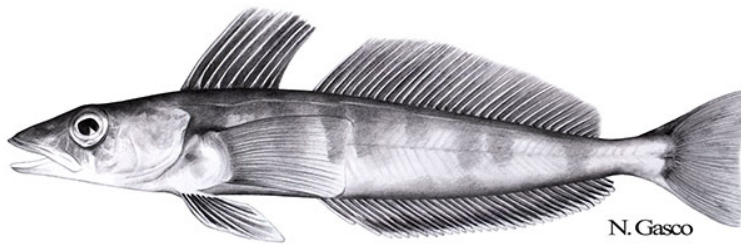


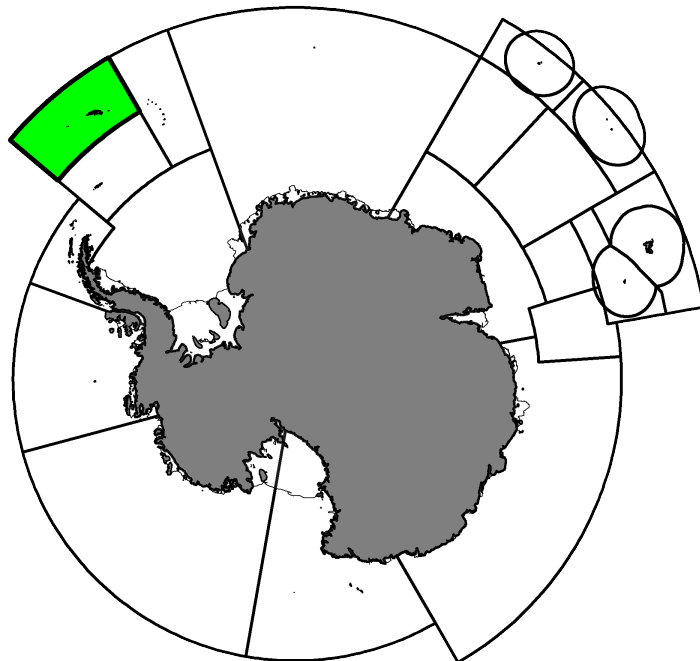
# Stock Assessment Report 2024: *Champscephalus gunnari* in Subarea 48.3

CCAMLR Secretariat

20 December 2024



Mackerel icefish, *Champscephalus gunnari* Lönnberg, 1905.



Map of the management areas within the CCAMLR Convention Area. The region discussed in this report is shaded in green. Coastlines and ice shelves: UK Polar Data Centre/BAS and Natural Earth. Projection: EPSG 6932.



CCAMLR

Commission for the Conservation of Antarctic Marine Living Resources  
Commission pour la conservation de la faune et la flore marines de l'Antarctique  
Комиссия по сохранению морских живых ресурсов Антарктики  
Comisión para la Conservación de los Recursos Vivos Marinos Antárticos

WG-FSA-2023/38

15 September 2023

Original: English

WG-FSA

**Preliminary Assessment of Mackerel Icefish (*Champsocephalus gunnari*) in Subarea 48.3 based on the 2023 Groundfish Survey**

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# Preliminary Assessment of Mackerel Icefish (*Champscephalus gunnari*) in Subarea 48.3 based on the 2023 Groundfish Survey

Jessica Marsh and Tim Earl

## Abstract

The CCAMLR Statistical Subarea 48.3 icefish assessment was conducted by applying the standard projection methodology that has been agreed for this stock by CCAMLR Scientific Committee and its Working Groups. The stratified bootstrap of UK 2023 demersal fish survey icefish catch density and catch rate data indicate a precautionary biomass estimate of 75,170 tonnes (lower one-sided 5<sup>th</sup> percentile: 47,395 tonnes) within Subarea 48.3. Projections for the 2024<sup>1</sup> and 2025 seasons applying the CCAMLR Decision Rule imply catch limits (TAC) of 5,138 tonnes for 2024 and 3,579 tonnes for 2025.

The assessment would lead to a recommendation from Working Group FSA to Scientific Committee that the catch limit for *C. gunnari* in Subarea 48.3 should be set at 5,138 tonnes for 2023/24 and 3,579 tonnes for 2024/25.

## Introduction

CCAMLR has agreed that, for mackerel icefish (*Champscephalus gunnari*, henceforward icefish) in Subarea 48.3, future catch limit advice should be given in accordance with the CCAMLR Decision Rules (WG-FSA 2010 §.5.164), as implemented by the length-based method described in Edwards et al. (2010a), with minor changes agreed in 2017 (Earl, 2017; WG-FSA 2017 §3.4). Diagnostics are presented in Appendix 1 consistent with Maschette et al. (2018) as recommended by WG-SAM (2018 §.3.10-11).

Studies of the application of the Decision Rule to icefish have demonstrated that the length-based approach provides robust, precautionary estimates of catch limits (Hillary et al., 2009; Hillary et al., 2010; Edwards et al., 2010a; Edwards et al., 2010b; Darby et al., 2013). CCAMLR WG-SAM (2013 §.4.33) noted that the biomass projections upon which the catch advice is based are consistent with the objectives of the CCAMLR Convention Article II and that the rule generates future levels of exploitation that are considered precautionary.

The UK demersal fish trawl survey, which is used as the basis of the assessment and catch forecast, is undertaken annually or bi-annually at the beginning of the calendar year as part

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<sup>1</sup> The seasons are labelled according to calendar year in which the season finishes e.g. the 2024 season refers to the season from 1st December 2023 to 30th November 2024.

of its regular monitoring program. The survey is typically run every two years in January or February (Table 1). The results of the 2023 survey are described in Hollyman et al. (2023).

Based on the demersal trawl icefish density data collected by the survey, this paper presents a preliminary assessment of the Subarea 48.3 demersal icefish biomass and applies the CCAMLR length-based method to derive catch limit advice for the 2024 and 2025 seasons.

## Catch History

In recent years, the effort directed towards catching icefish has been low, resulting in a low percentage uptake of the catch (Figure 1). There has been no commercial fishing since 2018, with the fishing in 2019, 2021 and 2023 as part of surveys.

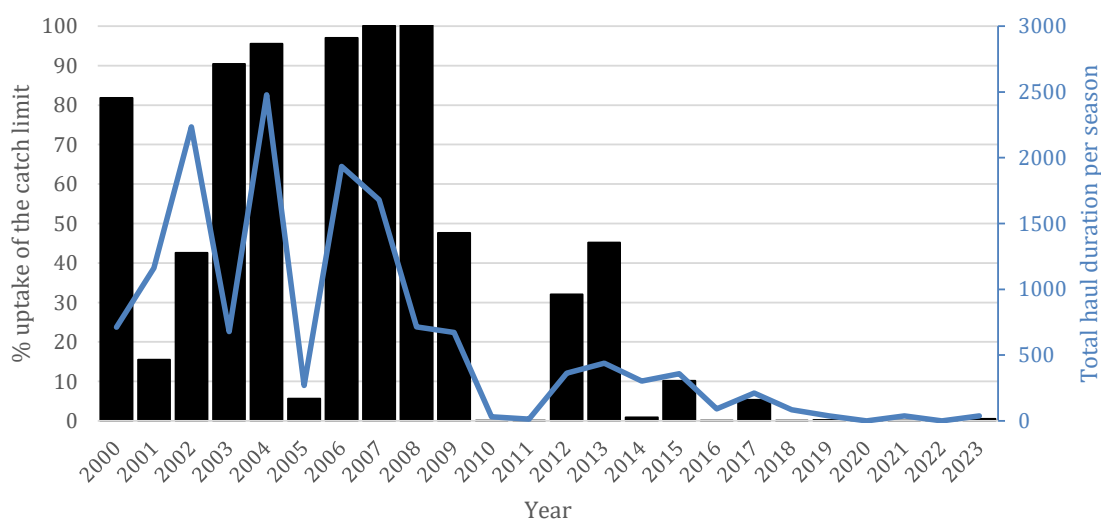


Figure 1: Uptake of the Catch Limit (black, left axis) and effort (blue, right axis)

## Survey Demersal Biomass Estimates - Methods

The 2023 survey comprised 75 successfully completed demersal trawls within Subarea 48.3, as described in the cruise report (Hollyman et al., 2023). The previous survey in 2021 was carried out relatively later in the year than usual due to disruption from the Covid-19 pandemic, however there is no information to suggest that the timing of the survey affects catch rates. The 2023 survey took place during the beginning of February, the standard timing for this survey (Table 1).

For each haul in the survey, the total weight of icefish caught was recorded. Full biological information was taken from 30 representative samples, and the lengths of the remaining fish (or a subsample for large catches) were recorded. The survey is stratified into five areas, each with two depth bands, as shown in Figure 2.

*Table 1 Dates of the UK demersal fish trawl survey in each year used in the icefish assessment.*

<b>Year of survey</b>	<b>Survey date</b>
2023	01/02/23 – 10/02/23
2021	08/05/21 – 28/05/21
2019	27/01/19 – 05/02/19
2017	30/01/17 – 07/02/17
2015	13/01/15 – 23/01/15
2013	22/01/13 – 29/01/13
2011	26/01/11 – 06/02/11
2010	29/01/10 – 31/01/10
2009	15/01/09 – 23/01/09
2008	16/04/08 – 30/04/08
2007	27/08/07 – 21/09/07
2006	03/01/06 – 01/02/06
2004	07/01/05 – 05/02/04
2002	12/01/02 – 01/02/02
2000	16/01/00 – 30/01/00

The survey data are bootstrapped in accordance with the method used in Mitchell and Martin (2011). The weightings used in the bootstraps are based on the number of hauls by stratum and the fishable area within each stratum, as shown in Table 2. A correction factor of 1.241 is applied to the UK survey data following comparative studies with the Russian survey in 2002 (WG-FSA 2002 § 5.103 – 5.111). The R code used in this assessment is provided as an appendix. The assessment was run in R version 4.2.1 (R Core Team, 2022).

The biomass estimates using the agreed CCAMLR assessment method in this paper differ from the survey biomass estimates presented in Hollyman et al. (2023) due to the inclusion of the correction factor in the assessment, but not the survey biomass estimate. The bootstrap in that work is performed separately within each strata, whereas the assessment presented here weights the data from each stratum, and then a bootstrap is then performed from all the weighted hauls.

*Table 2: Icefish in Subarea 48.3 - Characteristics of the ten strata used within the stratified bootstrap of biomass estimates.*

<b>Strata</b>	<b>Description</b>	<b>Stratum area (km<sup>2</sup>)</b>	<b>Number of hauls</b>	<b>Weighting</b>
SR1	Shag Rocks <200m	2,553	9	0.57
SR2	Shag Rocks ≥200m	1,438	10	0.29

NW1	North West <200m	3,371	15	0.45
NW2	North West ≥200m	2,059	11	0.38
NE1	North East <200m	2,766	6	0.93
NE2	North East ≥200m	3,576	5	1.44
SW1	South West <200m	4,276	5	1.73
SW2	South West ≥200m	6,637	6	2.23
SE1	South East <200m	6,617	4	3.34
SE2	South East ≥200m	3,780	4	1.91

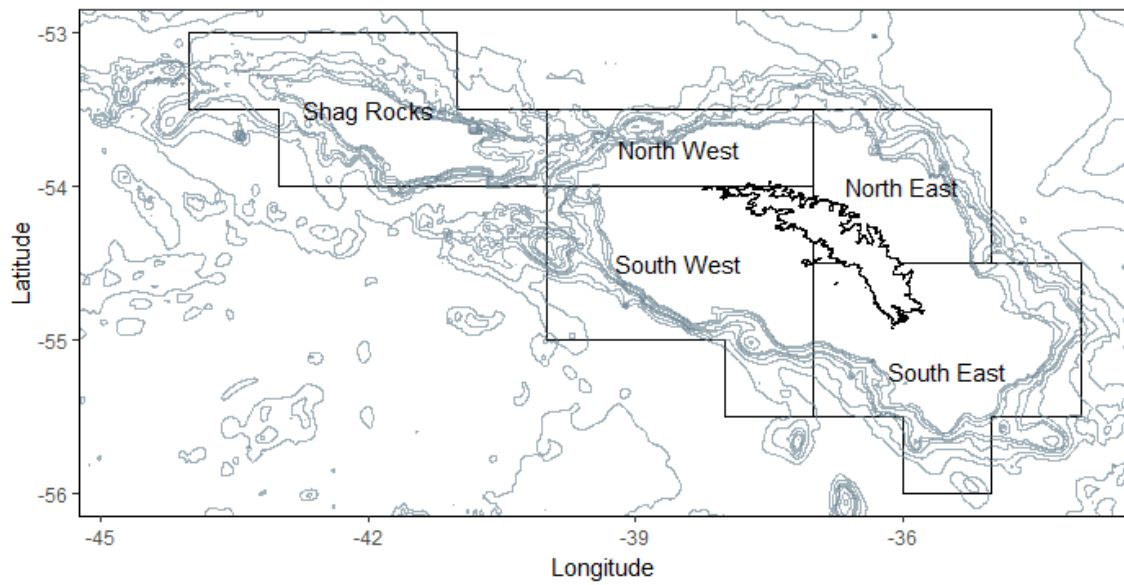
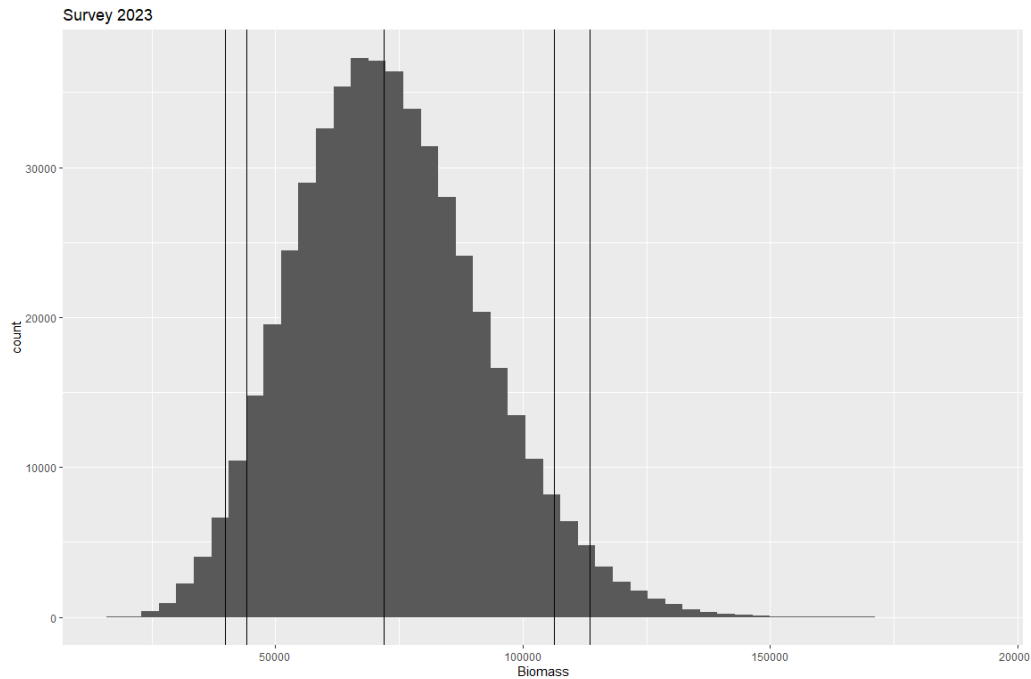


Figure 2: Icefish in Subarea 48.3 - The five area strata used in the demersal biomass bootstrap.

## Survey Demersal Biomass Estimates – Results

The bootstrap approach provides an estimate of biomass at the time of the 2023 demersal fish survey at 75,170 tonnes with the lower and upper five percentiles at 47,395 and 109,617 tonnes, respectively (Figure 3). The biomass is estimated to have increased since the 2021 survey, and be greater than the average for the time series (Figure 4). The biomass estimates are a known underestimate of the actual icefish biomass, due to the presence of icefish in the water column at the time of the survey (Darby et al., 2013).



*Figure 3: Icefish in Subarea 48.3 - Bootstrap estimation of biomass (tonnes) at the time of the 2023 survey. Vertical lines indicate bootstrap estimates of the one sided 2.5, 5, 50, 95 and 97.5<sup>th</sup> percentiles of the mean. Vertical scale indicates the number of simulations (from 500,000) in each biomass interval.*

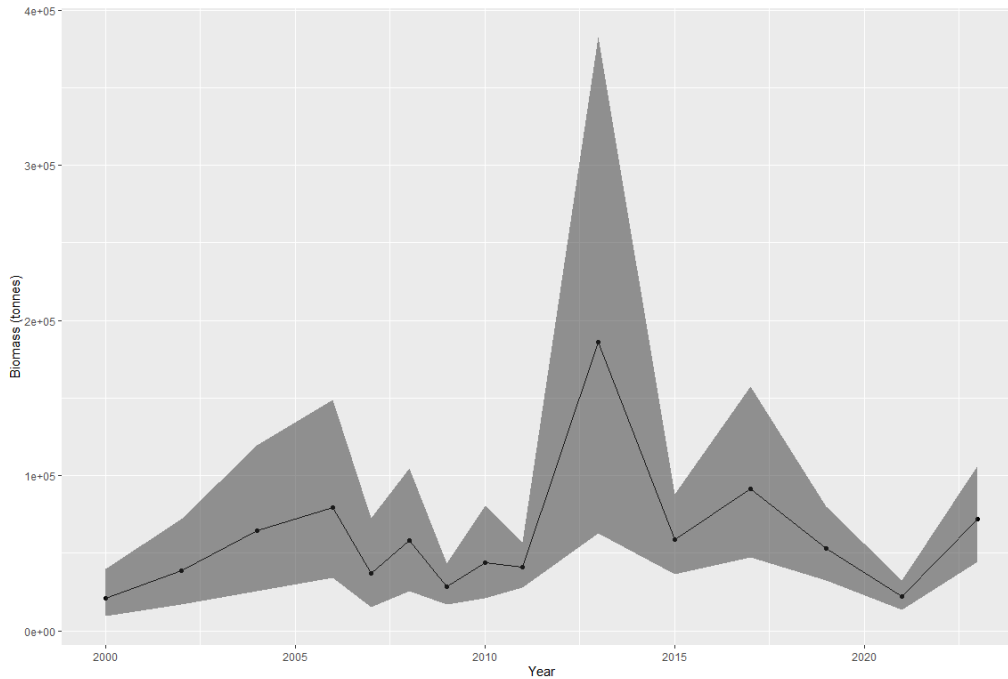


Figure 4: Icefish in Subarea 48.3 – Biomass estimates from demersal surveys between 2000 to 2023. The shaded area indicates the 5 percentile to 95 percentile range.

## Length Distribution Estimation

The length distribution data from individual hauls has been combined using a weighted average since 2010, as described in Edwards et al. (2010a), and revised in 2017 (Earl, 2017) and endorsed by WG-FSA-17 (§3.4).

Figure 5 shows the simple aggregation of length data by area stratum. Differences in distribution by stratum can be seen, but also differences compared with the length distributions from the 2021 survey. In 2023, in the North East, North West and the South East, the distributions suggest clear age-classes within the catch, whereas the length distributions in the South West and Shag Rocks appear unimodal. In 2021, a large proportion of fish caught in the North East, South West and South East were small (<20cm) fish, with larger fish making up a greater proportion of the catch in the North West and Shag Rocks (Earl, 2021). Comparatively, in 2023, the South East is the only stratum where the catch is dominated by small fish. The weighted average of binned numbers at length across all strata is shown in Figure 6.

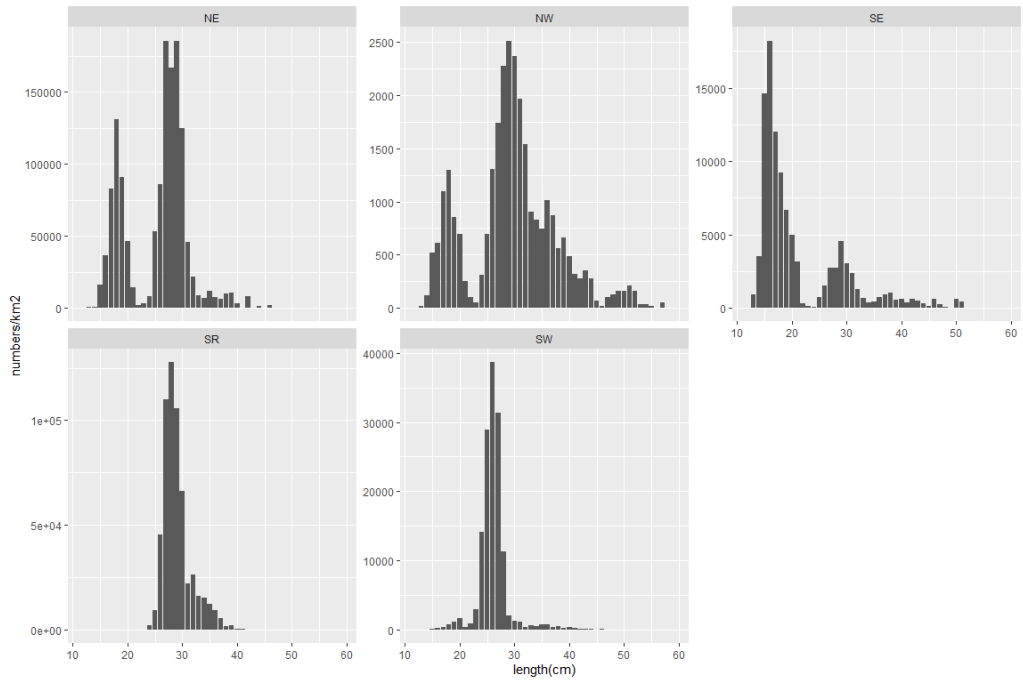


Figure 5: Icefish in Subarea 48.3 – Sum of haul numbers/km<sup>2</sup> in the 2023 survey by length (cm).

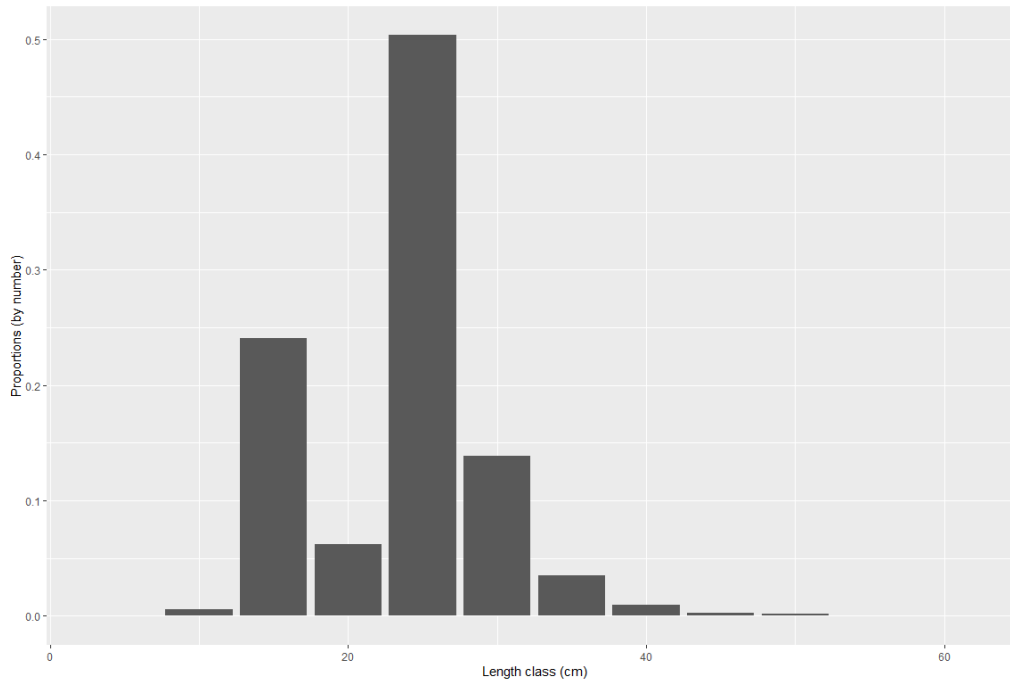


Figure 6: Icefish in Subarea 48.3 - 2023 proportions (by number) in the survey by length class (cm).

## Length-weight relationship

Figure 7 shows the length and weight data from the 2023 survey, and the fitted length-weight relationship (n=1,848). Icefish condition is often indicated by length-weight relationships. As icefish feed predominately on Antarctic krill (*Euphausia superba*), previous studies suggest icefish condition to be poor in years of low krill availability with potential implications for subsequent spawning and survival (Kock and Everson, 2003; North, 2005; Main et al., 2009). With the cumulative effects of climate change hypothesised to negatively impact krill in Antarctic ecosystems (Flores et al., 2012), identifying changes in icefish length-weight relationships over time might indicate an indirect impact of climate change on icefish populations. When comparing the length-weight relationship estimated using data collected in the 2023 survey with data collected in the previous four icefish surveys (2015, 2017, 2019 and 2021, respectively), there appears to be negligible differences in expected weight at length across all sectors (Figure 8). The length-weight relationships differ mostly at lengths > 50 cm, where there are fewer individuals to inform the model fit (Figure 8).

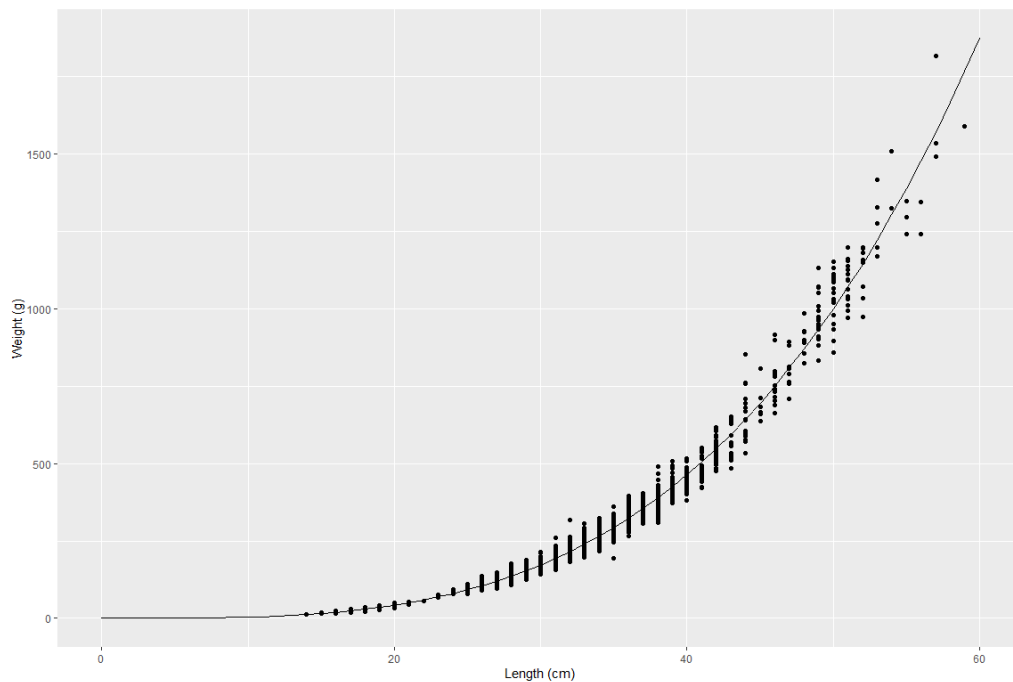


Figure 7: Icefish in Subarea 48.3 - Length-weight data from 2023 South Georgia icefish survey.

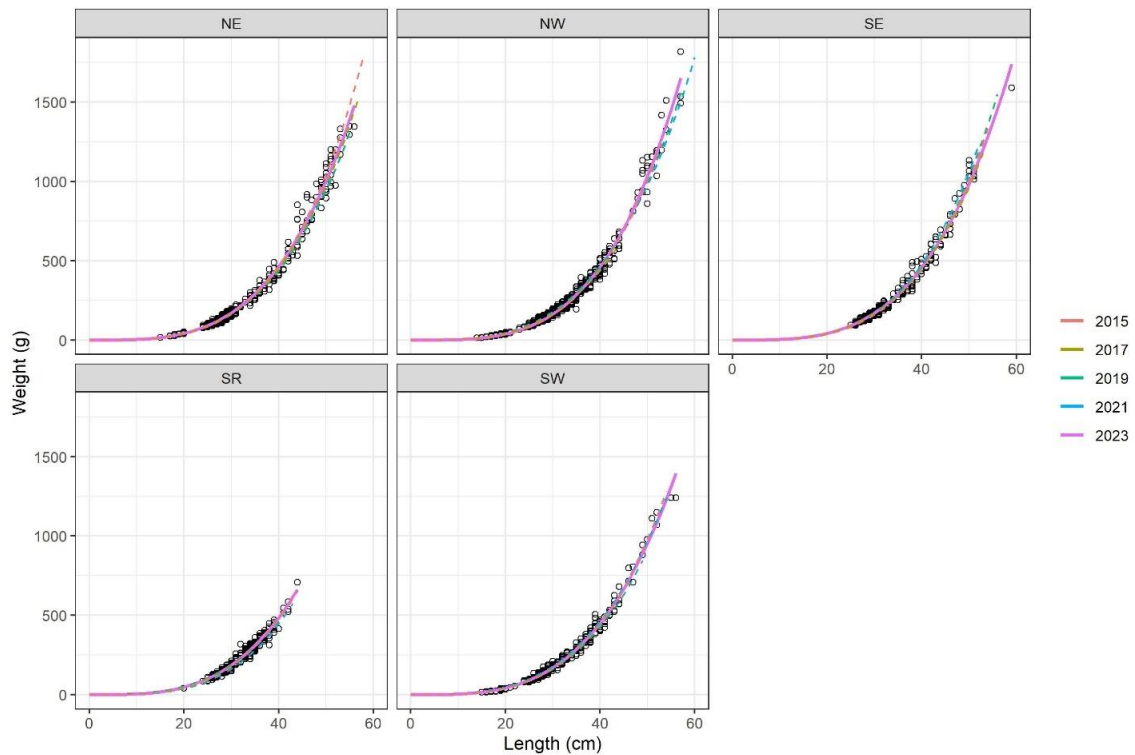


Figure 8: Icefish in Subarea 48.3 – 2023 raw length-weight data (black circles) and length-weight relationship plotted alongside historic length-weight relationships estimated from data collected in the previous four icefish surveys.

## Catch Projections

The CCAMLR agreed Decision Rule for icefish calculates a Catch Limit that leaves on average 75% of the stock biomass that would be expected after two seasons if there were no fishing. To be conservative, the lower 5<sup>th</sup> percentile of survey biomass is used for this projection, and no recruitment is assumed. The parameters used are shown in Table 3.

Table 3: Icefish in Subarea 48.3 - Assumptions made in projection of current biomass.

Parameter	Value	Justification
Recruitment	0	Precautionary assumption given a lack of knowledge about stock-recruit dynamics
Catch after survey in current season	2,132 t	2021 CCAMLR Catch Limit – none was taken prior to survey
Proportion of natural mortality that occurs after survey	0.81	Based on Season starting 1 <sup>st</sup> December, survey early February
Biomass at time of survey	47,395 t	Lower 5 percentile of biomass bootstrap
Selectivity of fishery	Knife edged at age 2.5	Edwards et. al. (2010a)
Length-weight parameters	$W = 0.00142L^{3.442}$ (cm to g)	Estimated from 2023 survey data
Age-length parameters	$L = 55.7(1 - e^{-0.17(a+0.58)})$	CCAMLR (2010) in Edwards et. al. (2010a)
Natural mortality	0.71 (y <sup>-1</sup> )	Edwards et. al. (2010a)

## Catch Projections – Results

Table 4: Icefish in Subarea 48.3 - Stock projections under the 'fishing' and 'no fishing' scenarios, showing the effect of fishing on biomass over the next two seasons.

Quantity	No fishing	Fishing
Harvest rate (year 1&2)	0	0.144
Biomass at time of survey (t)	47,395	47,395
Biomass at time of survey (t) reduced by remaining available catch	45,687	45,687
Biomass one year after survey (t)	37,151	32,309
Biomass two years after survey (t)	26,703	20,027
Catch in year 1 (t)	0	5,138
Catch in year 2 (t)	0	3,579

These rules are implemented in R, in the file shown in Appendix 1. Catches of 5,138 tonnes in 2024 and 3,579 tonnes in 2025 at a harvest rate of 0.144 in both seasons would be consistent with the Decision Rule application as agreed by CCAMLR WG-FSA (2010).

### Summary

The UK Subarea 48.3 trawl survey conducted in February 2023 (Hollyman et al. 2023) indicated that the estimated icefish stock biomass has increased relative to the previous two assessments in 2019 and 2021, and was similar to the biomass estimated for the stock in 2017.

The predictions from the 2021 assessment (Earl, 2021) under the scenario of no fishing in 2022 and 2023 seasons indicated an expected lower 5<sup>th</sup> percentile biomass at the end of this period of 8,956 tonnes. The current estimate of the lower 5<sup>th</sup> percentile at this the end of the season is 47,395 tonnes, considerably greater than was projected, likely an artifact of the low biomass estimated in the 2021 assessment (one of the lowest of the time series), possibly due to the later timing of the 2021 survey coinciding with a period when icefish are less catchable (Earl, 2021).

The CCAMLR agreed HCR using the length-based approach has previously been demonstrated to provide robust, precautionary estimates of catch limits and exploitation

rates for Subarea 48.3 icefish (Darby et. al., 2013). Application of the method to the UK 2023 demersal trawl survey indicates a catch limit for icefish in Subarea 48.3 of 5,138 tonnes in 2024 and 3,579 tonnes in 2025.

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# Icefish assessment

April 2023

## Libraries

```
library(ggplot2)
library(FLCore)
library(bootstrap)
library(rgdal)
library(gtable)
library(rgeos)
library(here)

set.seed(0)
```

## Parameters

```
surv <- "23"
pcs <- c(2.5,5,50,95,97.5)
nrep <- 500000 # number of bootstrap samples
linc <- 5
lbins <- seq(linc,60,linc)

TAC <- 1708 #2023 TAC, tonnes
catch_taken <- 0 #before survey, tonnes

# growth parameters
t0 <- -0.58
k <- 0.17
Linf <- 55.7

# SELECTIVITIES

# survey selectivity
selsurv <- 1+0*lbins
selsurv

## [1] 1 1 1 1 1 1 1 1 1 1 1 1

# commercial selectivity
commsel <- 0*lbins

# assumed knife-edge selectivity at age
asel <- 2.5

# equivalent length
lsel <- Linf*(1-exp(-k*(asel-t0)))
```

```

commssel[lbins>lssel] <- 1
commssel

## [1] 0 0 0 0 1 1 1 1 1 1 1 1

#Maturity
matl <- 1+0*lbins
matl

## [1] 1 1 1 1 1 1 1 1 1 1 1 1

```

## Biomass Estimation

### Read in data

```

#a.df <- read.csv(file.path(path,"hist data","stratum_area.csv"),header=T)
a.df <- read.csv(file.path(here('Data',"hist data","stratum_area.csv")),header=T)
sectors <- as.character(a.df$Strata)

# biomass data
#dat <- read.csv(file.path(path,"hist data",paste0("ani_bm_dataSG",surv,".csv")),header=T)
dat <- read.csv(file.path(here('Data',"hist data",paste0("ani_bm_dataSG",surv,".csv"))),header=T)
names(dat) <- c("SURVCODE", "EVENTNUM", "SECTOR", "CombinedStrata", "SumOfANI_KG_km2", "SumOfANI_n_km2")
dat$CombinedStrata <- paste0(dat$SECTOR,substr(dat$CombinedStrata,7,7)) #Convert to previous style of strata

# correct for pelagic component
dat[, 'SumOfANI_KG_km2'] <- dat[, 'SumOfANI_KG_km2'] * 1.241
dat <- unique(dat[,1:5]) ##Duplicate haul records appear when only a sample measured, remove these

#biomass.prev <- read.csv(file.path(path,"hist biomass 2019.csv"), stringsAsFactors=TRUE)
biomass.prev <- read.csv(file.path(here('Data',"hist biomass 2021.csv")), stringsAsFactors=TRUE)

```

Haul data

	SURVCODE	EVENTNUM	SECTOR	CombinedStrata	SumOfANI_KG_km2
1	SG23	1	NE	NE2	117.935208
2	SG23	2	NE	NE2	648.903015
3	SG23	3	NE	NE1	82.139680

	SURVCODE	EVENTNUM	SECTOR	CombinedStrata	SumOfANI_KG_km2
4	SG23	4	NE	NE2	11.229685
5	SG23	5	NE	NE1	447.282709
6	SG23	6	NE	NE1	866.517453
7	SG23	7	NW	NW1	1237.065906
8	SG23	8	NW	NW1	613.230594
9	SG23	9	NW	NW1	926.724941
10	SG23	10	NW	NW2	529.584464
11	SG23	11	NW	NW2	238.637226
12	SG23	12	NW	NW2	9.827975
13	SG23	13	NW	NW2	165.550765
14	SG23	14	NW	NW1	183.733401
15	SG23	15	NW	NW1	651.757563
16	SG23	16	NW	NW1	280.598663
17	SG23	17	NW	NW2	8.305020
18	SG23	18	NW	NW1	114.752292
19	SG23	19	NW	NW1	20.859100
20	SG23	20	NW	NW2	174.033745
21	SG23	21	NW	NW1	293.261330
22	SG23	22	NW	NW1	254.632848
23	SG23	23	NW	NW2	67.008664
24	SG23	24	NW	NW2	0.000000
25	SG23	25	NW	NW2	180.230182
26	SG23	26	NW	NW1	501.484005
27	SG23	27	SR	SR2	21.680518
28	SG23	28	SR	SR1	788.972700
29	SG23	29	SR	SR1	2896.502439
30	SG23	30	SR	SR2	586.325590
31	SG23	31	SR	SR1	34119.222406
32	SG23	32	SR	SR2	5163.853246
33	SG23	33	SR	SR1	5433.658063
34	SG23	34	SR	SR2	28.688073
35	SG23	35	SR	SR2	0.000000
36	SG23	36	SR	SR2	3.372045
37	SG23	37	SR	SR2	12743.824905
38	SG23	38	SR	SR1	4129.153611

	SURVCODE	EVENTNUM	SECTOR	CombinedStrata	SumOfANI_KG_km2
39	SG23	39	SR	SR1	6623.047479
40	SG23	40	SR	SR2	1794.102283
41	SG23	41	SR	SR2	258.206679
42	SG23	42	SR	SR1	1887.409970
43	SG23	43	SR	SR1	4686.663057
44	SG23	44	SR	SR1	1502.290440
45	SG23	45	SR	SR2	27.452657
46	SG23	46	NW	NW1	2.512777
47	SG23	47	NW	NW2	0.000000
48	SG23	48	NW	NW2	0.000000
49	SG23	49	NW	NW1	9.121846
50	SG23	50	NW	NW1	2609.148889
51	SG23	51	NW	NW1	326.920974
52	SG23	52	SW	SW1	519.316927
53	SG23	53	SW	SW2	378.401749
54	SG23	54	SW	SW1	143.231008
55	SG23	55	SW	SW2	785.828626
56	SG23	56	SW	SW2	357.967195
57	SG23	57	SW	SW1	105.896764
58	SG23	58	SW	SW1	108.330613
59	SG23	59	SW	SW2	2487.965983
60	SG23	60	SW	SW1	7943.766093
61	SG23	61	SW	SW2	10339.433074
62	SG23	63	SW	SW2	318.198605
63	SG23	64	SE	SE2	511.702275
64	SG23	65	SE	SE1	759.690932
66	SG23	66	SE	SE1	918.412474
67	SG23	67	SE	SE1	721.459693
69	SG23	68	SE	SE2	638.552951
70	SG23	69	SE	SE2	942.309046
71	SG23	70	SE	SE1	396.772396
72	SG23	71	SE	SE2	1939.189454
73	SG23	72	NE	NE2	583.932446
74	SG23	73	NE	NE1	20526.979785
75	SG23	74	NE	NE1	4609.107755

	SURVCODE	EVENTNUM	SECTOR	CombinedStrata	SumOfANI_KG_km2
77	SG23	75	NE	NE1	6684.564594
79	SG23	76	NE	NE2	7382.775394

## Haul CPUEs

Haul by haul CPUE

```

#Map plots
#Load(file.path(path, "SG_basemap.rdata"))
load(file.path(here('Data', "SG_basemap.rdata")))

###get haul locations from database
#locs <- read.csv(file.path(path, "hist data", paste0("ani_ev_dataSG", surv, ".csv")), header=T)
locs <- read.csv(file.path(here('Data', "hist data", paste0("ani_ev_dataSG", surv, ".csv"))), header=T)
colnames(locs)[c(1,2,5,6)] <- c("SURVCODE", "EVENTNUM", "STLAT", "STLON")
#locs <- merge(locs, dat, all.x=TRUE)
locs <- merge(locs, dat) # removed 'all.x=TRUE' statement as one haul (#62) w
as invalid and we want to remove this point from the map

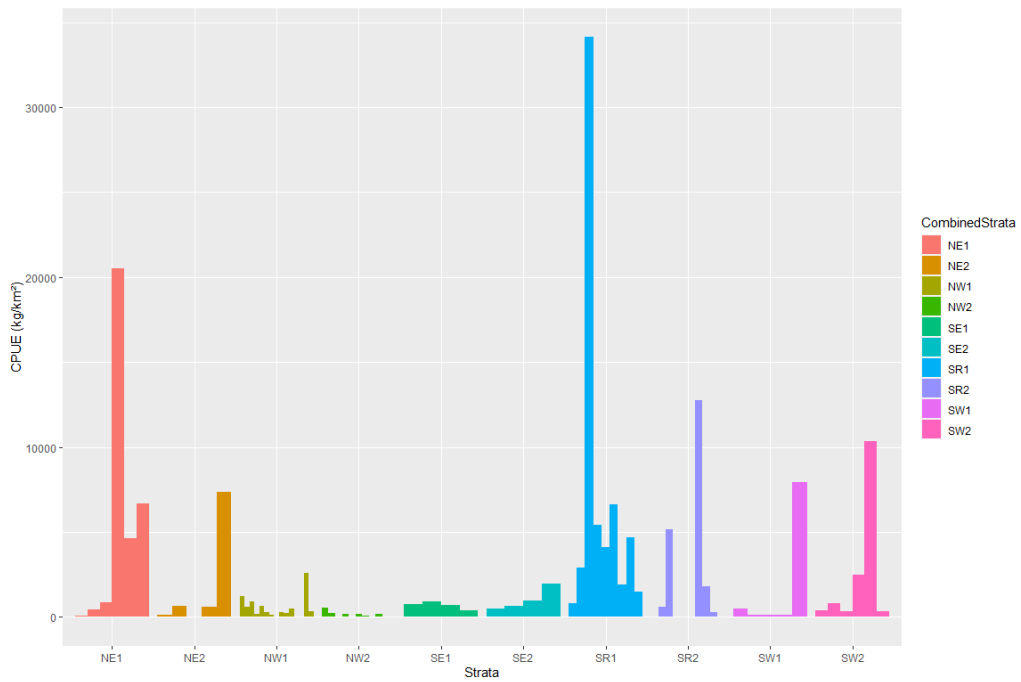
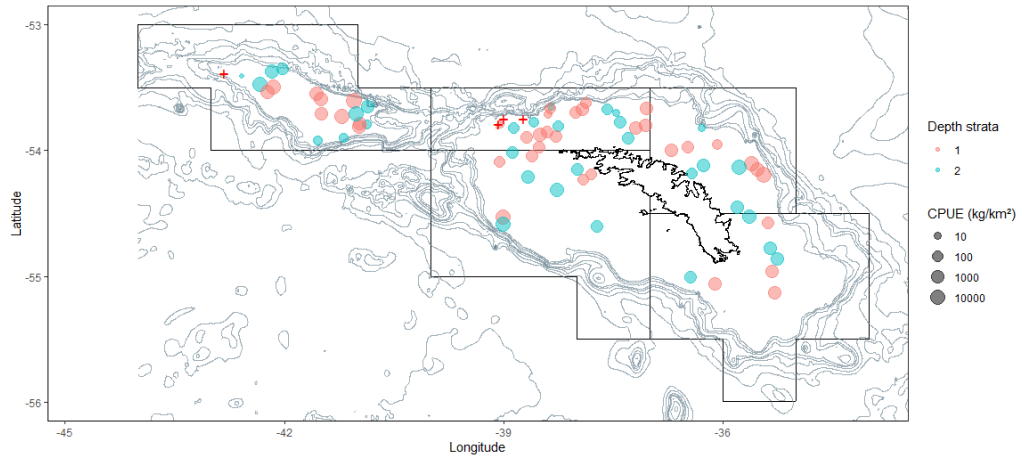
locs$cat <- cut(locs$SumOfANI_KG_km2, c(0,100,10000,Inf))
locs$depth <- substr(locs$CombinedStrata,3,3)

## OGR data source with driver: ESRI Shapefile
## Source: "W:\FCOSO\Working_Area\3. GIS_open\shapefiles", layer: "48_bathy_S
G_sub"
## with 1447 features
## It has 2 fields
## Integer64 fields read as strings: ID CONTOUR

## OGR data source with driver: ESRI Shapefile
## Source: "W:\FCOSO\Working_Area\3. GIS_open\shapefiles", layer: "COAST"
## with 816 features
## It has 9 fields

## OGR data source with driver: ESRI Shapefile
## Source: "W:\FCOSO\Working_Area\3. GIS_open\shapefiles", layer: "SGSSI_rese
archstrata_boxes"
## with 33 features
## It has 4 fields

```



## Apply weighting

See de la Mare and Williams WG-FSA-96/38

```

dat$CombinedStrata <- factor(dat$CombinedStrata, levels=a.df$Strata)
a.df$nhaul <- table(dat$CombinedStrata)
a.df$nweight <- (a.df$Area / sum(a.df$Area)) * (sum(a.df$nhaul) / a.df$nhaul)
dat$weighted <- dat$SumOfANI_KG_km2 * a.df$nweight[dat$CombinedStrata]

```

Strata1	Strata2	Strata	Area	nhaul	nweight
SD48321	SR	SR1	2553	9	0.5738678
SD48322	SR	SR2	1438	10	0.2909125
SD48331	NW	NW1	3371	15	0.4546435
SD48332	NW	NW2	2059	11	0.3786755
SD48341	NE	NE1	2766	6	0.9326194
SD48342	NE	NE2	3576	5	1.4468751
SD48351	SW	SW1	4276	5	1.7301001
SD48352	SW	SW2	6637	6	2.2378146
SD48361	SE	SE1	6617	4	3.3466067
SD48362	SE	SE2	3780	4	1.9117687

```

btstrap <- bootstrap(dat$weighted, nrep, mean)[['thetastar']] ##weighted version

```

```

btstrap.biomass <- btstrap * sum(a.df$Area) * 0.001 #tonnes
biomass <- quantile(btstrap.biomass, pcs/100, na.rm=T)
#save(biomass, file=file.path(path, "biomass.rdata"))
#save(biomass, file=file.path(here("biomass.rdata")))
biomass

```

```

##      2.5%      5%      50%      95%      97.5%
## 42948.31 47395.43 75170.47 109616.56 116872.57

```

```

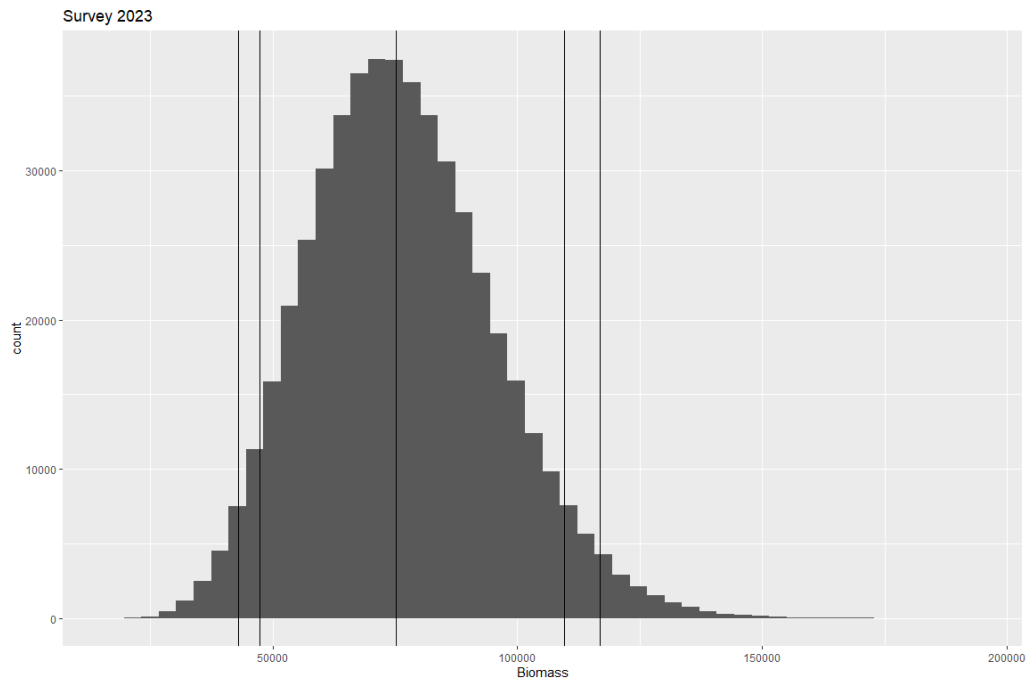
mean(btstrap.biomass)

```

```

## [1] 76395.15

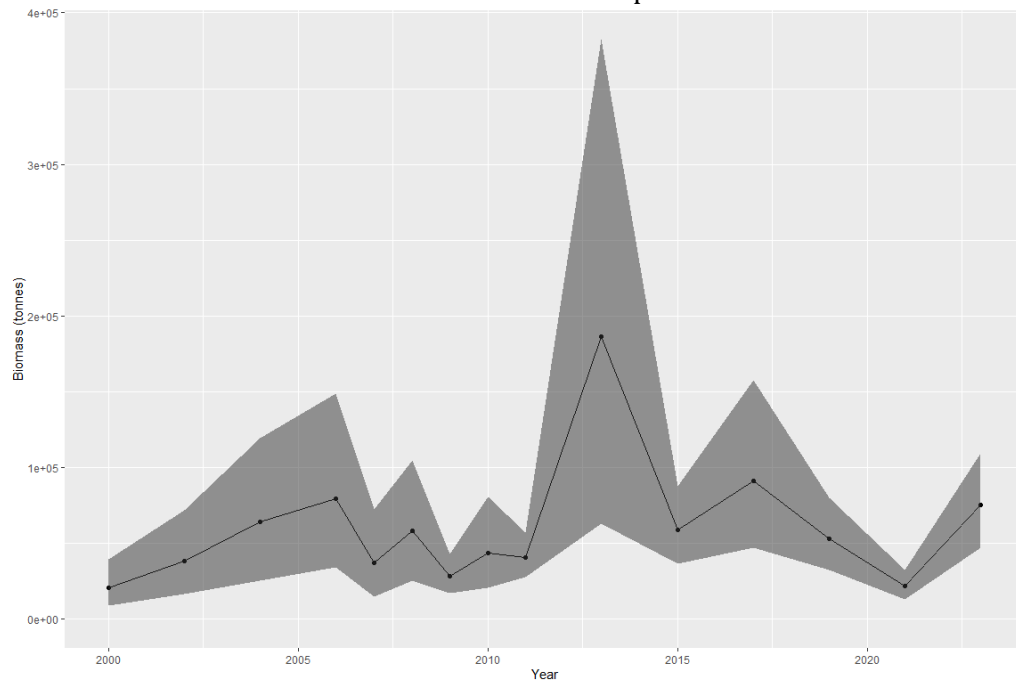
```



### Comparison to previous years

```
biomass.all <- rbind(biomass.prev, data.frame(X5=biomass["5%"], X50=biomass["50%"], X95=biomass["95%"], n=length(dat[[1]]), year=2000+as.numeric(surv), proj_1=NA, proj_2=NA, row.names="current"))
```

Median estimates of biomass with 5-95% bootstrap mean estimates shaded.



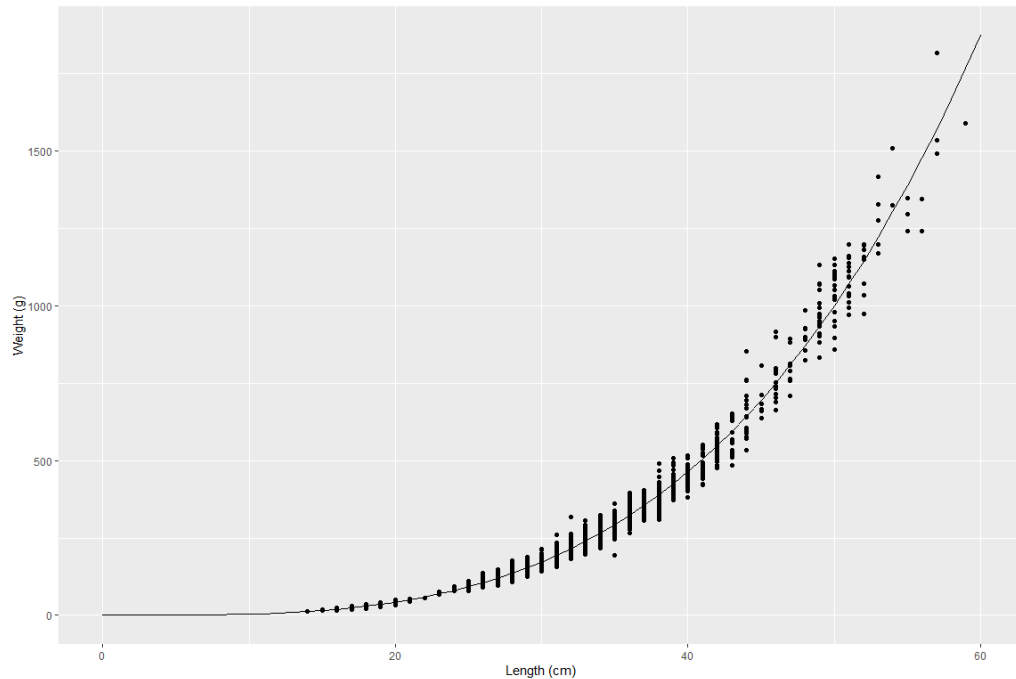
## Length Distribution

### Calculate length-weight parameters

```
#lw.data <- read.csv(file.path(path, "hist data", paste0("ani_lw_dataSG", surv, ".csv")), header=T)
lw.data <- read.csv(file.path(here('Data', "hist data", paste0("ani_lw_dataSG", surv, ".csv")), header=T)

lw.model <- nls(Weight.g. ~ a * Length.cm. ^b, data = lw.data, start=list(a=0.001, b=3))
lw.pred <- data.frame(Length.cm.=0:60)
lw.pred$Weight.g. <- predict(lw.model, lw.pred)

# weight-at-length (mm and kg) in mid-point of length partition
ggplot(lw.data, aes(x=Length.cm., y=Weight.g.)) + geom_point() +
  geom_line(aes(x=Length.cm., y=Weight.g.), lw.pred) + labs(x="Length (cm)", y="Weight (g)")
```



```
a <- coef(lw.model)[["a"]]
b <- coef(lw.model)[["b"]]
a
## [1] 0.001420627
b
## [1] 3.441844
wt1 <- predict(lw.model, list(Length.cm.=lbins+linc/2))
```

## Load data

### ###Length Data

```
#raw.data <- read.csv(file.path(path,"hist data",paste0("ani_ld_dataSG",surv, ".csv")),header=T)
raw.data <- read.csv(file.path(here('Data',"hist data",paste0("ani_ld_dataSG",surv, ".csv"))),header=T)
names(raw.data) <- c("Survcode", "EVENTNUM", "SECTOR", "CombinedStrata", "Water.Dep", "CM", "numbers_km2")
# strata (no depth stratification)

#a.df <- read.csv(file.path(path, "hist data","stratum_area.csv"),header=T)
a.df <- read.csv(file.path(here('Data',"hist data","stratum_area.csv")),header=T)
a.df <- aggregate(a.df$Area, list(Strata=a.df$Strata2), sum)
names(a.df)[2] <- "Area"
a.df$Nhaul <- sapply(a.df$Strata, function(x)length(unique(raw.data$EVENTNUM
```

```
UM[raw.data$SECTOR==x]))))
```

```
#see de La Mare and Williams WG-FSA-96/38
```

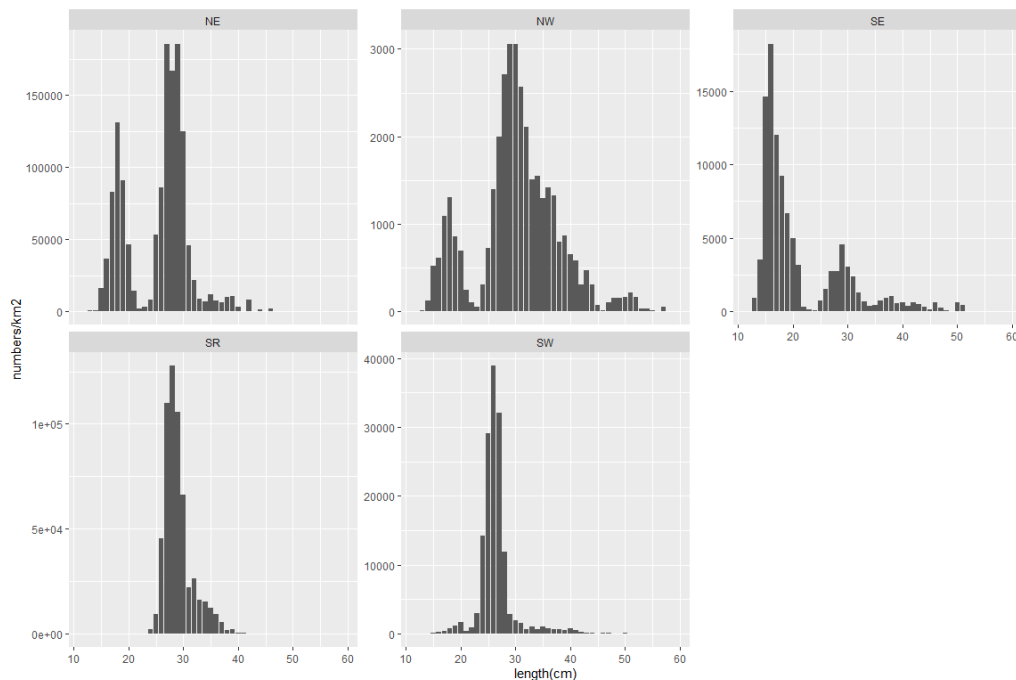
```
a.df$Weight <- a.df$Area / sum(a.df$Area) * (sum(a.df$Nhaul) / a.df$Nhaul)
```

Strata	Area	Nhaul	Weight
NE	6342	11	1.1663720
NW	5430	26	0.4225032
SE	10397	8	2.6291877
SR	3991	19	0.4249440
SW	10913	11	2.0070353

### Raw length Frequencies

```
ggplot(dat=raw.data, aes(x=CM, y=numbers_km2, group=SECTOR)) + geom_col() + facet_wrap(~SECTOR, scale="free_y") + labs(y="numbers/km2", x="length(cm)")
```

```
## Warning: Removed 5 rows containing missing values (`position_stack()`).
```



```
raw.data <- merge(raw.data, a.df[,c("Strata", "Weight")], all.x=TRUE, by.x="SECTOR", by.y="Strata")
```

```
raw.data$Weighted_n <- raw.data$numbers_km2 * raw.data$Weight
```

```
raw.data$lbin <- factor(linc*floor(raw.data$CM/linc), levels=lbins)
```

```
lfreq <- aggregate(raw.data$Weighted_n, list(lbin=raw.data$lbin), sum, drop=FALSE)
```

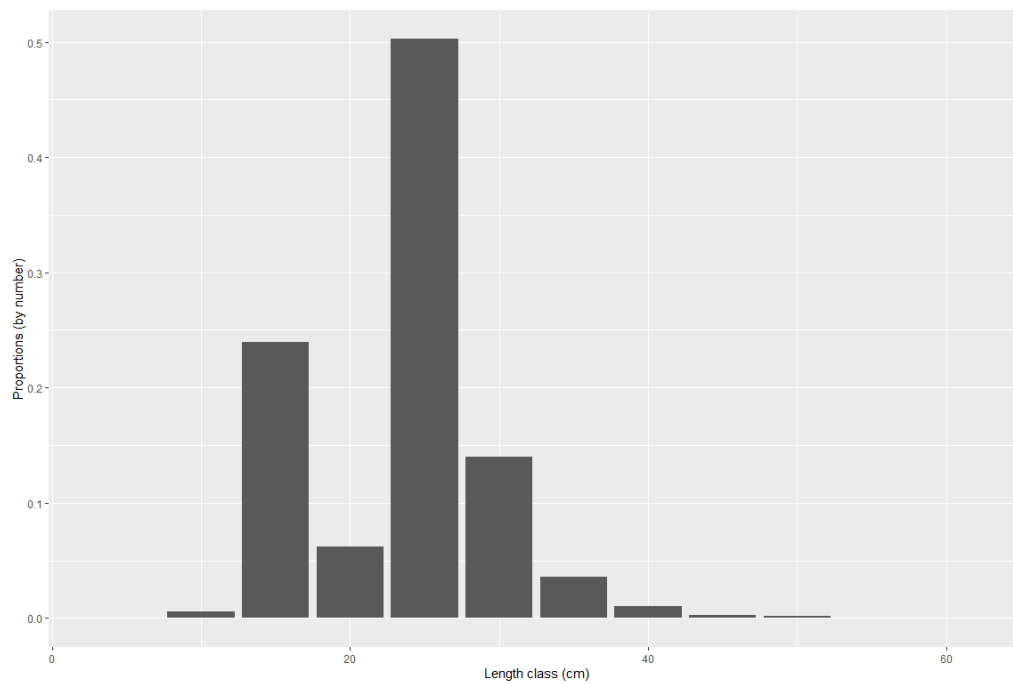
```

lfreq$x[is.na(lfreq$x)] <- 0
lfreq <- merge(data.frame(lbin=lbins), lfreq, all.x=TRUE)
lfreq$density <- lfreq$x/sum(lfreq$x, na.rm=TRUE)
lfreq$density[is.na(lfreq$density)] <- 0

lfreq$numbers <- lfreq$density * biomass["5%"] / sum(wt1*selsurv*lfreq$dens
ity,na.rm=T) * 10^6

```

lbin	x	density	numbers
5	0.000	0.0000000	0.00
10	13985.355	0.0057280	2089481.50
15	584525.404	0.2394052	87331000.27
20	151270.524	0.0619562	22600568.04
25	1226734.523	0.5024360	183280234.42
30	342042.633	0.1400910	51102869.31
35	86619.165	0.0354768	12941333.66
40	25896.137	0.0106063	3869011.49
45	6590.912	0.0026995	984715.06
50	3653.880	0.0014965	545907.85
55	255.295	0.0001046	38142.34
60	0.000	0.0000000	0.00



## Biomass Projection

### Parameters

```
Cpsurv <- TAC - catch_taken

# define fraction of a year after survey in which catch is taken
# (survey is 1-10 Feb and season starts 1st Dec)
TACtime <- 0.81

# natural mortality - pre-fishery/post-fishery division
Mtot <- 0.71
```

### Useful functions

```
# UTILITY CODE FOR 48.3 ICEFISH LENGTH BASED ASSESSMENT

#####
# Projection code #
#####
pop.proj <- function(Nsurv,Cpsurv,N,M,k,Linf,wtlen,sel,ftime,tmat1,tmat2,H) {

  # number of seasons and length-classes

  dm <- dim(N)
  dmn <- dimnames(N)
  n <- array(dim=dm)
  m <- array(dim=dm)
  wtl <- array(dim=dm)
  commsel <- array(dim=dm)
  TAC <- vector(length=2)

  # set up the initial population from the survey
  # (strip data from FLQuants)

  n[,1,1,1,1,1] <- Nsurv@.Data[,,,,,]
  m[] <- M@.Data[]
  wtl[] <- wtlen@.Data[]
  commsel[] <- sel@.Data[]

  # calculate post-survey harvest rates
  cat("\nH",H,"\n")
  cat("Initial biomass: ", sum(n[,1,1,1,1,1]*wtl[,1,1,1,1,1])/1e6, '\n')

  hpsurv <- n[,1,1,1,1,1]
  Hpsurv <- Cpsurv/sum(n[,1,1,1,1,1]*wtl[,1,1,1,1,1]*commsel[,1,1,1,1,1])
  for(l in 1:dm[1])
    hpsurv[l] <- commsel[l,1,1,1,1,1] * Hpsurv

  # adjust population size assuming the remaining catch from previous year is
```

```

taken
# instantaneous after survey

n[,1,1,1,1] <- n[,1,1,1,1] * (1 - hpsurv)
cat("Biomass at start of Year 1: ", sum(n[,1,1,1,1]*wtl[,1,1,1,1])/1e6,
'\n')

# given fixed harvest rate H we adjust population (via growth and M) to whe
n catch was taken
# then remove the relevant proportion of each length class

for(l in 1:dm[1])
  n[l,1,1,2,1,1] <- sum(n[,1,1,1,1,1]*exp(-m[,1,1,1,1,1])*tmat1[,1])

# calculate the catch taken from population at this time given the harvest
rate

TAC[1] <- sum(n[,1,1,2,1,1]*wtl[,1,1,2,1,1]*H*commsel[,1,1,2,1,1])

# THE SECOND YEAR

# adjust the population to 1 year after survey using growth and remaining M

for(l in 1:dm[1])
  n[l,2,1,1,1,1] <- sum(n[,1,1,2,1,1]*exp(-m[,1,1,2,1,1])*(1-H*commsel[,1,1
,2,1,1])*tmat2[,1])

  cat("Biomass at start of Year 2: ", sum(n[,2,1,1,1,1]*wtl[,1,1,1,1,1])/1e6,
'\n')
  # move the population forward to the time of fishing via M and growth

for(l in 1:dm[1])
  n[l,2,1,2,1,1] <- sum(n[,2,1,1,1,1]*exp(-m[,2,1,1,1,1])*tmat1[,1])

# calculate the catch taken from population at this time given the harvest
rate

TAC[2] <- sum(n[,2,1,2,1,1]*wtl[,2,1,2,1,1]*H*commsel[,2,1,2,1,1])

# calculate the numbers after the second TAC is taken
# with the extra M accounted for to complete the 2 year projection

nfin <- n[,1,1,1,1,1] * 0

for(l in 1:dm[1])
  nfin[l] <- sum(n[,2,1,2,1,1]*exp(-m[,2,1,2,1,1])*(1-H*commsel[,2,1,2,1,1]
)*tmat2[,1])

```

```

cat("Biomass at end of Year 2: ", sum(nfin*wtl[,1,1,1,1,1])/1e6, '\n')

TAC <- TAC/1e6 #kg to tonnes

return(list(N=nfin, harvest=H, TAC=TAC,
           B=c(sum(n[,2,1,1,1,1]*wtl[,1,1,1,1,1])/1e6, sum(nfin*wtl[,1,1,1,1,1])/1e6)))
}

#####
# TAC calculator #
# - Estimate 75% escapement after 2 year projection #
#####

tac.ani483 <- function(Nsurv,Cpsurv,N,M,k,Linf,wtlen,matlen,sel,ftime,H.min,
H.max,TAC.only=TRUE) {
  # calculate the transition matrices given the time at which the fishery will operate

  lbins2 <- vector(length=length(lbins)+1)
  del <- lbins[2]-lbins[1]
  lbins2[-c(length(lbins2))] <- lbins[]
  lbins2[length(lbins2)] <- lbins[length(lbins)]+del
  tmat1 <- tmat.calc(k,Linf,ftime,lbins2)
  tmat2 <- tmat.calc(k,Linf,1-ftime,lbins2)

  # call the projection code with zero catch

  stk.unfished <- pop.proj(Nsurv,Cpsurv,N,M,k,Linf,wtlen,sel,ftime,tmat1,tmat2,as.double(0))

  # extract final SSB values

  ssb.unfished <- as.vector(quantSums(stk.unfished[['N']][,]*wtlen[,2,,2,]*matlen[,2,,2,]))

  # define the objective function

  obj.fn <- function(x) {

    # call the projection code with zero catch

    stk.fished <- pop.proj(Nsurv,Cpsurv,N,M,k,Linf,wtlen,sel,ftime,tmat1,tmat2,x)
    ssb.fished <- as.vector(quantSums(stk.fished[['N']][,]*wtlen[,2,,2,]*matlen[,2,,2,]))

    # calculate the conditions for the HCR - probability that ssb.TAC < 0.75
    * ssbzer0TAC = 0.05
  }
}

```

```

    tmp <- ssb.fished-0.75*ssb.unfished
    cat(ssb.fished/1e6, '\n', ssb.unfished/1e6, '\n', ssb.fished/ssb.unfished,
        "\n\n")

    return(tmp)
  }

  # use uniroot to solve for the target harvest rate
  # (find H so that fished biomass is equal to 75% unfished biomass)
  Htarg <- uniroot(obj.fn, interval=c(H.min, H.max))[['root']]
  cat("Target exploitation rate: ", Htarg, "\n")

  # calculate TAC given target harvest rate

  if(!TAC.only) return(pop.proj(Nsurv, Cpsurv, N, M, k, Linf, wtlen, sel, ftime, tmat1
, tmat2, Htarg))
  #browser()
  TAC <- pop.proj(Nsurv, Cpsurv, N, M, k, Linf, wtlen, sel, ftime, tmat1, tmat2, Htarg)[
['TAC']]
  return(TAC)
}

#####
# Transition matrix calculator #
# - Hillary 2010 Biometrics #
#####

tmat.calc <- function(k, Linf, tau, lbins2) {
  # LVB growth increment

  lvbinc <- function(lrel, tau, k, Linf) {

    return(max((Linf-lrel)*(1-exp(-k*tau)), 0))
  }

  tmat <- matrix(nrow=length(lbins2)-1, ncol=length(lbins2)-1)

  for(i in 1:dim(tmat)[1]) {

    lx <- lbins2[i]
    ly <- lbins2[i+1]

    for(j in 1:dim(tmat)[2]) {

      llj <- lbins2[j]
      lu j <- lbins2[j+1]

```

```

lli <- lx + lvbinc(lx,tau,k,Linf)
lui <- ly + lvbinc(ly,tau,k,Linf)

# need to work out Lebesgue measure of intersection
# of image and actual length bin / length bin

if(lli > llj & lui < luj) {
  ptmp <- 1
} else {
  tmp <- c(max(llj,lli),min(luj,lui))
  mu <- ifelse(tmp[1] < tmp[2],tmp[2]-tmp[1],0)
  nu <- lui-lli
  ptmp <- mu/nu
}

tmat[i,j] <- ptmp
}
}

return(tmat)
}

```

## Setup structures

```

# set up the FLQuant for the initial survey length distribution
Nsurv <- FLQuant(quant='length',dim=c(length(lbins),1,1,1,1),units='numbers
')
dimnames(Nsurv)[['length']] <- as.character(lbins)
N <- FLQuant(quant='length',dim=c(length(lbins),2,1,2,1,1))
dimnames(N)[['length']] <- as.character(lbins)
# commercial selectivity
sel <- N
sel[] <- commsel

# weight-at-length
wtlen <- N
wtlen[] <- wtl

# maturity
matlen <- N
matlen[] <- matl

M <- N
M[,,,1,,] <- Mtot * TACtime
M[,,,2,,] <- Mtot * (1-TACtime)

```

## Run

```

H.min <- 0
H.max <- 0.9999

```

```

TAC_proj <- matrix(NA,2,1,TRUE,list(c("y1","y2"),surv))
ssbfwd <- TAC

NatL <- list()

##Read in catch data, Line up years, add NAs
y <- as.numeric(surv)
Nsurv[] <- lfreq$numbers
proj.results <- tac.ani483(Nsurv,Cpsurv*1e6,N,M,k,Linf,wtlen,matlen,sel,TAC
time,H.min,H.max,
                           TAC.only = FALSE)

##
## H 0
## Initial biomass: 47395.43
## Biomass at start of Year 1: 45687.43
## Biomass at start of Year 2: 37151.07
## Biomass at end of Year 2: 26702.69
##
## H 0
## Initial biomass: 47395.43
## Biomass at start of Year 1: 45687.43
## Biomass at start of Year 2: 37151.07
## Biomass at end of Year 2: 26702.69
## 26702.69
## 26702.69
## 1
##
##
## H 0.9999
## Initial biomass: 47395.43
## Biomass at start of Year 1: 45687.43
## Biomass at start of Year 2: 3423.521
## Biomass at end of Year 2: 153.5718
## 153.5718
## 26702.69
## 0.005751173
##
##
## H 0.251421
## Initial biomass: 47395.43
## Biomass at start of Year 1: 45687.43
## Biomass at start of Year 2: 28670.41
## Biomass at end of Year 2: 15642.06
## 15642.06
## 26702.69
## 0.5857859
##

```

```

##
## H 0.1517458
## Initial biomass: 47395.43
## Biomass at start of Year 1: 45687.43
## Biomass at start of Year 2: 32032.54
## Biomass at end of Year 2: 19674.57
## 19674.57
## 26702.69
## 0.7368012
##
##
## H 0.143471
## Initial biomass: 47395.43
## Biomass at start of Year 1: 45687.43
## Biomass at start of Year 2: 32311.66
## Biomass at end of Year 2: 20030.16
## 20030.16
## 26702.69
## 0.7501176
##
##
## H 0.1435441
## Initial biomass: 47395.43
## Biomass at start of Year 1: 45687.43
## Biomass at start of Year 2: 32309.19
## Biomass at end of Year 2: 20027
## 20027
## 26702.69
## 0.7499995
##
##
## H 0.1435441
## Initial biomass: 47395.43
## Biomass at start of Year 1: 45687.43
## Biomass at start of Year 2: 32309.19
## Biomass at end of Year 2: 20027
## 20027
## 26702.69
## 0.7499995
##
## Target exploitation rate: 0.1435441
##
## H 0.1435441
## Initial biomass: 47395.43
## Biomass at start of Year 1: 45687.43
## Biomass at start of Year 2: 32309.19
## Biomass at end of Year 2: 20027

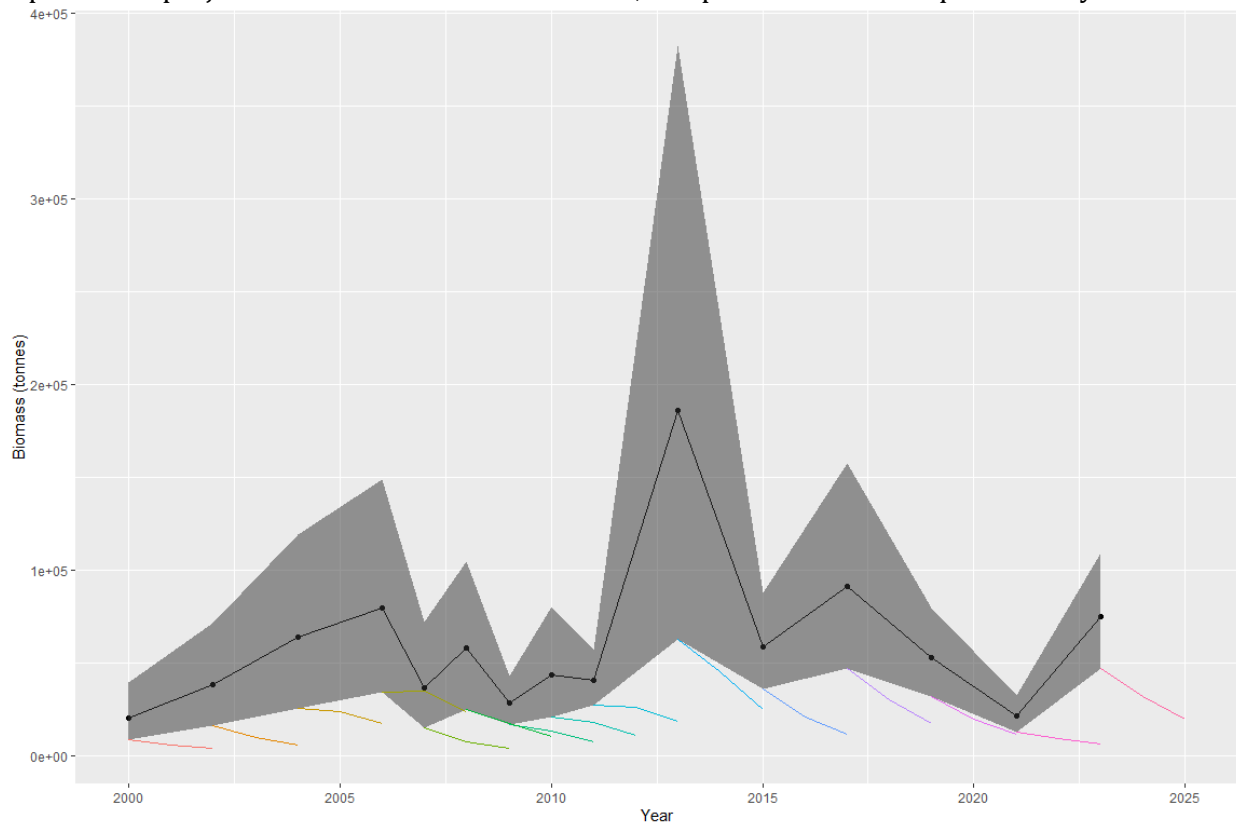
TAC_proj[,surv] <- proj.results$TAC
biomass.all["current",c("proj_1","proj_2")] <- proj.results$B

```

```
#write.csv(biomass.all, paste0(path, "/hist biomass 20",surv,".csv"), row.names = FALSE)
write.csv(biomass.all, paste0('Data', "/hist biomass 20",surv,".csv"), row.names = FALSE)
```

## Previous performance of assessment

A plot of the projections based on each assessment, compared to the subsequent survey.

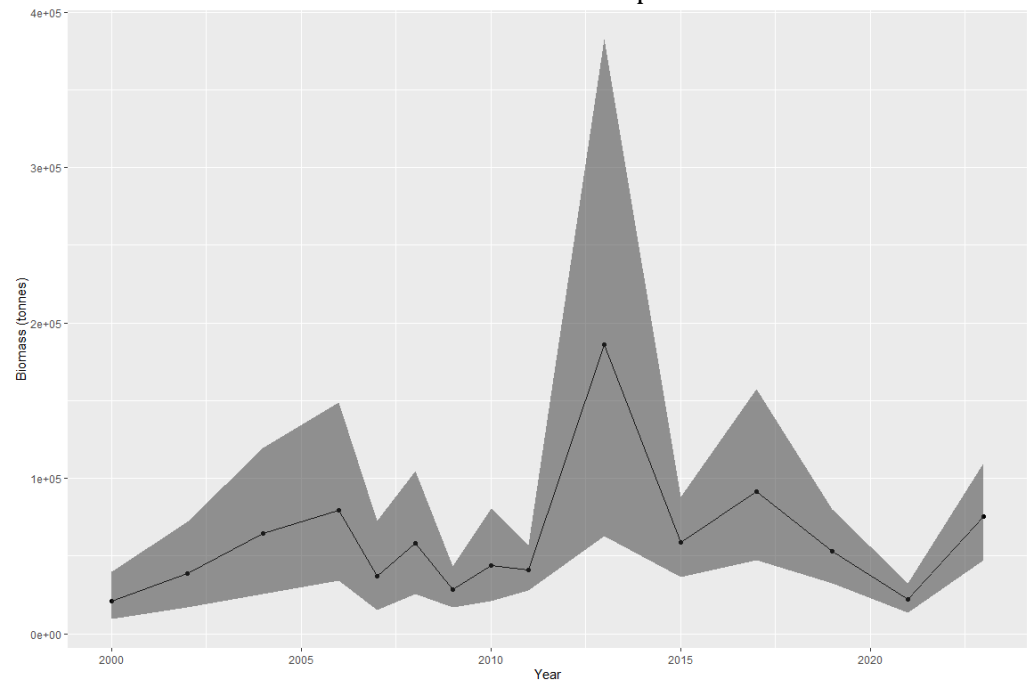


## Final answer

TAC\_proj

```
##          23
## y1 5137.900
## y2 3579.482
```

Median estimates of biomass with 5-95% bootstrap mean estimates shaded.



## **Additional Resources**

- Fishery Summary: [pdf](#), [html](#)
- Fishery Report: [pdf](#), [html](#)
- Species Description: [pdf](#), [html](#)
- Stock Annex: [pdf](#)
- [Fisheries Documents Browser](#)