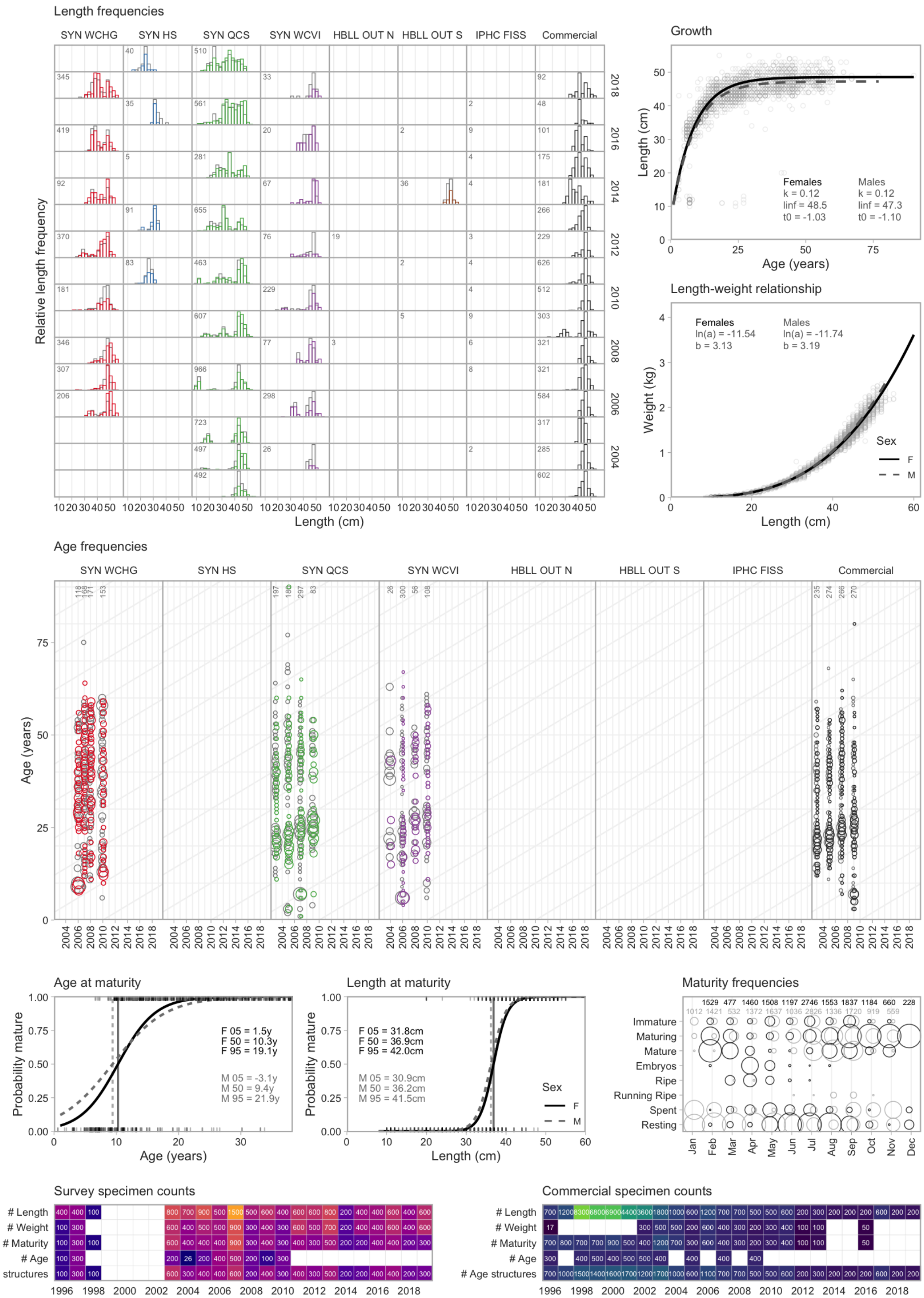




5.70 YELLOWMOUTH ROCKFISH

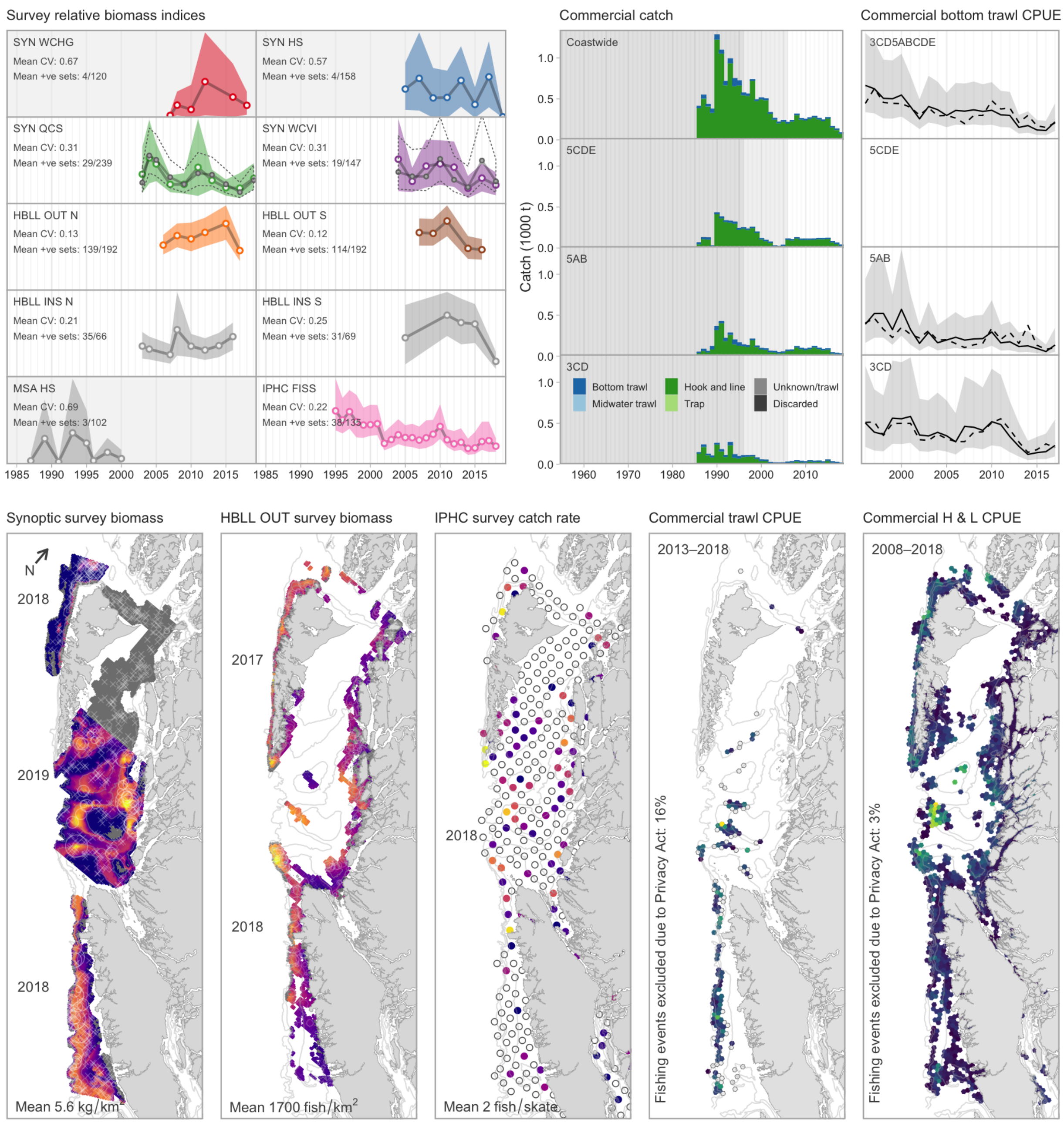
Sebastes reedi (440)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Edwards et al. (2012)
Last Science Advisory Report: DFO (2011c)
COSEWIC Status Report: COSEWIC (2010b)
COSEWIC Status: Threatened, SARA Status: No Status

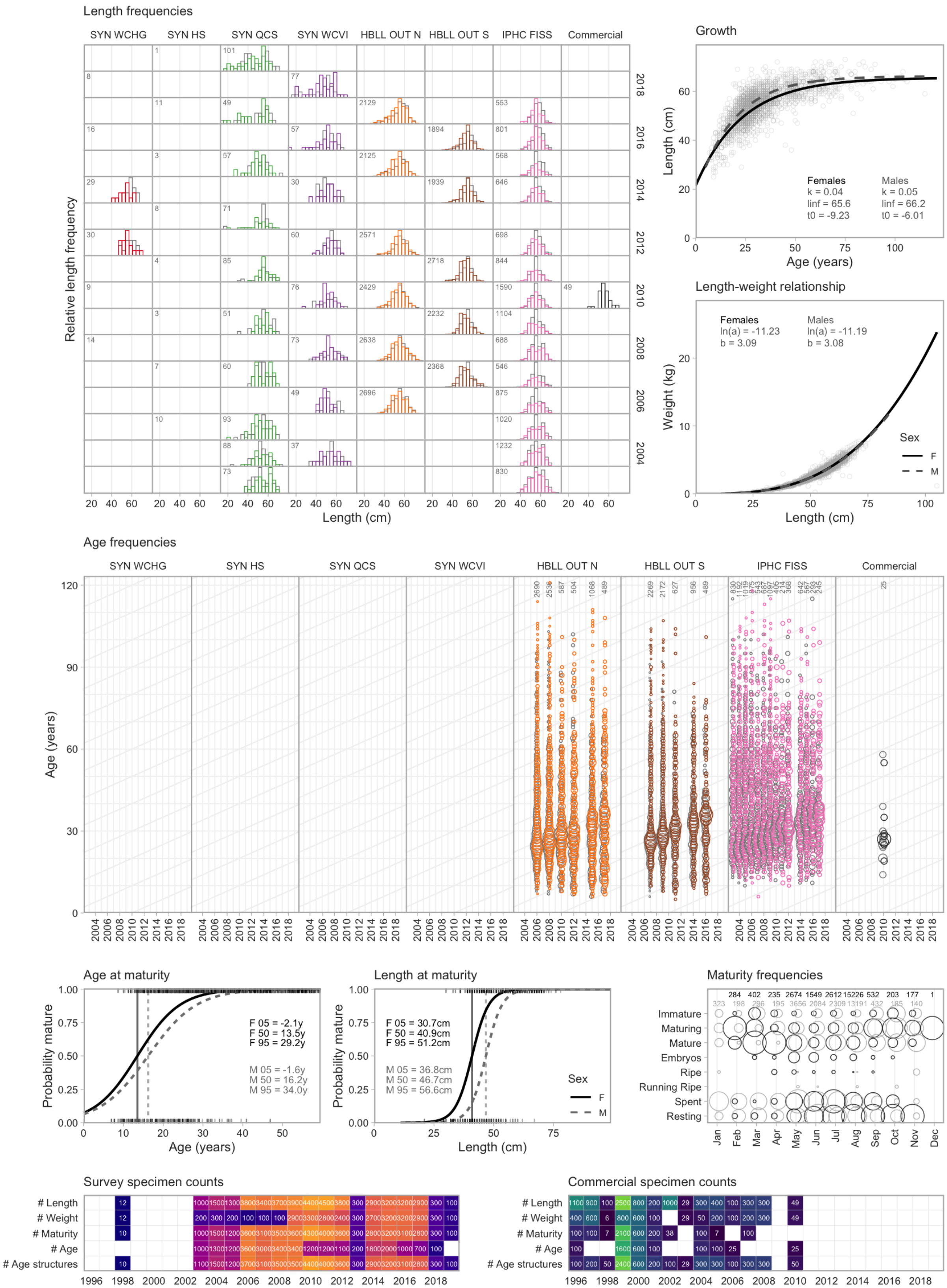



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.12
linf = 48.5
t0 = -1.03
Males
k = 0.12
linf = 47.3
t0 = -1.10
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -11.54
b = 3.13
Males
ln(a) = -11.74
b = 3.19
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 1.5y
F 50 = 10.3y
F 95 = 19.1y
M 05 = -3.1y
M 50 = 9.4y
M 95 = 21.9y
Length at maturity
Probability mature
Length (cm)
F 05 = 31.8cm
F 50 = 36.9cm
F 95 = 42.0cm
M 05 = 30.9cm
M 50 = 36.2cm
M 95 = 41.5cm
Sex
F
M
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.71 YELLOWEYE ROCKFISH

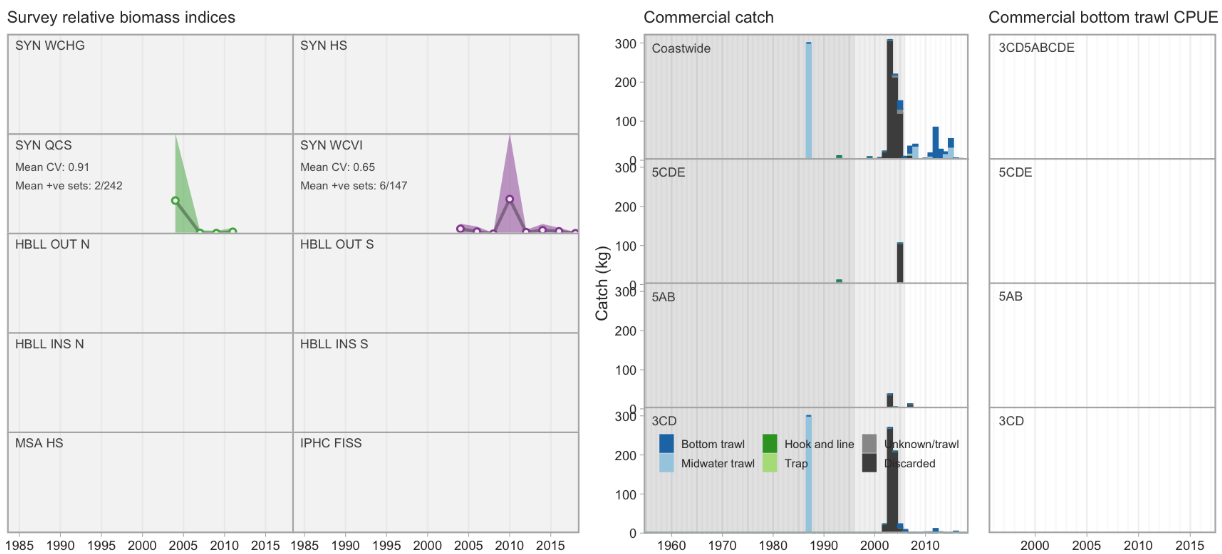
Sebastes ruberrimus (442)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Documents: Yamanaka et al. (2011b), Yamanaka et al. (2018)
Last Science Advisory Reports: DFO (2011d), DFO (2015b)
Pre-COSEWIC Review: Keppel and Olsen (2019)
COSEWIC Status Report: COSEWIC (2008)
COSEWIC Status: Special Concern, SARA Status: Special Concern

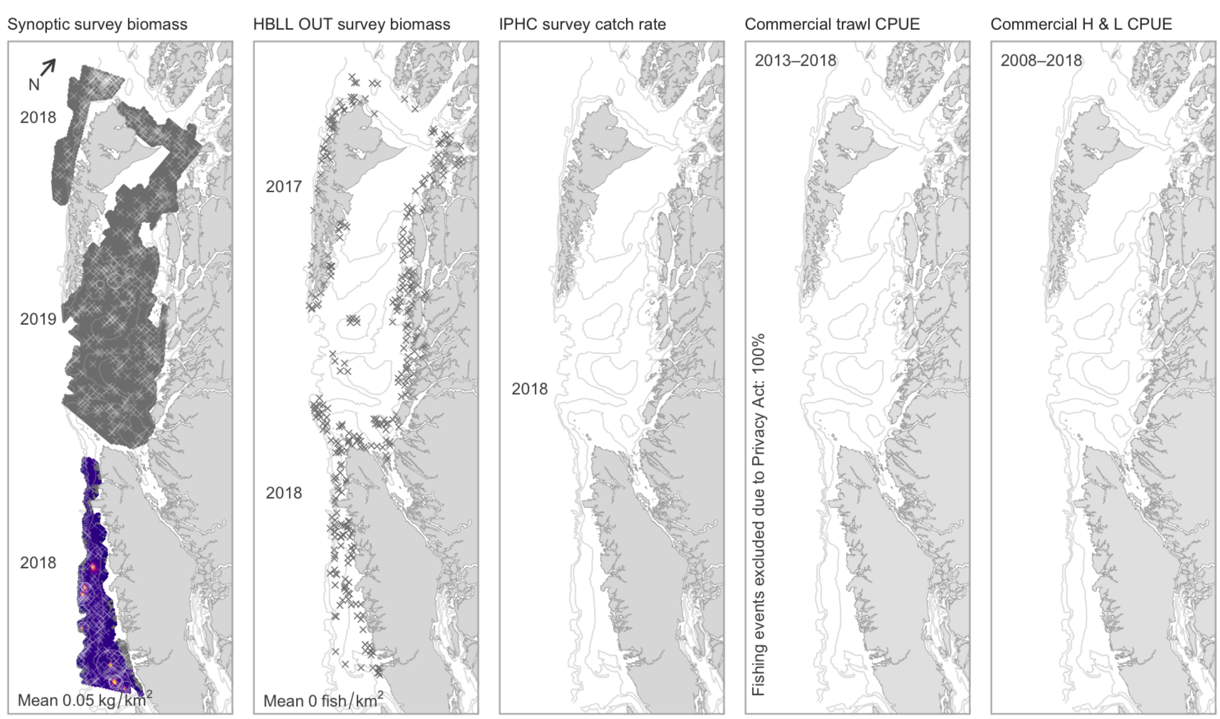


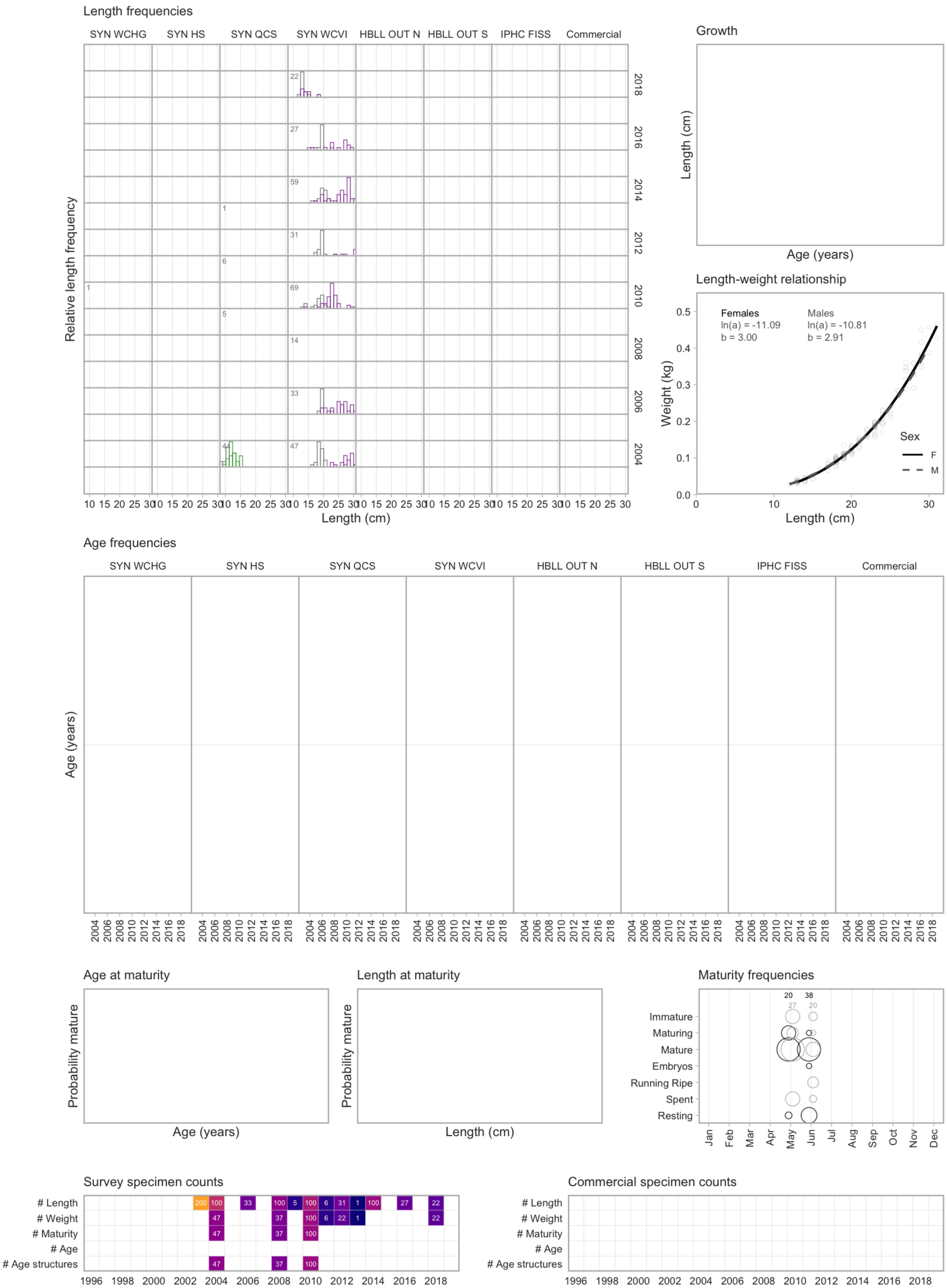

Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.04
linf = 65.6
t0 = -9.23
Males
k = 0.05
linf = 66.2
t0 = -6.01
Length-weight relationship
Females
ln(a) = -11.23
b = 3.09
Males
ln(a) = -11.19
b = 3.08
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
F 05 = -2.1y
F 50 = 13.5y
F 95 = 29.2y
M 05 = -1.6y
M 50 = 16.2y
M 95 = 34.0y
Age (years)
Length at maturity
F 05 = 30.7cm
F 50 = 40.9cm
F 95 = 51.2cm
M 05 = 36.8cm
M 50 = 46.7cm
M 95 = 56.6cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.72 STRIPETAIL ROCKFISH

Sebastes saxicola (444)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

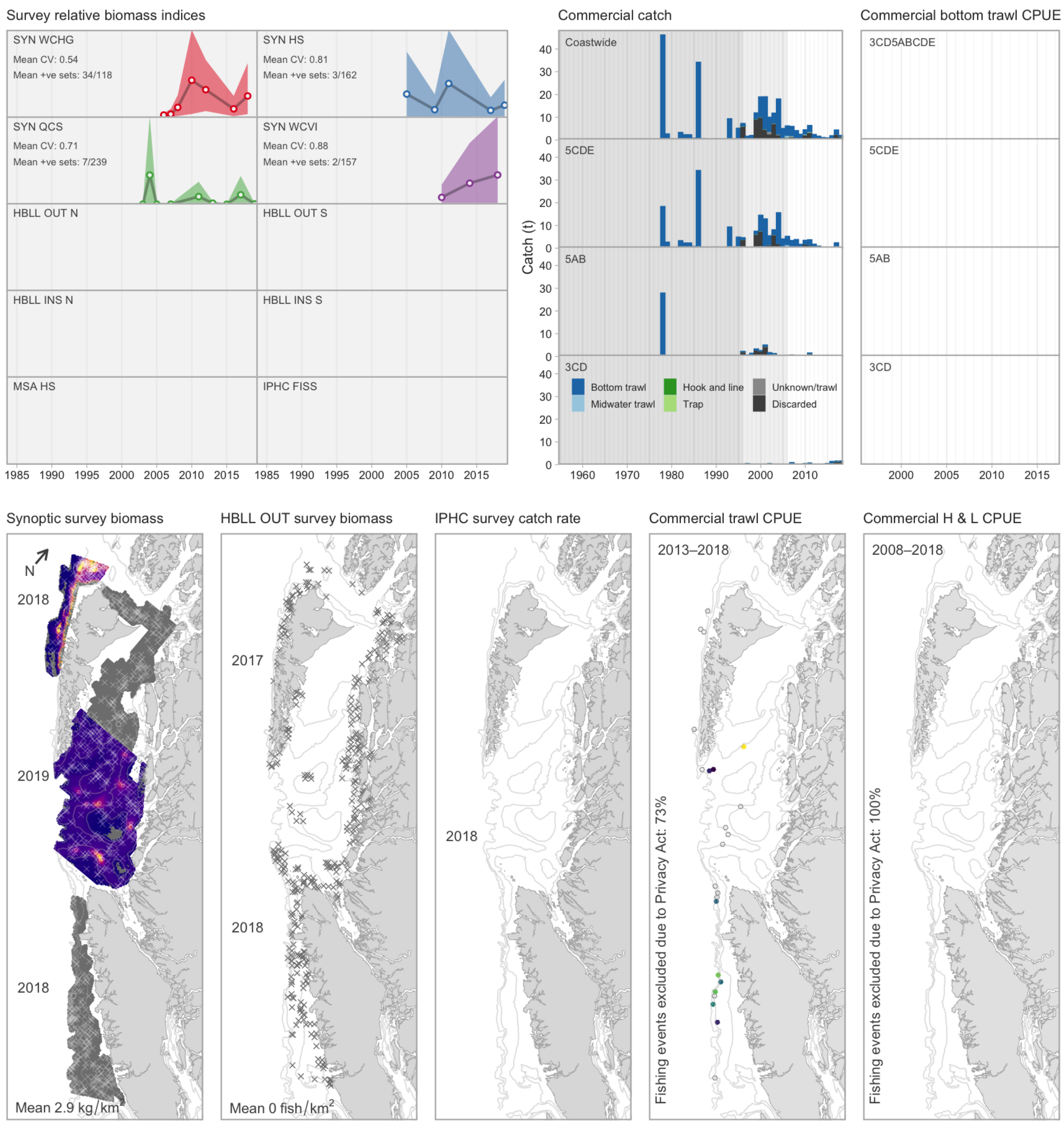


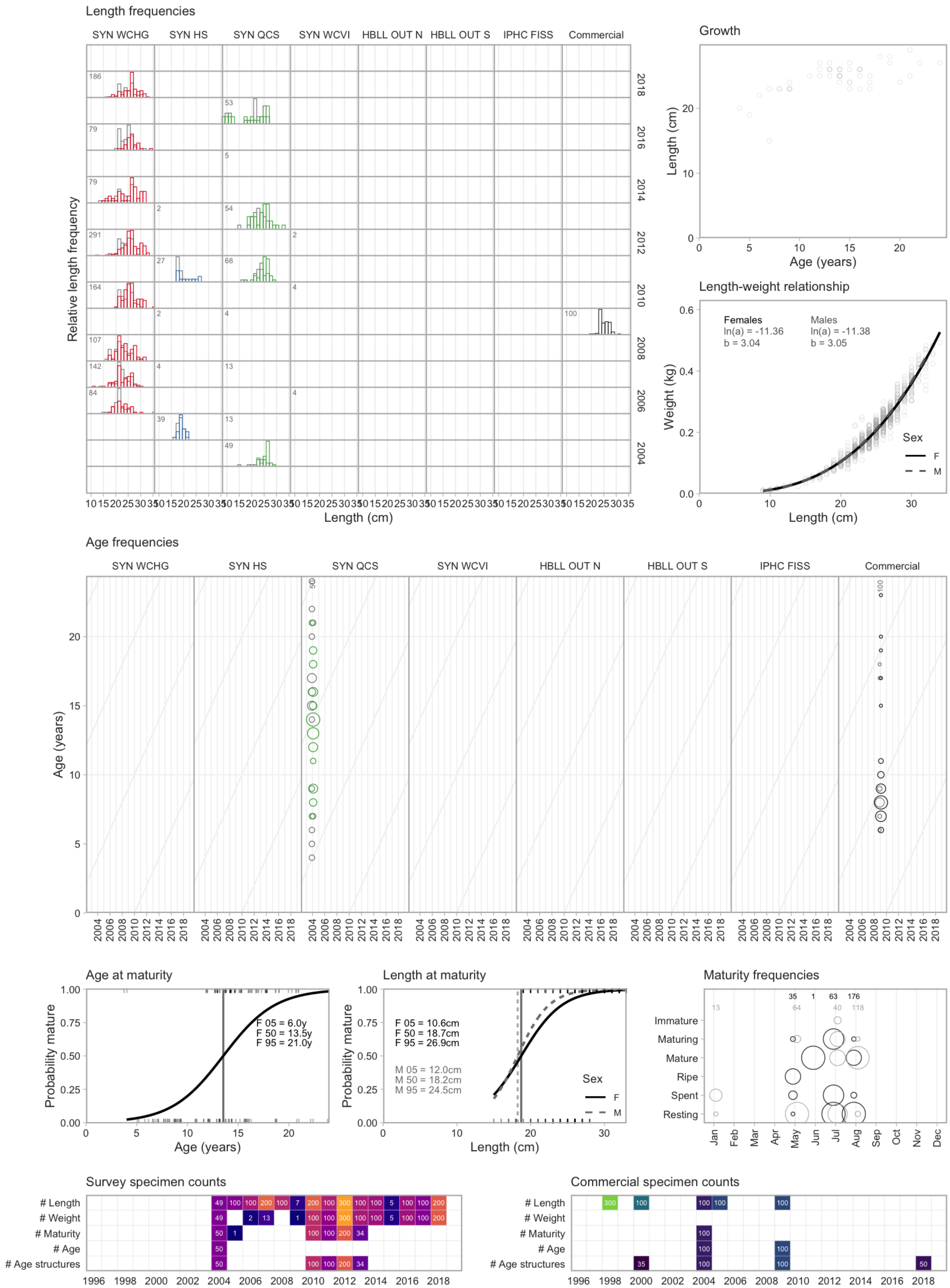



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.09
b = 3.00
Males
ln(a) = -10.81
b = 2.91
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.73 HARLEQUIN ROCKFISH

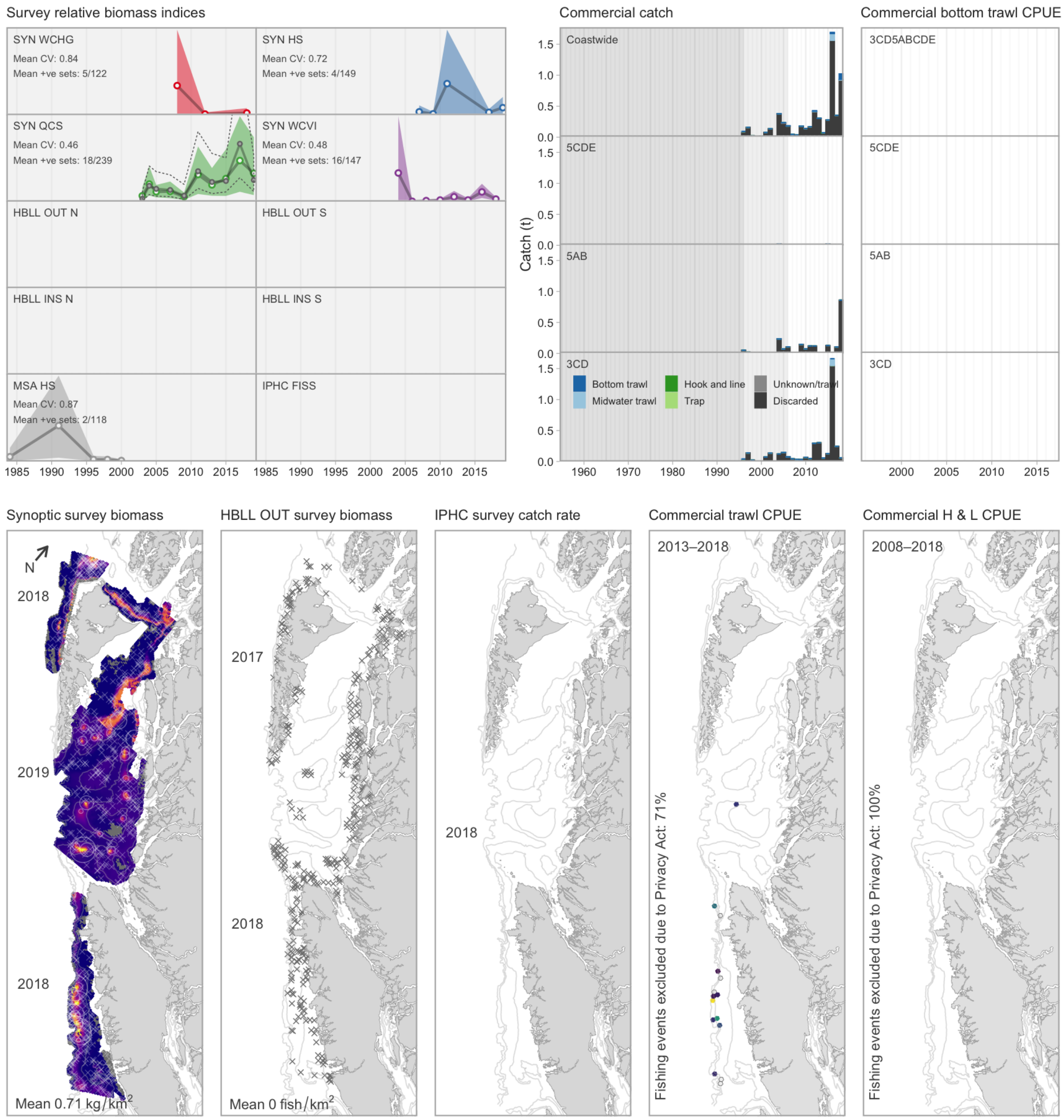
Sebastes variegatus (446)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

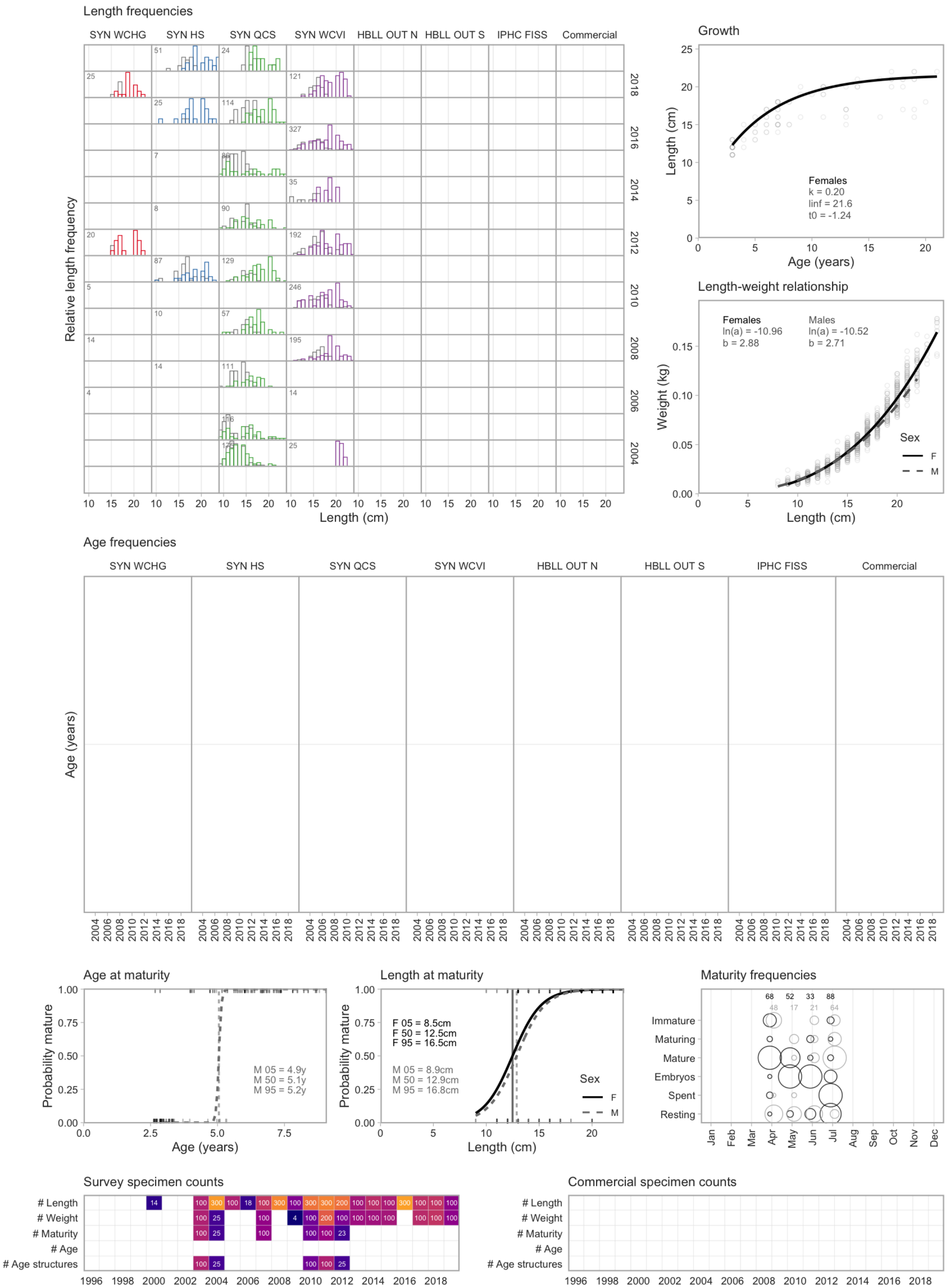



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.36
b = 3.04
Males
ln(a) = -11.38
b = 3.05
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
F 05 = 6.0y
F 50 = 13.5y
F 95 = 21.0y
Probability mature
Age (years)
Length at maturity
F 05 = 10.6cm
F 50 = 18.7cm
F 95 = 26.9cm
M 05 = 12.0cm
M 50 = 18.2cm
M 95 = 24.5cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.74 PYGMY ROCKFISH

Sebastes wilsoni (448)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

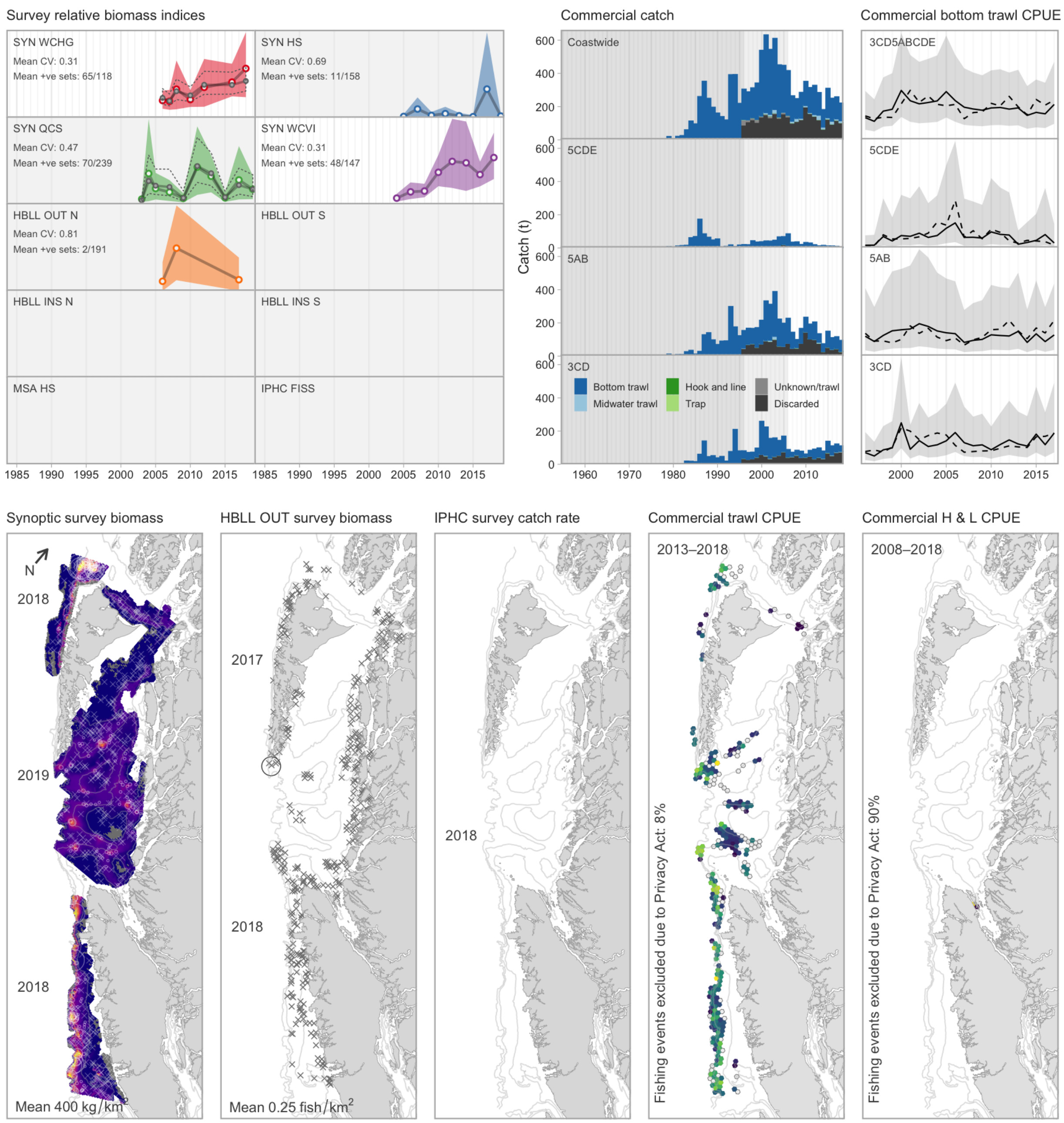


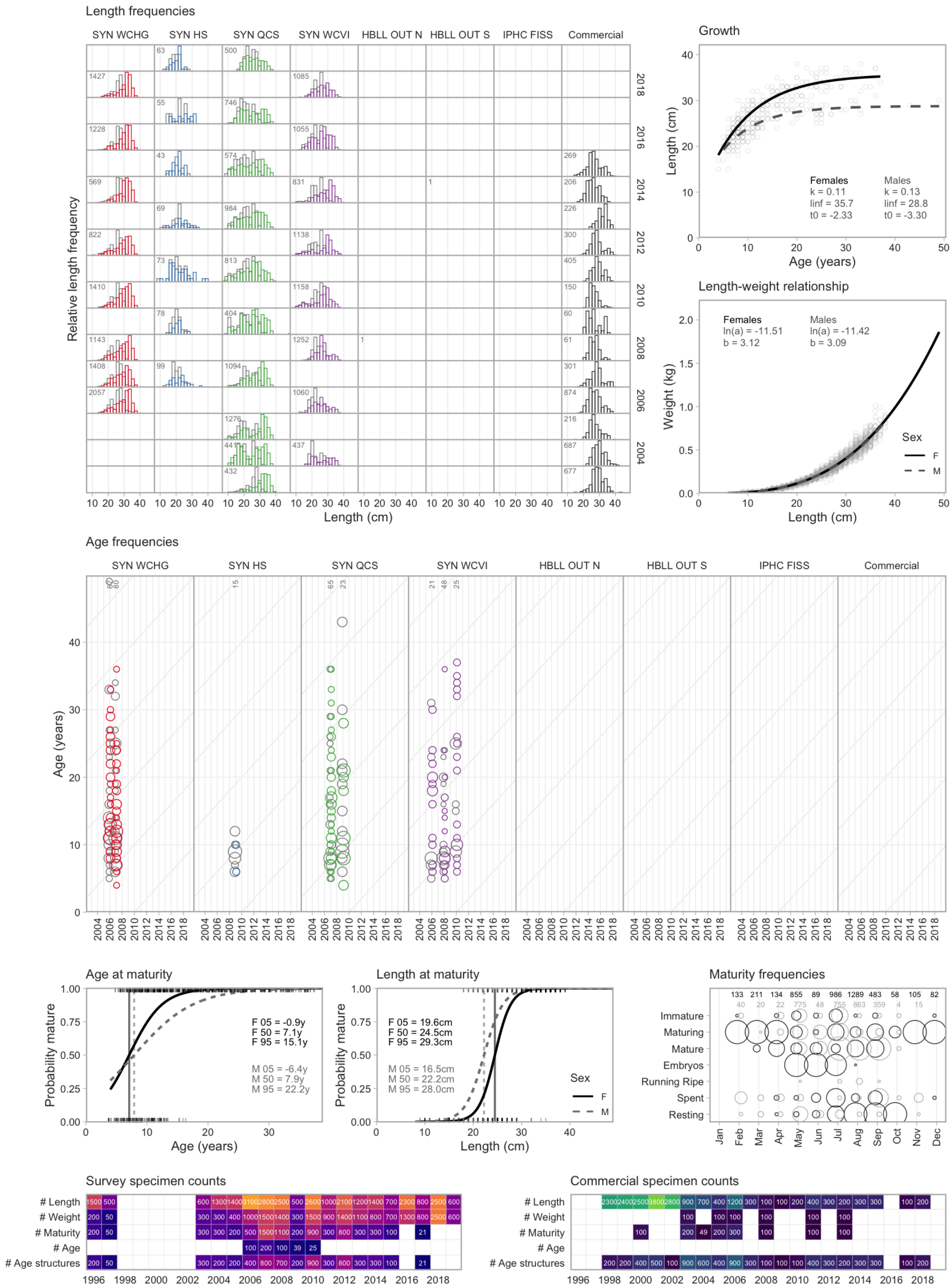


Length frequencies
Growth
Females
k = 0.20
linf = 21.6
t0 = -1.24
Length-weight relationship
Females
ln(a) = -10.96
b = 2.88
Males
ln(a) = -10.52
b = 2.71
Age frequencies
Age at maturity
M 05 = 4.9y
M 50 = 5.1y
M 95 = 5.2y
Length at maturity
F 05 = 8.5cm
F 50 = 12.5cm
F 95 = 16.5cm
M 05 = 8.9cm
M 50 = 12.9cm
M 95 = 16.8cm
Maturity frequencies
Survey specimen counts
Commercial specimen counts

5.75 SHARPCHIN ROCKFISH

Sebastes zacentrus (450)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS

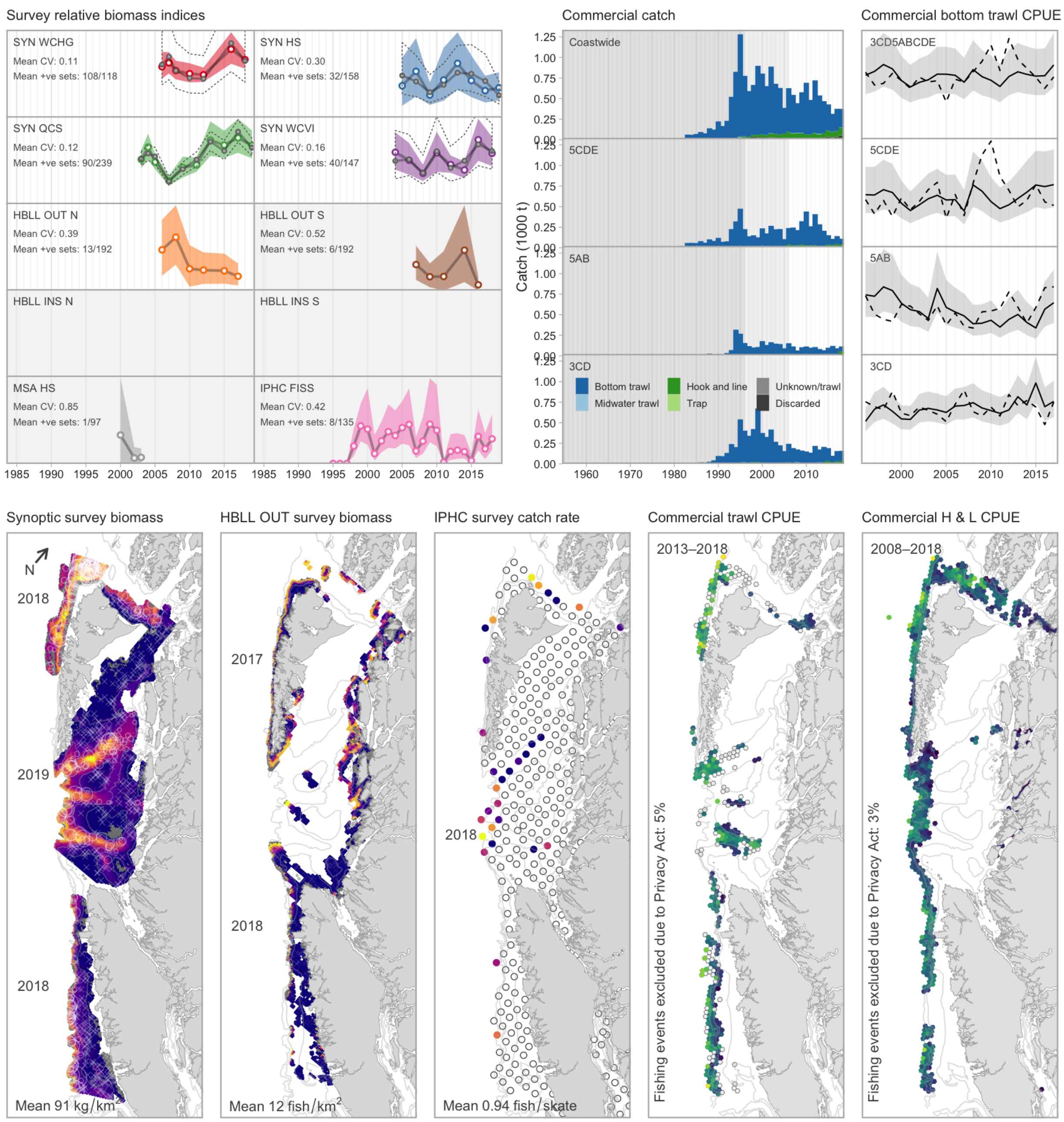


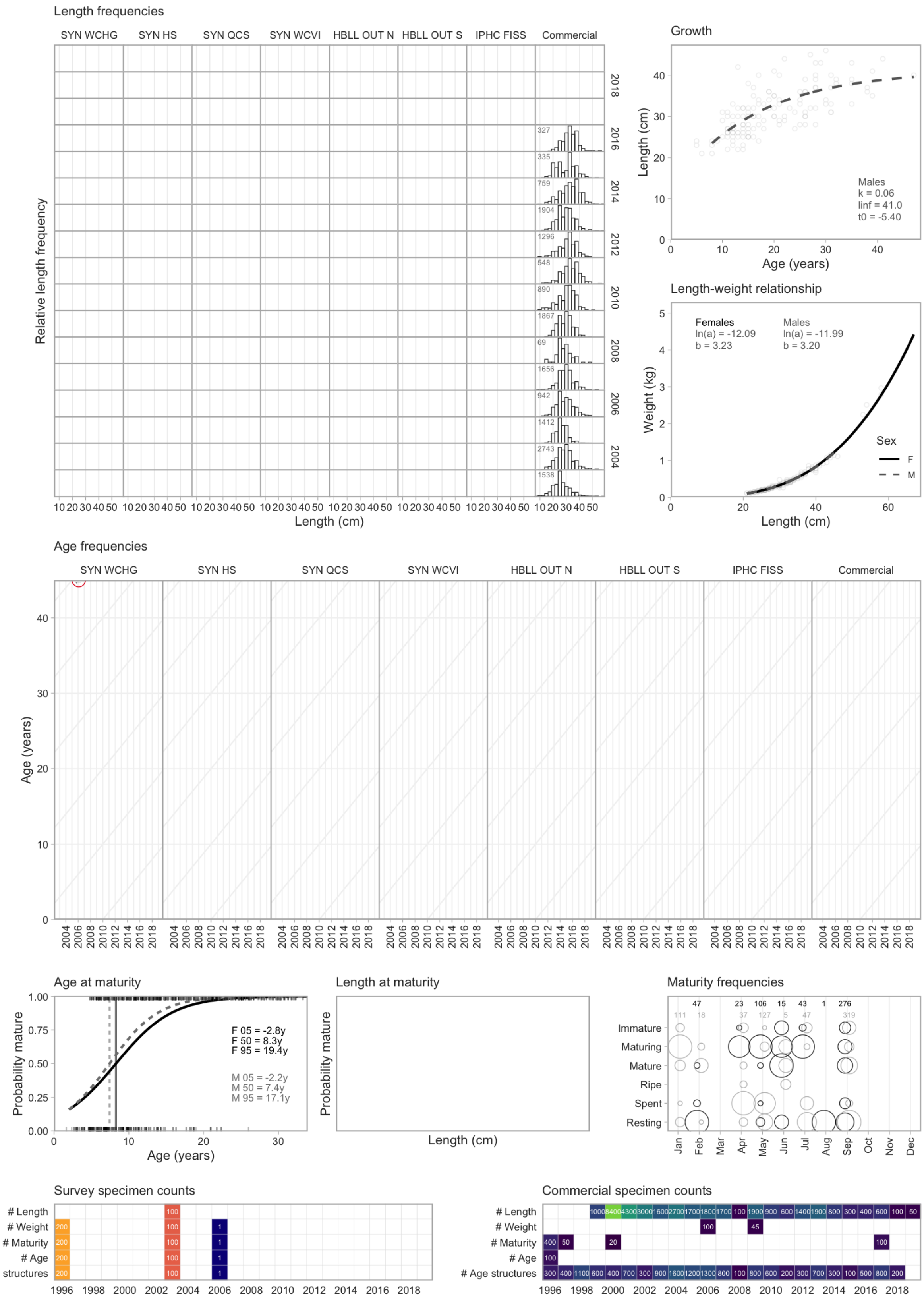


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.11
linf = 35.7
t0 = -2.33
Males
k = 0.13
linf = 28.8
t0 = -3.30
Length-weight relationship
Females
ln(a) = -11.51
b = 3.12
Males
ln(a) = -11.42
b = 3.09
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
F 05 = -0.9y
F 50 = 7.1y
F 95 = 15.1y
M 05 = -6.4y
M 50 = 7.9y
M 95 = 22.2y
Age (years)
Length at maturity
Probability mature
F 05 = 19.6cm
F 50 = 24.5cm
F 95 = 29.3cm
M 05 = 16.5cm
M 50 = 22.2cm
M 95 = 28.0cm
Sex
F
M
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.76 SHORTSPINE THORNYHEAD

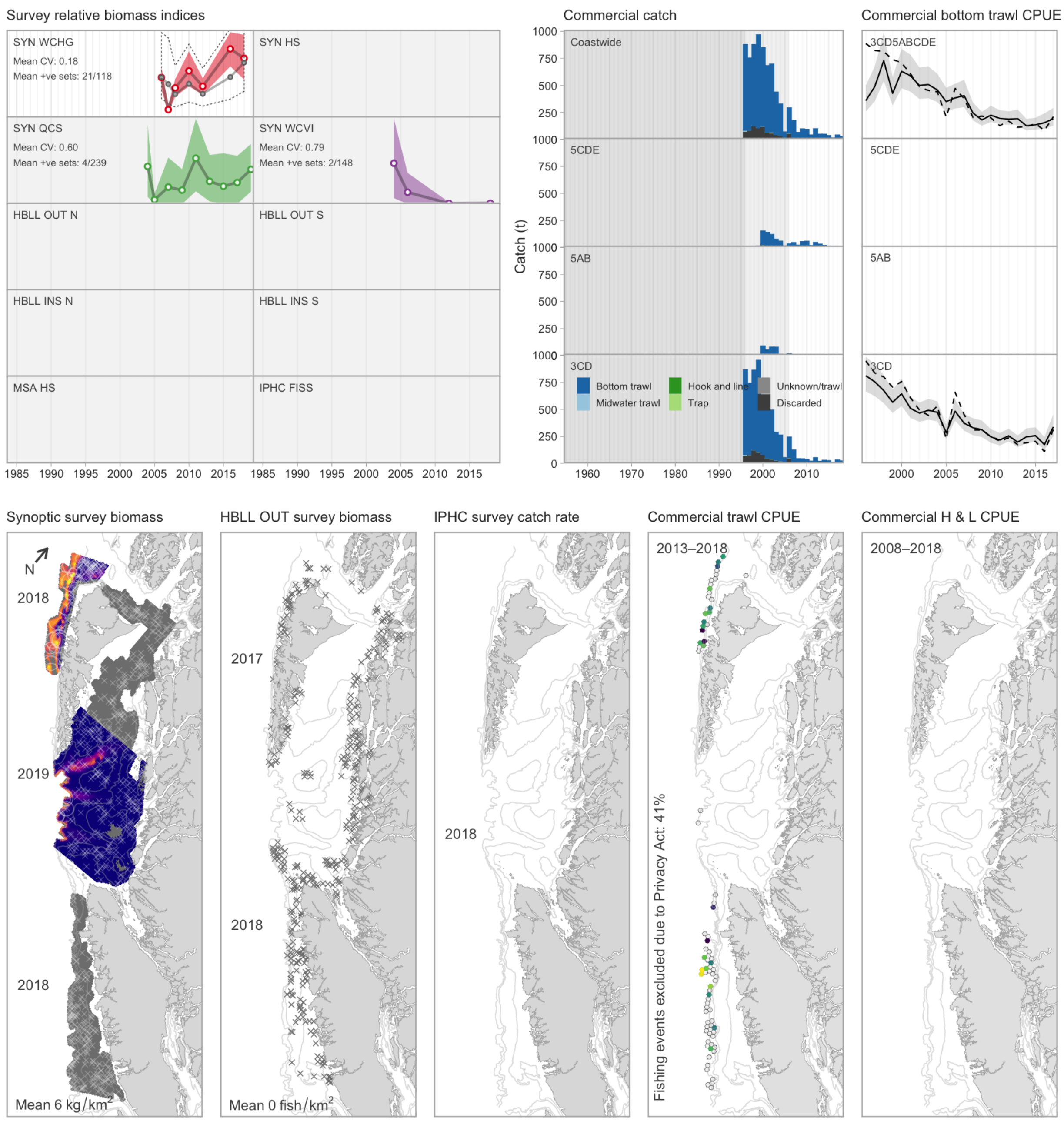
Sebastolobus alascanus (451)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Starr and Haigh (2017)
Last Science Advisory Report: DFO (2016b)

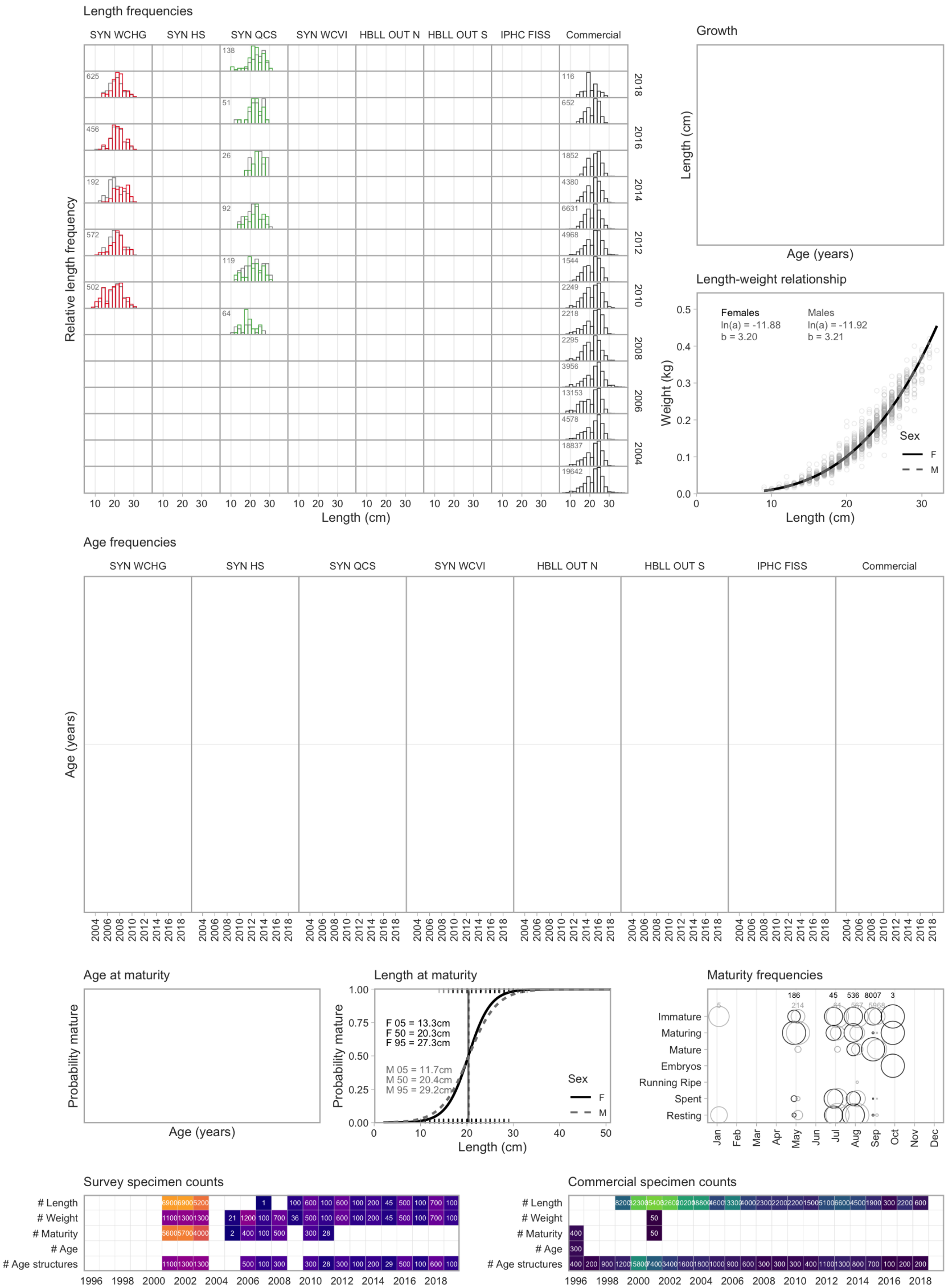



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Males
k = 0.06
linf = 41.0
t0 = -5.40
Length-weight relationship
Females
ln(a) = -12.09
b = 3.23
Males
ln(a) = -11.99
b = 3.20
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
F 05 = -2.8y
F 50 = 8.3y
F 95 = 19.4y
M 05 = -2.2y
M 50 = 7.4y
M 95 = 17.1y
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.77 LONGSPINE THORNYHEAD

Sebastolobus altivelis (453)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase, WoRMS
Last Research Document: Haigh et al. (2005a)
Species at Risk Act Management Plan Series: DFO (2012c)
COSEWIC Status Report: COSEWIC (2007f)
COSEWIC Status: Special Concern, SARA Status: Special Concern

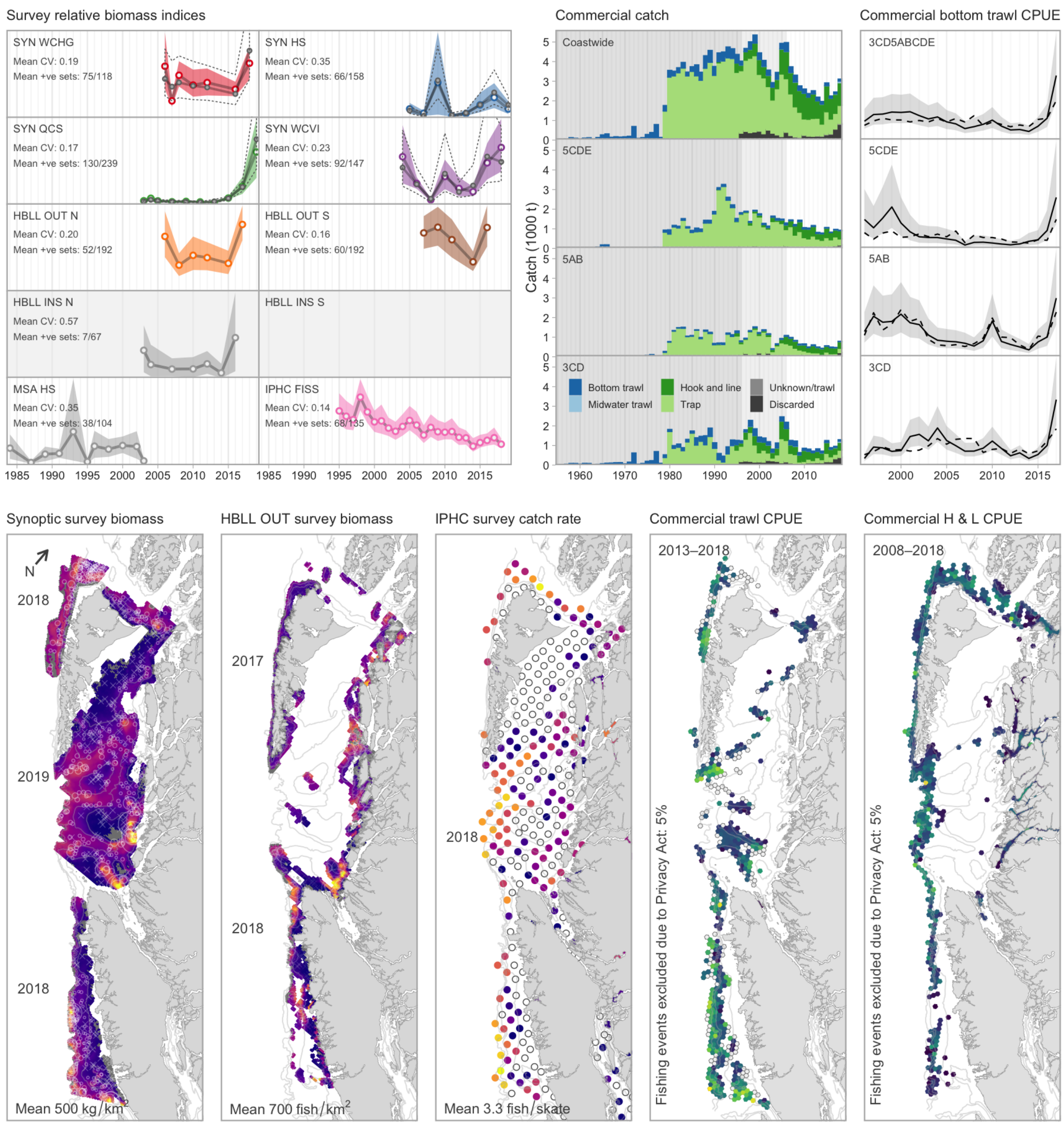


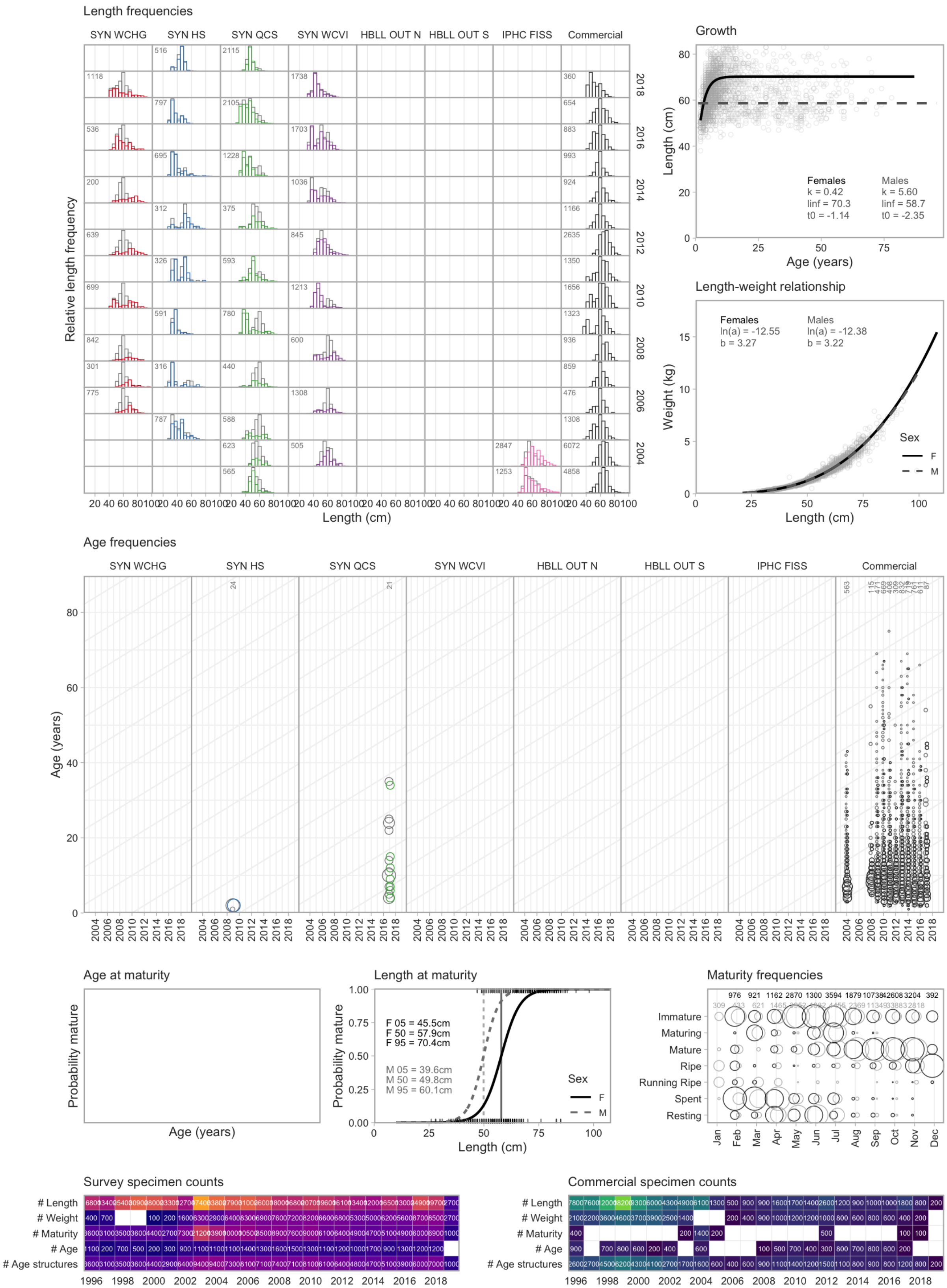


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.88
b = 3.20
Males
ln(a) = -11.92
b = 3.21
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 13.3cm
F 50 = 20.3cm
F 95 = 27.3cm
M 05 = 11.7cm
M 50 = 20.4cm
M 95 = 29.2cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Embryos
Running Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.78 SABLEFISH

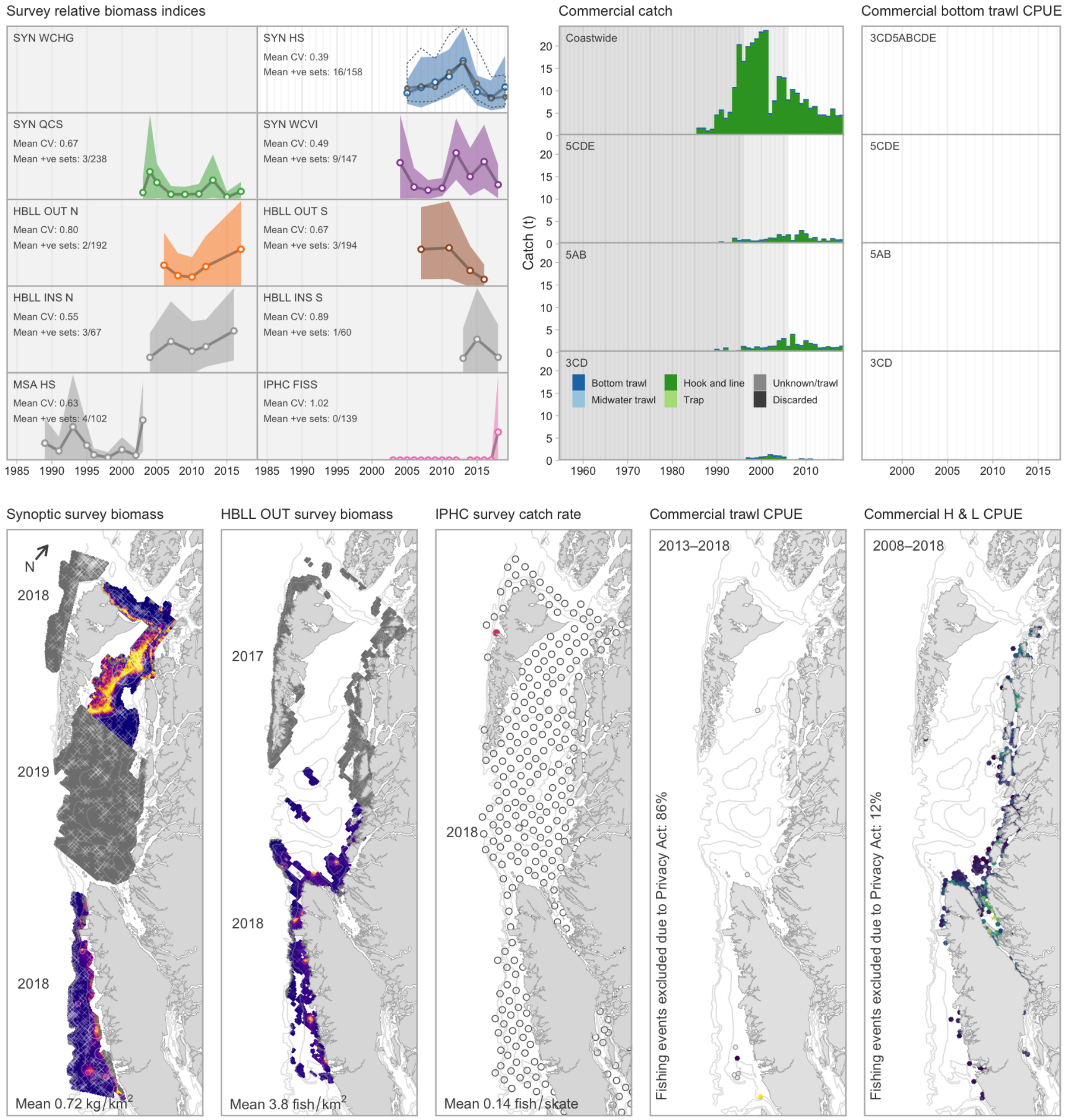
Anoplopoma fimbria (455)
Order: Scorpaeniformes, Family: Anoplopomatidae, FishBase, WoRMS
Last Research Document: Cox et al. (2011)
Last Science Advisory Report: DFO (2017b)
Note that Sablefish undergoes directed annual trap surveys, which are used for stock assessment and are not included in this report. The most recent stock assessment should be consulted for details on stock status.

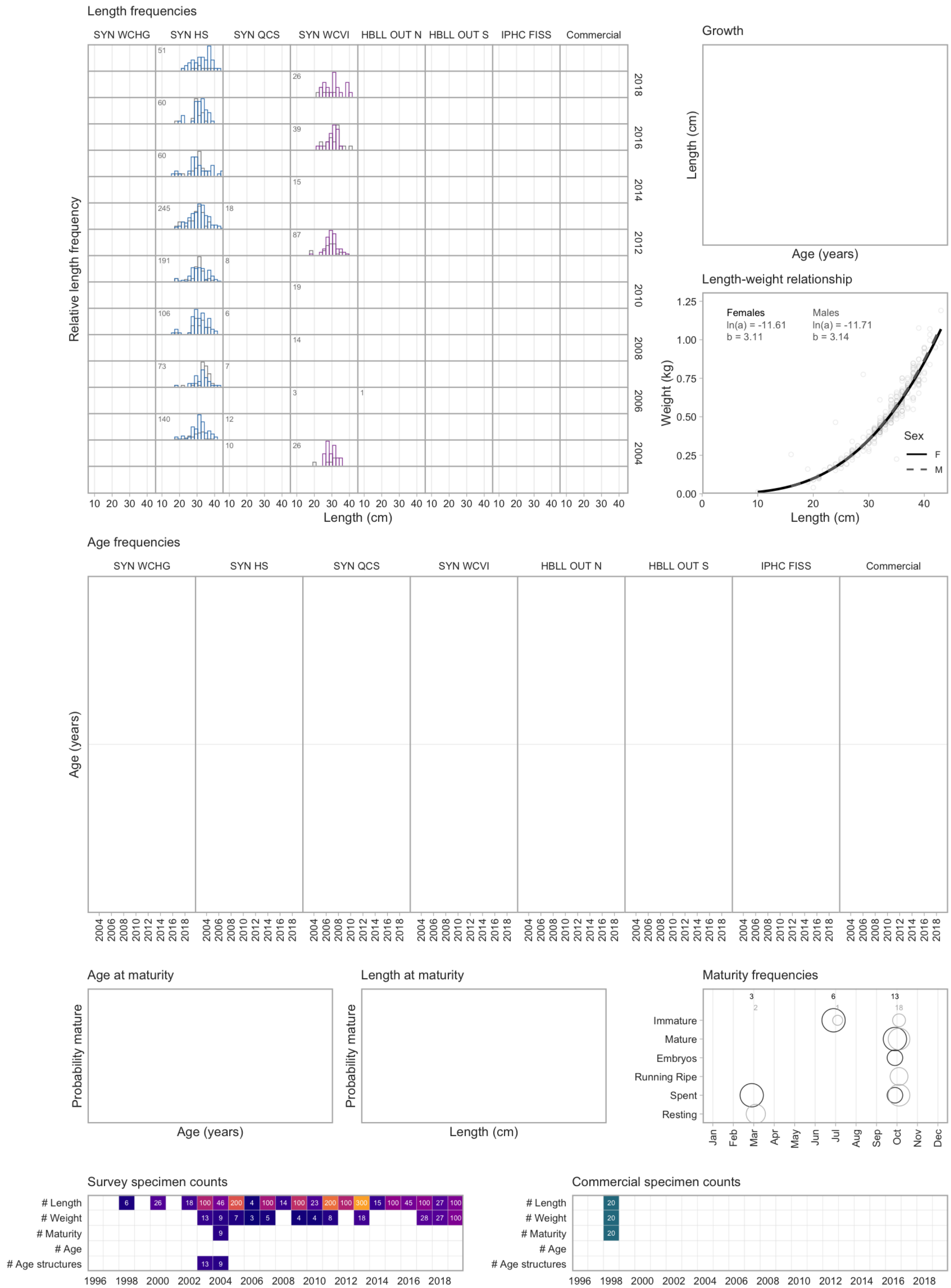



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.42
linf = 70.3
t0 = -1.14
Males
k = 5.60
linf = 58.7
t0 = -2.35
Length-weight relationship
Females
ln(a) = -12.55
b = 3.27
Males
ln(a) = -12.38
b = 3.22
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 45.5cm
F 50 = 57.9cm
F 95 = 70.4cm
M 05 = 39.6cm
M 50 = 49.8cm
M 95 = 60.1cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.79 KELP GREENLING

Hexagrammos decagrammus (461)
Order: Scorpaeniformes, Family: Hexagrammidae, FishBase, WoRMS

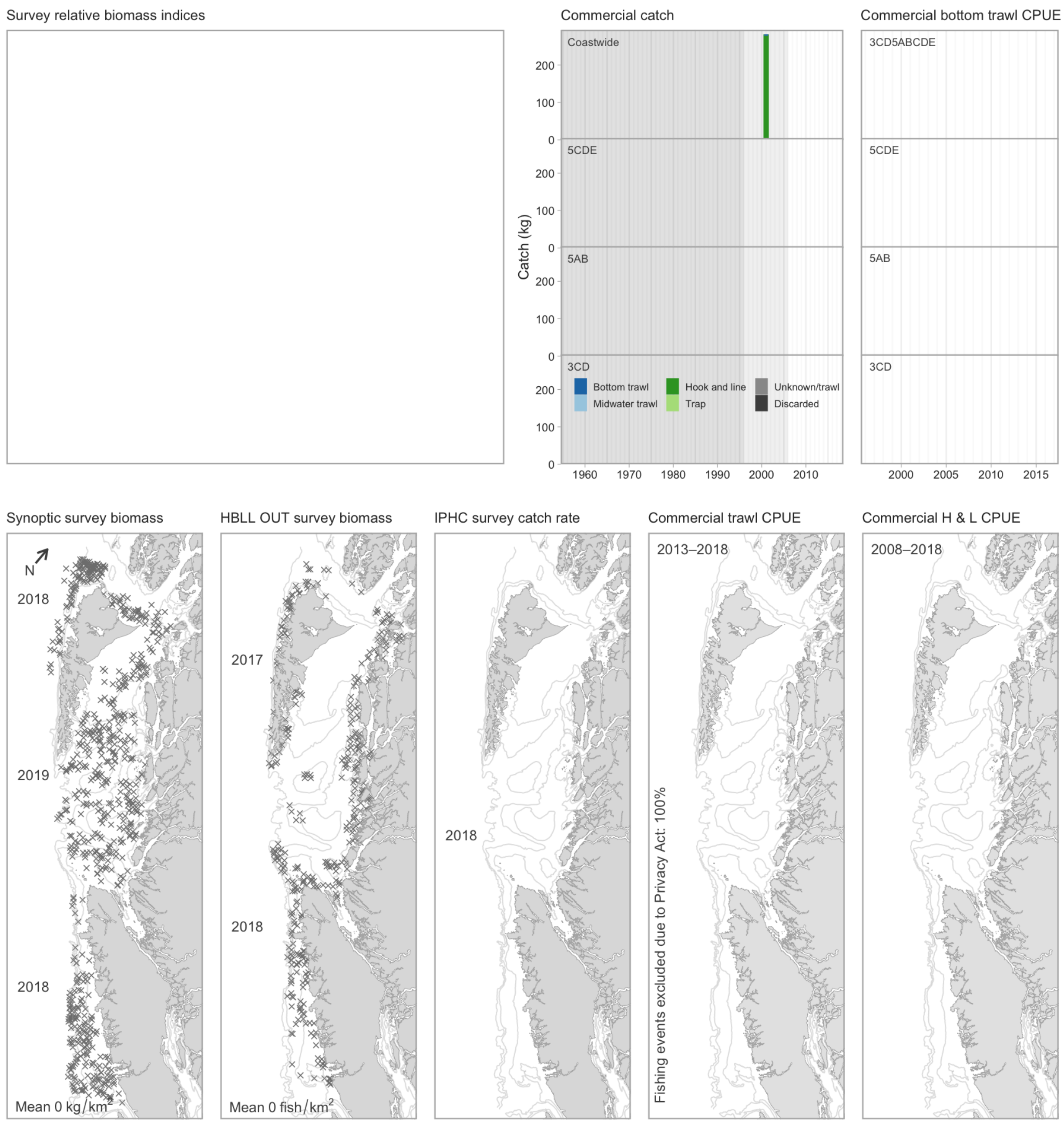


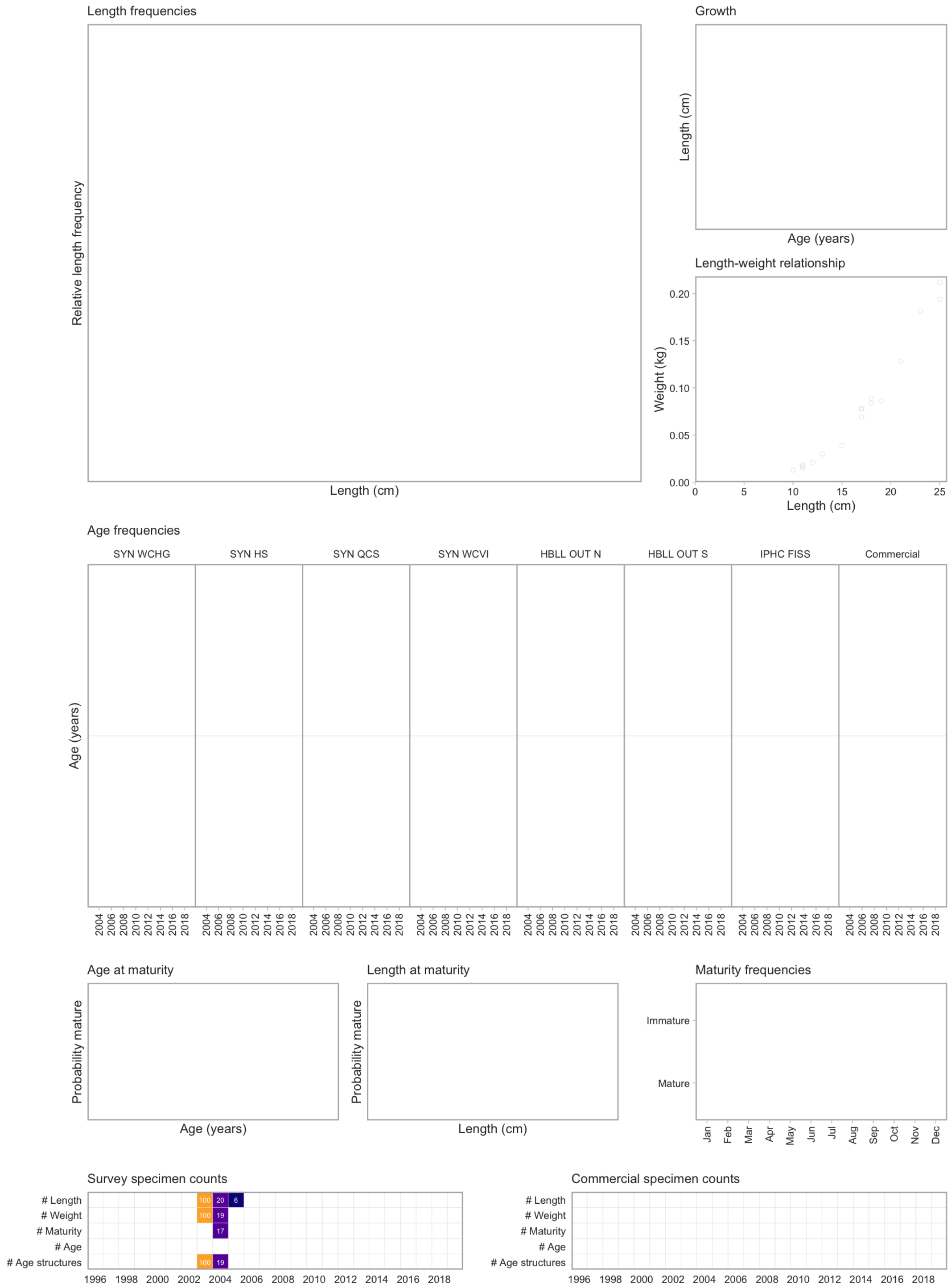


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.61
b = 3.11
Males
ln(a) = -11.71
b = 3.14
Weight (kg)
Sex
F
M
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Mature
Embryos
Running Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.80 WHITESPOTTED GREENLING

Hexagrammos stelleri (466)
Order: Scorpaeniformes, Family: Hexagrammidae, FishBase, WoRMS

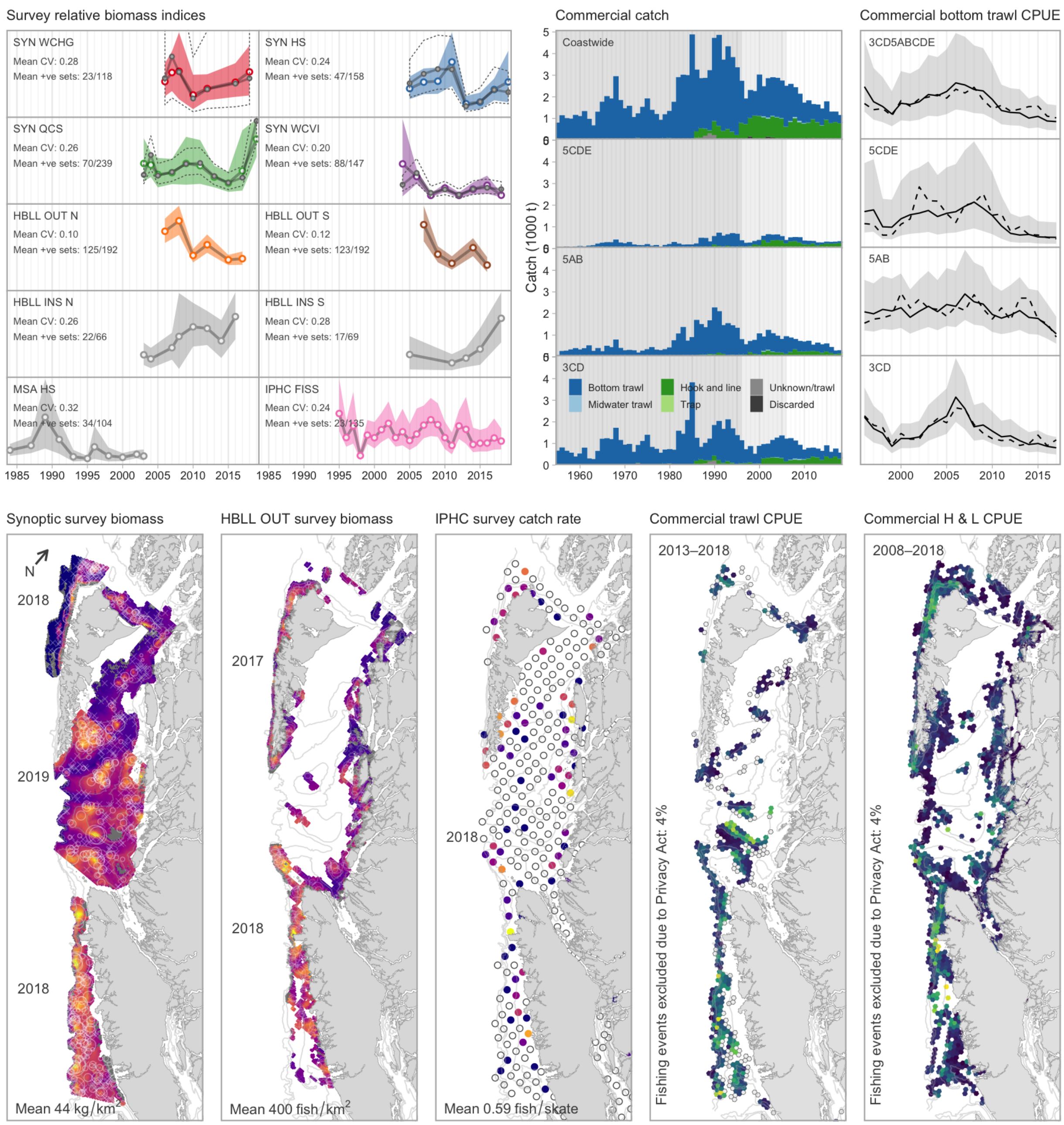


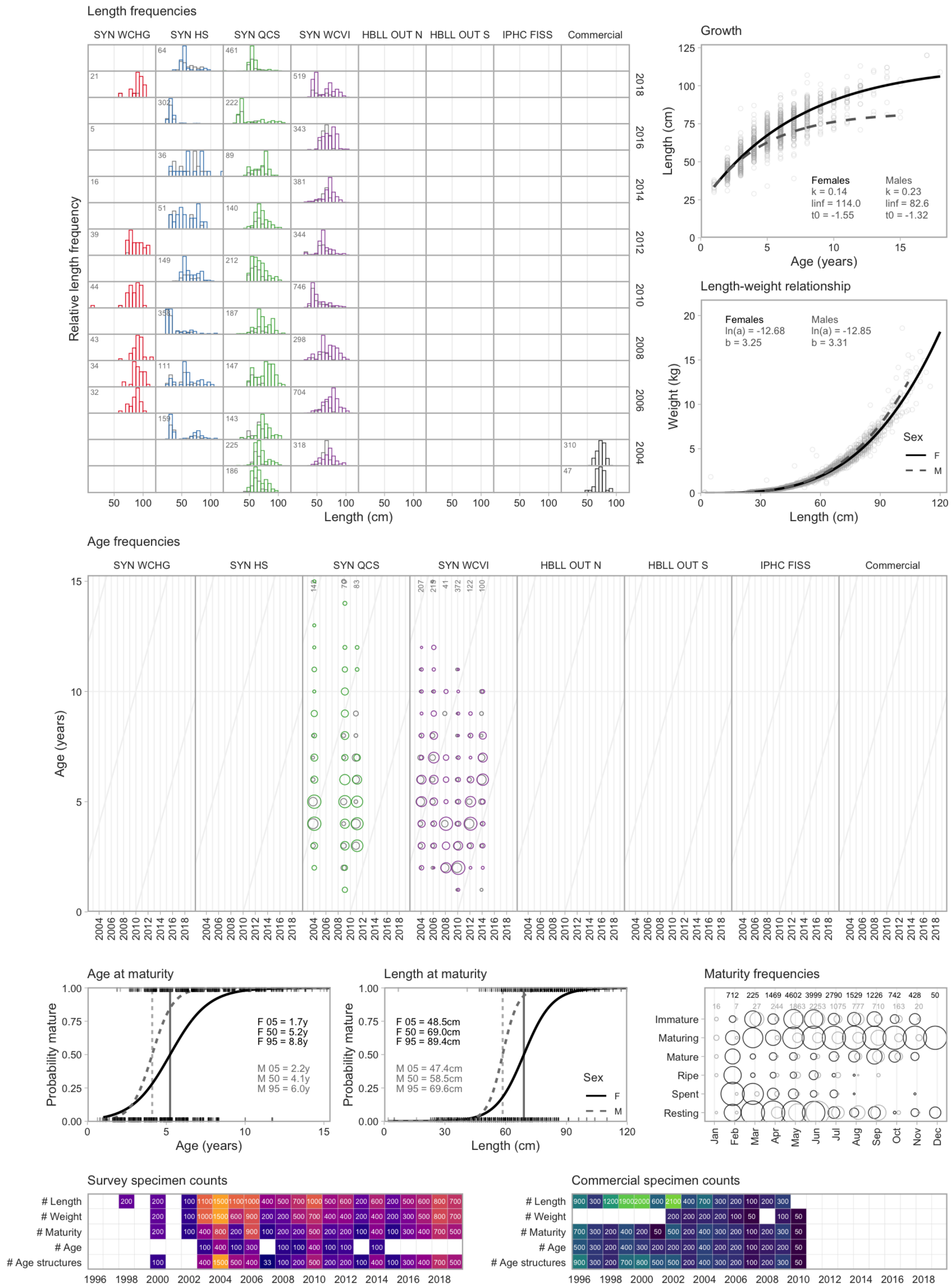


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Mature
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.81 LINGCOD

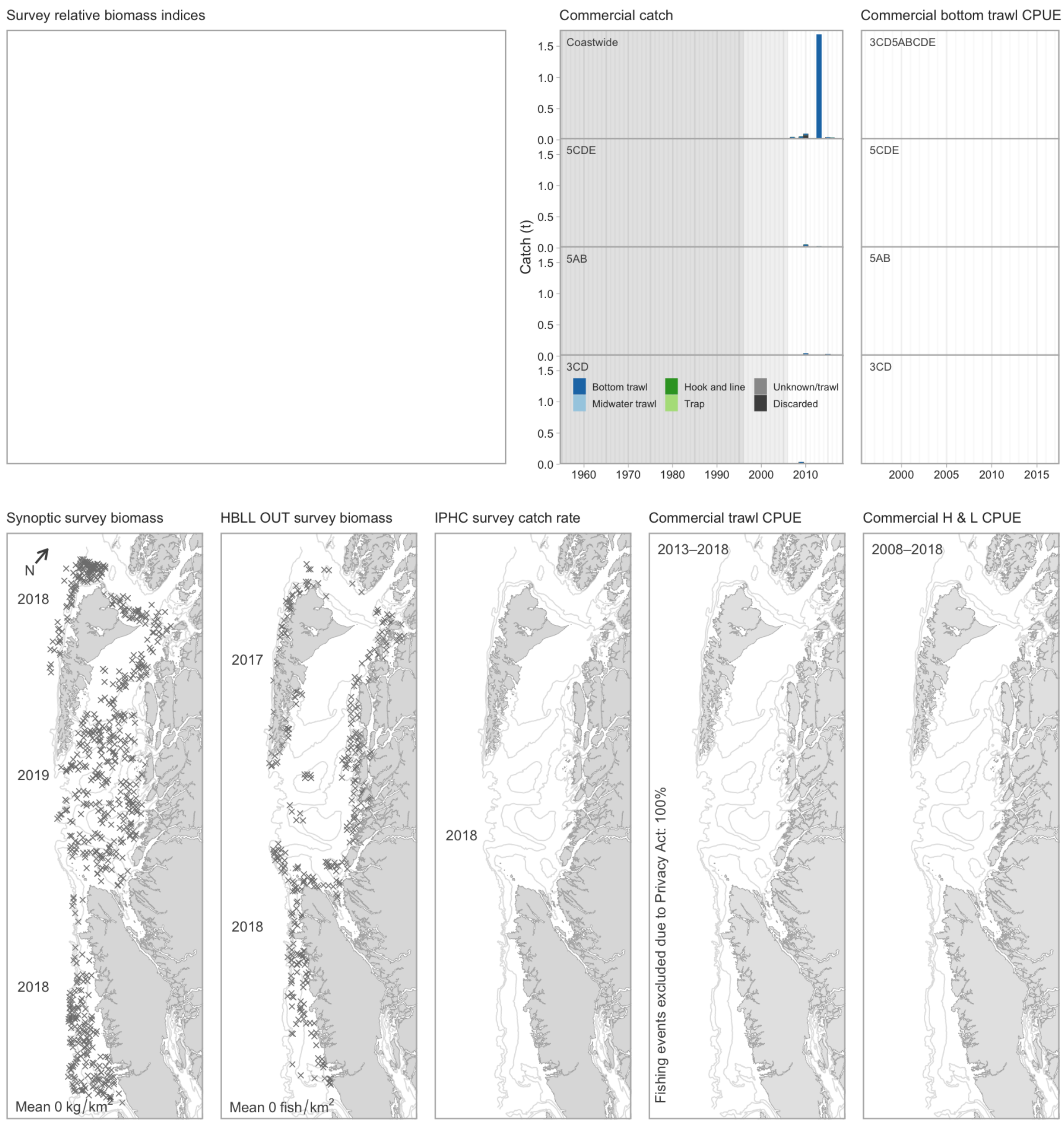
Ophiodon elongatus (467)
Order: Scorpaeniformes, Family: Hexagrammidae, FishBase, WoRMS
Last Research Documents: King et al. (2011), Holt et al. (2016a)
Last Science Advisory Reports: DFO (2011e), DFO (2015c)

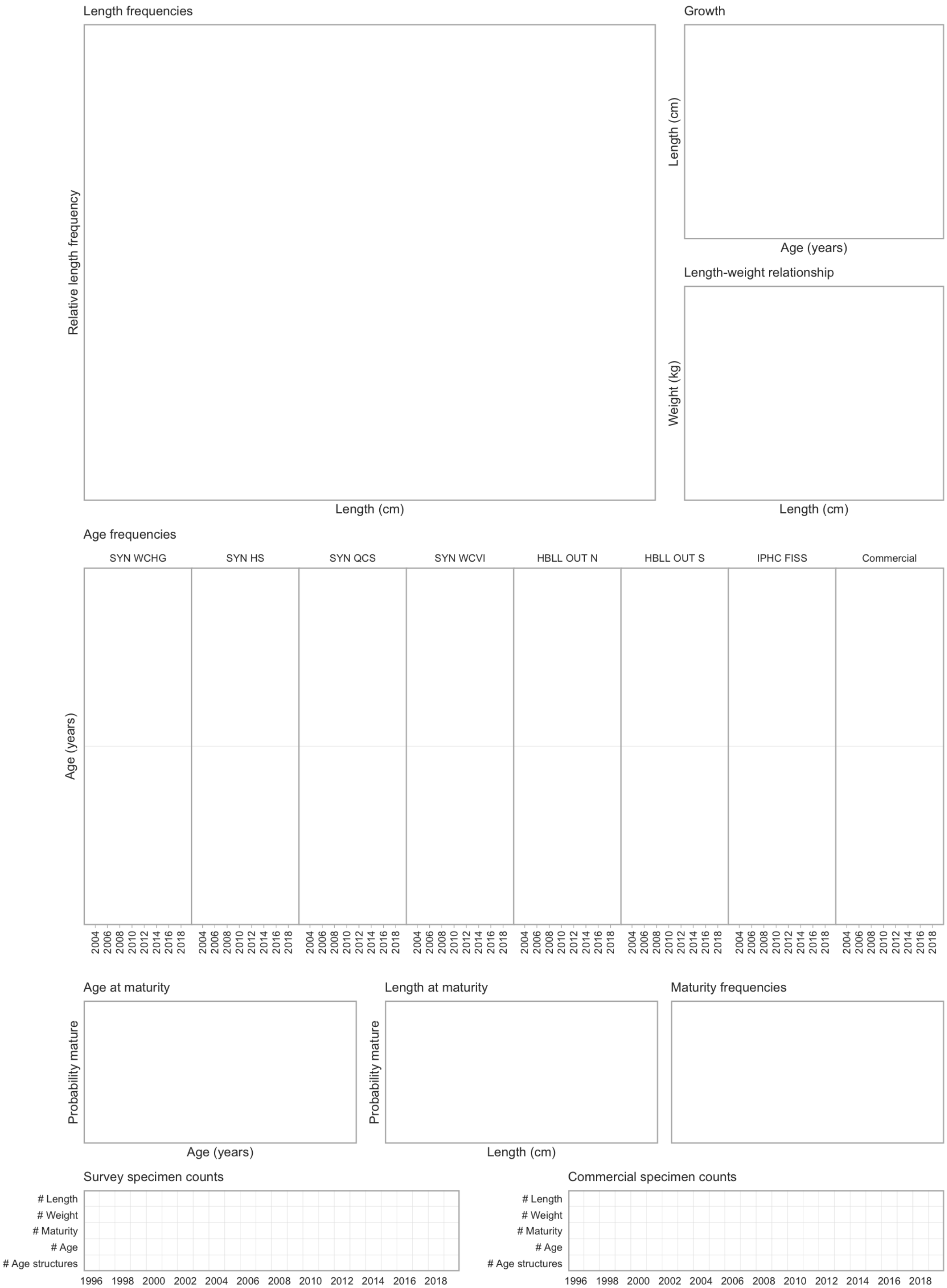



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.14
linf = 114.0
t0 = -1.55
Males
k = 0.23
linf = 82.6
t0 = -1.32
Length-weight relationship
Females
ln(a) = -12.68
b = 3.25
Males
ln(a) = -12.85
b = 3.31
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 1.7y
F 50 = 5.2y
F 95 = 8.8y
M 05 = 2.2y
M 50 = 4.1y
M 95 = 6.0y
Length at maturity
Length (cm)
F 05 = 48.5cm
F 50 = 69.0cm
F 95 = 89.4cm
M 05 = 47.4cm
M 50 = 58.5cm
M 95 = 69.6cm
Maturity frequencies
Immature
Maturing
Mature
Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.82 SPINYHEAD SCULPIN

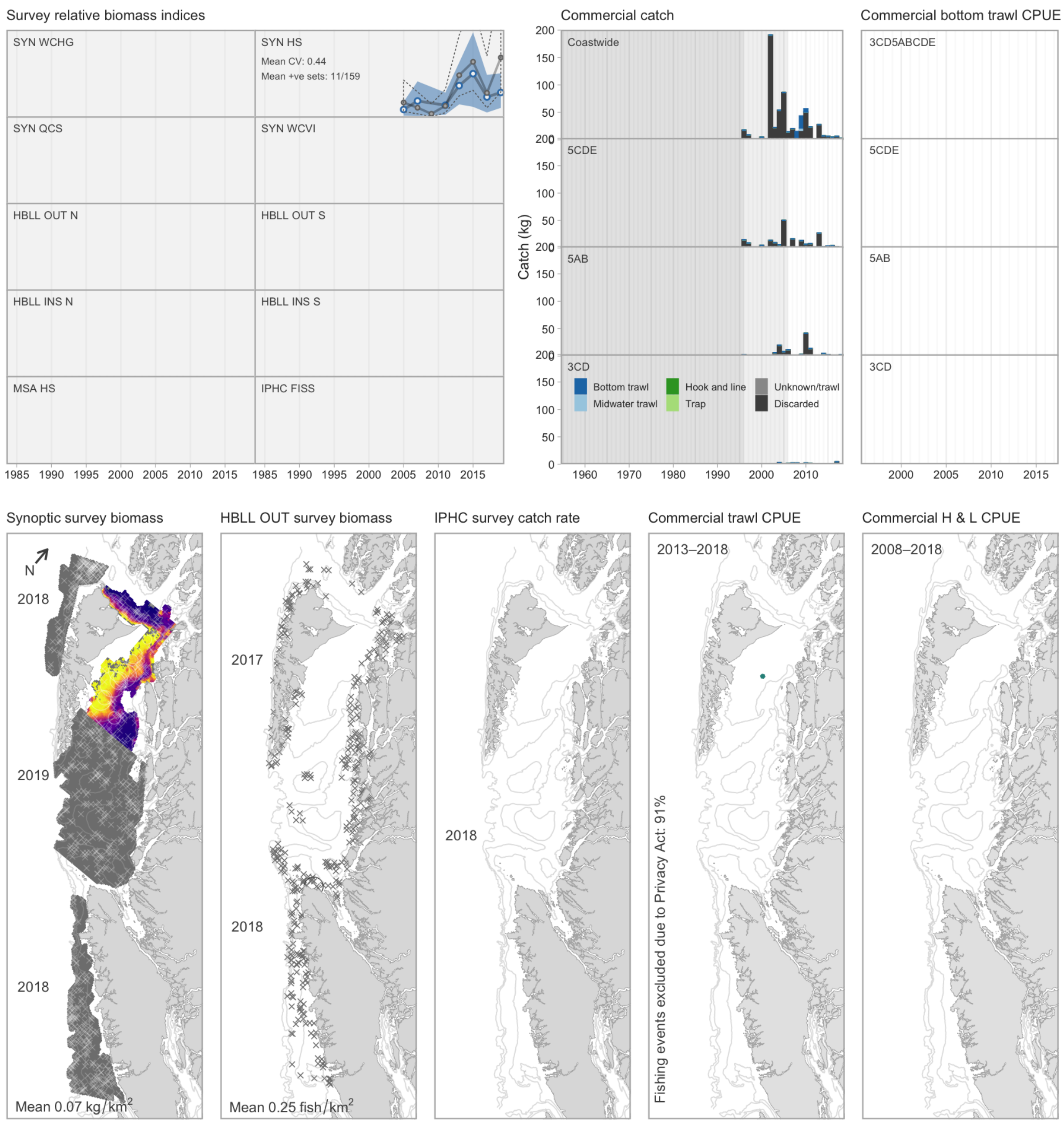
Dasycottus setiger (497)
Order: Scorpaeniformes, Family: Psychrolutidae, FishBase, WoRMS

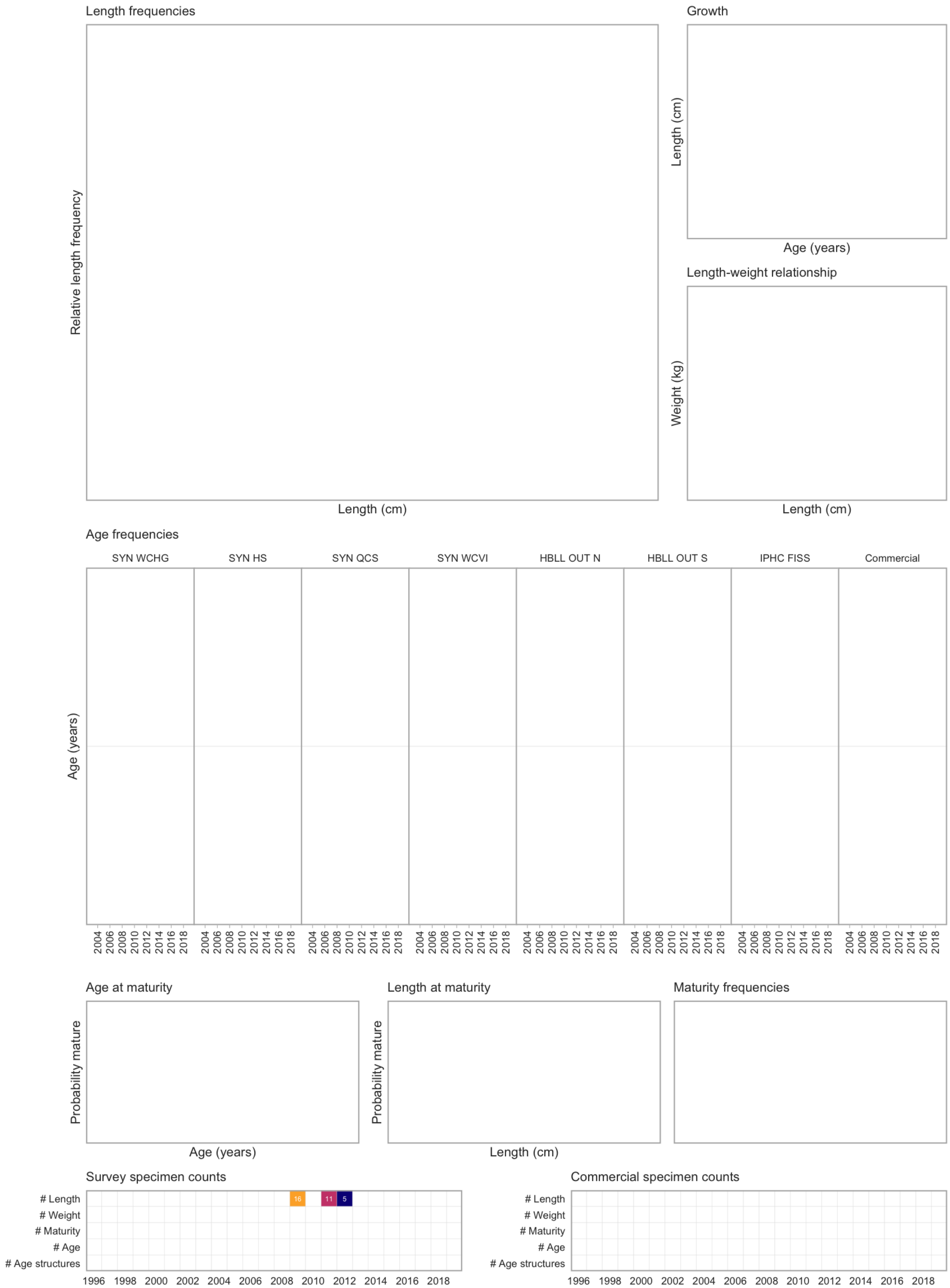



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.83 BUFFALO SCULPIN

Enophrys bison (499)
Order: Scorpaeniformes, Family: Cottidae, FishBase, WoRMS

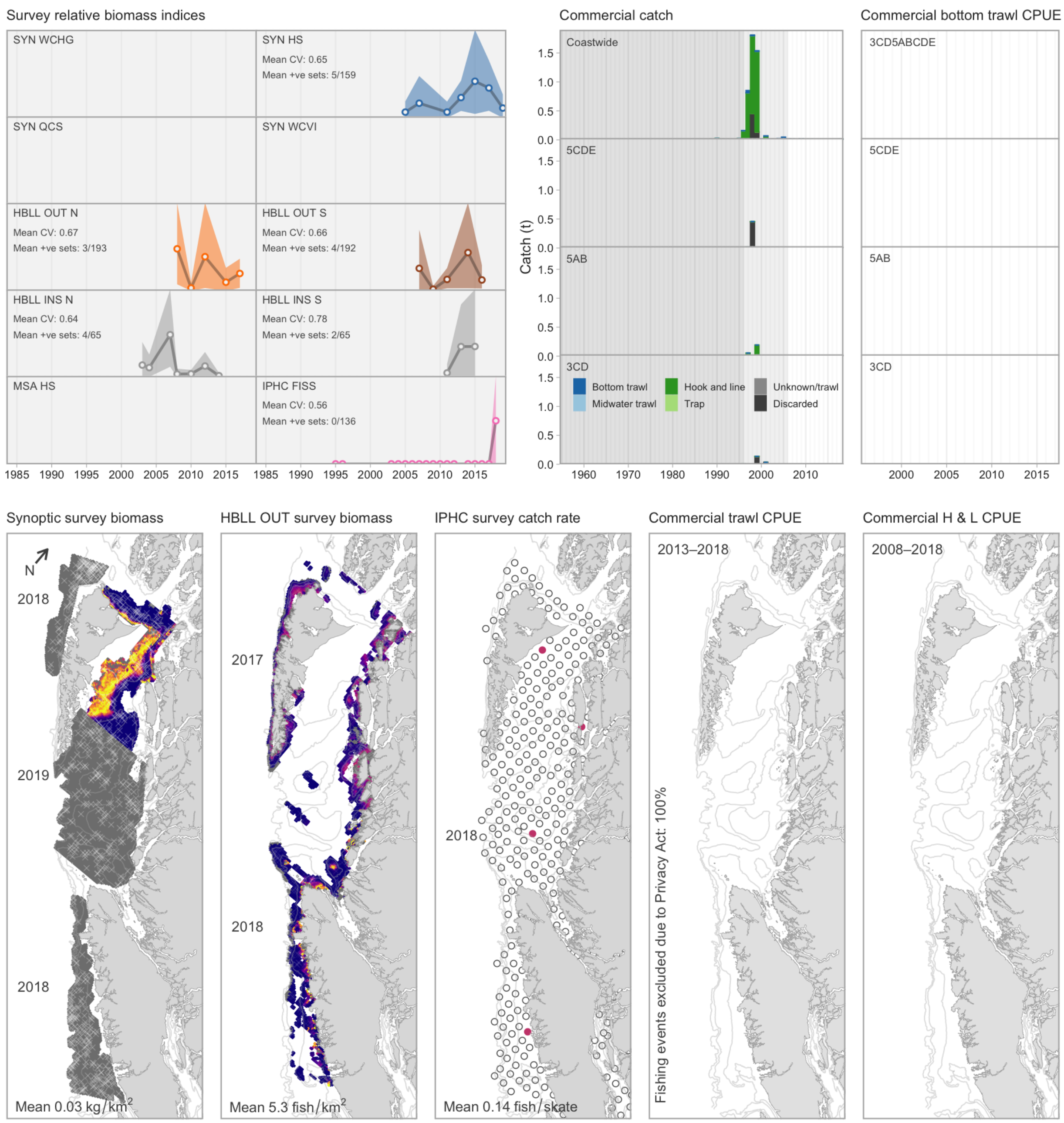


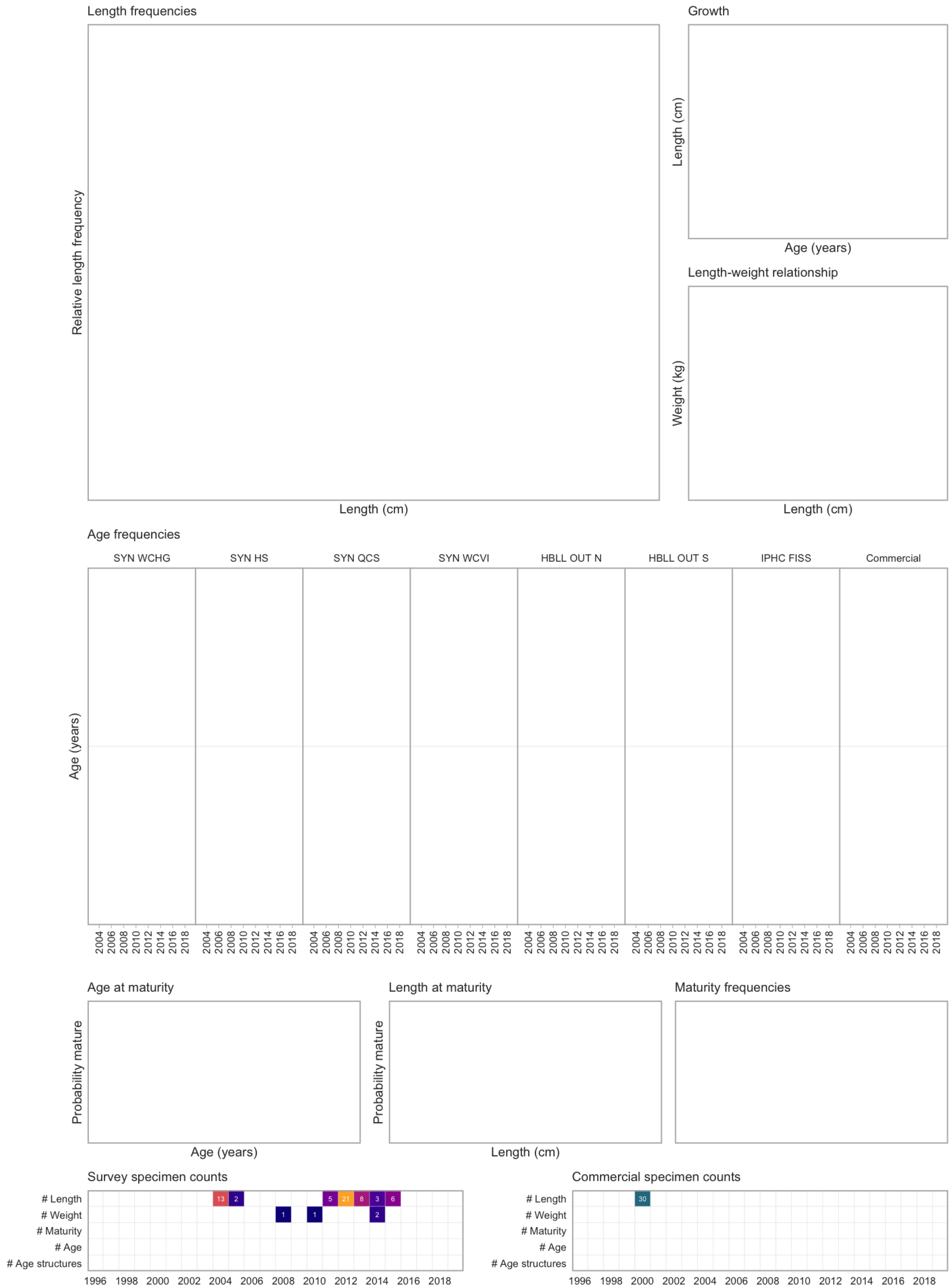


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
16
11
5
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.84 RED IRISH LORD

Hemilepidotus hemilepidotus (502)
Order: Scorpaeniformes, Family: Cottidae, FishBase, WoRMS

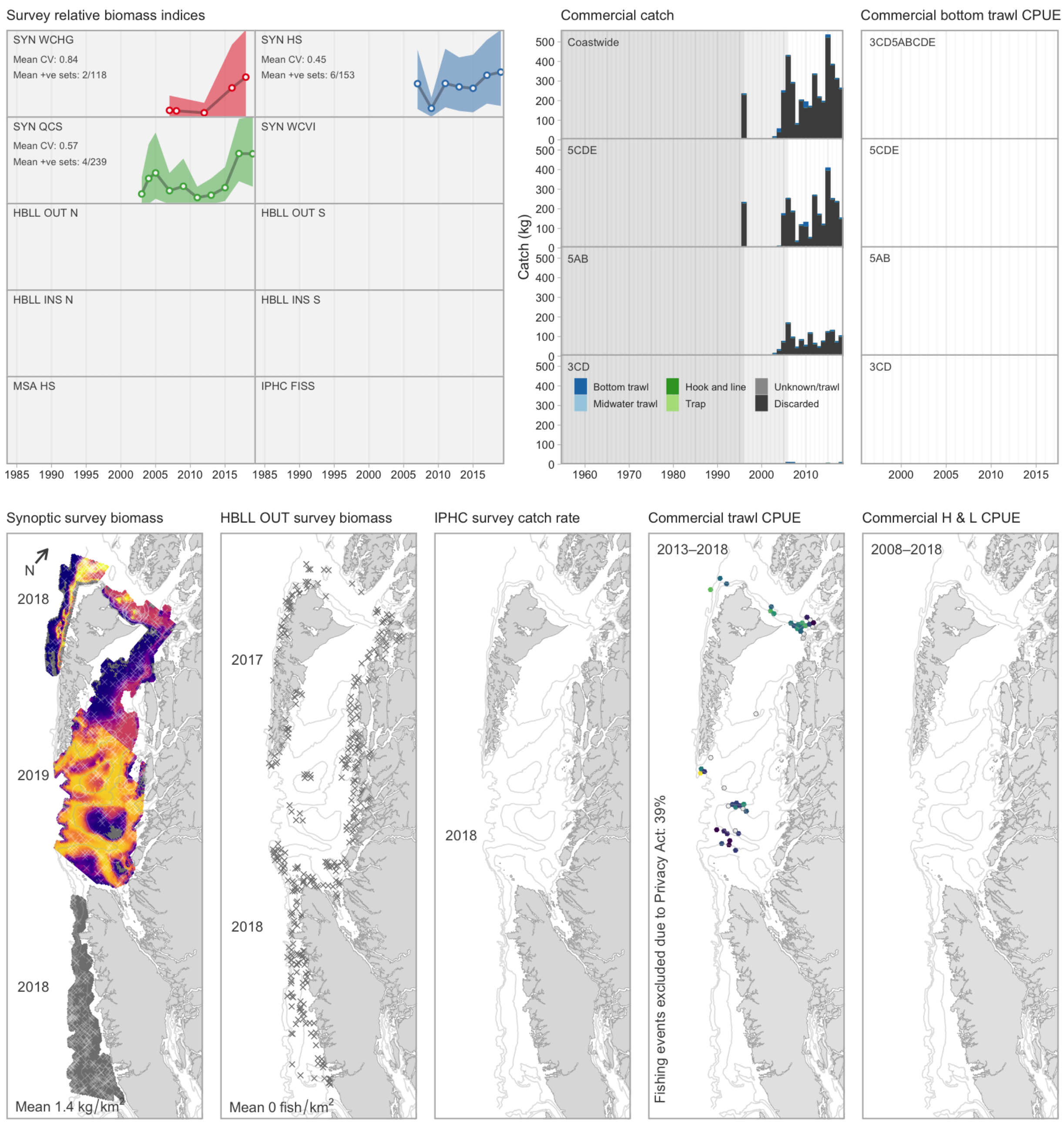


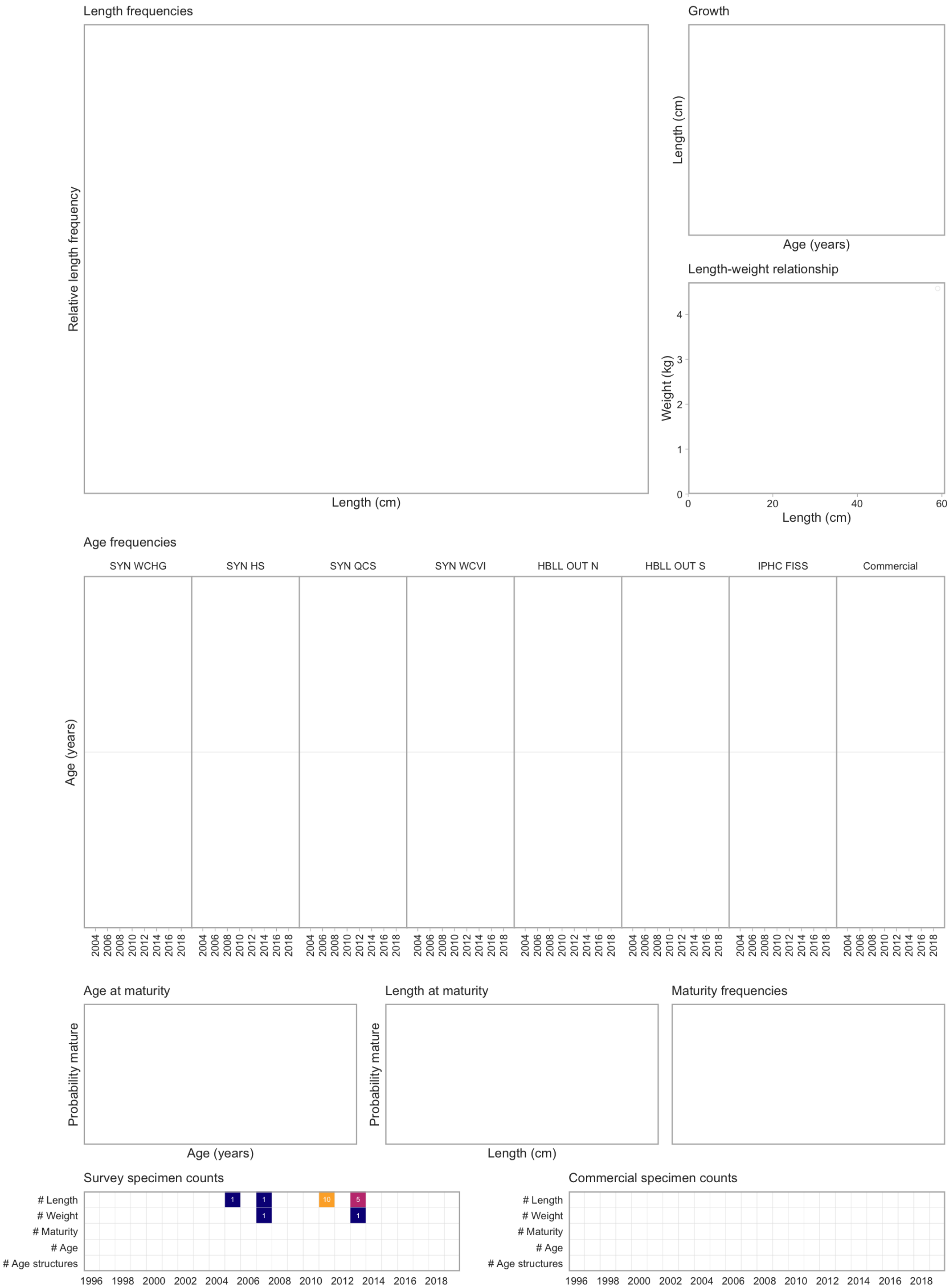


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004
2006
2008
2010
2012
2014
2016
2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
13
2
5
21
8
3
6
1
1
2
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
30
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

5.85 BIGMOUTH SCULPIN

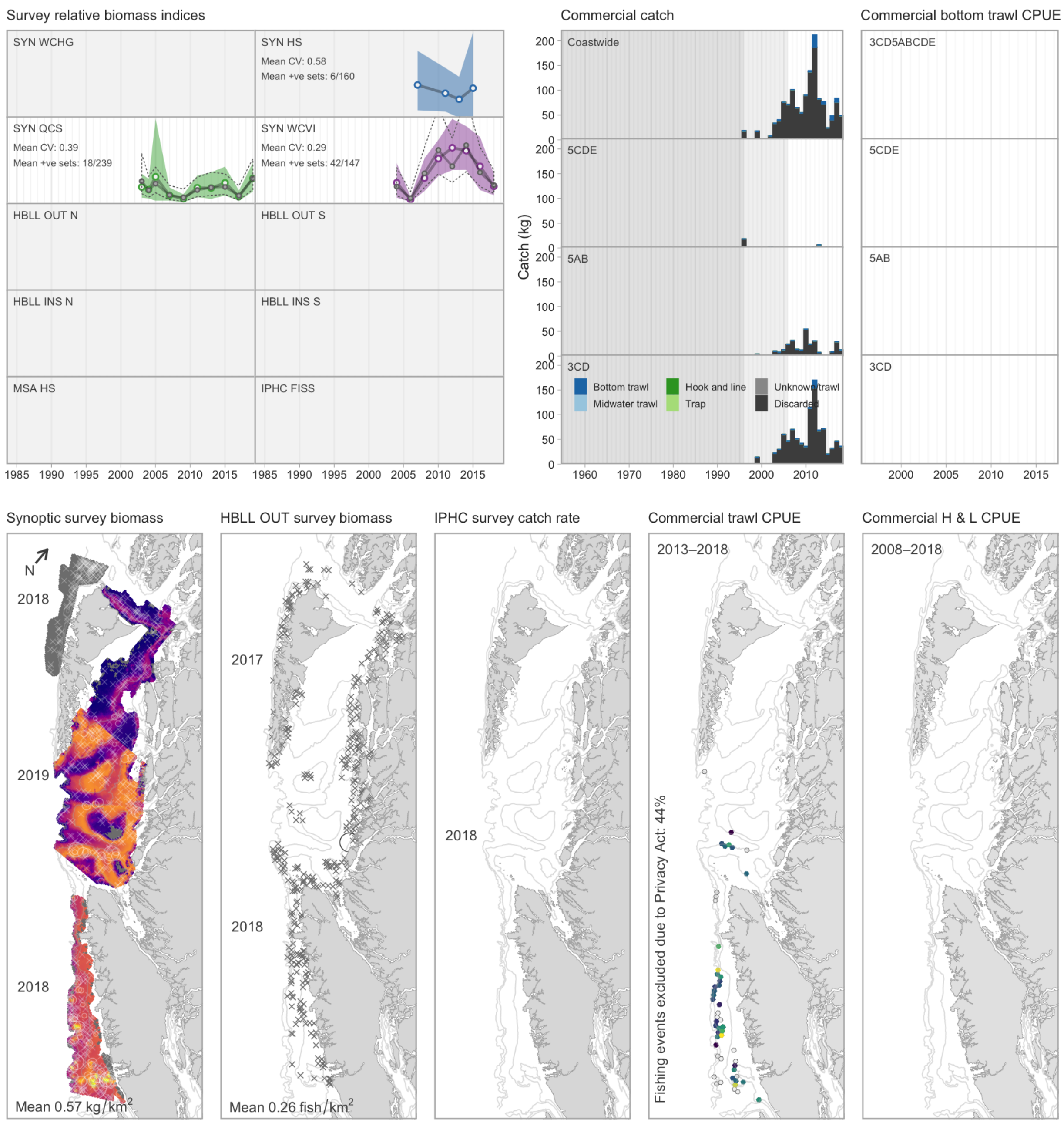
Hemitripterus bolini (505)
Order: Scorpaeniformes, Family: Hemitripteridae, FishBase, WoRMS

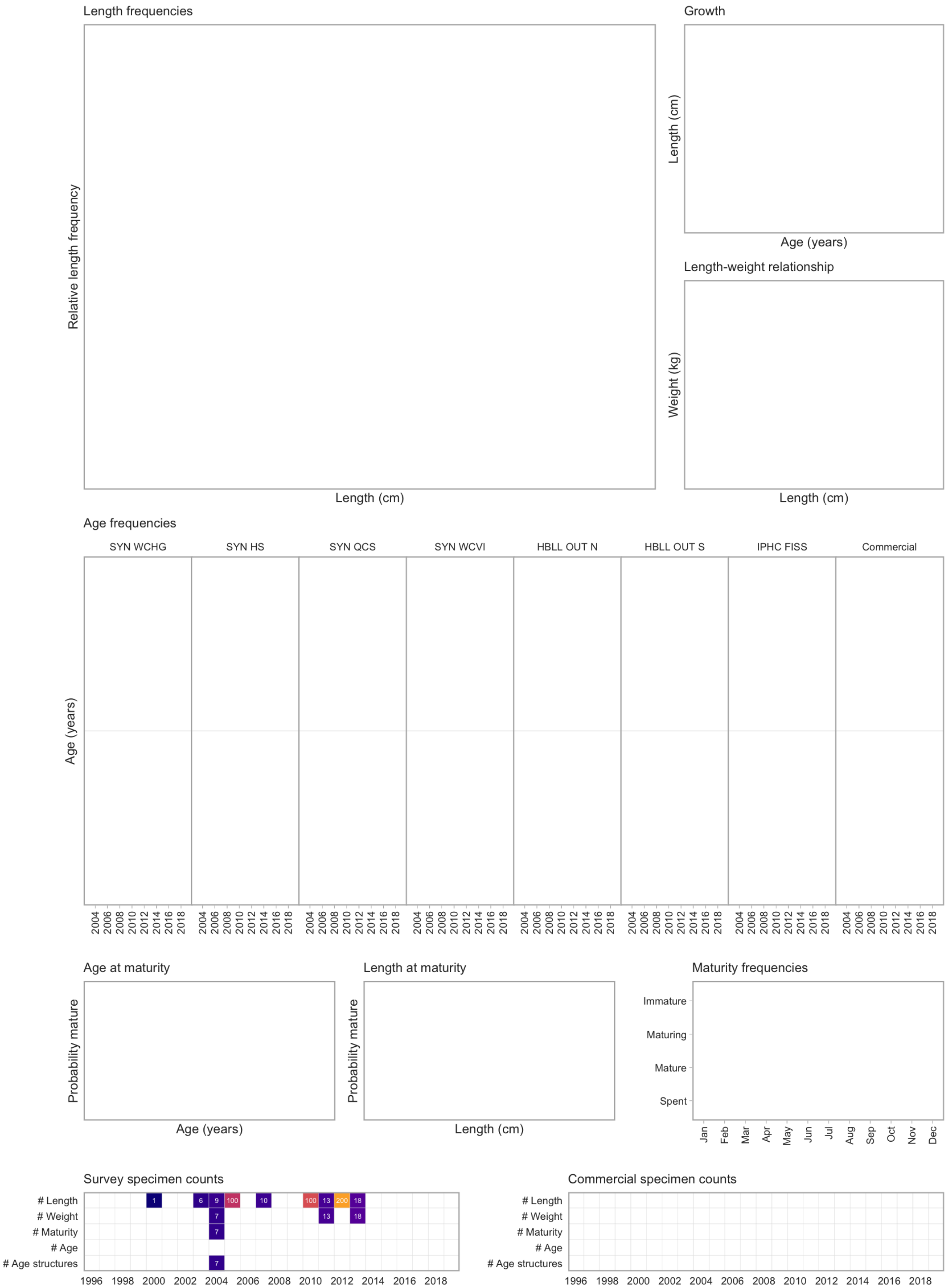



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.86 THREADFIN SCULPIN

Icelinus filamentosus (510)
Order: Scorpaeniformes, Family: Cottidae, FishBase, WoRMS

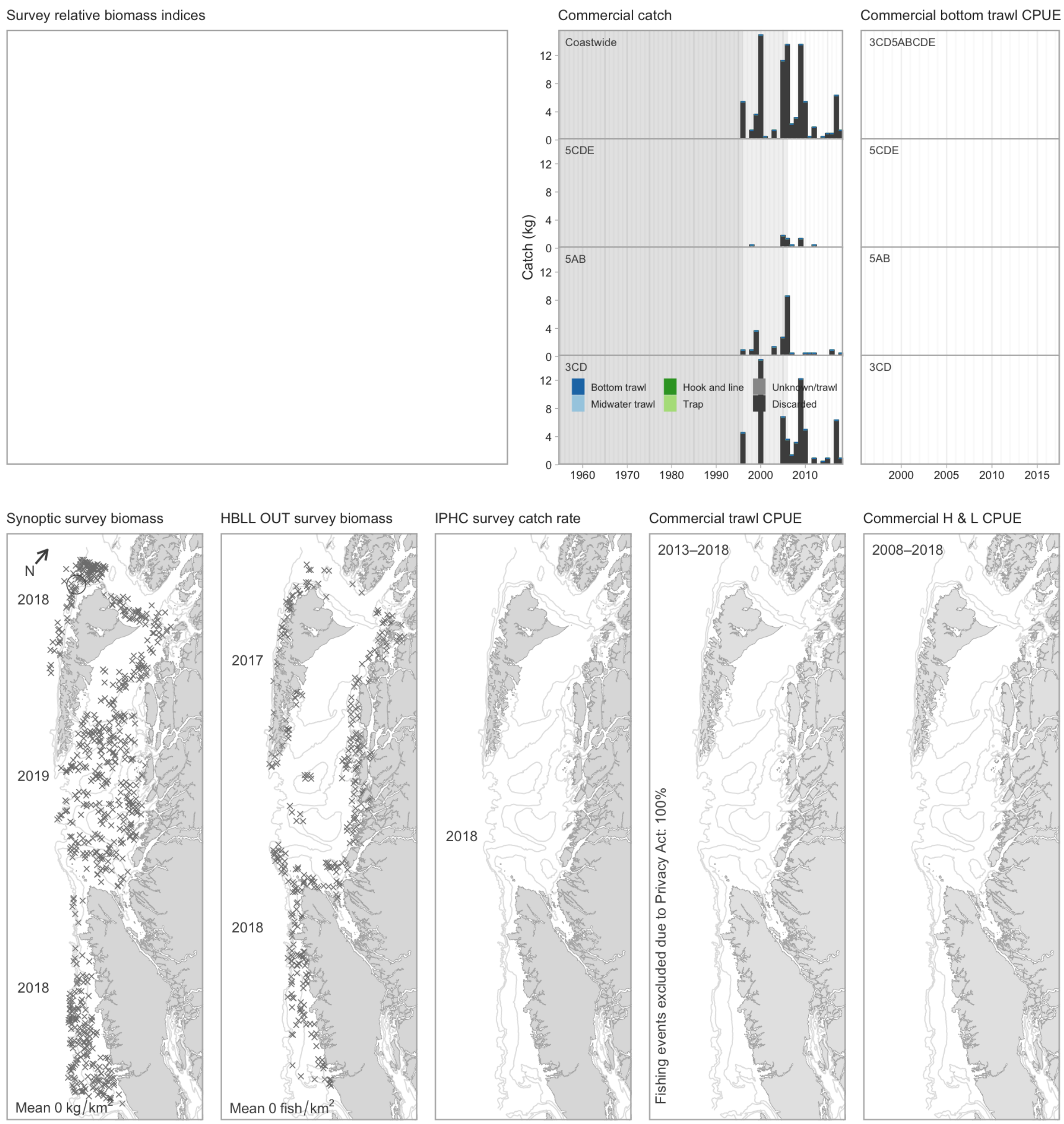


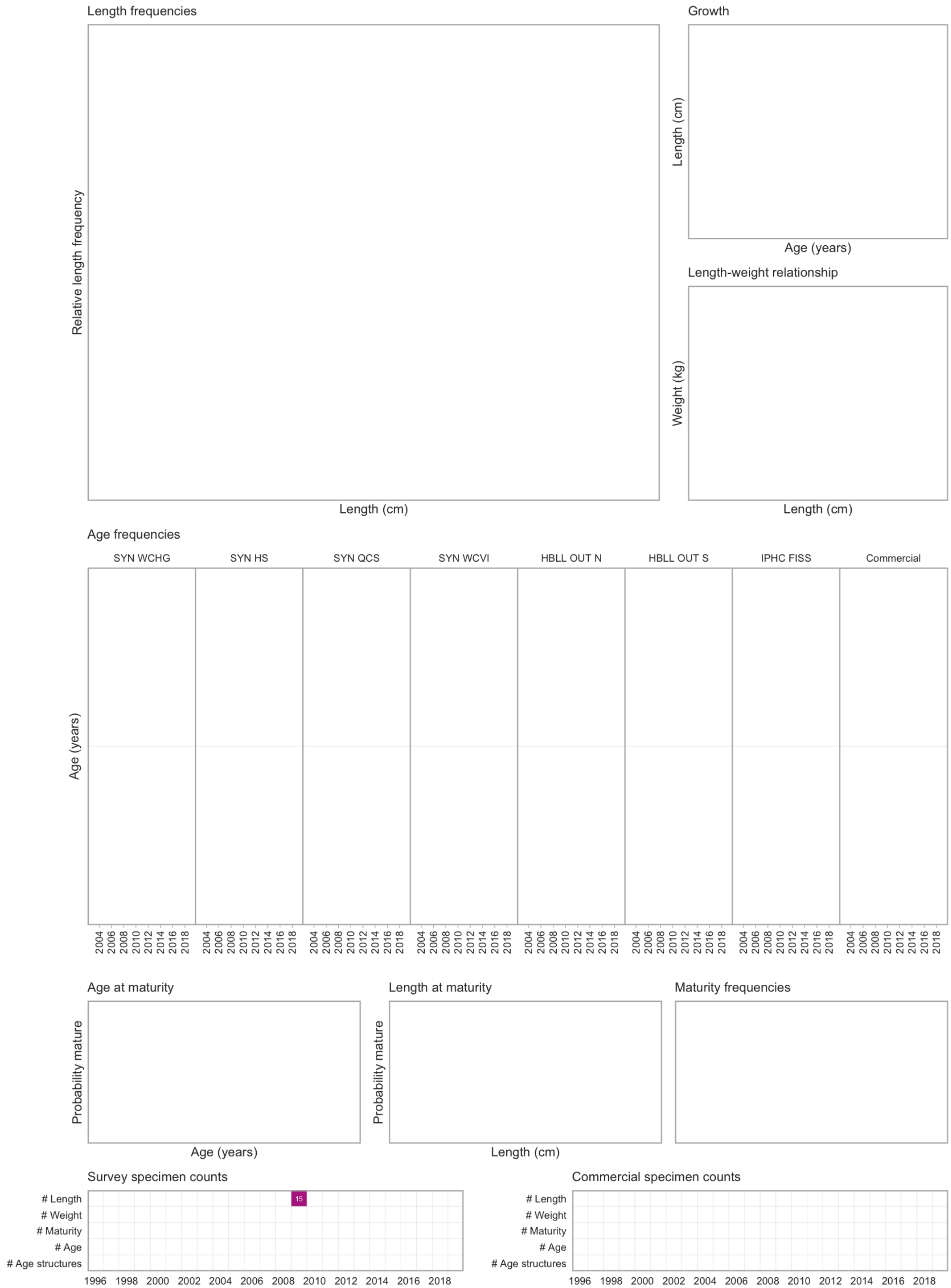


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Spent
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1 6 9 100 10 100 13 200 18
7 13 18
7
7
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.87 SPOTFIN SCULPIN

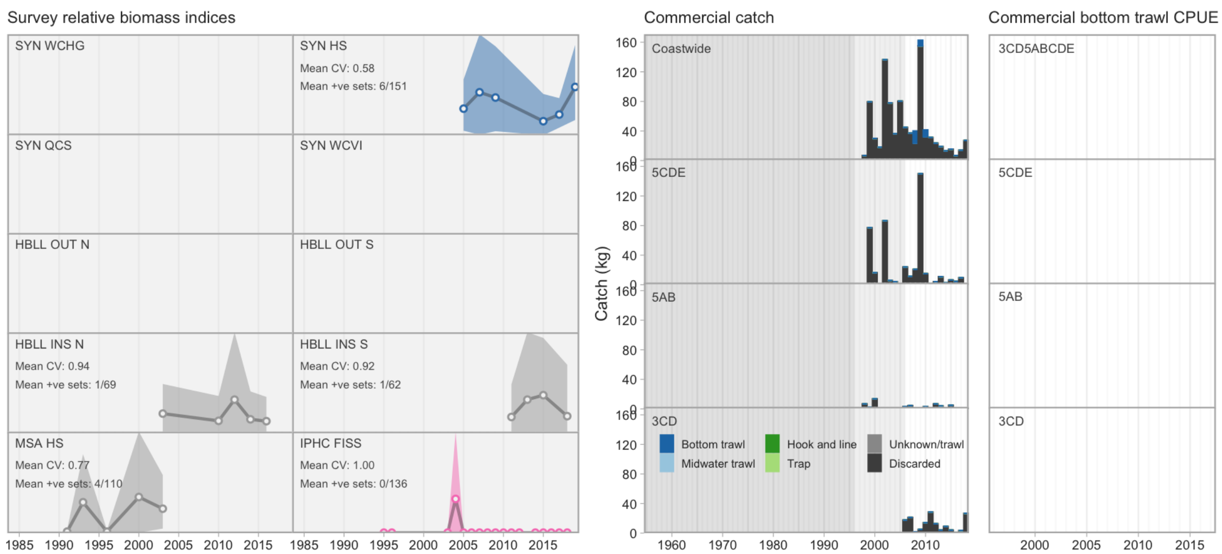
Icelinus tenuis (513)
Order: Scorpaeniformes, Family: Cottidae, FishBase, WoRMS

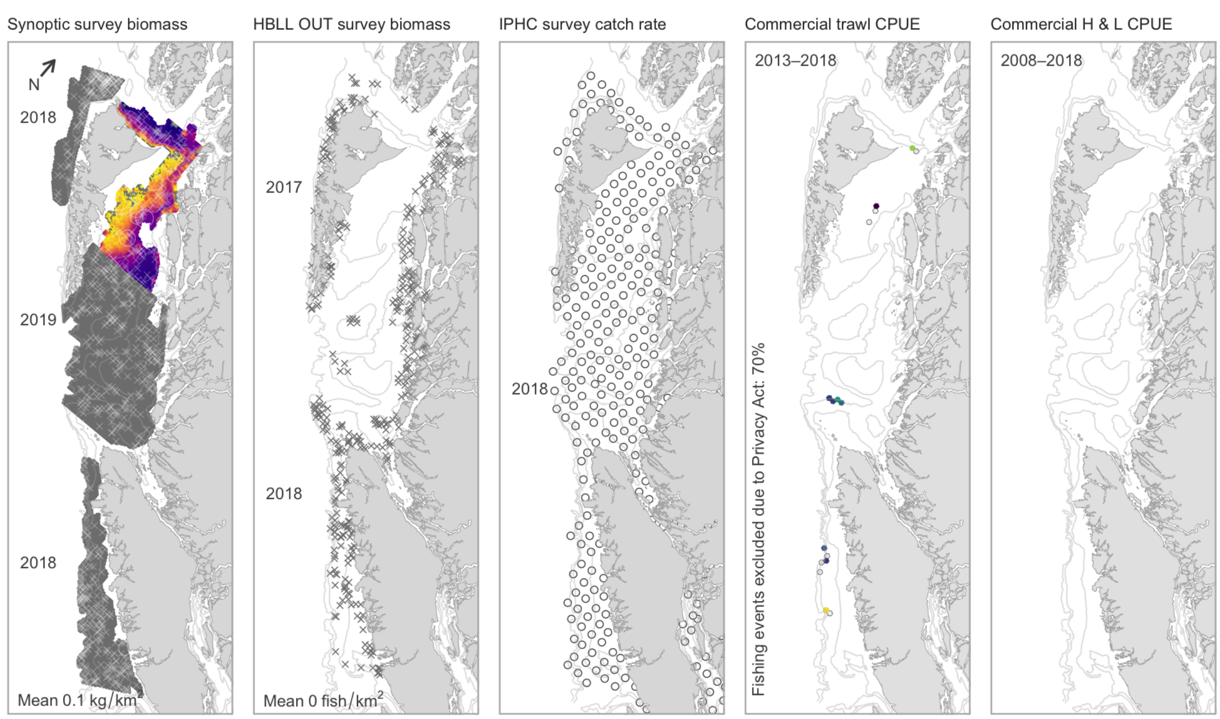


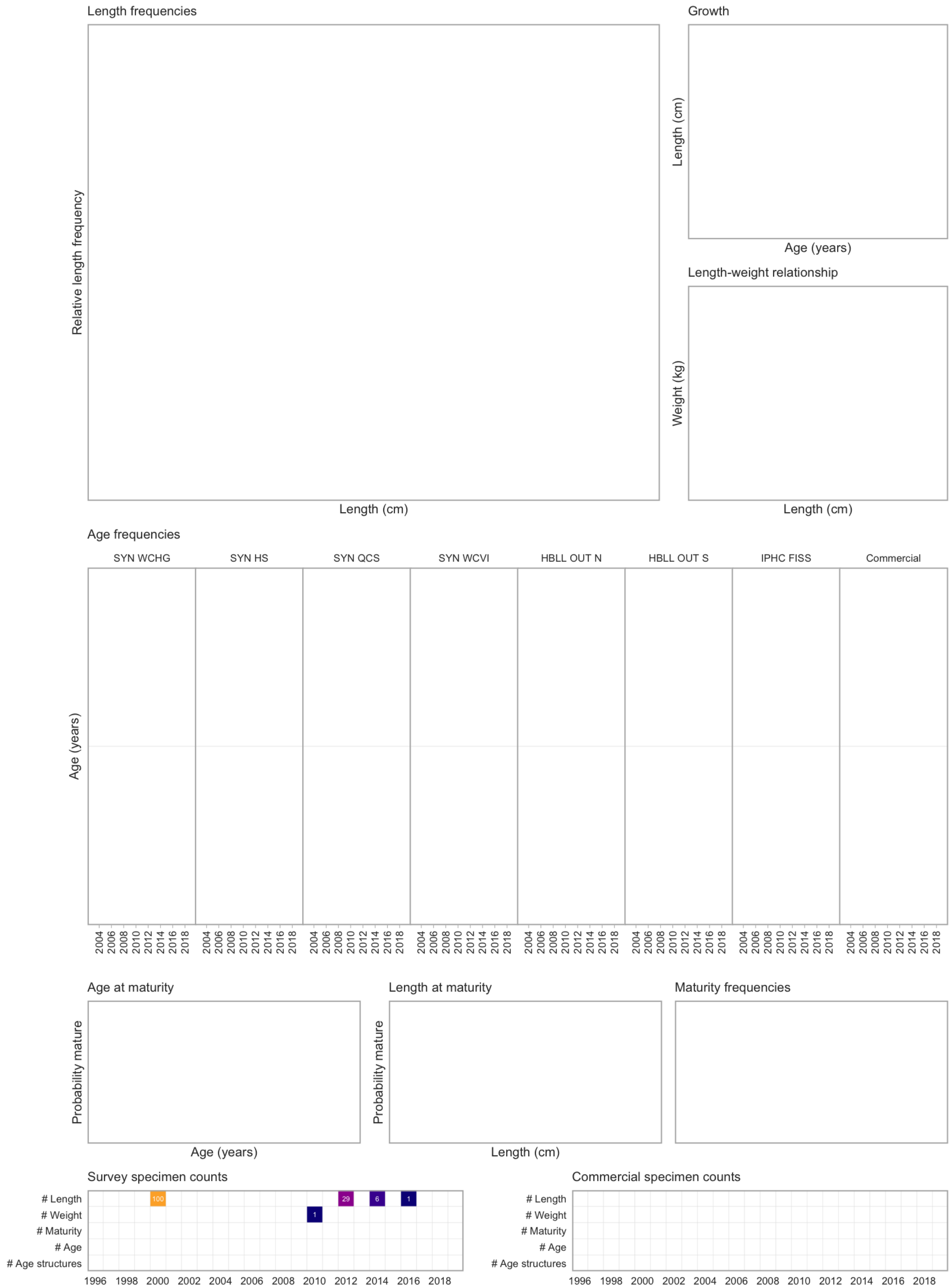

Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
15
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.88 PACIFIC STAGHORN SCULPIN

Leptocottus armatus (518)
Order: Scorpaeniformes, Family: Cottidae, FishBase, WoRMS



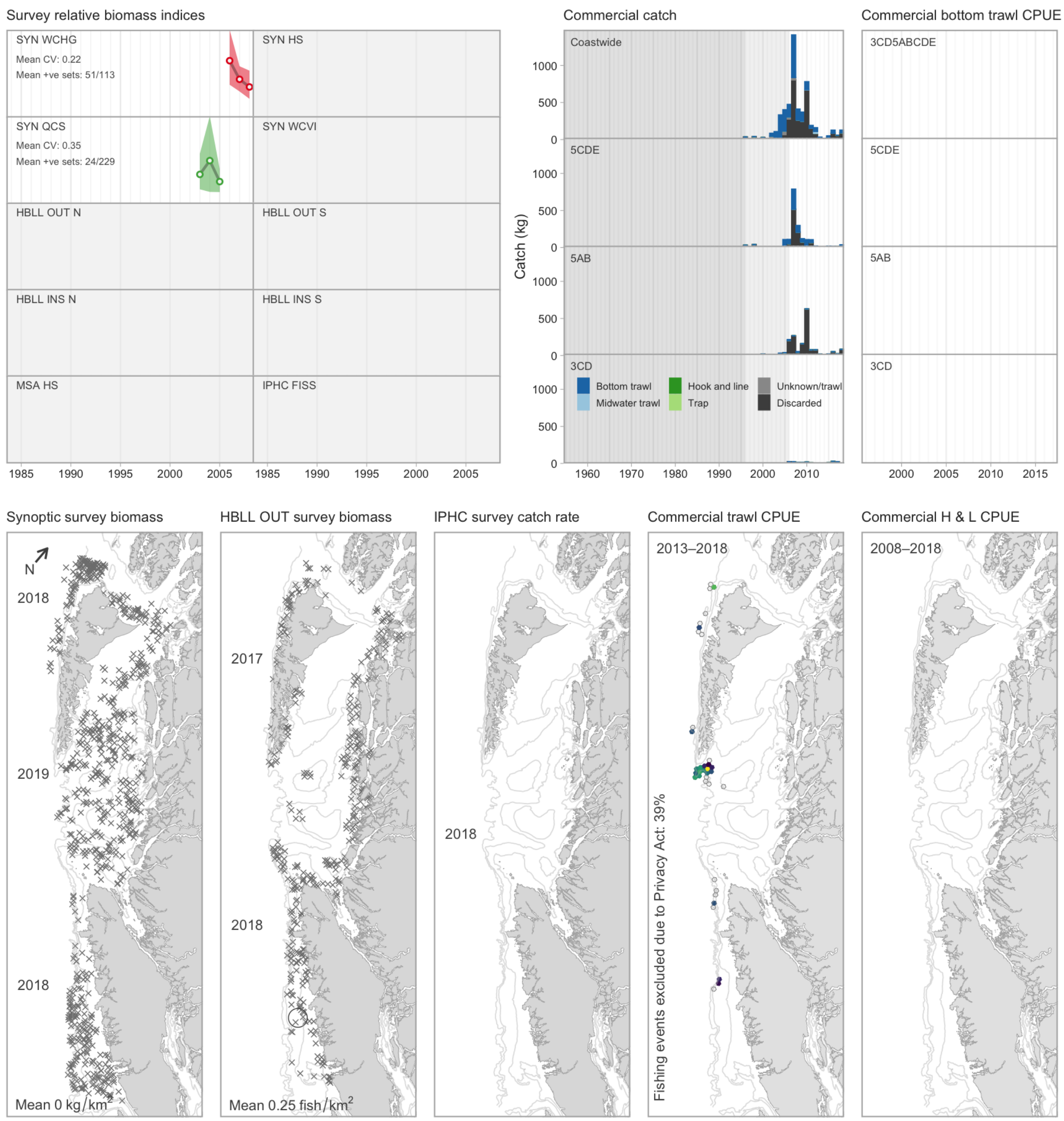


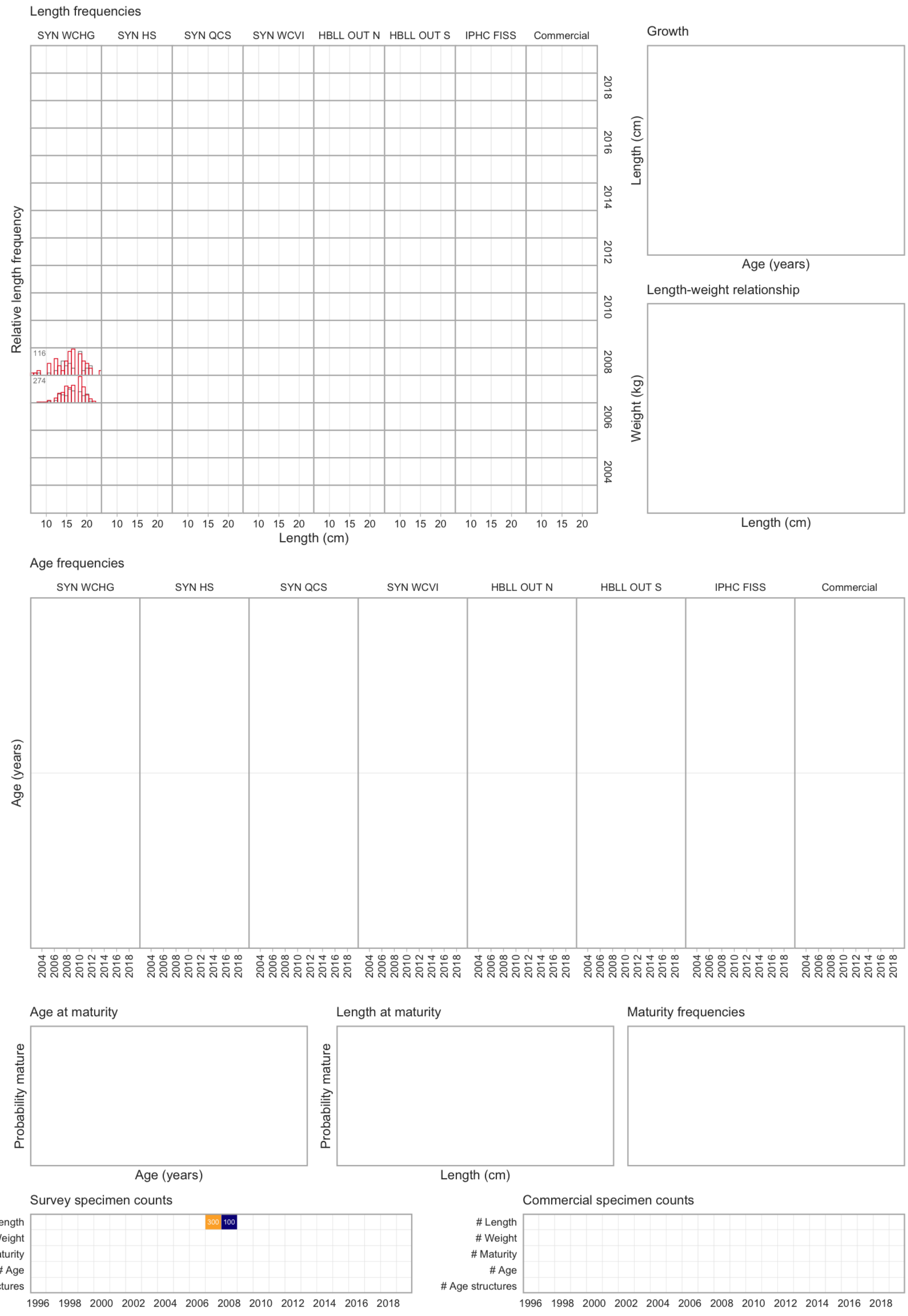


Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
100
29
6
1
1
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.89 BLACKFIN SCULPIN

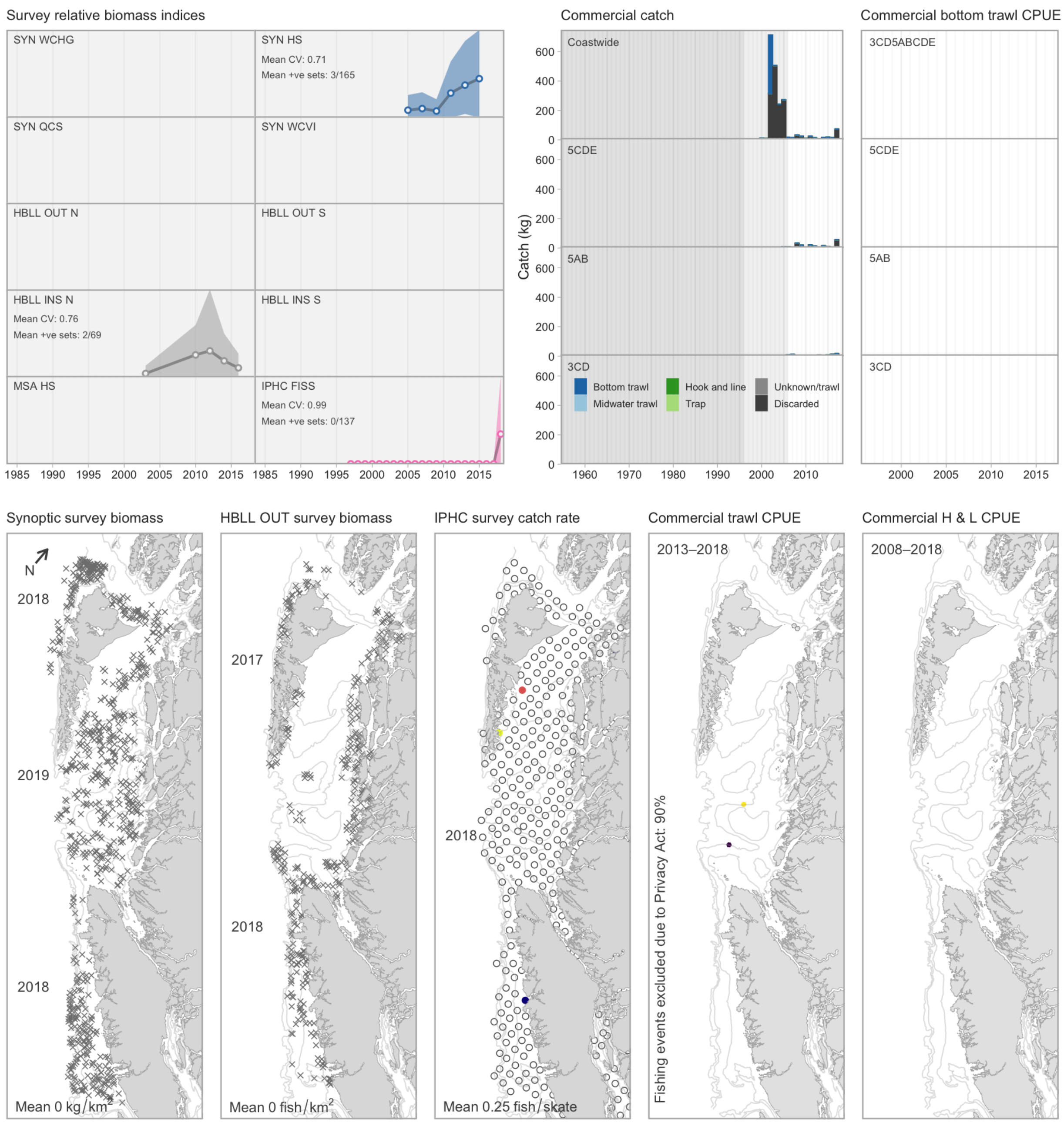
Malacocottus kincaidi (519)
Order: Scorpaeniformes, Family: Psychrolutidae, FishBase, WoRMS

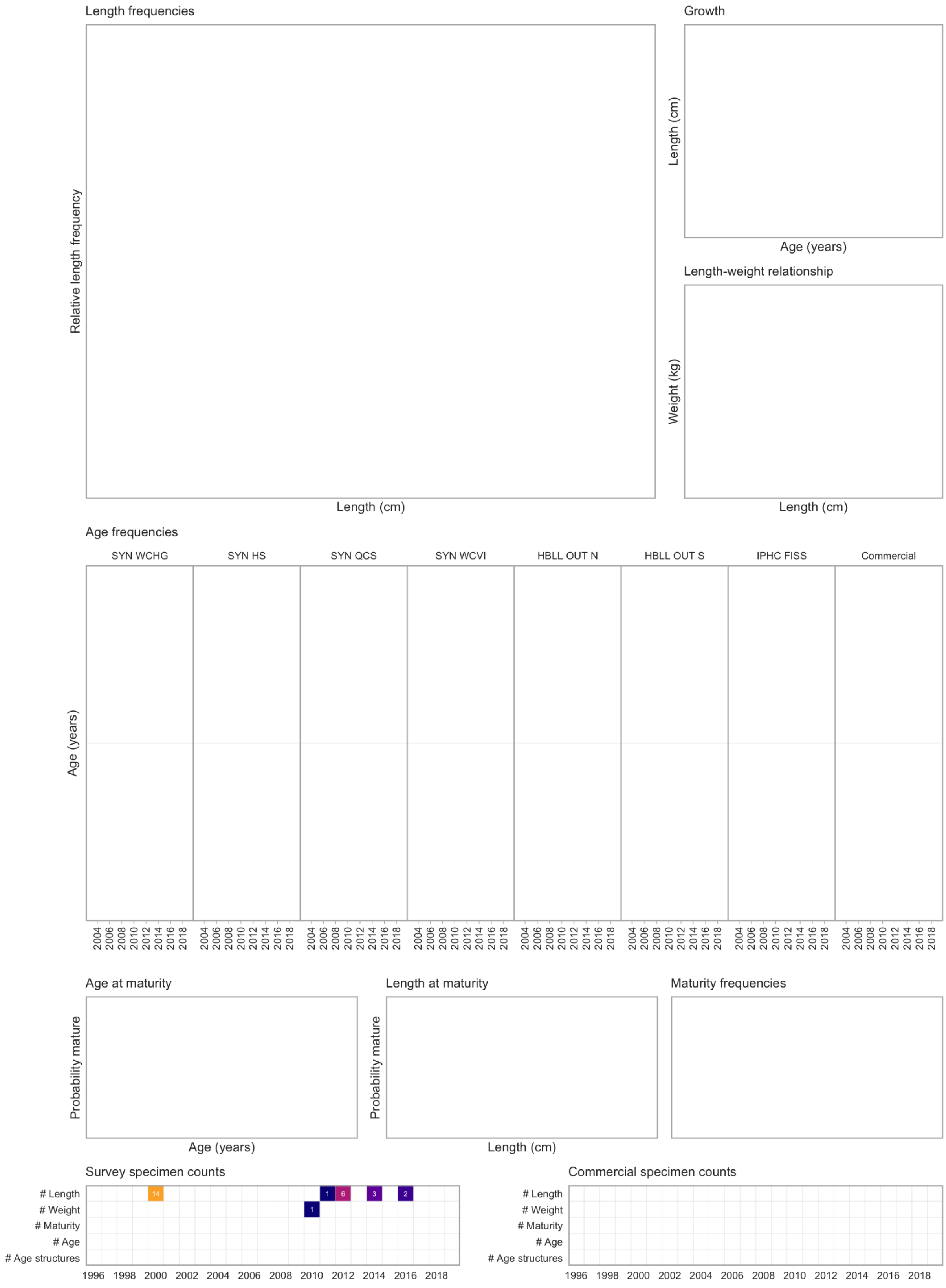



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
116
274
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Length at maturity
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
300
100
Commercial specimen counts

5.90 GREAT SCULPIN

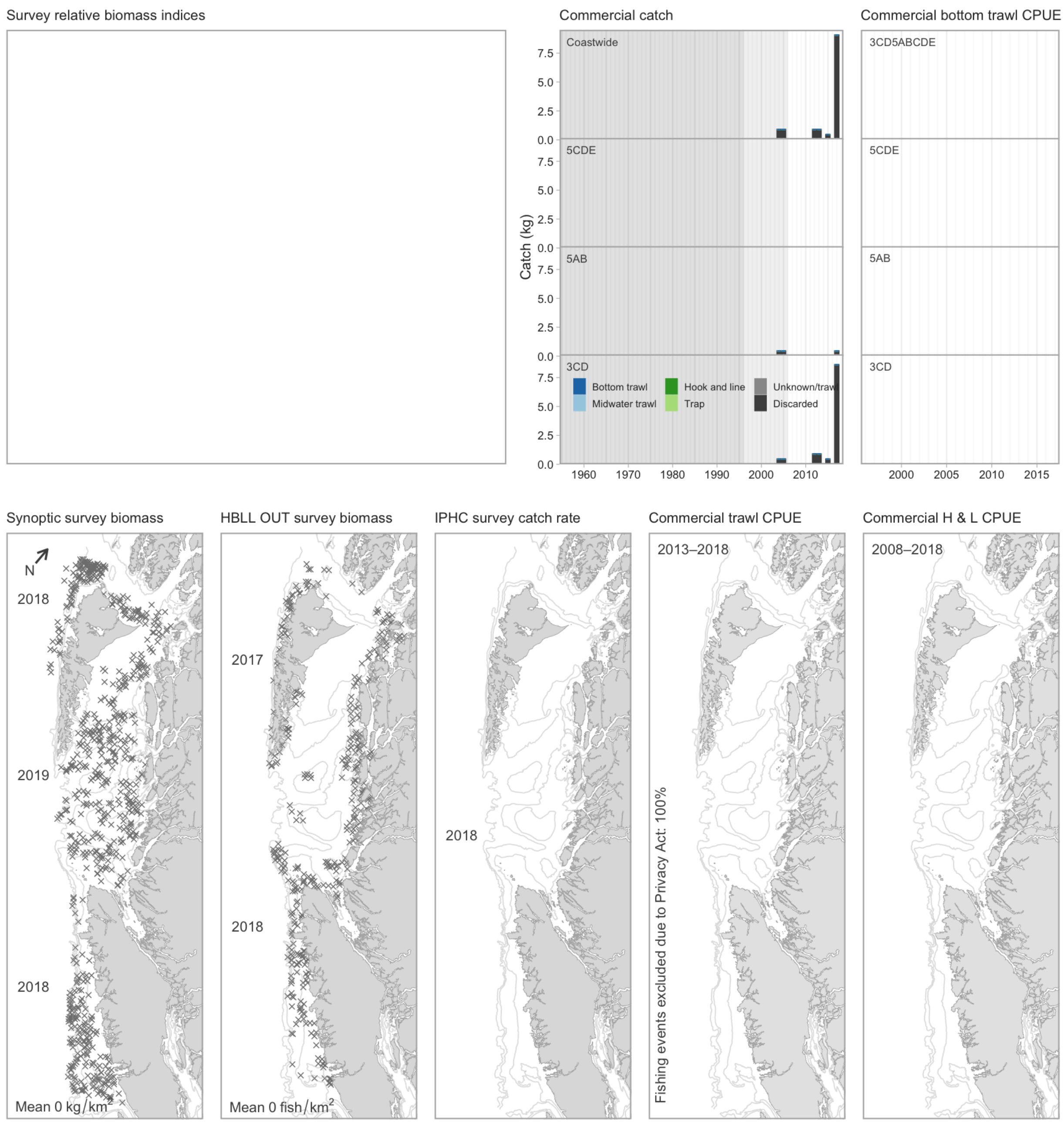
Myoxocephalus polyacanthocephalus (521)
Order: Scorpaeniformes, Family: Cottidae, FishBase, WoRMS

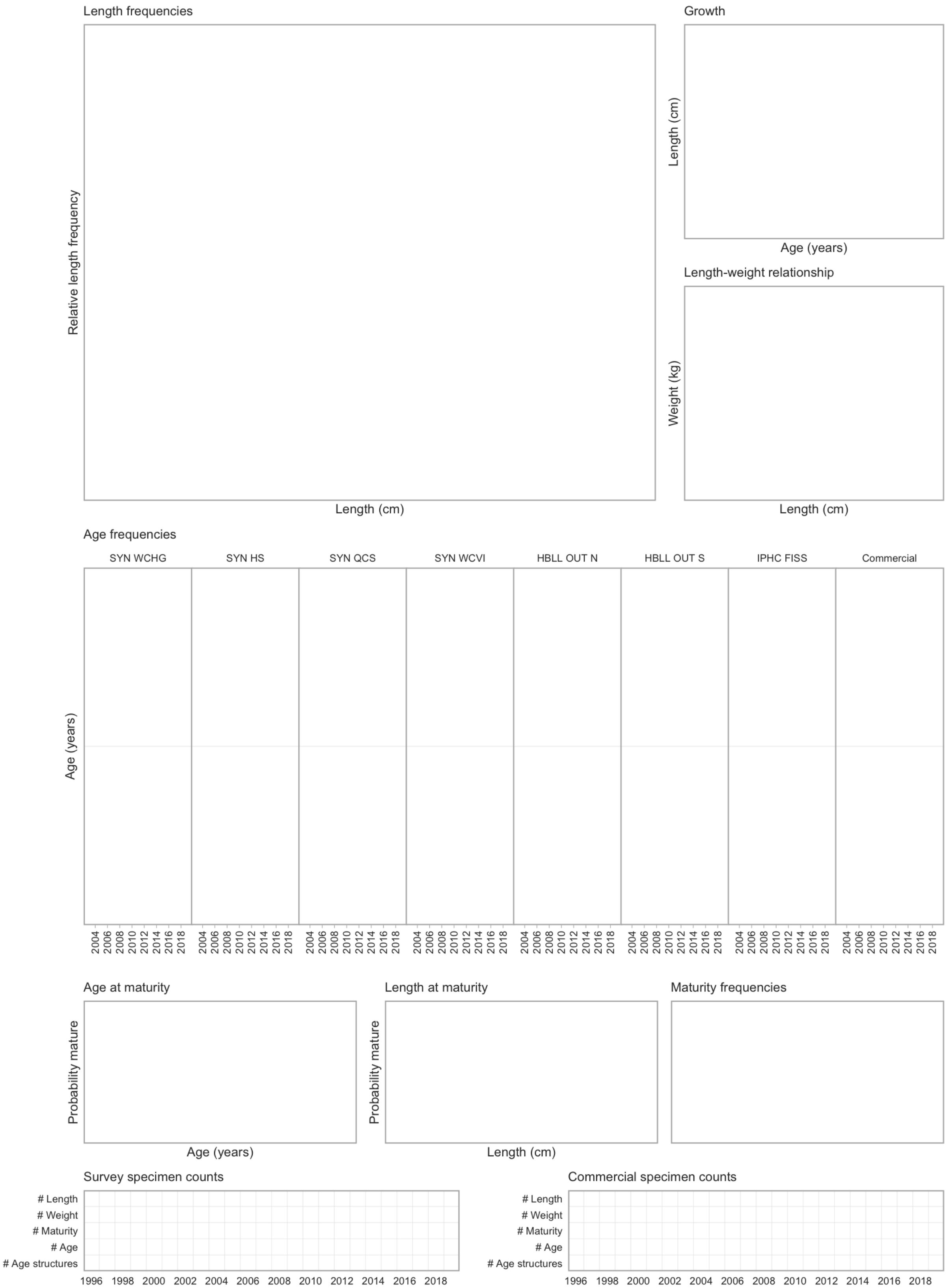



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
14
1
6
3
2
1
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.91 THORNBACK SCULPIN

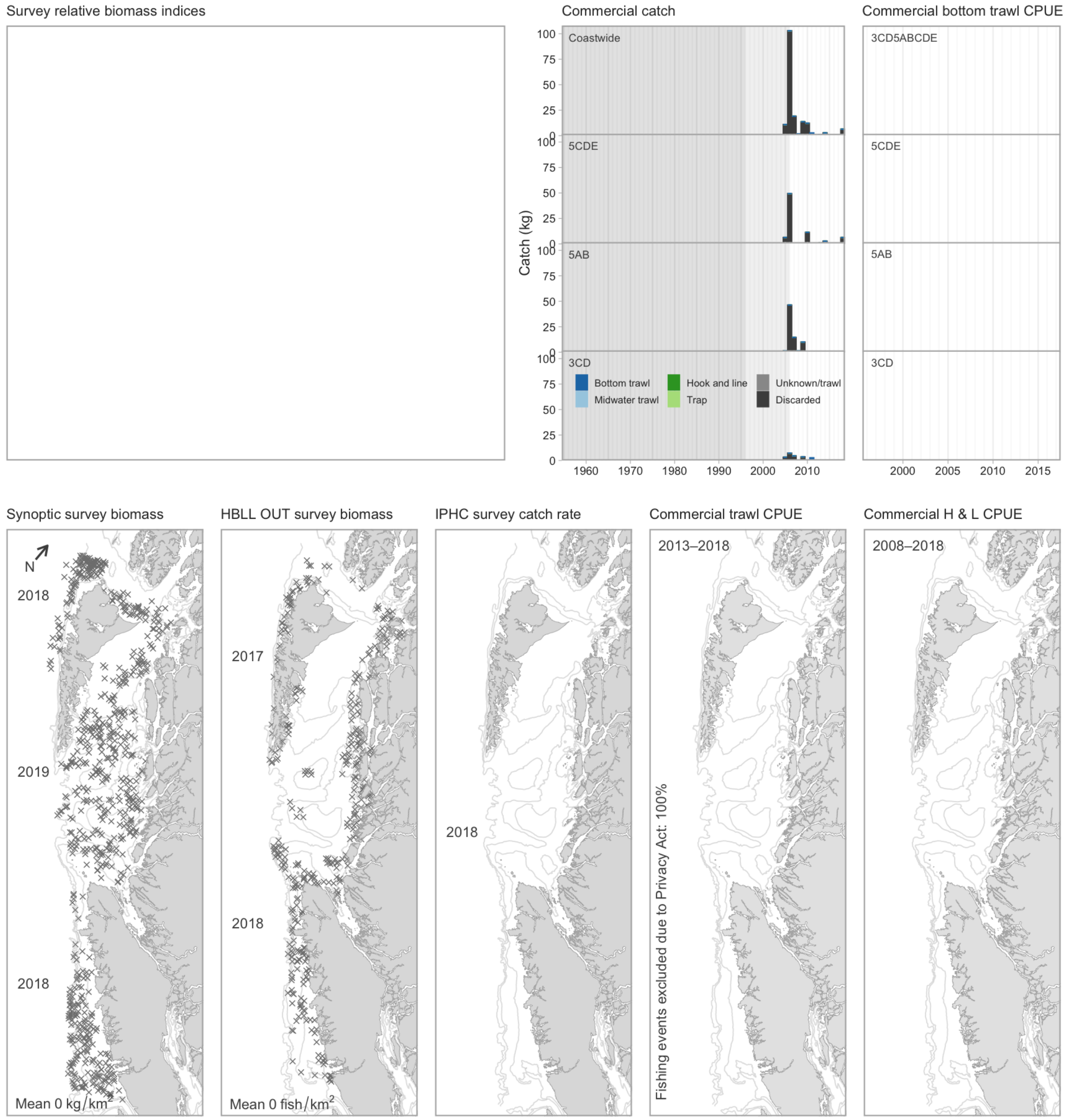
Paricelinus hoplitícus (532)
Order: Scorpaeniformes, Family: Cottidae, FishBase, WoRMS

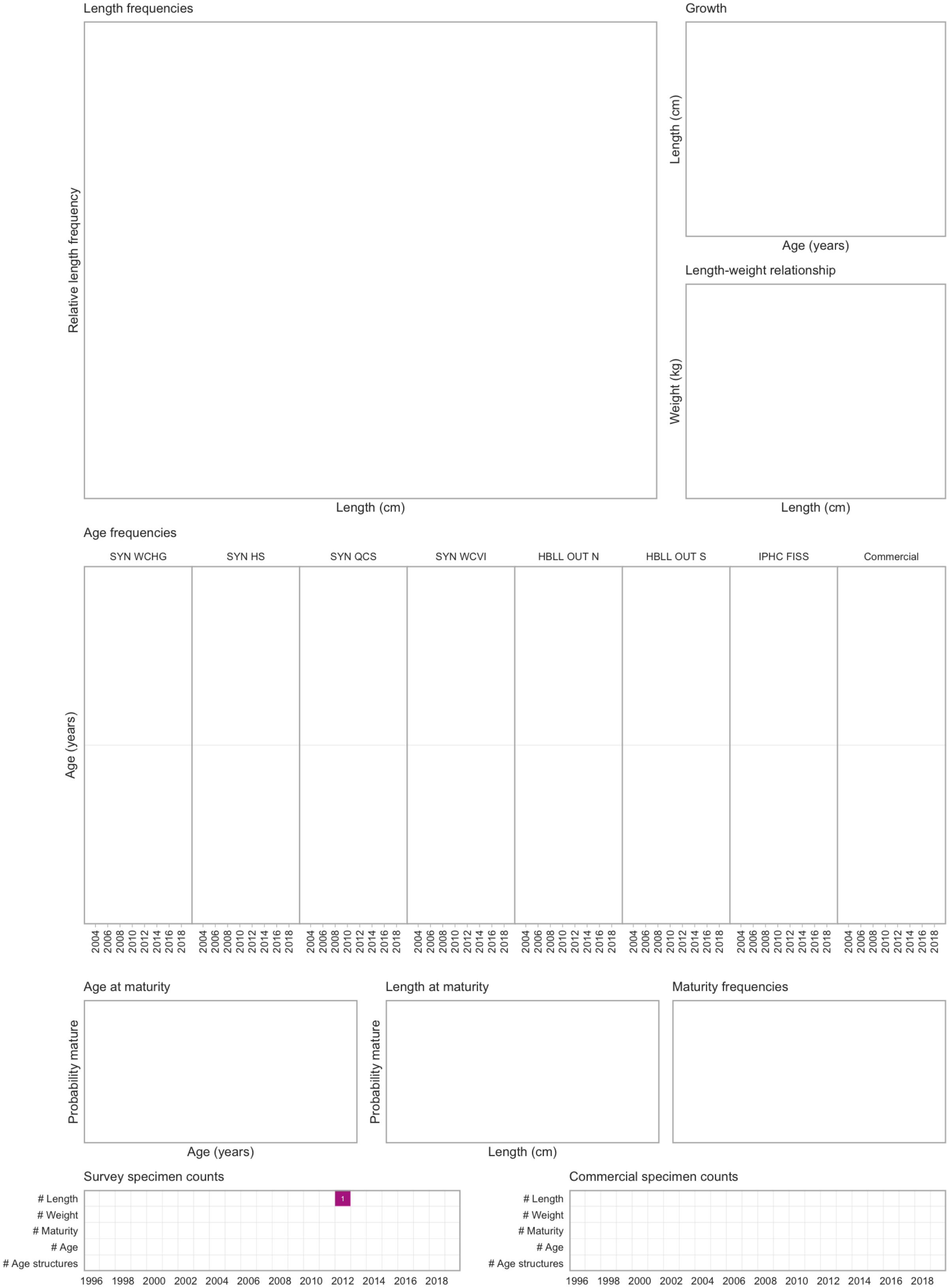



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.92 GIANT BLOBSCULPIN

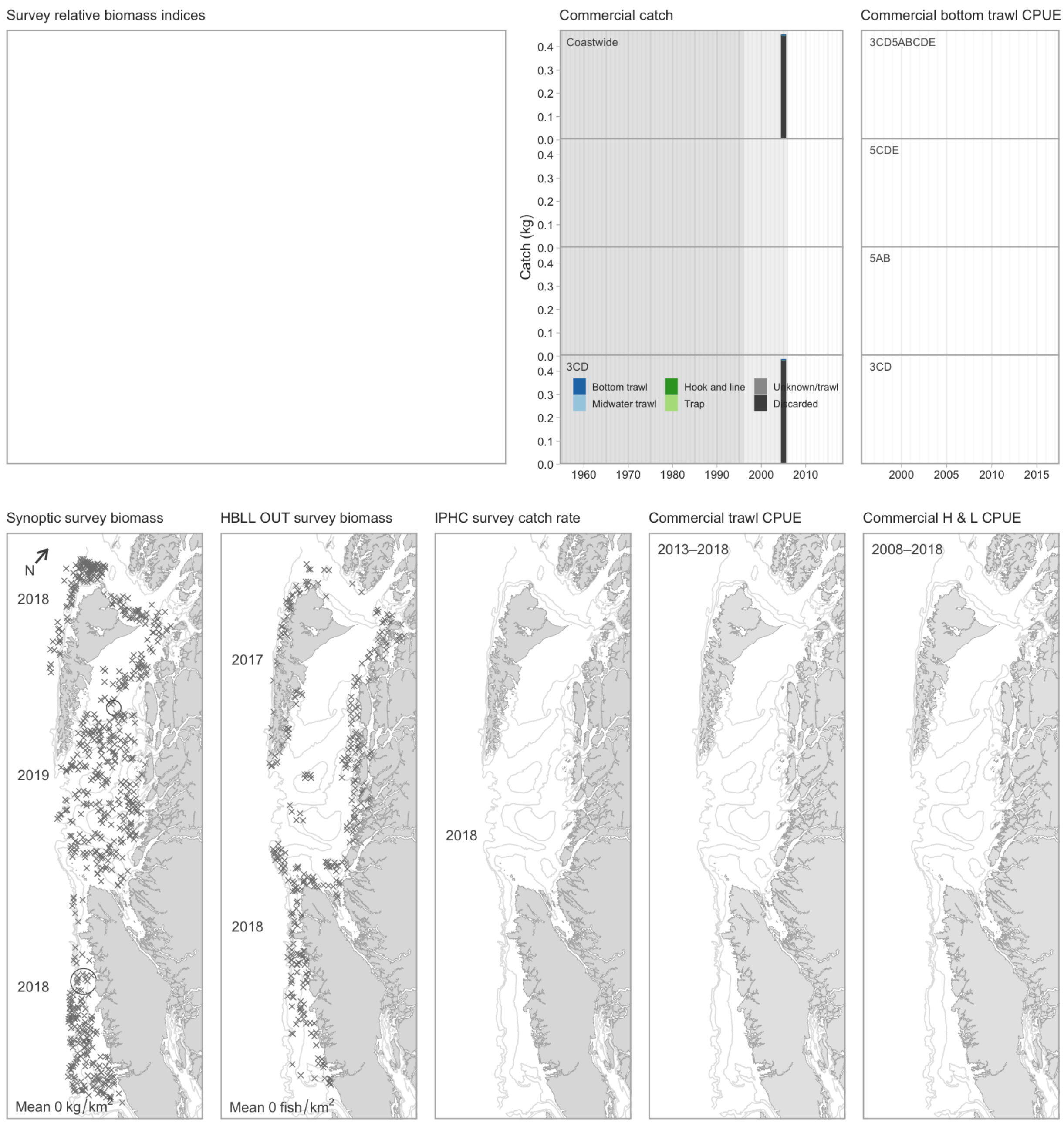
Psychrolutes phrictus (534)
Order: Scorpaeniformes, Family: Psychrolutidae, FishBase, WoRMS

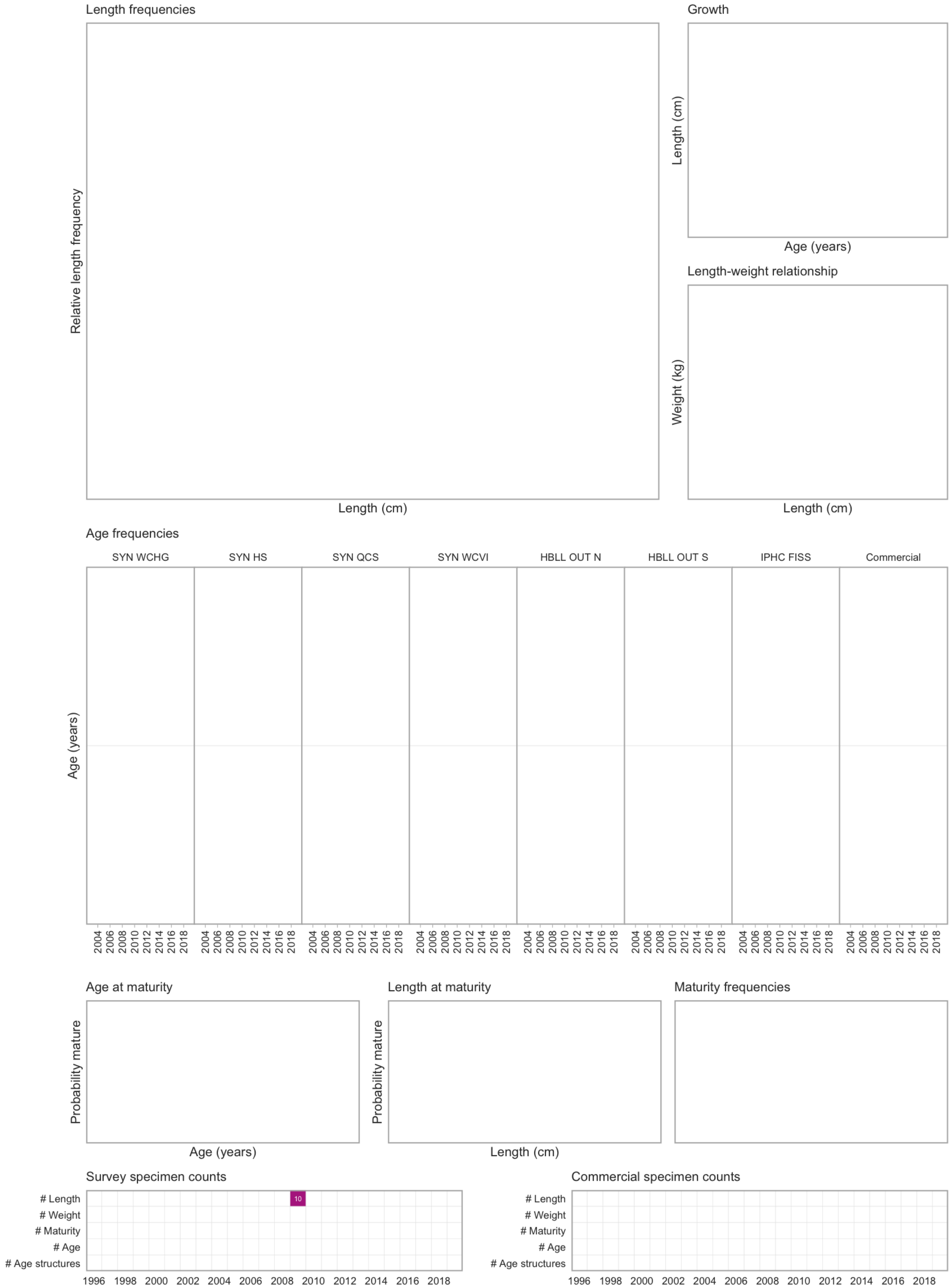



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.93 SLIM SCULPIN

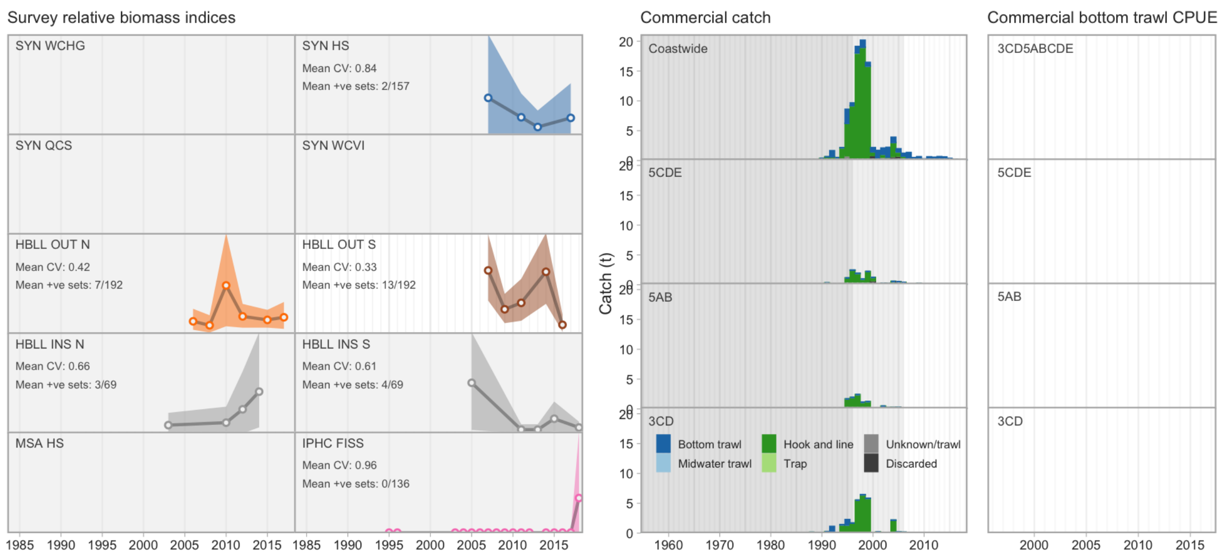
Radulinus asprellus (535)
Order: Scorpaeniformes, Family: Cottidae, FishBase, WoRMS

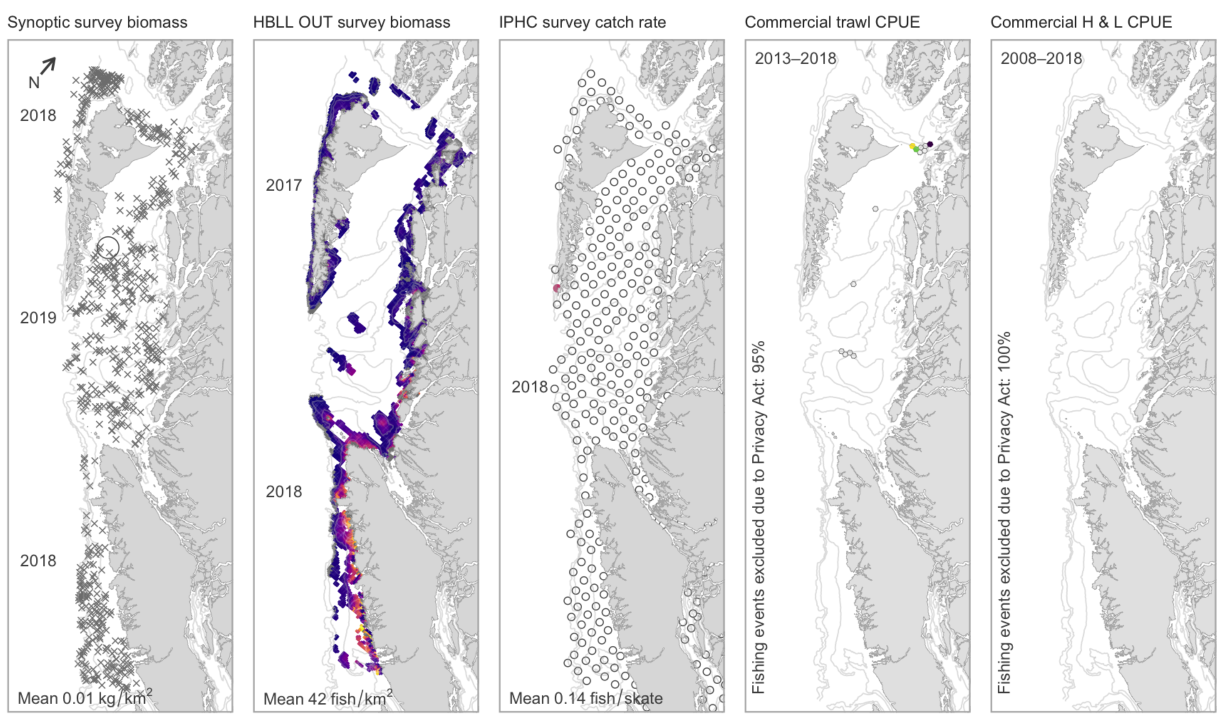


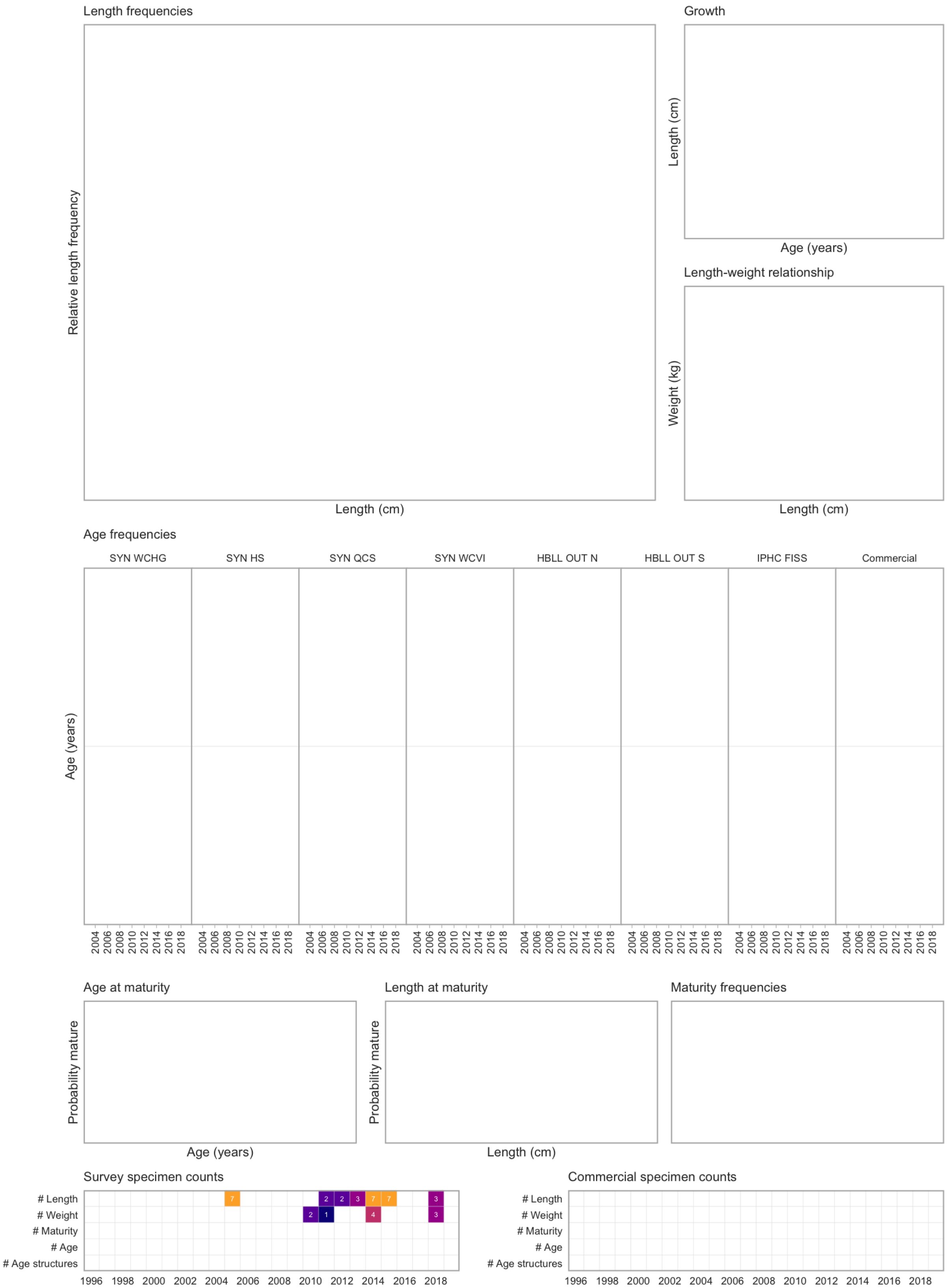

Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
10
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.94 CABEZON

Scorpaenichthys marmoratus (540)
Order: Scorpaeniformes, Family: Cottidae, FishBase, WoRMS

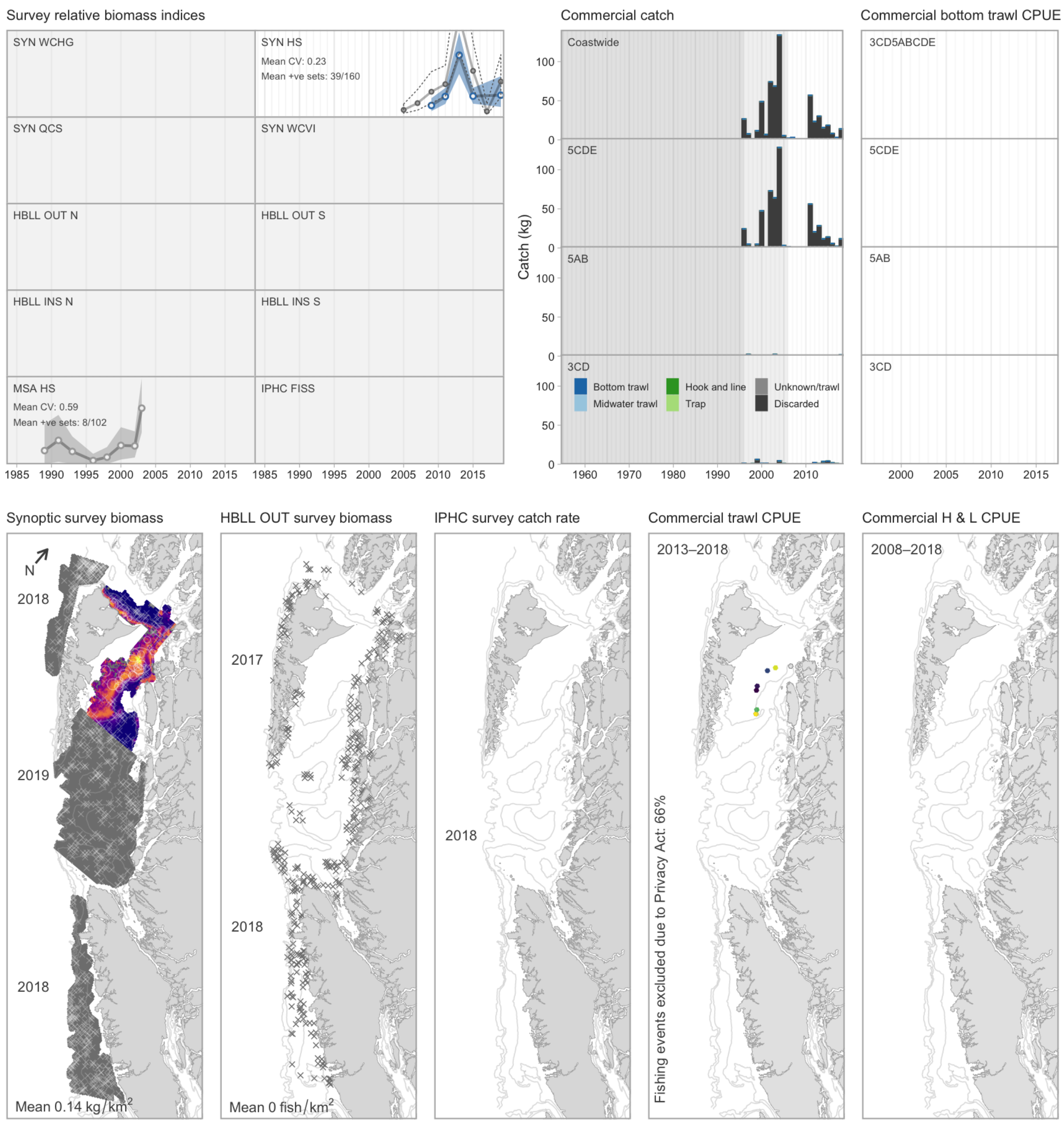


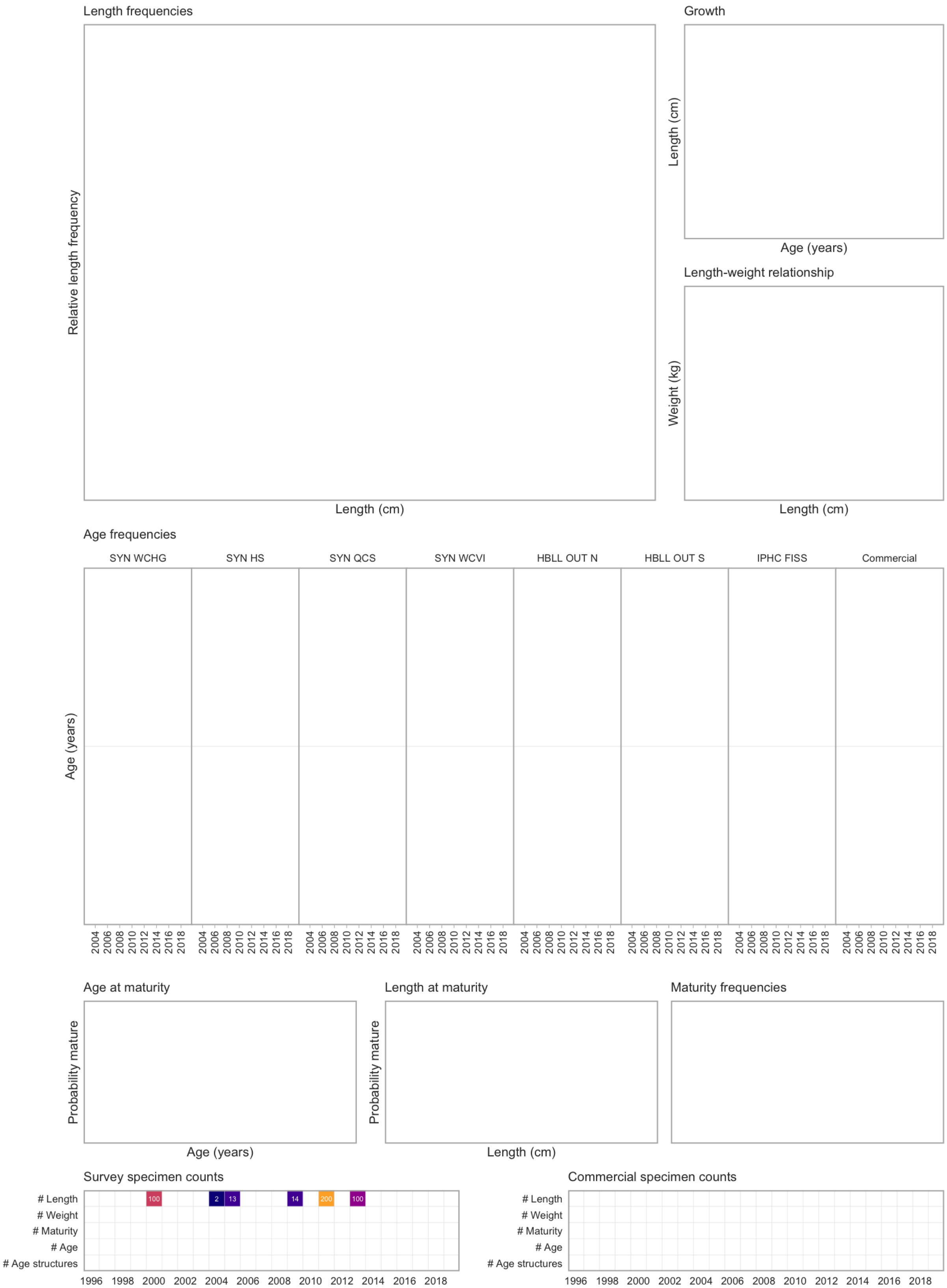



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
7 2 2 3 7 7 3
2 1 4 3
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.95 STURGEON POACHER

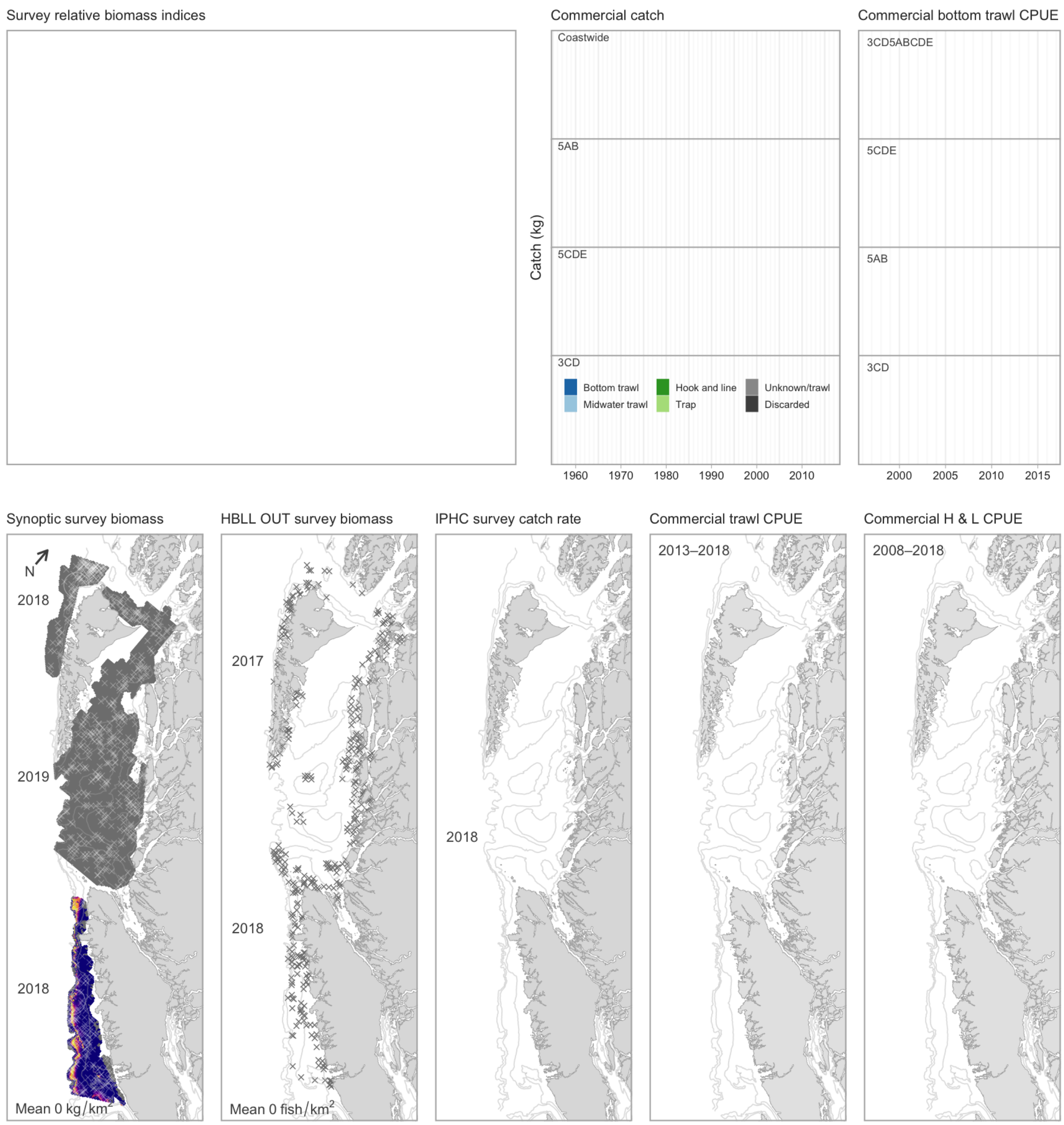
Podothecus accipenserinus (550)
Order: Scorpaeniformes, Family: Agonidae, FishBase, WoRMS

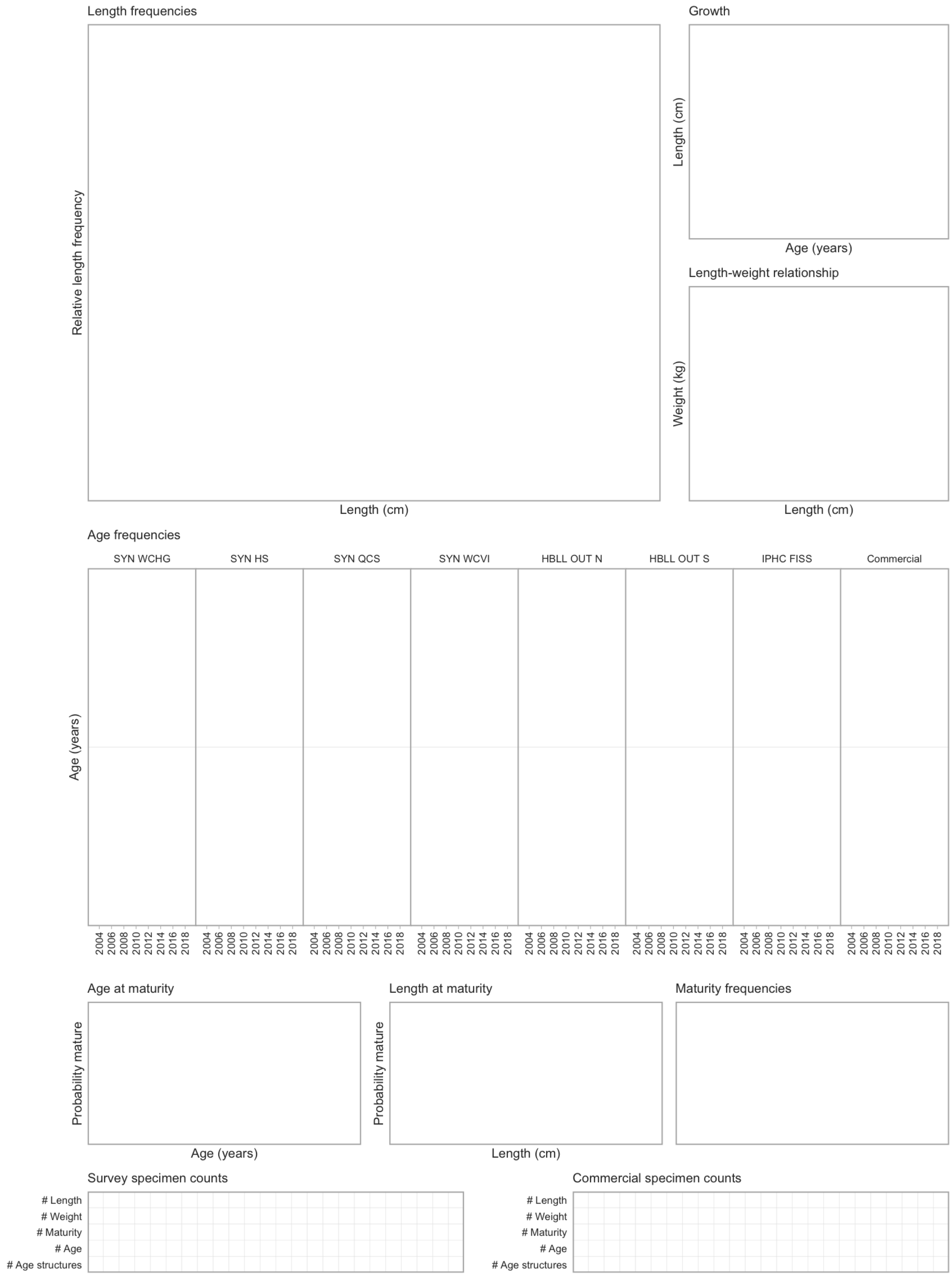



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
100
2
13
14
200
100
Commercial specimen counts
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.96 SMOOTHEYE POACHER

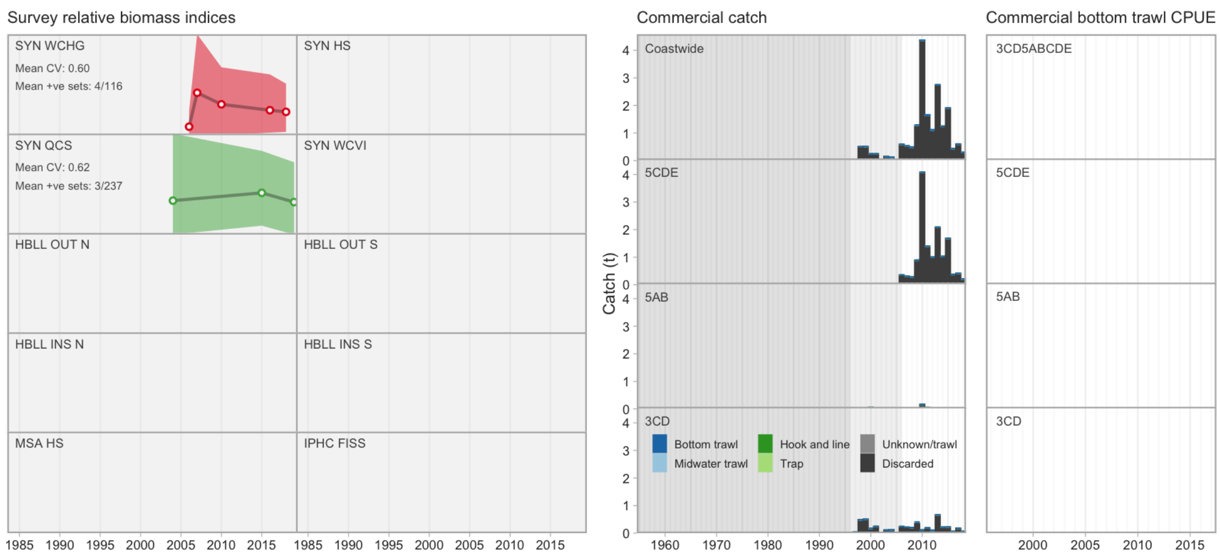
Xeneretmus leiops (555)
Order: Scorpaeniformes, Family: Agonidae, FishBase, WoRMS

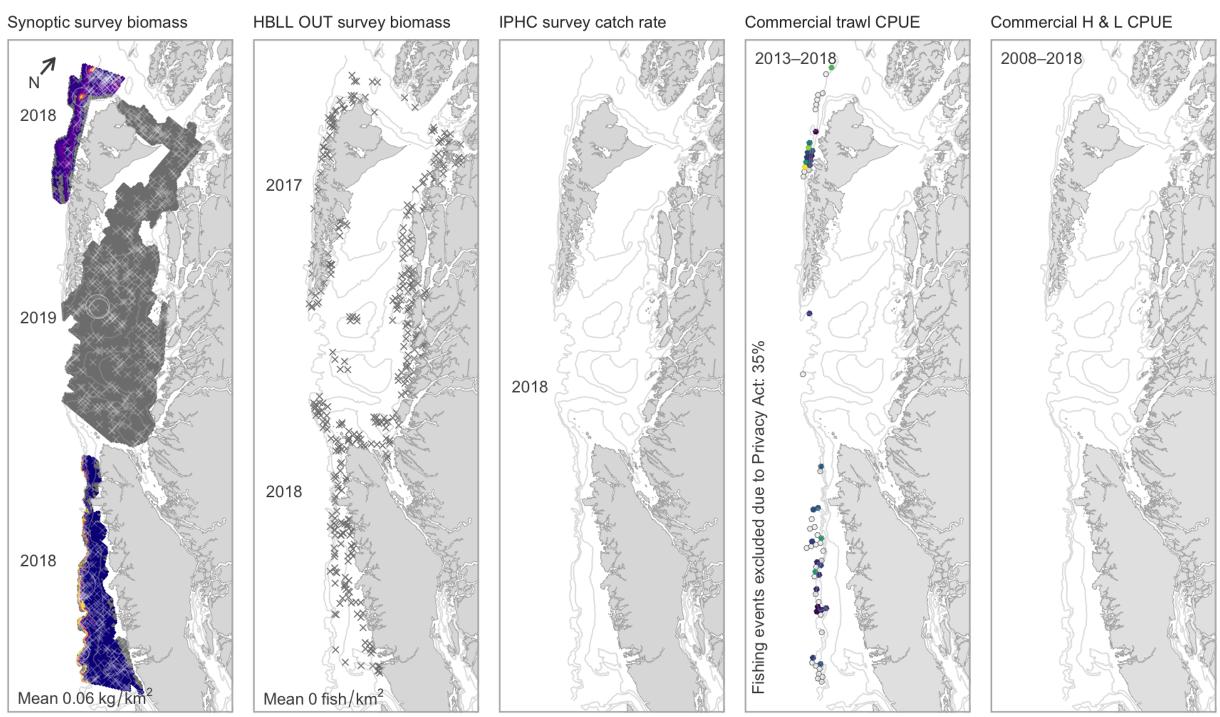


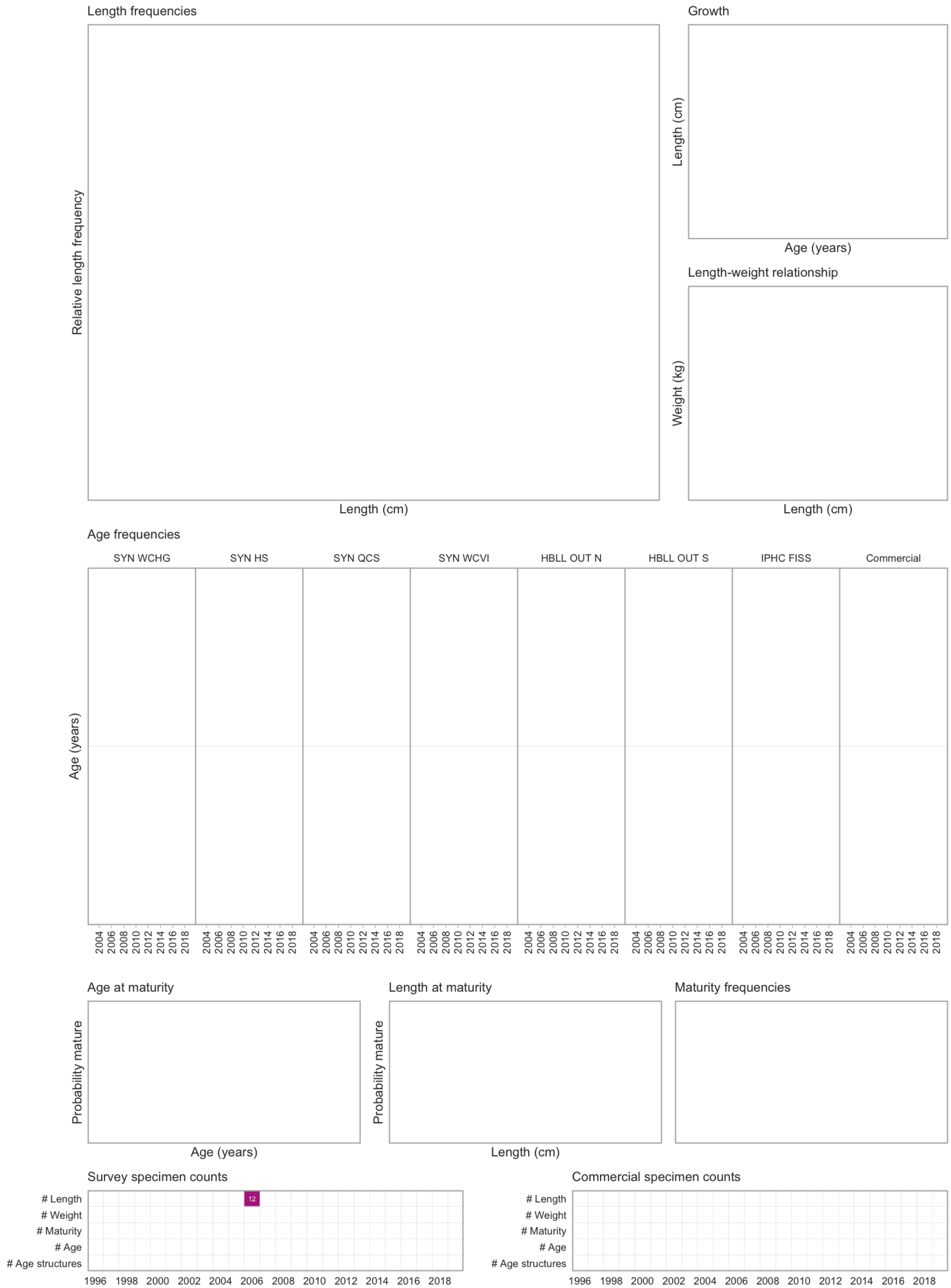

Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.97 BLACKTAIL SNAILFISH

Careproctus melanurus (574)
Order: Scorpaeniformes, Family: Liparidae, FishBase, WoRMS

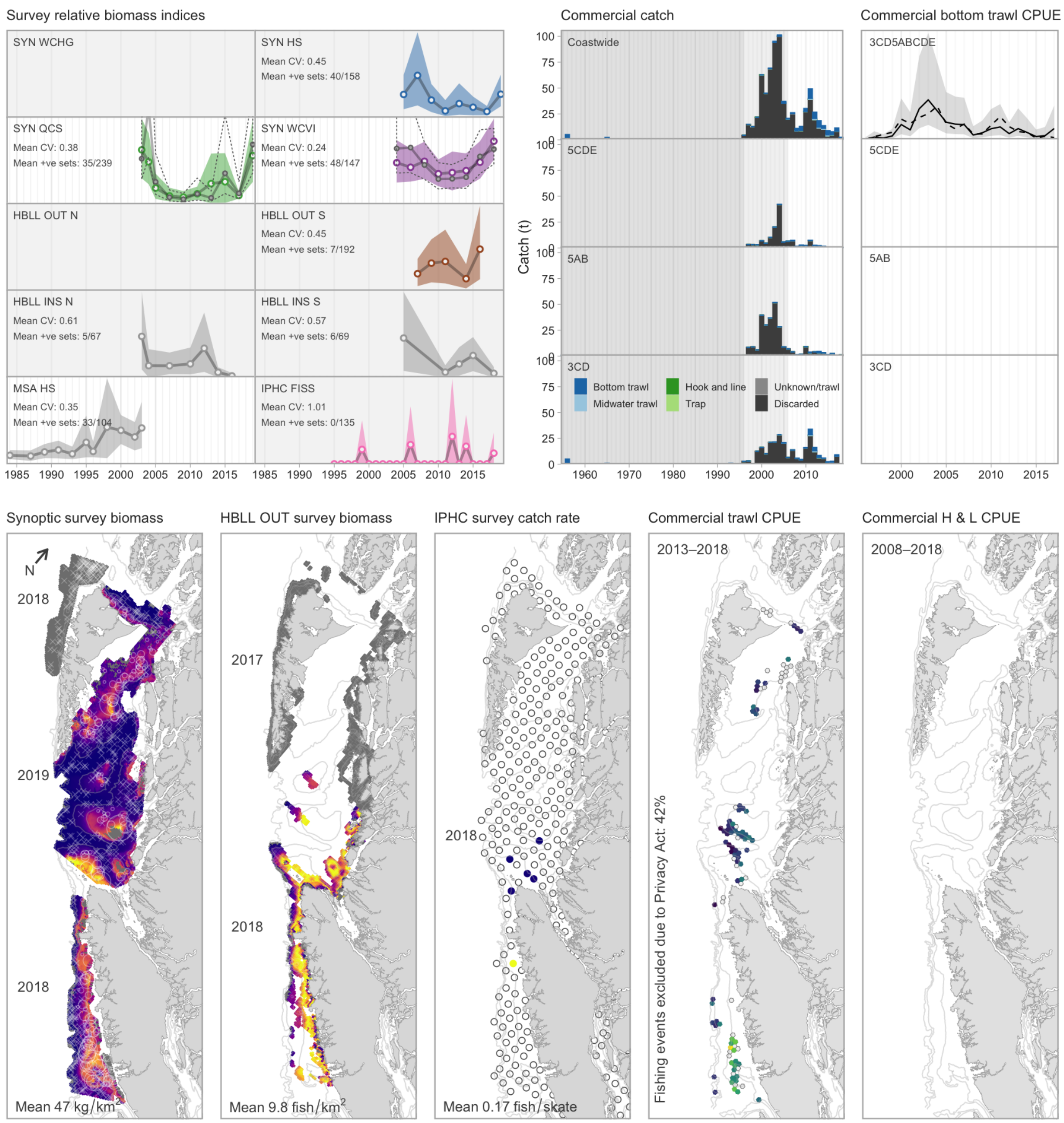


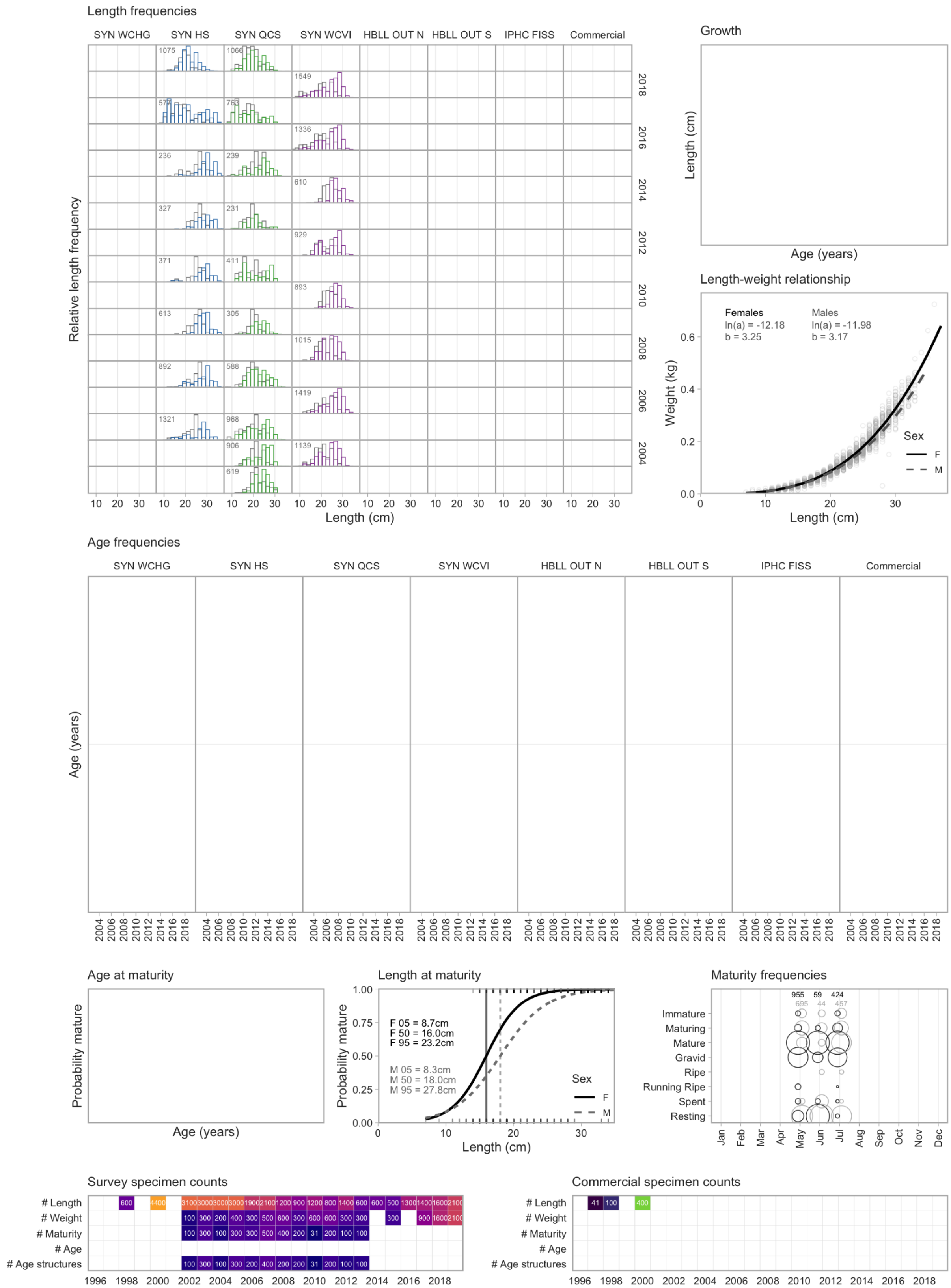



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
12
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.98 PACIFIC SANDDAB

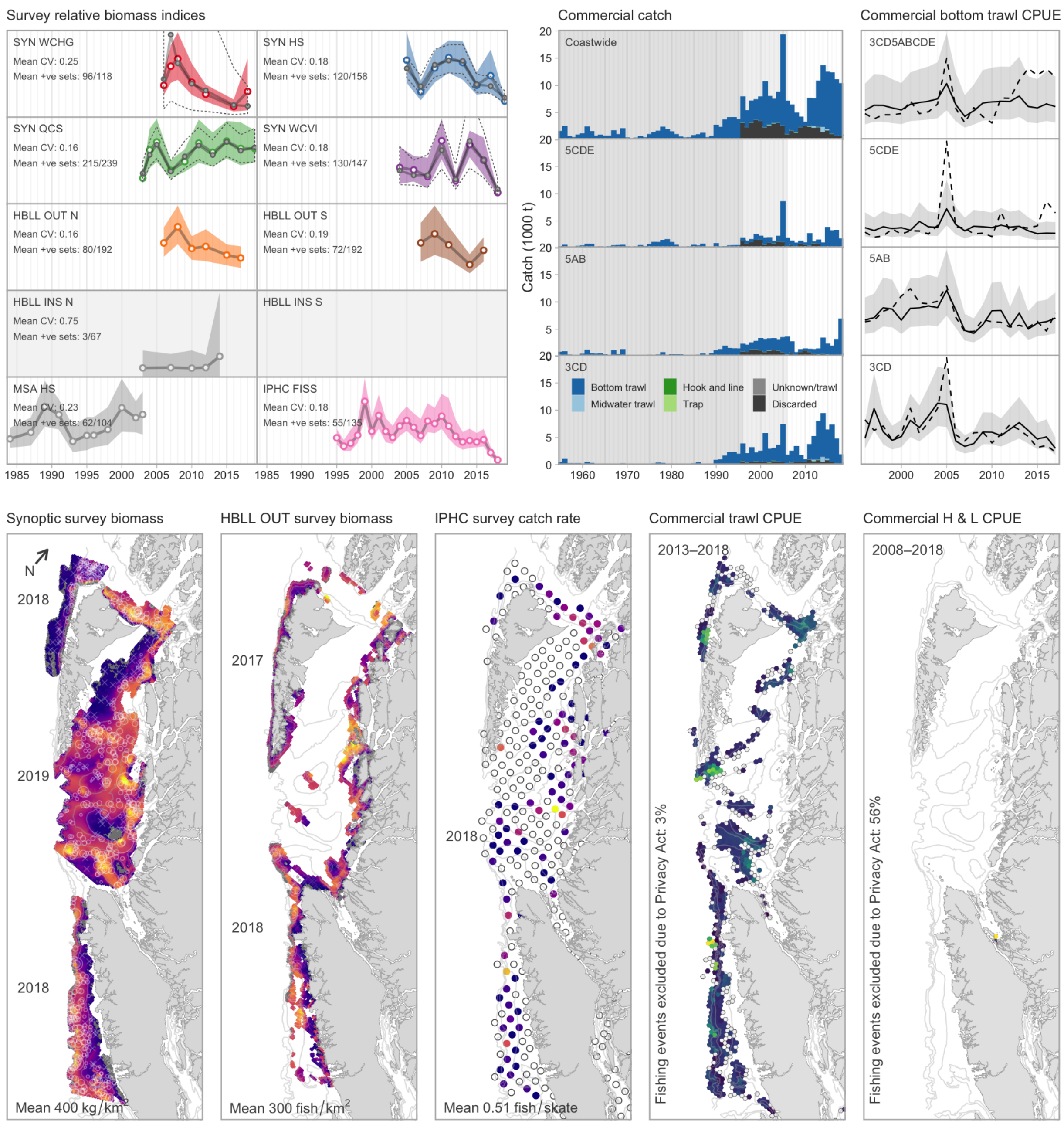
Citharichthys sordidus (596)
Order: Pleuronectiformes, Family: Paralichthyidae, FishBase, WoRMS

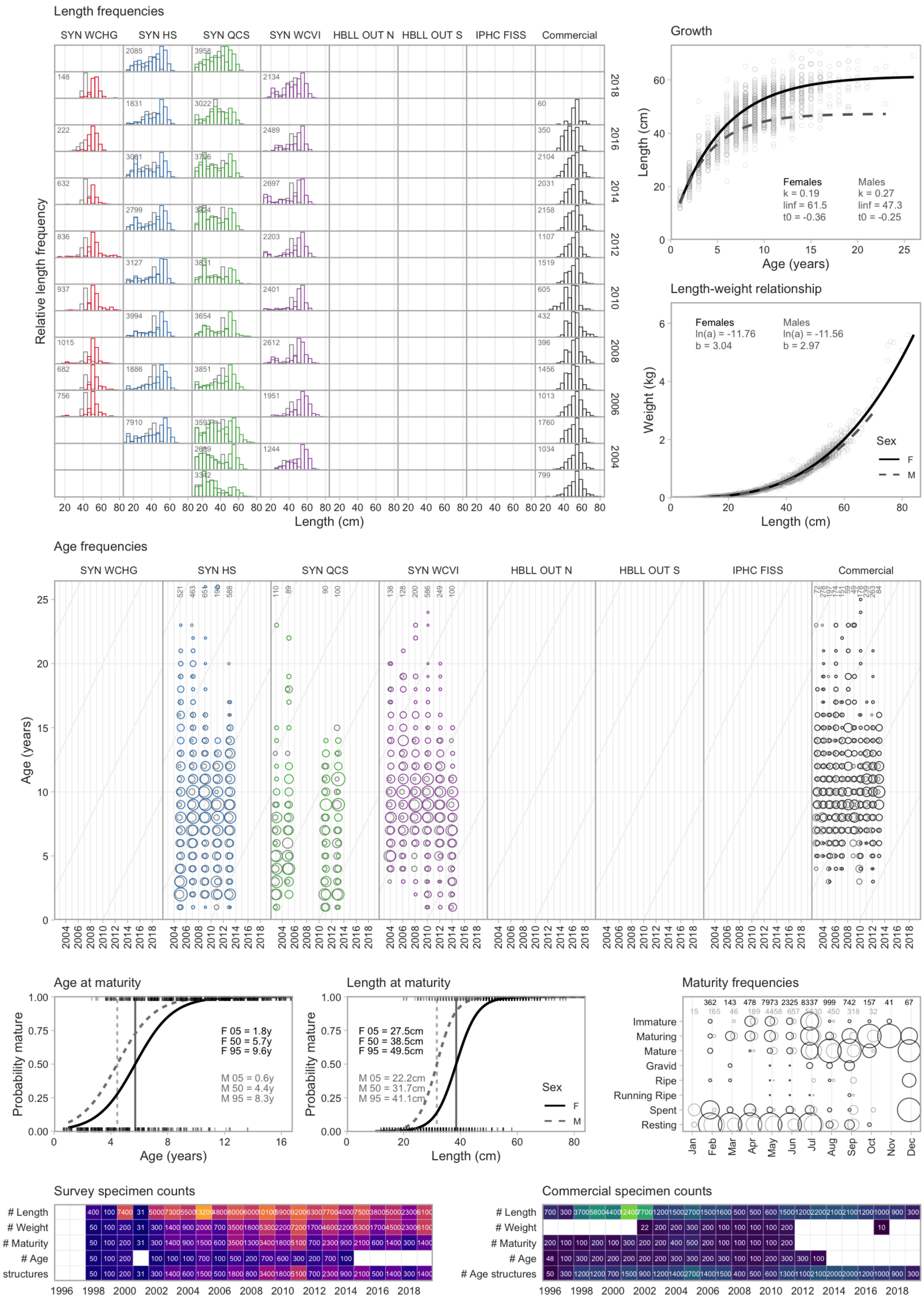



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -12.18
b = 3.25
Males
ln(a) = -11.98
b = 3.17
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 8.7cm
F 50 = 16.0cm
F 95 = 23.2cm
M 05 = 8.3cm
M 50 = 18.0cm
M 95 = 27.8cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.99 ARROWTOOTH FLOUNDER

Atheresthes stomias (602)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS
Last Research Document: Grandin and Forrest (2017)
Last Science Advisory Report: DFO (2015d)

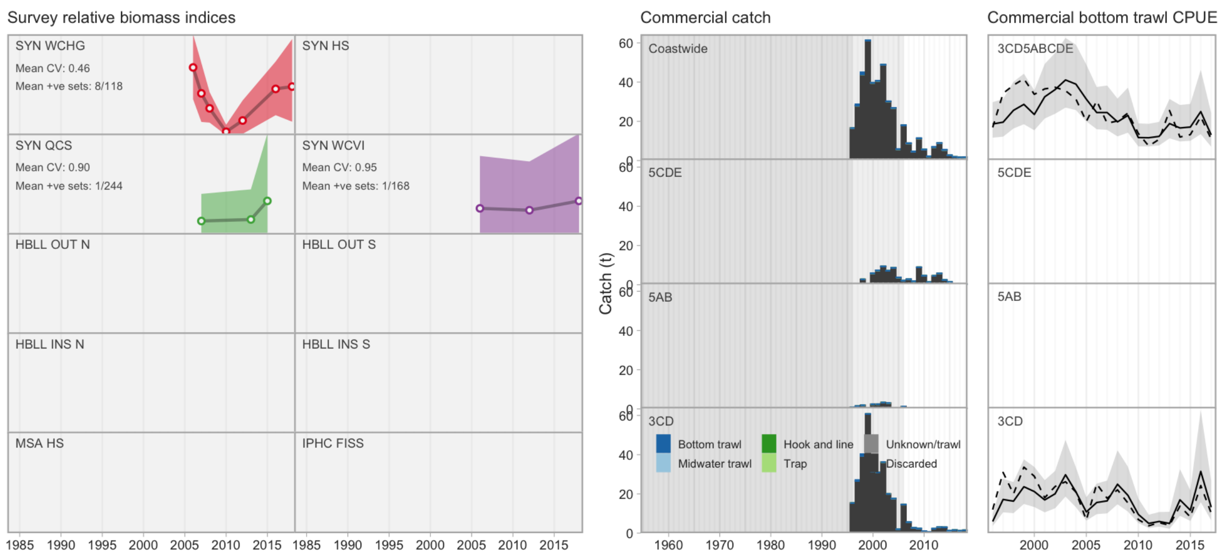


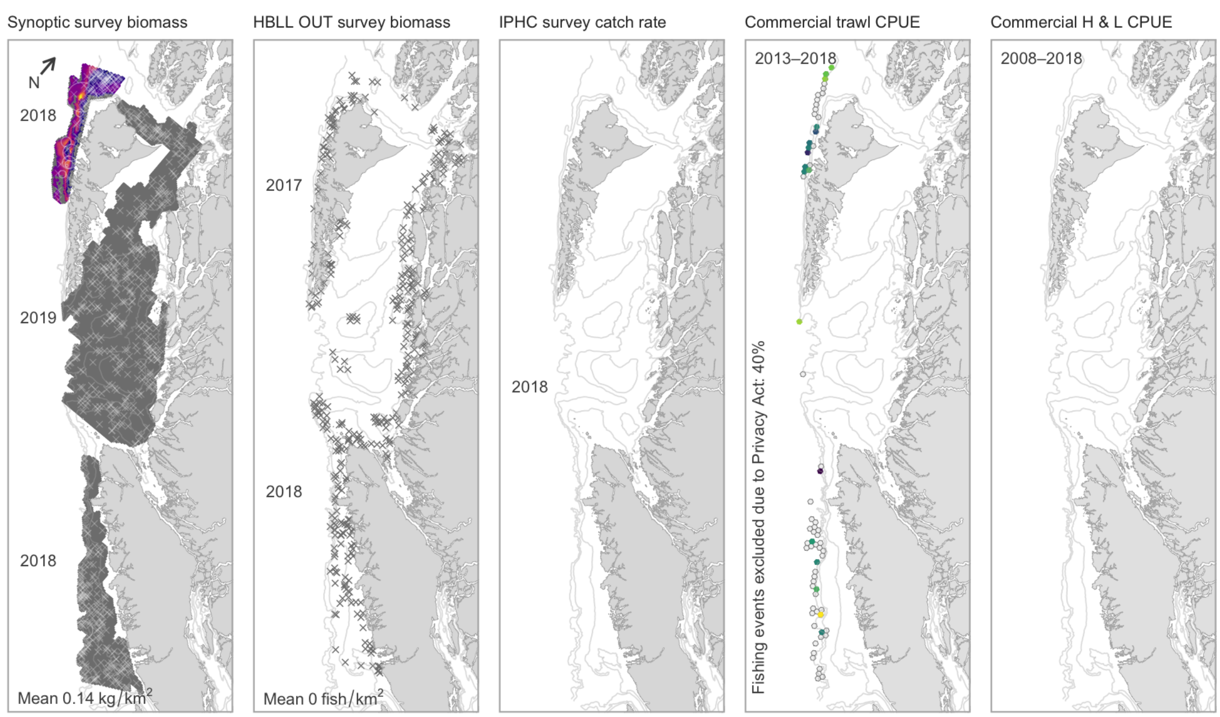


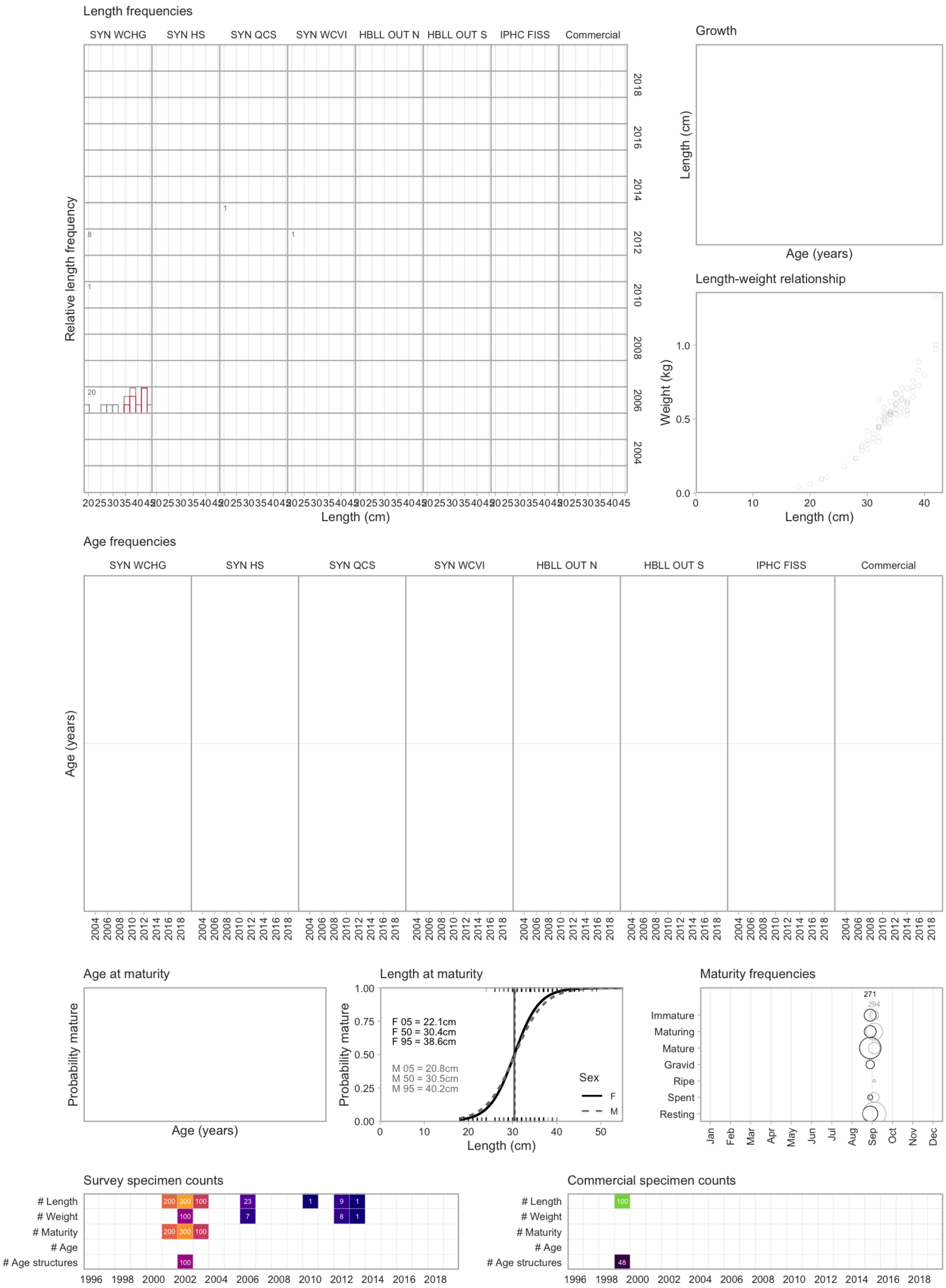
Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Females
k = 0.19
linf = 61.5
t0 = -0.36
Males
k = 0.27
linf = 47.3
t0 = -0.25
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.76
b = 3.04
Males
ln(a) = -11.56
b = 2.97
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
F 05 = 1.8y
F 50 = 5.7y
F 95 = 9.6y
M 05 = 0.6y
M 50 = 4.4y
M 95 = 8.3y
Probability mature
Age (years)
Length at maturity
F 05 = 27.5cm
F 50 = 38.5cm
F 95 = 49.5cm
M 05 = 22.2cm
M 50 = 31.7cm
M 95 = 41.1cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.100 DEEPSEA SOLE

Embassichthys bathybius (605)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS



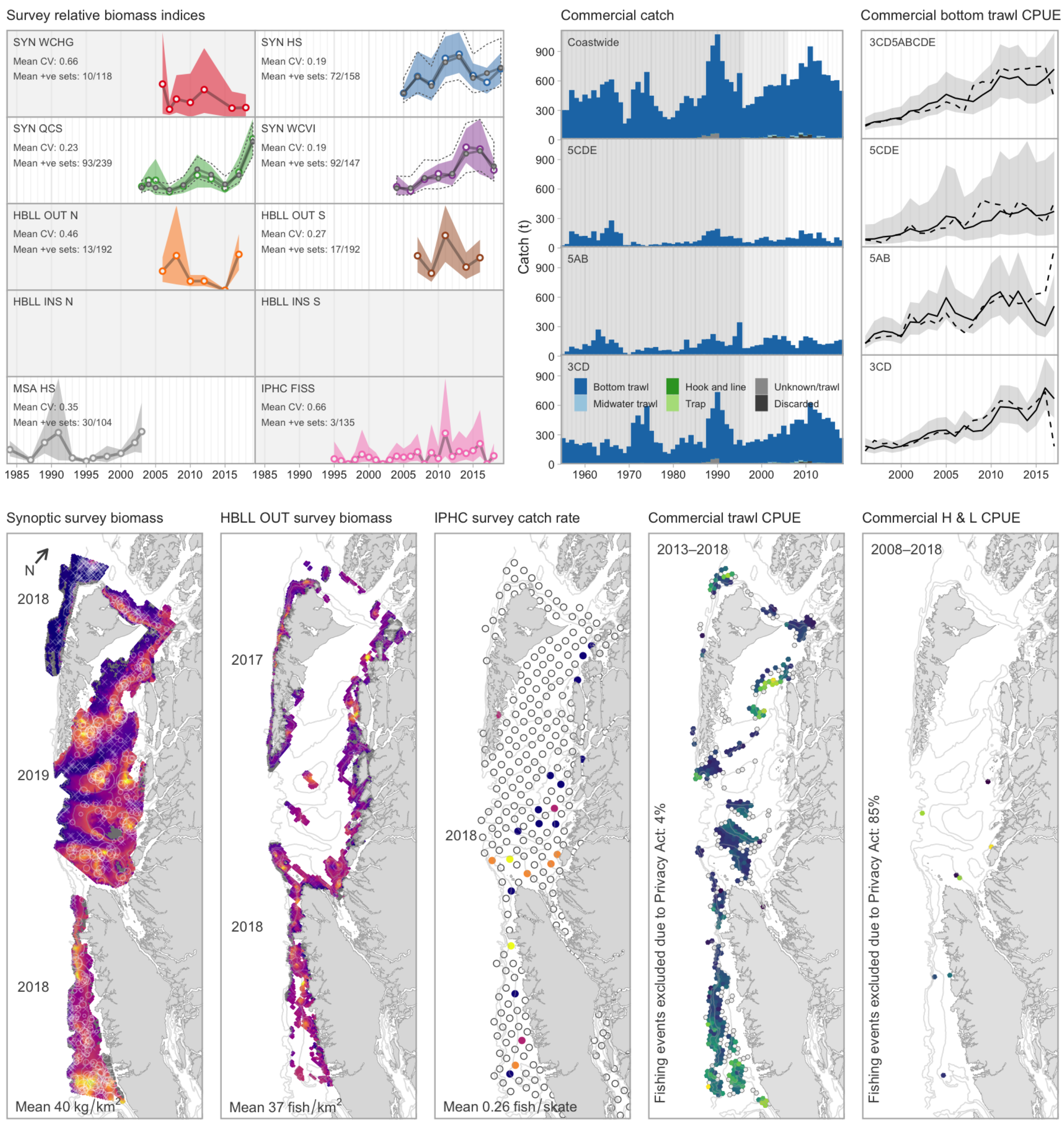


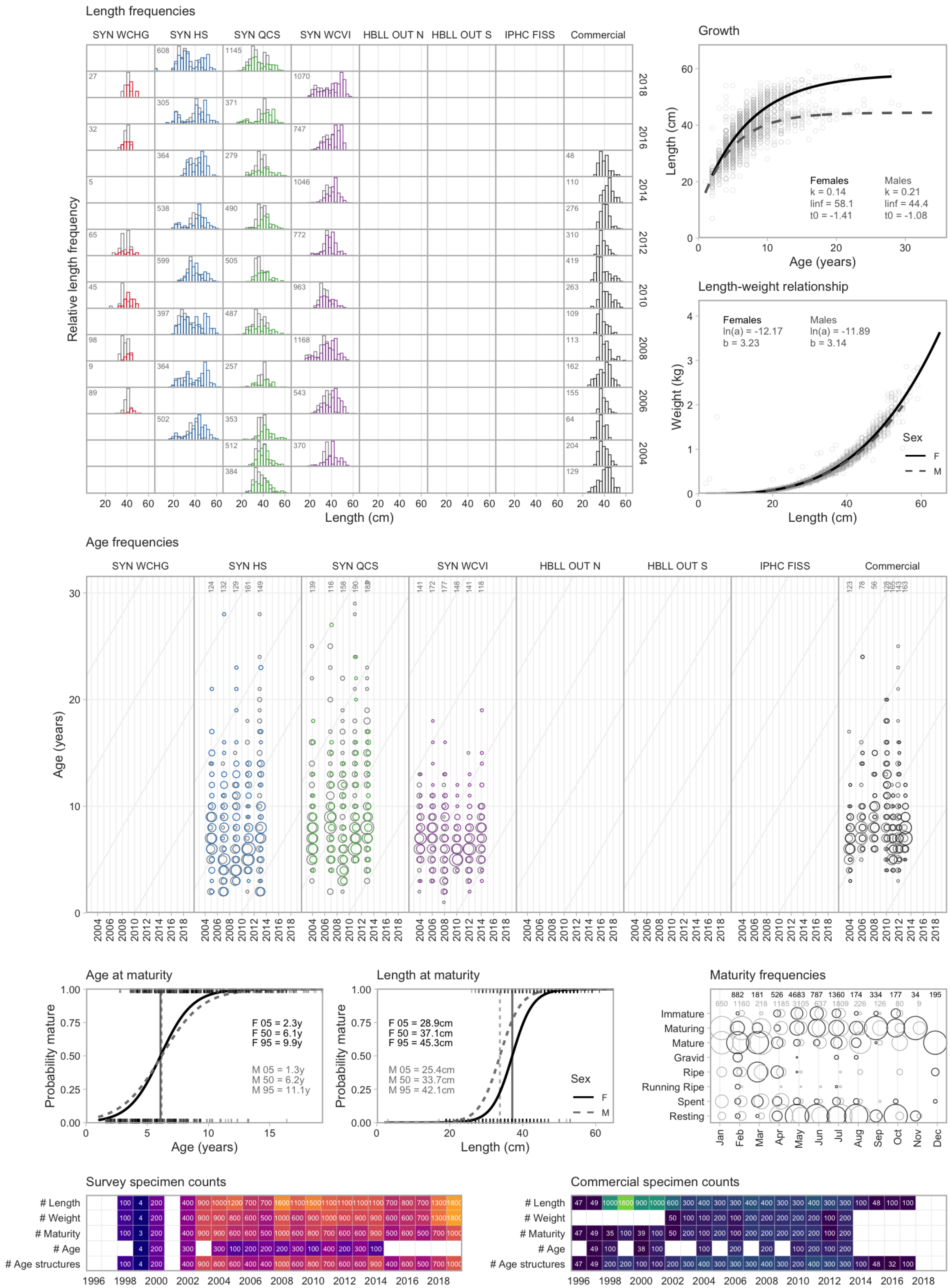


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 22.1cm
F 50 = 30.4cm
F 95 = 38.6cm
M 05 = 20.8cm
M 50 = 30.5cm
M 95 = 40.2cm
Sex
F
M
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.101 PETRALE SOLE

Eopsetta jordani (607)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS
Last Research Document: Starr (2009a)
Last Science Advisory Report: DFO (1999c)

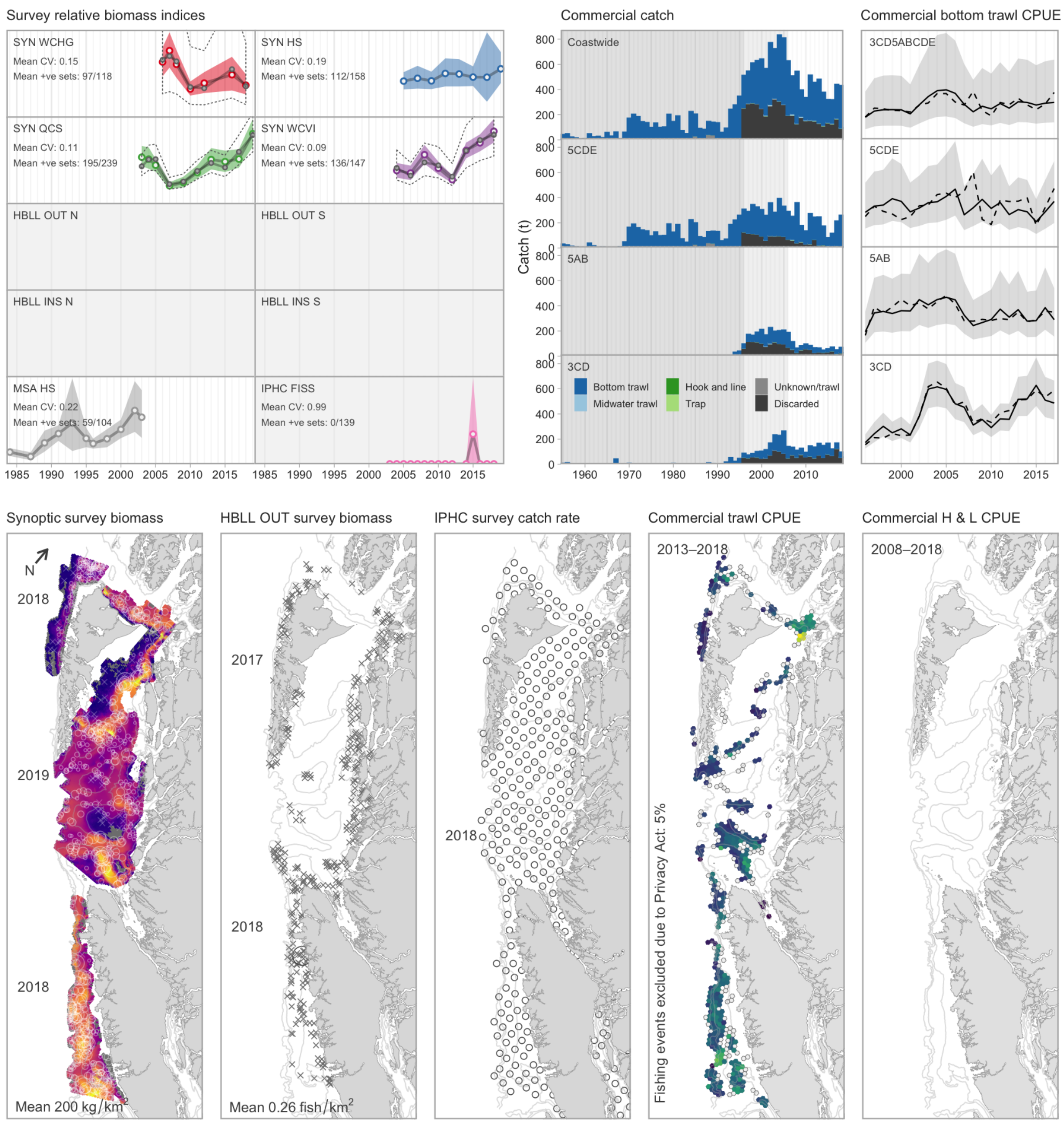


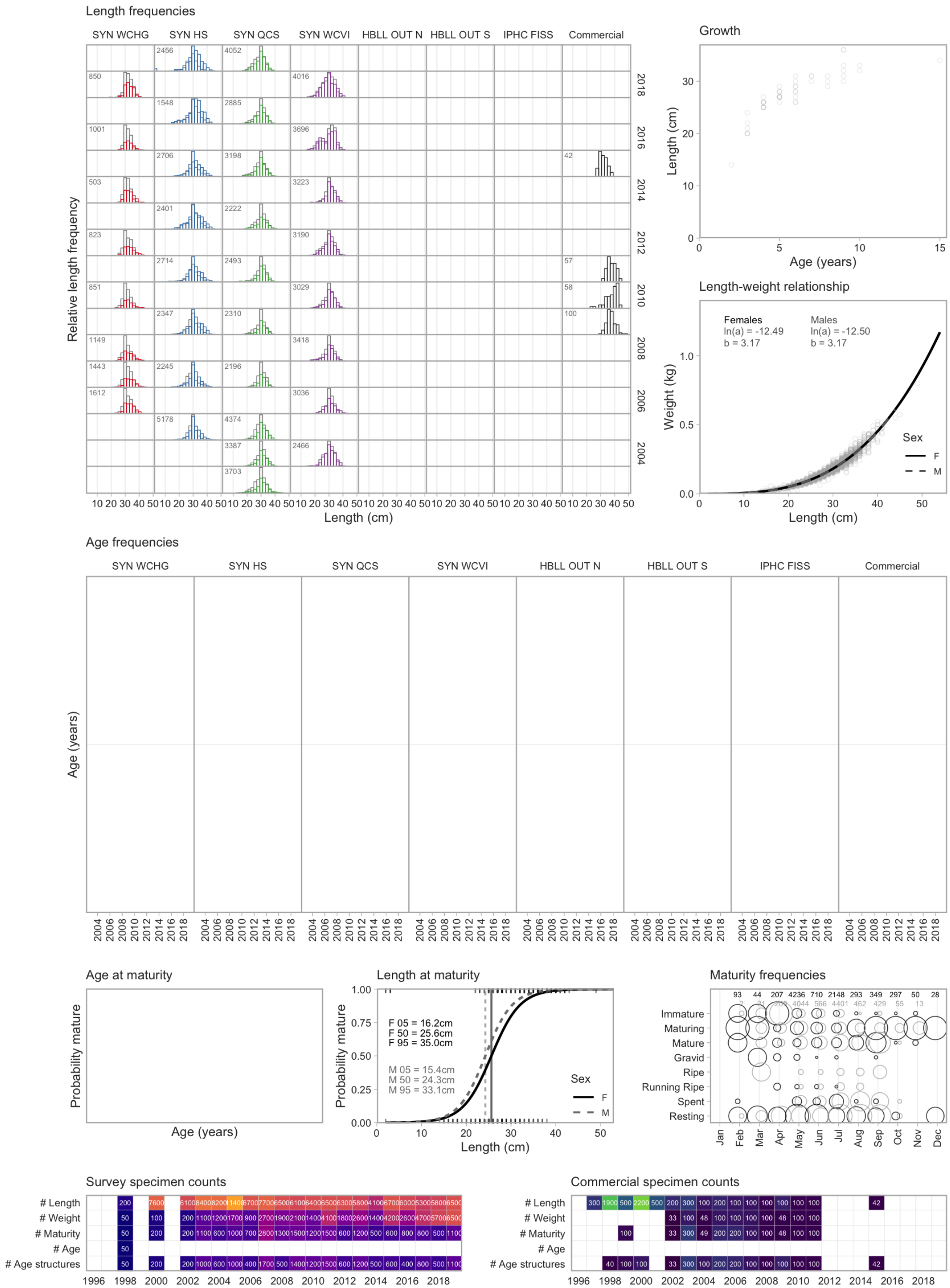


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.14
linf = 58.1
t0 = -1.41
Males
k = 0.21
linf = 44.4
t0 = -1.08
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -12.17
b = 3.23
Males
ln(a) = -11.89
b = 3.14
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 2.3y
F 50 = 6.1y
F 95 = 9.9y
M 05 = 1.3y
M 50 = 6.2y
M 95 = 11.1y
Length at maturity
Length (cm)
F 05 = 28.9cm
F 50 = 37.1cm
F 95 = 45.3cm
M 05 = 25.4cm
M 50 = 33.7cm
M 95 = 42.1cm
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.102 REX SOLE

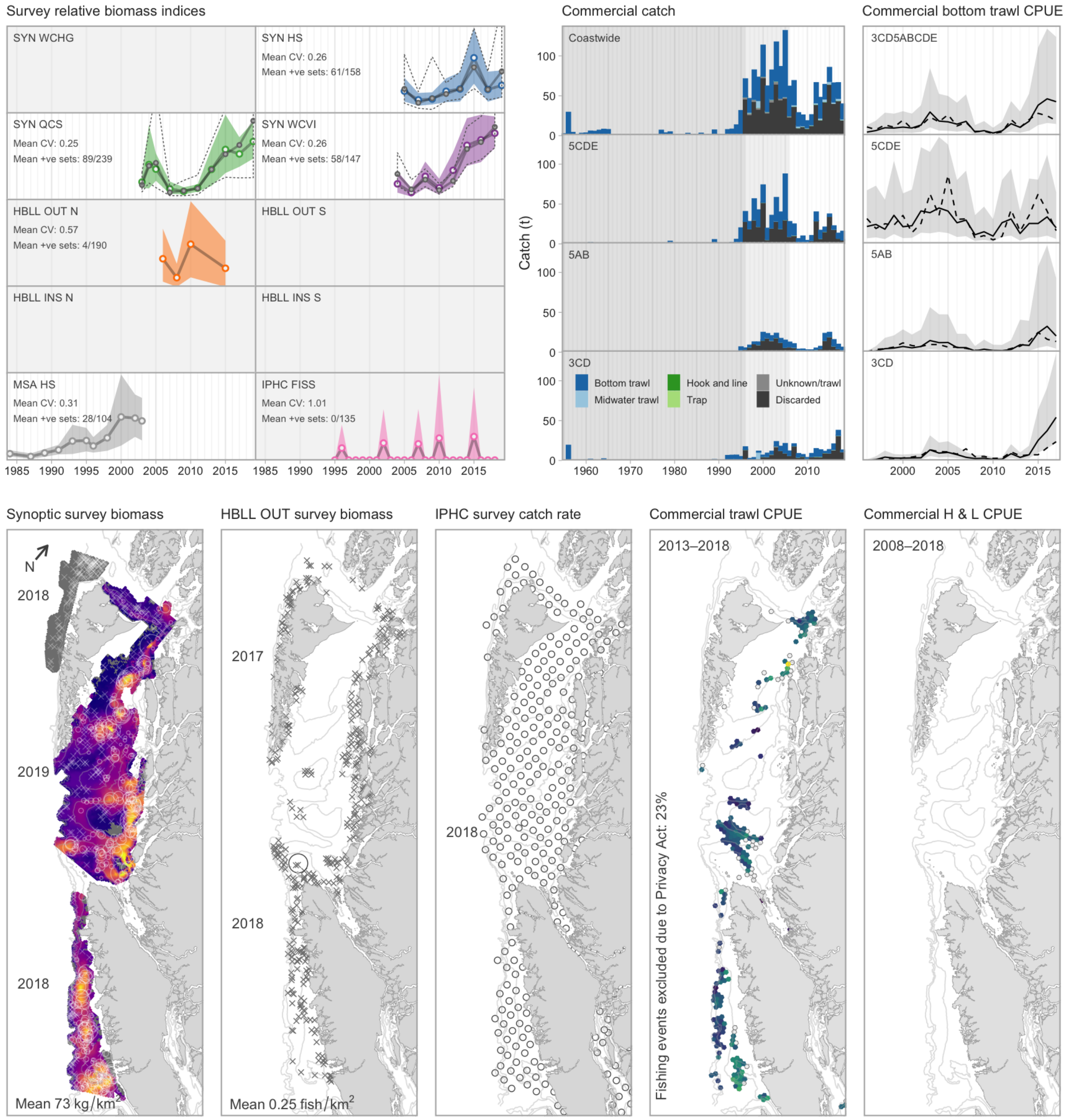
Glyptocephalus zachirus (610)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS

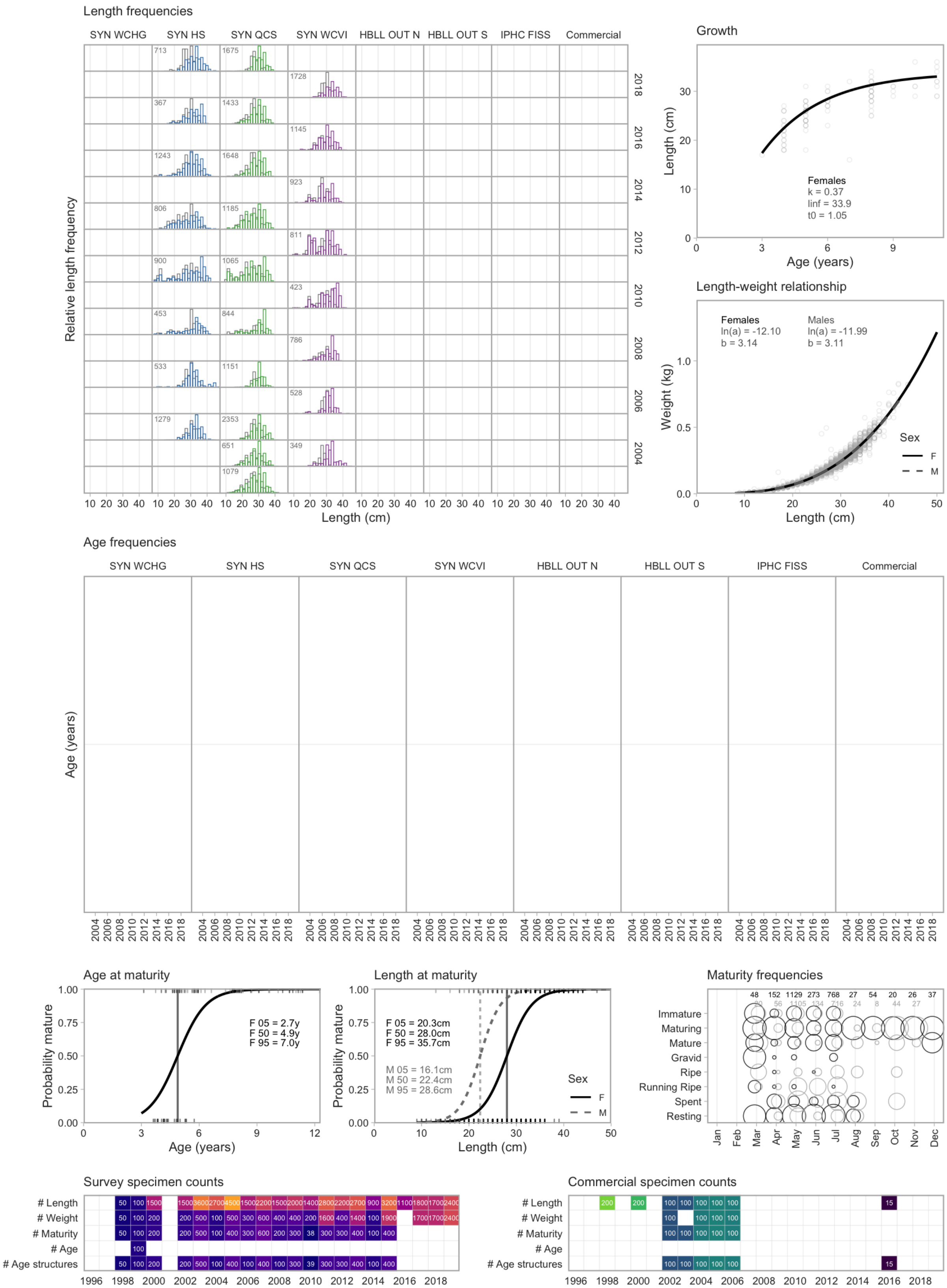



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -12.49
b = 3.17
Males
ln(a) = -12.50
b = 3.17
Weight (kg)
Sex
F
M
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 16.2cm
F 50 = 25.6cm
F 95 = 35.0cm
M 05 = 15.4cm
M 50 = 24.3cm
M 95 = 33.1cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.103 FLATHEAD SOLE

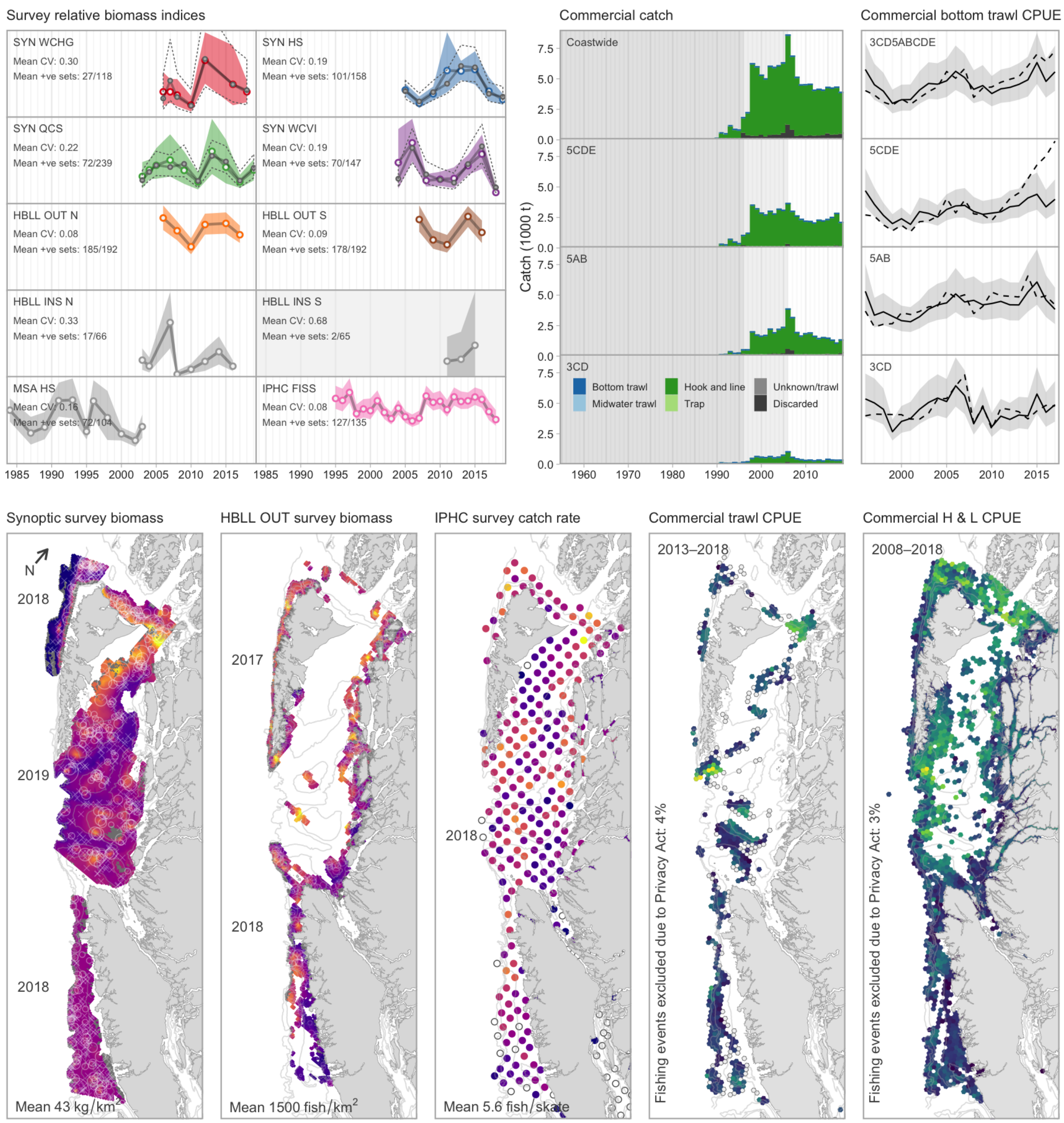
Hippoglossoides elassodon (612)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS

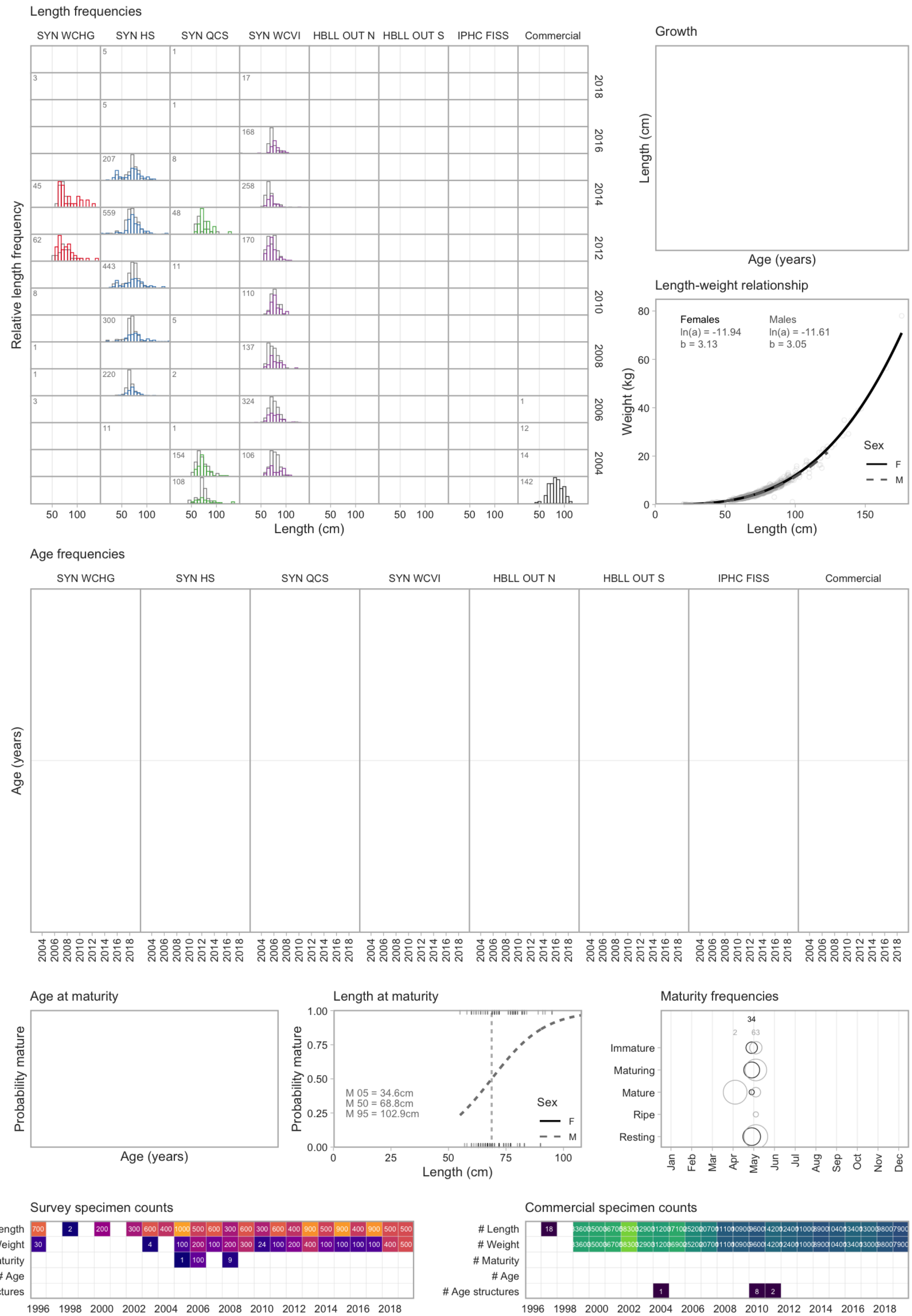



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Females
k = 0.37
linf = 33.9
t0 = 1.05
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -12.10
b = 3.14
Males
ln(a) = -11.99
b = 3.11
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
F 05 = 2.7y
F 50 = 4.9y
F 95 = 7.0y
Probability mature
Age (years)
Length at maturity
F 05 = 20.3cm
F 50 = 28.0cm
F 95 = 35.7cm
M 05 = 16.1cm
M 50 = 22.4cm
M 95 = 28.6cm
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.104 PACIFIC HALIBUT

Hippoglossus stenolepis (614)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS
IPHC Report of Assessment and Research Activities: IPHC (2017)
Note that Pacific Halibut undergoes thorough assessment by the International Pacific Halibut Commission based on the annual standardized setline survey. The most recent stock assessment should be consulted for details on stock status.

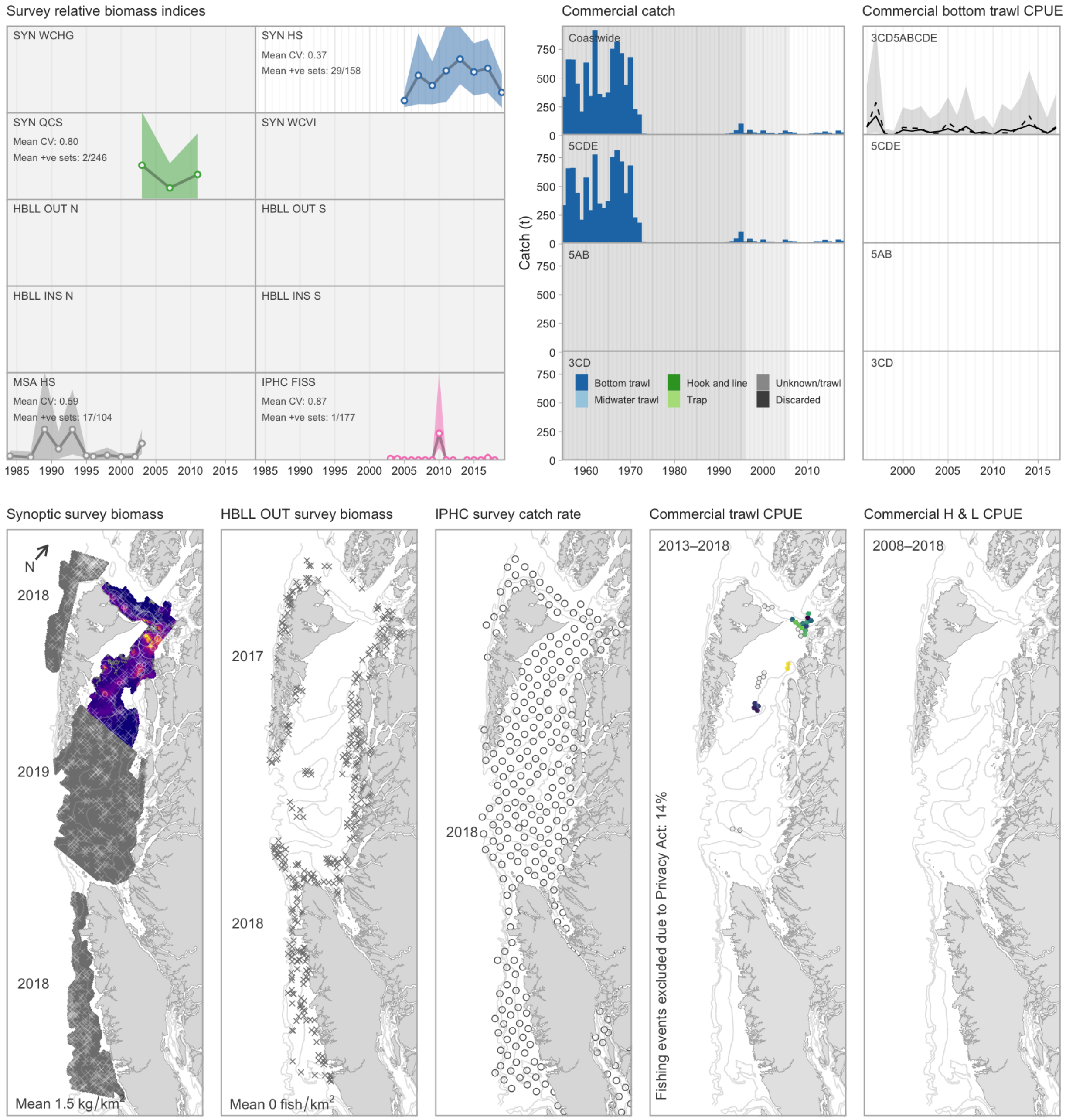


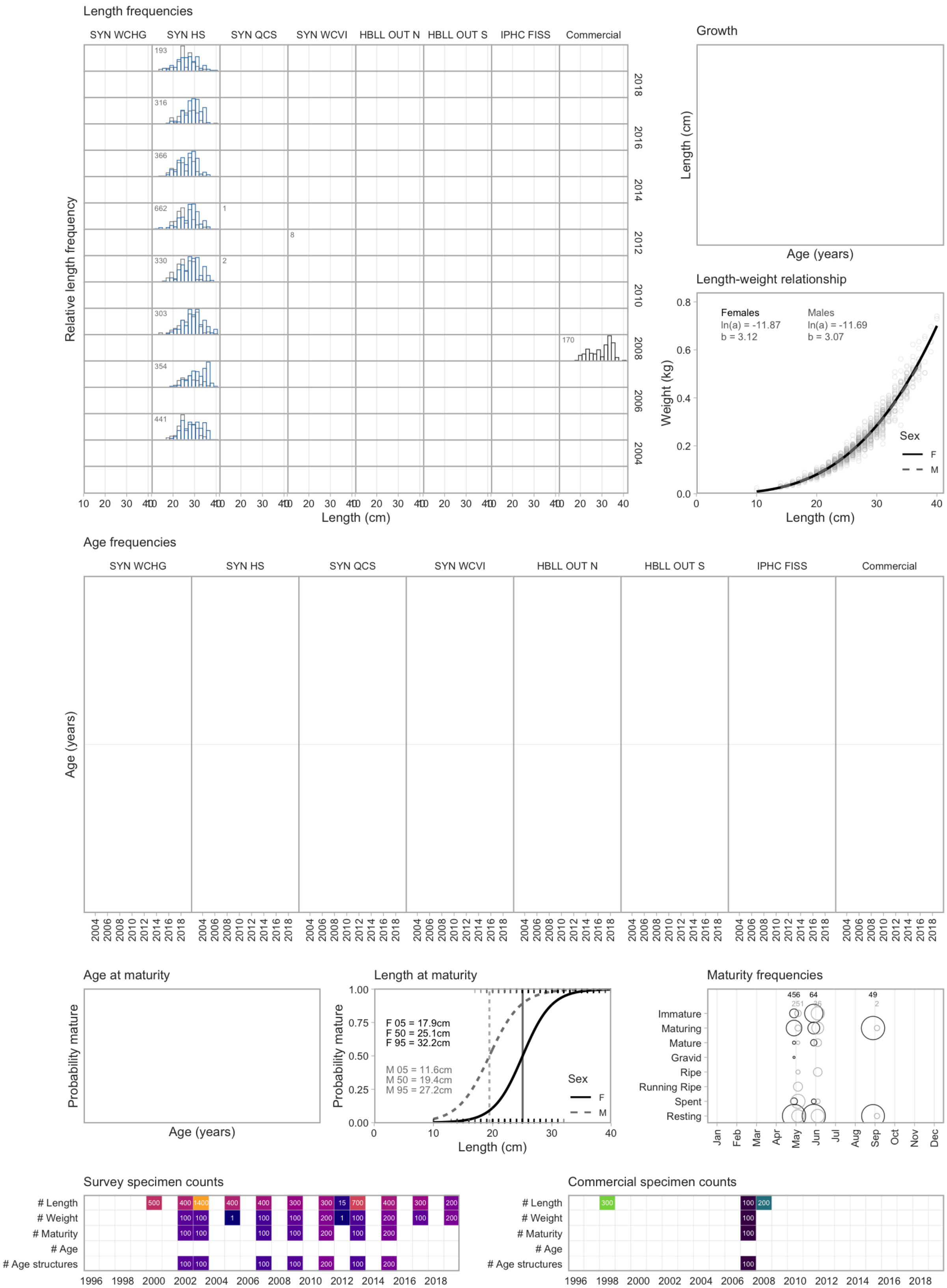


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.94
b = 3.13
Males
ln(a) = -11.61
b = 3.05
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
M 05 = 34.6cm
M 50 = 68.8cm
M 95 = 102.9cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Ripe
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.105 BUTTER SOLE

Isopsetta isolepis (619)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS

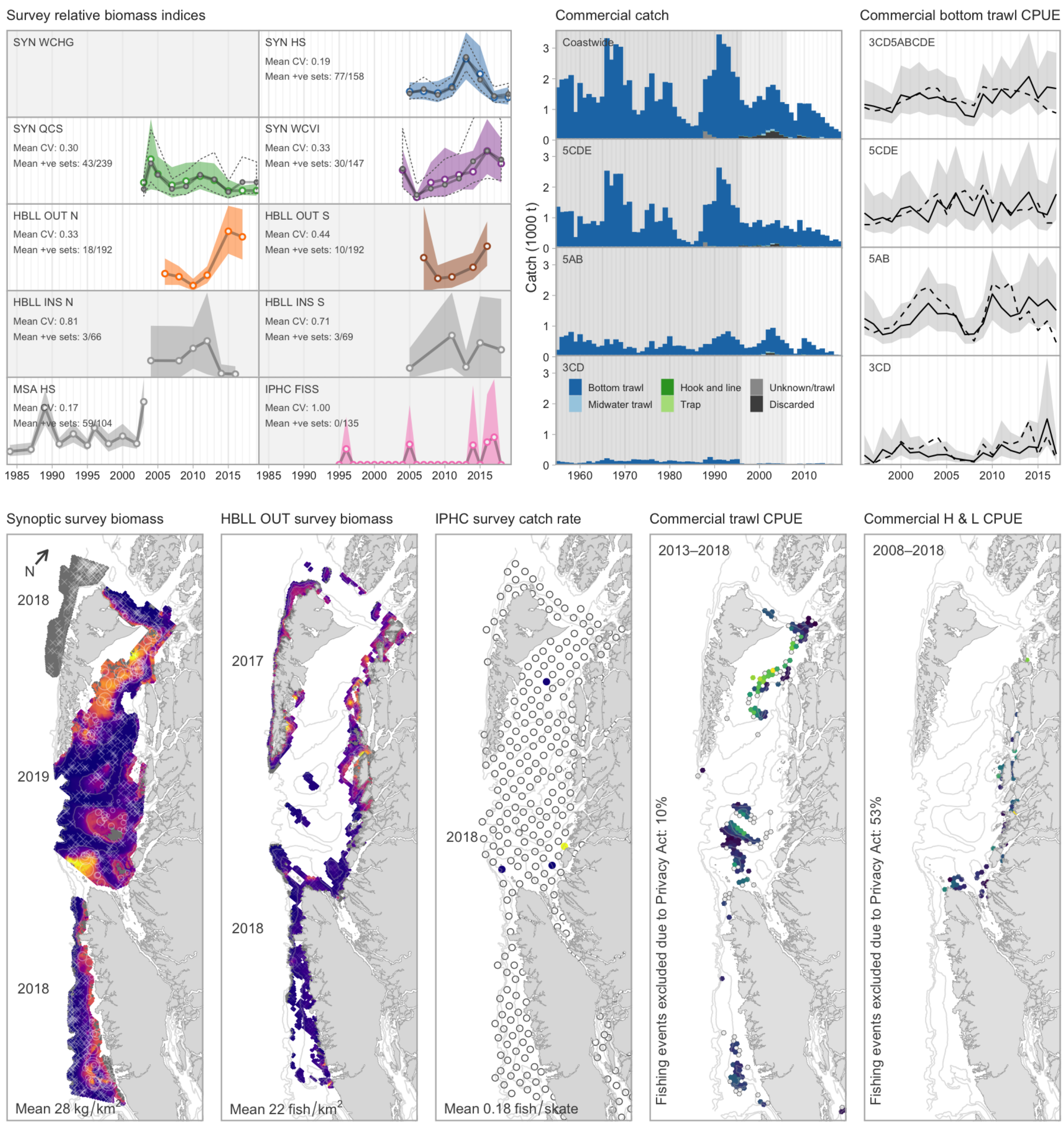


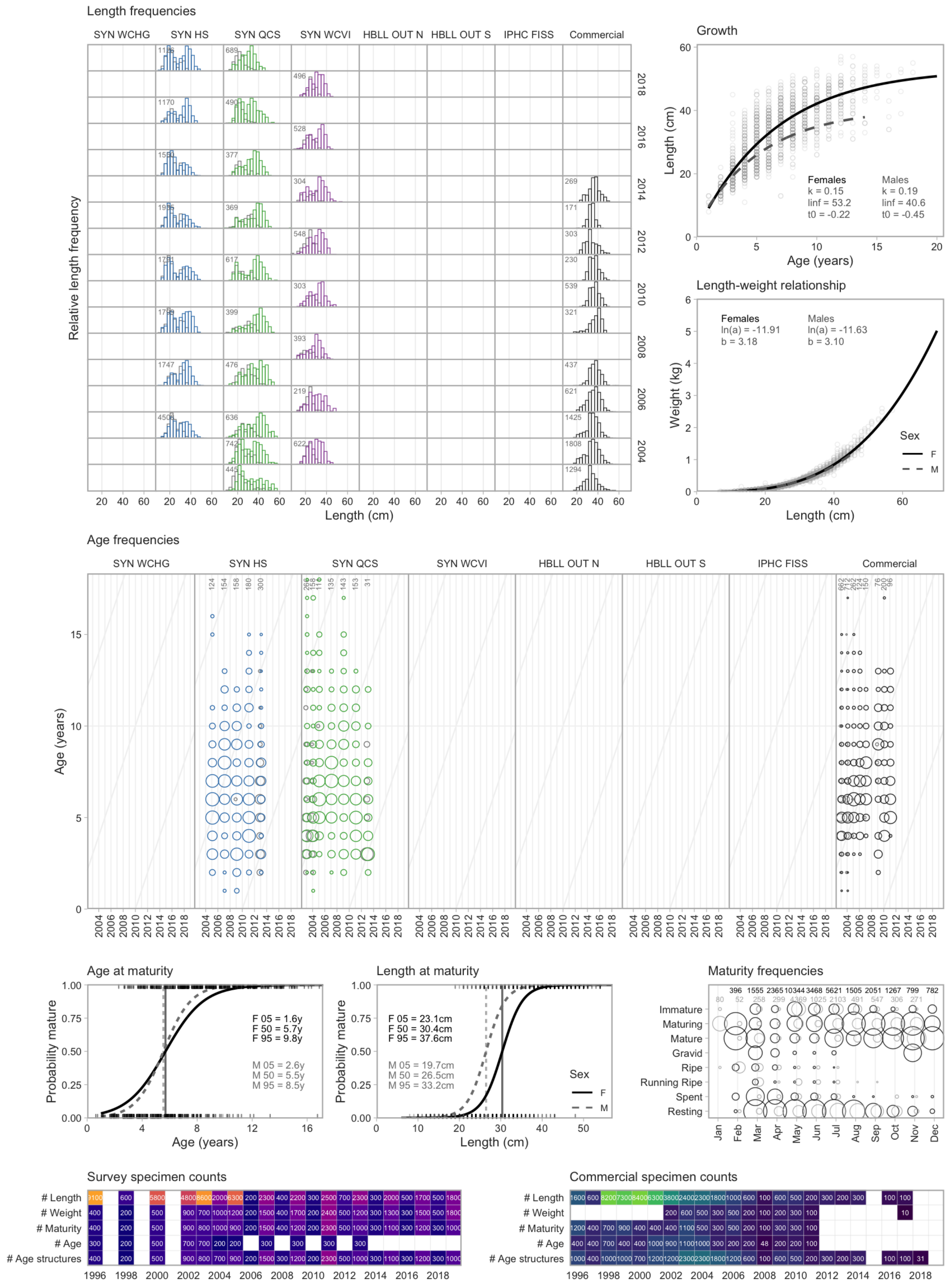


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.87
b = 3.12
Males
ln(a) = -11.69
b = 3.07
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 17.9cm
F 50 = 25.1cm
F 95 = 32.2cm
M 05 = 11.6cm
M 50 = 19.4cm
M 95 = 27.2cm
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.106 SOUTHERN ROCK SOLE

Lepidopsetta bilineata (621)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS
Last Research Document: Holt et al. (2016b)
Last Science Advisory Report: DFO (2014c)

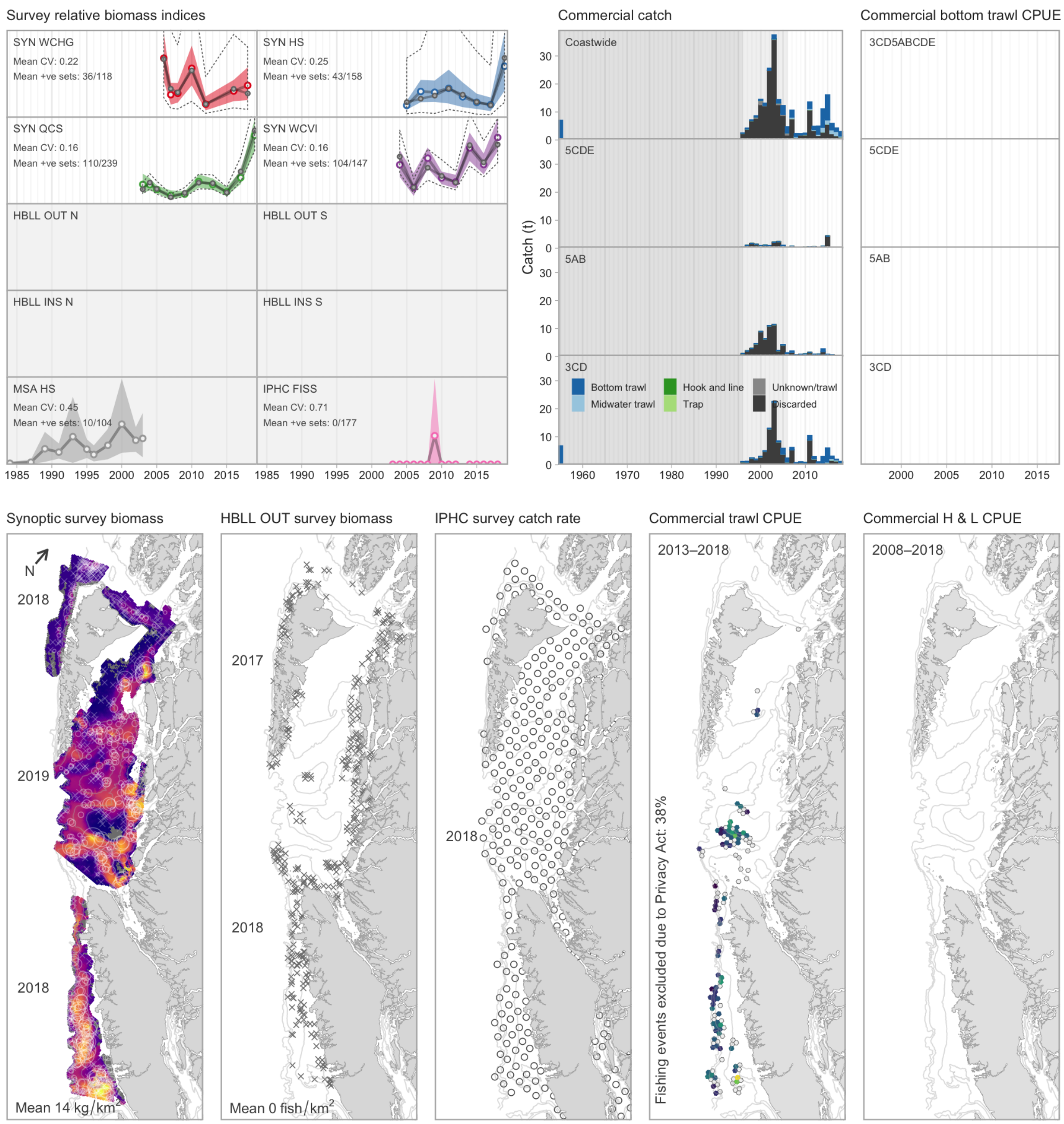


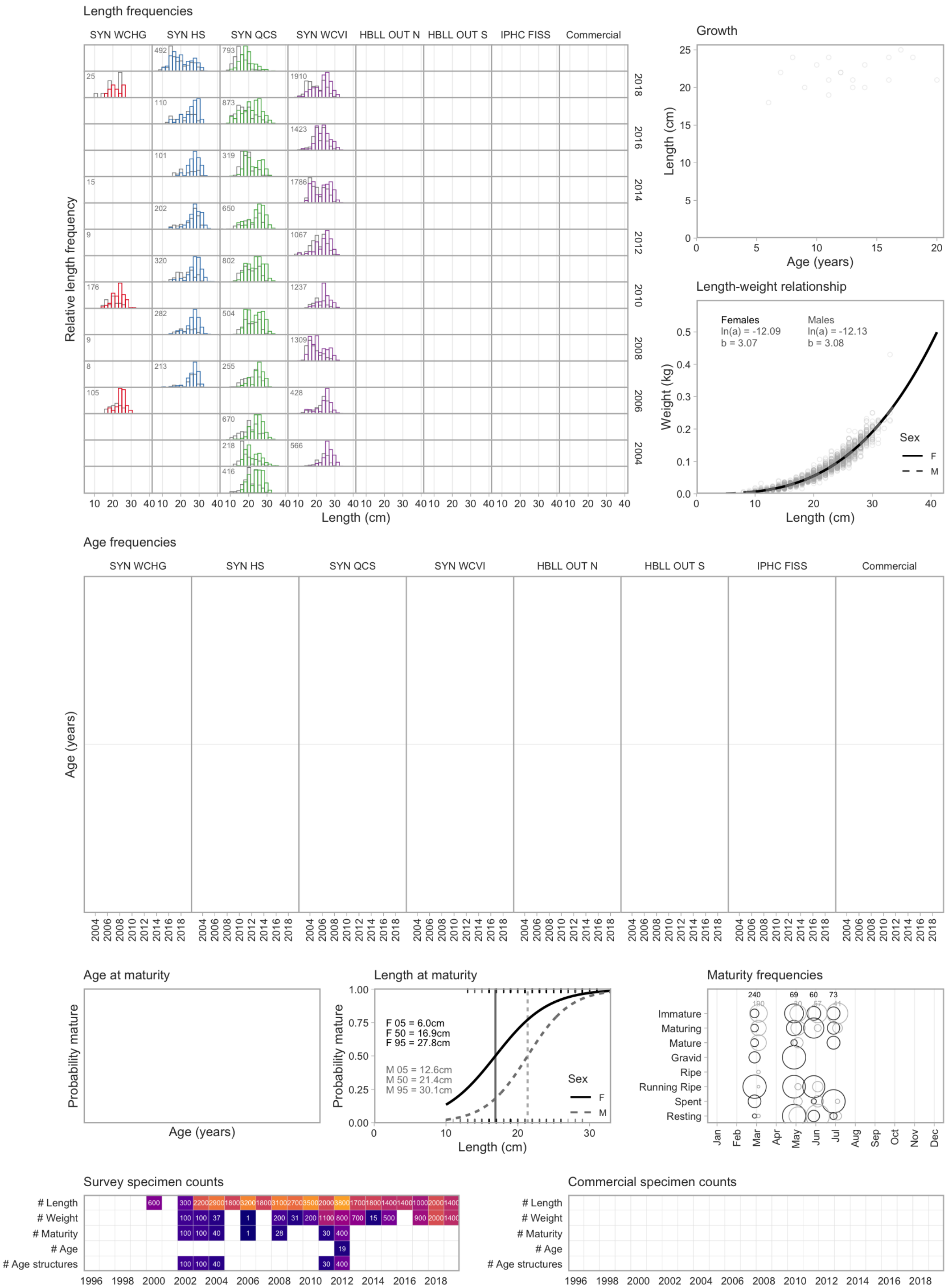


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.15
linf = 53.2
t0 = -0.22
Males
k = 0.19
linf = 40.6
t0 = -0.45
Length-weight relationship
Females
ln(a) = -11.91
b = 3.18
Males
ln(a) = -11.63
b = 3.10
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 1.6y
F 50 = 5.7y
F 95 = 9.8y
M 05 = 2.6y
M 50 = 5.5y
M 95 = 8.5y
Length at maturity
Probability mature
Length (cm)
F 05 = 23.1cm
F 50 = 30.4cm
F 95 = 37.6cm
M 05 = 19.7cm
M 50 = 26.5cm
M 95 = 33.2cm
Sex
F
M
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.107 SLENDER SOLE

Lyopsetta exilis (625)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS

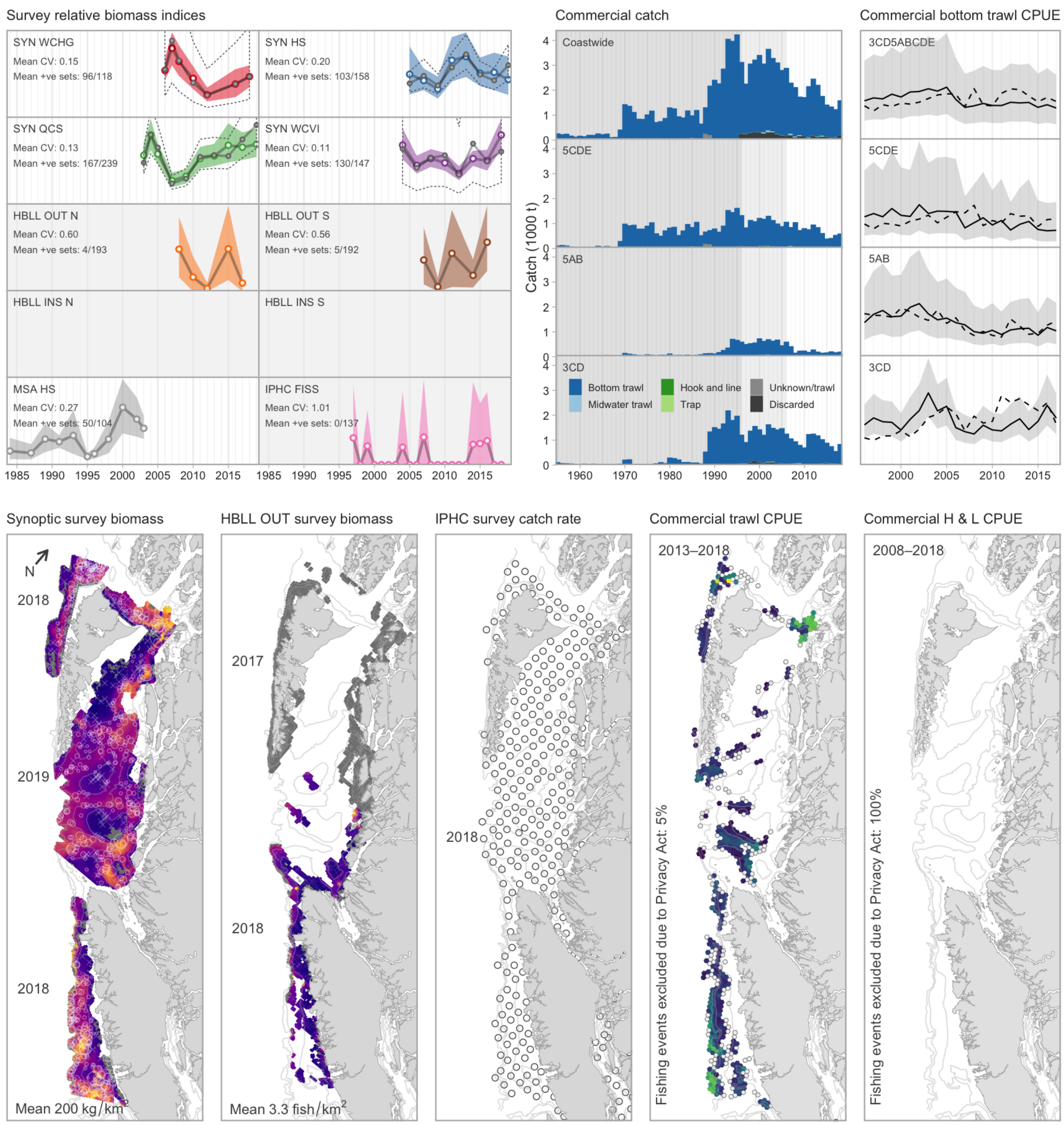


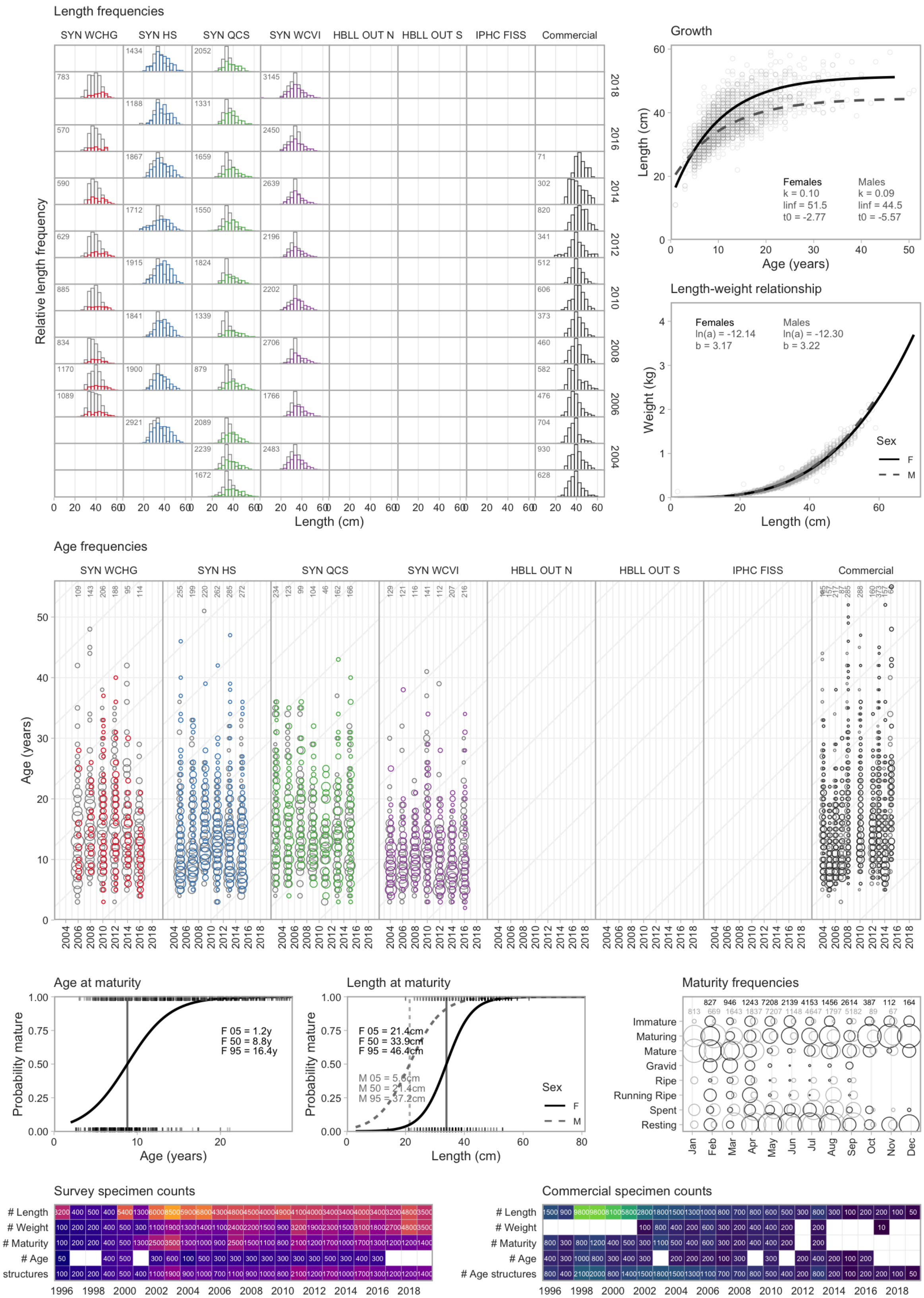


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -12.09
b = 3.07
Males
ln(a) = -12.13
b = 3.08
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 6.0cm
F 50 = 16.9cm
F 95 = 27.8cm
M 05 = 12.6cm
M 50 = 21.4cm
M 95 = 30.1cm
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.108 DOVER SOLE

Microstomus pacificus (626)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS
Last Science Advisory Report: DFO (1999d)

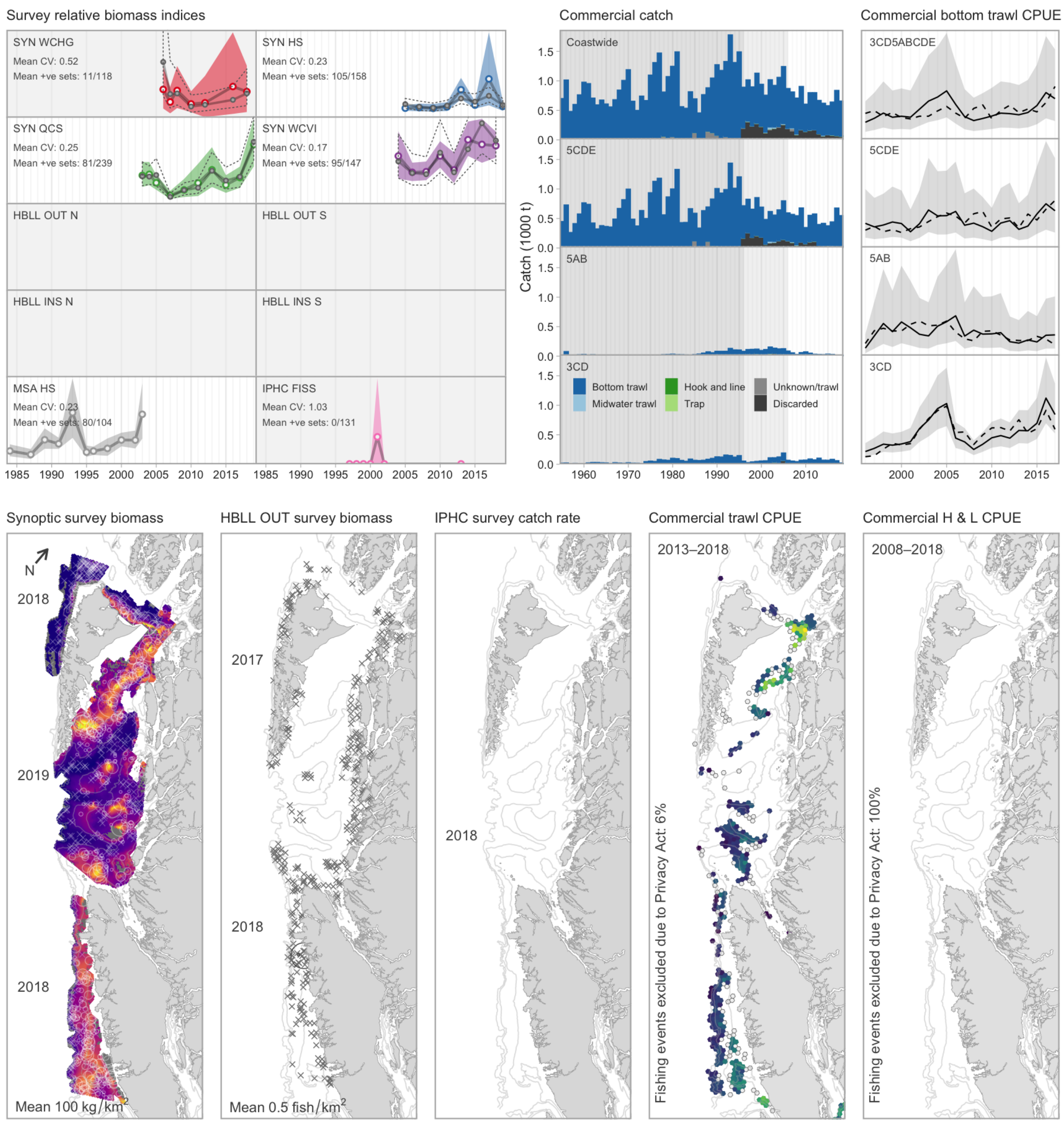


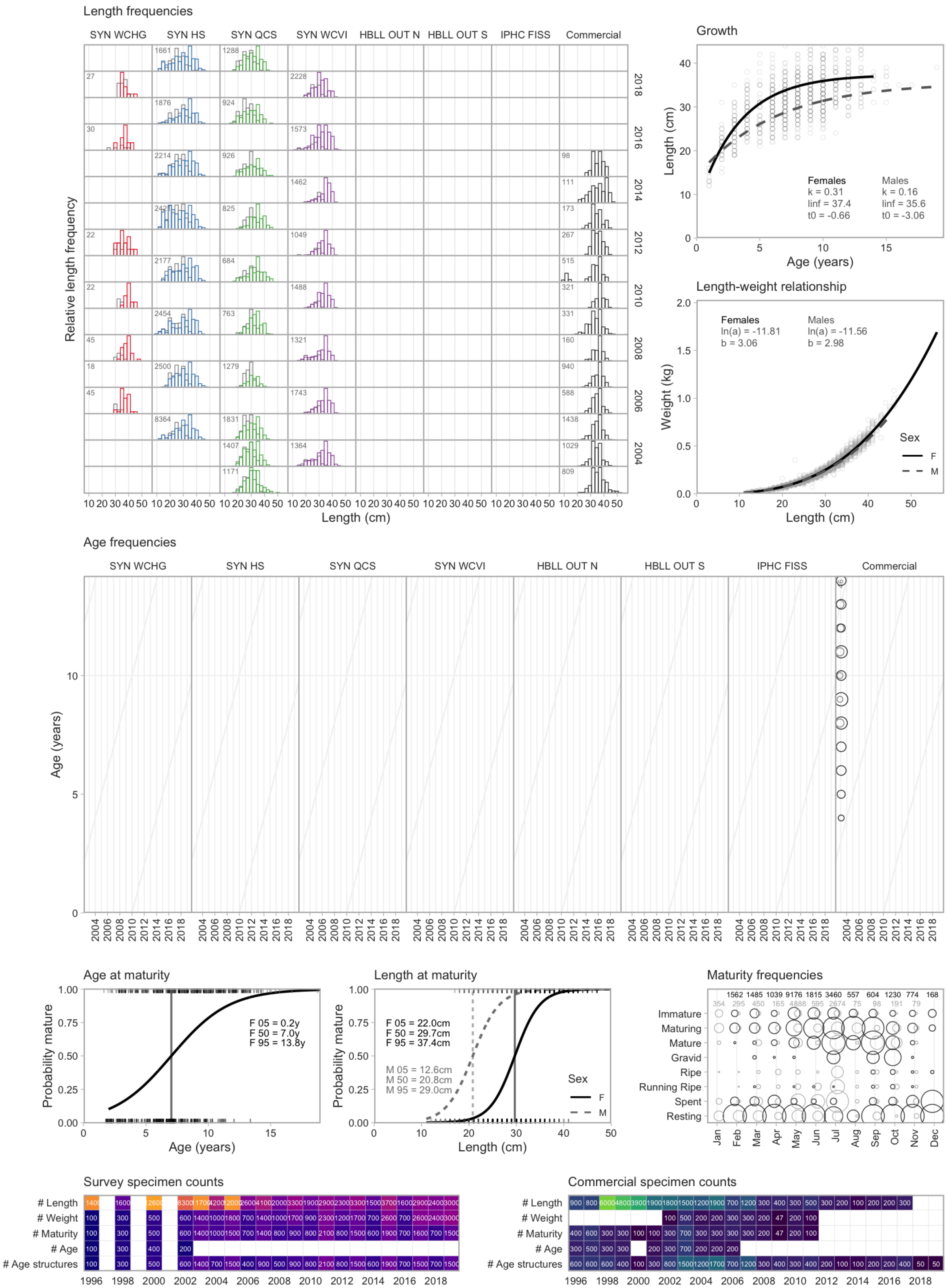


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.10
linf = 51.5
t0 = -2.77
Males
k = 0.09
linf = 44.5
t0 = -5.57
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -12.14
b = 3.17
Males
ln(a) = -12.30
b = 3.22
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 1.2y
F 50 = 8.8y
F 95 = 16.4y
Length at maturity
Probability mature
Length (cm)
F 05 = 21.4cm
F 50 = 33.9cm
F 95 = 46.4cm
M 05 = 5.6cm
M 50 = 21.4cm
M 95 = 37.2cm
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.109 ENGLISH SOLE

Parophrys vetulus (628)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS
Last Research Document: Starr (2009b)
Last Science Advisory Report: DFO (1999e)

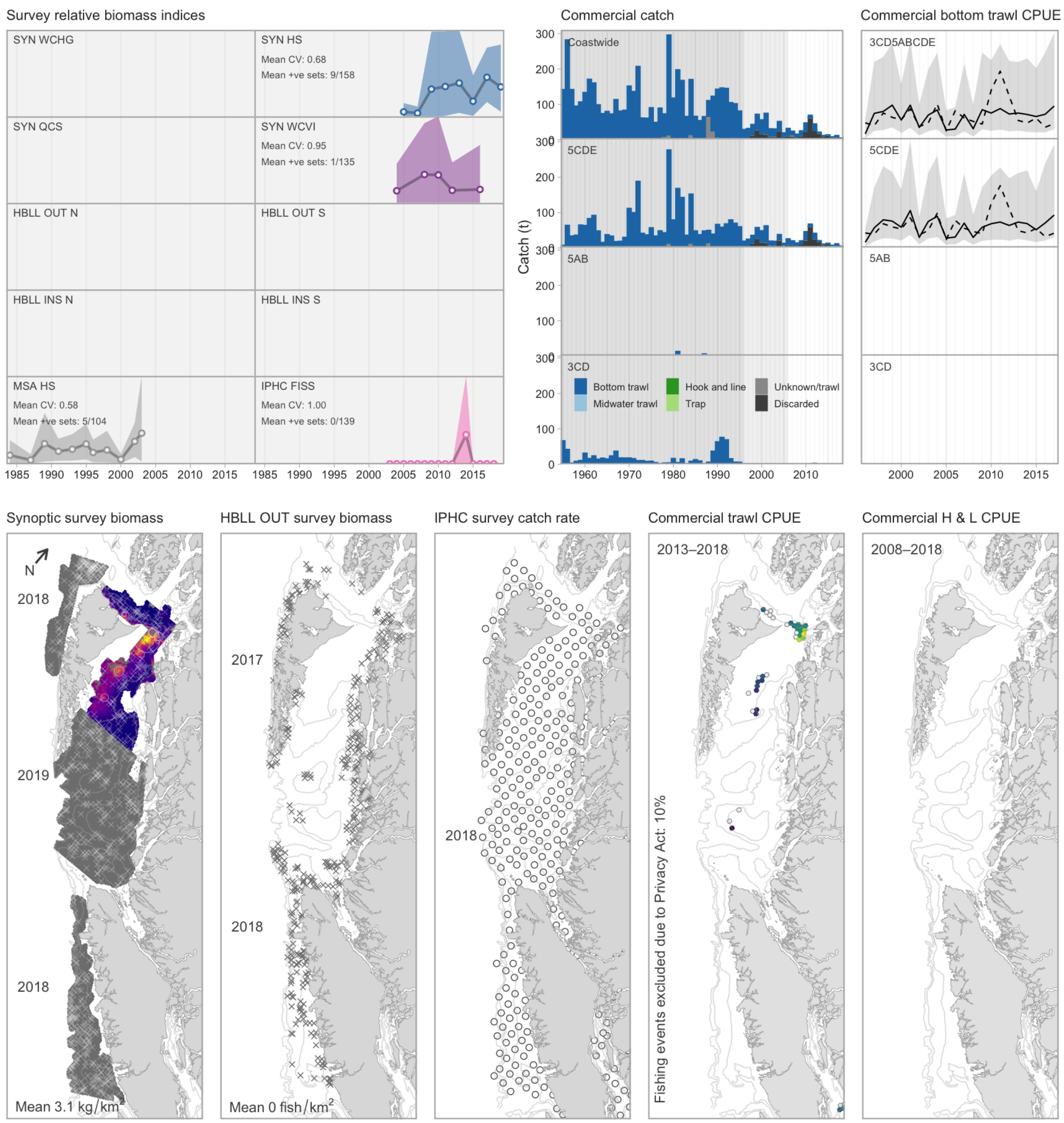


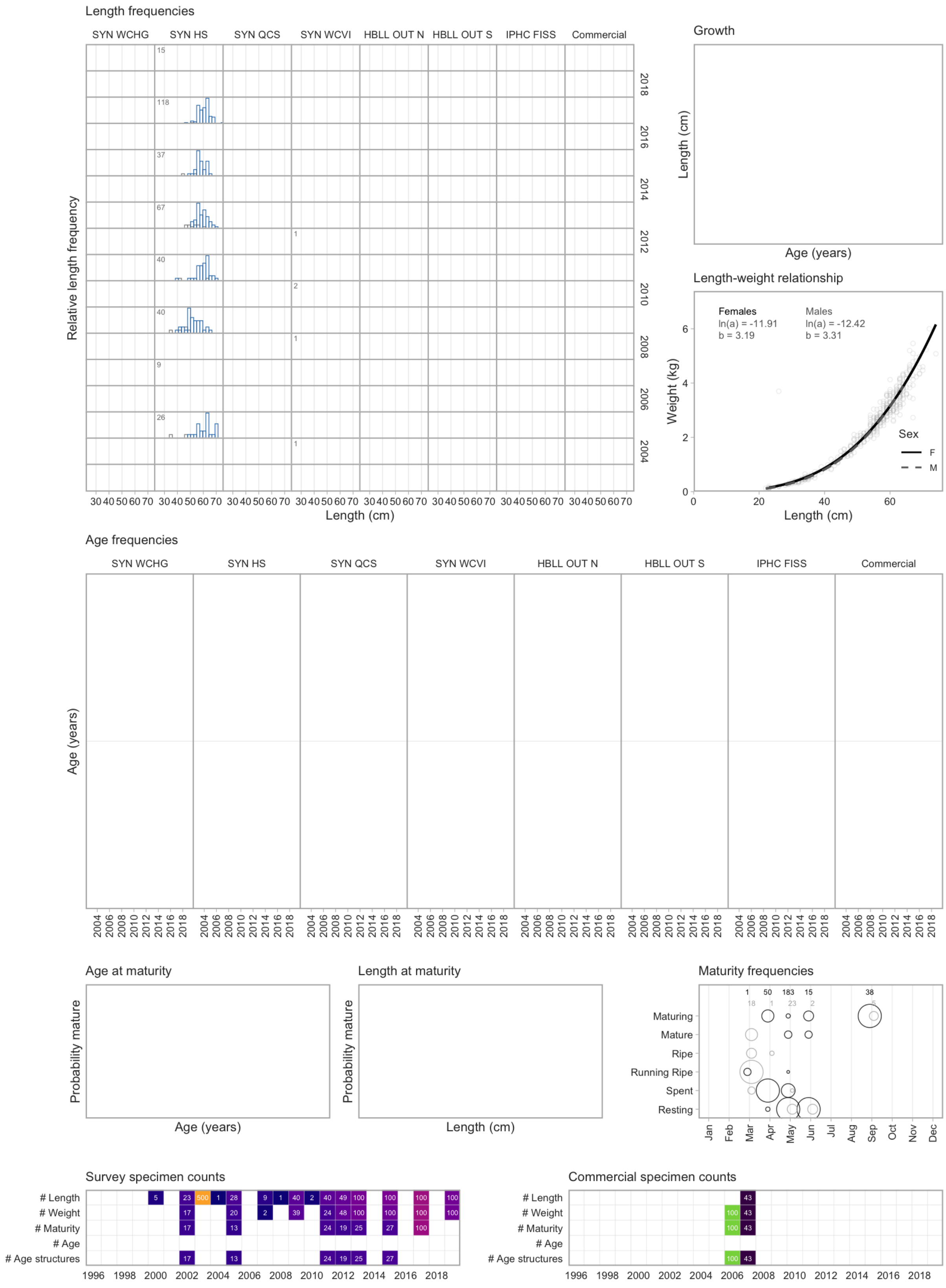


Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.31
linf = 37.4
t0 = -0.66
Males
k = 0.16
linf = 35.6
t0 = -3.06
Length-weight relationship
Weight (kg)
Length (cm)
Females
ln(a) = -11.81
b = 3.06
Males
ln(a) = -11.56
b = 2.98
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
F 05 = 0.2y
F 50 = 7.0y
F 95 = 13.8y
Length at maturity
Probability mature
Length (cm)
F 05 = 22.0cm
F 50 = 29.7cm
F 95 = 37.4cm
M 05 = 12.6cm
M 50 = 20.8cm
M 95 = 29.0cm
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.110 STARRY FLOUNDER

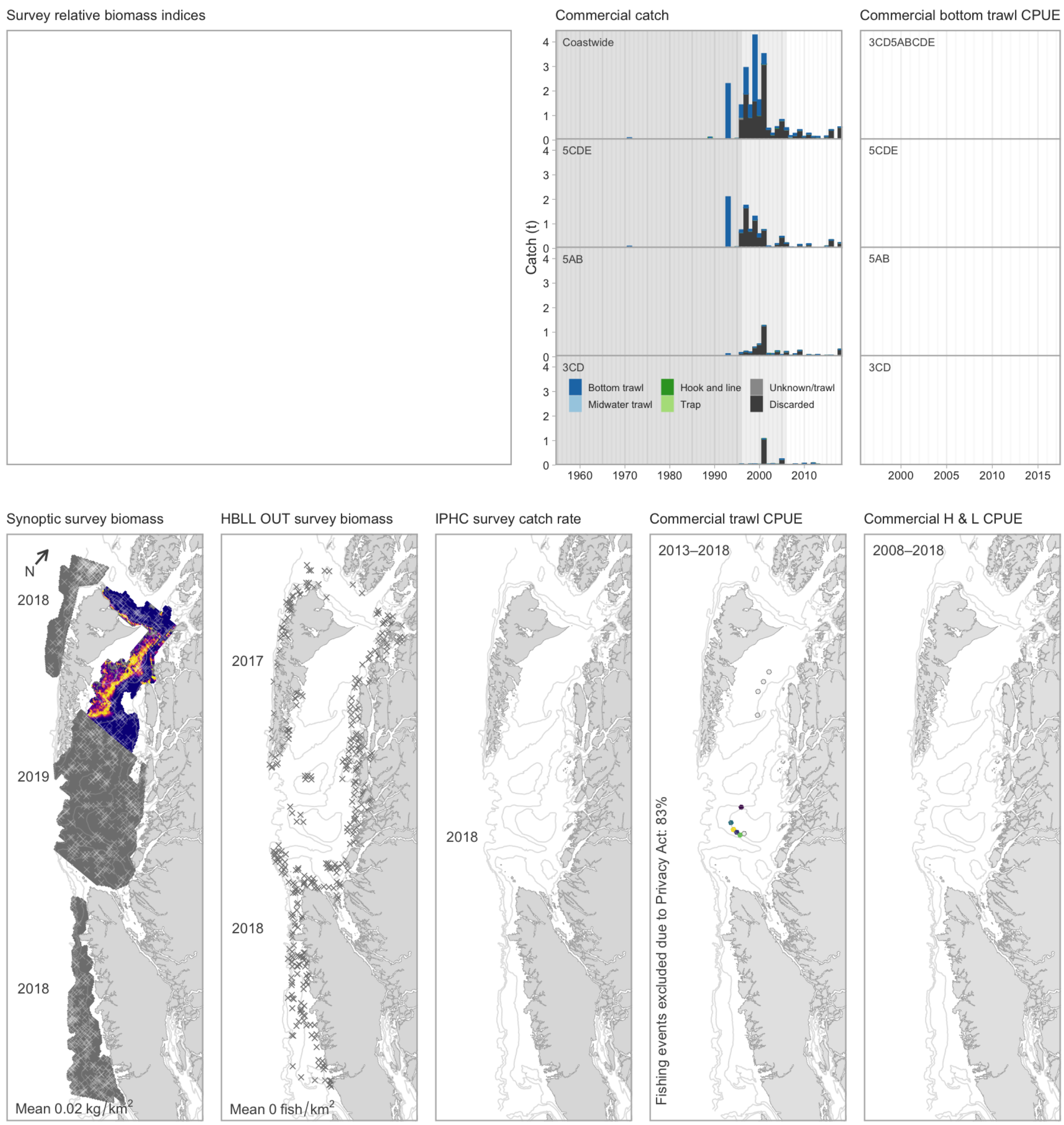
Platichthys stellatus (631)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS

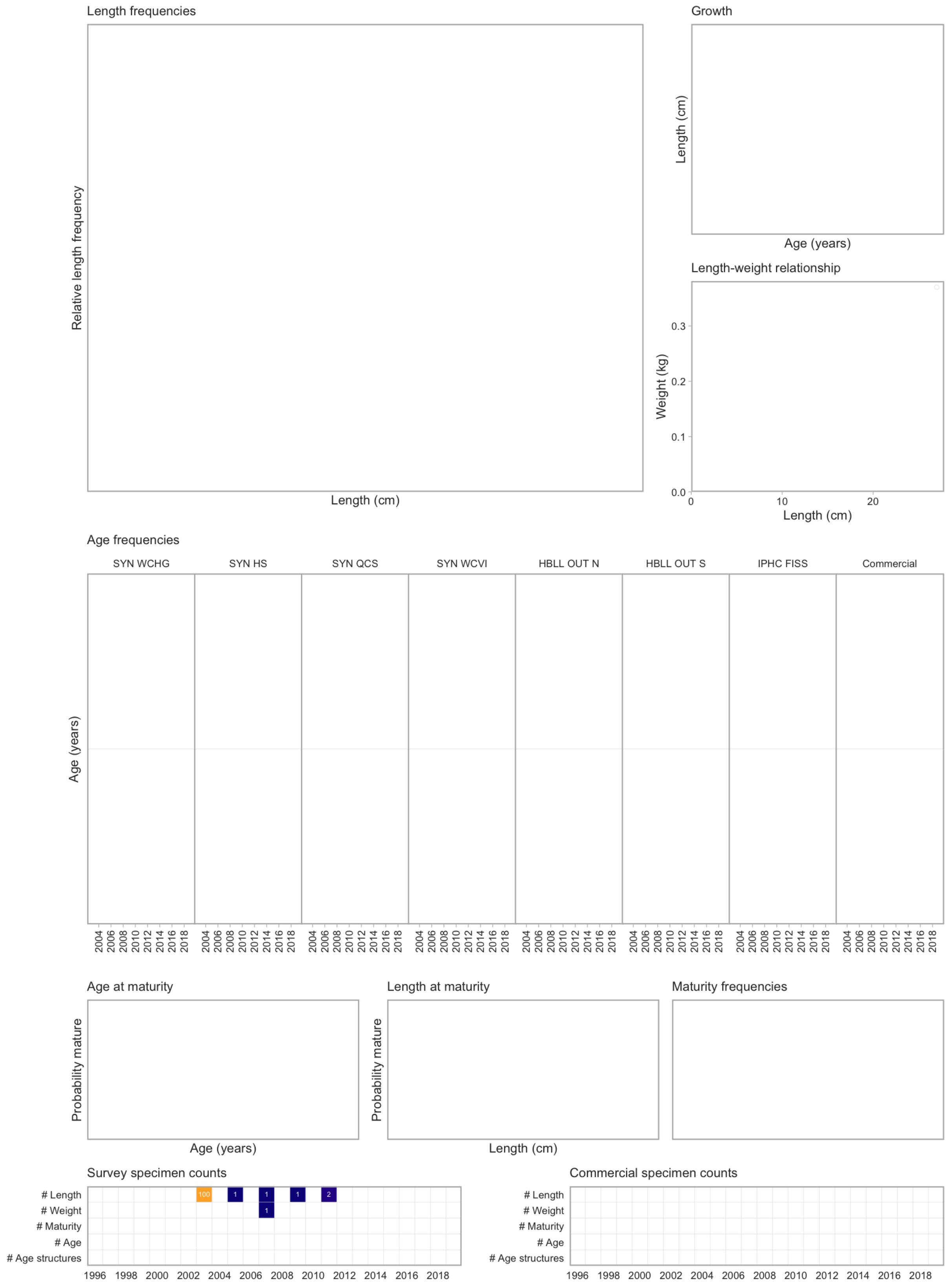



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.91
b = 3.19
Males
ln(a) = -12.42
b = 3.31
Sex
F
M
Weight (kg)
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Maturing
Mature
Ripe
Running Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

5.111 C-O SOLE

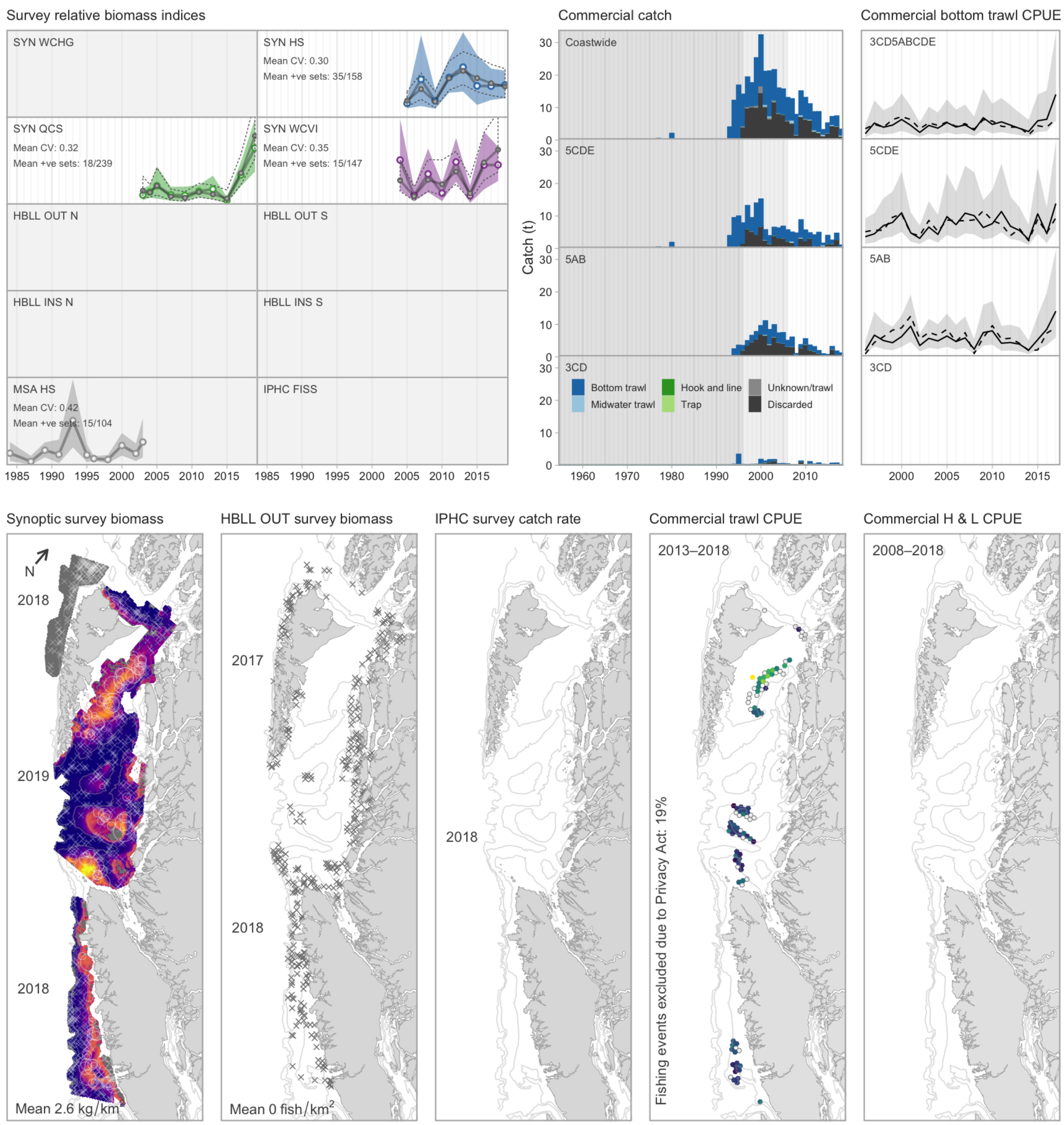
Pleuronichthys coenosus (633)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS

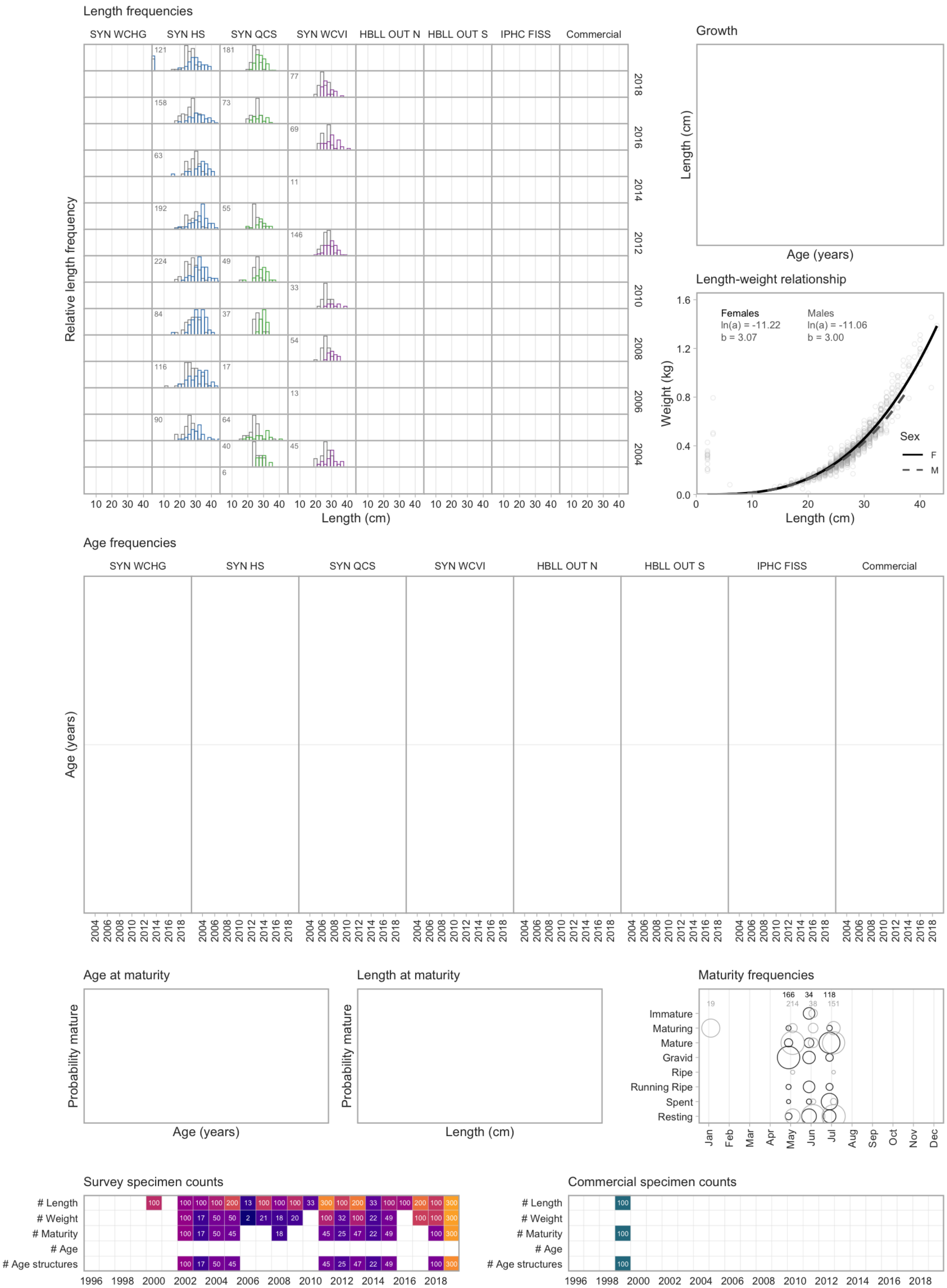



Length frequencies
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Weight (kg)
0.0
0.1
0.2
0.3
0
10
20
Length (cm)
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
2004 2006 2008 2010 2012 2014 2016 2018
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
100
1
1
1
2
1
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

5.112 CURLFIN SOLE

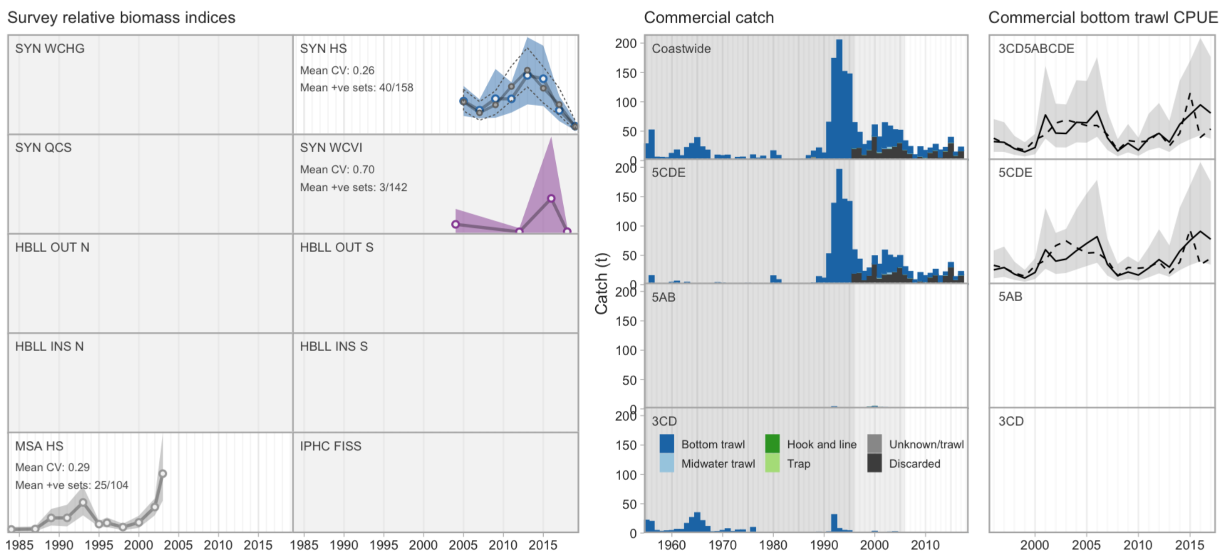
Pleuronichthys decurrens (635)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS

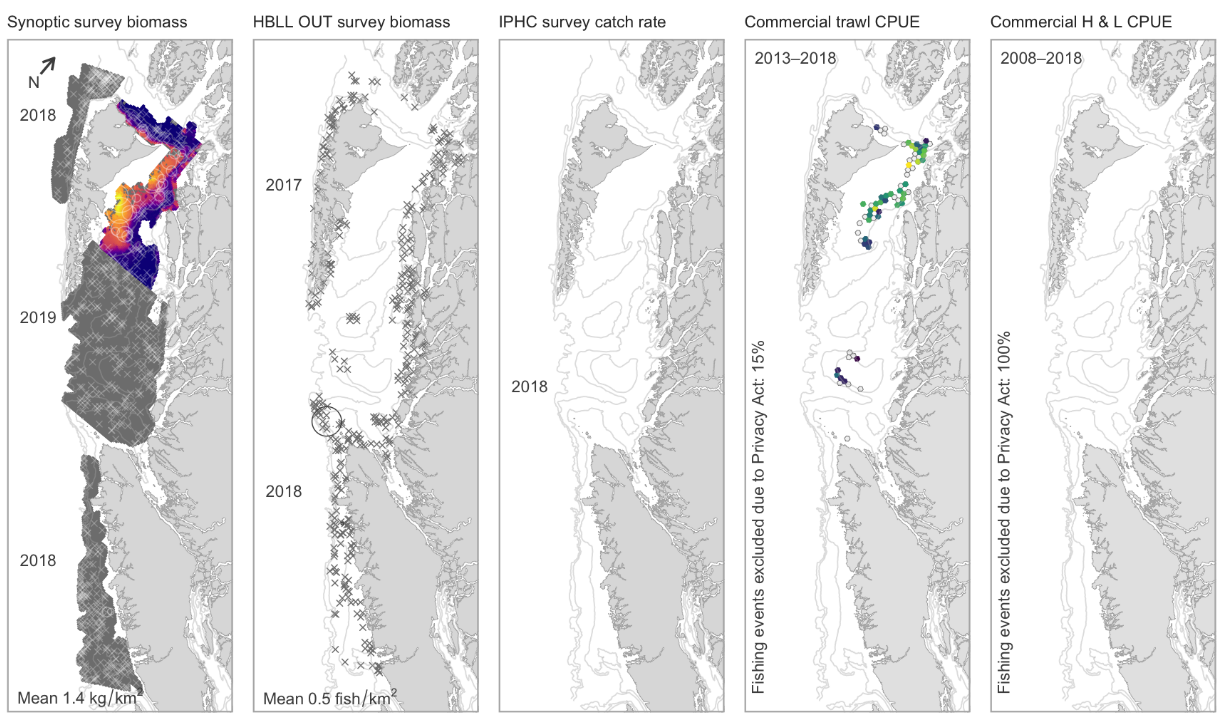


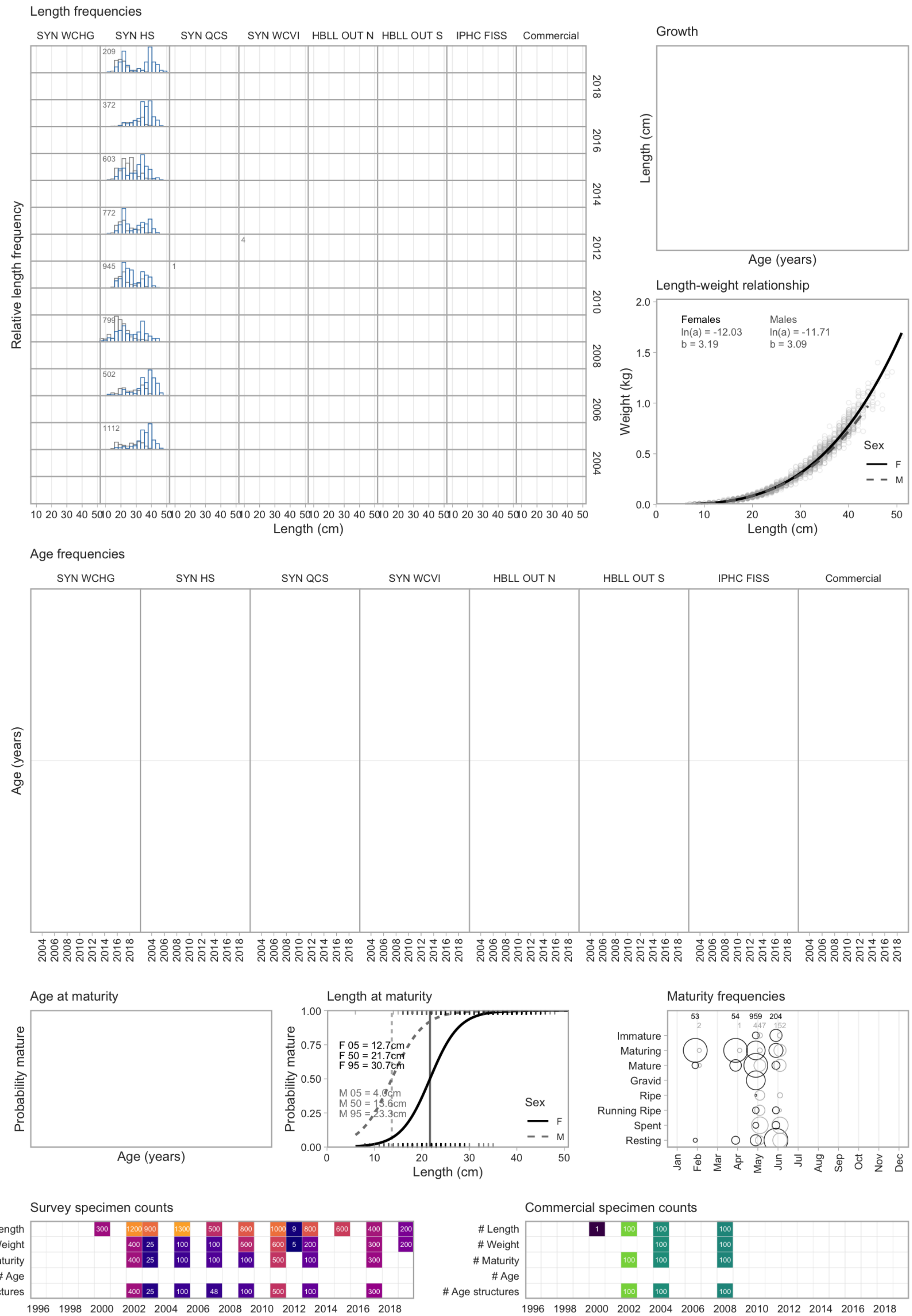

Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -11.22
b = 3.07
Males
ln(a) = -11.06
b = 3.00
Weight (kg)
Sex
F
M
Length (cm)
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts

5.113 SAND SOLE

Psettichthys melanostictus (636)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase, WoRMS







Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Length-weight relationship
Females
ln(a) = -12.03
b = 3.19
Males
ln(a) = -11.71
b = 3.09
Weight (kg)
Length (cm)
Sex
F
M
Age frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 12.7cm
F 50 = 21.7cm
F 95 = 30.7cm
M 05 = 4.0cm
M 50 = 13.6cm
M 95 = 23.3cm
Sex
F
M
Probability mature
Length (cm)
Maturity frequencies
Immature
Maturing
Mature
Gravid
Ripe
Running Ripe
Spent
Resting
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Survey specimen counts
Length
Weight
Maturity
Age
Age structures
Commercial specimen counts
Length
Weight
Maturity
Age
Age structures

6 ACKNOWLEDGEMENTS

We are grateful for the ongoing collaboration between DFO, commercial fishers, First Nations, and non-governmental organizations, which has made possible the collection of the valuable data that underlies this report. We thank the project's steering committee (Greg Workman, Robyn Forrest, Dana Haggarty, Chris Grandin, and Rob Kronlund) for invaluable input into the report design and feedback throughout its production. We thank Chris Rooper and Daniel Ricard for their thorough and helpful reviews. We thank Mary Thiess and Kieran Forge for chairing and rapporteuring the review meeting, respectively. We thank Christie Whelan for her support initiating this project. We thank Norm Olsen, Maria Surry, and Malcolm Wyeth for providing support on data extraction and general database structure and content. We thank the participants of the peer review meeting on tiered approaches in May 2016 (DFO 2016a), which included a data scorecard by Norm Olsen, from which this report takes inspiration. We also thank Norm Olsen for his work on GFASTeR, from which this project takes inspiration and borrows some data queries. We thank Rowan Haigh for his work maintaining the PBSmapping and PBSdata R packages, and indeed the authors of all the R packages necessary to build this report (Appendix I).

APPENDIX A. AGEING PRECISION

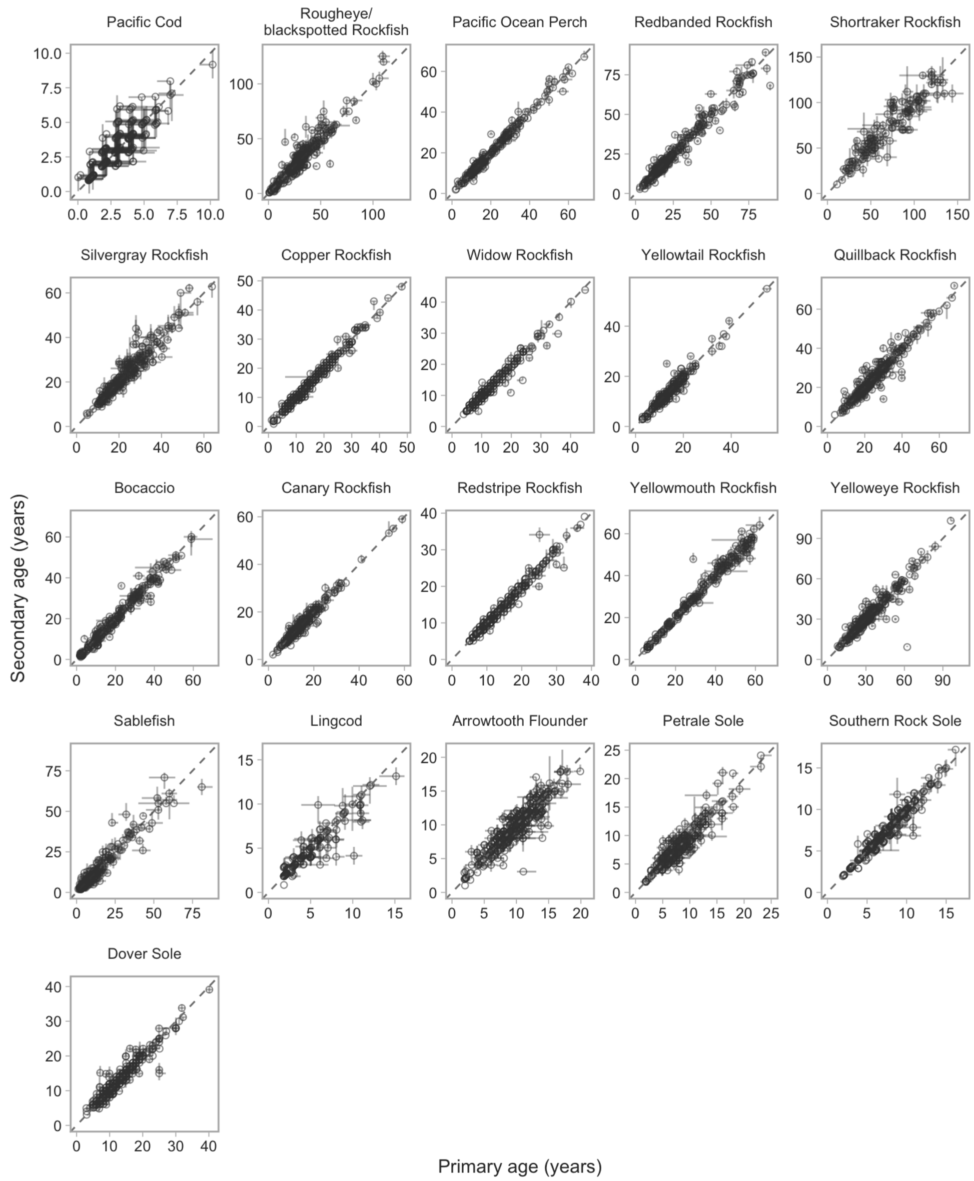


Figure A.1. Ageing precision plots for all species in the report with data. Each dot and cross-hatch represents an individual fish that has been aged twice. The x-axis represents the age and upper and lower possible ages recorded by the initial ('primary') individual ageing the fish. The y-axis represents the equivalent values recorded by the second ('precision') individual ageing the fish. The dashed diagonal line represents a perfect one-to-one agreement between the two ages. Up to 300 fish have been randomly sampled from all fish precision-aged for a species, and a small amount of random jitter has been added to both axes to reduce overplotting with the same jitter value added to both the x and y axes for a given fish.

APPENDIX B. RELATIONSHIPS BETWEEN FISH SURVEY DENSITY AND DEPTH

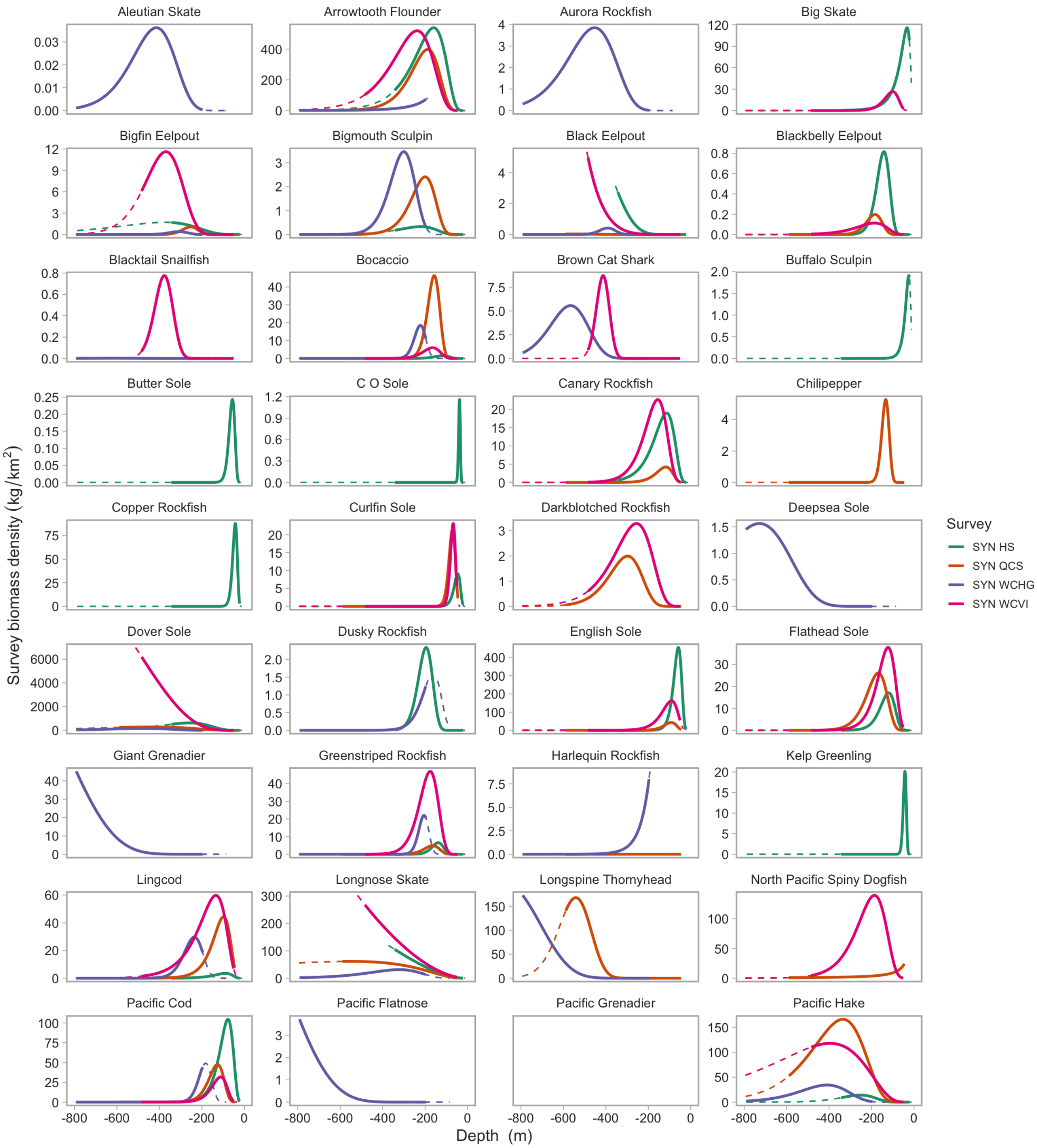


Figure B.1. Predicted relationships between depth and biomass density for all species across the four synoptic surveys (Part 1 of 2). Solid lines indicate relationships predicted within the depth range of the survey and dashed lines indicate extrapolated relationships beyond the observed depth. These relationships are derived from the depth coefficients in the spatial models that generate the map plots (e.g., Figure 5). These plots provide a visual indication of which surveys encompass the entirety of the depth distribution for particular species. See Appendix E for details on the models underlying these predictions.

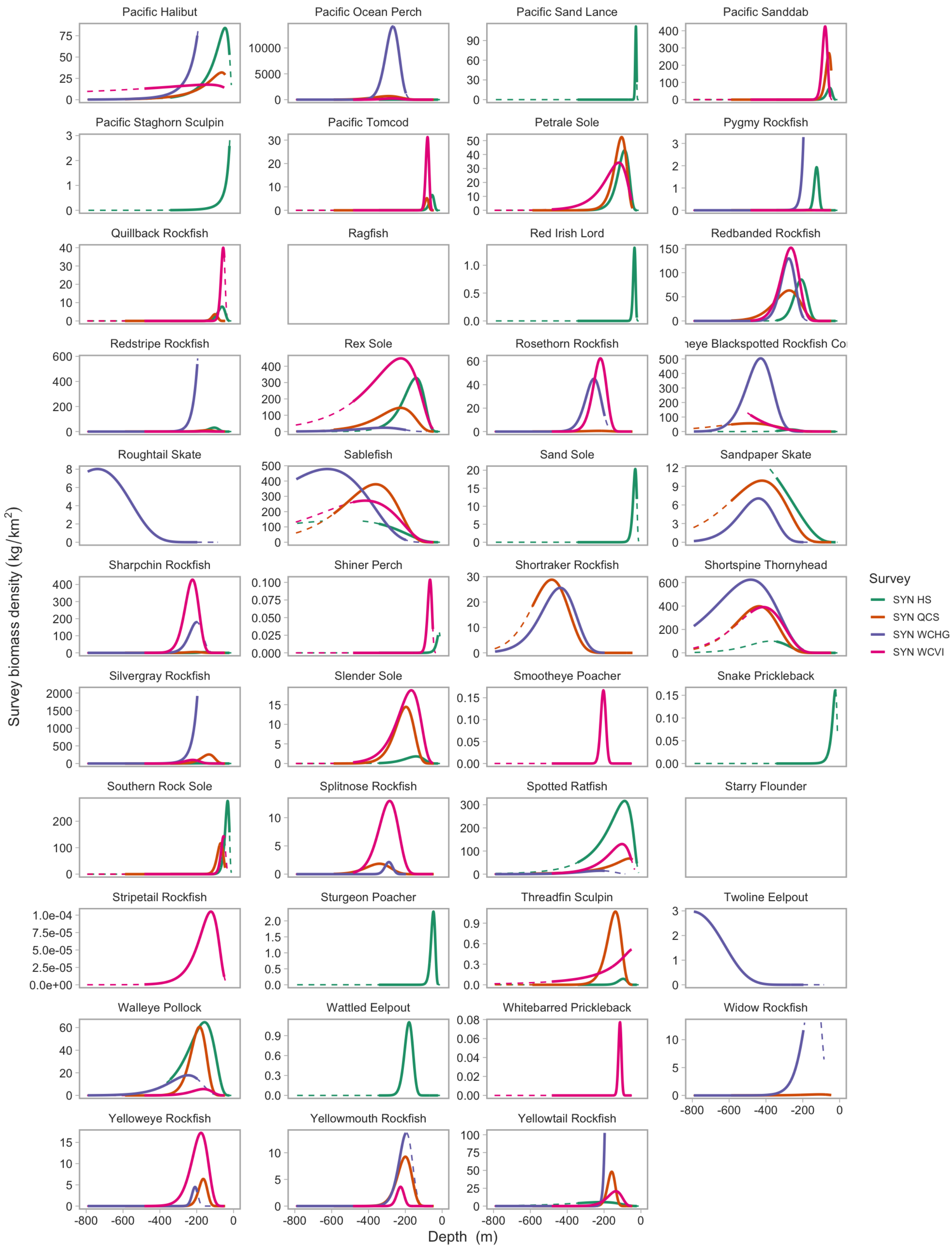


Figure B.2. Part 2 of Figure B.1. Caption is the same otherwise.

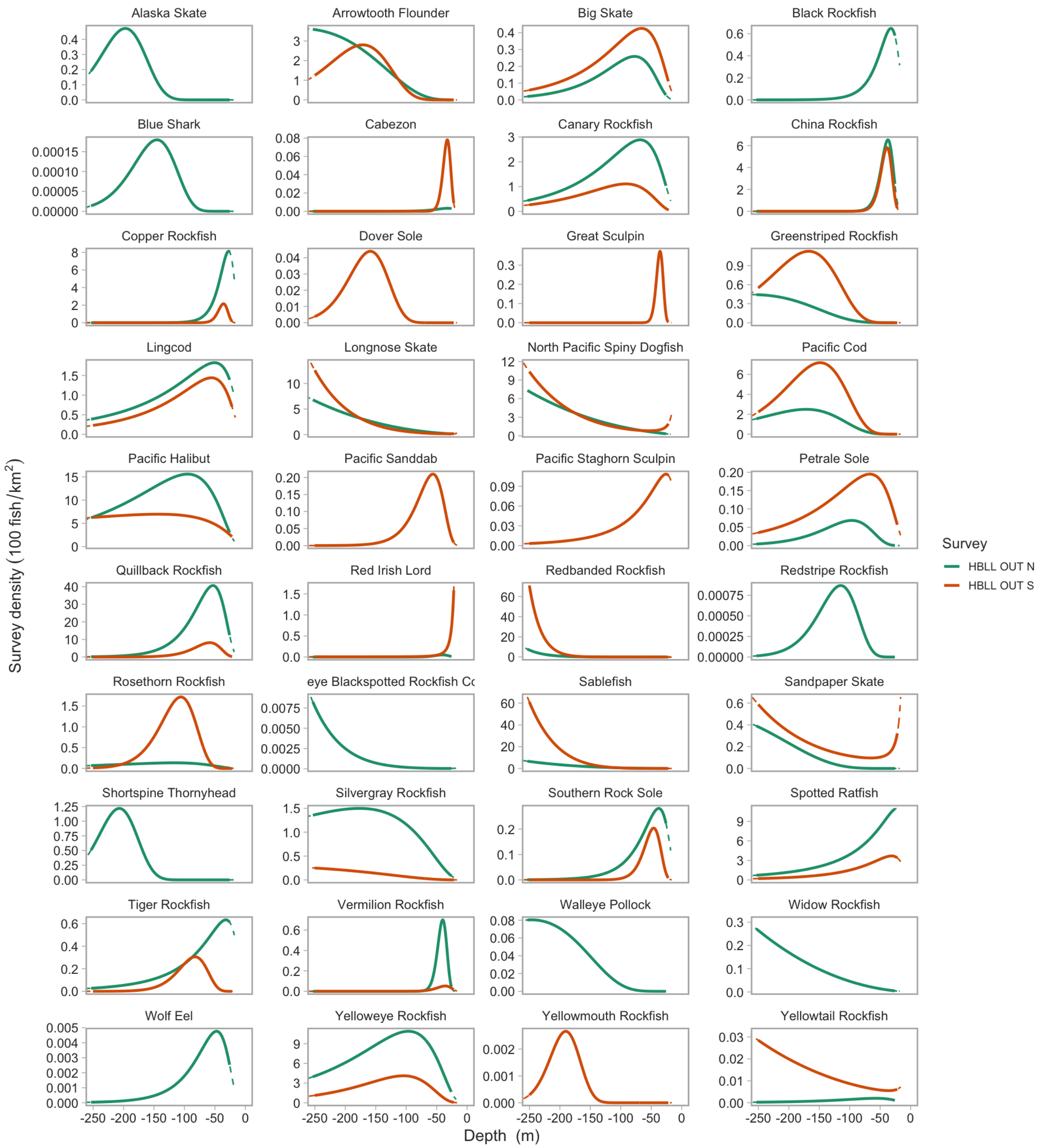


Figure B.3. Same as Figure B.1 but for the outside hard bottom long line surveys. Caption is the same otherwise. Note that these panels do not extend as deep as the depths shown in Figures B.1 and B.2.

APPENDIX C. DATA SOURCES

Commercial and research catch, effort, and biological data for groundfish are archived by the Groundfish Data Unit (Fisheries and Oceans Canada, Science Branch, Pacific Region) and housed in a number of relational databases (DFO, Pacific Region Groundfish Data Unit 2019). Historical commercial catch and effort data from 1954–2006/2007 are housed in GFCatch, PacHarvest, PacHarvHL, and PacHarvSable, depending on the fishery and time period. Modern (2006/2007 to present) commercial catch data are housed in GFFOS, a groundfish-specific view of the Fishery Operations System (FOS) database (Fisheries and Oceans Canada, Fisheries and Aquaculture Management, Pacific Region). Research survey data and commercial biological data from the 1940s to present are housed in GFBio, the Groundfish Biological Samples database. Additional historical commercial sales slips records may exist from the Halibut, Sablefish and Dogfish-Lingcod fisheries in the PacHarv3 database. These additional data require more detailed analysis for inclusion in catch reconstructions and are not included in this report.

C.1 `GF_MERGED_CATCH` FOR COMMERCIAL CATCH AND EFFORT DATA

Commercial catch and effort data for the synopsis report and gfplot functions are sourced from the table `GF_MERGED_CATCH` in the GFFOS database. In each commercial database there is an official catch table that provides the best available estimate of landed catch per location by applying the proportion of catch per set or area to trip-level landing data. Since 2015, the official catch tables from the various databases have been merged together into `GF_MERGED_CATCH` to facilitate and standardize commercial data extraction.

Catch proportions are calculated from the most spatially detailed information available on how much of each species was harvested per set or per area. In most cases this will be catch reported in observer logs or fisher logs. Older data contain records where set-level information was rolled up, for example, by area (see Rutherford (1999) for details on how catch was recorded in databases). The proportions are applied to the best available information on how much of each species was harvested on a trip. In most cases this will be the landed weight as recorded by the Dockside Monitoring Program (DMP). Earlier harvest data are recorded from sales slips or observer or fisher logs (see Rutherford (1999) for details on data sources).

Below are details of how the official catch tables are created in each of the databases populating `GF_MERGED_CATCH`.

C.1.1 GFCATCH 1954–1995 (TRAWL AND TRAP)

Catch data are extracted by trip and separated by retained weights (recorded on sales slips/landing records) or discarded weights (no counts) using utilization codes in the view `vw_Total_Catch`. The landings and discards are combined with trip, event, area and vessel tables to present the catches with associated details: trip ID, fishing event ID, sector, gear, vessel, best date (trip end date), best depth (in preferential order: average depth, minimum depth, maximum depth), species, area, and latitude and longitude (from start if available, otherwise from end). Set (trawl tow or trap line) proportions of total landings are not calculated as most older data do not include set-level information from observer or fisher logs (data are rolled up by area). When source = 1 (trawl trip report) or 2 (trawl sales slip or landing record only), then the gear type is set to trawl. When source = 5 (trap trip report) or 6 (trap sales slip or landing record only), the gear type is set to trap.

C.1.2 PACHARVEST 1996–2007 (TRAWL ONLY)

In the PacHarvest database, retained catch weights are extracted from recorded on-board observer logs by hail-in number (usually representing a trip) and by set (trawl tow) to calculate the set proportion of total trip/hail-in catch. This proportion derived from the observer log data is then applied to the hail-in catch weights in dockside records to obtain a more accurate landed weight per set. These landings as well as retained weights from fisher logs are combined with trip level (as for GFCatch above) and set-level details to create the `D_Official_Catch` table for PacHarvest.

C.1.3 PACHARVSABLE 1996–2006 (TRAP AND HOOK AND LINE)

In PacHarvSable, the table `D_Merged_Catches` combines unique set numbers for each hail-in number with retained and discarded weights from fisher logs and landed weights from sales slips or dockside validation records. These catch data are combined with trip- and set-level data in the `D_Official_Catch` table with landed weight presenting landings or, if landings are not available, retained weights.

C.1.4 PACHARVHL 1985–2006 (HOOK AND LINE ONLY)

Catch data in PacHarvHL are combined with trip- and set-level data. Catch is recorded as the best of landed weight (sales slips or DMP records) or retained weight (fisher logs) and the source (either landed or retained) is indicated in the source column. Latitude and longitude records correspond to the beginning of a fishing event. The best available depth for the fishing event is given for each fishing event as, in preferential order, the average of the start and end depths, average of the minimum and maximum depths, start depth, end depth, minimum depth, or maximum depth. The best available date is given as, in preferential order, the fishing event end date, the fishing event start date, or the trip end date.

C.1.5 GFFOS 2007–PRESENT (TRAWL, TRAP AND HOOK AND LINE)

To create the official catch table in GFFOS, first the average weight per piece (individual fish) is calculated for each species by trip for later populating catch weight where only catch count is available. DMP landings are extracted by trip. Catch is extracted from observer and fisher log data by trip and separated by released/retained, legal/sublegal, liced, and bait using utilization codes. Average kg per piece is calculated by species from DMP data as `ROUND_KG_PER_OFFLOAD_PIECE` = `OFFLOAD WT/OFFLOAD CT`. When this is not available for a trip, `ROUND_KG_PER_RETAINED_PIECE` is calculated by species from log data. If this too is not available, kg per piece by species is calculated for all `trips = EST_KG_PER_PIECE`. and fisher log 'retained catch' data are extracted by fishing event. If there is no retained weight recorded but there is a retained count, then `BEST_RETAINED_WT` is calculated as the retained count multiplied by the best available average kg per piece from, in preferential order, `ROUND_KG_PER_OFFLOAD_PIECE`, `ROUND_KG_PER_RETAINED_PIECE`, `EST_ROUND_KG_PER_PIECE`. Similarly, if there is no retained count recorded but there is a retained weight, then the retained weight is divided by the best available average weight per piece to give `BEST_RETAINED_COUNT`. Trip totals are then calculated for landed weight, retained catch weight, landed count, and retained catch count, and ratios are calculated for trip landed weight:trip retained catch weight and trip landed count:trip retained catch count.

All best retained, landed and discarded catch weights and counts are combined in one view, `GF_D_MERGED_FE_CATCH2_SUMRY_VW`. Where `LANDED_ROUND_KG` is `NULL` but retained weight is reported and a landed weight:retained catch weight ratio exists then landed weight is given as `BEST_RETAINED_ROUND_KG` × `MTFEC.KG_RATIO`. Similarly, if no landed count is reported, then `LANDED_COUNT` is given as `BEST_RETAINED_COUNT` × `MTFEC.COUNT_RATIO`.

All catch and landings weight and count data by fishing event are then joined with several other pieces of data by fishing event including vessel ID and name, data source, fishery sector, and area. Several fields present "best" data when there are multiple options. `BEST_DATE` is the offload date when there are fewer than 3 months difference between offload date and best available logbook date (in preferential order of fishing event best, end or start date, or trip best, end or start date); otherwise, it is the best available logbook date. `LATITUDE` and `LONGITUDE` are, in preferential order, the reported start latitude/longitude, mid-latitude/longitude or end latitude/longitude. `BEST_DEPTH` is calculated as the average of start and end depth and converted from fathoms to meters. These data are combined in the view `GF_D_OFFICIAL_FE_CATCH_VW2` with the additional fishing event or trip data generally obtained from observer logs, or from fisher logs when observer or validation logs are not available.

The official catch tables populate the `GF_MERGED_CATCH` table directly. Where there are duplicate records for a fishing event in GFFOS and either PacHarvHL or PacHarvSable, records from GFFOS are not incorporated into `GF_MERGED_CATCH`.

C.2 DATA EXTRACTION DETAILS

We developed a package gfplot for the statistical software R (R Core Team 2018) to automate data extraction from these databases in a consistent, reproducible manner. The functions extract data using SQL queries, developed with support from the Groundfish Data Unit, which select and filter for specific data depending on the purpose of the analysis. The SQL file names mentioned in this section can be viewed on GitHub and will be archived on a local server with the final version of this document.

C.2.1 COMMERCIAL CATCH DATA EXTRACTION

We extracted commercial catch with `get-catch.sql`. All landings and discards are extracted by species, fishery sector, gear type and year, and are not filtered in any further way.

We extracted commercial trawl catch and effort data (for later standardization) using `get-cpue-index.sql` and we filtered the data to include only records with valid start and end dates (Table C.1) which include set start and end time and are later used to calculate effort (expressed in hours). Catch (kg), year, gear type and Pacific Fishery Management Area (PFMA) are extracted for each tow. Gear type, PFMA and minimum year are given as arguments and are set at defaults of bottom trawl, all areas, and 1996, respectively.

Data were not filtered by success of tows, which is recorded in the database as undefined success, checked but unknown success, fully useable, malfunction/damage, lost gear, or water haul. This could be incorporated in future versions of the report.

We extracted commercial trawl spatial CPUE data using `get-cpue-spatial.sql`, pulling out latitude, longitude, gear type, catch (kg) and CPUE (total catch/ effort in kg/hour) for every tow by species. The data are filtered to extract only records with valid start and end dates, to remove records with erroneous latitude and longitude values, and to include only records from the

Table C.1. Description of filters in SQL queries extracting commercial trawl catch and effort data from `GFFOS.GF_MERGED_CATCH` with `get-cpue-index.sql`

Filters	Rationale
Filtered for `END_DATE IS NOT NULL` AND START_DATE `IS NOT NULL`	To remove records with missing dates
Filtered for `YEAR(FE_START_DATE) = YEAR(FE_END_DATE)` and `FE_END_DATE` > `FE_START_DATE`	To remove records with erroneous dates

groundfish trawl sector with positive tows since 2013 following the implementation of the trawl footprint in 2012 (Table C.2).

Table C.2. Description of filters in SQL queries extracting commercial trawl spatial catch per unit effort (kg/hr) from `GFFOS.GF_D_OFFICIAL_CATCH` with `get-cpue-spatial.sql`

Filters	Rationale
Filtered for `LAT` between 47.8 and 55 and `LON` between -135 and -122	To remove erroneous location records
Filtered for `YEAR(BEST_DATE)` greater than 2012	To extract only records since the trawl fishery footprint was established
Filtered for `YEAR(START_DATE) = YEAR(END_DATE)` and `END_DATE` > `START_DATE`	To remove records with erroneous dates
Filtered for `FISHERY_SECTOR` = `GROUNDFISH TRAWL`	To extract only records in the groundfish trawl fishery
Filtered for `ISNULL(LANDED_ROUND_KG,0) + ISNULL(TOTAL_RELEASED_ROUND_KG,0)` > 0	To extract only records with positive catch

We extracted commercial hook and line spatial CPUE data using `get-cpue-spatial-ll.sql`, which pulls out latitude and longitude, gear type, catch (pieces) and years for all fishing events (sets, as a unit of effort) by species. The data are filtered to extract only records with valid start and end dates, to remove records with erroneous latitude and longitude values, and to only include records with hook and line gear with non-zero catch. Data include all records since 2008 after implementation of the Integrated Groundfish Management Plan (Table C.3). CPUE is represented by landed catch in pieces per fishing event (set). Discards are not included in hook and line spatial CPUE because discarded pieces are not reliably recorded in all years. Species names are given as an argument to the gfplot function.

C.2.2 SURVEY CATCH DATA EXTRACTION

We extracted survey biomass index data `get-survey-index.sql`. Calculated bootstrapped biomass, year and survey series identification code (SSID) are filtered for active records of the

Table C.3. Description of filters in SQL queries extracting commercial hook and line spatial catch per unit effort (kg/set) from `GFFOS.GF_D_OFFICIAL_CATCH` with `get-cpue-spatial-ll.sql`

Filters	Rationale
Filtered for `LAT` between 47.8 and 55 and `LON` between -135 and -122	To remove erroneous location records
Filtered for `YEAR(BEST_DATE)` greater than or equal to 2008	To extract only records since 2008 after implementation of IFMP
Filtered for `YEAR(START_DATE) = YEAR(END_DATE)` and `END_DATE` > `START_DATE`	To remove records with erroneous dates
Filtered for `GEAR` IN `(HOOK AND LINE, LONGLINE, LONGLINE OR HOOK AND LINE)`	To extract only records in the hook and line fishery

calculated biomass in the database (Table C.4). Species and SSID codes are given as arguments to the gfplot function.

Table C.4. Description of filters in SQL queries extracting bootstrapped survey biomass index from `GFBio` with `get-survey-index`

Filters	Rationale
Filter for `ACTIVE_IND` 1	To extract only active (useable) bootstrapped index records

C.2.3 BIOLOGICAL DATA EXTRACTION

We extracted biological data using `get-survey-samples.sql` and `get-comm-samples.sql` for research survey and commercial samples, respectively. Records of all biological samples are extracted by species, including available length, weight, age and maturity data. Standard length measurements differ by species (for example, rockfish and Pacific cod length are recorded as the length to where the tail forks, while Pacific halibut and arrowtooth flounder are recorded as total length to the end of the tail. Spotted ratfish were filtered for only lengths recorded as from the snout to the end of the second dorsal fin, which is the standard as their tails are often damaged) as there were some specimens where total length was recorded.

Records include available metadata including PFMA, fishery, gear type, SSID and survey identification code (SID, only available for research survey data), survey sampling types, and sampling protocol codes for maturity and ageing data. Data are filtered by the `TRIP_SUBTYPE_CODE` to extract either survey (Table C.5) or commercial (Table C.6) samples.

Some survey or commercial catches are deemed unuseable for analysis. For example, when gear is lost, faulty or damaged or all or a portion of the catch is lost then the full catch data are not available and the partial data may not be representative of the full catch. Data from unuseable catches are excluded in this report.

In addition, samples are designated as one of three sample descriptions based on combinations of two codes relating to sampling protocols: `SPECIES_CATEGORY_CODE` (Table C.7) and `SAMPLE_SOURCE_CODE` (Table C.8). Samples can be designated as 'unsorted samples' in which data were collected for all specimens in the sample, or 'sorted samples' where specimens were sorted or selected into 'keepers', which were sampled, and 'discards' which were not sampled:

1. Specimens with a `SPECIES_CATEGORY_CODE` of 0 are of unknown species category and are not usable. Those with a `SPECIES_CATEGORY_CODE` of 1 (unsorted) and a `SAMPLE_SOURCE_CODE` of 0 (unknown) or 1 (unsorted), or with a `SPECIES_CATEGORY_CODE` of 5 (remains) or 6 (fish heads only) and a `SAMPLE_SOURCE_CODE` of 1 (unsorted) are classified as 'unsorted'.
2. Specimens with a `SAMPLE_SOURCE_CODE`of 2 (keepers) and a `SPECIES_CATEGORY_CODE` of 1 (unsorted), 2 (sorted) or 3 (keepers), or with a `SPECIES_CATEGORY_CODE` of 3 (keepers) and a `SAMPLE_SOURCE_CODE`of 1 (unsorted) are classified as 'keepers'.
3. Specimens with a `SPECIES_CATEGORY_CODE` of 4 (discards) and a `SAMPLE_SOURCE_CODE` of 1 (unsorted) or 3 (discards), or a `SAMPLE_SOURCE_CODE`of 3 (discards) and a `SPECIES_CATEGORY_CODE` of 1 (unsorted) are 'discards'.

In the synopsis report, we are only including unsorted biological samples. Data are also filtered by `SAMPLE_TYPE_CODE` to extract only total or random samples and exclude samples selected by specified criteria.

Age data extracted with the biological sample queries are filtered by `AGEING_METHOD_CODE` to select current ageing methods verified with the ageing lab at the Pacific Biological Station in order to remove experimental ageing methods that may also be recorded in the database (Table C.9).

Maturity codes are assigned at the time of sampling following a chosen convention. The various conventions have different scales and classifications appropriate for different species or species groups. We worked with the survey staff, data team and biologists for the various taxa to select codes at and above which an individual fish is considered 'mature' in order to assign a maturity status to each specimen based on a combination of maturity convention, maturity code and sex (Table C.10).

The ageing precision data are extracted with `get-age-precision.sql`. Data are filtered to bring in only records for which a secondary (precision) reading was performed by a different technician in addition to the primary reading (Table C.11).

Table C.5. Description of filters in SQL queries extracting research survey sample data from GFBio with `get-survey-samples.sql`.

Filters	Rationale
Filtered for `TRIP_SUBTYPE_CODE` `2, 3` (research trips)	To extract only research data
Filtered for `SAMPLE_TYPE_CODE` `1, 2, 6, 7, 8` (random or total)	To extract only those records of sample type 'random' or 'total'
Filtered for `SPECIES_CATEGORY_CODE` `NULL, 0, 1, 3, 4, 5, 6, 7`	To remove samples sorted on unknown criteria
Filtered for `SAMPLE_SOURCE_CODE` `NULL, 1, 2, 3`	To extract both sorted and unsorted samples for later filtration for desired analysis (removes stomach contents samples)

Table C.6. Description of filters in SQL queries extracting commercial sample data from GFBio with `get-comm-samples.sql`.

Filters	Rationale
Filtered out `TRIP_SUBTYPE_CODE` `2, 3` (research trips)	To extract only commercial data
Filtered for `SAMPLE_TYPE_CODE` `1, 2, 6, 7, 8` (random or total)	To extract only those records of sample type 'random' or 'total'
Filtered for `SPECIES_CATEGORY_CODE` `NULL, 0, 1, 3, 4, 5, 6, 7`	To remove samples sorted on unknown criteria
Filtered for `SAMPLE_SOURCE_CODE` `NULL, 1, 2, 3`	To extract both sorted and unsorted samples for later filtration for desired analysis (removes stomach contents samples)

Table C.7. Species category codes lookup table, which describes sampling protocols at the catch level.

Species Category Code	Species Category Description
0	Unknown
1	Unsorted
2	Sorted (unknown criterion)
3	Keepers
4	Discarded
5	Remains
6	Longline – fish head only
7	Longline – whole fish and fish head only
8	Longline/jig – fish lost at rail/lost at surface

Table C.8. Sample source codes lookup table, which describes sampling protocols at the sample level.

Sample Source Code	Sample Source Description
0	Unknown
1	Unsorted
2	Keepers
3	Discards
4	Stomach contents

Table C.9. Ageing method codes from GFBio considered valid throughout the synopsis document for groundfish species in British Columbia. The acceptable ageing method codes for each species were chosen with the support of the PBS Schlerochronology Lab. 1 = 'Otolith Surface Only', 3 = 'Otolith Broken and Burnt', 4 = 'Otolith Burnt and Thin Sectioned', 6 = 'Dorsal Fin XS', 7 = 'Pectoral Fin', 11 = 'Dorsal Spine', 12 = 'Vertebrae', 16 = 'Otolith Surface and Broken and Burnt', 17 = 'Otolith Broken and Baked (Break and Bake)'.

Common name	Scientific name	Species code	Ageing codes
Bluntnose Sixgill Shark	*Hexanchus griseus*	027	12
Basking Shark	*Cetorhinus maximus*	034	12
Salmon Shark	*Lamna ditropis*	036	12
Brown Cat Shark	*Apristurus brunneus*	038	12
Blue Shark	*Prionace glauca*	041	12
Pacific Sleeper Shark	*Somniosus pacificus*	043	12
North Pacific Spiny Dogfish	*Squalus suckleyi*	044	11
Aleutian Skate	*Bathyraja aleutica*	052	12
Abyssal Skate	*Bathyraja abyssicola*	054	12
Broad Skate	*Amblyraja badia*	055	12
Big Skate	*Beringraja binoculata*	056	12
Roughtail Skate	*Bathyraja trachura*	057	12
Sandpaper Skate	*Bathyraja interrupta*	058	12
Longnose Skate	*Raja rhina*	059	12
Alaska Skate	*Bathyraja parmifera*	061	12
Pacific Cod	*Gadus macrocephalus*	222	6
Pacific Hake	*Merluccius productus*	225	1, 3, 16, 17
Walleye Pollock	*Gadus chalcogrammus*	228	7
Rougheye/Blackspotted	*S. aleutianus/melanostictus*	394	1, 3, 16, 17
Pacific Ocean Perch	*Sebastes alutus*	396	1, 3, 16, 17
Aurora Rockfish	*Sebastes aurora*	400	1, 3, 16, 17
Redbanded Rockfish	*Sebastes babcocki*	401	1, 3, 16, 17
Shortraker Rockfish	*Sebastes borealis*	403	1, 3, 4, 16, 17
Silvergray Rockfish	*Sebastes brevispinis*	405	1, 3, 16, 17
Copper Rockfish	*Sebastes caurinus*	407	1, 3, 16, 17
Dusky Rockfish	*Sebastes variabilis*	409	1, 3, 16, 17
Darkblotched Rockfish	*Sebastes crameri*	410	1, 3, 16, 17
Splitnose Rockfish	*Sebastes diploproa*	412	1, 3, 16, 17
Greenstriped Rockfish	*Sebastes elongatus*	414	1, 3, 16, 17
Puget Sound Rockfish	*Sebastes emphaeus*	415	1, 3, 16, 17
Widow Rockfish	*Sebastes entomelas*	417	1, 3, 16, 17
Yellowtail Rockfish	*Sebastes flavidus*	418	1, 3, 16, 17
Chilipepper	*Sebastes goodei*	420	1, 3, 16, 17
Rosethorn Rockfish	*Sebastes helvomaculatus*	421	1, 3, 16, 17
Quillback Rockfish	*Sebastes maliger*	424	1, 3, 16, 17
Black Rockfish	*Sebastes melanops*	426	1, 3, 16, 17
Blackgill Rockfish	*Sebastes melanostomus*	427	1, 3, 16, 17
Vermilion Rockfish	*Sebastes miniatus*	428	1, 3, 16, 17
Deacon Rockfish	*Sebastes diaconus*	429	1, 3, 16, 17
China Rockfish	*Sebastes nebulosus*	431	1, 3, 16, 17

Common name	Scientific name	Species code	Ageing codes
Tiger Rockfish	*Sebastes nigrocinctus*	433	1, 3, 16, 17
Bocaccio	*Sebastes paucispinis*	435	1, 3, 16, 17
Canary Rockfish	*Sebastes pinniger*	437	1, 3, 16, 17
Redstripe Rockfish	*Sebastes proriger*	439	1, 3, 16, 17
Yellowmouth Rockfish	*Sebastes reedi*	440	1, 3, 16, 17
Yelloweye Rockfish	*Sebastes ruberrimus*	442	1, 3, 16, 17
Stripetail Rockfish	*Sebastes saxicola*	444	1, 3, 16, 17
Harlequin Rockfish	*Sebastes variegatus*	446	1, 3, 16, 17
Pygmy Rockfish	*Sebastes wilsoni*	448	1, 3, 16, 17
Sharpchin Rockfish	*Sebastes zacentrus*	450	1, 3, 16, 17
Shortspine Thornyhead	*Sebastolobus alascanus*	451	1, 3, 4, 16, 17
Longspine Thornyhead	*Sebastolobus altivelis*	453	1, 3, 4, 16, 17
Sablefish	*Anoplopoma fimbria*	455	1, 3, 16, 17
Lingcod	*Ophiodon elongatus*	467	6
Pacific Sanddab	*Citharichthys sordidus*	596	1, 3, 16, 17
Arrowtooth Flounder	*Atheresthes stomias*	602	1, 3, 16, 17
Deepsea Sole	*Embassichthys bathybius*	605	1, 3, 16, 17
Petrale Sole	*Eopsetta jordani*	607	1, 3, 16, 17
Rex Sole	*Glyptocephalus zachirus*	610	1, 3, 16, 17
Flathead Sole	*Hippoglossoides elassodon*	612	1, 3, 16, 17
Butter Sole	*Isopsetta isolepis*	619	1, 3, 16, 17
Southern Rock Sole	*Lepidopsetta bilineata*	621	1, 3, 16, 17
Slender Sole	*Lyopsetta exilis*	625	1, 3, 16, 17
Dover Sole	*Microstomus pacificus*	626	1, 3, 16, 17
English Sole	*Parophrys vetulus*	628	1, 3, 16, 17
Starry Flounder	*Platichthys stellatus*	631	1, 3, 16, 17
C-O Sole	*Pleuronichthys coenosus*	633	1, 3, 16, 17
Curlfin Sole	*Pleuronichthys decurrens*	635	1, 3, 16, 17
Sand Sole	*Psettichthys melanostictus*	636	1, 3, 16, 17

Table C.10. Maturity convention codes ('Mat. conv. code'), maturity convention descriptions, sex, and the maturity convention value at which a fish is deemed to be mature for the purposes of the synopsis report. Note that fish may be considered mature at other maturity convention values in particular stock assessments where other values are chosen for specific reasons.

Mat. conv. code	Maturity convention description	Sex	Mature at
1	ROCKFISH (1977+)	M	3
1	ROCKFISH (1977+)	F	3
1	ROCKFISH	M	3
1	ROCKFISH	F	3
4	FLATFISH (1978+)	M	3
4	FLATFISH (1978+)	F	3
6	PACIFIC COD (1973-75)	M	2
6	PACIFIC COD (1973-75)	F	2
7	PACIFIC COD (1975+)	M	3
7	PACIFIC COD (1975+)	F	3
8	LINGCOD (1985+)	M	3
8	LINGCOD (1985+)	F	3
10	DOGFISH	M	90
10	DOGFISH	F	77
11	PORT SAMPLES	M	3
11	PORT SAMPLES	F	3
12	THORNYHEAD SIMPLIFIED	M	2
12	THORNYHEAD SIMPLIFIED	F	2
13	AMR	M	3
13	AMR	F	3
15	ROCKFISH (1975-77)	M	3
15	ROCKFISH (1975-77)	F	3
16	SARDINES (I, M OR R)	M	2
16	SARDINES (I, M OR R)	F	2
17	SKATE (2002+)	M	2
17	SKATE (2002+)	F	2
21	GENERAL GROUNDFISH (LATE 1960'S-EARLY 1970'S)	M	3
21	GENERAL GROUNDFISH (LATE 1960'S-EARLY 1970'S)	F	3
22	SIMPLIFIED - OLD	M	2
22	SIMPLIFIED - OLD	F	2
23	MISC. SPECIES SIMPLIFIED	M	2
23	MISC. SPECIES SIMPLIFIED	F	2
24	LINGCOD 7-STAGE	M	3
24	LINGCOD 7-STAGE	F	3
25	HAKE-POLLOCK 7-STAGE	M	3
25	HAKE-POLLOCK 7-STAGE	F	3
26	RATFISH	M	3
26	RATFISH	F	3

Table C.11. Description of filters in SQL queries extracting all age records with a precision test reading to determine ageing precision from GFBio with $get\_age\_precision.sql$

Filters	Rationale
Filter for `AGE_READING_TYPE_CODE` 2, 3	To extract primary and precision test readings

C.3 DATA ACCESSIBILITY

Data from the Bottom Trawl Synoptic Surveys are available through the Open Government Data Portal. Hook and line survey data are currently being prepared for upload to the Open Data Portal. Commercial data will be uploaded in a rolled-up format in compliance with the Federal Privacy Act.

Requests for data held by DFO Pacific Region can be made through Pacific Fisheries Catch Statistics.

APPENDIX D. CPUE INDEX STANDARDIZATION

We sought to generate an index of abundance from commercial trawl catch per unit effort data that was standardized for depth, fishing locality (defined spatial regions; Figure D.1), month, vessel, and latitude. Before fitting a standardization model, we had to filter and manipulate the available catch and effort data to generate a dataset appropriate for model fitting. In the following sections we describe those decisions for the data from 1996–2017 and then describe our index standardization model. This model and the following description draws heavily from a recent assessment of Pacific Cod (in parts copied verbatim), where this model was first developed and applied (Forrest et al. 2019).

D.1 DEFINING THE 1996–2018 FLEET

Commercial groundfish bottom trawl data from 1996 to present have been recorded to the fishing-event level in the presence of on-board observers or video monitoring. Although catch and effort data are available for earlier years for most species, they are not of the same quality, and for most years do not contain information on latitude or vessel ID. These earlier data are likely useful in the assessment of some species, but we have restricted the presentation of commercial CPUE data in this report to the higher-quality 1996-onwards data to avoid exploring the numerous caveats that would need to be considered on a species-by-species and decade-by-decade basis. We think the presentation of historical CPUE is better left to species-specific stock assessments that can more thoroughly consider these data.

Since we have data on individual vessels for this modern fleet, and in keeping with previous analyses for Pacific groundfish stocks, we defined a 'fleet' that includes only vessels that qualify by passing some criteria of regularly catching Pacific Cod. We follow the approach used in a number of recent BC groundfish stock assessments by requiring vessels to have caught the species in at least 100 tows across all years of interest, and to have passed a threshold of five trips (trips that recorded some of the species) for at least five years — all from 1996 to 2018.

D.2 DEFINING THE STANDARDIZATION MODEL PREDICTORS

For depth and latitude, we binned the values into a sequence of bands to allow for nonlinear relationships between these predictors and CPUE (e.g., Maunder and Punt 2004). For depth, we binned trawl depth into bands 25m wide. For latitude, we used bands that were 0.1 degrees wide. To ensure sufficient data to estimate a coefficient for each factor level, we limited the range of depth bins to those that fell within the 0.1% to 99.9% cumulative probability of positive observations and then removed any factor levels (across all predictors) that contained fewer than 0.1% of the positive observations.

Predictors that are treated as factors in a statistical model need a reference or base level — a level from which the other coefficients for that variable estimate a difference. The base level then becomes the predictor value that is used in the prediction for the standardized index. We chose the most frequent factor level as the base level — a common choice for these types of models (Maunder and Punt 2004). For example, we set the base month as the most common month observed in the dataset filtered for only tows where the species was caught. This choice of base level only affects the intercept or relative magnitude of our index because of the form of our model (discussed below) and makes no functional difference in the commercial CPUE time series presented in this report since they are all scaled to that same maximum and displayed without units.

D.3 A TWEEDIE GLMM INDEX STANDARDIZATION MODEL

Fisheries CPUE data contains both zeros and positive continuous values. A variety of approaches have been used in the fishery literature to model such data. One approach has been to fit a delta-GLM (generalized linear model) — a model that fits the zero vs. non-zero values with a logistic regression (a binomial GLM and a logit link) and the positive values with a linear regression fit to log-transformed data or a Gamma GLM with a log link (e.g., Maunder and Punt 2004, Thorson and Ward 2013). The probability of a non-zero CPUE from the first component can then be multiplied by the expected CPUE from the second component to derive an unconditional estimate of CPUE. However, this approach suffers from a number of issues:

1. The delta-GLM approach adds complexity by needing to fit and report on two models.
2. In the typical delta-GLM approach, the two models are fit with separate links and so the coefficients cannot be combined.
3. The delta-GLM approach assumes independence among the two components (e.g., Thorson 2017).
4. Perhaps most importantly for our purpose, a delta-GLM in which the two models use different links renders a final index in which the index trend is dependent on the specific reference levels that the predictors are set to (e.g., Maunder and Punt 2004).

The Tweedie distribution (Jorgensen 1987) solves the above problems (e.g., Candy 2004, Shono 2008, Foster and Bravington 2013, Lecomte et al. 2013, Thorson 2017) but has not seen widespread use presumably mostly because of the computational expense of calculating the Tweedie probability density function. Recently, the Tweedie density function has been introduced to the software TMB (Kristensen et al. 2016) and can be fit relatively quickly to large datasets and for models with many fixed and random effect parameters either with custom written TMB models or via the glmmTMB R package (Brooks et al. 2017).

In addition to a mean parameter, the Tweedie distribution has two other parameters: a power parameter p and a dispersion parameter ϕ. If $1 < p < 2$ then the Tweedie distribution represents a compound distribution between the Poisson ($p = 1$) and the Gamma distribution ($p = 2$) (Figure D.2). In fact, the Tweedie is alternatively referred to as the compound-Poisson-Gamma distribution in this bounded case. We note, however, that the compound-Poisson-Gamma distribution is often used to refer to a re-parameterization in which the Poisson and Gamma components are fit so that they are not assumed to have the same predictive coefficients as they are in the Tweedie distribution (e.g., Foster and Bravington 2013, Lecomte et al. 2013).

We fit the Tweedie GLMM (generalized linear mixed effects model) as

$$y_i \sim \mathrm{Tweedie}(\mu_i, p, \phi), \quad 1 < p < 2, \tag{D.1}$$

$$\mu_i = \exp\left(\boldsymbol{X}_i \boldsymbol{\beta} + \alpha^{\mathrm{locality}}_{j[i]} + \alpha^{\mathrm{locality-year}}_{k[i]} + \alpha^{\mathrm{vessel}}_{l[i]} \right) \Bigg(\tag{D.2}$$

$$\alpha^{\mathrm{locality}}_{j} \sim \mathrm{Normal}(0, \sigma^2_{\alpha \text{ locality}}), \tag{D.3}$$

$$\alpha^{\mathrm{locality-year}}_{k} \sim \mathrm{Normal}(0, \sigma^2_{\alpha \text{ locality-year}}), \tag{D.4}$$

$$\alpha^{\mathrm{vessel}}_{l} \sim \mathrm{Normal}(0, \sigma^2_{\alpha \text{ vessel}}), \tag{D.5}$$

where i represents a single tow, y_i represents the catch (kg) per unit effort (hours trawled), $\boldsymbol{X_i}$

represents a vector of fixed-effect predictors (year, depth bins, months, latitude bins), $\boldsymbol{\beta}$ represents a vector of coefficients, and μ_i represents the expected CPUE in a tow. The random effect intercepts (α symbols) are allowed to vary from the overall intercept by locality (Figure D.1 j ($\alpha_j^{\mathrm{locality}}$), locality-year k ($\alpha_k^{\mathrm{locality-year}}$), and vessel l ($\alpha_l^{\mathrm{vessel}}$) and are constrained by normal distributions with respective standard deviations denoted by σ parameters. By including the locality-year interactions, we allow the individual localities to have unique CPUE index trends (somewhat constrained by the random effect distribution) while estimating the overall average trend (Figure D.3).

We can then calculate the standardized estimate of CPUE for year t, μ_t, as

$$\mu_t = \exp\left(\boldsymbol{X}_t \boldsymbol{\beta}\right) \tag{D.6}$$

where $\boldsymbol{X_t}$ represents a vector of predictors set to the reference (r) levels with the year set to the year of interest. Because each of the α random intercepts is set to zero, the index is predicted for an average locality, locality-year, and vessel. We estimated the fixed effects with maximum marginal likelihood while integrating over the random effects with the statistical software TMB via the R package glmmTMB. We used standard errors (SE) as calculated by TMB on $\log(\mu_t)$ via the generalized delta method. We then calculated the 95% Wald confidence intervals as $\exp(\mu_t \pm 1.96\mathrm{SE}_t)$. For comparison, we calculated an unstandardized time series by summing the catch each year and dividing it by the summed effort each year (the dashed lines on the figure pages).

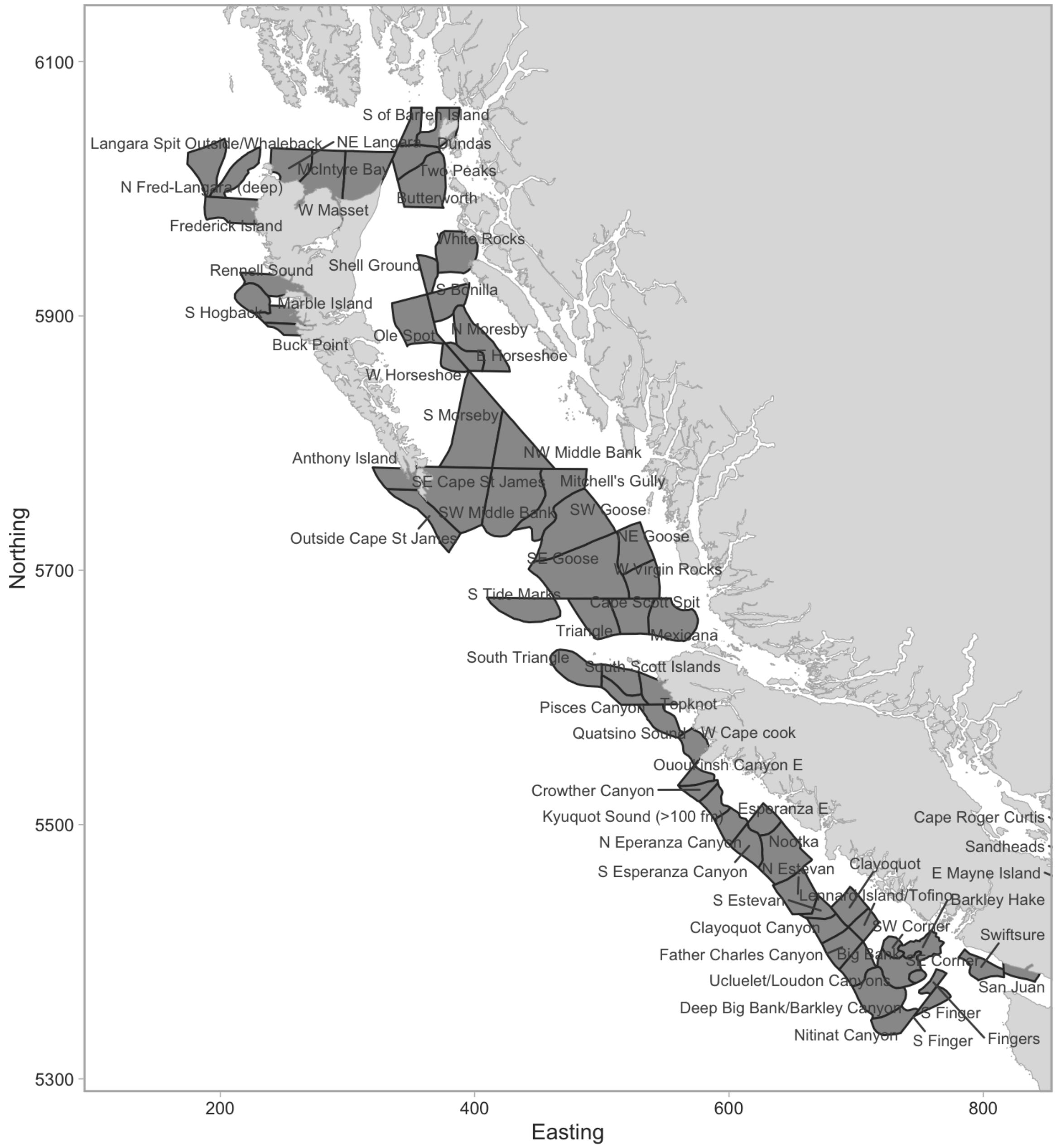


Figure D.1. Top 100 DFO localities (by fishing event count) used in the commercial CPUE standardization models. In total there are 226 possible localities recorded in the data set.

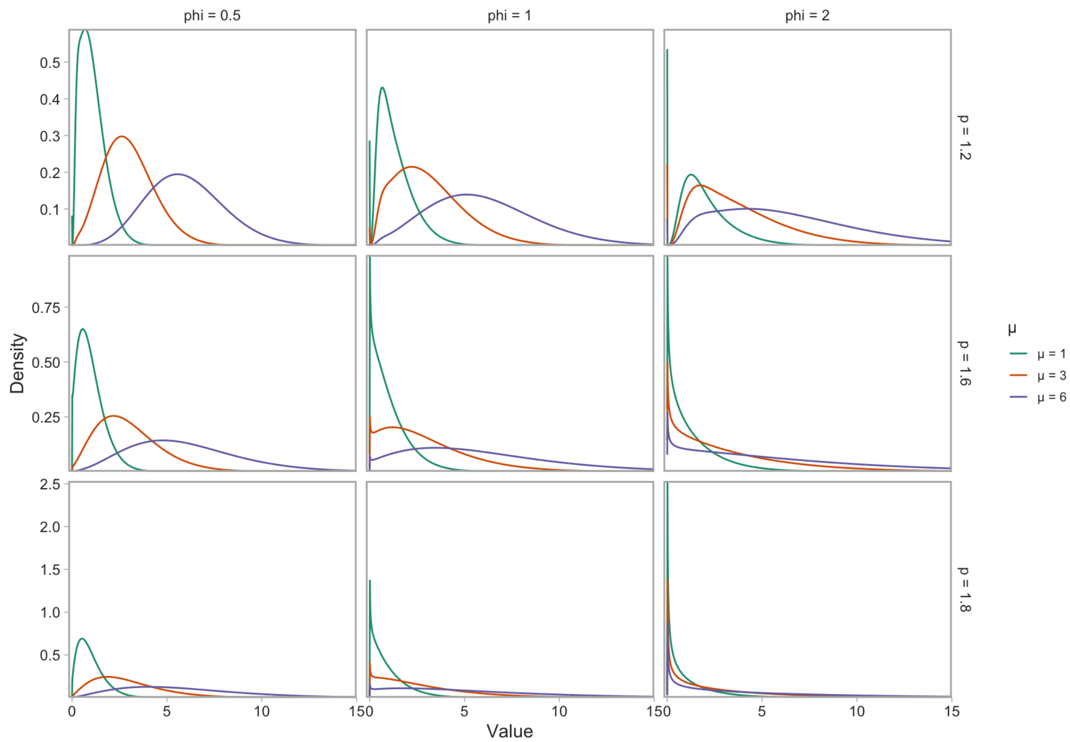


Figure D.2. Example density functions for the Tweedie distribution. The symbol ϕ (written as phi in this figure) represents the dispersion parameter, p represents the power parameter, and μ represents the mean. Note that the spike in density that is seen towards the left of the panels is at a value of 0 on the x axis.

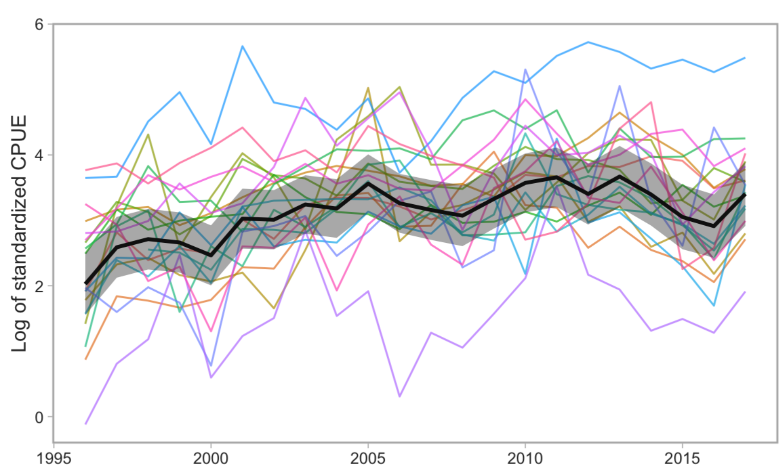


Figure D.3. Example locality-specific CPUE index trends for the Petrale Sole in area 5AB with a standardization model that allows for locality-year (space-time) interactions. The coloured lines indicate the locality-specific estimates with all other predictors set to their base levels. The black line and shaded ribbon indicate the overall average annual CPUE and 95% CI, respectively.

Table D.1. Parameter estimates from CPUE standardization GLMMs.

Species name	Area	ϕ	p	τ_{vessel}	τ_{locality}	$\tau_{\mathrm{year-locality}}$
Arrowtooth Flounder	3CD	12.4	1.9	0.1	1.0	0.7
Arrowtooth Flounder	3CD5ABCDE	10.4	1.9	0.3	1.3	0.6
Arrowtooth Flounder	5AB	9.2	1.9	0.3	0.6	0.4
Arrowtooth Flounder	5CDE	10.5	1.9	0.1	1.0	0.4
Big Skate	3CD	18.0	1.7	0.1	0.4	0.4
Big Skate	3CD5ABCDE	16.7	1.7	0.1	0.6	0.5
Big Skate	5AB	16.6	1.7	0.2	0.3	0.4
Big Skate	5CDE	13.1	1.8	0.0	1.3	0.4
Bocaccio	3CD	16.2	1.8	0.4	0.8	1.1
Bocaccio	3CD5ABCDE	15.3	1.8	0.2	1.9	0.8
Bocaccio	5AB	13.9	1.8	0.1	2.5	0.4
Bocaccio	5CDE	16.4	1.7	0.1	3.6	0.8
Brown Cat Shark	3CD5ABCDE	2.9	1.7	0.2	0.0	1.8
Butter Sole	3CD5ABCDE	44.3	1.8	0.2	1.9	2.9
Canary Rockfish	3CD	13.4	1.9	0.2	2.1	0.8
Canary Rockfish	5AB	16.0	1.9	0.1	1.3	0.7
Canary Rockfish	5CDE	21.9	1.8	0.2	8.2	2.1
Copper Rockfish	5CDE	14.4	1.7	0.3	0.4	1.1
Curlfin Sole	3CD5ABCDE	9.6	1.7	0.1	0.4	1.1
Curlfin Sole	5AB	8.3	1.7	0.1	0.2	0.5
Curlfin Sole	5CDE	10.7	1.7	0.1	0.4	1.1
Darkblotched Rockfish	3CD	22.9	1.8	0.1	0.8	0.7
Darkblotched Rockfish	3CD5ABCDE	24.7	1.8	0.1	0.8	1.1
Darkblotched Rockfish	5AB	23.5	1.8	0.2	1.0	1.1
Darkblotched Rockfish	5CDE	26.4	1.8	0.1	0.9	1.4
Deepsea Sole	3CD	2.3	1.7	0.2	0.0	0.2
Deepsea Sole	3CD5ABCDE	2.5	1.7	0.2	0.0	0.5
Dover Sole	3CD	11.5	1.9	0.1	1.0	0.2
Dover Sole	3CD5ABCDE	13.4	1.8	0.1	3.8	0.4
Dover Sole	5AB	14.0	1.8	0.2	2.3	0.3
Dover Sole	5CDE	17.2	1.8	0.1	3.4	0.9
English Sole	3CD	12.5	1.7	0.1	1.1	0.3
English Sole	3CD5ABCDE	13.3	1.8	0.1	1.5	0.4
English Sole	5AB	13.4	1.8	0.1	3.4	0.7
English Sole	5CDE	11.9	1.8	0.0	1.9	0.5
Flathead Sole	3CD	26.3	1.7	0.1	1.4	1.4
Flathead Sole	3CD5ABCDE	25.4	1.8	0.1	1.9	1.3
Flathead Sole	5AB	19.7	1.7	0.0	4.4	1.0
Flathead Sole	5CDE	25.1	1.8	0.1	1.9	1.2
Greenstriped Rockfish	3CD	9.6	1.8	0.1	1.2	0.5
Greenstriped Rockfish	3CD5ABCDE	10.4	1.8	0.1	0.9	0.5
Greenstriped Rockfish	5AB	11.0	1.8	0.1	1.4	0.7
Greenstriped Rockfish	5CDE	10.7	1.7	0.4	0.5	1.5
Lingcod	3CD	9.9	1.9	0.2	0.7	0.7
Lingcod	3CD5ABCDE	9.9	1.9	0.1	2.2	0.6

Species name	Area	ϕ	p	τ_{vessel}	τ_{locality}	$\tau_{\text{year-locality}}$
Lingcod	5AB	8.5	1.8	0.1	1.1	0.3
Lingcod	5CDE	10.6	1.8	0.1	2.1	0.6
Longnose Skate	3CD	10.0	1.7	0.1	0.3	0.2
Longnose Skate	3CD5ABCDE	11.4	1.7	0.1	0.4	0.3
Longnose Skate	5AB	11.7	1.7	0.1	0.3	0.2
Longnose Skate	5CDE	12.6	1.8	0.1	0.5	0.2
Longspine Thornyhead	3CD	5.7	1.6	0.0	0.0	0.0
Longspine Thornyhead	3CD5ABCDE	6.1	1.6	0.0	0.0	0.4
North Pacific Spiny Dogfish	3CD	10.7	1.9	0.1	0.2	0.6
North Pacific Spiny Dogfish	3CD5ABCDE	11.7	1.9	0.1	0.6	0.7
North Pacific Spiny Dogfish	5AB	11.4	1.9	0.1	2.5	0.4
North Pacific Spiny Dogfish	5CDE	11.2	1.9	0.1	0.5	0.7
Pacific Cod	3CD	11.3	1.8	0.1	0.2	0.5
Pacific Cod	3CD5ABCDE	11.0	1.8	0.1	0.8	0.5
Pacific Cod	5AB	11.4	1.8	0.1	1.4	0.4
Pacific Cod	5CDE	9.2	1.9	0.1	1.4	0.9
Pacific Hake	3CD	18.1	1.9	0.6	0.9	3.0
Pacific Hake	3CD5ABCDE	18.3	1.9	0.3	0.6	2.6
Pacific Hake	5AB	17.1	1.8	0.2	0.6	1.1
Pacific Hake	5CDE	14.4	1.8	0.5	0.4	2.1
Pacific Halibut	3CD	8.9	1.7	0.1	0.2	0.3
Pacific Halibut	3CD5ABCDE	8.7	1.8	0.2	0.2	0.2
Pacific Halibut	5AB	8.9	1.8	0.2	0.2	0.1
Pacific Halibut	5CDE	7.8	1.7	0.1	0.2	0.2
Pacific Ocean Perch	3CD	26.3	1.9	0.2	1.5	1.0
Pacific Ocean Perch	3CD5ABCDE	24.4	1.8	0.1	1.1	0.6
Pacific Ocean Perch	5AB	24.8	1.8	0.1	0.9	0.4
Pacific Ocean Perch	5CDE	25.4	1.8	0.2	2.6	1.1
Pacific Sanddab	3CD5ABCDE	27.7	1.8	0.5	1.2	1.9
Petrale Sole	3CD	11.5	1.8	0.1	0.3	0.3
Petrale Sole	3CD5ABCDE	12.4	1.8	0.1	0.7	0.4
Petrale Sole	5AB	11.6	1.8	0.1	0.4	0.3
Petrale Sole	5CDE	13.8	1.8	0.1	3.1	0.6
Quillback Rockfish	3CD5ABCDE	11.0	1.7	0.4	0.7	1.2
Quillback Rockfish	5AB	7.8	1.7	0.2	0.1	1.1
Quillback Rockfish	5CDE	11.7	1.7	0.7	0.6	0.8
Redbanded Rockfish	3CD	11.4	1.8	0.2	0.8	0.5
Redbanded Rockfish	3CD5ABCDE	11.4	1.8	0.1	1.0	0.5
Redbanded Rockfish	5AB	10.8	1.8	0.1	0.9	0.4
Redbanded Rockfish	5CDE	12.6	1.8	0.1	2.1	0.6
Redstripe Rockfish	3CD	24.9	1.8	0.4	3.8	1.0
Redstripe Rockfish	3CD5ABCDE	26.3	1.9	0.2	2.2	1.1
Redstripe Rockfish	5AB	27.5	1.9	0.2	1.4	0.7
Redstripe Rockfish	5CDE	25.0	1.8	0.2	10.0	1.6
Rex Sole	3CD	11.2	1.8	0.1	0.3	0.2
Rex Sole	3CD5ABCDE	11.1	1.8	0.1	2.2	0.3

Species name	Area	ϕ	p	τ_{vessel}	τ_{locality}	$\tau_{\text{year-locality}}$
Rex Sole	5AB	10.3	1.8	0.1	1.6	0.2
Rex Sole	5CDE	11.4	1.8	0.1	1.2	0.5
Rosethorn Rockfish	3CD	11.8	1.8	0.1	1.2	0.4
Rosethorn Rockfish	3CD5ABCDE	13.2	1.8	0.2	1.9	0.6
Rosethorn Rockfish	5AB	13.7	1.8	0.3	3.7	0.8
Rougheye/Blackspotted Rockfish	3CD	14.6	1.7	0.1	0.1	0.3
Rougheye/Blackspotted Rockfish	3CD5ABCDE	19.1	1.8	0.1	0.6	0.8
Rougheye/Blackspotted Rockfish	5AB	22.0	1.8	0.1	0.6	0.6
Rougheye/Blackspotted Rockfish	5CDE	19.8	1.8	0.2	0.7	1.1
Sablefish	3CD	8.3	1.9	0.1	1.0	0.7
Sablefish	3CD5ABCDE	9.0	1.8	0.1	0.9	1.0
Sablefish	5AB	9.3	1.8	0.1	0.9	0.6
Sablefish	5CDE	9.4	1.8	0.2	1.6	1.3
Sand Sole	3CD5ABCDE	17.4	1.8	0.2	0.4	0.7
Sand Sole	5CDE	17.3	1.8	0.2	0.5	0.7
Sandpaper Skate	3CD5ABCDE	10.3	1.7	0.2	0.6	0.8
Sandpaper Skate	5AB	11.3	1.7	0.3	0.4	0.5
Sandpaper Skate	5CDE	9.8	1.7	0.1	0.7	1.1
Sharpchin Rockfish	3CD	24.5	1.8	0.3	3.1	0.9
Sharpchin Rockfish	3CD5ABCDE	27.9	1.8	0.3	2.5	0.7
Sharpchin Rockfish	5AB	28.4	1.8	0.3	5.0	0.6
Sharpchin Rockfish	5CDE	28.6	1.8	0.6	4.2	1.2
Shortraker Rockfish	3CD	12.3	1.7	0.1	0.1	0.3
Shortraker Rockfish	3CD5ABCDE	14.3	1.7	0.1	0.5	0.4
Shortraker Rockfish	5AB	17.8	1.7	0.2	1.0	0.8
Shortraker Rockfish	5CDE	12.3	1.7	0.1	0.1	0.5
Shortspine Thornyhead	3CD	7.6	1.6	0.1	0.1	0.1
Shortspine Thornyhead	3CD5ABCDE	8.8	1.7	0.1	0.4	0.2
Shortspine Thornyhead	5AB	9.7	1.7	0.1	0.3	0.2
Shortspine Thornyhead	5CDE	10.3	1.7	0.1	0.4	0.2
Silvergray Rockfish	3CD	13.7	1.9	0.2	2.4	0.6
Silvergray Rockfish	3CD5ABCDE	13.3	1.9	0.1	3.9	0.7
Silvergray Rockfish	5AB	11.6	1.9	0.1	1.6	0.4
Silvergray Rockfish	5CDE	17.3	1.9	0.1	5.6	0.9
Southern Rock Sole	3CD	13.7	1.7	0.1	1.6	1.4
Southern Rock Sole	3CD5ABCDE	15.6	1.7	0.1	0.5	0.4
Southern Rock Sole	5AB	15.2	1.7	0.1	0.5	0.1
Southern Rock Sole	5CDE	16.1	1.8	0.1	0.6	0.4
Splitnose Rockfish	3CD	31.6	1.8	0.1	0.6	1.3
Splitnose Rockfish	5AB	32.1	1.8	0.2	1.9	1.6
Spotted Ratfish	3CD	9.8	1.9	0.1	0.7	0.4
Spotted Ratfish	3CD5ABCDE	9.8	1.9	0.1	0.7	0.3
Spotted Ratfish	5AB	8.4	1.9	0.1	0.4	0.2
Spotted Ratfish	5CDE	10.1	1.9	0.1	0.9	0.3
Starry Flounder	3CD5ABCDE	14.5	1.8	0.1	0.6	1.6
Starry Flounder	5CDE	14.5	1.8	0.1	0.6	1.5

Species name	Area	ϕ	p	τ_{vessel}	τ_{locality}	$\tau_{\text{year-locality}}$
Walleye Pollock	3CD	20.5	1.8	0.4	4.1	2.9
Walleye Pollock	3CD5ABCDE	16.9	1.8	0.2	5.1	2.0
Walleye Pollock	5AB	14.7	1.8	0.1	3.9	1.3
Walleye Pollock	5CDE	15.8	1.8	0.1	3.6	1.5
Widow Rockfish	3CD	31.1	1.9	0.4	3.4	1.5
Widow Rockfish	3CD5ABCDE	26.7	1.9	0.2	4.1	1.4
Widow Rockfish	5AB	24.4	1.8	0.1	4.6	0.9
Widow Rockfish	5CDE	23.2	1.8	0.2	15.1	1.8
Wolf Eel	3CD5ABCDE	4.7	1.6	0.1	0.2	0.4
Wolf Eel	5AB	4.3	1.6	0.1	0.1	0.3
Wolf Eel	5CDE	6.0	1.6	0.1	0.4	0.3
Yelloweye Rockfish	3CD	11.0	1.7	0.3	1.0	0.5
Yelloweye Rockfish	3CD5ABCDE	13.7	1.7	0.3	1.3	0.6
Yelloweye Rockfish	5AB	14.2	1.7	0.4	1.5	0.5
Yellowmouth Rockfish	3CD	34.9	1.8	0.4	0.6	2.1
Yellowmouth Rockfish	3CD5ABCDE	25.5	1.9	0.2	2.7	1.0
Yellowmouth Rockfish	5AB	22.5	1.9	0.1	5.2	0.6
Yellowmouth Rockfish	5CDE	26.1	1.8	0.5	2.6	0.8
Yellowtail Rockfish	3CD	18.6	1.9	0.2	2.6	1.0
Yellowtail Rockfish	3CD5ABCDE	21.0	1.9	0.2	1.9	1.0
Yellowtail Rockfish	5AB	21.3	1.9	0.1	0.9	0.7
Yellowtail Rockfish	5CDE	24.4	1.9	0.2	3.3	1.5

APPENDIX E. SPATIAL MODELLING OF SURVEY BIOMASS

We modelled the expected biomass density in space for each species using geostatistical models applied to data from the fisheries independent bottom trawl and longline surveys (e.g., Figure 5). Our modeling approach is consistent with recent models used for spatial modelling and spatiotemporal index standardization of groundfish populations (e.g., Shelton et al. 2014, Thorson et al. 2015, 2016, Ward et al. 2015), but has not, to our knowledge, previously been applied in DFO Research Documents. Such models have been shown, for example, to improve estimates of rockfish abundance and distribution (Shelton et al. 2014) and improve precision when estimating relative abundance indices for groundfish (Thorson et al. 2015). Our specific model is fit with TMB (Kristensen et al. 2016) in R (R Core Team 2018) with the help of INLA (Rue et al. 2009, Lindgren and Rue 2015) via the R package sdmTMB, which we wrote for this purpose (Appendix I).

At a high level, these models predict relative biomass or catch rate in space as a continuous process with a quadratic effect for bottom depth, spatial random effects that represent an amalgamation of spatial processes not explicitly included in the model, and an observation error component. After fitting the model to survey sets from trawl or longline surveys, we then project the model predictions onto a 2 km $\times$ 2 km grid in a UTM 9 projection to derive estimates of biomass throughout the survey domain.

Similarly to the commercial catch per unit effort standardization models (Appendix D), these models can be represented as Tweedie GLMMs with a log link:

$$y_s \sim \mathrm{Tweedie}(\mu_s, p, \phi), \quad 1 < p < 2, \tag{E.1}$$

$$\mu_s = \exp\left(\boldsymbol{X}_s \boldsymbol{\beta} + \omega_s\right), \tag{E.2}$$

where s represents a spatial location, y_s represents observed fish density for a survey set, μ_s represents expected fish density, p represents the Tweedie power parameter, and ϕ represents the Tweedie dispersion parameter. The symbol $\boldsymbol{X_s}$ represents a vector of predictors (an intercept, log depth, and log depth squared) and $\boldsymbol{\beta}$ represents a corresponding vector of coefficients. The spatial random effects ω_s are assumed to be drawn from a multivariate normal distribution with a covariance matrix $\boldsymbol{\Sigma}_\omega$ that is centered on zero:

$$\boldsymbol{\omega} \sim \mathrm{MVNormal}\left(\boldsymbol{0}, \boldsymbol{\Sigma}_\omega\right).$$

We constrained the spatial random effects to follow a Matérn covariance function, which defines the rate with which spatial correlation decays with distance (Figure E.1). The Matérn function describes the covariance $\Phi\left(s_j, s_k\right)$ between spatial locations s_j and s_k as:

$$\Phi\left(s_j, s_k\right) = \tau^2 / \Gamma(\nu) 2^{\nu-1} (\kappa d_{jk})^\nu K_\nu \left(\kappa d_{jk}\right),$$

where τ^2 represents the spatial variance, Γ represents the Gamma function, K_ν represents the Bessel function, d_{jk} represents the Euclidean distance between locations s_j and s_k, and κ represents a scaling parameter that is estimated (e.g., Lindgren et al. 2011). The parameter ν controls the smoothness of the covariance function. We set $\nu = 1$, which lets us take advantage of the Stochastic Partial Differential Equation (SPDE) approximation to Gaussian Markov Random Fields (GMRF) to greatly increase computational efficiency (Lindgren et al. 2011).

Our spatial model falls into the general category of "predictive process" models (e.g., Latimer et al. 2009, Shelton et al. 2014, Anderson and Ward 2019), in which the model keeps track of a limited number of “knots” that approximate unexplained spatial variation (Figure E.2). By keeping track of a smaller number of knots than the full spatial data set, we can increase computational efficiency. The model predictions can be projected to the original data locations or any new set of locations as long as an appropriate covariance matrix can be calculated (e.g., Latimer et al. 2009). Higher numbers of knots result in a better approximation of the spatial random effects at a greater computational cost. We fit the spatial models with one less knot than the number of observations if there were fewer than 200 observations and 200 knots otherwise. Following one common practice (e.g., Shelton et al. 2014, Thorson and Barnett 2017, Anderson and Ward 2019) we chose the location of the knots with a k-means clustering algorithm with a fixed random seed to ensure reproducible results.

Instead of directly modelling the effects of depth and depth squared, we first standardized the log-transformed depth covariate by subtracting its mean and scaling it by its standard deviation. We then calculated ‘depth squared’ from this centred and scaled variable. This ensures the covariate values are not too large or small to avoid computational issues and the centring separates the linear and quadratic predictor components.

We fit the four synoptic survey data sets separately because only two of the surveys are conducted each year and the surveys are disjointed in space and time. Similarly, we fit the North and South HBLL surveys independently. We combined the predictions to generate the map plots but labelled the years in which the various surveys were conducted.

As an example, we illustrate the model components for Pacific Cod in Queen Charlotte Sound (Figure E.3). We begin with a bathymetry layer and biomass density value for each survey set in space (Figure E.3A). After fitting the model, we can inspect the effect of the bottom depth quadratic fixed effect predictors (Figure E.3B) as well as the spatial random effects (Figure E.3C). If we add the fixed effect predictions to the spatial random effects in link (log) space and exponentiate the result, we derive model predictions that include both the fixed and random effects (Figure E.3D). We can inspect randomized quantile residuals in space to check for any remaining spatial correlation (Figure E.4). We can also look at the predicted relationship between depth and biomass density across all the species (Figures B.1, B.2).

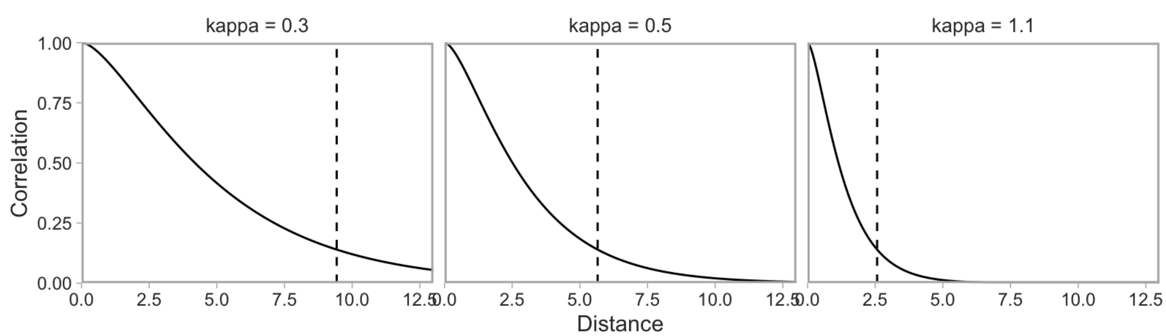


Figure E.1. An illustration of the effect of the κ parameter ('kappa') on the shape of the Matérn correlation function with $\nu = 1$. The vertical dashed line illustrates $\sqrt{8\nu}/\kappa$, referred to as the 'range', which is a point at which the correlation decreases below 0.1.

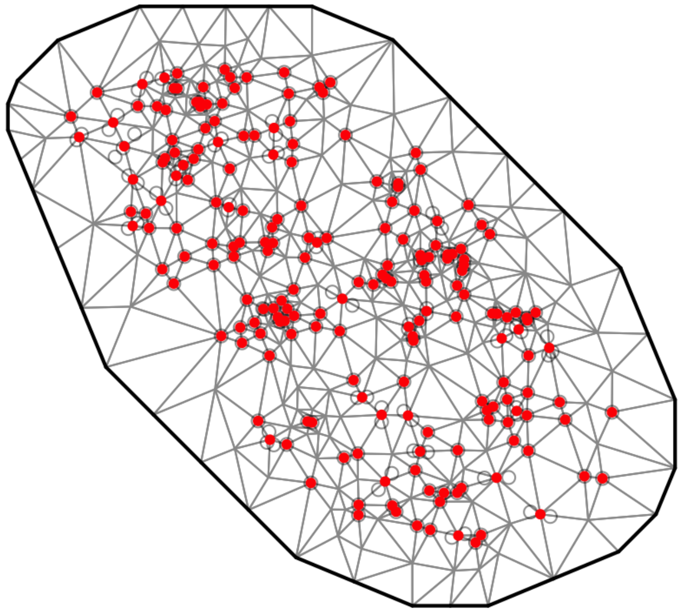


Figure E.2. Example triangularization mesh for Pacific Cod and the Queen Charlotte Sound survey in 2017. The red dots indicate knot locations. The open grey circles in the background represent the locations of the observed data. The lines show the triangularization mesh used in the SPDE approximation. In this case, many of the knots overlap the observed data. A greater number of knots will increase the accuracy of the approximation at the expense of computational time.

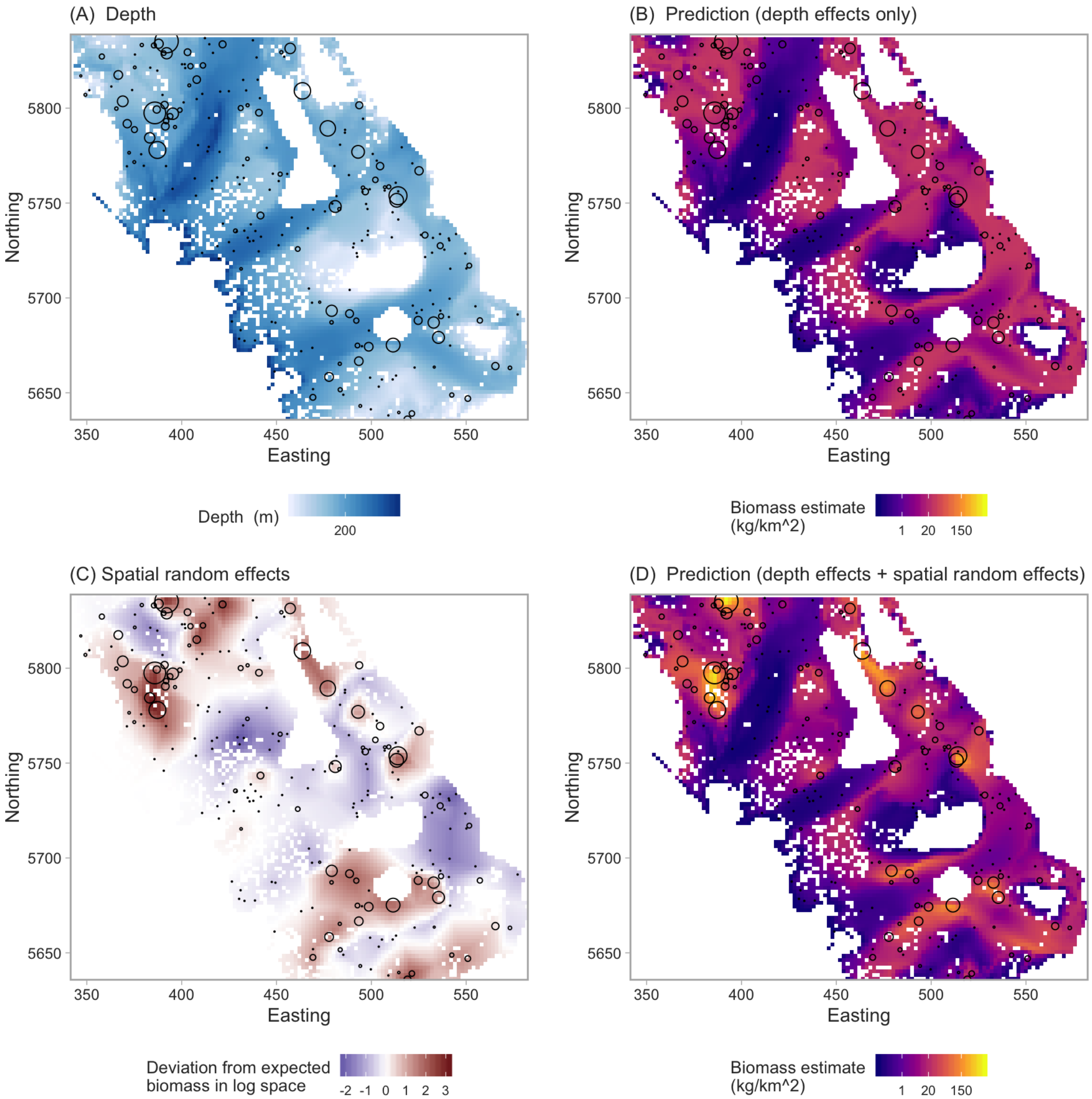


Figure E.3. Example spatial model components in Queen Charlotte Sound for Pacific Cod. (A) Bottom depth data that is used as a predictor. (B) Predicted biomass density from the quadratic effect of depth only. (C) Spatial random effect deviations. These deviations represent only modelled correlated spatial effects. (D) Model predictions that include both the depth fixed effects and the spatial random effects. Circles represent the biomass density for each survey set with the area of the circle proportional to the density.

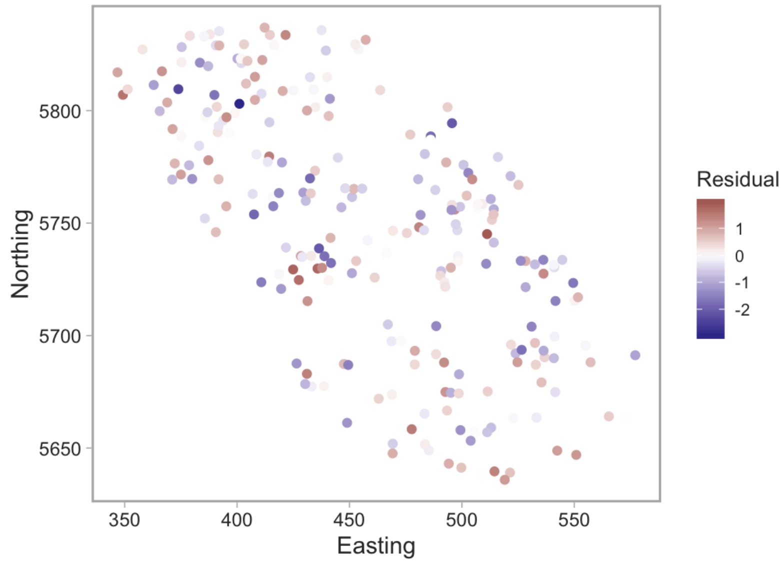


Figure E.4. Spatial randomized quantile residuals on the link (log) scale.

APPENDIX F. SURVEY BIOMASS INDEX TRENDS

Fisheries and Oceans Canada conducts a number of fishery-independent multispecies research surveys annually or biannually. These include four synoptic bottom trawl surveys and two longline hook surveys (Figure 1). The survey areas correspond roughly with Groundfish Management areas (Figure 2) where fishery quotas are allocated in British Columbia waters. For the synoptic trawl surveys, the West Coast Vancouver Island survey corresponds roughly to management areas 3CD, the Queen Charlotte Sound survey corresponds roughly to areas 5AB, the Hecate Strait survey corresponds roughly to areas 5CD, and the West Coast Haida Gwaii surveys corresponds roughly to area 5E. The Hard Bottom Longline survey is split into northern and southern segments. The southern survey area corresponds roughly to management areas 3CD and 5AB while the northern survey area corresponds roughly to areas 5CDE.

F.1 SYNOPTIC BOTTOM TRAWL SURVEYS

DFO, together with the Canadian Groundfish Research and Conservation Society, implemented a coordinated set of bottom trawl surveys that together cover the continental shelf and upper slope of most of the BC coast. The surveys follow a random depth stratified design and use the same bottom trawl fishing gear and fishing protocols (Sinclair et al. 2003). The surveys were designed to provide a synopsis of all species available to bottom trawl gear as opposed to focusing on specific species. There are a total of four synoptic (SYN) surveys: Hecate Strait (HS), West Coast Vancouver Island (WCVI), Queen Charlotte Sound (QCS), and West Coast Haida Gwaii (WCHG) (Figure 1). The Queen Charlotte Sound and West Coast Haida Gwaii surveys have been conducted on chartered commercial fishing vessels, while the Hecate Strait and West Coast Vancouver Island surveys have been conducted on the Canadian Coast Guard research trawler WE Ricker or chartered commercial fishing vessels when the WE Ricker was not available. Two of the synoptic surveys are conducted each year on an alternating basis so that each survey is conducted every two years.

F.2 HARD BOTTOM LONGLINE SURVEYS

The Pacific Halibut Management Association, in consultation with DFO, initiated a depth-stratified, random design research longline survey conducted with chartered commercial fishing vessels in 2006. These are referred to as the Hard Bottom Longline Outside surveys. The survey employs standardized longline snap gear and fishing methods and alternates annually between the northern and southern portions of BC. The survey is designed to provide catch rates of all species and biological samples of rockfish from the outside coastal waters of BC for stock assessment.

Hard Bottom Longline Inside surveys are conducted within management area 4B. These surveys were designed to provide fishery independent indices of abundance together with biological samples to improve the assessment of Yelloweye (*Sebastes ruberrimus*) and Quillback (*S. maliger*) Rockfish for the 4B management region. They began in Johnstone Strait and Discovery Passage in Pacific Fishery Management areas 12 and 13 in 2003 and 2004, and now alternate years to cover the northern (areas 12 and 13) and southern (areas 14–20, 28, 29) portions of the inside waters. These surveys also employ standardized longline snap gear and fishing methods.

F.3 INTERNATIONAL PACIFIC HALIBUT COMMISSION FISHERY INDEPENDENT SURVEY

The International Pacific Halibut Commission's (IPHC) fishery independent setline survey is the longest times series of longline survey data in BC. It provides distribution, biomass, age, growth and maturity data that are used in the annual assessment of Pacific Halibut (*Hippoglossus stenolepis*). In Appendix G we describe how we use data from the survey to construct a consistent index of abundance for other species over as long a time series as possible, despite the survey design changing through the years.

F.4 FURTHER DETAILS OF SURVEYS

Details on the design of the various surveys referenced in this report can be found in the following documents:

1. Synoptic Survey, Queen Charlotte Sound (SYN QCS): Williams et al. (2018a)
2. Synoptic Survey, West Coast Vancouver Island (SYN WCVI): Nottingham et al. (2017)
3. Synoptic Survey, Hecate Strait (SYN HS): Wyeth et al. (2018)
4. Synoptic Survey, West Coast Haida Gwaii (SYN WCHG): Williams et al. (2018b)
5. Hard Bottom Longline Survey, Outside (HBLL OUT): Doherty et al. (2019)
6. Hard Bottom Longline Survey, Inside (HBLL INS): Lochead and Yamanaka (2007)
7. Hecate Strait Multispecies Assemblage Survey (MSA HS): Choromanski et al. (2004)
8. International Pacific Halibut Commission fishery independent survey (IPHC FISS): Flemming et al. (2012)

Table F.1. Other surveys conducted by DFO in the Pacific region that may be applicable for species-specific analyses. Within this report, these surveys are only featured in the survey-data-availability panels in the lower right of each set of figure pages.

Survey	**Surveys conducted since 2008**
Queen Charlotte Sound Multispecies Small-mesh Bottom Trawl	7
West Coast Vancouver Island Multispecies Small-mesh Bottom Trawl	11
Strait of Georgia Ecosystem Research Initiative Acoustic	4
Sablefish Research and Assessment	3
Hard Bottom Longline Inside North	5
Hard Bottom Longline Inside South	5
Inlet Standardized Sablefish Trap	11
Offshore Standardized Sablefish Trap	3
Offshore Stratified Random Sablefish Trap	11
Strait of Georgia Synoptic Bottom Trawl	2
Joint Canada/US Hake Acoustic	8
Strait of Georgia Dogfish Longline	3
Eulachon Migration Study Bottom Trawl (South)	2

The main biomass index trends illustrated on the figure pages represent the 'design-based' index trends that have historically been used in Pacific Biological Station groundfish stock assessments. We extracted the trawl and longline survey relative biomass index trends from GFBio, which are generated using the same approach that has been used in all recent BC groundfish stock assessment reports. The code to perform the calculations was originally written by Norm Olsen at Pacific Biological Station and is automatically applied to the available survey data to generate the indices in the GFBio database. We have included the relevant equations below for clarity. We also compare geostatistical model-based estimates of biomass index trends for the trawl surveys (Section F.8).

F.5 TRAWL SURVEY DESIGN-BASED ESTIMATION

For all trawl surveys, and for a given species, we calculated the relative biomass density B in year t as:

$$B_t = \sum_{i=1}^{k} C_{t,i} A_i \tag{F.1}$$

where $C_{t,i}$ represents the mean CPUE in kg/km^2 for the species in year t and stratum i, A_i represents the area of stratum i in km^2, and k represents the number of strata. We calculated the CPUE ($C_{t,i}$) for a given species in year t and stratum i as:

$$C_{t,i} = \frac{\sum_{j=1}^{n_{t,i}} \left(W_{t,j} / D_{t,j} w_{t,j} \right)}{n_{t,i}} \tag{F.2}$$

where $W_{t,j}$ represents the catch weight (kg) for the species in year t, stratum i, and tow j; $D_{t,j}$ represents the distance travelled in km by tow j in year y; $w_{t,j}$ represents the net opening width in km for year y and tow j; and $n_{t,i}$ represents the number of tows in year t and stratum i.

F.6 LONGLINE SURVEY DESIGN-BASED ESTIMATION

For the HBLL surveys, and for a given species, we calculated the relative biomass density B in year t as:

$$B_t = \sum_{i=1}^{k} C_{t,i} A_i \tag{F.3}$$

where $C_{t,i}$ represents the mean CPUE in pieces (fish) per km^2 for the species in year t and stratum i, A_i represents the area of stratum i in km^2, and k represents the number of strata. We calculated the CPUE ($C_{t,i}$) for a given species in year t and stratum i as:

$$C_{t,i} = \frac{\sum_{j=1}^{n_{t,i}} \left(N_{t,j}/H_{t,j} w_{t,j}\right)}{n_{t,i}} \tag{F.4}$$

where $N_{t,j}$ represents the number of fish caught for the species in year t, stratum i, and set j; $H_{t,j}$ represents the number of hooks $\times$ the hook spacing in km in set j in year t; $w_{t,j}$ represents an arbitrary swept width of 30 feet or 0.009144 km for year t and tow j; and $n_{t,i}$ represents the number of sets in year t and stratum i. The hook spacing is 8 feet or 0.0024384 km for the inside and outside HBLL surveys.

Details on the design-based estimation of biomass density index for the IPHC survey are shown in Appendix G.

F.7 DESIGN-BASED-INDEX CONFIDENCE INTERVALS

We calculated bootstrap confidence intervals on B_t by repeatedly calculating B_t given the above equations but each time re-sampling, with replacement, from the available tows within each stratum. We drew 1000 bootstrap replicates of B_t, B_t^{rep}, and calculated 95% bias-corrected and adjusted (BCa) confidence intervals (Efron 1987) on B_t^{rep}.

F.8 GEOSTATISTICAL SPATIOTEMPORAL BIOMASS INDEX TRENDS

The above-described design-based estimates assume that average fish density is the same throughout each survey stratum and that the only source of variance between samples is sampling stochasticity itself (Petitgas 2001). However, we know this is not true — a substantial portion of fish density variation within a stratum can be attributed to habitat being of better or poorer suitability for a given fish and this suitability can be because of many factors beyond depth alone, on which the strata are stratified (Shelton et al. 2014). We also know that fish do not perceive their habitat according to these exact strata boundaries and that ecological processes in general tend to be spatially correlated with processes closer to each other being more similar than those further apart. Design-based estimates do not take advantage of this possible spatial correlation.

Geostatistical modelling of survey data aims to address these issues by modelling fish density as a smooth spatial surface — possibly the result of explicit habitat variables such as depth — but also as the product of other unobserved or 'latent' spatial effects. In recent years, there has been a movement toward such 'model-based' standardization of survey biomass index trends (e.g., Shelton et al. 2014, Thorson et al. 2015, Webster 2017). We include model-based index trends for the synoptic trawl surveys as a point of comparison so the reader can gauge when the two approaches may differ. Large differences are likely a result of the random positioning of the survey sets for a given year ending up in particularly good or poor habitat for a given species. Authors of BC groundfish stock assessments may want to consider model-based index standardization on a case-by-case basis.

We use the geostatistical model as described in Appendix E with the addition of spatiotemporal random effects ($\epsilon_{s,t}$; defined for locations in space s and time t) and annual predictors for the mean biomass each year:

$$y_{s,t} \sim \mathrm{Tweedie}(\mu_{s,t}, p, \phi), \quad 1 < p < 2, \tag{F.5}$$

$$\mu_{s,t} = \exp\left(\boldsymbol{X}_{s,t}\boldsymbol{\beta} + \omega_s + \epsilon_{s,t}\right). \tag{F.6}$$

As with the spatial model, the spatial random effects (ω_s) are assumed to be drawn from a multivariate normal distribution with some covariance matrix $\boldsymbol{\Sigma}_\omega$:

$$\boldsymbol{\omega} \sim \mathrm{MVNormal}\left(\boldsymbol{0}, \boldsymbol{\Sigma}_\omega\right), \tag{F.7}$$

and we assume the same for the spatiotemporal random effects, with each time slice being given its own independent set of random effects ($\boldsymbol{\epsilon}_t$) with covariance matrix $\boldsymbol{\Sigma}_{\epsilon,t}$:

$$\boldsymbol{\epsilon}_t \sim \mathrm{MVNormal}\left(\boldsymbol{0}, \boldsymbol{\Sigma}_{\epsilon,t}\right). \tag{F.8}$$

The spatial random effects account for spatial factors that are constant across time, for example, depth and substrate type. The spatiotemporal random effects account for factors that vary from year to year spatially such as bottom temperature, water circulation patterns, species interactions, and species movement.

Here we use Pacific Cod as an example species to illustrate the model components. The approach includes the same generation of spatial 'knots' as in the spatial model described in Appendix E (Figure F.1). We use 200 knots, which for spatial coverage of the synoptic trawl surveys, seems to be of adequately high resolution to capture the spatial and spatiotemporal variation. We tested this assumption by increasing the number of knots for a selection of species and ensuring that the estimated trends did not qualitatively differ.

We can project predictions from the model to a fine-scale (2 km $\times$ 2 km) grid using the covariance projection matrix (Figures F.2, F.3). We can also look at the individual components of the model. For the models without fixed effect predictors for depth, the fixed effect predictions each year are constant spatially (Figure F.4). The spatial random effects are constant across years (Figure F.5) and the spatiotemporal random effects vary across years (Figure F.6). We can look at residuals through space and time to check if there appears to be remaining spatial or spatiotemporal autocorrelation (Figure F.7).

We can then calculate expected biomass B_t in year t as:

$$B_t = \sum_{j=1}^{n_j} w_j \cdot \exp\left(\boldsymbol{X}_{j,t}\boldsymbol{\beta} + \omega_j + \epsilon_{j,t}\right), \tag{F.9}$$

where j references a 2 km $\times$ 2 km grid cell within the survey domain and w_j represents the weight or area of that grid cell (4 km^2) (Figure F.8). In other words, we sum the predicted biomass across all grid cells within the survey domain for each year. We generated standard errors on the annual estimates of log biomass via the generalized Delta method as implemented in TMB (Kristensen et al. 2016). Similar to the findings of Thorson et al. (2015), we found that the model-based biomass index trends often had lower CVs (coefficient of variations) than the design-based index trends and often helped stabilize biomass estimates for outlying years compared to the design-based index trends (e.g., Figure F.8).

We found little difference in the predicted biomass index between models that included or did not include depth covariates (e.g., Figure F.8). We found that the main difference between models with or without depth covariates was in the models with depth covariates having slightly more spatially resolved estimates of biomass (Figure F.2 vs. Figure F.3). We chose to not include depth and depth squared as predictors in the main biomass index illustrated throughout this report. Whereas in nearly all cases including depth covariates generated a similar index to excluding them, in a few cases including them generated what appeared to be unrealistic deviations in biomass when the quadratic shape of the relationship between depth and biomass generated exceedingly high or low estimates of biomass on the border of the survey polygons. This remains a topic of research and will be investigated by the authors in the future.

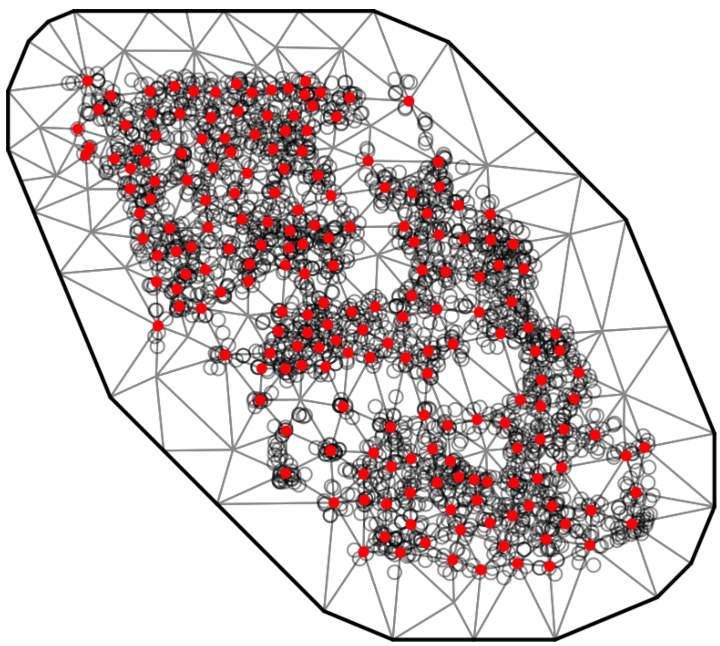


Figure F.1. Example triangularization mesh for Pacific Cod and the Queen Charlotte Sound survey across all years. Red dots represent the knot locations and open black circles represent the location of the survey sets.

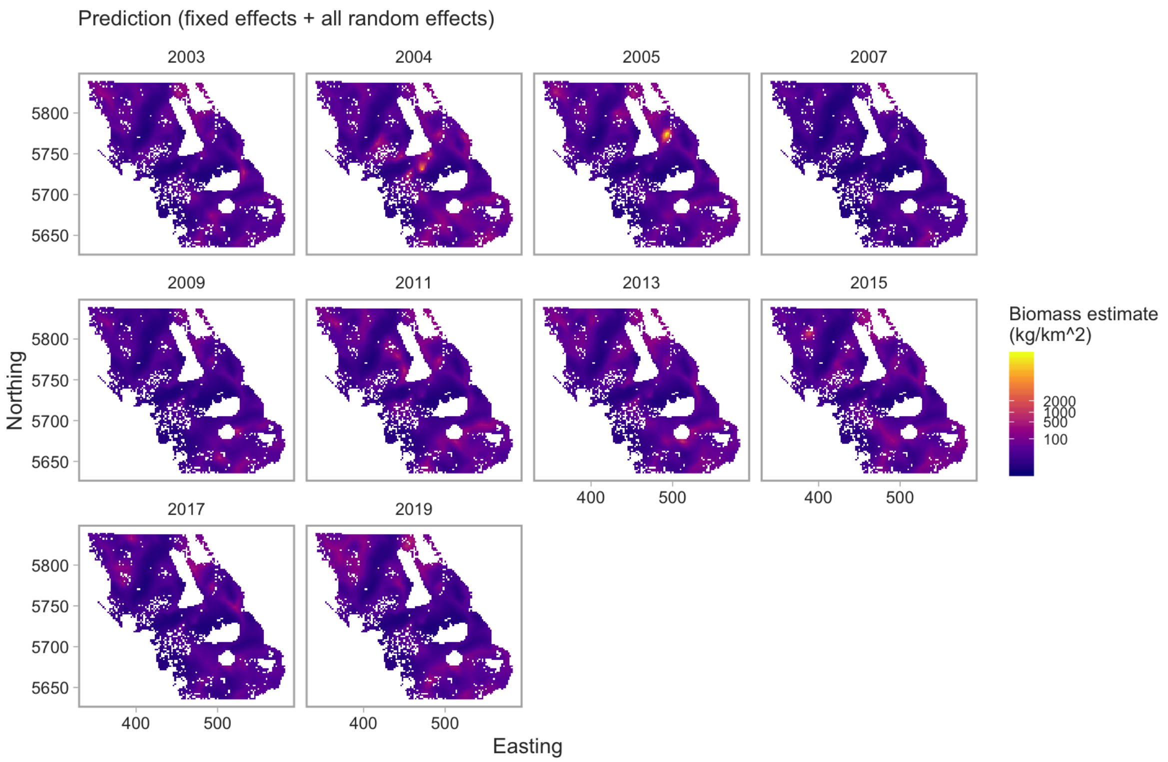


Figure F.2. Predictions from geostatistical spatiotemporal model for Pacific Cod in Queen Charlotte Sound. Predicted biomass is shown with a fourth-root-distributed colour scale.

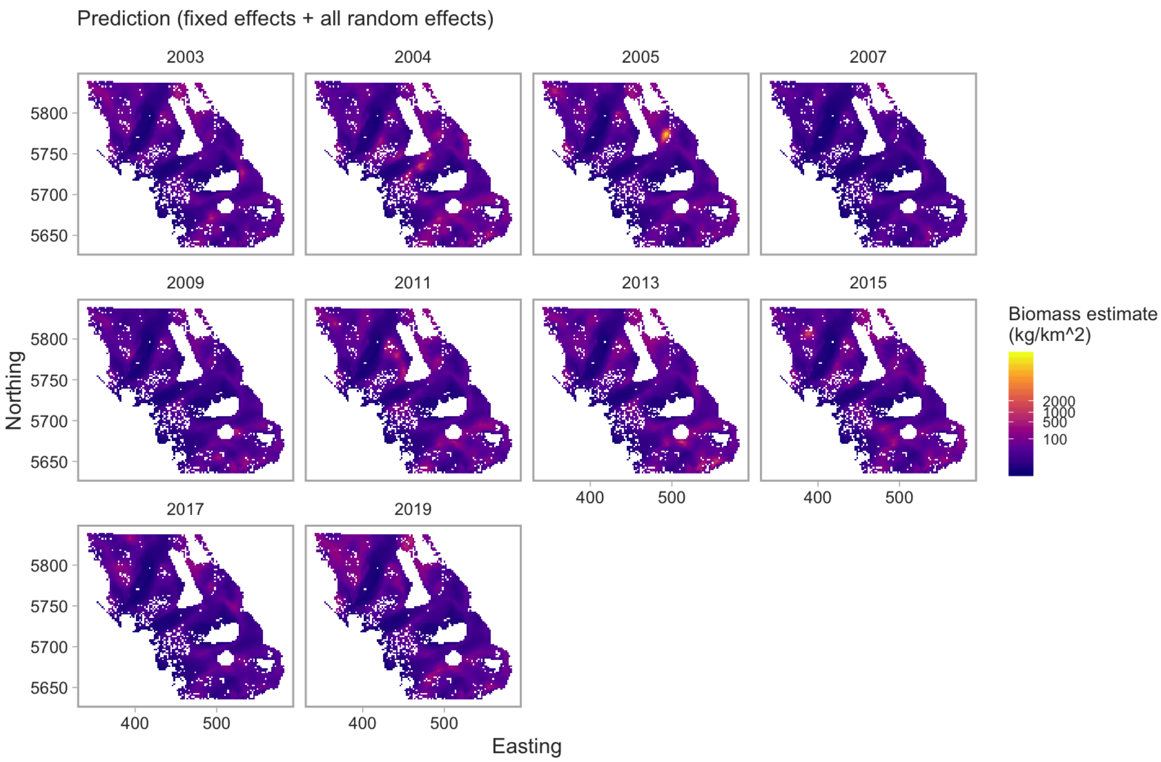


Figure F.3. Predictions from a geostatistical spatiotemporal model that includes the effects of depth and depth squared for Pacific Cod in Queen Charlotte Sound. Predicted biomass is shown with a fourth-root-distributed colour scale. Note the similarity to the previous figure which does not include the depth predictors.

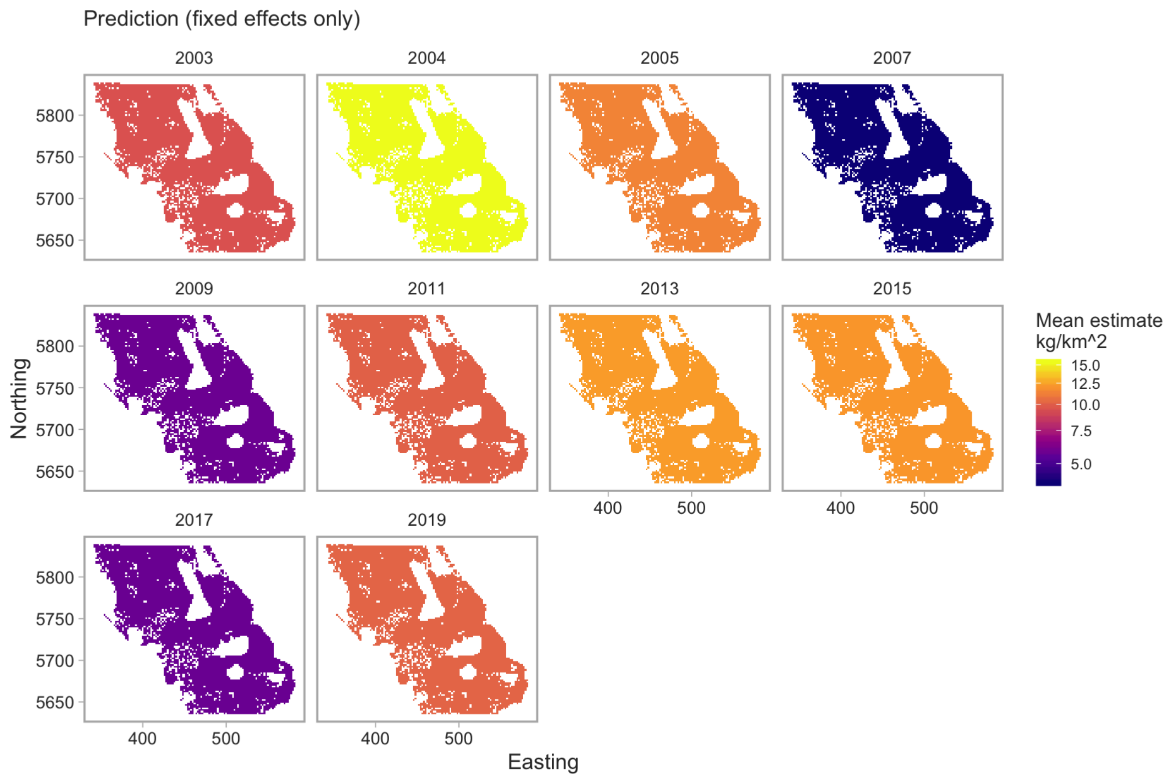


Figure F.4. Fixed effect predictions from a geostatistical spatiotemporal model for Pacific Cod in Queen Charlotte Sound. Here the only fixed effects are the mean effects for each year resulting in fixed effect predictions that are same throughout the spatial region for each year.

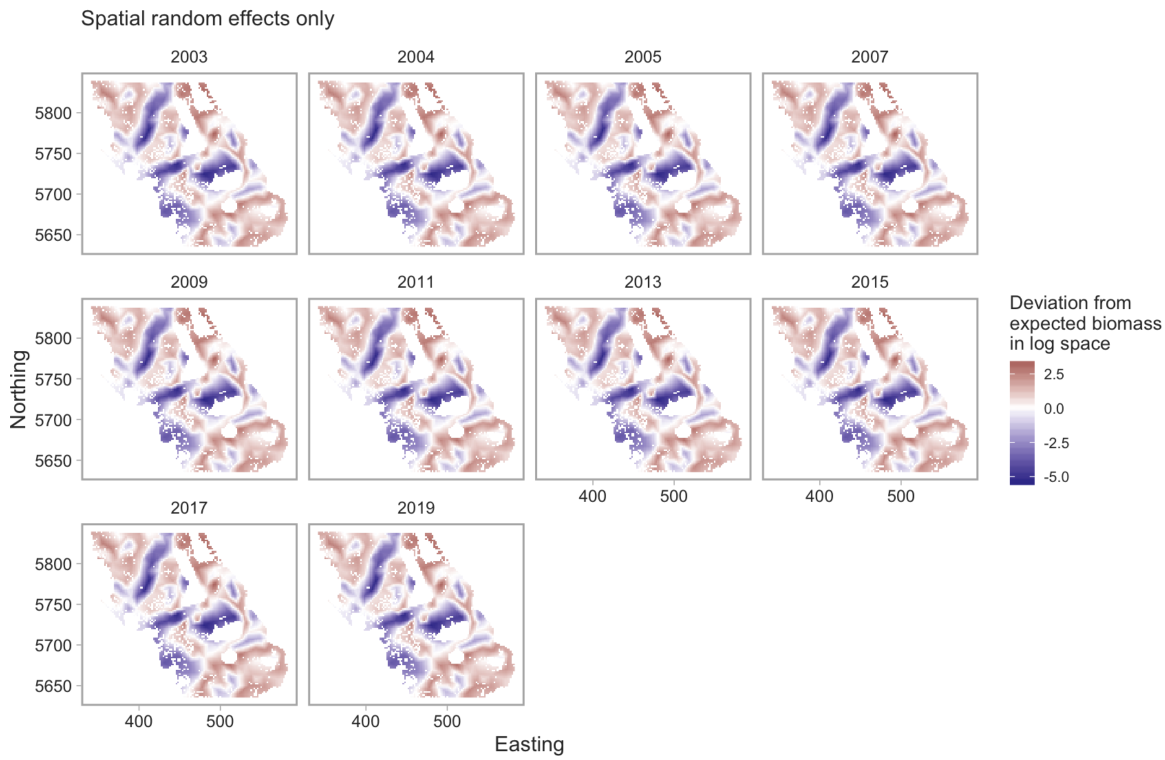


Figure F.5. Spatial random effect predictions from a geostatistical spatiotemporal model for Pacific Cod in Queen Charlotte Sound. The spatial random effects account for spatial factors that are constant across years, for example, depth and substrate type.

Figure F.6. Spatiotemporal random effect predictions from a geostatistical spatiotemporal model for Pacific Cod in Queen Charlotte Sound. The spatiotemporal random effects account for factors that vary from year to year spatially such as bottom temperature, water circulation patterns, and species interactions.

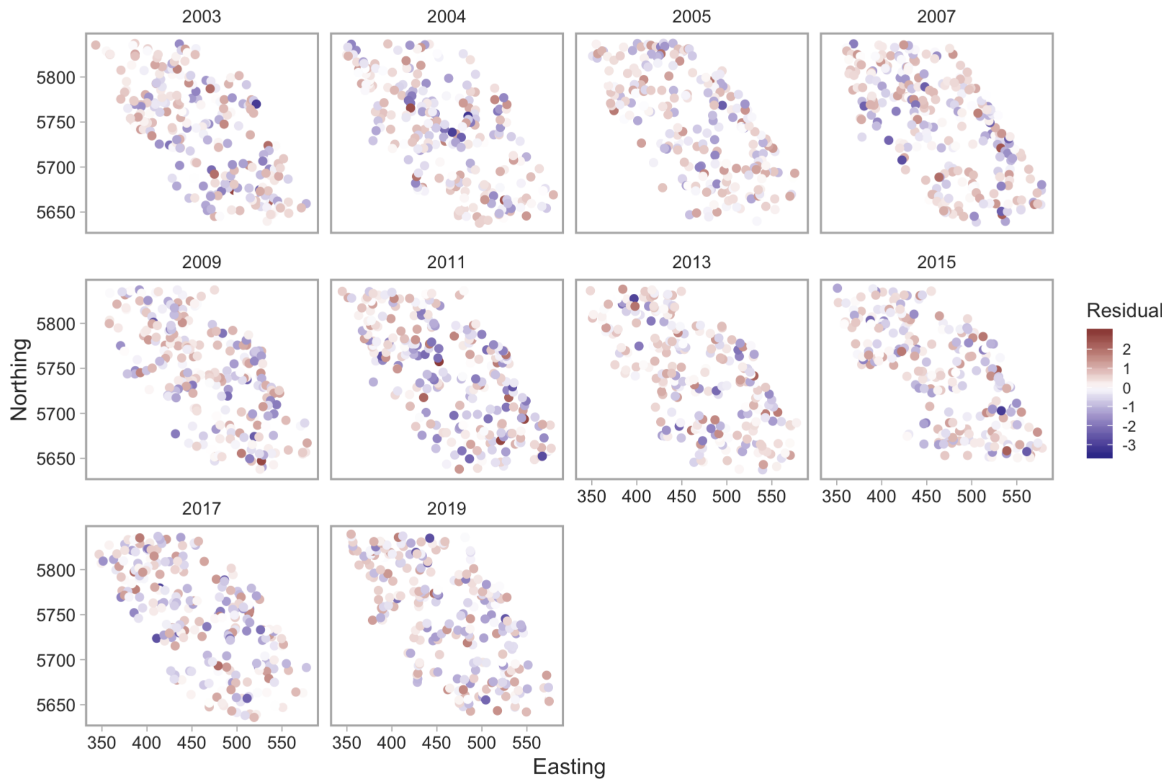


Figure F.7. Spatial residuals plotted through time on the link (log) scale.

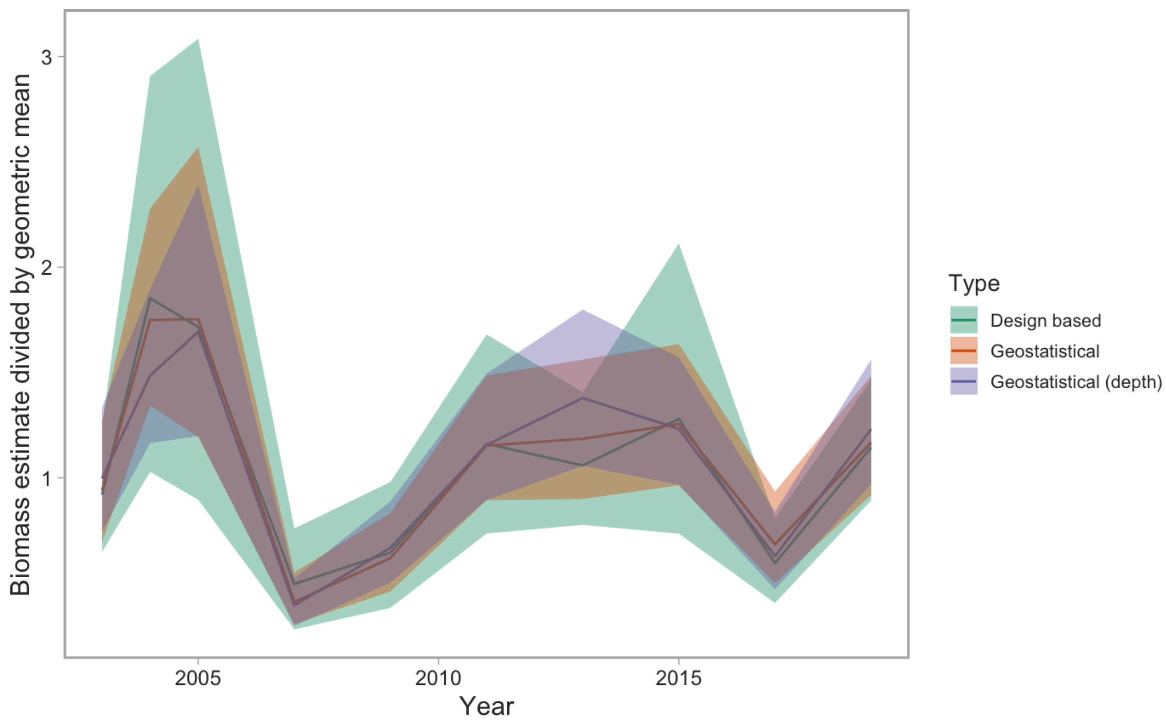


Figure F.8. Relative biomass index predictions from the design-based approach, the geostatistical approach without covariates, and the geostatistical approach with depth covariates. The y-axis denotes relative biomass from each method divided by its geometric mean. Note the similarity between the two geostatistical models.

APPENDIX G. IPHC SURVEY INDEX

The International Pacific Halibut Commission (IPHC) conducts an annual stock assessment longline survey in waters from California to Alaska, including British Columbia waters (Flemming et al. 2012). The survey's main goal is to provide data on Pacific Halibut (*Hippoglosus stenolepis*) for stock assessment purposes.

At each station, the fishing gear consists of a set of skates each of about 100 hooks. Up to eight skates are on each set, with the number of skates per set varying between years. For each set the IPHC calculates an 'effective skate number', which we use here to scale the count of each species of interest and obtain a catch rate for each set (described below). The effective skate number "standardizes survey data in years when the number of hooks, hook spacing, or hook type varied" (Yamanaka et al. 2008). An effective skate of one represents a skate of 100 circle hooks with 18-foot spacing (Yamanaka et al. 2008).

For British Columbia waters, the survey has enumerated non-halibut species since 1995 (to varying degrees of species identification). For each species, the catch rate of a set is the number of individuals caught per effective skate. We bootstrap these catch rates within each year to give annual bootstrapped means, bias-corrected and adjusted (BCa) bootstrapped 95% confidence intervals, and bootstrapped coefficients of variation (CV) (Efron 1987).

However, complications arise because of differing data collection protocols in different years. We seek a survey index that spans as long a time period as possible, and, ideally, also covers all the coastwide waters off British Columbia (excluding the Strait of Georgia which the IPHC survey does not enter). Although the spatial coverage and the technical details of the survey are not consistent from year to year (as described below), we attempt to construct a survey index for as many species as possible for as long a time period as possible. We also determine whether each index can be considered representative of all British Columbia waters. For each species, the resulting index gives what we term the International Pacific Halibut Commission fishery independent survey series (IPHC FISS).

The approach taken is described below and builds on that developed for assessments of Redbanded Rockfish (Edwards et al. 2017) and Yelloweye Rockfish (Yamanaka et al. 2018). The Redbanded assessment was the first to develop an abundance index from the IPHC survey that went back to 1995, and included data up to 2012. For the Yelloweye assessment the methods were extended to demonstrate that the index based on waters north of Vancouver Island could be considered representative of the coastwide population. See those examples for worked examples of most of the following calculations.

G.1 IPHC DATA

In British Columbia waters (IPHC area 2B), since 2003 a third observer has been deployed on the IPHC survey to identify all catch to the species level on a hook-by-hook basis and to conduct biological sampling (Flemming et al. 2012), although in 2013 there was no such observer. Observers were also deployed prior to 2003, although data are not available in such detail, as summarised in Table G.1. For some years only the first 20 hooks from each skate were enumerated, and for other years all hooks were enumerated but the data are only available at the set level (i.e. we do not know which hook caught which species, only how many individuals from each species were caught on the whole set). The data were extracted from various spreadsheets and the DFO database GFBio, and all originally came from the IPHC. For only some of the years

Table G.1. Summary of available data from the IPHC stock assessment longline surveys. 'Data resolution' indicates at what level the data are available, and 'WCVI?' indicates whether or not the survey included locations off the west coast of Vancouver Island. 'Location of data' indicates where the data were accessed from, either our DFO GFBio database or from spreadsheets. [1] For 1995, the biological data were in the file "1995_IPHC_SSA_Rockfish_catch_from_Kelly_Ames.xls" on DFO's Inshore Rockfish shared drive, and effective skates were obtained from Aaron Ranta (IPHC) in the file "1995EffSktValues by Station.xlsx". [2] For 1996-2002, the data were in the file "2B AllSpecies 96-02 roundIII.xls", which originally came from the IPHC. [3] For 2013 the data were in the file "2013 20-Hook Data.xls", which originally came from the IPHC. For easier access, the data from spreadsheets are now all included in our gfplot package.

Year	Hooks enumerated	Data resolution	Location of data	WCVI?
1995	All	Set-by-set	Spreadsheets[1]	N
1996	All	Set-by-set	Spreadsheet[2]	N
1997-1998	First 20 of each skate	Set-by-set	Spreadsheet[2]	N
1999	First 20 of each skate	Set-by-set	Spreadsheet[2]	Y
2000	First 20 of each skate	Set-by-set	Spreadsheet[2]	N
2001-2002	First 20 of each skate	Set-by-set	Spreadsheet[2]	Y
2003-2011	All	Hook-by-hook	DFO database GFBio	Y
2012	All (bait experiment)	Hook-by-hook	DFO database GFBio	Y
2013	First 20 of each skate	Set-by-set	Spreadsheet[3]	Y
2014-2018	All	Hook-by-hook	DFO database GFBio	Y

were the locations off the west coast of Vancouver Island (WCVI) sampled. Note that, for simplicity we use the term 'first 20 hooks' since samplers on the vessels generally targeted the first 20 hooks deployed from each skate. However, for operational reasons (particularly in areas of high catch rates), sometimes the 20 hooks would come from elsewhere within a skate but would always consist of 20 consecutive hooks (e.g., Dykstra et al. 2002).

From Table G.1, four issues are apparent:

1. For 1997-2002 and 2013 only the first 20 hooks of each skate were enumerated, whereas for all other years all hooks were enumerated. Thus, the data from each year cannot simply be considered as comparable and analysed as one consecutive time series.
2. For the datasets for 1995, 1996, 1997-2002 and 2013, data are only available at the set-by-set level, in terms of numbers of a given species per effective skate. Which species was caught on each hook is not available, unlike for 2003-2012 and 2014-2018. Thus, for 1995 and 1996 we cannot calculate catch rates based on the first 20 hooks (because we only have set-by-set level data), whereas we can do that for 2003-2012 and 2014-2018, and the 20-hook data is the only information we have for 1997-2002 and 2013.
3. In 2012 a bait experiment was conducted such that data from all skates could not be used; see Section G.3.
4. The WCVI was not visited in every year, so the spatial coverage is not consistent across years.

To address issues 1, 2 and 4 we therefore construct four time series (whose structure is summarised in Table G.2) for each species:

Series A – 1997-2018 stations north of WCVI, with catch rates based on first 20 hooks only (which is all we have for 1997-2002 and 2013).

Series B – 1995, 1996, 2003-2012 and 2014-2018 stations north of WCVI, with catch rates based on all hooks (which is all we have for 1995 and 1996).

Table G.2. Summary of how the four Series **A***,* **B***,* **C** *and* **D** *are constructed. Numbers in parentheses indicate the number of years for which data for each Series are available. 'Only north of WCVI' indicates Series that only consider stations north of Vancouver Island (thus excluding those off the WCVI), 'Full coast' indicates Series that use all stations from the whole coast. The rows indicate how many hooks the catch rates for each Series are based on.*

	Only north of WCVI	Full coast
First 20 hooks from each skate	**A**(22)	**D**(19)
All hooks from each skate	**B**(17)	**C**(15)

Series C – 2003-2012 and 2014-2018 stations coastwide (including WCVI), with catch rates based on all hooks.

Series D – 1999 and 2001-2018 stations coastwide (including WCVI), with catch rates based on first 20 hooks only (which is all we have for 1999, 2001-2002 and 2013).

We would like to obtain an index series with as long a timespan as possible, and, ideally, over as broad a geographic region as possible. Since Series A is the longest time series, we take this and expand it to Series AB, defined as:

Series AB – for stations north of WCVI, combine the 1995 and 1996 values from Series B, based on all hooks, with the 1997-2018 values from Series A that are based on first 20 hooks only. See Section G.4.

The resulting Series AB covers the stations north of WCVI. In Sections G.4.5 and G.4.6 we show how we determine, for each species, whether we can consider this series to be representative of the full coast (i.e. including the WCVI), by comparing the series that exclude stations off the WCVI (Series A and B) with those that include the stations off the WCVI (Series C and D, respectively).

G.2 SPATIAL LOCATIONS OF STATIONS

For the IPHC survey, from 1995-1997 the stations were arranged in Y-shapes; they were not exactly the same locations each year, but fairly close to each other. Since 1998 the stations have been positioned equidistant from one another on a fixed 10-nautical-mile square grid (Flemming et al. 2012). In 1999 the survey first went to the WCVI, did not go there in 2000, but has since 2001. See Edwards et al. (2017) and Yamanaka et al. (2018) for maps that demonstrate the different coverage (and that show stations that caught Yelloweye and Redbanded Rockfish, respectively).

Given the difference in coverage between years, for Series A and B we exclude those stations south of 50.6° latitude, which is near the northern tip of Vancouver Island. This latitude was chosen so that all the stations from 1995-1997 are included. The stations for 1995-1997 show good overlap (north of Vancouver Island) with the stations from 1998 onwards, despite not being on the exact same 10-nautical-mile square grid (Yamanaka et al. 2018). Series C and D use all stations coastwide (by definition).

Each year, a few stations may be declared unusable by the IPHC and are excluded from our analyses (e.g., the hook-tally sheet got blown overboard for station 2113 in the year 2008), with description and usability codes described in Tables G.3 and G.4. In particular, we include stations deemed as 'Usable but omit from any geospatial analysis', but these should be excluded for

Table G.3. Description of hook observation classifications and corresponding codes in theGFBio database.

Description	HOOK_YIELD_CODE
Unknown	0
Empty hook	1
Bait on hook	2
Animal on hook (fish or invertebrate)	3
Species head on hook	4
Species dropped off hook	5
Bait skin on hook	6
Hook not observed	7
Eaten or bitten (by shark, etc.)	8

Table G.4. Description of classification of IPHC sets, and indication of which we include in our analyses.

Description	USABILITY_CODE	Included here?
Fully usable	1	Y
Usable but omit from swept area calculations	21	N
Usable but removed due to re-definition of survey area	22	N
Usable but omit from any biomass calculations	27	N
Usable but omit from any geospatial analysis	52	Y

complex spatial analyses.

G.3 CHUM SALMON BAIT EXPERIMENT

Prior to 2012, Chum Salmon (*Oncorhynchus keta*) was used for bait. But in 2012, a bait experiment was conducted (Henry et al. 2013). At each station three different bait types were used on the same set: a consecutive four-skate Chum Salmon treatment, a one-skate Pink Salmon (*Oncorhynchus gorbuscha*) treatment, and a one-skate Walleye Pollock (*Gadus chalcogramma*) treatment. The location of the three treatments on each set was randomized throughout the survey, and each treatment was separated by one skate (1,800 ft) of hookless groundline. For consistency with previous years, we only consider the four skates that used Chum Salmon as bait.

The effective skate number provided by the IPHC is for all skates used, which in 2012 will include skates that were not baited with Chum Salmon (Eric Soderlund, IPHC, Seattle, WA, USA, pers. comm.). But we wish to only include the Chum Salmon baited skates, and so we need to modify the effective skate number (see below). The effective skate number depends on the number of observed hooks (Eric Soderlund, IPHC, Seattle, WA, USA, pers. comm.), rather than the number of hooks that were deployed. The bait experiment has not been repeated.

G.4 CATCH RATE EQUATIONS

G.4.1 CATCH RATE BASED ON ALL CHUM-BAIT HOOKS

For each species of interest, we wish to obtain a catch rate index which, for each year, will be the mean catch rate across all sets that year. The units will be numbers of individuals caught per effective skate. We only want to consider hooks that used Chum Salmon as bait (hereafter 'chum-bait hooks'), because we have no information as to how catch rates change depending on the bait used. For our data, 2012 was the only year that hooks were not exclusively chum-bait hooks.

Define:

H_{it} – number of observed chum-bait hooks in set i in year t,

H^*_{it} – number of observed hooks for all bait types ($H_{it} \neq H^*_{it}$ only for 2012),

E_{it} – effective skate number of set i in year t, which needs to be based on observed chum-bait hooks,

E'_{it} – effective skate number from IPHC, which is based on all observed hooks (regardless of bait).

Thus, E_{it} is

$$E_{it} = \frac{H_{it}}{H^*_{it}} E'_{it}. \tag{G.1}$$

Adapting equations on page 3 of (Yamanaka et al. 2008), define:

N_{it} – the number of fish of a given species caught on set $i = 1, 2, ..., n_t$ in year t, based on observed chum-bait hooks,

n_t – the number of sets in year t,

C_{it} – catch rate (with units of numbers per effective skate) for set i in year t, based on observed chum-bait hooks, given by

$$C_{it} = \frac{N_{it}}{E_{it}}. \tag{G.2}$$

The catch rate index for year t, I_t (numbers per effective skate), is then the mean catch rate across all sets:

$$I_t = \frac{1}{n_t} \sum_{i=1}^{n_t} C_{it} = \frac{1}{n_t} \sum_{i=1}^{n_t} \frac{N_{it}}{E_{it}}. \tag{G.3}$$

G.4.2 CATCH RATE BASED THE FIRST 20 CHUM-BAIT HOOKS OF EACH SKATE

Let $\tilde{X}$ indicate a calculation of some value X that is based only on the first 20 hooks of each skate. These are the first 20 *numbered* hooks, not the first 20 *observed* hooks (so not all of the numbered hooks may have been observed). Thus, we have:

$\tilde{H}_{it}$ – number of observed chum-bait hooks in the first 20 hooks of all skates in set i in year t,

$\tilde{E}_{it}$ – effective skate number of set i in year t based on the first 20 chum-bait hooks that were sent out on each skate.

Since effective skate number is a linear function of the number of hooks in a set (Yamanaka et al. 2008), we have

$$\tilde{E}_{it} = \frac{\tilde{H}_{it}}{H_{it}} E_{it} \quad = \frac{\tilde{H}_{it}}{H^*_{it}} E'_{it} \Bigg) \Bigg(\tag{G.4}$$

The resulting notation for the index will be:

$\tilde{I}_t$ – catch rate index for year t (in numbers of individuals per effective skate) based on only the first 20 hooks sent out for each skate,

$\tilde{N}_{it}$ – the number of individuals caught on set $i = 1, 2, ..., n_t$ in year t, based on observed chum-bait hooks and only the first 20 hooks sent out for each skate,

$\tilde{C}_{it}$ – catch rate (with units of numbers per effective skate) for set i in year t, based only on the first 20 hooks of each skate (and only skates with chum as bait), such that

$$\tilde{C}_{it} = \frac{\tilde{N}_{it}}{\tilde{E}_{it}}. \tag{G.5}$$

The catch rate index for year t, $\tilde{I}_t$ (in units of numbers per effective skate), based on only the first 20 hooks of each skate, is then the mean catch rate across all sets:

$$\tilde{I}_t = \frac{1}{\tilde{n}_t} \sum_{i=1}^{\tilde{n}_t} \tilde{C}_{it} = \frac{1}{\tilde{n}_t} \sum_{i=1}^{\tilde{n}_t} \frac{\tilde{N}_{it}}{\tilde{E}_{it}}. \tag{G.6}$$

We base calculations on bootstrapped means, and so I_t and $\tilde{I}_t$ are calculate, for each year, by re-sampling the catch rates (C_{it} or $\tilde{C}_{it}$) 1,000 times and calculating a bootstrapped mean and 95% bias-corrected and adjusted confidence interval.

G.4.3 EQUIVALENCY OF CATCH RATES BASED ON ALL HOOKS AND ON JUST THE FIRST 20 HOOKS

Equation (G.5) can be written as

$$\tilde{C}_{it} = \frac{\tilde{N}_{it}}{\tilde{E}_{it}} = \frac{H_{it}}{\tilde{H}_{it}} \frac{\tilde{N}_{it}}{E_{it}}. \tag{G.7}$$

If all hooks are equally likely to catch an individual of the given species, then the catch rates based on the first 20 hooks of each skate should be an unbiased sample of the catch rates based on all the hooks. The ratio of individuals caught, $\tilde{N}_{it}/N_{it}$, should equal (on average) the ratio of hook numbers, $\tilde{H}_{it}/H_{it}$, because a proportionally reduced number of fish are caught on the proportionally fewer hooks. Thus

$$\frac{\tilde{H}_{it}}{H_{it}} = \frac{\tilde{N}_{it}}{N_{it}} \tag{G.8}$$

such that

$$\tilde{C}_{it} = \frac{N_{it}}{\tilde{N}_{it}} \frac{\tilde{N}_{it}}{E_{it}} = \frac{N_{it}}{E_{it}} = C_{it}. \tag{G.9}$$

If the catch rates are greatly different, then this suggests that the catch rates from the first 20 hooks are not equivalent to the catch rates based on all the hooks. This is why we compare Series A and Series B in Figure G.1.

G.4.4 CONSTRUCTING SERIES AB

For each species, we wish to join up the 1995 and 1996 data from Series B (based on all hooks) to the 1997-2018 data from Series A. The 1995 and 1996 data are only available as numbers of individuals caught for all hooks, and not as numbers caught in the first 20 hooks. For 1997-2002 and 2013 we only have numbers caught for the first 20 hooks. But for 2003-2012 and 2014 onwards we have hook-by-hook data, and so can compute catch rates for all hooks or based on just the first 20 hooks (i.e. these overlapping years are the only years that contribute to both Series A and Series B).

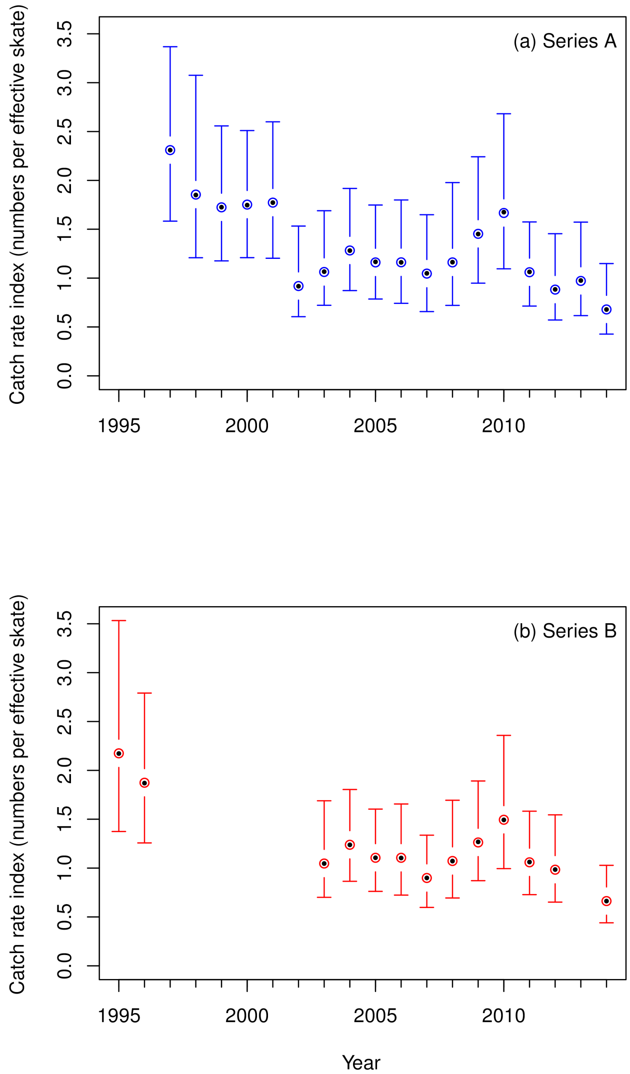


Figure G.1. Catch rate index (number of individual Yelloweye Rockfish caught per skate) for (a) Series A and (b) Series B from the Yelloweye Rockfish assessment (Yamanaka et al., 2018), to demonstrate the calculations. For a given year, the catch rate for each set was calculated from (G.2) or (G.5). These catch rates were then re-sampled for 10,000 bootstrap values, from which a bootstrapped mean (open circles) and 95% bias-corrected and adjusted confidence intervals (bars) were calculated. Small black closed circles are sample means (not bootstrapped), and essentially equal the bootstrapped means.

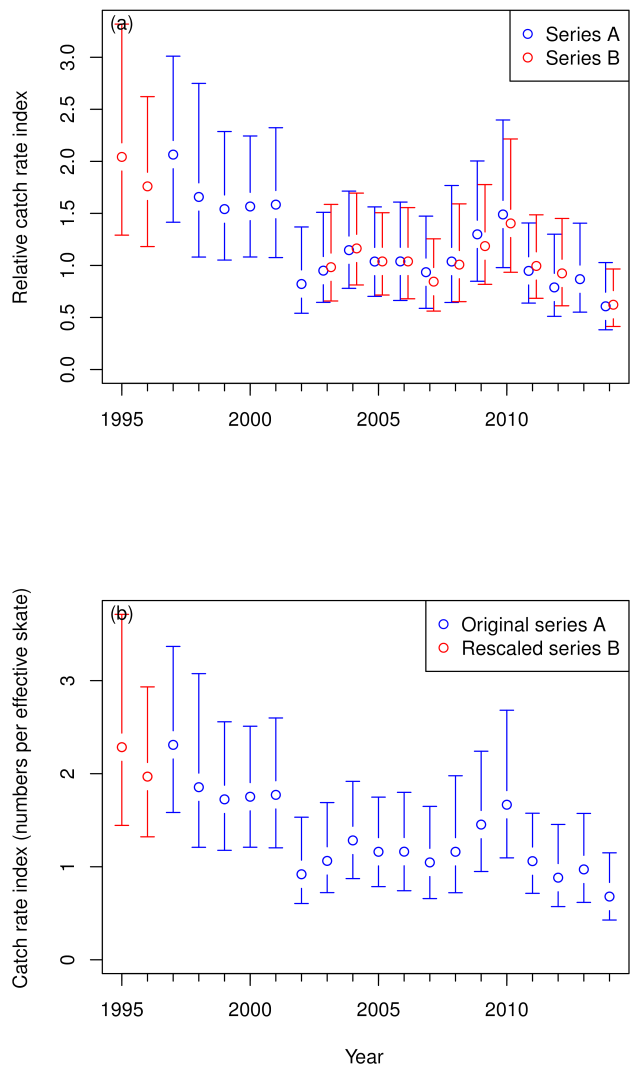


Figure G.2. (a) Each of the two catch rate series from Figure G.1 is divided by the geometric mean of its bootstrapped annual means (with the geometric mean based on the overlapping years only). (b) The catch rate index Series AB, which extends the original Series A by incorporating the suitably scaled 1995 and 1996 values from Series B (see text).

For Series A, define G_A to be the geometric mean of the bootstrapped annual means, with the geometric mean based only on the overlapping years (2003-2012 and 2014 onwards). Define G_B similarly for Series B. By dividing the bootstrapped values for each series by their respective geometric means, we obtain Figure G.2a. This shows that the rescaled Series A and Series B are very similar for the overlapping years. Thus, on this scale, the 1995 and 1996 values from Series B look comparable to the full Series A data.

We statistically test the comparability by conducting a paired t-test (Crawley 2002) on the scaled annual means for the overlapping years, to test the null hypothesis that there is no difference between the scaled annual means, with resulting p-value defined as p_{AB}. If $p_{AB} \geq 0.05$ then we cannot reject the null hypothesis. Then we join up the two series in Figure G.2(a) by taking the rescaled 1995 and 1996 values from Series B and joining to the rescaled Series A. Equivalently, we just multiply the original Series-B means and confidence intervals for 1995 and 1996 by G_A/G_B, and then join them up to the original Series A, as in Figure G.2b, to get the longest time series possible, based on the first 20 hooks from each skate, rescaled for 1995 and 1996 for which numbers for the first 20 hooks are not available.

If $p_{AB} < 0.05$ then we cannot join the series, and so we stick with Series A as being the longest.

G.4.5 CONSTRUCTING SERIES D (20 HOOKS, COASTWIDE) AND COMPARING IT WITH SERIES A (20 HOOKS, NORTH OF VANCOUVER ISLAND)

We now consider Series D, which is for the first 20 hooks of each skate (like for Series A) but covers the whole coast, including the WCVI (unlike Series A), as was summarised in Table G.2.

In the same way that we just compared Series A and Series B, we divide each series by its geometric mean (G_A or G_D, based on the overlapping years of A and D) and conduct a paired t-test on the scaled annual bootstrapped means for the overlapping years to give a p-value (p_{AD}). Again, if $p_{AD} \geq 0.05$ then we consider the two series comparable.

For Series A and Series D this means that we can consider the relative changes in Series A (that excludes WCVI) to be the same as those in Series D (that includes the full coast), and hence we can consider Series A to be representative of the full coast. So the population off the WCVI is not showing a different relative trend to the rest of the coast.

We do not need to join up the two series, we just wish to verify whether the relative changes in Series A can be considered representative of the full coast. If $p_{AD} < 0.05$ then this is not the case.

For the last Yelloweye Rockfish assessment (Yamanaka et al. 2018), the relative scaled patterns for Series A and Series D appeared similar for the overlapping years (though no statistical test was done). But the *absolute* catch rates were different, with inclusion of the WCVI stations in Series D consistently reducing the mean annual catch rates from those of Series A (that did not include the WCVI stations), with $G_A/G_D = 1.12$ for the overlapping years (it would equal 1 if the catch rates were the same). The stations off the WCVI had lower average catch rates of Yelloweye Rockfish than the remaining stations.

So, while inclusion of the WCVI stations does not appear to change the *relative* pattern of the index of the population, it does change the absolute values. Therefore, the stations off the WCVI have to be included or excluded consistently to construct an index series; since we have more years that do not have stations off the WCVI (Table G.2), we consistently exclude these stations (giving Series A).

G.4.6 CONSTRUCTING SERIES C (ALL HOOKS, COASTWIDE) AND COMPARING IT WITH SERIES B (ALL HOOKS, NORTH OF VANCOUVER ISLAND)

Similarly, we also construct Series C, which is for all hooks from each skate (like for Series B) but covers the whole coast, including the WCVI (unlike Series B), as was summarised in Table G.2.

We again compare each series scaled by its geometric mean of the overlapping years and conduct a paired t-test on the scaled annual bootstrapped means for the overlapping years, giving a p-value p_{BC}. If $p_{BC} \geq 0.05$ then we consider the two series comparable. This means that we can consider the relative changes in Series B to reflect those of the full coast (Series C).

For the last Yelloweye Rockfish assessment (Yamanaka et al. 2018), similarly to Series A and D just discussed, the relative scaled patterns for Series B and Series C appeared similar for the overlapping years. But the *absolute* catch rates were different, with inclusion of the WCVI stations in Series C consistently reducing the mean annual catch rates from those of Series B (that did not include the WCVI stations), with $G_B/G_C = 1.11$ for the overlapping years.

So, the stations off the WCVI had lower average catch rates of Yelloweye Rockfish than the remaining stations. This holds whether we look at all hooks (here) or just the first 20 by comparing Series A and D (above).

G.4.7 RESULTING LONGEST INDEX FROM THE IPHC SURVEY

So, if $p_{AB} \geq 0.05$ then Series AB can be created and that is the longest IPHC survey index that can be constructed. If $p_{AD} \geq 0.05$ and $p_{BC} \geq 0.05$ then Series A and Series B can be considered representative of the full coast, and thus so can Series AB.

If $p_{AB} \geq 0.05$ but either $p_{AD} < 0.05$ or $p_{BC} < 0.05$ then Series AB is still the longest time series possible but can only be considered to represent the waters north of Vancouver Island, not the full coast. If $p_{AB} < 0.05$ then Series A is the longest time series.

For some special cases of species that are rarely caught (or that weren't specifically enumerated in 1995 and 1996, for example), then Series A may be the longest, or even possibly Series C or D if the species was not caught in some years. Some rare special cases may not yet be fully accounted for in our code and may need to be verified on a species-by-species basis, particularly to ascertain whether a given species was being actively identified in a given year (resulting in a zero catch rate rather than 'no data'). Also, a shorter time series from all hooks (Series B or C) may be more informative than a longer time series based on just the first 20 hooks. All series are calculated for all species and should be examined further to make any subsequent inferences.

Furthermore, although some species are rarely caught in IPHC survey, we have shown all available data (rather than setting a minimum requirement that a certain number of individuals need to be caught in any one year or over the full time series). This sometimes creates strange see-saw patterns when a species is caught in only some years (e.g., Greenstriped Rockfish in Section 5.54). However, this is unavoidable given our aim of showing all the available data, and further demonstrates the need to examine the data for a thorough understanding regarding any particular species.

G.5 HOOK COMPETITION

The above approach was used by Yamanaka et al. (2018) to show how to construct an index for Yelloweye Rockfish that was representative of the full coast and went back to 1995. Another approach was used to generate an index for the assessment model (Marie Etienne et al., *Extracting abundance indices from longline surveys: a method to account for hook competition and unbaited hooks*, unpublished manuscript). This attempted to account for the effect of individual fish competing for the bait that is on the hooks.

If some of the hooks on a set have caught individual fish, then those hooks are no longer actively fishing. Incorporation of such 'hook competition' involves scaling up the catch rates to account for the fact that not all of the observed hooks were fishing for the duration of the soak time.

Clark (2008) and Webster et al. (2011) investigated this for the IPHC survey, to help estimate Pacific Halibut indices, and here we derive a model for hook competition based on their work (and our earlier notation). This has not yet been incorporated into our analyses but can be in the future, though this requires decisions concerning what to do in cases where none of the hooks are returned with bait on them (discussed below), which was not possible for this report.

Extending the earlier notation, define:

$N_{its}^{(0)}$ – the number of fish of species s that we would expect to catch *in the absence of hook competition* on set $i = 1, 2, ..., n_t$ in year t, based on observed chum-bait hooks,

F_{its} – the local rate of capture of bait by species s around set i in year t.

The number $N_{its}^{(0)}$ is proportional to the true local density of that species, and so is what we wish to use as an index of abundance. And, by definition,

$$N_{its}^{(0)} = F_{its} H_{it}, \tag{G.10}$$

where, as earlier, H_{it} is the number of observed chum-bait hooks in set i in year t. Clark (2008) noted that "Mathematically the process of baits being removed from a longline by different species is the same as the process of fish being removed from a population by different fisheries and natural predators". Each species removes a certain proportion of the baits per unit time, so the Baranov catch equation can be used to give

$$N_{its} = F_{its} H_{it} \frac{\left(1 - \mathrm{e}^{-Z_{it}}\right)}{Z_{it}} \Bigg(\tag{G.11}$$

where Z_{it} is the sum of the instantaneous rates of capture by all species, i.e.

$$Z_{it} = \sum_s F_{its}, \tag{G.12}$$

and the soak time can be left out because there is no significant difference between shorter and longer soak times (Webster et al. 2011); the sets soak for at least five hours. Substituting $F_{its} H_{it}$ from (G.10) into (G.11) gives

$$N_{its} = \frac{N_{its}^{(0)} \left(1 - \mathrm{e}^{-Z_{it}}\right)}{Z_{it}}, \tag{G.13}$$

which upon rearranging gives

$$N_{its}^{(0)} = \frac{Z_{it}}{1 - \mathrm{e}^{-Z_{it}}} N_{its}. \tag{G.14}$$

Define P_{it} to be the proportion of observed chum-bait hooks (for set i in year t) that are returned still having the bait on them (and are therefore assumed to be continuously actively fishing). The remaining baits are captured by a fish or lost (either dropped off the hook or taken by a fish that was not subsequently caught by the hook). Considering lost bait (empty hooks) to be another 'species', the proportion of hooks returned with bait is, by definition,

$$P_{it} = 1 - \frac{\sum_s N_{its}}{H_{it}}, \tag{G.15}$$

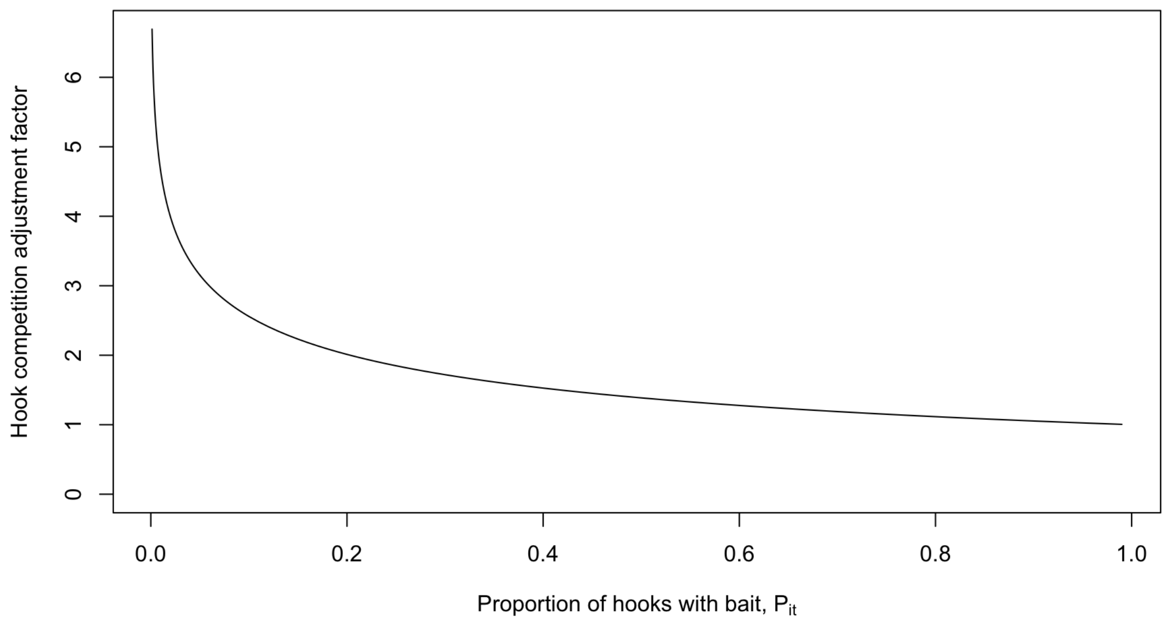


Figure G.3. Plot of how the hook competition adjustment factor, A_{it}, varies with the proportion of hooks that are returned with bait, with the lowest proportion set to 1/800.

such that (upon rearrangement)

$$\sum_s N_{its} = H_{it} \left(1 - P_{it}\right). \tag{G.16}$$

Now, summing (G.11) over all species s gives

$$\sum_s N_{its} = \sum_s F_{its} H_{it} \frac{\left(1 - \mathrm{e}^{-Z_{it}}\right)}{Z_{it}} \Bigg(\tag{G.17}$$

Substituting from (G.16) and (G.12) gives

$$\begin{aligned} H_{it} \left(1 - P_{it}\right) &= Z_{it} H_{it} \frac{\left(1 - \mathrm{e}^{-Z_{it}}\right)}{Z_{it}} \Bigg(&& \text{(G.18)} \\ 1 - P_{it} &= 1 - \mathrm{e}^{-Z_{it}} && \text{(G.19)} \\ Z_{it} &= -\ln P_{it}. && \text{(G.20)} \end{aligned}$$

Substituting (G.19) and (G.20) into (G.14), gives

$$\begin{aligned} N_{its}^{(0)} &= \frac{-\ln P_{it}}{1 - P_{it}} N_{its} && \text{(G.21)} \\ &= A_{it} N_{its}, && \text{(G.22)} \end{aligned}$$

where

$$A_{it} = \frac{-\ln P_{it}}{1 - P_{it}} \tag{G.23}$$

is the competition adjustment factor for each set in each year and is shown in Figure G.3. It scales up the observed number of each species caught, N_{its}, to give the expected number of species caught accounting for hook competition, $N_{its}^{(0)}$, depending on the proportion P_{it} of observed hooks that are returned still with bait on them.

Note that, by definition, $0 \leq P_{it} \leq 1$, and so $\ln P_{it} \leq 0$. As $P_{it} \to 1$ then by L'Hôpital's Rule

$$\lim_{P_{it} \to 1} A_{it} = \lim_{P_{it} \to 1} \frac{-\ln P_{it}}{1 - P_{it}} \tag{G.24}$$

$$= \frac{\lim_{P_{it} \to 1}(-1/P_{it})}{\lim_{P_{it} \to 1}(-1)} \tag{G.25}$$

$$= 1, \tag{G.26}$$

such that $N_{its}^{(0)} = N_{its}$, which equals 0 (because if all hooks are returned with bait on then $N_{its} = 0$ for all species s).

However, as $P_{it} \to 0$, $A_{it} \to \infty$, such that the expected number $N_{its}^{(0)} \to \infty$. In practice this happens fairly often. There are 3973 sets in the data. Of the 2909 for which all hooks on each skate were enumerated, 332 had $P_{it} = 0$. Considering the 3731 sets for which we can calculate catch rates based on the first 20 hooks of each skate (i.e. all years except 1995 and 1996), 722 had $P_{it} = 0$ for the first 20 hooks.

Therefore, the choice of what to use for A_{it} when $P_{it} = 0$ is important, since it will often scale up the observed catch rates via equation (G.22). One option would be to set it to the value obtained if only one hook with bait is returned for a set. For a set with 800 observed hooks (essentially the maximum), the smallest possible positive value is $P_{it} = 1/800$, which gives $A_{it} = 6.69$ (Figure G.3).

Figures G.4 and G.5 show how the number of hooks returned with baits in each set varies between years (though some of this is due to varying numbers of hooks returned). These show that the influence of hook competition may well vary between years, and thus if hook competition is to be considered it needs to be carefully implemented.

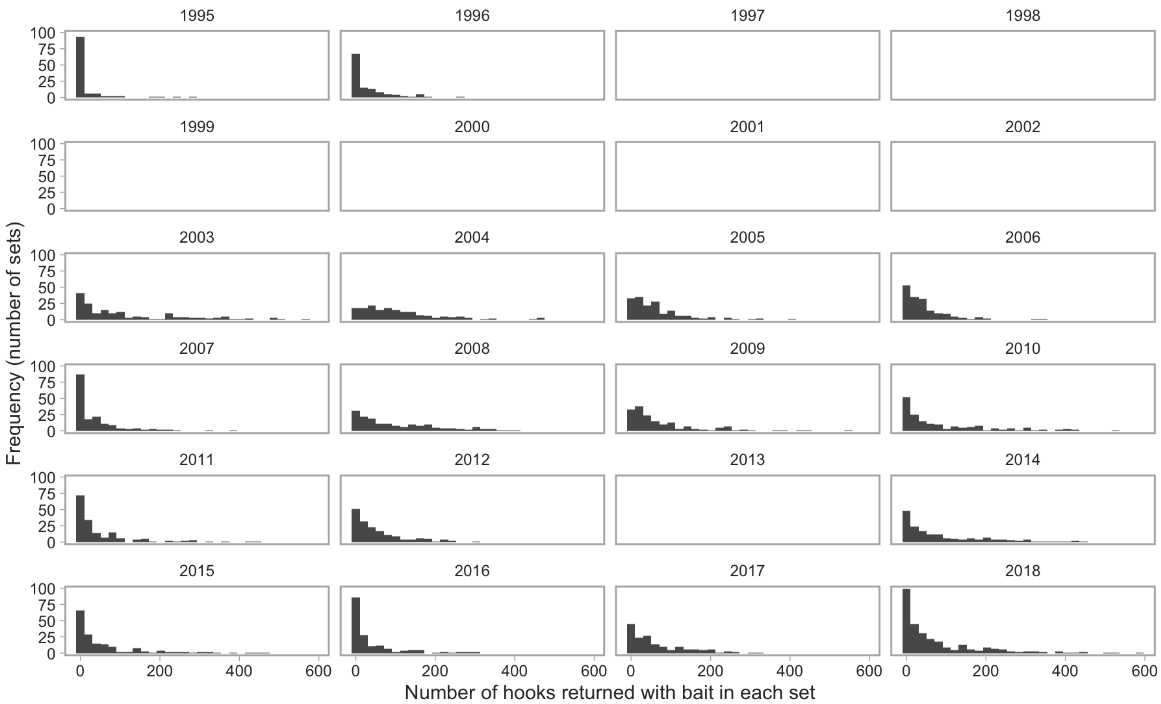


Figure G.4. Histograms of number of hooks returned with bait in each set for each year in which all hooks were enumerated.

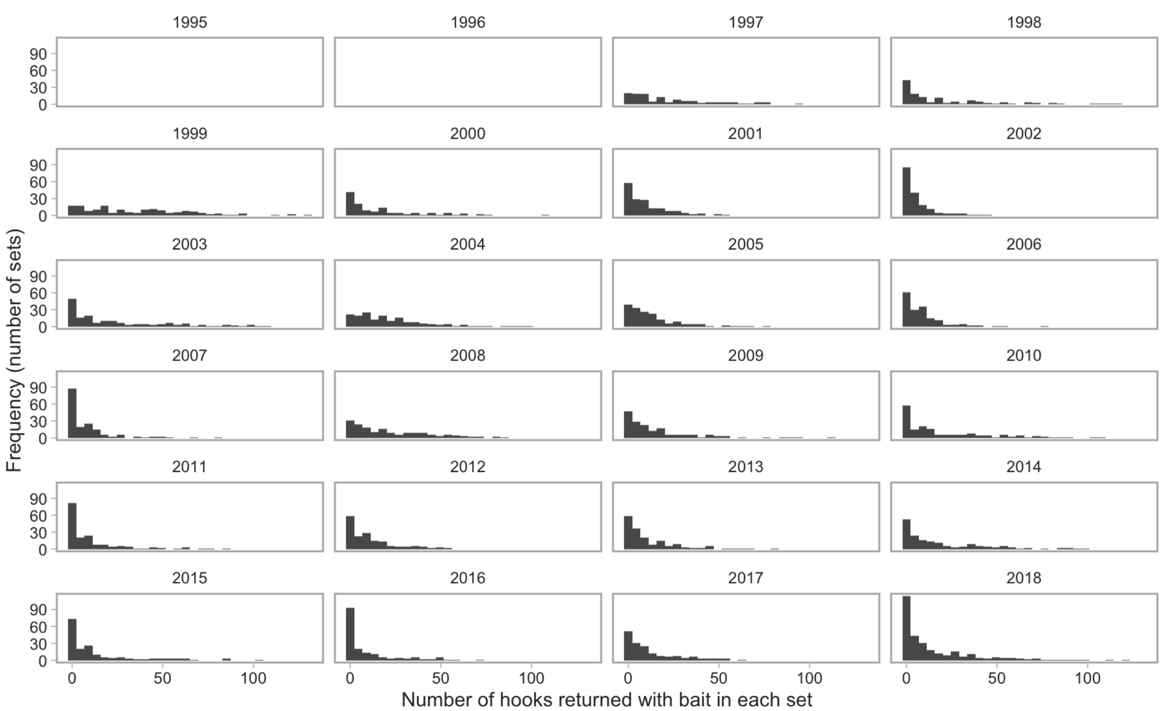


Figure G.5. Histograms of number of hooks out of the first 20 of each skate that were returned with bait for each year (except 1995 and 1996 for which this cannot be calculated).

APPENDIX H. GROWTH AND MATURITY

H.1 MATURITY OGIVES

We fit maturity ogives as logistic regressions of maturity (mature vs. not mature) against length or age:

$$y_i \sim \mathrm{Binomial}(\pi_i) \tag{H.1}$$

$$\mathrm{logit}\,(\pi_i) = \beta_0 + \beta_1 x_i + \beta_2 F_i \tag{H.2}$$

where y_i represents a 1 if fish i is considered mature and a 0 if fish i is considered immature. The β parameters represent estimated coefficients, x_i represents either the length or age of fish i, and F_i represents a binary predictor that is 1 if the fish is female and 0 if the fish is male. The variable π_i represents the expected probability of fish i being mature. We only fit these models if there are at least 20 mature males, 20 immature males, 20 mature females, and 20 immature females to ensure reasonably representative sampling and sufficient sample sizes.

H.2 LENGTH-AGE MODELS

We fit von Bertalanffy length-age growth models (Von Bertalanffy 1938) as:

$$L_i \sim \text{Log-normal}\left(\log(l_{\mathrm{inf}}(1 - \exp(-k(A_i - t_0)))) - \sigma^2/2, \sigma\right) \tag{H.3}$$

where L_i and A_i represent the length and age of fish i, l_{inf}, k, and t_0 represent the von Bertalanffy growth parameters, and σ represents the log standard deviation or scale parameter. The term $-\sigma^2/2$ represents a lognormal bias adjustment term so we model the mean length rather than the median. We fit the models with Template Model Builder (TMB) (Kristensen et al. 2016) with starting values of $k = 0.2$, $l_{\mathrm{inf}} = 40$, $\ln(\sigma) = \ln(0.1)$, and $t_0 = -1$.

H.3 LENGTH-WEIGHT MODELS

We fit the length-weight models as robust linear regressions of log(length) on log(weight) with Student-t error and a degrees of freedom parameter fixed to 3. By using Student-t error instead of Gaussian error we down-weight the influence of outlying values (e.g. Anderson et al. 2017) and help generate reasonable model fits across all species without handpicking outlying measurements to discard. The underlying growth model can be written as:

$$W_i = a \cdot L_i^b \cdot e_i, \tag{H.4}$$

with W_i and L_i representing the weight and length for fish i and e_i representing error. The variables a and b represent the estimated length-weight parameters. We fit the model as:

$$\log(W_i) \sim \text{Student-t}(df = 3, \log(a) + b\log(L_i), \sigma) \tag{H.5}$$

using Template Model Builder (Kristensen et al. 2016), where a and b have the same meaning, df represents the degrees of freedom, and σ represents the scale parameter.

APPENDIX I. REPRODUCIBILITY

One goal of this report is to generate standardized data sets, model fits, and visualizations to facilitate stock assessment. We intend for the data extraction and plots developed here to be useful for the upcoming management-procedure framework for data-limited and data-moderate groundfish stocks in BC, and also for the preparation of other groundfish stock assessments and to facilitate data-to-document workflows that go straight from databases to the final report via code and can be quickly updated in future years. To that end, the data extraction, data manipulation, model fitting, and visualization for this report are automated.

The data extraction was accomplished with the gfdata R package Git SHA (Secure Hash Algorithm) 8e55fd7; model fitting and plots were accomplished with the gfplot R package (Figure I.1) Git SHA d5baf03. The spatial and spatiotemporal models were fit with the sdmTMB package Git SHA 54fdbeb. The IPHC survey index calculations were performed with the gfiphc package Git SHA 0dcf7f6. The plots were assembled on figure pages and this text was written with the package gfsynopsis Git SHA 0556068. The document was compiled with the csasdown package Git SHA version `ed08179`.

The specific versions used to generate this report can be viewed at:

https://github.com/pbs-assess/gfdata/tree/8e55fd7
https://github.com/pbs-assess/gfplot/tree/d5baf03
https://github.com/pbs-assess/sdmTMB/tree/54fdbeb
https://github.com/pbs-assess/gfiphc/tree/0dcf7f6
https://github.com/pbs-assess/gfsynopsis/tree/0556068
https://github.com/pbs-assess/csasdown/tree/ed08179

or installed via:

```
devtools::install_github('pbs-assess/gfdata', ref = '8e55fd7')
devtools::install_github('pbs-assess/gfplot', ref = 'd5baf03')
devtools::install_github('pbs-assess/sdmTMB', ref = '54fdbeb')
devtools::install_github('pbs-assess/gfiphc', ref = '0dcf7f6')
devtools::install_github('pbs-assess/gfsynopsis', ref = '0556068')
devtools::install_github('pbs-assess/csasdown', ref = 'ed08179')
```

Copies of these R package versions and a copy of the cached data will be archived on a local Pacific Biological Station server to ensure future reproducibility.

Our functions dynamically scrape COSEWIC and SARA status information from the Species at risk public registry with rvest (Wickham 2016a) and join it to the species list by scientific name. We scrape taxonomic information from the Integrated Taxonomic Information System (ITIS) with the taxize package (Chamberlain and Szocs 2013).

The figure pages can be built while on the PBS network by (1) installing the above packages, (2) cloning the gfsynopsis repository, and (3) following instructions found in the gfsynopsis `README.md` file.

The master function is `gfsynopsis::make_pages()`, which generates two `.png` files comprising the two pages of plots for each species. Within this function, individual plots are generated by gfplot as ggplot objects (Wickham 2016b) and ggplot 'Grobs' are laid out on each page using the packages egg (Auguie 2018) and gridExtra (Auguie 2017). gfplot draws heavily on the R 'tidyverse', and especially dplyr (Wickham et al. 2018).

This report can then be rendered using knitr (Xie 2015), bookdown (Xie 2016), and csasdown by running:

```
bookdown::render_book("index.Rmd")
```

from the `gfsynopsis/report/report-rmd` folder or by clicking the 'Knit' button in RStudio with `report/report-rmd/index.Rmd` open.

This version of the document was generated on 2019-11-12 11:32:14 with R version 3.6.1 (2019-07-05) (R Core Team 2018) and R package versions:

Package	Version	Date
bookdown	0.14	2019-10-01
csasdown	0.0.7	2019-09-20
dplyr	0.8.3	2019-07-04
egg	0.4.5	2019-07-13
gfplot	0.1.4	2019-09-20
gfsynopsis	0.0.2	2019-10-16
ggplot2	3.2.1	2019-08-10
gridExtra	2.3	2017-09-09
INLA	18.07.12	2018-07-12
kableExtra	1.1.0	2019-03-16
knitr	1.25	2019-09-18
PBSdata	1.26.0	2019-06-06
PBSmapping	2.72.1	2019-03-15
purrr	0.3.3	2019-10-18
rmarkdown	1.16	2019-10-01
rstan	2.19.2	2019-07-09
rvest	0.3.4	2019-05-15
sdmTMB	0.0.2.9000	2019-11-08
TMB	1.7.15	2018-11-09

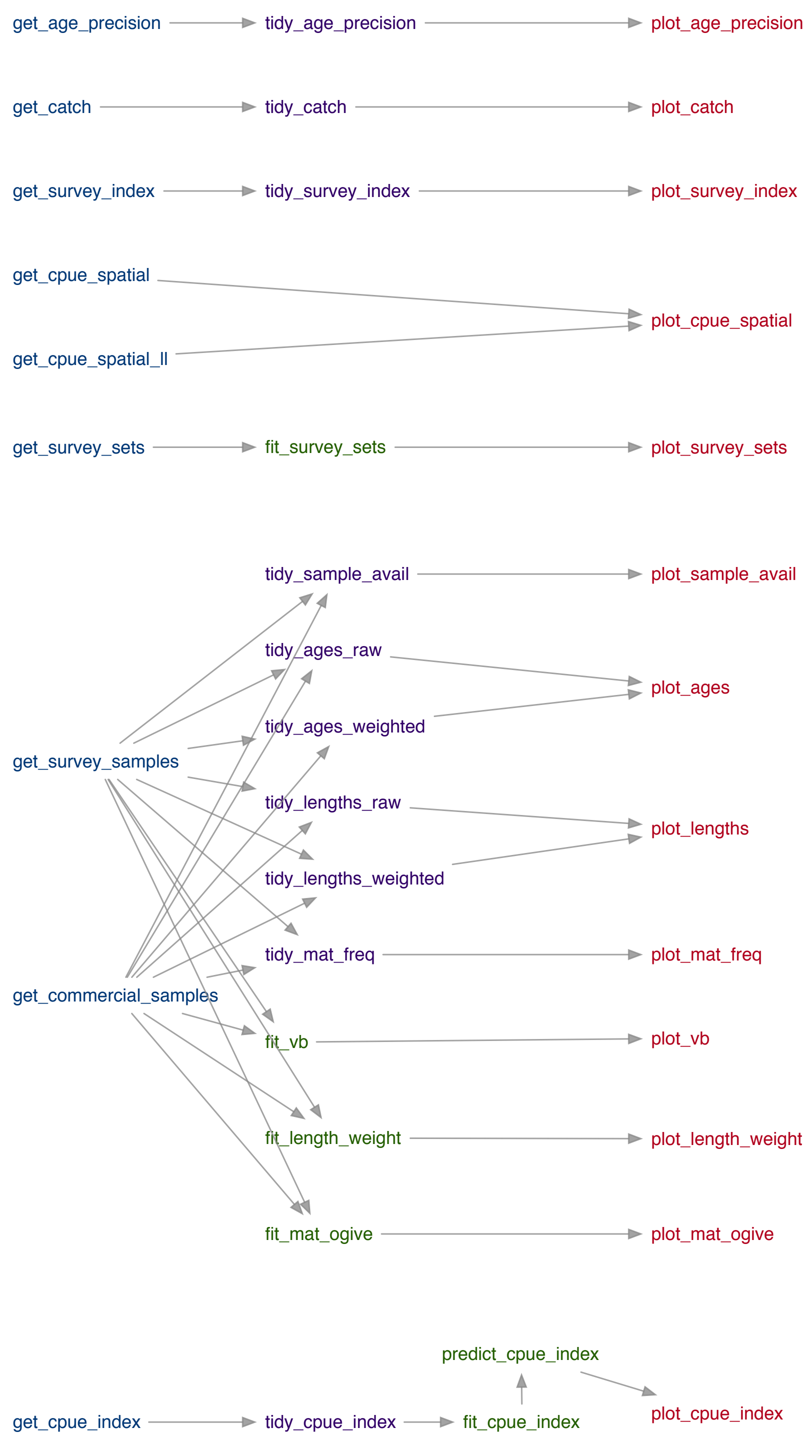


Figure I.1. An illustration of the gfplot functions and how they interact. `get` *functions extract raw data from the relational databases,* `tidy` *and* `fit` *functions manipulate the data or fit statistical models, and* `plot` *functions take the output from the tidying or fitting functions to make visualizations.*

REFERENCES

Anderson, S.C., Branch, T.A., Cooper, A.B., and Dulvy, N.K. 2017. Black-swan events in animal populations. Proceedings of the National Academy of Sciences 114(12): 3252–3257.

Anderson, S.C., and Ward, E.J. 2019. Black swans in space: Modelling spatiotemporal processes with extremes. Ecology 114(43): E8955–E8956.

Auguie, B. 2017. gridExtra: Miscellaneous functions for 'grid' graphics.

Auguie, B. 2018. Egg: Extensions for 'ggplot2': Custom geom, plot alignment, mmetrised scale, and fixed panel size.

Brooks, M.E., Kristensen, K., van Benthem, K.J., Magnusson, A., Berg, C.W., Nielsen, A., Skaug, H.J., Maechler, M., and Bolker, B.M. 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. The R Journal 9(2): 378–400.

Candy, S.G. 2004. Modelling catch and effort data using generalised linear models, the Tweedie distribution, random vessel effects and random stratum-by-year effects. CCAMLR Science 11: 59–80.

Chamberlain, S., and Szocs, E. 2013. Taxize — taxonomic search and retrieval in R. F1000Research.

Choromanski, E.M., Fargo, J., Workman, G.D., and Mathias, K. 2004. Multispecies trawl survey of Hecate Strait, *F/V Viking Storm*, June 10 – 28, 2002. DFO Can. Data Rep. Fish. Aquat. Sci. 2004/1124: 81 p.

Clark, W.G. 2008. Effect of hook competition on survey CPUE. *In* Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2007. pp. 211–215.

COSEWIC. 2002. COSEWIC assessment and status report on Bocaccio *Sebastes paucispinis* in Canada. COSEWIC CW69-14/315-2003E-IN: vii + 43 p.

COSEWIC. 2007a. COSEWIC assessment and status report on the bluntnose sixgill shark *Hexanchus griseus* in Canada. COSEWIC CW69-14/524-2007E-PDF: vii + 33 p.

COSEWIC. 2007b. COSEWIC assessment and status report on the basking shark *Cetorhinus maximus* (Pacific population) in Canada. COSEWIC CWS69-14/522-2007E-PDF: vii + 34 p.

COSEWIC. 2007c. COSEWIC assessment and status report on the Tope *Galeorhinus galeus* in Canada. COSEWIC CW69-14/523-2007E-PDF: vii + 29 p.

COSEWIC. 2007d. COSEWIC assessment and status report on the rougheye rockfish *Sebastes* sp. Type i and *Sebastes* sp. Type ii in Canada. COSEWIC CW69-14/526-2007E-PDF: viii + 36 p.

COSEWIC. 2007e. COSEWIC assessment and status report on the canary rockfish *Sebastes pinniger* in Canada. COSEWIC CW69-14/538-2008E-PDF: vii + 71 p.

COSEWIC. 2007f. COSEWIC assessment and status report on the longspine thornyhead *Sebastolobus altivelis* in Canada. COSEWIC CW69-14/527-2007E-PDF: vii + 27 p.

COSEWIC. 2008. COSEWIC assessment and status report on the Yelloweye Rockfish *Sebastes ruberrimus*, Pacific Ocean inside waters population and Pacific Ocean outside waters population, in Canada. COSEWIC CW69-14/571-2009E-PDF: vii + 75 p.

COSEWIC. 2009. COSEWIC assessment and status report on the Quillback Rockfish *Sebastes maliger* in Canada. COSEWIC CW69-14/589-2010E-PDF: vii + 71 p.

COSEWIC. 2010a. COSEWIC assessment and status report on the Darkblotched Rockfish, *Sebastes crameri*, in Canada. COSEWIC CWS69-14/590-2010E-PDF: vii + 48 p.

COSEWIC. 2010b. COSEWIC assessment and status report on the Yellowmouth Rockfish *Sebastes reedi* in Canada. COSEWIC CW69-14/605-2010E-PDF: vii + 57 p.

COSEWIC. 2011. COSEWIC assessment and status report on the North Pacific Spiny Dogfish *Squalus suckleyi* in Canada. COSEWIC CW69-14/644-2012E-PDF: x + 45 p.

COSEWIC. 2016. COSEWIC assessment and status report on the Blue Shark *Prionace glauca*, North Atlantic population and North Pacific population, in Canada. COSEWIC CW69-14/463-2017E-PDF: xv + 50 p.

Cox, S.P., Kronlund, A.R., and Lacko, L. 2011. Management procedures for the multi-gear sablefish (*Anoplopoma fimbria*) fishery in British Columbia, Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011-063: viii + 45 p.

Crawley, M.J. 2002. Statistical Computing: An Introduction to Data Analysis using S-Plus. John Wiley & Sons Ltd., Chichester, UK.

DFO. 1999a. Rougheye Rockfish British Columbia coast. DFO Sci. Stock Status Rep. 1999/A6-15: 3 p.

DFO. 1999b. Shortraker Rockfish British Columbia coast. DFO Sci. Stock Status Rep. 1999/A6-14: 3 p.

DFO. 1999c. Petrale Sole (*Eopsetta jordani*) British Columbia, Canada (Areas 3C-5D). DFO Sci. Stock Status Rep. A6-06: 3 p.

DFO. 1999d. Dover Sole west coast Vancouver Island (Areas 3C, D) to Queen Charlotte Islands (Areas 5A-E). DFO Sci. Stock Status Rep. A6-04: 3 p.

DFO. 1999e. English Sole Hecate Strait (Areas 5C/D). DFO Can. Sci. Advis. Sec. DFO Sci. Stock Status Rep. A6-05: 3 p.

DFO. 2009. Stock assessment update for British Columbia Canary Rockfish. DFO Can. Sci. Advis. Sec. Sci. Resp. 2009/019.

DFO. 2010. Assessment of Spiny Dogfish (*Squalus acanthias*) in British Columbia in 2010. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/057.

DFO. 2011a. Recovery strategy for the Basking Shark (*Cetorhinus maximus*) in Canadian Pacific waters. *Species at Risk Act* Recovery Strategy En3-4/95-2011E-PDF: v + 25 p.

DFO. 2011b. Stock assessment and recovery potential assessment for Quillback Rockfish (*Sebastes maliger*) on the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/072.

DFO. 2011c. Recovery potential assessment for Yellowmouth Rockfish (*Sebastes reedi*) along the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/060.

DFO. 2011d. Stock assessment for the inside population of Yelloweye Rockfish (*Sebastes ruberrimus*) for British Columbia, Canada for 2010. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/084.

DFO. 2011e. Lingcod (*Ophiodon elongatus*) stock assessment and yield advice for outside stocks in British Columbia. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/051.

DFO. 2012a. Management plan for the Rougheye/Blackspotted Rockfish Complex (*Sebastes aleutianus* and *S. melanostictus*) and Longspine Thornyhead (*Sebastolobus altivelis*) in Canada. DFO *Species at Risk Act* Management Plan Series En3-5/24-2011E-PDF: vi + 49 p.

DFO. 2012b. Stock assessment update for Bocaccio (*Sebastes paucispinis*) in British Columbia waters for 2012. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/059.

DFO. 2012c. Management plan for the Rougheye/Blackspotted Rockfish Complex (*Sebastes aleutianus* and *S. melanostictus*) and Longspine Thornyhead (*Sebastolobus altivelis*) in Canada. DFO (*Species at Risk Act*) Management Plan Series En3-5/24-2011E-PDF: vi + 49 p.

DFO. 2013. Pacific Ocean Perch (*Sebastes alutus*) stock assessments for the west coast of Vancouver Island and the north and west coasts of Haida Gwaii, British Columbia. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/038.

DFO. 2014a. Big Skate (*Raja binoculata*) and Longnose Skate (*R. rhina*) stock assessments for British Columbia. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/027.

DFO. 2014b. Stock assessment for Silvergray Rockfish (*Sebastes brevispinis*) along the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/028.

DFO. 2014c. Stock assessment and harvest advice for Rock Sole (*Lepidopsetta* spp.) in British Columbia. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/039.

DFO. 2015a. Yellowtail Rockfish (*Sebastes flavidus*) stock assessment for the coast of British Columbia, Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/010.

DFO. 2015b. Stock assessment for the outside population of Yelloweye Rockfish (*Sebastes ruberrimus*) for British Columbia, Canada in 2014. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/060.

DFO. 2015c. Stock assessment for Lingcod (*Ophiodon elongatus*) in the Strait of Georgia, British Columbia in 2014. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/014.

DFO. 2015d. Arrowtooth Flounder (*Atheresthes stomias*) stock assessment for the west coast of British Columbia. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/055.

DFO. 2016a. Proceedings of the Pacific Regional Peer Review on a review of international best practices to assigning species to tiers for the purposes of stock assessment based on data availability and richness; May 30–31. DFO Can. Sci. Advis. Sec. Proceed. Ser. (2016/051).

DFO. 2016b. Stock assessment of the coastwide population of Shortspine Thornyhead (*Sebastolobus alascanus)* for British Columbia, Canada in 2015. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/016.

DFO. 2017a. Pacific Ocean Perch (*Sebastes alutus*) stock assessments for Queen Charlotte Sound, British Columbia in 2017. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/043.

DFO. 2017b. Evaluating the robustness of management procedures for the sablefish (*Anoplopoma fimbria*) fishery in British Columbia, Canada for 2017–18. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/017.

DFO. 2018a. Walleye Pollock (*Theragra chalcogramma*) stock assessment for British Columbia in 2017. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/020.

DFO. 2018b. Redstripe Rockfish *Sebastes proriger* stock assessment for British Columbia in 2018. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/049.

DFO. 2019a. Assessment of British Columbia Pacific Cod for areas 3CD and 5ABCD in 2018. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/008.

DFO. 2019b. Widow Rockfish (*Sebastes entomelas*) stock assessment for British Columbia in 2019. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/044.

DFO, Pacific Region Groundfish Data Unit. 2019. Pacific Region commercial and research databases (GFCatch, PacHarvest, PacHarvHL, PacHarvSable, GFFOS and GFBio) archived on-site at the Pacific Biological Station, Nanaimo, BC). Accessed February, 2019.

Doherty, B., Benson, A.J., and P., C.S. 2019. Data summary and review of the PHMA hard bottom longline survey in British Columbia after the first 10 years (2006-2016). DFO Can. Tech. Rep. Fish. Aquat. Sci. 2019/3276: ix + 75 p.

Dunn, P.K., and Smyth, G.K. 1996. Randomized quantile residuals. Journal of Computational and Graphical Statistics 5(3): 236–244.

Dykstra, C.L., Wormer, K.L. van, and Ranta, A.M. 2002. 2001 standardized stock assessment survey. *In* Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2001. pp. 335–353.

Edwards, A.M., Haigh, R., and Starr, P.J. 2012. Stock assessment and recovery potential assessment for Yellowmouth Rockfish (*Sebastes reedi*) along the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/095: iv + 188 p.

Edwards, A.M., Haigh, R., and Starr, P.J. 2013. Pacific Ocean Perch (*Sebastes alutus*) stock assessment for the north and west coasts of Haida Gwaii, British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/092: vi + 126 p.

Edwards, A.M., Haigh, R., and Starr, P.J. 2014. Pacific Ocean Perch (*Sebastes alutus*) stock assessment for the west coast of Vancouver Island, British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/093: vi + 135 p.

Edwards, A.M., Haigh, R., and Starr, P.J. 2017. Redbanded Rockfish (*Sebastes babcocki*) stock assessment for the Pacific coast of Canada in 2014. DFO Can. Sci. Advis. Sec. Res. Doc.

2017/058: v + 182 p.

Edwards, A.M., Taylor, I.G., Grandin, C.J., and Berger, A.M. 2018. Status of the Pacific Hake (whiting) stock in U.S. and Canadian waters in 2018. Prepared by the Joint Technical Committee of the U.S. and Canada Pacific Hake/Whiting Agreement, National Marine Fishery Service and Fisheries and Oceans Canada. 222 p.

Efron, B. 1987. Better bootstrap confidence intervals. Journal of the American statistical Association 82(397): 171–185.

Flemming, R.G., Yamanaka, K.L., Cooke, K., and Dykstra, C. 2012. Summary of non-Halibut catch from the standardized stock assessment survey conducted by the International Pacific Halibut Commission in British Columbia from June 3 to August 27, 2010. DFO Can. Tech. Rep. Fish. Aquat. Sci. 2012/2989: viii + 99 p.

Forrest, R.E., Anderson, S.C., Grandin, C.J., and J., S.P. 2019. Assessment of Pacific Cod (*Gadus macrocephalus*) for Hecate Strait and Queen Charlotte Sound (Area 5ABCD), and West Coast Vancouver Island (Area 3CD) in 2018. DFO Can. Sci. Advis. Sec. Res. Doc. In press.

Foster, S.D., and Bravington, M.V. 2013. A PoissonGamma model for analysis of ecological non-negative continuous data. Environmental and Ecological Statistics 20(4): 533–552.

Galluci, V., Taylor, I., King, J., McFarlane, G.A., and McPhie, R. 2011. Spiny Dogfish (*Squalus acanthias*) assessment and catch recommendations for 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/034: xii + 69 p.

Garnier, S. 2018. Viridis: Default color maps from 'matplotlib'.

Grandin, C.J., and Forrest, R.E. 2017. Arrowtooth Flounder (*Atheresthes stomias*) stock assessment for the west coast of British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/25: v + 87 p.

Haigh, R., Olsen, N., and Starr, P. 2005a. A review of Longspine Thornyhead (*Sebastolobus altivelis*) along the Pacific coast of Canada: Biology, distribution, and abundance trends. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/097: 44 p.

Haigh, R., Olsen, N., and Starr, P.J. 2005b. A review of Rougheye Rockfish (*Sebastes aleutianus*) along the Pacific coast of Canada: Biology, distribution, and abundance trends. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/096: vi + 68 p.

Haigh, R., and Starr, P. 2008. A review of Darkblotched Rockfish (*Sebastes crameri*) along the Pacific coast of Canada: Biology, distribution, and abundance trends. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/056.

Haigh, R., Starr, P.J., Edwards, A.M., King, J.R., and Lecomte, J.-B. 2018. Stock assessment for Pacific Ocean Perch (*Sebastes alutus*) in Queen Charlotte Sound, British Columbia in 2017. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/038: ix + 230 p.

Harley, S.J., Myers, R.A., and Dunn, A. 2001. Is catch-per-unit-effort proportional to abundance? Can. J. Fish. Aquat. Sci. 58(9): 1760–1772.

Hart, J.L., Clemens, W.A., and Fisheries Research Board of Canada. 1988. Pacific fishes of

Canada. Fisheries Research Board of Canada.

Henry, E., Soderlund, E., Dykstra, C.L., Geernaert, T.O., and Ranta, A.M. 2013. 2012 standardized stock assessment survey. *In* Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2012. pp. 503–538.

Holt, K.R., King, J.R., and Krishka, B.A. 2016a. Stock assessment for Lingcod (*Ophiodon elongatus*) in the Strait of Georgia, British Columbia in 2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/013: xi + 186 p.

Holt, K.R., Starr, P.J., Haigh, R., and Krishka, B. 2016b. Stock assessment and harvest advice for rock sole (*Lepidopsetta* spp.) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/009: ix + 256 p.

IPHC. 2017. Report of Assessment and Research Activities. Int. Pac. Halibut Comm. IPHC-2017-RARA27-R: 149 p.

Jorgensen, B. 1987. Exponential dispersion models. Journal of the Royal Statistical Society. Series B (Methodological) 49(2): 127–162.

Keppel, E.A., and Olsen, N. 2019. Pre-COSEWIC review of Yelloweye Rockfish (*Sebastes ruberrimus*) along the Pacific coast of Canada: Biology, distribution and abundance trends. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/014: x + 109.p.

King, J.R., McAllister, M., Holt, K.R., and Starr, P.J. 2011. Lingcod (*Ophiodon elongatus*) stock assessment and yield advice for outside stocks in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/124: viii + 177 p.

King, J.R., Surry, A.M., Garcia, S., and Starr, P.J. 2015. Big Skate (*Raja binoculata*) and Longnose Skate (*R. rhina*) stock assessments for British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/070: ix + 329 p.

Kristensen, K., Nielsen, A., Berg, C.W., Skaug, H., and Bell, B.M. 2016. TMB: Automatic differentiation and Laplace approximation. J. Stat. Softw. 70(5): 1–21.

Latimer, A.M., Banerjee, S., Sang Jr, H., Mosher, E.S., and Silander Jr, J.A. 2009. Hierarchical models facilitate spatial analysis of large data sets: A case study on invasive plant species in the northeastern United States. Ecology Letters 12(2): 144–154.

Lecomte, J.-B., Benoît, H.P., Ancelet, S., Etienne, M.-P., Bel, L., and Parent, E. 2013. Compound Poisson-gamma vs. Delta-gamma to handle zero-inflated continuous data under a variable sampling volume. Methods in Ecology and Evolution 4(12): 1159–1166.

Lindgren, F., and Rue, H. 2015. Bayesian spatial modelling with R-INLA. J. Stat. Softw. 63(19): 1–25.

Lindgren, F., Rue, H., and Lindström, J. 2011. An explicit link between Gaussian fields and Gaussian Markov random fields: The stochastic partial differential equation approach. Journal of the Royal Statistical Society: Series B (Statistical Methodology) 73(4): 423–498.

Lochead, J.K., and Yamanaka, K.L. 2007. Summary report for the inshore rockfish (*sebastes* spp.) longline survey conducted in Statistical Areas 14 to 20, 28 and 29, from August 11 to September 6, 2005. DFO Can. Tech. Rep. Fish. Aquat. Sci. 2007/2690: viii + 53 p.

Maunder, M.N., and Punt, A.E. 2004. Standardizing catch and effort data: A review of recent approaches. Fisheries Research 70(2): 141–159.

McFarlane, G., King, J., Leask, K., and Christensen, L.B. 2008. Assessment of information used to develop a recovery potential assessment for Basking Shark (*Cetorhinus maximus*) (Pacific population) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/071: vi + 104 p.

Nottingham, M.K., Williams, D.C., Wyeth, M.R., and Olsen, N. 2017. Summary of the West Coast Vancouver Island synoptic bottom trawl survey, May 28 – June 21, 2014. DFO Can. Manuscr. Rep. Fish. Aquat. Sci. 2017/3140: viii + 55 p.

Petitgas, P. 2001. Geostatistics in fisheries survey design and stock assessment: Models, variances and applications. Fish and Fisheries 2(3): 231–249.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rue, H., Martino, S., and Chopin, N. 2009. Approximate Bayesian Inference for Latent Gaussian models using Integrated Nested Laplace Approximations (with discussion). J. R. Stat. Soc. Series B 71: 319–392.

Rutherford, K.L. 1999. A brief history of GFCatch (1954–1995), the groundfish catch and effort database at the Pacific Biological Station. DFO Can. Tech. Rep. Fish. Aquat. Sci. 2299: 66 p.

Saunders, M.W., and Andrews, W. 1998. Walleye Pollock stock assessment for 1997 and recommended yield options for 1998. DFO Pacific Stock Assessment PSARC Working Paper 2009/021: 18 p.

Schnute, J.T., Olsen, N., and Haigh, R. 1999a. Slope rockfish assessment for the west coast of Canada in 1998. DFO Can. Stock Assess. Sec. Res. Doc. 99/16: vi + 79 p.

Schnute, J.T., Olsen, N., and Haigh, R. 1999b. Slope rockfish assessment for the west coast of Canada in 1998. DFO Can. Stock Assess. Sec. Res. Doc. 99-16: 79 p.

Shelton, A.O., Thorson, J.T., Ward, E.J., and Feist, B.E. 2014. Spatial semiparametric models improve estimates of species abundance and distribution. Can. J. Fish. Aquat. Sci. 71(11): 1655–1666.

Shono, H. 2008. Application of the Tweedie distribution to zero-catch data in CPUE analysis. Fisheries Research 93(1): 154–162.

Sinclair, A., Schnute, J., Haigh, R., Starr, P., Stanley, R., Fargo, J., and Workman, G. 2003. Feasibility of multispecies groundfish trawl surveys on the BC coast. DFO Can. Sci. Adv. Sec. Res. Doc. 2003/049: i + 34 p.

Stanley, R. 1999. Shelf rockfish stock assessment for 1998 and recommended yield options for 1999. DFO Can. Stock Assess. Sec. Res. Doc. 99/53: 57 p.

Stanley, R.D., McAllister, M., and Starr, P. 2012. Updated stock assessment for Bocaccio (*Sebastes paucispinis*) in British Columbia waters for 2012. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/109: vii + 73 p.

Stanley, R.D., Starr, P.J., and Olsen, N. 2009. Stock assessment for canary rockfish (*Sebastes* *pinniger*) in British Columbia waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/013: xxii + 198 p.

Starr, P.J. 2009a. Petrale Sole (*Eopsetta jordani*) in British Columbia, Canada: Stock assessment for 2006/07 and advice to managers for 2007/08. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/070: v + 134 p.

Starr, P.J. 2009b. English Sole (*Parophrys vetulus*) in British Columbia, Canada: Stock assessment for 2006-07 and advice to managers for 2007/08. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/069: v + 149 p.

Starr, P.J., and Haigh, R. 2017. Stock assessment of the coastwide population of Shortspine Thornyhead (*Sebastolobus alascanus)* in 2015 off the British Columbia coast. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/015: ix + 174 p.

Starr, P.J., and Haigh, R. 2019. Walleye Pollock (*Theragra chalcogramma*) stock assessment for British Columbia in 2017. DFO Can. Sci. Advis. Sec. Res. Doc. In press.

Starr, P.J., Haigh, R., and Grandin, C. 2016. Stock assessment for Silvergray Rockfish (*Sebastes brevispinis*) along the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/042: vi + 170 p.

Stocker, M., and Fargo, J. 1995. Groundfish stock assessments for the west coast of Canada in 1994 and recommended yield options for 1995. DFO Can. Tech. Rep. Fish. Aquat. Sci. 2069: v + 440 p.

Thorson, J.T. 2017. Three problems with the conventional delta-model for biomass sampling data, and a computationally efficient alternative. Canadian Journal of Fisheries and Aquatic Sciences.

Thorson, J.T., and Barnett, L.A.K. 2017. Comparing estimates of abundance trends and distribution shifts using single- and multispecies models of fishes and biogenic habitat. ICES Journal of Marine Science 74(5): 1311–1321.

Thorson, J.T., Pinsky, M.L., and Ward, E.J. 2016. Model-based inference for estimating shifts in species distribution, area occupied and centre of gravity. Methods Ecol. Evol. 7(8): 990–1002.

Thorson, J.T., Shelton, A.O., Ward, E.J., and Skaug, H.J. 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES J. Mar. Sci. 72(5): 1297–1310.

Thorson, J.T., and Ward, E.J. 2013. Accounting for space–time interactions in index standardization models. Fisheries Research 147(0): 426–433.

Von Bertalanffy, L. 1938. A quantitative theory of organic growth (inquiries on growth laws II). Hum. Biol. 10(2): 181–213.

Ward, E.J., Jannot, J.E., Lee, Y.-W., Ono, K., Shelton, A.O., and Thorson, J.T. 2015. Using spatiotemporal species distribution models to identify temporally evolving hotspots of species co-occurrence. Ecol. Appl. 25(8): 2198–2209.

Webster, R. 2017. Space-time modelling of fishery-independent setline survey data.

IPHC-2018-AM094-07: 27 p.

Webster, R.A., Hare, S.R., Valero, J.L., and Leaman, B.M. 2011. Notes on the IPHC setline survey design, alternatives for estimating biomass distribution, and the hook competition adjustment. *In* Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2010. pp. 229–240.

Wickham, H. 2016a. rvest: Easily harvest (scrape) web pages.

Wickham, H. 2016b. ggplot2: Elegant graphics for data analysis. Springer-Verlag New York.

Wickham, H., François, R., Henry, L., and Müller, K. 2018. dplyr: A grammar of data manipulation.

Williams, D.C., Nottingham, M.K., Olsen, N., and Wyeth, M.R. 2018a. Summary of the Queen Charlotte Sound synoptic bottom trawl survey, July 6 – August 8, 2015. DFO Can. Manuscr. Rep. Fish. Aquat. Sci. 3136: viii + 64 p.

Williams, D.C., Nottingham, M.K., Olsen, N., and Wyeth, M.R. 2018b. Summary of the West Coast Haida Gwaii synoptic bottom trawl survey, August 25 – October 2, 2014. DFO Can. Manuscr. Rep. Fish. Aquat. Sci. 2018/3134: viii + 42 p.

Wyeth, M.R., Olsen, N., Nottingham, M.K., and Williams, D.C. 2018. Summary of the Hecate Strait synoptic bottom trawl survey, May 26 – June 22, 2015. DFO Can. Manuscr. Rep. Fish. Aquat. Sci. 2018/3126: viii + 55 p.

Xie, Y. 2015. Dynamic documents with R and knitr. *In* 2nd editions. Chapman; Hall/CRC, Boca Raton, Florida.

Xie, Y. 2016. Bookdown: Authoring books and technical documents with R markdown. Chapman; Hall/CRC, Boca Raton, Florida.

Yamanaka, K.L., McAllister, M.K., Etienne, M.-P., and Flemming, R. 2011a. Stock assessment and recovery potential assessment for Quillback Rockfish (*Sebastes maliger*) on the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/135: vii + 151 p.

Yamanaka, K.L., McAllister, M.K., Olesiuk, P.F., Etienne, M.-P., Obradovich, S.G., and Haigh, R. 2011b. Stock assessment for the inside population of Yelloweye Rockfish (*Sebastes ruberrimus*) for British Columbia, Canada for 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/129: xiv + 131 p.

Yamanaka, K.L., McAllister, M.M., Etienne, M.-P., Edwards, A.M., and Rowan Haigh. 2018. Stock assessment for the outside population of Yelloweye Rockfish (*Sebastes ruberrimus*) for British Columbia, Canada in 2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/001: ix + 150 p.

Yamanaka, K.L., Obradovich, S.G., Cooke, K., Lacko, L.C., and Dykstra, C. 2008. Summary of non-halibut catch from the Standardized Stock Assessment Survey conducted by the International Pacific Halibut Commission in British Columbia from May 19 to July 22, 2006. Can. Tech. Rep. Fish. Aquat. Sci. 2796: vii + 58 p.