Black Rockfish Analysis OCNMS

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Data description

These are derived data products relevant to estimating black rockfish abundance and size stemming from NWFSC dive surveys in the Olympic Coast National Marine Sanctuary (OCNMS) conducted between 2015 and 2022. Description of survey methods and aims are detailed in Tolimieri et al. (2023). We provide a brief summary of methods relevant to fish surveys here.

Divers on SCUBA conducted in situ surveys to count fish at each site along benthic belt transects (30 m by 2 m) following slightly modified procedures described in Malone et al.(2022). Transects were conducted within or directly adjacent to canopy kelp beds (consisting of giant *Macrocystis pyrifera* or bull *Nereocystis luetkeana* kelps). From 2016 on, we surveyed at 5 sites (Fig. 1), sampling at 2 locations within each site separated by >100 m, and 2 depths within each location (5 and 10 m) Our goal was to complete 6 replicate transects at each year-site-depth combination. In 2015 surveyed at 10 sites and conducted 4 transects per site at 5 m depth (Fig. 1).

During each fish transect, we counted and estimated the size (total length to nearest cm) of all fishes >5 cm total length; the exception was rockfishes *Sebastes* spp., for which we estimated sizes of all individuals. Rockfishes $\leq$ 10 cm were considered young of year. Divers also estimated horizontal visibility on each transect by determining the distance at which the lead diver could distinguish their buddy's extended fingers. Transects with visibility less than 2 m were excluded from analyses.

Because it is difficult to visually distinguish many rockfish species when they are small, we categorized juvenile rockfishes into 5 groups established in the literature (Johansson et al. 2018, Markel and Shurin 2020). (1) Yellowtail and black (YTB) included both yellowtail (*S. flavidus*) and black (*S. melanops*) rockfishes. (2) The copper/quillback/brown (CQB) group included copper (*S. caurinus*), quillback (*S. maliger*), and brown (*S. auriculatus*) rockfishes. We were able to identify (3) canary (*S. pinniger*) and (4) blue rockfish (*S. mystinus*) to species. (5) Unidentified individuals were categorized as juvenile rockfishes.

Citations from the above section

Johansson ML, Litz MN, Brodeur RD, Britt TA, Vanegas CA, Hyde JR, Banks MA (2018) Seasonal distribution of late larval and juvenile rockfish (Sebastes spp.) and associated environmental conditions off Oregon and Washington: new insights based on genetics. Fish Bull 116: 266-80.

Malone DP, Davis K, Lonhart SI, Parsons-Field A, Caselle JE, Carr MH (2022) Large scale, multi-decade monitoring data from kelp forest ecosystems in California and Oregon (USA). Ecology 103: e3630

Markel RW, Shurin JB (2020) Contrasting effects of coastal upwelling on growth and recruitment of nearshore Pacific rockfishes (genus Sebastes). Can J Fish Aquat Sci 77: 950-962

[Tolimeiri et al. 2023. Changes in kelp forest communities off Washington, USA, during and after the 2014-2016 marine heatwave and sea star wasting syndrome. Marine Ecology Progress Series 703:47-63]

As a result of our 2m visibility requirements, there were transects that were omitted from the analyses. The following tables show is how the number fish transects with visibility >2m were distributed across sites and

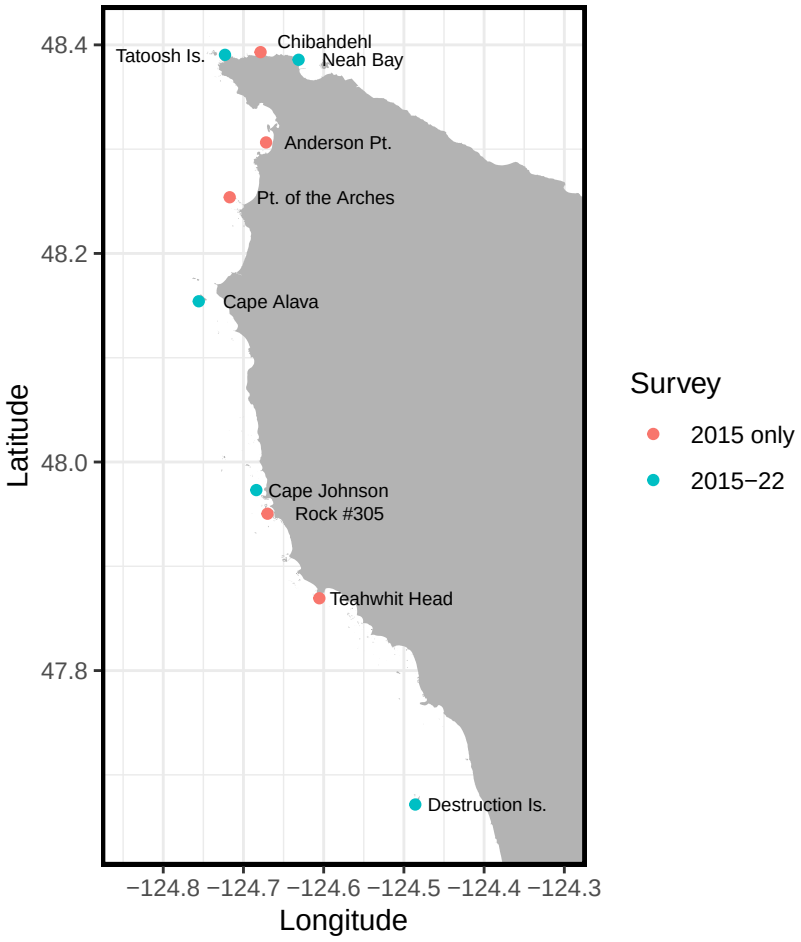


Figure 1: Dive survey locations along the coast of Washington state.

years. 2015 includes only surveys conducted at 5m depth. Other years have data approximately evenly split between 5m and 10m depths.

Table 1: Number of transects conducted by year, site and depth zone. Only transects that had at least 2m visibility are included

year	zone	Destruction Island	Teahwhit Head	Cape Johnson	Rock 305	Cape Alava	Point of the Arches	Anderson Point	Tatoosh Island	Chibadehl Rocks	Neah Bay	Total
2015	5	0	4	4	4	4	4	4	4	4	4	36
2016	5	0	0	4	0	6	0	0	4	0	4	18
2016	10	3	0	6	0	6	0	0	4	0	6	25
2017	5	3	0	5	0	4	0	0	3	0	4	19
2017	10	0	0	4	0	6	0	0	4	0	4	18
2018	5	0	0	4	0	4	0	0	8	0	4	20
2018	10	0	0	3	0	8	0	0	7	0	8	26
2019	5	4	0	4	0	8	0	0	8	0	7	31
2019	10	8	0	7	0	8	0	0	6	0	8	37
2021	5	4	0	8	0	7	0	0	8	0	8	35
2021	10	3	0	8	0	7	0	0	6	0	8	32
2022	5	0	0	0	0	4	0	0	8	0	8	20
2022	10	0	0	0	0	7	0	0	6	0	5	18

Table 2: Number of transects conducted by year and site. Only transects that had at least 2m visibility are included

site	2015	2016	2017	2018	2019	2021	2022
Destruction Island	0	3	3	0	12	7	0
Teahwhit Head	4	0	0	0	0	0	0
Cape Johnson	4	10	9	7	11	16	0
Rock 305	4	0	0	0	0	0	0
Cape Alava	4	12	10	12	16	14	11
Point of the Arches	4	0	0	0	0	0	0
Anderson Point	4	0	0	0	0	0	0
Tatoosh Island	4	8	7	15	14	14	14
Chibadehl Rocks	4	0	0	0	0	0	0
Neah Bay	4	10	8	12	15	16	13
TOTAL	36	43	37	46	68	67	38

Abundance trends

Large (>10 cm total length) Black rockfish trends

To calculate the average density of black rockfish in each year, we first calculate the mean density and standard error per site in each year. This approach means we are treating each transect as a i.i.d. sample of black rockfish density within each site and thus we ignore differences in abundance by depth zone.

From these site-year level means, we calculated a year-specific mean density by simulation. Specifically, for each year we independently drew a mean density for each site using a t-distribution with μ (the estimated site mean), σ (the estimated site-specific standard error) and degrees of freedom, τ. So for the i^{th} realization, for site s in year y we have a predicted density, X_{isy}

$$X_{isy} \sim T(\mu_{sy}, \sigma_{sy}, \tau_{sy}) \tag{1}$$

$$\tag{2}$$

and then the predicted density for a single realization in a given year is the mean among sites observed. We repeat the simulation 100,000 times to provide an estimated mean density and uncertainty for a given year (Fig. 2)

Young of year black rockfish

Unlike adult black rockfish, small (<10 cm total length) rockfish cannot be unequivocally visually identified to species. In most cases, species can be identified to a complex of a few species. For small rockfish, black rockfish occur in a complex of two species, black rockfish and yellowtail rockfish. Yellowtail rockfish are rare in Washington state and we consider their contribution to small rockfish size categories to be trivial. Nearly all small rockfish fall into the 4 to 7cm length range and all are considered to have recruited from the plankton during the calender year of the survey. Therefore, we view the density of <10cm rockfish to be an indicator of black rockfish recruitment.

To derive estimates of overall young-of-year densities, we use identical methods to those described for adult rockfish densities and provide estimated densities per year for our survey area (Fig. 3)

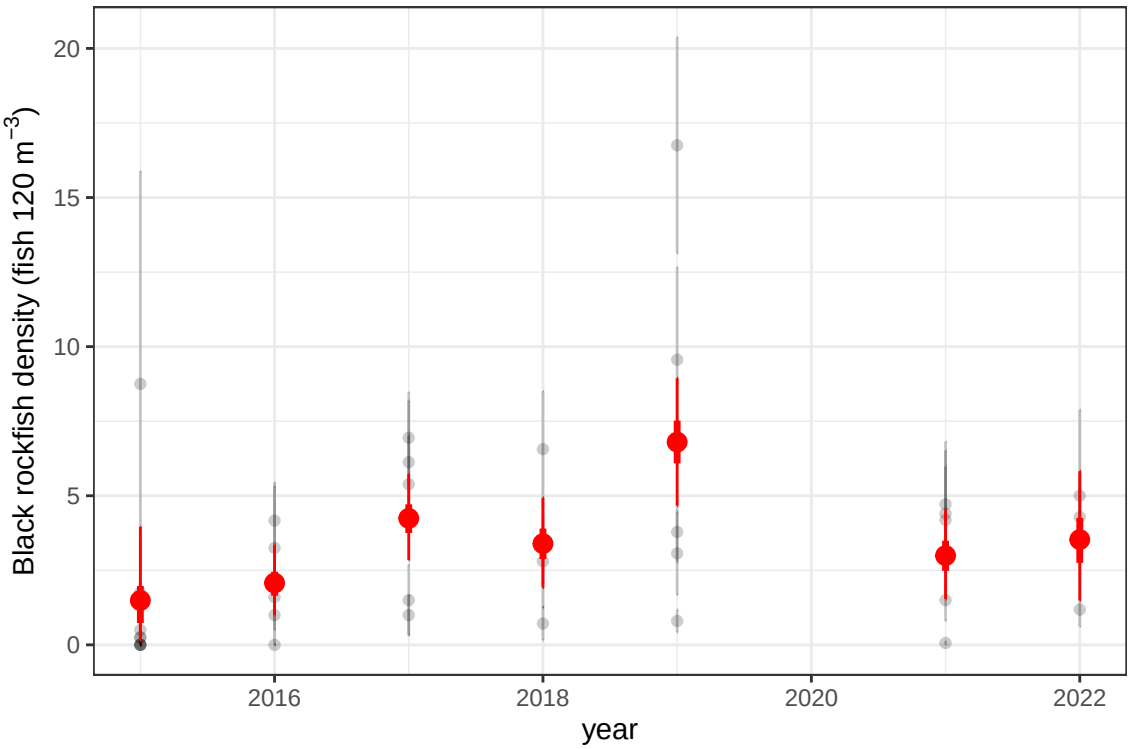


Figure 2: Time-series of estimated black rockfish density on the Washington coast. Black points show means and standard errors for individual sites. Red points show coastwide density estimates, interquartile range and 95% intervals for each year.

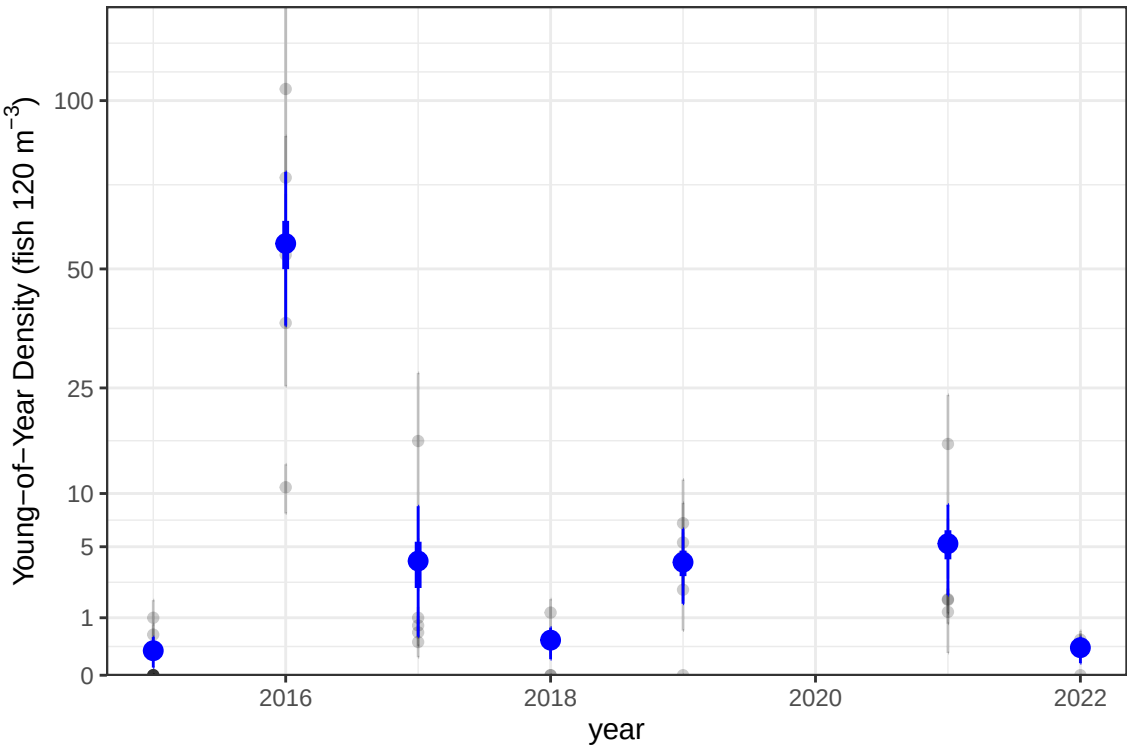
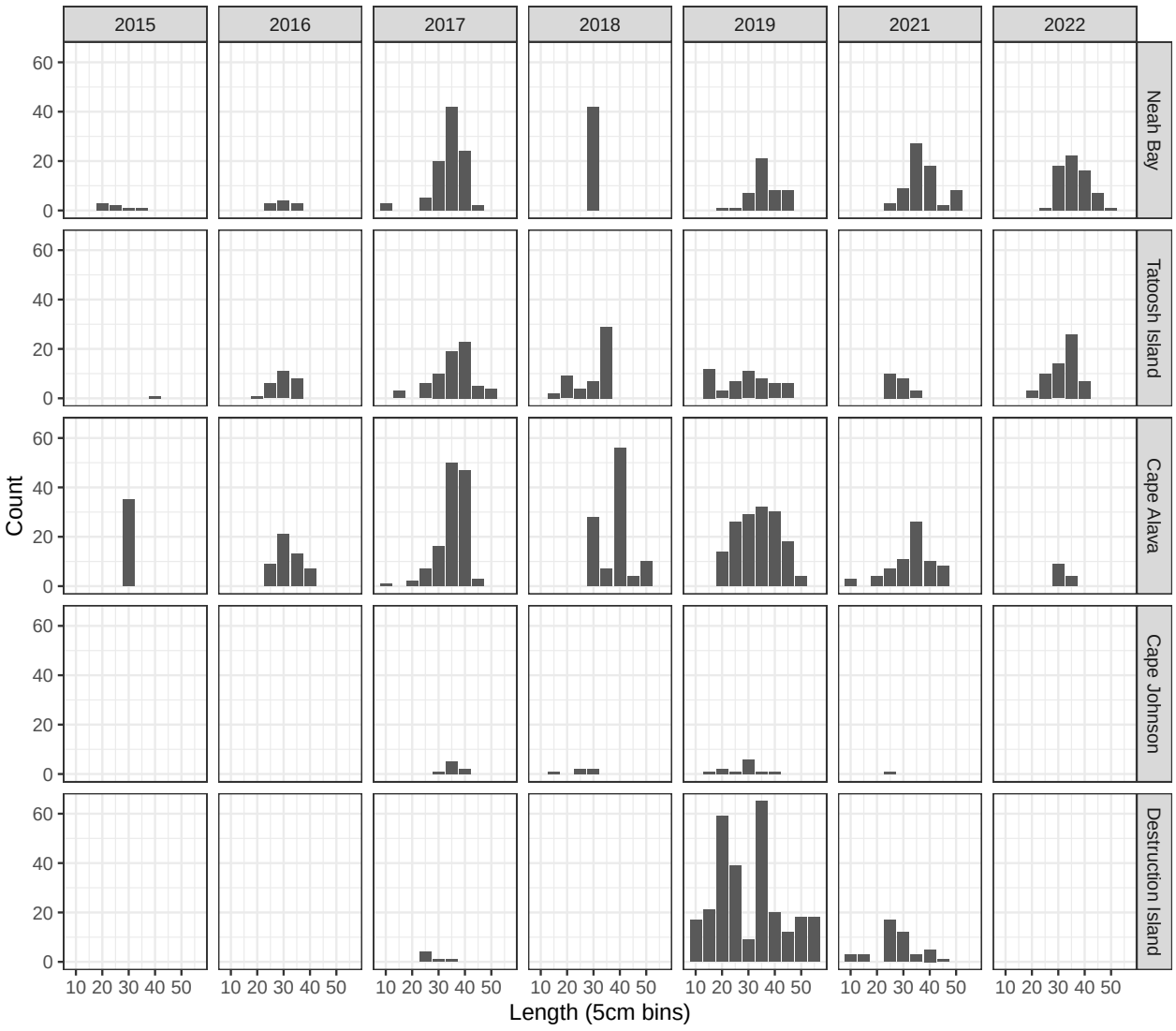


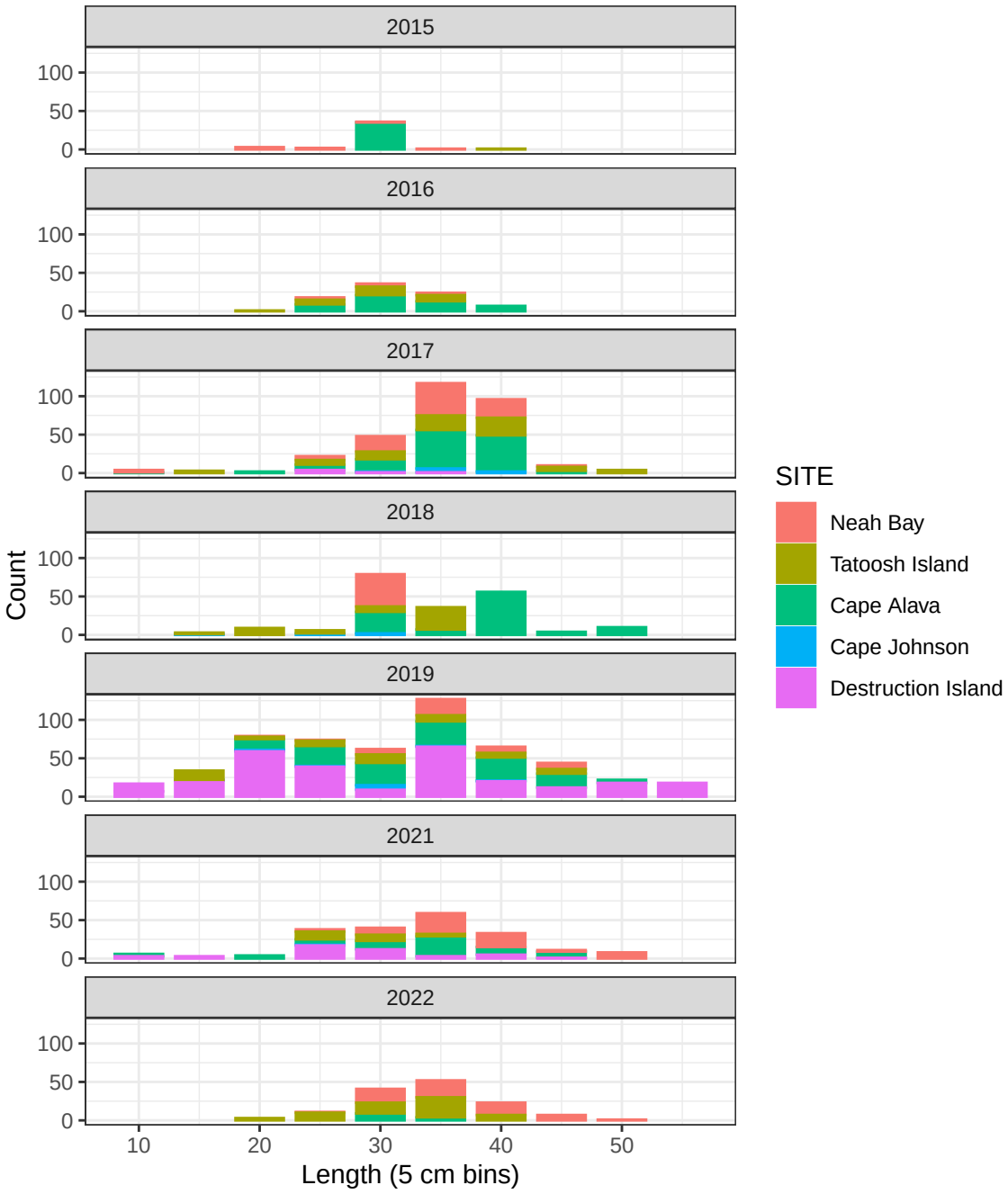
Figure 3: Time-series of estimated young-of-year rockfish (black-yellowtail complex) density on the Washington coast. Black points show means and standard errors for individual sites. Blue points show coastwide density estimates, interquartile range and 95% intervals for each year. Note y-axis is square root

Information on size data for black rockfish 2015-2022

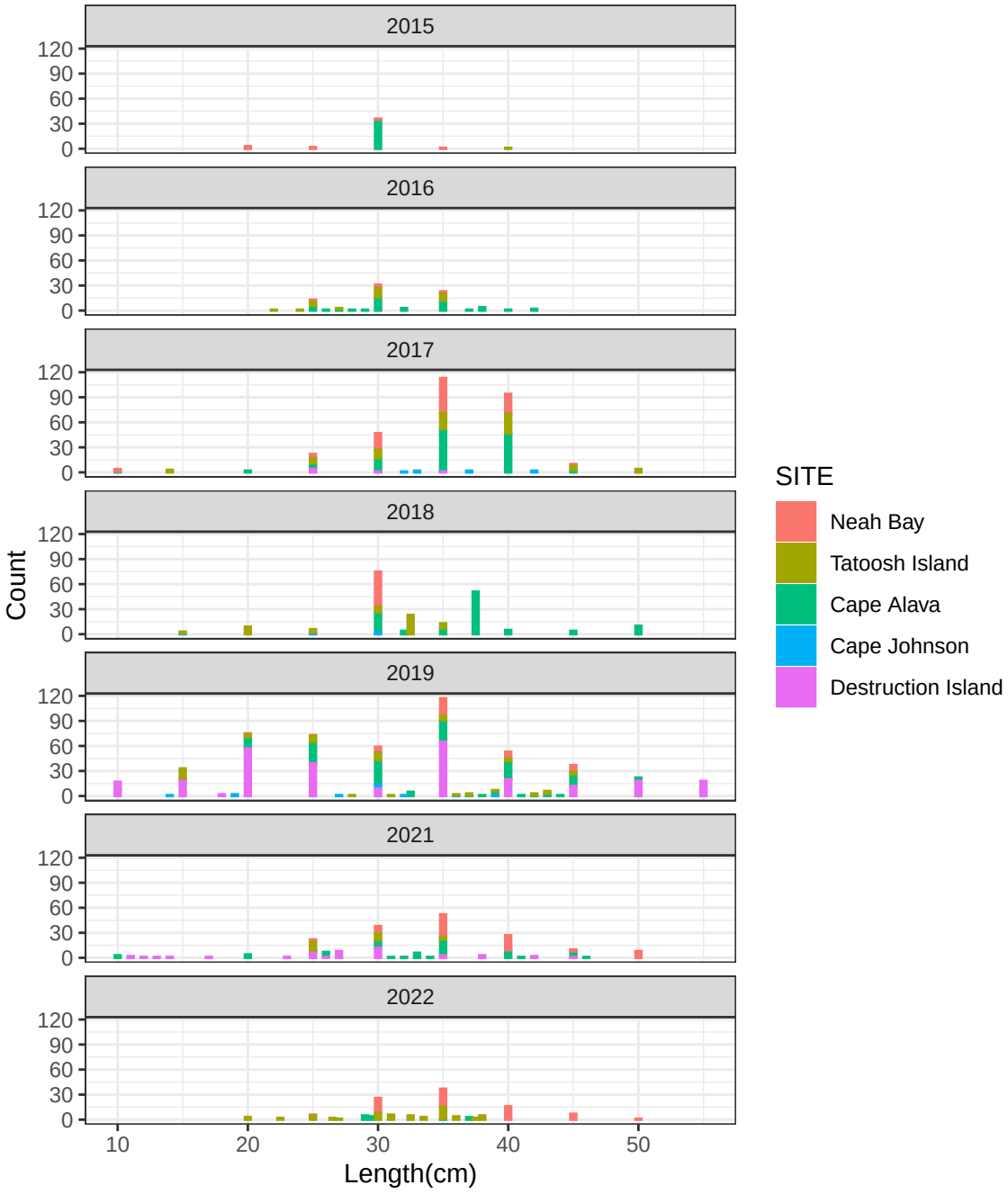
In addition to abundance data, we visually estimate size (total length) for all individuals observed during the surveys. Young-of-year show remarkably limited variation in size and so we exclude them from the analysis.

Plots of size distribution grouped into 5 cm bins.




2015
2016
2017
2018
2019
2021
2022
100
50
0
Count
10
20
30
40
50
Length (5 cm bins)
SITE
Neah Bay
Tatoosh Island
Cape Alava
Cape Johnson
Destruction Island

Plots of size distribution, but without 5cm bins. While nominally sizes are recorded in 1cm increments, in practice sizes in 5cm increments are recorded.



```r
# Write output from analysis to file for ease of use
bk.rockfish.output <- list(
  yoy.trend = yoy.trend, # year-specific estimates of density for young of year
  bk.trend = bk.trend   # year-specific estimates of density for >10cm black rockfish.
)

save(bk.rockfish.output,file="Black_rockfish_OCNMS_indices.Rdata")
```