ASAM Metadata 2021 Krill Biomass Estimate

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Krill biomass estimates from ASAM 2021 metadata

This Rmarkdown scripts works with a reduced version of the ASAM 2021 metadata spreadsheet, generated by "ASAM_2021_BiomassSummaryStats.Rmd". In summary, the original metadata spreadsheet was:

1. formatted to be R friendly
2. cleaned of duplicated data
3. cleaned of data with missing values of Density, CV or Area required in calculations

This script reads in the cleaned data file *"ASAM_metadata_2021_v3_reduced.csv"*. Some plots of data for all area sampled are produced before restricting data to area 48.1 only.

Prepare data for plottng

Data Summary

Area by contributor

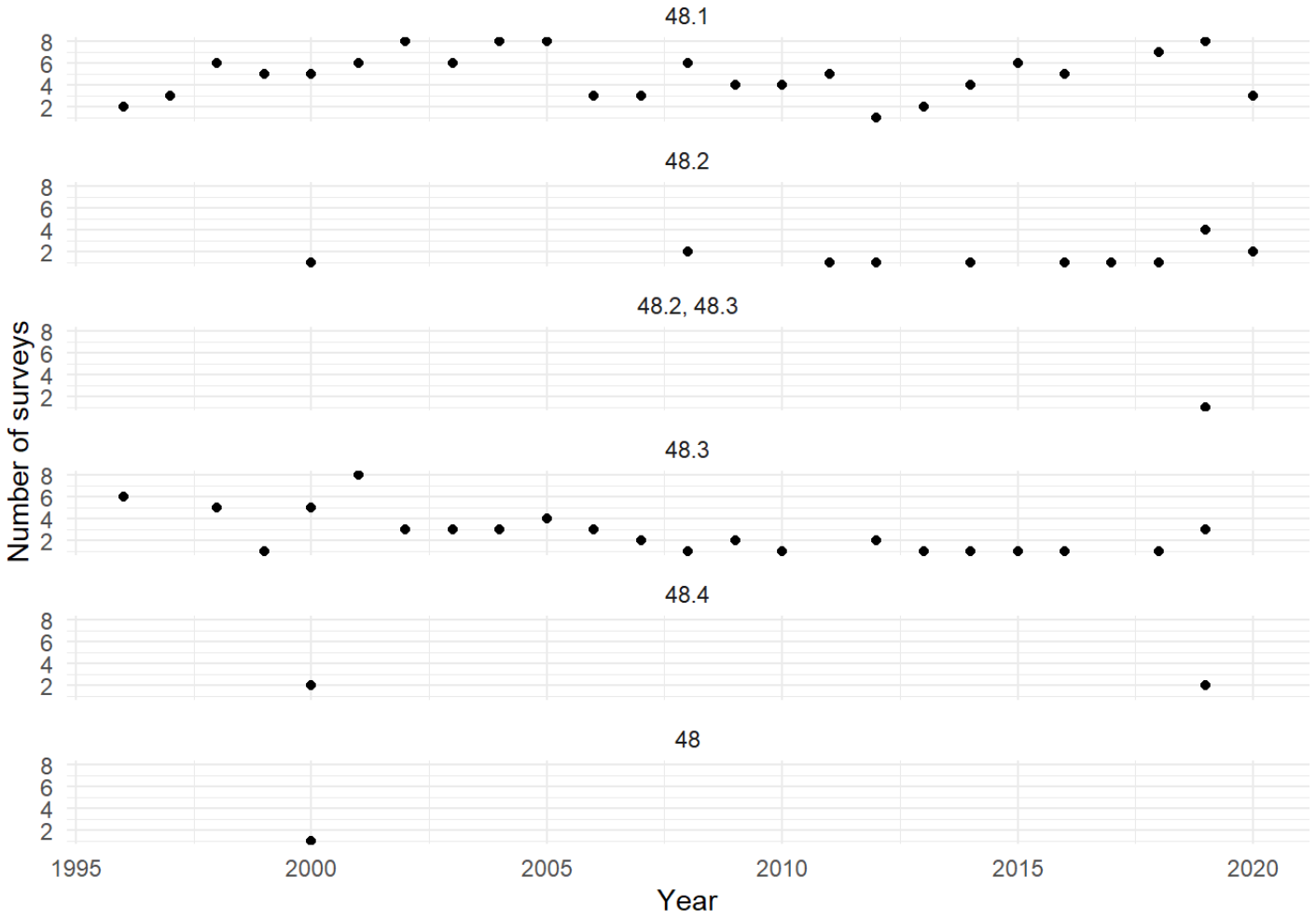
	ARK,China,Korea,Norway,Ukraine,United Kingdom	CCAMLR2000	China	Germany, China, Australia	IMR	IMR, YSFRI	IMR, YSFRI, BAS	Russia	UK	USA
48	0	1	0	0	0	0	0	0	0	0
48.1	6	2	10	5	0	0	0	2	0	92
48.1/48.2	0	0	0	0	0	0	0	1	0	0
48.2	3	1	0	0	5	1	1	2	0	2
48.2, 48.3	1	0	0	0	0	0	0	0	0	0
48.3	2	1	0	0	0	0	0	0	54	0
48.4	2	2	0	0	0	0	0	0	0	0

Time series plots

Number of surveys for each year by subarea

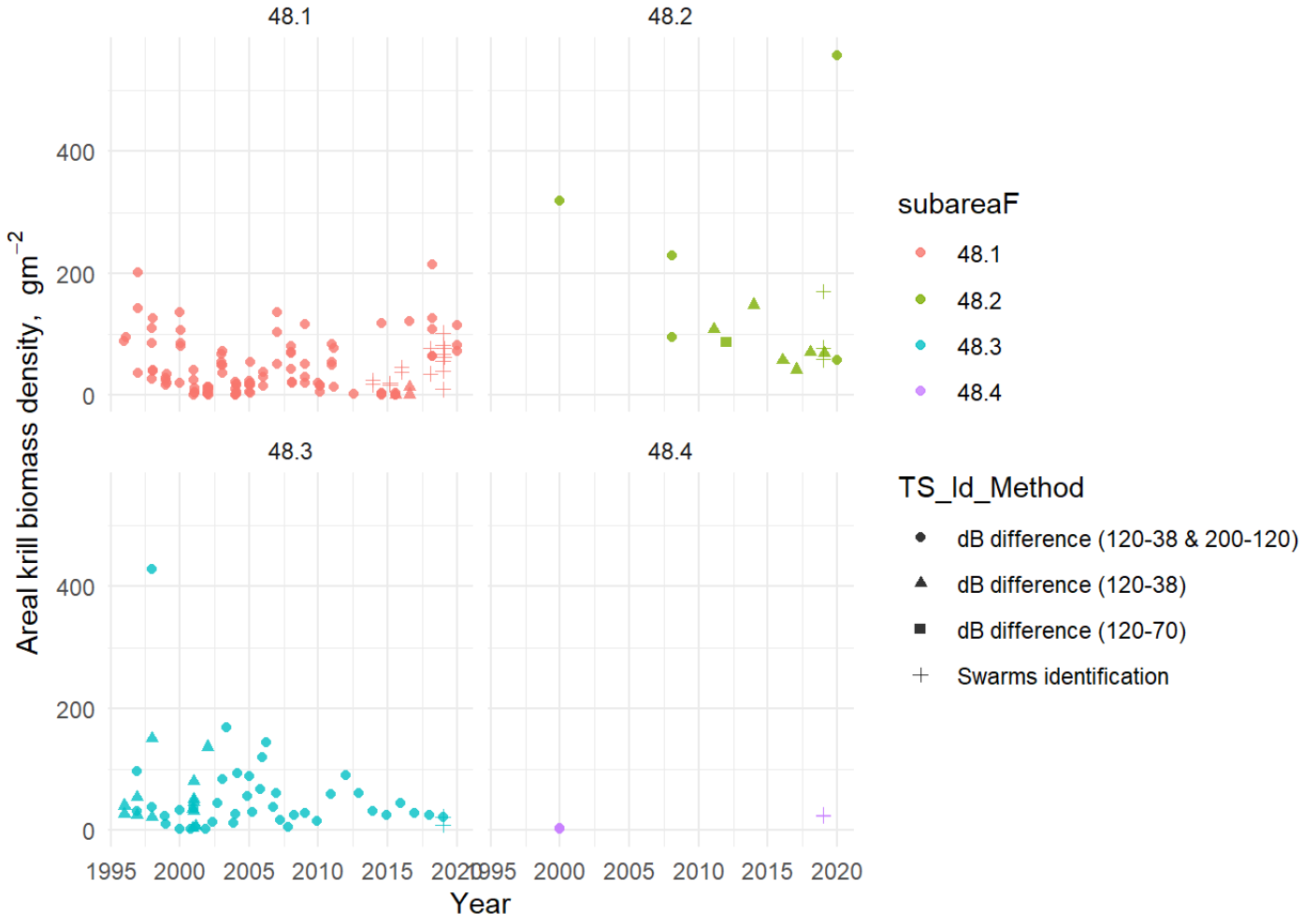
subareaF	Year_yyyy	n
48.3	1996	6
48.3	1998	5
48.3	1999	1
48.3	2000	5
48.3	2001	8
48.3	2002	3
48.3	2003	3
48.3	2004	3
48.3	2005	4
48.3	2006	3
48.3	2007	2
48.3	2008	1
48.3	2009	2
48.3	2010	1
48.3	2012	2
48.3	2013	1
48.3	2014	1
48.3	2015	1
48.3	2016	1
48.3	2018	1
48.3	2019	3
48.1	1996	2
48.1	1997	3
48.1	1998	6
48.1	1999	5
48.1	2000	5
48.1	2001	6
48.1	2002	8
48.1	2003	6
48.1	2004	8
48.1	2005	8
48.1	2006	3

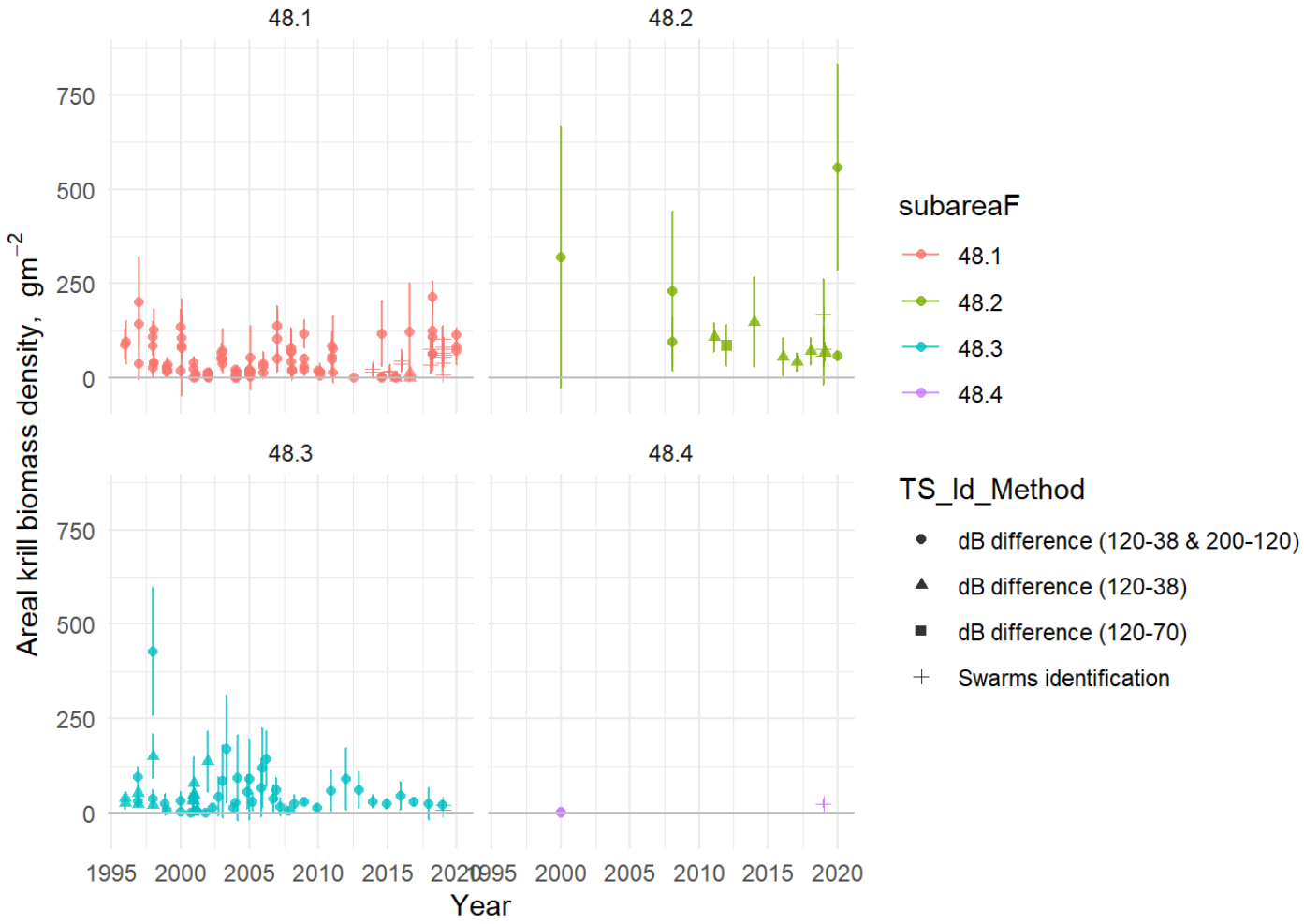
subareaF	Year_yyyy	n
48.1	2007	3
48.1	2008	6
48.1	2009	4
48.1	2010	4
48.1	2011	5
48.2	2008	2
48.1	2012	1
48.1	2014	4
48.1	2015	6
48.1	2016	5
48.1	2018	7
48.2	2011	1
48.2	2012	1
48.2	2014	1
48.2	2016	1
48.2	2017	1
48.2	2018	1
48.2	2019	4
48.1	2019	8
48.2, 48.3	2019	1
48.4	2019	2
48	2000	1
48.4	2000	2
48.2	2000	1
48.2	2020	2
48.1	2020	3
48.1	2013	2



Number of surveys carried outduring each year by subarea.

NOTE: Areas labeled with “48.2, 48.3” and “48” are not plotteded below to ease visualisation





Focus on Area 48.1

Years & Months available for 48.1 data:

```
##  [1] 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
## [16] 2011 2012 2013 2014 2015 2016 2018 2019 2020
```

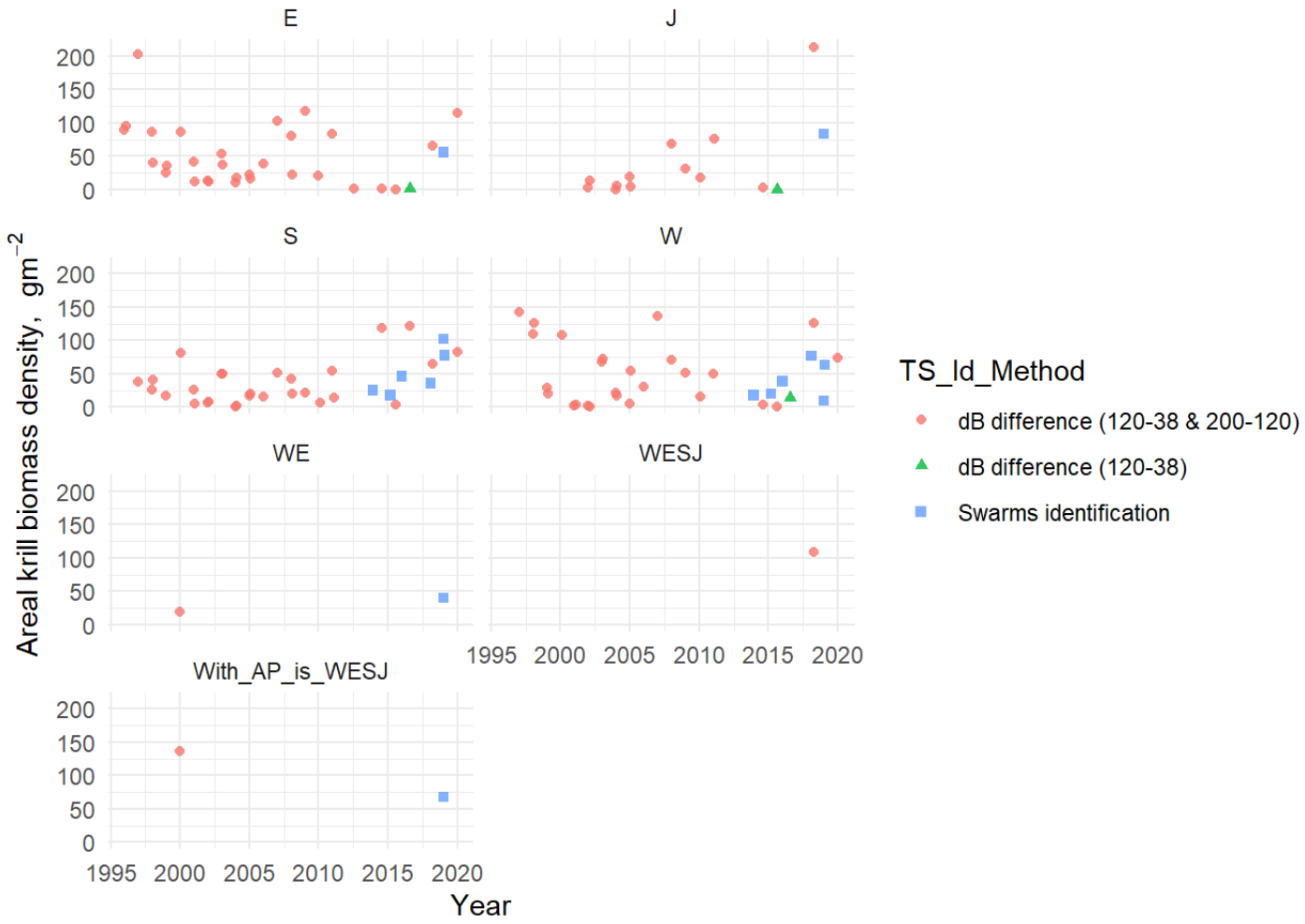
```
## [1] "Apr"           "Aug"           "Dec"           "Dec,Jan,Feb,Mar"
## [5] "Feb"           "Jan"           "Jan, Feb"      "Mar"
```

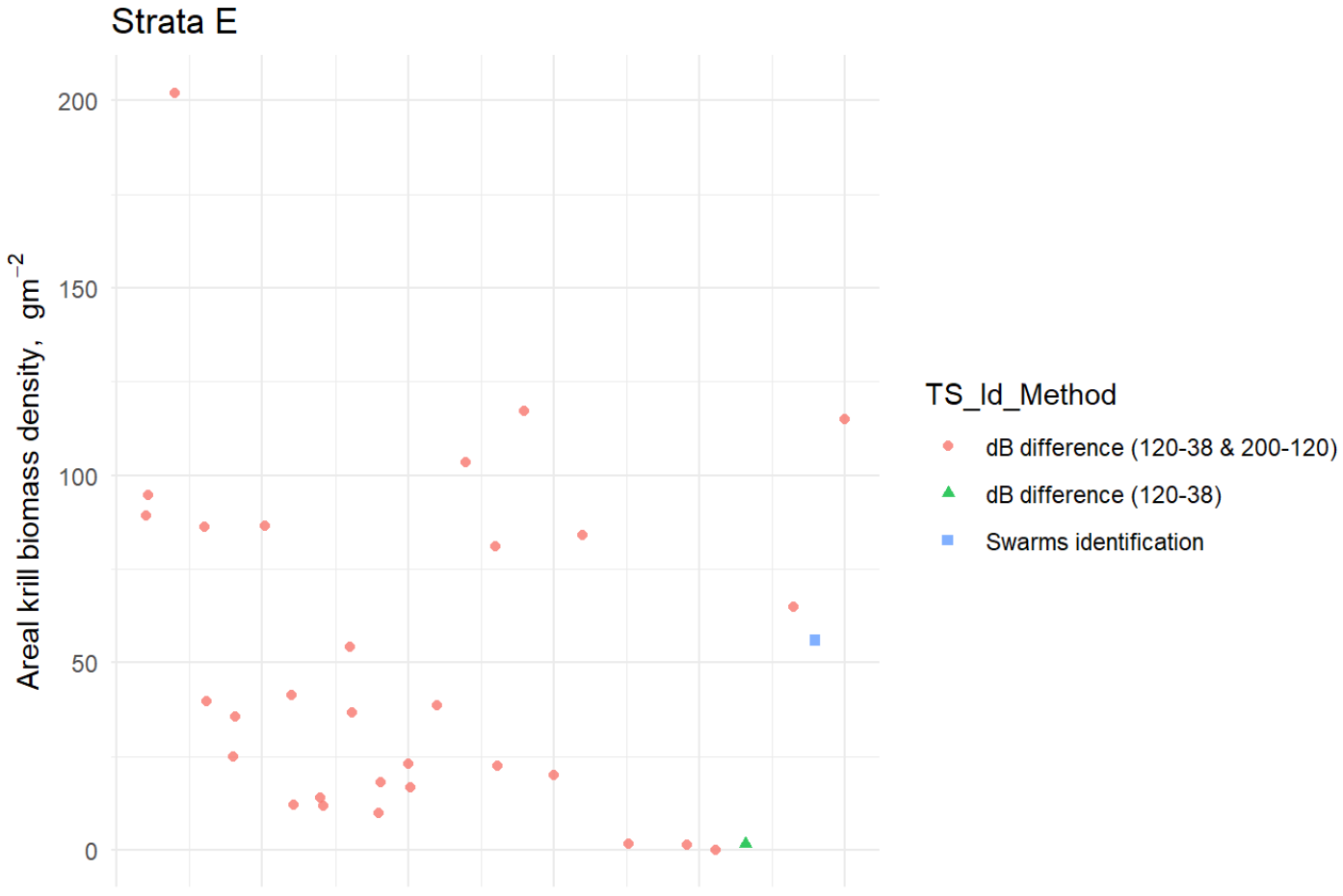
Strata available

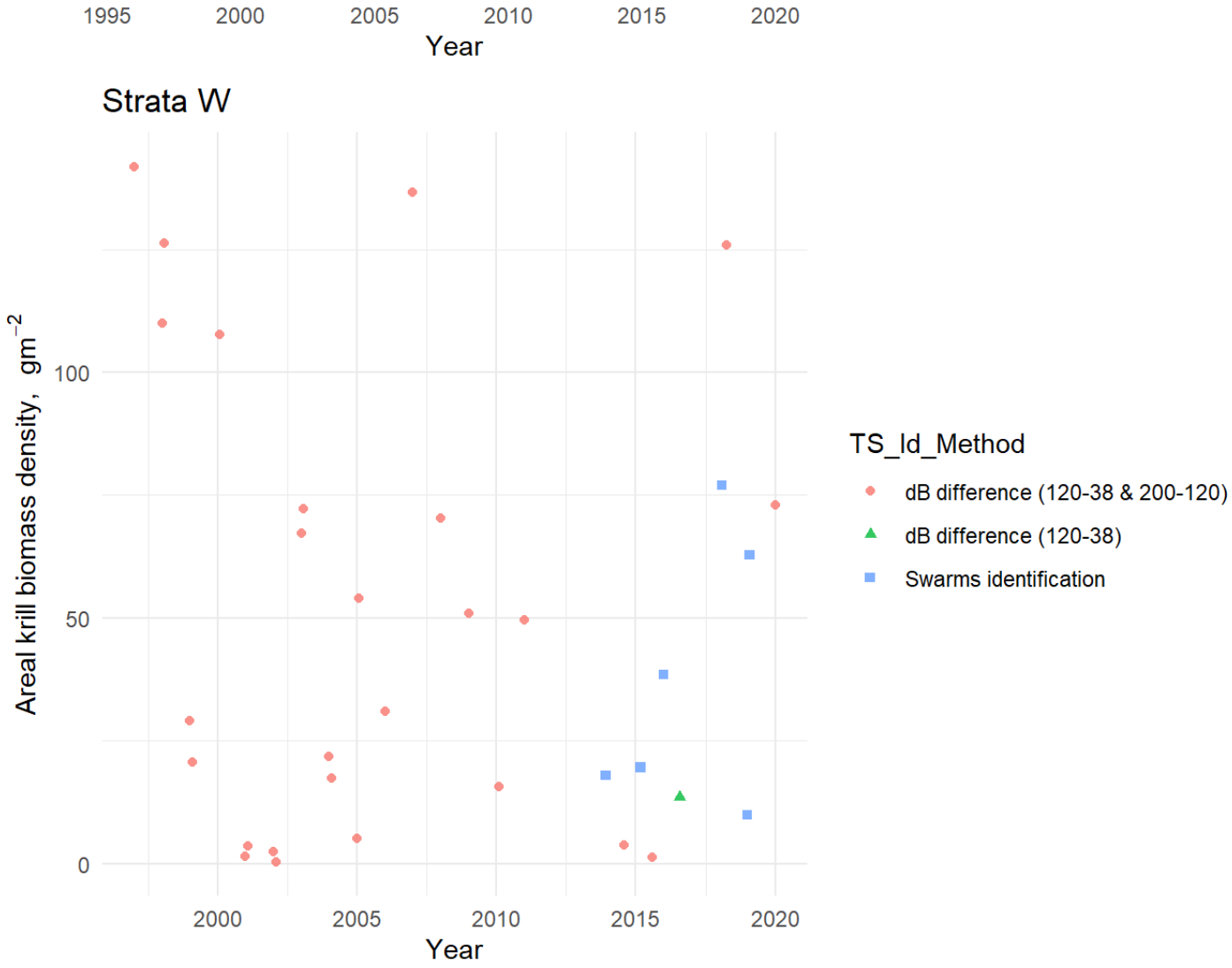
Strata which did not have a strata code already identified have been assigned one based on the closest area they resemble.

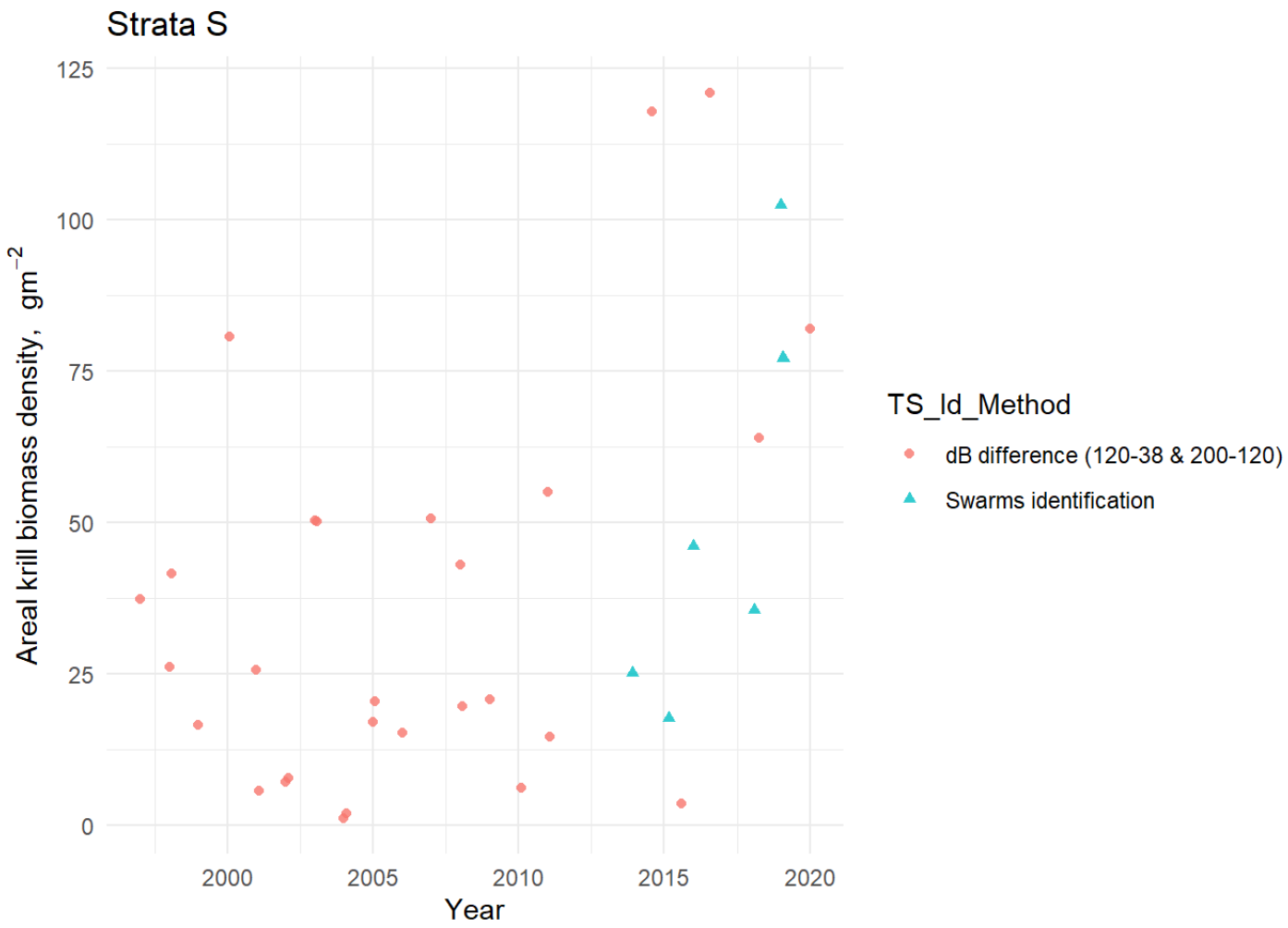
Stratum_name	Number_surveys	strata_code	Min_Area	Max_Area	Mean_Area
Elephant Island	31	E	41673	48231	43752
West	31	W	18870	38524	34398
South	26	S	8102	24479	20070
Joinville	14	J	17057	18322	18066
entire survey area	1	WESJ	115526	115526	115526
Bransfield	2	S	24479	24479	24479
South Shetland Islands North	1	W	29031	29031	29031
AP	2	WE	473318	473318	473318
SSI	2	With_AP_is_WESJ	48654	48654	48654
South Shetland Island (SSI)	1	W	120980	120980	120980
Bransfield Strait (BS)	6	S	22416	77707	31631
Elephant Island (EL)	1	E	53921	53921	53921

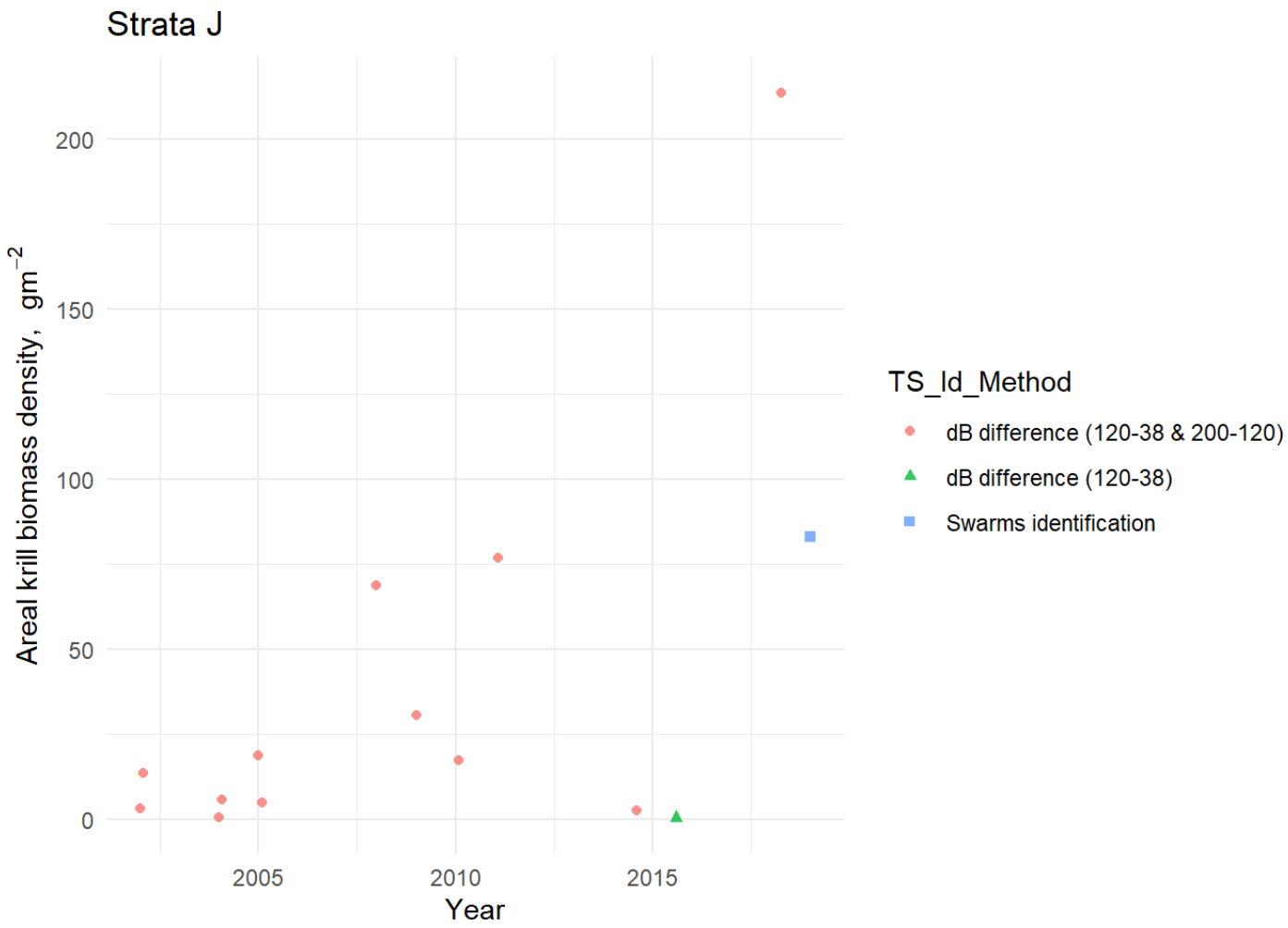
Area 48.1 Strata plots


E
J
S
W
WE
WESJ
With_AP_is_WESJ
Areal krill biomass density, gm^{-2}
0
50
100
150
200
1995
2000
2005
2010
2015
2020
Year
TS_Id_Method
dB difference (120-38 & 200-120)
dB difference (120-38)
Swarms identification


Strata E
Areal krill biomass density, gm^{-2}
0
50
100
150
200
TS_Id_Method
dB difference (120-38 & 200-120)
dB difference (120-38)
Swarms identification


1995
2000
2005
2010
2015
2020
Year
Strata W
Areal krill biomass density, gm^{-2}
100
50
0
2000
2005
2010
2015
2020
Year
TS_Id_Method
dB difference (120-38 & 200-120)
dB difference (120-38)
Swarms identification


Strata S
125
100
75
50
25
0
Areal krill biomass density, gm^{-2}
2000
2005
2010
2015
2020
Year
TS_Id_Method
dB difference (120-38 & 200-120)
Swarms identification


Strata J
Areal krill biomass density, gm^{-2}
200
150
100
50
0
2005
2010
2015
Year
TS_Id_Method
dB difference (120-38 & 200-120)
dB difference (120-38)
Swarms identification

Biomass calculations

Strategy

The data will be assessed sequentially starting at the smallest strata combining all data within each of “E”, “W”, “S”, “J” .

Then combining all data with “WE” codes and finally combining all in the large scale full area “WESJ”.

NOTE: the 2019 synoptic survey was aggregated over “Dec,Jan,Feb,Mar” & data available broadly spans months of Dec-Mar.

April is represented by a single 2018 survey carried out on *Polarstern*. In addition the CV were simply calculated as the S.E/Mean x 100% for each stratum or entire survey area, which covered: * South Shetland Islands North - W * Elephant Island - E * Bransfield - S * Joinville - J * entire survey area - WESJ

August data was all collected by the *Nathaniel B. Palmer* in 2012, 2014, 2015, 2016

Given the available data, summary stats are initially being calculated for the combined months of “December, January, February and March” data only.

Methodology

1) identify the various surveys that will be included in computing an average

2) compute weighted mean density using the survey areas as weights

- TotalArea <- sum(Survey_area_km2)
- AreaWeighting := Survey_area_km2/TotalArea
- Mean_Wt_Density_gm2 <- weighted.mean(x =Density_gm2, w = AreaWeighting)

since CVs are reported in the metadata spreadsheet these need to be converted to variances for use in the next step as variance of survey density = (reported CV * reported density)^2

- Var_Density := (Density_gm2 * (CV_of_density_Perc / 100))^2

3) compute the variance of the weighted mean density using equation 3 in Jolly and Hampton (1990)

$$\mathrm{Var}(\hat{\bar{\rho}}) = \frac{\sum_i A_i^2 \, \mathrm{Var}(\hat{\bar{\rho}}_i)}{\left(\sum_i A_i\right)^2}$$

- JH_Numerator := (Survey_area_km2^2 * Var_Density)
- Var_WtMeanDensity <- (sum(tmpdt$JH_Numerator)) / (TotalArea)^2

4) CV = sqrt of variance from step 3 / mean from step 2

- CV <- (sqrt(Var_WtMeanDensity) / Mean_Wt_Density_gm2)*100

5) compute extrapolated biomass estimate as mean from step 2 * area to which extrapolation applies

(in Tonnes Per Square Kilometer (t/km2))

- biomass_extra <- Mean_Wt_Density_gm2 * Area_of_Extrapolation

6) compute variance of estimate from step 5 as variance from step 3 * (area to which extrapolation applies)^2

- var_biomass_extra <- Var_WtMeanDensity *(Area_of_Extrapolation^2)

7) CV = sqrt of variance from step 6 / biomass estimate from step 5

- CV_of_TotalBiomass <- (sqrt(var_biomass_extra) / biomass_extra)*100

Notes: • Steps 2-3 of this pseudocode can be applied to multiple surveys within a single stratum, surveys that cover multiple strata, or any combination of both. • Steps 3 and 6 aren't necessary but the results of those two should be equal and provide a nice double-check that everything is working OK. • For those interested in application to the Grym later on - the outcome from Step 7 (or Step 4) might yield a useful estimate of the parameter "B0logSD," where B0logSD = sqrt(log(1+CV^2))

Strata Areas for extrapolation

Strata areas are the maximum area recorded in the metadata from each of the strata.

AMLR areas are smaller than maximum Strata area, and the areas AMLR traditionally used to survey.

48.1 area is 640583 km^2 as taken from Table 1. WG-ASAM-21/14

PLEASE NOTE: I do not have WG-ASAM-21/14 so if someone can check that this is copied correctly that would be excellent!

strata	n	Strata_Area	AMLR_Area
E	32	53921	43865
W	33	120980	38524
S	34	77707	24479
J	14	18322	18151
WESJ	1	115526	NA
WE	2	473318	NA
With_AP_is_WESJ	2	48654	NA
CCAMLR_48_1	NA	640583	NA

Step 1 - working by area

Year codes

```
y3 =  2020 2019 2018

y5 = 2020 2019 2018 2016 2015

y5107 = 2020 2019 2018 2016 2015 2014 2013 2012 2011 2010 2009

yall = All available =  2020 2019 2018 2016 2015 2014 2013 2012 2011 2010 2009 2008 2007 2006 2005 2004 2003 2002
2001 2000 1999 1998 1997 1996
```

Joinville

Years available: 2002, 2004, 2005, 2008, 2009, 2010, 2011, 2014, 2015, 2018, 2019

Mean Joinville survey area from all data in analysis: 18066km^2 for extrapolation

```
## [1] "Joinville"
```

Strata	N	Density gm2	Var Wt Density	CV Wt Density %	Strata Area	Strata Biomass T km-2	CV Strata Biomass %	Strata Area AMLR	AMLR Biomass T km-2	CV AMLR Biomass %	Years_included
Joinville	1	83.01	723.28	32.4	18322	1520941	32.4	18151	1506746	32.4	y3
Joinville	1	83.01	723.28	32.4	18322	1520941	32.4	18151	1506746	32.4	y5
Joinville	4	51.87	187.89	26.43	18322	950409	26.43	18151	941538	26.43	y5107
Joinville	11	29.48	28.19	18.01	18322	540112	18.01	18151	535071	18.01	yall

Elephant

Years available: 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2014, 2015, 2016, 2018, 2019, 2020

Mean Elephant survey area from all data in analysis: 44070km^2

Strata	N	Density gm2	Var Wt Density	CV Wt Density %	Strata Area	Strata Biomass T km-2	CV Strata Biomass %	Strata Area AMLR	AMLR Biomass T km-2	CV AMLR Biomass %	Years_included
Elephant	1	56.03	427.32	36.89	53921	3021278	36.89	43865	2457825	36.89	y3
Elephant	1	56.03	427.32	36.89	53921	3021278	36.89	43865	2457825	36.89	y5
Elephant	4	69.33	73.26	12.35	53921	3738094	12.35	43865	3040958	12.35	y5107
Elephant	26	55.57	16.32	7.27	53921	2996454	7.27	43865	2437630	7.27	yall

Bransfield

Years available: 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2014, 2015, 2016, 2018, 2019, 2020, 2013

Mean Bransfield survey area from all data in analysis: 22369km^2

Strata	N	Density gm2	Var Wt Density	CV Wt Density %	Strata Area	Strata Biomass T km-2	CV Strata Biomass %	Strata Area AMLR	AMLR Biomass T km-2	CV AMLR Biomass %	Years_included
Bransfield	3	72.65	81.99	12.46	77707	5645309	12.46	24479	1778367	12.46	y3
Bransfield	5	56.64	41.65	11.4	77707	4401161	11.4	24479	1386439	11.4	y5
Bransfield	10	40.05	17.01	10.3	77707	3112044	10.3	24479	980346	10.3	y5107
Bransfield	29	31.2	6.43	8.13	77707	2424801	8.13	24479	763853	8.13	yall

West

Years available: 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2014, 2015, 2016, 2018, 2019, 2020, 2013

Mean West survey area from all data in analysis: 36859km^2

Strata	N	Density gm2	Var Wt Density	CV Wt Density %	Strata Area	Strata Biomass T km-2	CV Strata Biomass %	Strata Area AMLR	AMLR Biomass T km-2	CV AMLR Biomass %	Years_included
West	3	41.65	34.02	14	120980	5038735	14	38524	1604498	14	y3
West	5	37.43	19.75	11.87	120980	4528001	11.87	38524	1441864	11.87	y5
West	9	37.04	7.78	7.53	120980	4480619	7.53	38524	1426776	7.53	y5107
West	28	48.68	12.59	7.29	120980	5888913	7.29	38524	1875223	7.29	yall

All strata together

Years available: 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2014, 2015, 2016, 2018, 2019, 2020, 2013

The strategy for combining all data is as before. All data is weighted by the survey area, however it is then extrapolated to a biomass for the entire survey area by summing the previous AMLR survey areas.

The sum of the AMLR areas were used for a region wide survey biomass estimate as some of the surveys were already combined over large areas and there was considerable overlap.

Strata	N	Density gm2	Var Wt Density	CV Wt Density %	Strata Area	Strata Biomass T km-2	CV Strata Biomass %	Strata Area AMLR	AMLR Biomass T km-2	CV AMLR Biomass %	Years_included
All 48.1	10	47.43	12.49	7.45	NA	NA	NA	125019	5929790	7.45	y3
All 48.1	14	45.64	10.29	7.03	NA	NA	NA	125019	5705583	7.03	y5
All 48.1	29	45.44	6.15	5.46	NA	NA	NA	125019	5680410	5.46	y5107
All 48.1	98	43.91	3.31	4.14	NA	NA	NA	125019	5490124	4.14	yall

Table of strata area biomass estimates

“N” = Number of surveys
“Density gm2” = Weighted mean density gm^{-2} across all surveys contributing (weighted by original survey area)
“Var Wt Density” = Variance of weighted mean density “CV Wt Density %” = Coefficient of Variation (percent) of weighted mean density
“Strata Area” = Maximum Area (km^2) of any survey contributing to the calculation of Weighted mean density
“Strata Area AMLR” = Previous AMLR survey areas (km^2) covering “Joinville”, “Elephant Island”, “Bransfield” and “West”
“Strata Biomass T km-2” = Biomass (Tones per km^2) extrapolated to Maximum Strata area surveyed
“CV Strata Biomass %” = Coefficient of Variation (percent) of Biomass extrapolated to Maximum Strata area surveyed “AMLR Biomass T km-2” = Biomass (Tones per km^2) extrapolated to AMLR defined area surveyed - in the case of combined data this is the sum of areas covering “Joinville”, “Elephant Island”, “Bransfield” and “West” “CV AMLR Biomass %” = Coefficient of Variation (percent) of Biomass extrapolated to AMLR survey areas “Years” = see “Year codes” above

Strata	N	Density gm2	Var Wt Density	CV Wt Density %	Strata Area	Strata Biomass T km-2	CV Strata Biomass %	Strata Area AMLR	AMLR Biomass T km-2	CV AMLR Biomass %	Years_included
Joinville	1	83.01	723.28	32.40	18322	1520941	32.40	18151	1506746	32.40	y3
Joinville	1	83.01	723.28	32.40	18322	1520941	32.40	18151	1506746	32.40	y5
Joinville	4	51.87	187.89	26.43	18322	950409	26.43	18151	941538	26.43	y5107
Joinville	11	29.48	28.19	18.01	18322	540112	18.01	18151	535071	18.01	yall
Elephant	1	56.03	427.32	36.89	53921	3021278	36.89	43865	2457825	36.89	y3
Elephant	1	56.03	427.32	36.89	53921	3021278	36.89	43865	2457825	36.89	y5
Elephant	4	69.33	73.26	12.35	53921	3738094	12.35	43865	3040958	12.35	y5107
Elephant	26	55.57	16.32	7.27	53921	2996454	7.27	43865	2437630	7.27	yall
Bransfield	3	72.65	81.99	12.46	77707	5645309	12.46	24479	1778367	12.46	y3
Bransfield	5	56.64	41.65	11.40	77707	4401161	11.40	24479	1386439	11.40	y5
Bransfield	10	40.05	17.01	10.30	77707	3112044	10.30	24479	980346	10.30	y5107
Bransfield	29	31.20	6.43	8.13	77707	2424801	8.13	24479	763853	8.13	yall
West	3	41.65	34.02	14.00	120980	5038735	14.00	38524	1604498	14.00	y3
West	5	37.43	19.75	11.87	120980	4528001	11.87	38524	1441864	11.87	y5
West	9	37.04	7.78	7.53	120980	4480619	7.53	38524	1426776	7.53	y5107
West	28	48.68	12.59	7.29	120980	5888913	7.29	38524	1875223	7.29	yall
All 48.1	10	47.43	12.49	7.45	NA	NA	NA	125019	5929790	7.45	y3
All 48.1	14	45.64	10.29	7.03	NA	NA	NA	125019	5705583	7.03	y5
All 48.1	29	45.44	6.15	5.46	NA	NA	NA	125019	5680410	5.46	y5107
All 48.1	98	43.91	3.31	4.14	NA	NA	NA	125019	5490124	4.14	yall

CCAMLR subarea 48.1

This data has not been extrapolated to the entire CCAMLR sub area 48.1 as some decisions need to be made around how to do that given that some of the areas that are not sampled are likely to be low density.

To extrapolate to the Entire subarea as is would involve running code chunk 756 - 830 but replacing

```
Area_of_Extrapolation_AMLR <- sum(AreaExtra[strata %in% c("W", "E", "S", "J")]$AMLR_Area)

with:

 Area_of_Extrapolation_AMLR <- 640583
```

In the interests of completion I have set up the code to run in the R markdown script BUT not included it in the final table.

This to me is unwise as all of this area has not been sampled