Supplementary Material

The supplementary material includes a detailed description of the data sources, data compilation and standardization process (Supplementary Material (SM) Section 1). Sensitivity studies for the choice of bin size is presented in SM Section 2, sensitivity studies regarding the MA, maximum age and number of spawning events are shown in SM Section 3, and a sensitivity study regarding the ELEFAN\_GA model settings is shown in Section 4. We present the correlation between the Linf and K estimates for both species in SM Section 6. SM Section 7 includes a literature review of growth and natural mortality estimates of the two species. Lastly, we present preliminary results of growth and mortality estimates from other regions: Iceland and the Bay of Biscay (SM Section 8).

# Detailed data description and data cleaning

## Norwegian shelf and offshore areas

Length data of *M. muelleri* and *B. glaciale* in the Norwegian fjords, the Norwegian shelf and offshore areas were sampled by the Institute of Marine Research (IMR) during MEESO surveys and other ecosystem monitoring and project cruises. The dataset included a total of 283 hauls from 2008 to 2020, where samples were taken during different times of the year. All hauls were performed with non-graded macrozooplankton trawls with a 8 mm mesh size. Standard lengths (SL) in mm were recorded, and we did not include any hauls from fjords in our analyses.

## Data compilation, extraction and sorting

We removed one observation of *M. muelleri* of 5 mm, as it is unlikely an individual this size is retained by the net and it was significantly smaller than the second smallest observation (10 mm). From the *B. glaciale* observations we removed 50 observations from two hauls that were measured on a 10 mm accuracy instead of 1 mm or 5 mm accuracy. We only included samples in our analysis where 100 or more individuals were found. The length frequencies were raised according to raising factors provided. If information on raising factors was unavailable those data were removed. An overview of the final dataset with the total number fish measured in each year and month, the minimum and maximum observed length and the survey ID is shown in Table 1.

## Data overview

Table . Data overview of *Maurolicus muelleri* and *Benthosema glaciale*, with an overview of the total number fish measured in each year and month, the minimum and maximum observed length (standard length, SL) and the survey ID.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Month | No. of fish measured, and the raised number of fish in between brackets | Min. length (SL, mm) | Max. length (SL, mm) |
| *Maurolicus muelleri* | | | | |
| 2009 | 5 | 110 (122) | 27 | 50 |
| 2010 | 7 | 133 (1320) | 40 | 60 |
| 2011 | 5 | 193 (673) | 25 | 52 |
| 2011 | 8 | 321 (18604) | 10 | 53 |
| 2016 | 10 | 682 (43700) | 11 | 51 |
| 2020 | 3 | 585 (5235) | 18 | 66 |
| *Benthosema glaciale* | | | | |
| 2008 | 6 | 185 (223) | 20 | 67 |
| 2009 | 4 | 530 (2275) | 15 | 73 |
| 2009 | 5 | 535 (1456) | 16 | 73 |
| 2009 | 7 | 470 (925) | 22 | 70 |
| 2010 | 5 | 590 (2560) | 20 | 70 |
| 2010 | 7 | 504 (1539) | 20 | 73 |
| 2011 | 6 | 125 (264) | 20 | 70 |
| 2012 | 5 | 152 (275) | 18 | 72 |
| 2013 | 5 | 360 (638) | 18 | 73 |
| 2013 | 6 | 441 (1989) | 21 | 70 |
| 2014 | 5 | 185 (1182) | 17 | 66 |
| 2015 | 5 | 352 (858) | 15 | 73 |
| 2016 | 10 | 1573 (35899) | 13 | 73 |
| 2017 | 5 | 797 (930) | 15 | 73 |
| 2018 | 5 | 128 (685) | 20 | 72 |
| 2018 | 6 | 129 (1095) | 21 | 71 |

## Length distributions without restructuring

A group of graphs with numbers

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Figure . Length distributions of *Maurolicus muelleri*. In each panel the year and month are indicated in the top left box, the raised number of individuals is indicated in the top right box.

A screenshot of a graph

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Figure . Length distributions of *Benthosema glaciale*. In each panel the year and month are indicated in the top left box, the raised number of individuals is indicated in the top right box.

# Selection of bin size

## Maurolicus muelleri

A graph of the year

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Figure . The restructured length-frequency distributions of *Maurolicus muelleri* using a bin size of 2 mm.

A graph of different times

Description automatically generated with medium confidence

Figure . The restructured length-frequency distributions of *Maurolicus muelleri* using a bin size of 3 mm.

A graph of the year

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Figure . The restructured length-frequency distributions of *Maurolicus muelleri* using a bin size of 4 mm.

A graph of a graph of the year

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Figure . The restructured length-frequency distributions of *Maurolicus muelleri* using a bin size of 5 mm.

A graph of a number of months

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Figure . The restructured length-frequency distributions of *Maurolicus muelleri* using a bin size of 6 mm.

A graph of a graph of a number of years

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Figure . The restructured length-frequency distributions of *Maurolicus muelleri* using a bin size of 7 mm.

A graph of different times

Description automatically generated with medium confidence

Figure . The restructured length-frequency distributions of *Maurolicus muelleri* using a bin size of 8 mm.

A graph of different times

Description automatically generated with medium confidenceFigure . The restructured length-frequency distributions of *Maurolicus muelleri* using a bin size of 9 mm.

A graph of different times

Description automatically generated with medium confidence

Figure . The restructured length-frequency distributions of *Maurolicus muelleri* using a bin size of 10 mm.

## Benthosema glaciale

A graph of different numbers

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Figure . The restructured length-frequency distributions of *Benthosema glaciale* using a bin size of 2 mm.

A graph of the year

Description automatically generated with medium confidence

Figure . The restructured length-frequency distributions of *Benthosema glaciale* using a bin size of 3 mm.

A graph of different numbers

Description automatically generated with medium confidence

Figure . The restructured length-frequency distributions of *Benthosema glaciale* using a bin size of 4 mm.

A graph of different numbers

Description automatically generated with medium confidenceFigure . The restructured length-frequency distributions of *Benthosema glaciale* using a bin size of 5 mm.

A graph of different numbers and a number of years

Description automatically generated with medium confidence

Figure . The restructured length-frequency distributions of *Benthosema glaciale* using a bin size of 6 mm.

A graph of different numbers

Description automatically generated with medium confidenceFigure . The restructured length-frequency distributions of *Benthosema glaciale* using a bin size of 7 mm.

A graph of different numbers

Description automatically generated with medium confidenceFigure . The restructured length-frequency distributions of *Benthosema glaciale* using a bin size of 8 mm.

A graph of different numbers

Description automatically generated with medium confidence

Figure . The restructured length-frequency distributions of *Benthosema glaciale* using a bin size of 9 mm.

A graph of different numbers

Description automatically generated with medium confidence

Figure . The restructured length-frequency distributions of *Benthosema glaciale* using a bin size of 10 mm.

# Sensitivity of the model results to length frequency restructuring parameters and maximum age

For each species we performed a sensitivity study considering aggregation according to a bin size of 5, changing the MA to 3 or 7 and maximum ages that fall within the maximum age reported in literature (2 and 4 for *M. muelleri* and 6 and 10 for *B. glaciale*). For each species we present the estimated parameters and the growth model fits.

## *Maurolicus muelleri*

The sensitivity study showed very similar *Linf* estimates in all cases (57-58 mm) (Table 2. The results of the different sensitivity studies of model settings for *M. muelleri* compared to the selected model.). The estimated *K* was slightly lower with a bin size of 5 (1.11 year-1) and with a MA of 3 (0.81 year-1) compared to the selected model and other sensitivity studies, which ranged between 1.22-1.28 year-1. In the case of ta the MA of 3 also resulted in a lower estimate of 0.21, which corresponds to a spawning time in March. In the case of the model with two spawning events, the spawning is estimated in May and September. The reduced *K* estimates for a bin of 5 mm and MA of 3 are also reflected in the *Mempirical* estimates of 1.15 and 0.92 year-1, respectively, and in the *Mcatch curve, 2020* estimates of 1.35 and 0.91 year-1 *.* For the scenario with two spawning events the *Mempirical* estimates (1.1 year-1) were slightly lower compared to the selected model (1.51 year-1), while the *Mcatch curve, 2020* estimates were slightly higher (1.61 year-1). There were no clear differences between the estimates from the selected model, the MA of 7 and varying maximum ages.

Table . The results of the different sensitivity studies of model settings for *Maurolicus muelleri* compared to the selected model.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Selected model** | **Bin = 5** | **MA = 3** | **MA = 7** | **Max. age = 2** | **Max. age = 4** | **Two spawning events** |
| ***Linf* (mm)** | 57.98 (50.99 - 83.48) | 57.85 (36.45 - 85.82) | 57.15 (50.47 - 80.82) | 58.95 (52.29 - 80) | 58.07 (48.59 - 80.65) | 57.75 (49.32 - 82.57) | 58.85 (54 - 97.27) |
| ***K* (year-1)** | 1.28 (0.26 - 1.80) | 1.11 (0.26 - 1.97) | 0.81 (0.27 - 1.5) | 1.22 (0.29 - 1.64) | 1.26 (0.29 - 1.87) | 1.26 (0.29 - 1.92) | 1.28 (0.53 - 1.74) |
| ***ta*** | 0.33 (0.04 - 1.00) | 0.32 (0.01 - 0.95) | 0.21 (0.01 - 1) | 0.33 (0.01 - 0.98) | 0.33 (0 - 0.99) | 0.32 (0.00 - 0.99) | 1: 0.7 (0.2 - 0.96)  2: 0.36 (0.21 - 0.94) |
| *Mempirical* **(year-1)** | 1.29 (0.41 - 1.45) | 1.15 (0.43 - 1.66) | 0.92 (0.41 - 1.43) | 1.22 (0.45 - 1.42) | 1.27 (0.42 - 1.43) | 1.29 (0.42 - 1.44) | 1.1 (0.71 - 1.57) |
| *Mcatch curve, 2020* **(year-1)** | 1.51 (0.68 - 2.82) | 1.35 (0.81 - 2.2) | 0.91 (0.67 - 1.82) | 1.5 (0.77 - 1.79) | 1.5 (0.68 - 2.49) | 1.52 (0.76 - 2.70) | 1.61 (1.38 - 3.35) |
| ***L50*(mm)** | 19.69 (19.53 - 20.10) | 19.94 (19.58 - 20.41) | 19.9 (19.48 - 20.18) | 19.83 (19.48 - 20.08) | 19.74 (19.44 - 20.08) | 19.74 (19.44 - 20.10) | 19.87 (19.5 - 20.28) |
| ***L75*(mm)** | 20.30 (19.90 - 20.78) | 20.6 (20.05 - 21.22) | 20.56 (19.85 - 20.98) | 20.48 (19.9 - 20.88) | 20.37 (19.82 - 20.84) | 20.34 (19.78 - 20.85) | 20.49 (19.86 - 21.09) |

A graph of different times

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Figure . The length-frequency distributions of *Maurolicus muelleri* together with the growth curves from the maximum density estimate using a bin size of 5, as indicated by the orange lines.

A graph of different numbers

Description automatically generated with medium confidence

Figure . The length-frequency distributions of *Maurolicus muelleri* together with the growth curves from the maximum density estimate using a moving average of 3, as indicated by the orange lines.

A graph of different times

Description automatically generated with medium confidenceFigure . The length-frequency distributions of *Maurolicus muelleri* together with the growth curves from the maximum density estimate using a moving average of 7, as indicated by the orange lines.

A graph of different times

Description automatically generated with medium confidence

Figure . The length-frequency distributions of *Maurolicus muelleri* together with the growth curves from the maximum density estimate using a maximum age of 2, as indicated by the orange lines.

A graph of different numbers

Description automatically generated with medium confidence

Figure . The length-frequency distributions of *Maurolicus muelleri* together with the growth curves from the maximum density estimate using a maximum age of 4, as indicated by the orange lines.

A graph of different times

Description automatically generated with medium confidence

Figure . The length-frequency distributions of *Maurolicus muelleri* together with the growth curves from the maximum density estimate when allowing for two spawning events, as indicated by the orange lines.

## *Benthosema glaciale*

There were no significant differences between the parameter estimates from the different sensitivity studies (Table 3). The estimates of *Mempirical*  and *Mcatch curve, 2018* were slightly lower for a bin size of 5 mm.

Table . The results of the different sensitivity studies of model settings for *Benthosema glaciale* compared to the selected model.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Selected model** | **Bin = 5** | **MA = 3** | **MA = 7** | **Max. age = 6** | **Max. age = 10** |
| ***Linf* (mm)** | 78.93 (60.61­ - 108.71) | 79.19 (57.01 - 108.78) | 79.17 (71.18 - 104.65) | 80.51 (43.61 - 108.54) | 76.91 (56.64 - 107.21) | 79.7 (71.72 - 108.08) |
| ***K* (year-1)** | 0.41 (0.19 - 0.8) | 0.37 (0.18 - 0.8) | 0.4 (0.2 - 0.82) | 0.39 (0.19 - 1.6) | 0.43 (0.2 - 0.78) | 0.4 (0.19 - 0.65) |
| ***ta*** | 0.39 (0.01 - 1) | 0.23 (0.01 - 1) | 0.4 (0.06 - 0.99) | 0.37 (0.01 - 0.98) | 0.39 (0.03 - 0.99) | 0.38 (0.01 - 0.99) |
| ***Mempirical* (year-1)** | 0.5 (0.28 - 0.76) | 0.33 (0.27 - 0.87) | 0.5 (0.3 - 0.63) | 0.49 (0.28 - 0.76) | 0.52 (0.3 - 0.8) | 0.49 (0.28 - 0.64) |
| ***Mcatch curve, 2018*** **(year-1)** | 0.75 (0.28 - 1.76) | 0.66 (0.59 - 1.62) | 0.9 (0.64 - 1.29) | 0.88 (0.63 - 1.65) | 0.87 (0.61 - 1.04) | 0.89 (0.65 - 1.71) |
| ***L50*(mm)** | 23.67 (22.82 - 24.14) | 23.74 (22.75 - 24.19) | 23.69 (22.79 - 24.15) | 23.59 (22.82 - 24.19) | 23.07 (22.63 - 24.07) | 23.73 (22.83 - 24.16) |
| ***L75*(mm)** | 24.5 (23.43 - 25.62) | 24.49 (23.31 - 25.53) | 24.45 (23.45 - 25.36) | 24.39 (23.37 - 25.52) | 24.27 (23.2 - 25.27) | 24.49 (23.47 - 25.41) |

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Description automatically generated with medium confidence

Figure . The length-frequency distributions of *Benthosema glaciale* together with the growth curves from the maximum density estimate using a bin size of 5, as indicated by the orange lines.

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Description automatically generated with medium confidence

Figure . The length-frequency distributions of *Benthosema glaciale* together with the growth curves from the maximum density estimate using a moving average of 3, as indicated by the orange lines.

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Description automatically generated with medium confidence

Figure . The length-frequency distributions of *Benthosema glaciale* together with the growth curves from the maximum density estimate using a moving average of 7, as indicated by the orange lines.

A group of numbers and lines

Description automatically generated with medium confidence

Figure . The length-frequency distributions of *Benthosema glaciale* together with the growth curves from the maximum density estimate using a maximum age of 6, as indicated by the orange lines.

A group of numbers and lines

Description automatically generated with medium confidence

Figure . The length-frequency distributions of *Benthosema glaciale* together with the growth curves from the maximum density estimate using a maximum age of 10, as indicated by the orange lines.

# Sensitivity study of ELEFAN\_GA model settings

We performed a sensitivity study on the ELEFAN\_GA bootstrapping model settings to identify any influential model settings that should be selected carefully for the estimation of growth parameters for the species. None of the setting changed the distributions of the bootstrapped estimates for *M. muelleri* (Figure 32) and for *B. glaciale* (Figure 33). Therefore we used the default ELEFAN\_GA model settings for the parameter estimation.

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Figure . The results of the sensitivity study of the ELEFAN bootstrapping settings of *Maurolicus muelleri*.

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Figure . The results of the sensitivity study of the ELEFAN bootstrapping settings of *Benthosema glaciale*.

# Additional results

## Simplified ELEFAN\_GA model fits

For a simplified visualization we have added up all samples in the same months and different years. We then scaled all samples in each month to sum to 1. Those figures are easier to read but should be looked at with caution: they do not reflect the fitting procedure accurately and might suggest a poor fit to the length distributions. In these figures a single month where cohorts do not fit well to the growth curves has equal weight as multiple months where cohorts and growth curves align that were aggregated into a single month. Further, part of the information is lost by aggregating duplicate months: this is especially an issue for *B. glaciale*, where e.g. samples from 8 years are aggregated into one length distribution for May (Table 1 in main text).

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Figure . Simplified ELEFAN\_GA model fits for *Maurolicus muelleri.*

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Figure . Simplified ELEFAN\_GA model fits for *Benthosema glaciale*.

## Correlation between *Linf* and *K*

The parameters *Linf, K* and *t0* are strongly correlated (Jensen, 2011). For *M. muelleri* correlation plots between *Linf* and *K* shows two peaks: a primary peak at a combination of *Linf* = 57 mm and *K* = 1.3 year-1, and a secondary distribution of correlated estimates within a 50% confidence interval around an estimated *Linf* = 57 mm and *K* = 0.7-1.0 year-1.

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Figure 36. Response surface analysis plot of the estimates of *Linf* and *K* of *Maurolicus muelleri.*

Correlation plots between *Linf* and *K* of *B. glaciale* showed one main aggregation of *Linf* -*K* combinations with a slight negative relationship where increasing *Linf* estimates corresponded with lower K estimates (Figure 37).

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Figure 37. Response surface analysis plot of the estimates of *Linf* and *K* of *Benthosema glaciale.*

# Natural mortality

## *Maurolicus muelleri*

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Figure . The model fit of the catch curve estimated in each year for *Maurolicus muelleri.* The blue line indicates the maximum density estimate, the 95% confidence interval is indicated by the light blue area.

Table . Overview of the estimates of *Mcatch curve* for *Maurolicus muelleri* by year and for all year combined. The 95% confidence interval is indicated in between brackets.

|  |  |
| --- | --- |
| **Year** | ***Mcatch curve* (year-1)** |
| 2020 | 1.51 (0.68 - 2.82) |
| 2016 | 9.11 (4.02 - 15.21) |
| 2011 | 4.23 (1.85 - 6.89) |
| 2010 | 2.42 (0.43 - 4.87) |
| 2009 | 3.42 (1.97 - 15.85) |
| All years | 2.89 (1.25 - 4.66) |

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Figure . The estimated selectivity ogive and 95% confidence interval resulting from the bootstrapping of *Maurolicus muelleri* in 2020.

## *Benthosema glaciale*

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Figure . The model fit of the catch curve estimated in each year for *Benthosema glaciale.* The blue line indicates the maximum density estimate, the 95% confidence interval is indicated by the light blue area.

Table . Overview of the estimates of *Mcatch curve* for *Benthosema glaciale* by year and for all year combined. The 95% confidence interval is indicated in between brackets.

|  |  |
| --- | --- |
| **Year** | ***Mcatch curve* (year-1)** |
| 2008 | 0.89 (0.63 - 1.71) |
| 2009 | 0.97 (0.67 - 2.02) |
| 2010 | 0.99 (0.75 - 1.93) |
| 2011 | 0.52 (0.18 - 1.75) |
| 2012 | 1.13 (0.68 - 2.34) |
| 2013 | 0.78 (0.54 - 1.51) |
| 2014 | 0.57 (0.26 - 1.03) |
| 2015 | 0.5 (0.17 - 1.09) |
| 2016 | 1.44 (0.96 - 3.01) |
| 2017 | 1.39 (0.88 - 2.96) |
| 2018 | 0.75 (0.28 - 1.76) |
| All years | 1.01 (0.75 - 1.94) |

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Description automatically generated with medium confidence

Figure . The estimated selectivity ogive and 95% confidence interval resulting from the bootstrapping of *Benthosema glaciale* for all years combined.

# Tables with overview of literature review

Table . Growth parameters from literature of *Maurolicus muelleri* and *Benthosema glaciale*, organized according to sea region.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| (mm) | K (year-1) | t0 (year-1) | **Study area** | **Reference** |
| ***Maurolicus muelleri*** | | | | |
| Norwegian fjords, shelf and offshore areas | | | | |
| Male: 43.8, Female: 45.0 | Male: 0.88, Female: 1.52 | Male: -0.02, Female: 0.6 | Herdlefjorden, 1995 | (Kristoffersen, 2007) |
| Male: 44.8, Female: 50.6 | Male: 0.98, Female: 0.63 | Male: 0.16, Female: -0.57 | Herdlefjorden, 1996 | (Kristoffersen, 2007) |
| Male: 44.9 | Male: 1.27 | Male: 0.32 | Sognefjordem, 1995 | (Kristoffersen, 2007) |
| Male: 45.8 | Male: 1.47 | Male: 1.11 | Storfjorden, 1995 | (Kristoffersen, 2007) |
| Male: 46.2, Female: 51.5 | Male: 1.11, Female: 2.00 | Male: 0.34, Female: 0.83 | Storfjorden, 1996 | (Kristoffersen, 2007) |
| Male: 57.2, Female: 61.2 | Male: 1.24, Female: 1.45 | Male: 0.62, Female: 0.61 | Trondheimsfjorden, 1996 | (Kristoffersen, 2007) |
| Male: 56.3, Female: 56.4 | Male: 1.22, Female: 1.29 | Male: 0.47, Female: 0.40 | Norwegian Sea, 1996 | (Kristoffersen, 2007) |
| 48.8 | 1.05 | -0.21 | Fjords, 1974 | (Gjosaeter, 1981b) |
| 59.4 | 0.88 | 0.06 | Norwegian Sea, 1974 | (Gjosaeter, 1981b) |
| 57.1 | 0.94 | -0.14 | Fjord and open water samples combined, 1974 | (Gjosaeter, 1981b) |
| ***Benthosema glaciale*** | | | | |
| Norwegian fjords, shelf and offshore areas | | | | |
| 75 | 0.45 | 0.25 | Fjord system in the Bergen area off the west coast of Norway, 1969 | (Gjosaeter, 1973) |
| 70-87 | 0.19-0.46 | -0.64 | Fjords and open waters, 1973-1975 | (Gjosaeter, 1981a) |
| 70.04 | 0.45 | 0.03 | Herdlefjorden, 1993-1997 | (Kristoffersen and Salvanes, 2009) |
| 69.7 | 0.60 | 0.22 | Masfjorden, 1993-1997 | (Kristoffersen and Salvanes, 2009) |
| 64.8 | 0.38 | -1.13 | Sognefjorden, 1993-1997 | (Kristoffersen and Salvanes, 2009) |
| 106.2 | 0.18 | -0.26 | Norwegian Sea, 1993-1997 | (Kristoffersen and Salvanes, 2009) |
| Other regions | | | | |
| 62.28 | 0.36 | 0.49 | Central Nova Scotia, 1967-1969 | (Halliday, 1970) |
| 69.5-70.1 | 0.47 | -0.40 | Flemish Cap, 2008-2010 | (García-Seoane et al., 2014) |

Table . Mortality parameters from literature of *Maurolicus muelleri* and *Benthosema galciale*. The estimates from (Rasmussen and Giske, 1994) are length-based, all other estimates are age-based. (F) = Female, (M) = Male.

|  |  |  |
| --- | --- | --- |
| **M (year-1)** | **Study area** | **Reference** |
| ***Maurolicus muelleri*** | | |
| Norwegian fjords, shelf and offshore areas | | |
| 1.15 (M), 0.97 (F) | Fjords, 1995-1996 | (Kristoffersen and Salvanes, 1998) |
| 2.25 (M), 2.00 (F) | Norwegian Sea, 1996 | (Kristoffersen and Salvanes, 1998) |
| 0.84 | Masfjorden, 1990 | (Rasmussen and Giske, 1994) |
| 1.8 | Fjord and open water samples combined, 1974 | (Gjosaeter, 1981b) |
| ***Benthosema glaciale*** | | |
| Norwegian fjords, shelf and offshore areas | | |
| 0.52 | Fjord system in the Bergan area off the west coast of Norway, 1969 | (Gjosaeter, 1973) |
| 0.74 | Norwegian Fjords, below 100 m | (Gjosaeter, 1973; Froese and Pauly, 2023) |
| 0.7 | Fjord and open water samples combined, 1973-1975 | (Gjosaeter, 1981a) |
| 1.03 | Herdlefjorden, 1993-1997 | (Kristoffersen and Salvanes, 2009) |
| 0.99 | Masfjorden, 1993-1997 | (Kristoffersen and Salvanes, 2009) |
| 1.50 | Sognefjorden, 1993-1997 | (Kristoffersen and Salvanes, 2009) |
| 1.04 | Norwegian Sea, 1993-1997 | (Kristoffersen and Salvanes, 2009) |
| Other regions | | |
| 0.65 | Flemish Cap, 2008-2010 | (García-Seoane et al., 2014) |
| 1.75 | Central Nova Scotia, 1967-1969 | (Halliday, 1970; Froese and Pauly, 2023) |

# Preliminary estimation of growth and natural mortality of the two species in other regions

Apart from the data in the Norwegian Sea presented in this manuscript, length-frequency data of *M. muelleri* and *B. glaciale* has also been collected in other areas around the Northeast Atlantic Ocean, such as in the Bay of Biscay, Iceland and around the Irish coast. We, however, decided not to show those results in the main material of this manuscript due to insufficient coverage or quality of the data. The length-frequency data of *M. muelleri* in the Bay of Biscay was recorded with a 0.5 mm accuracy, which is too low for the small species under investigation, and often only showed one length peak, which is unsuitable for the fitting of an ELEFAN bootstrapping model. Whether the presence of one length peak indicates the absence of larger individuals or if it is due to the sampling is unknown. The length-frequency data of *M. muelleri* in Iceland is a result from one survey covering two months, and therefore the temporal coverage is insufficient to provide reliable results. The data for *B. glaciale* in Iceland covered multiple years but with different gear and mesh sizes, but the mesh sizes were much larger compared to the data from other regions which resulted in under-sampling of younger size classes.

Below we show the results and model fits of preliminary analyses of those other regional datasets. For those models we used the same model settings for each species as was presented in the methods section of the manuscript. By including those analyses we show that the model settings are suitable also in other regions. We setimated differences in life-history parameters in the different regions, but whether those differences are due to regional variability in population dynamics or due to differences in sampleing remains unknown. For such evaluation more data should be consistently collected in the other regions necessary for an accurate evaluation of the sustainability of the potential exploitation of *M. Muelleri* and *B. glaciale*.

## Data overview

A map of the world with different continents

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Figure . Overview of the additional regional data presented in this preliminary results section of (a) *Maurolicus muelleri* and (b) *Benthosema glaciale* in Iceland (yellow points) and the Bay of Biscay (blue points).

### Icelandic waters and Irminger Sea

The observations of *M. muelleri* around Iceland and in the Irminger Sea originated from one survey in 2010 (B3-2010), that was provided by the Marine and Freshwater Research Institute (MFRI). During the survey in 2010 biological samples were collected using a pelagic Tor-net trawl with 9 mm mesh size lining in the codend. The vertical opening ranged between 10 and 14.4 m. This trawl has a mechanism allowing for opening and closing to sample at three different depths in three different codends. From each codend the standard length (SL) was measured for at least 100 individuals on a 1 mm resolution. From those individuals 20 were weighted and otoliths were extracted to determine the ages. Length data were complemented with additional information on position, date-time, trawl duration, and weight and age information on selected samples.

The data from *B. glaciale* were collected during the redfish surveys in June-July from 2009 - 2020, covering the deeper areas southwest of Iceland. Graded trawls were used, with mesh sizes of 22, 23 and 40 mm stretched.

### Bay of Biscay

Length data of *M. muelleri* in the Bay of Biscay were measured during the period 2013-2020. Total length (TL) was measured from a random sample of 100 individuals per haul: from 2013 until 2017 length distributions were measured by 10 mm, and from 2018 until 2020 by 5 mm. Other data such as position of capture, date and time, sampler and bottom depth, were also provided. The data was collected during the JUVENA survey (Boyra et al. 2013), an acoustic survey designed for the assessment of the juvenile part of the anchovy population in the Bay of Biscay in late summer. Since the sampling scheme of the survey is designed to cover the entire occupation area of anchovy, the study area of *M. muelleri* was limited by the presence of those species.

All hauls were performed with a Gloria HOD 352 pelagic trawl with 15m of vertical opening and a 10 mm mesh size (bar length) at the codend. Fishing trawls were performed between 15 and 400 m depth at a mean speed of 4 knots. During 2018 experiments were done to test if different mesh size codends were able to efficiently capture the entire length distribution of *M. muelleri*. With the same model of pelagic trawl two different codends were used: one with a mesh of 10 mm, the other with a gradual mesh size from 8-2 mm. Differences in codend size did not significantly affect the size range of the caught fish (Sobradillo et al. 2019), however for consistency the hauls with a gradual mesh size from 8-2 mm were removed from our analyses.

## Data compilation, extraction and sorting

Lengths of *M. muelleri* were recorded as Total length (TL) or Standard length (SL); all samples were transformed to SL, calculated following the relationship described by (Goodson et al., 1995):

All samples of *B. glaciale* were measured in SL. We only included observations that were measured with a 1mm or 5 mm accuracy, and only included months in our analysis where 100 or more individuals were found. The length frequencies were raised according to raising factors provided by the data collectors. If information on raising factors was unavailable those data were removed. An overview of the data used for the analyses is shown below in Table 7.

Table . Data overview of *Maurolicus muelleri* and *Benthosema glaciale* according to the different regions, with an overview of the gear and mesh size used, the total number fish measured in each year and month, the minimum and maximum observed length (standard length, SL).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | **Gear** | **Mesh size** | **No. of fish measured, and the raised number of fish in between brackets** | **Min. length (SL, mm)** | **Max. length (SL, mm)** |
| ***M. muelleri*** | | | | | | |
| Icelandic waters and Irminger Sea | | | | | | |
| 2010 | 1 | Pelagic Tor-net trawl | 9 mm | 1458 (25007) | 19 | 66 |
| 2010 | 2 | Pelagic Tor-net trawl | 9 mm | 572 (9088) | 20 | 62 |
| Bay of Biscay | | | | | | |
| 2013 | 9 | Gloria HOD 352 pelagic trawl | 10 mm | 1091 (80663) | 12.964 | 72.674 |
| 2014 | 9 | Gloria HOD 352 pelagic trawl | 10 mm | 386 (49290) | 12.964 | 64.144 |
| 2015 | 8 | Gloria HOD 352 pelagic trawl | 10 mm | 102 (1148) | 21.494 | 47.084 |
| 2015 | 9 | Gloria HOD 352 pelagic trawl | 10 mm | 994 (86927) | 21.494 | 55.614 |
| 2016 | 9 | Gloria HOD 352 pelagic trawl | 10 mm | 860 (194949) | 12.964 | 64.144 |
| 2017 | 9 | Gloria HOD 352 pelagic trawl | 10 mm | 1267 (155669) | 21.494 | 81.204 |
| 2018 | 9 | Gloria HOD 352 pelagic trawl | 10 mm | 1711 (369612) | 15.097 | 53.482 |
| 2019 | 9 | Gloria HOD 352 pelagic trawl | 10 mm | 1853 (246176) | 15.097 | 74.807 |
| ***Benthosema glaciale*** | | | | | | |
| Icelandic waters and Irminger Sea | | | | | | |
| 2009 | 7 | Graded trawl | 23 mm | 1826 (38149) | 24 | 94 |
| 2009 | 6 | Graded trawl | 23 mm | 469 (10898) | 24 | 85 |
| 2011 | 7 | Graded trawl | 22 mm | 621 (28624) | 30 | 80 |
| 2011 | 6 | Graded trawl | 22 mm | 573 (20331) | 25 | 90 |
| 2013 | 7 | Graded trawl | 22 mm | 205 (6435) | 27 | 72 |
| 2013 | 6 | Graded trawl | 22 mm | 1472 (49031) | 25 | 80 |
| 2015 | 6 | Graded trawl | 22 mm | 1692 (50618) | 30 | 90 |
| 2020 | 7 | Graded trawl | 40 mm | 227 (1374) | 38 | 85 |

## Preliminary results

### *M. muelleri* in Iceland

A graph with numbers and a line

Description automatically generated with medium confidence

Figure . The von Bertalanffy growth curves of *Maurolicus muelleri* in Iceland fitted to the length-frequency data.

Table . Overview of the growth, mortality and selectivity estimates of *Maurolicus Muelleri* in Iceland. The table shows for each parameter the maximum density estimate (MDE), indicating the maximum of the parameter distributions resulting from the bootstrapping, and the lower and upper bound of the 95% CI in between parenthesis.

|  |  |
| --- | --- |
| **Parameter** | **Estimate** |
| **Linf (mm)** | 56.39 (53.35 - 98.43) |
| **K (year-1)** | 1.41 (0.33 - 1.93) |
| **ta** | 0.47 (0.01 - 0.99) |
| *Mempirical* **(year-1)** | 1.4 (0.45 - 1.58) |
| *Mcatch curve* **(year-1)** | 1.72 (1.39 - 2.6) |
| **Gear selection L50 (mm) parameter** | 23.29 (23.18 - 29.34) |
| **Gear selection L75 (mm) parameter** | 24.49 (24.32 - 31.33) |

### *M. muelleri* in the Bay of Biscay

A group of graphs with numbers

Description automatically generated

Figure . The von Bertalanffy growth curves of *Maurolicus muelleri* in the Bay of Biscay fitted to the length-frequency data.

Table . Overview of the growth, mortality and selectivity estimates of *Maurolicus Muelleri* in the Bay of Biscay. The table shows for each parameter the maximum density estimate (MDE), indicating the maximum of the parameter distributions resulting from the bootstrapping, and the lower and upper bound of the 95% CI in between parenthesis.

|  |  |
| --- | --- |
| **Parameter** | **Estimate** |
| **Linf (mm)** | 51.63 (41.6 – 108.36) |
| **K (year-1)** | 0.48 (0.15 - 1.26) |
| **ta** | 0.65 (0.16 - 0.91) |
| *Mempirical* **(year-1)** | 0.8 (0.4 - 1.36) |
| *Mcatch curve, 2019* **(year-1)** | 1.02 **(**0.62 - 3.1) |
| **L50 (mm)** | 18.259 18.002 31.363 |
| **L75 (mm)** | 20.919 20.528 34.514 |

### *B. glaciale* in Iceland

A graph of different numbers

Description automatically generated with medium confidence

Figure . The von Bertalanffy growth curves of *Benthosema glaciale* in Iceland fitted to the length-frequency data.

Table . Overview of the growth, mortality and selectivity estimates of *Benthosema glaciale* in Iceland. The table shows for each parameter the maximum density estimate (MDE), indicating the maximum of the parameter distributions resulting from the bootstrapping, and the lower and upper bound of the 95% CI in between parenthesis.

|  |  |
| --- | --- |
| **Parameter** | **Estimate** |
| **Linf (mm)** | 61.5 (54.13 - 90.91) |
| **K (year-1)** | 1.12 (0.44 - 1.86) |
| **ta** | 0.41 (0.06 - 0.62) |
| *Mempirical* **(year-1)** | 1.47 (0.52 - 1.6) |
| *Mcatch curve, 2011* **(year-1)** | 1.52 (1.23 - 2.65) |
| **L50 (mm)** | 39.478 (39.173 - 41.08) |
| **L75 (mm)** | 41.105 (40.765 - 42.79) |

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