# 9 Northeast Arctic anglerfish

anf.27.1-2 – *Lophius budegassa, Lophius piscatorius* in subareas 1 and 2

## 9.1 General

Our present knowledge of anglerfish (*Lophius* spp.) in ICES subareas 1 and 2 is based on two masters' theses (Staalesen, 1995; Dyb, 2003), a report from a Nordic project (Thangstad *et al*., 2006), working documents to the ICES ASC, WGNSDS, and WGCSE, and more recent catch data collected by the Norwegian Reference Fleet since 2006 (Anon., 2013; Clegg and Williams, 2021). In February 2018, anglerfish in ICES subareas 1 and 2 was subject to a benchmark assessment (WKANGLER 2018). After this benchmark assessment, it was determined that this stock (or rather a stock component and a management unit) should be considered a category 3 stock, for which survey or other indices (e.g. total mortality, recruitment, abundance) that provide reliable indications on stock trends are available.

### 9.1.1 Species composition

Two European anglerfish species of the genus *Lophius* are distributed in the Northeast Atlantic: white (or white-bellied) anglerfish (*Lophius piscatorius*) and black (or black-bellied) anglerfish (*Lophius budegassa). L. budegassa* are rarely caught in Nordic waters. In Norwegian waters, 1 out of about 2600 anglerfish landed from the Møre coast north of 62°N (2.a) and 1 out of about 1000 from the North Sea were *L. budegassa* back in 2003 (Dyb, 2003; K. Nedreaas, pers. comm.). In the most recent period (2014–2021), the ratio of *L. budegassa* in Norwegian waters has been up to 1 out of 200 anglerfish for some years, but usually about 1 out of 1000.

### 9.1.2 Stock description and management units

The WGNSDS (Northern Shelf Demersal Stocks) considered the stock structure on a wider European scale in 2004, and found no conclusive evidence to indicate an extension of the stock area northwards to include Division 2.a. Anglerfish in 2.a have therefore been treated and described separately by the ICES Celtic Sea Ecoregion Working Group (WGCSE) who is now assessing the anglerfish in the neighbouring areas. Currently, anglerfish on the Northern Shelf are split into Subarea 6 (including 5.b (EC), 12 and 14) and the North Sea (and 2.a (EC)) for management purposes. However, genetic studies have found no evidence of separate stocks over these two regions (including Rockall) and particle-tracking studies have indicated interchange of larvae between the two areas and further towards ICES divisions 2.a, 5.a, and 5.b (Hislop *et al*., 2001). In fact, both microsatellite DNA analysis (O'Sullivan *et al*., 2006) and particle tracking studies carried out as part of EC 98/096 also suggested that anglerfish from further south (Subarea 7) could also be part of the same stock. Hislop *et al.* (2001) simulated the dispersal of *Lophius* eggs and larvae using a particle tracking model. Their results also showed the likelihood that *Lophius* around Iceland (Solmundsson *et al*., 2007), Faroe Islands (Ofstad, 2013) and Norwegian waters north of 62°N (i.e. subareas 1 and 2) were recruited from the area west of Scotland including Rockall. This finding was further supported by research survey data as a migration east-/north-eastwards with size was seen in the International Bottom Trawl Survey (IBTS) and other survey data (e.g. Dyb, 2003).

Results from the use of otolith shape analysis in stock identification of anglerfish (*L. piscatorius*) in the Northeast Atlantic (Cañás *et al.*, 2012) and previous references on *L. piscatorius* stock identification found no biological evidence to support the current separation of *Lophius* stocks in the Northeast Atlantic, but found substructures within the area.

Tagging studies neither revealed any advice on stock structure. Anglerfish were tagged during two IBTS surveys in the North Sea and five one-day trips using a small (15 m) Danish seiner off the Norwegian coast at around 62°40'N (Møre; Thangstad *et al.*, 2006; Otte Bjelland, IMR-Norway, pers. comm.). A total of 872 individuals were tagged with conventional Floy dart type tags, 123 in the North Sea (25–78 cm) and 749 at Møre (30–102 cm). Some of this is further described in Thangstad *et al*. (2006). The 2019 AFWG report showed the tagging locations and the hitherto recaptures and suggested that there were migrations in all directions, i.e. anglerfish were recaptured in the southern North Sea, around Shetland/Faroes, up to Lofoten. Most of the recaptures happened at Møre, where most of the fish were also tagged. Additionally, in 2000–2001, a total of 1768 trawl-caught *L. piscatorius* was tagged using conventional dart tags and released on inshore fishing grounds at Shetland (Laurenson *et al*., 2005). Anglerfish between 25 and 83 cm total length were tagged. The overall recapture rate was 4.5% and times at liberty ranged from 5 to 1078 days. After Laurenson *et al.* (2005), Dr Laurenson reported to www.fishupdate.com a 104 cm anglerfish caught off the Norwegian coast near Ålesund in 2006. The fish had been tagged and released in the Scalloway Deeps on 13 September 2000 when it was 45 cm long and had hence been at liberty for five years and nine months. This observation is of particular importance as it may indicate a wider mixing of stocks and validate the growth rate of anglerfish over several years.

In light of all these observations, WKANGLER (2018) considered that most recruitment in subareas 1 and 2 is from the more southerly stock unit, and this would require further R&D work in collaboration with ICES 3.a, 4, and 6 looking at egg and larval dispersion and transportation as well as tagging and genetic studies. To address stock structure, mixing rates, and growth estimates, WKANGLER (2018) recommended a tagging program coordinated between all countries harvesting *Lophius* and to align tagging methods, measurement protocols and outreach to industry. The WK further recommended a shared site for *Lophius* tagging data and other applicable research projects concerning *Lophius*. Until the true biological stock structure is better understood, WKANGLER (2018) recommends keeping the anglerfish in subareas 1 and 2 as a separate management unit for the time being.

### 9.1.3 Biology

Sex ratios in Subarea 2 show that females outnumber males (> 50%) above approximately 75 cm, and above 100 cm all fish were females (Thangstad *et al.*, 2006). This is very similar to the sex ratios reported from distant Portuguese and Spanish waters (Duarte *et al.*, 1997) and hence supports a sex growth difference independent of latitude.

Spawning has been documented to occur in ICES Division 2.a in spring, but the present abundance of anglerfish in subareas 1 and 2 seems to be dependent on the influx or migration of juveniles from ICES subareas 4 and 6. Estimates of GSI (gonad-somatic index) for females in Division 2.a indicate that ovaries develop from January to June. The highest values of GSI were found in June when some of the ovaries were 20–30% of the round weight. Only females bigger than 90 cm had elevated GSI values indicating developing or developed ovaries. Dyb (2003) found that the length at which 50% of the females were mature ($L_{50}$) was between 60–65 cm and that all females above 80 cm were mature.

Some age readings exist for anglerfish in Division 2.a, and comparative analyses of different structures, preparations and methods used for age readings were done by Staalesen (1995) and Dyb (2003). The Norwegian Institute of Marine Research adopted the ICES age reading criteria using the first dorsal fin ray (*illicium*) as its routine method, but few fish have been aged since the above-mentioned projects. The material collected and read was, however, considered sufficient for preliminary yield-per-recruit estimations (ICES, 2019). As a very simplified 'rule of thumb' one may divide the fish length by 10 get an approximate age, i.e. a fish of 100 cm is approximately 10 years old and 13 kg while a fish of 70 cm is about 7 years old and 7 kg.

Exploitation using gillnets with 300 mm mesh size will select for males and females in a more equal ratio than 360 mm gillnets (Dyb, 2003). However, a change to lower mesh size will, without additional regulations, not decrease the effort, but rather increase it, at least towards younger fish. A mesh size of 300 mm will catch more anglerfish down to 50 cm, i.e. more immature fish. Preliminary analyses have also shown that the maximum yield-per-recruit will be 22% less using 300 mm instead of 360 mm gillnets (Staalesen, 1995). A possible sudden increase in catch rates when going from 360 mm to 300 mm would therefore be of short duration. A mesh size of 360 mm is also more in line with the minimum legal catch size of 60 cm, the length at first maturity of females and the utilization of the species' (especially the females') growth potential.

Some basic biological input parameters for the current assessment approaches are shown in Table 9.3. Some of these are further described in WKANGLER (2018).

### 9.1.4 Fishery

In autumn 1992 a direct gillnet fishery for anglerfish (*L. piscatorius*) started on the continental shelf in ICES Division 2.a off the northwest coast of Norway (Norwegian statistical area 07; Figure 9.1). The anglerfish had previously only been taken as bycatch in trawls and gillnets. Until 2010–2011 there was a geographical expansion of the fishery which was largely due to a northward expansion of the Norwegian gillnet fishery (Figure 9.2). It is not known to what extent this northwards expansion of the fishing area is caused by an expansion of favourable environmental conditions for the anglerfish or the fishers discovering new anglerfish grounds.

Near Iceland, Solmundsson *et al.* (2007) concluded that changes in the distribution of anglerfish and increased stock size have co-occurred with rising water temperatures that have expanded suitable grounds for the species. Another observed feature of the fisheries is that regional peaks in the landings of anglerfish representing northward migration become visible after multiple years of data collection (Figure 9.2). The recent increase in landings first happened along the coast of western Norway but during the last year landings expanded to all subareas north of 62°N as well.

Norway is by far the largest exploiter of the anglerfish in subareas 1 and 2 accounting for 96–99% of the official landings (Table 9.1). The coastal gillnetting accounts for more than 90% of the landings (Table 9.2). The landings of anglerfish in subareas 1 and 2 have been about 1/4–1/3 of the total landings from the other Northern Shelf areas (3.a, 4, and 6), but was in 2017 only 7% of the total landings in these areas.

No TAC is given for subareas 1 and 2 of Norwegian waters. Catches of anglerfish in Division 2.a of the former European Union (EC) waters, now UK waters, are taken as a part of the combined EC/UK anglerfish quota for ICES areas 3, 4, and 6, or as part of the Norwegian 'others' quota in EC/UK waters. The Norwegian fishery is regulated through:

- A discard ban on anglerfish regardless of size.
- A prohibition against targeting anglerfish with other fishing gear than 360 mm (stretched mesh) gillnets.
- A minimum catch size of 60 cm in all gillnet fisheries, and maximum permission of 5% anglerfish (in numbers) below 60 cm when fishing with gillnets.
- 72 hours maximum soak time in the gillnet fishery.
- A maximum of 500 gillnets (each net being maximum 27.5 m long) per vessel.

- Closure of the gillnet fishery from 1 March to 20 May. This closure period was expanded to 20 December–20 May in the areas north of 65°N in 2008 and further expanded southwards to 64°N since 2009.
- A maximum of 15% bycatch (in weight) of anglerfish in the trawl- and Danish seine fisheries, and maximum 10% bycatch (in weight) of anglerfish in the shrimp trawl fishery. When fishing for argentines and Norway pout/sandeel a maximum of 0.5% bycatch is allowed within a maximum limit of 500 kg anglerfish per trip.
- A maximum of 5% bycatch (in weight) of anglerfish is allowed to be caught in gillnets targeting other species.

### 9.1.5 Scientific surveys

Anglerfish appear in demersal trawl surveys along the Norwegian shelf, but in very small numbers. The survey design has changed from single species to multispecies during recent years. The procedures for data collection on anglerfish have varied and, at present, no time-series from surveys in Division 2.a yields reliable information on the abundance of anglerfish. On the other hand, surveys in the North Sea and especially the SIAMISS (Scottish Irish Anglerfish Megrim Industry Science Survey; Figure 9.3), seem to be predictive for the recruitment of anglerfish to the ICES subareas 1 and 2 (Northeast Arctic). This is seen with the likely development of the large 2012 year class in the SIAMISS survey (Figure 9.4), which is corroborated with a subsequent decrease in mean catch length in Division 2.a in 2017 and an increase in fishing effort at the same time.

The SIAMISS is a dedicated anglerfish survey (see ICES 2021). It covers much of the known distribution of the northern shelf anglerfish (ICES divisions 4.a, 6.a and 6.b), with the exception of the central and southern parts of Subarea 4 and the Skagerrak and Kattegat (Division 3.a). The survey began in 2005 and has more or less been carried out on an annual basis (usually in spring, but sometimes in November). The total biomass estimate for the Northern Shelf in 2021, the most recent survey year was 48 355 t, a decrease of 19% compared to 2019, and the lowest value since 2013. A large proportion of total population numbers consisted of individuals <30 cm in 2021, suggesting reasonably strong recruitment (ICES 2021).

In Subarea 4, the International Bottom Trawl Surveys in the North Sea (indices NS-IBTS-Q1 and Q3) show declining mean weights per hour for the recent five years (now back to the level before 2014) across all length groupings (ICES 2021). The IBTS surveys are currently not used in the assessment of anglerfish in ICES subareas 4 and 6, and in Division 3.a.

## 9.2 Data

### 9.2.1 Landings data

The official landings as reported to ICES for subareas 1 and 2 for each country are shown in Table 9.1. Landings decreased rapidly from 2010 to 2015, to the lowest since 1997, but has since shown an increase until last year. It is worth noting that the recent increase in landings first happened along the coast of western Norway, and then in the following years also subsequently further north in ICES Subarea 2. And likewise, the decrease seen in 2021 happened first in the south, i.e. both along the coast of western Norway and in the southern part of ICES Subarea 2 while the northern areas still showed an increase. Norway has by far the largest reported catches of the anglerfish in subareas 1 and 2, accounting for 96–99% of the official international landings. The coastal gillnetting accounts for more than 90% of the landings, of which about 90% are caught by the special designed large-meshed gillnets (360 mm stretched meshes; Table 9.2).

The Norwegian coastal reference fleet (see Appendix figure and table H1) provide length measurements and catch per gillnet days from ICES subareas through 4, from 2007–present and these have been presented for the AFWG in recent years. The catch rates vary spatially and temporally, and the WKANGLER (2018) therefore recommended to model and standardize the catch rates to better represent the general abundance trend of anglerfish in the entire ICES Subarea 2. The available material is shown in Tables 9.4 and 9.5 for the Norwegian statistical coastal areas (Figure 9.1) and total for ICES subareas 1 and 2.

### 9.2.2 Discards

The absence of a TAC in Norwegian waters probably reduces the incentive to underreport landings. Anecdotal evidence from the industry, observer trips and data from the self-sampling fleet (the Norwegian reference fleet; Anon. 2013; Clegg and Williams 2021) suggest that up to 8–9% of the catch (not marketable) is discarded. This happens when the soaking time is too long, mostly due to bad weather. The average percentage of discarded anglerfish was higher south of 62°N (ICES 3 and 4) than north of 62°N (ICES 2.a). Average length of discarded anglerfish was on average only 6–7 cm smaller than the landed anglerfish. This is also confirmed by Berg and Nedreaas (2021) who estimated the annual discards of anglerfish by the Coastal reference fleet in subareas 1 and 2 to vary between 11 and 32 tonnes during 2014–2018 (i.e. 1.5–2.5% of total gillnet catch) but went up to 178 tonnes (7.2%) in 2012.

### 9.2.3 Length composition data

Length distributions are available from the directed gillnet fishery during the period 1992–2022, but data are lacking for 1997–2001 (Table 9.3). The length data indicates a drop in mean length of 15–20 cm occurring during the period without length samples (Figure 9.5). Since then, the mean length increased steadily during the last decade to about 95 cm (about 10 years old and 12 kg) in 2014–2016, i.e. the same size level as seen during the 1990s. One-third of the anglerfish measured during the 1990s were above 100 cm, this proportion was between 1–6% for the early 2000s, 12–17% in 2006–2013 and 15% in 2021. This indicates strong recruitment into Subarea 2 during 1997–2001, which has not been observed again until 2017–2019 when a new drop in mean length is seen, again indicating some recruitment of smaller sized anglerfish to the area (ref. Figure 9.4).

Length distributions of retained anglerfish (*L. piscatorius*) caught by the reference fleet as target species during 2007–2021 by the specially designed-large-meshed gillnets, and as bycatch in other gillnets or other gears are shown in Appendix figures H3-H5. All subsequent analyses (in the methods and results section) have only used the length distributions from the target fishery since 2007 using the large-meshed gillnets which represent more than 80% of the international landings in subareas 1 and 2.

### 9.2.4 Catch per unit effort (CPUE) data

The Norwegian coastal reference fleet (see Appendix figure and table H1) has reported catch per gillnet soaking time (CPUE) from their daily catch operations. For the current modelling and hence standardization of the annual CPUE from subareas 1 and 2, we have used the following data:

- Only catch rates of retained anglerfish from the fishery using special large-meshed anglerfish gillnets (stretched meshes = 360 mm).
- Years 2007–2022.
- Discards excluded.

- Adding zero catches where gillnets are used, but anglerfish not present.
- All coastal areas (i.e. ICES 3.a, 4.a, 2.a, and 1) included in the model since it is documented (e.g. WKANGLER 2018) that anglerfish are migrating across the ICES area borders.
- The area ($km^2$) of each subarea inside 12 nautical miles (covering most of the anglerfish distribution) is calculated and used as weighing factor when annual CPUEs are estimated for each subarea (Figure 9.6).

# 9.3 Methods and results

## 9.3.1 The length-based-spawning-potential-ratio (LBSPR) approach

The LBSPR method has been developed for data-limited fisheries, where only a few data are available: some representative sample of the size structure of the vulnerable portion of the population (i.e. the catch) and an understanding of the life history of the species (Hordyk *et al*., 2016). The LBSPR method does not require knowledge of the natural mortality rate (M) but instead uses the ratio of natural mortality and the von Bertalanffy growth coefficient (K; M/K), which is believed to vary less across stocks and species than M (Prince *et al*., 2015) although individual estimates of M and K can be used if available. Like any assessment method, the LBSPR model relies on a number of simplifying assumptions. In particular, the model is equilibrium-based, assumes that the length composition data are representative of the exploited population at steady state, and logistic selectivity (see the results section below for more discussion).

The LBSPR model originally developed by Hordyk *et al*. (2015a; 2015b) used a conventional age-structured equilibrium population model and a size-based selectivity. As a consequence, this approach could not account for "Lee's phenomenon"—the fact that larger specimens-at-age experience greater mortality than its cohort of smaller size because of the size-based selectivity. This is because the age-structured model has a 'regeneration assumption' i.e. it redistributes at each time-step the length-at-age using the same distribution. Hordyk *et al*. (2016) since developed a length-structured version of the LBSPR model that used growth-type-groups (GTG) to account for the above phenomenon and showed that the new approach reduced bias related to the "Lee's phenomenon"[1]. GTG LBSPR is therefore used for all subsequent analyses.

Some of the life-history parameters for the analysis were originally taken from WKANGLER (2018) but kept the same as in AFWG 2021. Hordyk *et al*. (2015a; 2015b) showed that the LBSPR approach was sensitive to the input parameters. We, therefore, drew 1000 random samples for each input parameter (i.e. from a bivariate normal distribution for $L_{inf}$ and K, a univariate normal distribution for M, $L_{50}$, $L_{95}$ (see Table 9.3)) and rerun the model in order to account for the effect of uncertainty around the input parameters on the results. We will refer to it as the "stochastic LBSPR approach" hereon.

Once the stochastic LBSPR runs were finished, we conducted some simulations through the LBSPR package to calculate some target SPR value. To do this, we used the mean input values from the stochastic LBSPR, the average estimated parameters values (from the stochastic LBSPR approach) and set the "steepness" to a value between 0.7 and 0.9 to perform a YPR analysis and determine the target reference points (which gives the maximum yield). Steepness values between 0.7 and 0.9 were chosen based on a literature search (values close to 1 are also found in the literature but were not included in the test as it seemed unrealistic for the species). The analysis gave a target reference point of SPR=0.37 (with F/M=1) and SPR=0.23 (with F/M=1.85) and for a steepness value of 0.7 and 0.9, respectively. The stochastic LBSPR runs show a relatively stable annual estimates of SPR (between 0.15 and 0.5 (the IQ range)) and F/M (between 1.0 and

[1] https://github.com/AdrianHordyk/LBSPR

2.5 (the IQ range; Figure 9.7). This would suggest that while there is a lot of uncertainty, the population is fully exploited (estimated values of F/M and SPR included the target reference point ranges).

The relationship between the biomass of reproductively mature individuals (spawning stock) and the resulting offspring added to the population (recruitment), the stock–recruitment relationship, is a fundamental and challenging problem in all population biology. The steepness of this relationship is the fraction of unfished recruitment obtained when the spawning-stock biomass is 20% of its unfished level. Steepness has become widely used in fishery management, where it is usually treated as a statistical quantity. If one has sufficient life-history information to construct a density-independent population model then one can derive an associated estimate of steepness (Mace and Doonan, 1988; Mangel *et al*., 2010; 2013).

As mentioned in the introduction, the LBSPR approach is an equilibrium-based method (i.e. assumes that the fishery experiences constant recruitment and F over time) and violation of this assumption can lead to biased SPR estimates. However, some management strategy evaluations conducted by Hordyk *et al*. (2015) on harvest control rules based on SPR-based size targets showed that while annual assessments of SPR may be imprecise due to the transitory dynamics of a population's size structure, smoothed trends estimated over several years may provide a robust metric for harvest control rules. SPR estimates in our study were relatively stable, thus large recruitment fluctuations may not be an issue.

## 9.3.2 CPUE standardization

Raw CPUE data are seldom proportional to population abundance as many factors (e.g. changes in fish distribution, catch efficiency, effort, etc) potentially affect its value. Therefore, CPUE standardization is a major step that attempts to derive an index that tracks relative population dynamics.

In the data preparation step, we quickly noticed that there was not enough data from ICES Subarea 1 to perform model inference. Therefore, we decided to omit data from this Subarea from the analyses. ICES Subarea 1 is the northern margin of *L. piscatorius* distribution, and only 3 tons were caught in this area in 2019, mostly as bycatch in other fisheries.

Below, we defined some important terms we used for the CPUE standardization.

Standardized effort (gillnet day) = gear count x soaking time (hours) / 24 hours

CPUE (per gillnet day) = catch weight / standardized effort

Based on plotting of raw data, catch weight and standardized effort were proportionally related. Therefore, all subsequent analysis on CPUE standardization was performed on the raw CPUE (per gillnet day). CPUE standardization was performed using the glmmTMB package (Brooks *et al*., 2017) and the best model was chosen based on AICc and residuals checks using the DHARMa package (Hartig 2020) i.e. the most parsimonious model had the lowest AICc while showing no problematic residuals pattern (i.e. overdispersion, underdispersion, etc). If problematic residual patterns were found, we tried to address the issue by either reconsidering the input data, changing model parameterization, or changing the model distribution assumption.

Like the last three assessments (AFWG 2020, 2021, 2022), data were filtered to keep only vessels that had more than 10 observations (as these rare vessel observations were causing deviations in the residual patterns due to difficulty in separating the vessel effect from other effects). However, the original model based on Tweedie distribution (AFWG 2020) showed a problematic residual pattern like the last assessment (AFWG 2022). In-depth investigation indicated that part of the problem was linked to the variability of vessel catchability per year.

Therefore, this year's final Tweedie model was configured using the following parameterization where the novelty lies in the use of the (1|vessel_year) random effect instead of (1|vessel). This enables capturing the variability of vessel catchability between years:

(eq 1)

$$"Presence = year + subarea + month + (1|vessel) + (1|subarea\neg\neg\_year) + (1|month\_\neg year) + (1|month\_subarea)"$$

The expression (1|xxx) indicates that the variable $xxx$ is considered as a random effect and acts on the intercept. The expression (1|xxx_yyy) indicates that the $xxx$ and $yyy$ variable were concatenated into a single variable and considered as a random effect. This is like modelling the interaction between $xxx$ and $yyy$, but the approach only considers existing interaction as opposed to all combination of $xxx$ and $yyy$ when including as fixed interaction effect (which would be unestimable). The inclusion of (1|vessel_year) random effect helped reduce some residual pattern but did not fully eliminate it. Therefore, a delta model was developed like in the last assessment (AFWG 2022) in the aim of removing the residual pattern.

A delta model consists of a pair of models: one that models the species occurrence (presence/absence) and another that models the positive values. All variables were kept the same as in the Tweedie model except for the use of (1|vessel) random effect for the occurrence model as species occurrence did not vary much between year per vessel (the occurrence model with the (1|vessel_year) random effect had a poorer residual performance).

(eq 2)

$$"Presence = year + subarea + month + (1|vessel) + (1|subarea\neg\neg\_year) + (1|month\_\neg year) + (1|month\_subarea)"$$

(eq 3)

$$"CPUE\_pos = year + subarea + month + (1|vessel\_year) + (1|subarea\neg\neg\_year) + (1|month\_ - year) + (1|month\_subarea)"$$

Anglerfish occurrence was modelled using a binomial model with logit transform and positive CPUE was modelled using a Student-t distribution with log link where the degree of freedom was estimated within the model (d.f.~1.55. This suggests a highly skewed distribution). The delta model specification eliminated all the residual pattern (Figure 9.8).

For all subsequent analysis, we considered the delta model results as the new default but still included the original Tweedie model results as a sensitivity test.

As in all previous assessments, the standardized annual CPUE index was created by summing up all predictions based on all combination of year (2007–2021), subarea (in ICES Area 2.a), and month (1–12) after weighting the prediction for each subarea by its surface (in km$^2$ within the 12 nautical miles as shown in Figure 9.6) relative to the total surface (sum of all subarea surfaces in the ICES Area 2.a). In this process, we removed the "vessel_year" random effect (assuming it equals 0, the mean value) as we assumed it captured the variability of vessel catchability but not the underlying fish abundance. We note that glmmTMB can handle any missing new levels for random effect variables when making prediction (it assumes it is equal to zero and inflates the prediction error by its associated random effect variance). The standard deviation of the summed prediction (for the original Tweedie model) was directly calculated in glmmTMB by modifying the source code ('glmmTMB.cpp' file).

A similar approach was taken for the delta model to derive an abundance index with a confidence interval except that model predictions and uncertainty were manually calculated. More precisely, fixed effect parameters were resampled 100.000 times based on their estimated mean and covariance for both components of the delta model while random effects were kept at their MLE except for the vessel_year effect that was replaced by 0. These values were then used to predict the probability of occurrence and positive CPUE value for all combination of year, subarea, and month (as in the Tweedie model) for each of the 100.000 samples. The estimated probability of occurrence and positive CPUE were then multiplied together to calculate the expected CPUE. The final index was calculated by weighted average of the predictions by area (like for the Tweedie model) and the mean CPUE trajectory over time along with its SD was calculated across the 100.000 samples.

The trend in the estimated index between the delta (default) and Tweedie (sensitivity) models were similar except for the last three years where the delta model suggested a steeper yet highly uncertain decline in the anglerfish population in ICES Subarea 2.a (Figure 9.9). That said, the five (and only) RF vessels participating in the fishery between 2020–2022 also showed contrasting yet variable trends in the average raw CPUE. Moreover, one out of the five vessels only started in the RF program in 2020. All of this contributed to the increasing uncertainty in the estimated trend.

### 9.3.3 JABBA

JABBA stands for 'Just Another Bayesian Biomass Assessment' and is an open-source modelling software that can be used for biomass dynamic stock assessment applications. It has emerged from the development of a Bayesian State-Space Surplus Production Model framework applied in stock assessments of sharks, tuna, and billfishes around the world (Winker *et al.*, 2018). JABBA requires at least two comma-separated value files as input (.csv): one for catch and another for abundance indices (with their SE) . The Catch input file contains the time-series of year and catch by weight, aggregated across fleets for the entire fishery. Missing catch years or catch values are not allowed. JABBA is formulated to accommodate abundance indices from multiple sources (i.e. fleets) in a single CPUE file, which contains all considered abundance indices. The first column of the CPUE input is year, which must match the range of years provided in the Catch file. In contrast to the Catch input, missing abundance index (and SE) values are allowed.

The catch data comes from the different fishing countries' official reporting of annual landings to ICES (see Table 9.1) and the CPUE data (along with its standard deviation) comes from the CPUE standardization process described above with values in 1992–1994 retrieved from Figure 9.14. We assumed that the CPUE index from ICES Subarea 2.a calculated using data from the anglerfish targeted fishery is representative of the stock status in ICES areas 1 and 2 together.

In addition to these .csv files, JABBA also requires users to define the prior distribution for the model parameters which will be subsequently updated with data to form the posterior distributions (e.g. Figure 9.10). In addition to the base case, 10 additional scenarios were run to examine the sensitivity of the model results to the choice of priors (Table 9.6).

Figure 9.11 shows the trajectory of the population estimates from 1990–2022 based on the 11 tested scenarios (Table 9.7). In general, population abundance seems to have fluctuated around $B_{MSY}$ (at least the mean trajectory) over the last ten years while fishing mortality might have been slightly above $F_{MSY}$ in more recent years (Figure 9.11). Figure 9.12 is the Kobe plot from the base model run showing the estimated trajectories of $B/B_{MSY}$ and $F/F_{MSY}$ along with the credibility intervals of the 2022 estimates of biomass and fishing mortality. The percentage numbers at the top right indicate how much of the 2022 population estimates falls within the green (not overfished, no overfishing), yellow (overfished, but no overfishing), orange (overfishing, but not overfished), and red (overfished and overfishing) zones, after accounting for all the parameter uncertainty (basically, the area under the oval shaped density plot that falls into each colored quadrant). The model estimates that there is a 45.7% (15%) probability that the 2022 population estimate falls within the red zone, 15.6% (30%) in the orange, 3.4% (0.5%) in the yellow, and 35.2% (54.5%) in the green zone (numbers in parentheses show the 2021 values from previous assessment) suggesting a worse stock condition than last year. Finally, retrospective analysis on the base model run has improved compared to the previous assessment cycle (AFWG 2022) without any worrisome patterns (Figure 9.13, Table 9.7).

Management considerations and recommended advice

The abundance of anglerfish in subareas 1 and 2 seems to depend on the influx or migration of juveniles from ICES subareas 4 and 6. An effective discard ban on anglerfish in subareas 4 and 6 will hence have a positive effect on the abundance north of 62°N. A variable mean size of the landed anglerfish observed during the last 30 years, when fishing with the same large-meshed gillnets, is an indication of variable influx of recruitment to the ICES subareas 1 and 2. It is recommended that people involved in this Northeast arctic anglerfish assessment hence participate at the ICES benchmark assessment for anglerfish in ICES Subareas 3, 4 and 6 planned for autumn 2023-spring 2024.

The three distinct assessment approaches tested in this report offer corroborative evidence that the anglerfish population has declined over time and that population might be at or below $B_{MSY}$ in 2022 but with a slightly high effort level (probably above $F_{MSY}$).

The spawning potential ratio and F/M values calculated by the LBSPR method suggests that while there is a lot of uncertainty, the population is fully exploited (estimated values of F/M and SPR included the target reference point ranges).

An increase in effort and CPUE after 2016 coincided with a sudden fall in mean size of the anglerfish caught with the standard large-meshed gillnets. This seems also to coincide with these year classes seen in the North Sea anglerfish survey as juveniles some years before. Since new recruits into ICES Subarea 2.a may temporarily reduce the overall mean weight of the anglerfish population in Subarea 2.a, and hence also the CPUE which is measured in weight or biomass, the fishing effort and mean length development may indicate recruitment immigration sooner and when it happens. The standardized CPUE analysis shows that anglerfish population in ICES Subarea 2.a has declined over the three most recent years but with a large uncertainty around the final year (2022) estimate. And since this CPUE decrease happens some years after the immigration of new recruits, it indicates a stock biomass reduction that only partly will be compensated by individual growth (mean length).

The relative population stock status in 2022 is around $B_{MSY}$, though fishing intensity could be close or slightly higher than $F_{MSY}$. Therefore, effort should be decreased at the risk of the population falling below the biomass and SPR targets.

**Candidate advice**

Following the ICES technical guidance for harvest control rules and stock assessment for stocks in category 2 (ICES 2022), the “fractile rules” based on the 35$^{th}$ percentile of the predicted catch distribution given a target fishing mortality was applied to the JABBA base-case scenario model. Due to the lack of official harvest control rule for assessment using JABBA, slight modification was made to the ICES “fractile rules” and the posterior distribution of the estimated MSY was used as basis for the catch recommendation.

The recommended TAC was estimated at 1930 t (Figure 9.15) and population projections were made for 2023–2025 using the base case model and assuming a constant annual catch of 1930, 2000, 2100, and 2200 t, respectively (Figure 9.16).

Figure 9.16 indicates that at the recommended TAC of 1930 t, the mean anglerfish population is expected to get back to $B_{MSY}$ and $F_{MSY}$ level by 2023.

## 9.4 Tables and figures

**Table 9.1. Nominal catch (t) of anglerfish in ICES subareas 1 and 2, 2009–2022, as officially reported to ICES.**

| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Denmark | + | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Faroes | 2 | 1 | + | + | 1 | + | + | 1 | 1 | + | + | 1 | - | + |
| France | - | - | 1 | 3 | 2 | - | 4 | 2 | 4 | 3 | 8 | 5 | 4 | 4 |
| Germany | + | 82 | 70 | 0 | - | + | + | + | 1 | 1 | 50 | - | - | - |
| Iceland | - | - | 7 | - | - | - | - | - | - | - | - | - | - | - |
| Norway | 4298 | 5391 | 5030 | 3758 | 2988 | 1655 | 933 | 1355 | 1473 | 1884 | 2750 | 2258 | 2584 | 2288 |
| Portugal | 6 | 1 | + | - | - | - | - | - | - | - | - | - | - | - |
| UK | 152 | 40 | 3 | 3 | 111 | 2 | 105 | 76 | 5 | 15 | + | 16 | 13 | - |
| Others | - | - | - | 1 | 1 | - | - | + | - | + | - | - | - | - |
| Total | 4458 | 5515 | 5112 | 3765 | 3103 | 1657 | 1043 | 1435 | 1484 | 1903 | 2809 | 2280 | 2601 | 2293 |

*Preliminary per 24 March 2023

**Table 9.2. Anglerfish in ICES subareas 1 and 2. Norwegian landings (tonnes) by fishery in 2008–2022. The coastal area is here defined as the area inside 12 nautical miles from the baseline.**

| Fleet NORWAY | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coastal gillnet | 3574 | 3934 | 4806 | 4573 | 3521 | 2758 | 1506 | 829 | 1231 | 1320 | 1727 | 2502 | 1939 | 2236 | 1977 |
| Offshore gillnet | 240 | 171 | 391 | 323 | 115 | 158 | 95 | 52 | 62 | 87 | 68 | 153 | 168 | 229 | 151 |
| Danish seine | 75 | 68 | 40 | 30 | 16 | 19 | 11 | 12 | 17 | 23 | 28 | 26 | 35 | 78 | 89 |
| Demersal trawl | 34 | 36 | 48 | 22 | 11 | 8 | 7 | 3 | 5 | 6 | 10 | 5 | 3 | 2 | 4 |
| Other gears | 84 | 89 | 106 | 82 | 96 | 45 | 36 | 37 | 40 | 31 | 51 | 64 | 113 | 39 | 67 |
| Total | 4007 | 4298 | 5391 | 5030 | 3759 | 2988 | 1655 | 934 | 1355 | 1468 | 1884 | 2750 | 2258 | 2584 | 2288 |

*Preliminary per 24 March 2023.

**Table 9.3. Basic input parameters and parameters for resampling as used for the LBSPR analysis.**

| Basic input parameters | Value |
|---|---|
| von Bertalanffy K parameter (mean) | 0.12 |
| von Bertalanffy Linf parameter (mean) | 146 |
| von Bertalanffy t0 parameter | −0.34 |
| Length-weight parameter a | 0.149 |
| Length-weight parameter b | 2.964 |
| Steepness | 0.8 |
| Maximum age | 25 |
| Length at 50% maturity ($L_{50}$; mean) | 82 |
| Length at 95% maturity ($L_{95}$; mean) | 100 |

| Basic input parameters | Value |
|---|---|
| ΔMat = $L_{95}$ - $L_{50}$ (mean) | 18 |
| Length at first capture | 40 |
| Length at full selection | 60 |
| M (mean) | 0.2 |
| M/k (mean) | 1.67 |
| **Parameters for resampling** | **Value** |
| $N_{samp}$ | 1000 |
| CV(M) | 0.15 |
| Cor ($L_{inf}$_K) | 0.9 |
| CV(K) | 0.3 |
| CV($L_{inf}$) | 0.15 |
| CV($L_{50}$) | 0.05 |
| CV(ΔMat) | 0.05 |

**Table 9.4. Number of coastal reference fleet fishing days with anglerfish, per national stat. subareas (0–7) and total for ICES subareas 1 and 2. Only large-meshed gillnets included.**

| Year/ area | 0 | 5 | 6 | 7 | ICES 1 and 2 |
|---|---|---|---|---|---|
| 2007 | 106 | 26 | | 280 | 412 |
| 2008 | 62 | 37 | 6 | 171 | 276 |
| 2009 | 86 | 35 | 36 | 176 | 333 |
| 2010 | 14 | 41 | 37 | 143 | 235 |
| 2011 | 64 | 19 | 51 | 116 | 250 |
| 2012 | 49 | 12 | 24 | 21 | 106 |
| 2013 | 64 | 20 | 18 | 81 | 183 |
| 2014 | 5 | | 19 | 107 | 131 |
| 2015 | 109 | | 5 | 116 | 230 |
| 2016 | 92 | | 22 | 35 | 149 |
| 2017 | 88 | | | 109 | 197 |
| 2018 | 108 | | | 89 | 197 |
| 2019 | 86 | 34 | | 63 | 183 |
| 2020 | 74 | 28 | 52 | 104 | 258 |
| 2021 | 66 | | 72 | 83 | 221 |
| 2022 | 7 | | 74 | 73 | 154 |

**Table 9.5. Number of fishing days with length measured anglerfish (left) and number of length measured fish (right). Only large-meshed gillnets included.**

| Year | ICES 1 and 2 |
|---|---|
| 2007 | 78 |
| 2008 | 43 |
| 2009 | 47 |
| 2010 | 67 |
| 2011 | 78 |
| 2012 | 39 |
| 2013 | 52 |
| 2014 | 29 |
| 2015 | 31 |
| 2016 | 45 |
| 2017 | 74 |
| 2018 | 64 |
| 2019 | 50 |
| 2020 | 83 |
| 2021 | 78 |
| 2022 | 43 |

| Year | ICES 1 and 2 |
|---|---|
| 2007 | 2265 |
| 2008 | 1407 |
| 2009 | 2325 |
| 2010 | 2171 |
| 2011 | 2423 |
| 2012 | 995 |
| 2013 | 1305 |
| 2014 | 546 |
| 2015 | 1063 |
| 2016 | 654 |
| 2017 | 1593 |
| 2018 | 1451 |
| 2019 | 1486 |
| 2020 | 2149 |
| 2021 | 1649 |
| 2022 | 1250 |

**Table 9.6. Eleven scenarios were run to examine the sensitivity of the model results to the choice of priors.**

| Scenario name | K | r | $\sigma_P$ | Initial depletion | $B_{MSY}$/K value |
|---|---|---|---|---|---|
| Base | LN(1e6,1) | LN(0.1,1) | IG(4,0.01) | LN(0.8,0.5) | 0.35 |
| Low_K | LN(5e5,1) | LN(0.1,1) | IG(4,0.01) | LN(0.8,0.5) | 0.35 |
| High_K | LN(1.5e6,1) | LN(0.1,1) | IG(4,0.01) | LN(0.8,0.5) | 0.35 |
| Low_r | LN(1e6,1) | LN(0.05,1) | IG(4,0.01) | LN(0.8,0.5) | 0.35 |
| High_r | LN(1e6,1) | LN(0.2,1) | IG(4,0.01) | LN(0.8,0.5) | 0.35 |
| Low_sigmaP | LN(1e6,1) | LN(0.1,1) | IG(4,0.005) | LN(0.8,0.5) | 0.35 |
| High_sigmaP | LN(1e6,1) | LN(0.1,1) | IG(4,0.02) | LN(0.8,0.5) | 0.35 |
| Low_initdep | LN(1e6,1) | LN(0.1,1) | IG(4,0.01) | LN(0.7,0.5) | 0.35 |
| High_initdep | LN(1e6,1) | LN(0.1,1) | IG(4,0.01) | LN(0.9,0.5) | 0.35 |
| Low_BmsyK | LN(1e6,1) | LN(0.1,1) | IG(4,0.01) | LN(0.8,0.5) | 0.30 |
| High_BmsyK | LN(1e6,1) | LN(0.1,1) | IG(4,0.01) | LN(0.8,0.5) | 0.40 |

***LN stands for lognormal and IG stands for inverse gamma distribution. $B_{MSY}$/K value controls for the position of the inflection point of the surplus production curve with respect to K (a value from 0 to 1).**

**Table 9.7. Relative error (RE) in parameter estimates between the base run with full dataset (Table 9.6) and the retrospective peels (1 to 5 years) and the associated Mohn's rho statistics (i.e. average RE from the 5 peels). Relative error is calculated as: RE = (peel-ref)/ref.**

| | B | F | B/$B_{MSY}$ | F/$F_{MSY}$ | procB | MSY |
|---|---|---|---|---|---|---|
| **RE_peel1(2021)** | 0.09 | −0.08 | 0.16 | −0.22 | 0.01 | 0.1 |
| **RE_peel2(2020)** | −0.03 | 0.04 | −0.07 | 0.01 | 0.01 | 0.07 |
| **RE_peel3(2019)** | 0.04 | −0.04 | −0.16 | 0.36 | −0.01 | −0.12 |
| **RE_peel4(2018)** | 0.15 | −0.13 | 0.15 | −0.11 | 0 | −0.01 |
| **RE_peel5(2017)** | −0.04 | 0.04 | −0.02 | 0.09 | 0 | −0.07 |
| **Mohn's rho** | 0.04 | −0.04 | 0.01 | 0.03 | 0 | −0.01 |

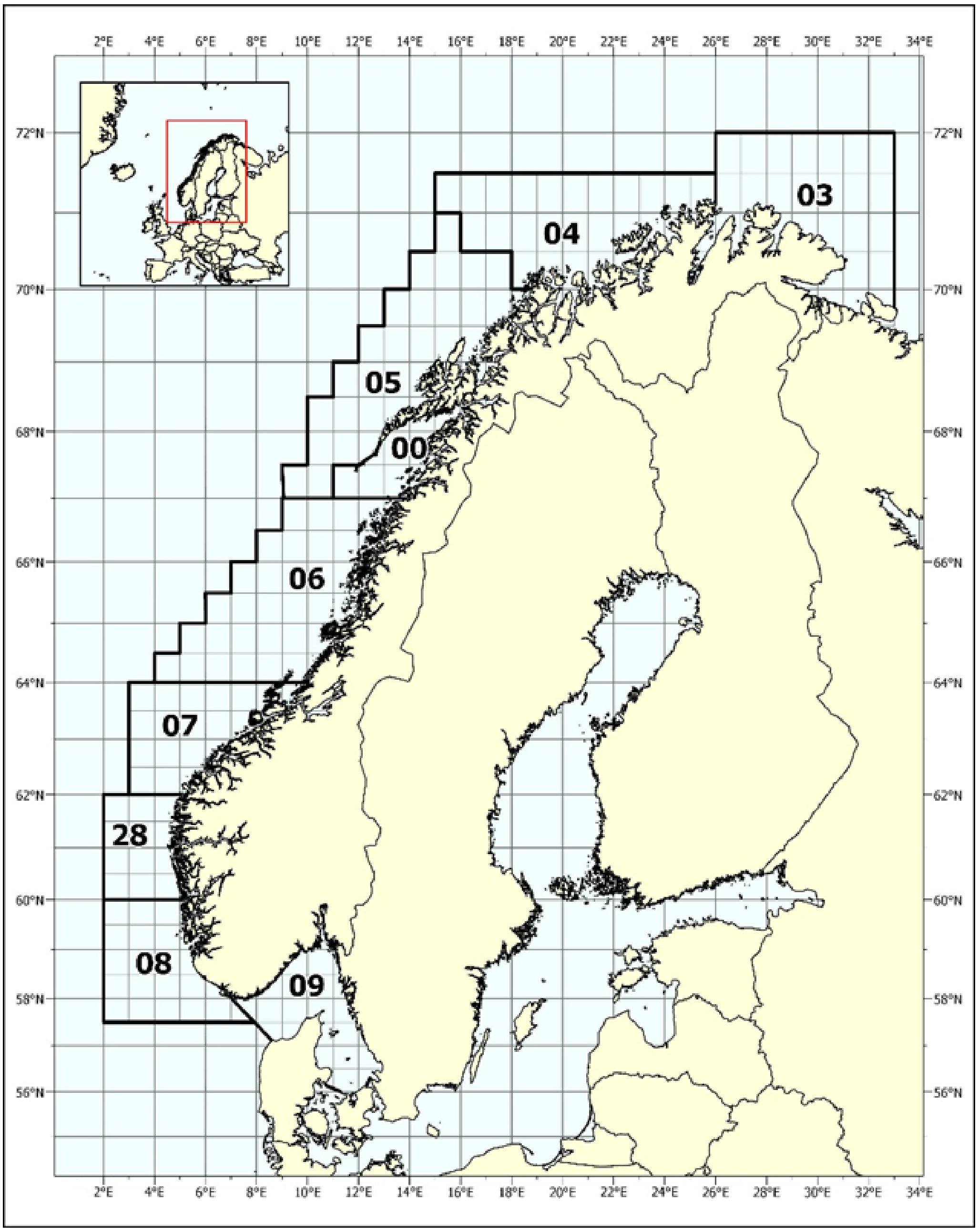



**Figure 9.1. Map showing the Norwegian statistical coastal areas. Area 03 is part of ICES Subarea 1; areas 04, 05, 00, 06, and 07 are part of ICES Subarea 2; Areas 28 and 08 are part of ICES Subarea 4, and Area 09 corresponds roughly with ICES Subarea 3.**

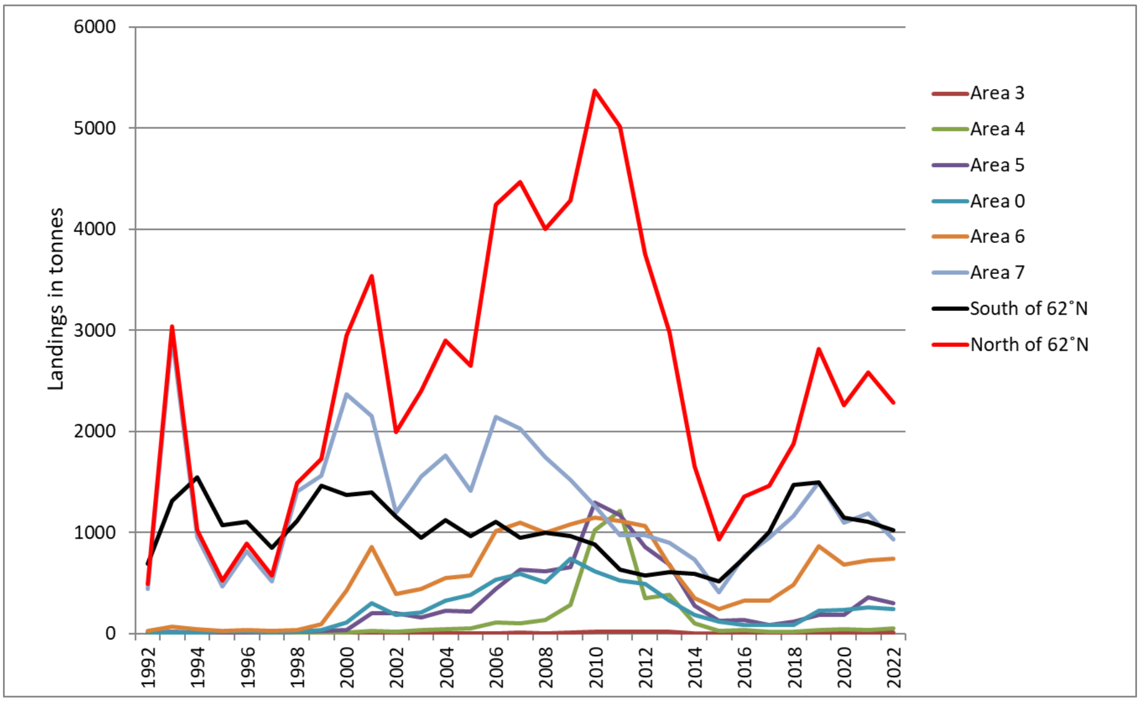



**Figure 9.2. Norwegian official landings (in tonnes) of anglerfish (*Lophius piscatorius*) per statistical area (see Figure 9.1) within ICES areas 1 and 2 during 1992–2022. Norwegian landings from the area south of 62°N (ICES 4 and 3) are shown for comparison.**

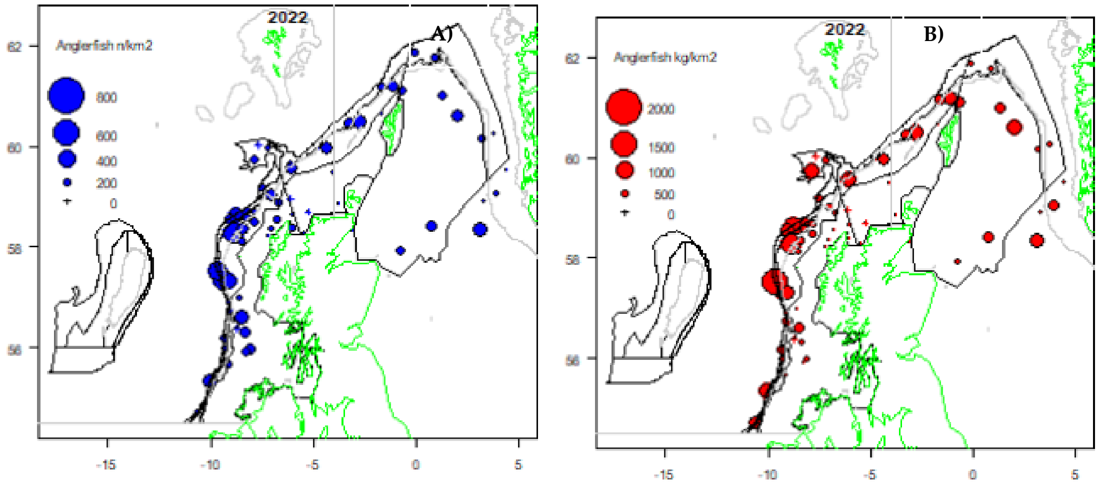



**Figure 9.3. Excerpt from WGCSE 2022: A) WGCSE 2022 figure 4.16 - Numbers of anglerfish per km2 observed by SIAMISS surveys 2022. B) WGCSE 2022 figure 4.17 - Weight of anglerfish (kg) per km2 observed by SIAMISS surveys 2022.**

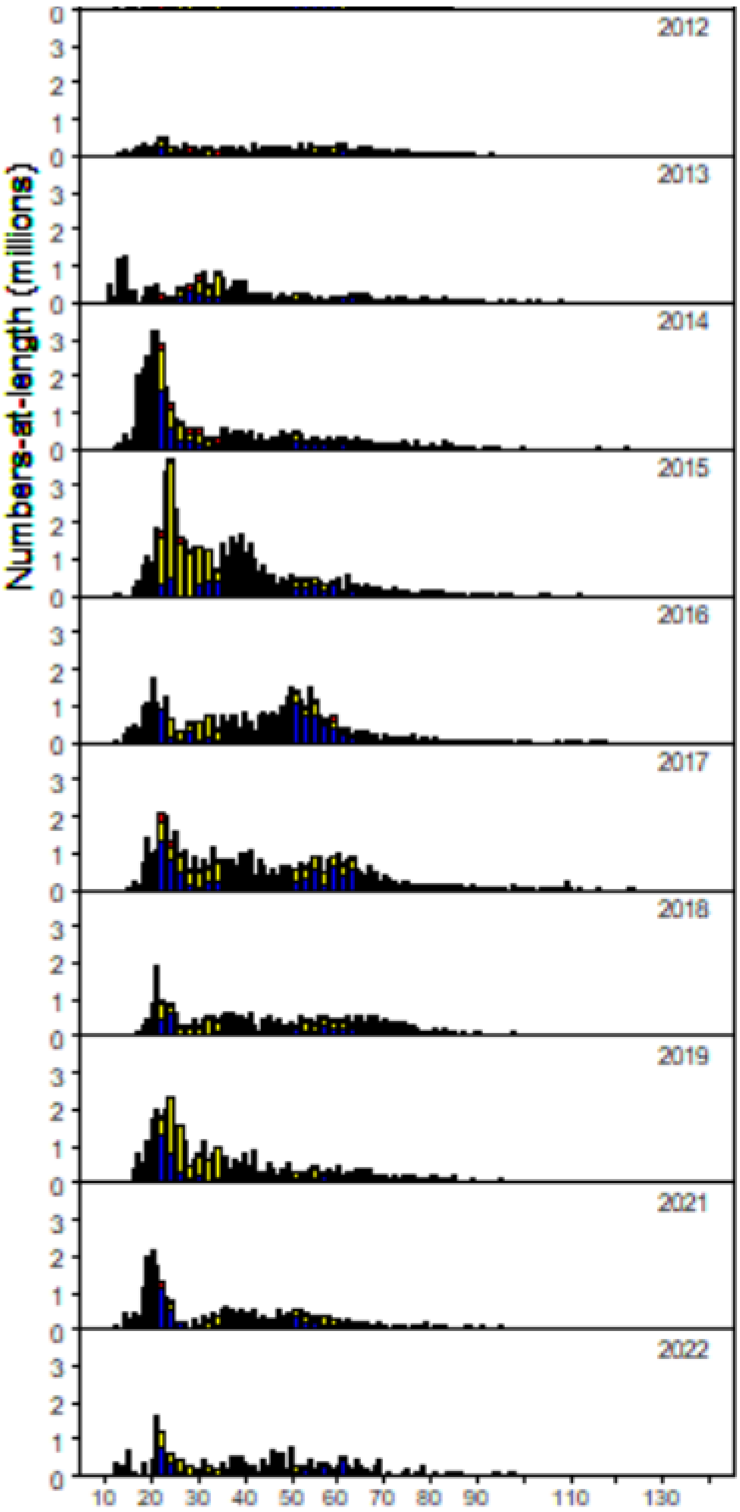



**Figure 9.4. Excerpt from WGCSE 2022: Figure 4.8. SIAMISS-Q2 estimates of total numbers (millions) at-length (cm) for subareas 4.a (blue)–c and 6.a (yellow)–b (red) combined, 2012–2022.**

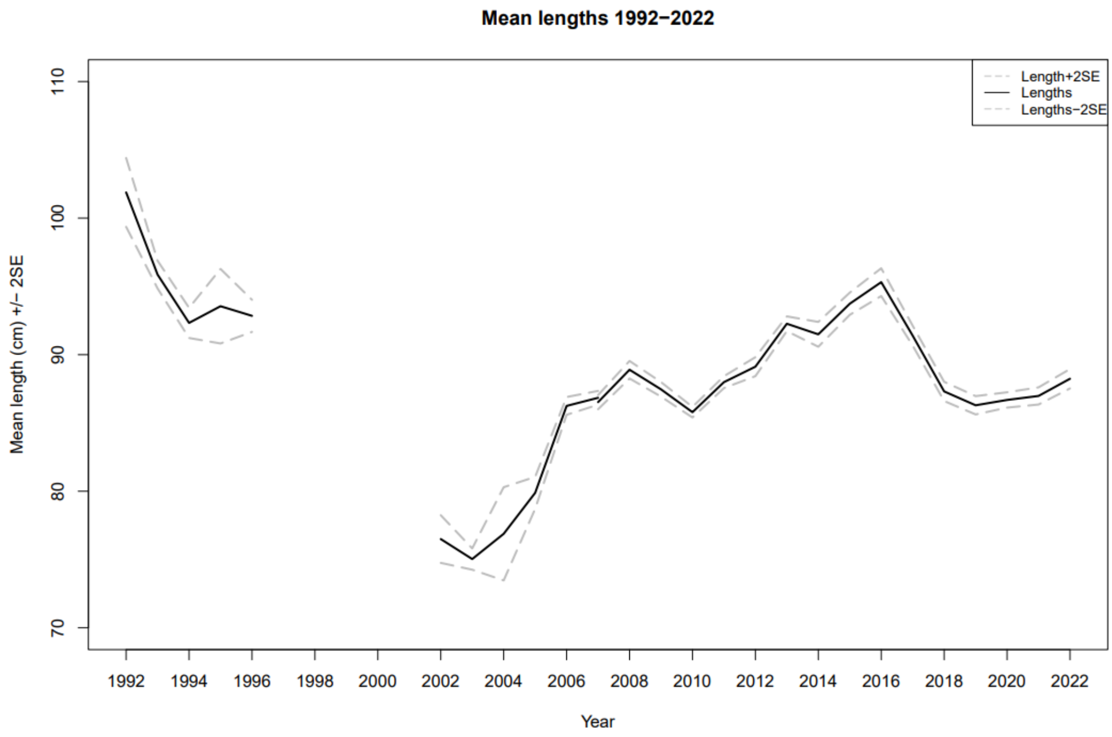



**Figure 9.5. Anglerfish (*Lophius piscatorius*) in ICES Subareas 1 and 2. Mean lengths for anglerfish caught in the directed coastal gillnetting in Division 2.a during 1992–2022, dotted lines represent ±2SE of the mean. Note that data are lacking for 1997–2001. This illustrates pulses of new recruitment entering Division 2.a from ICES subareas 4 and 6; last time during 2002–2003, and to a lesser extent in 2017–2019.**

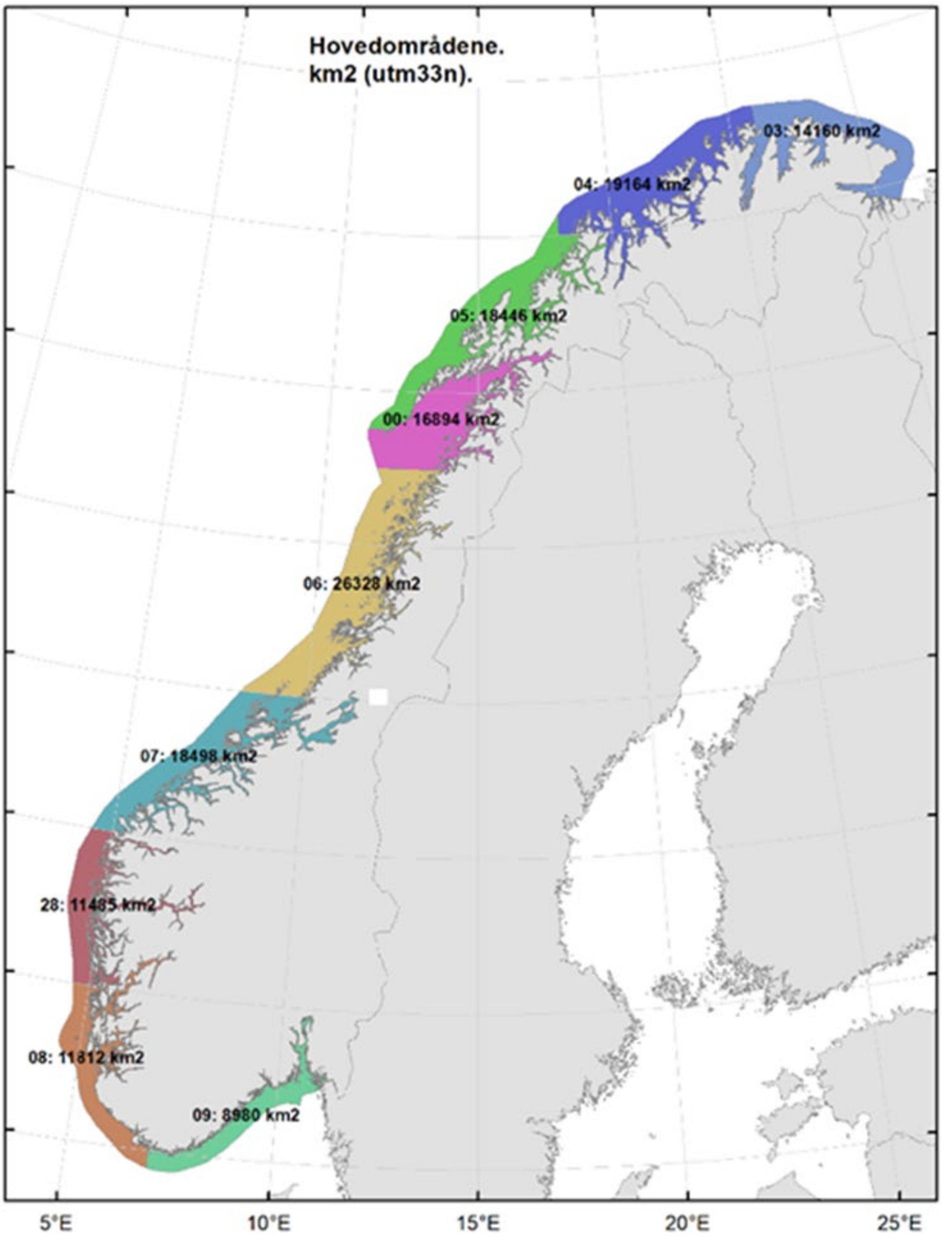



**Figure 9.6. Map showing the area (km2) of each Norwegian statistical subarea inside 12 nautical miles. The subareas 4, 5, 0, 6, and 7 belong to the ICES Division 2.a.**

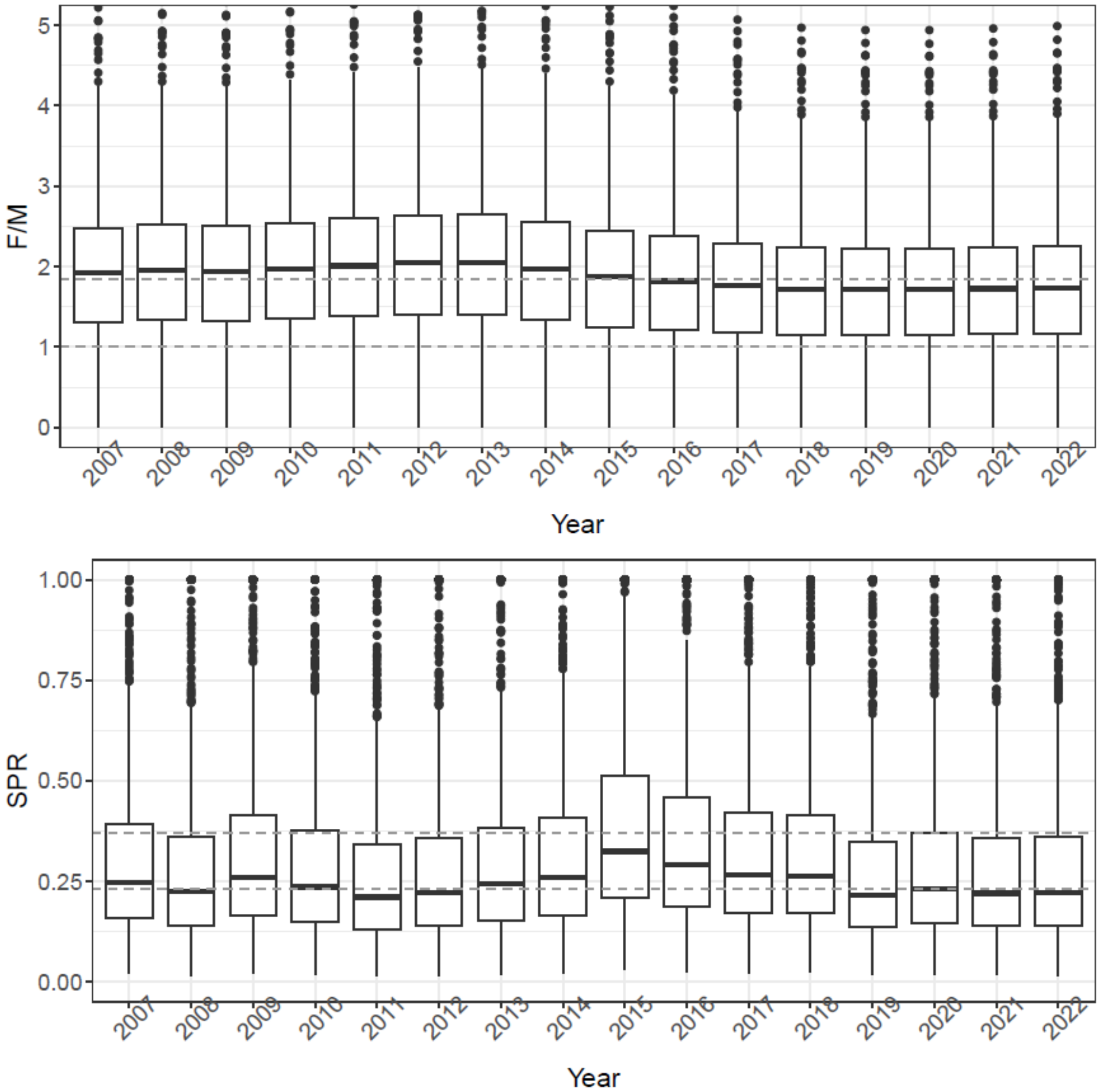



**Figure 9.7. Annual estimates of F/M (above) and SPR (below) from the stochastic LBSPR approach using the length composition data from 2007–2022.**

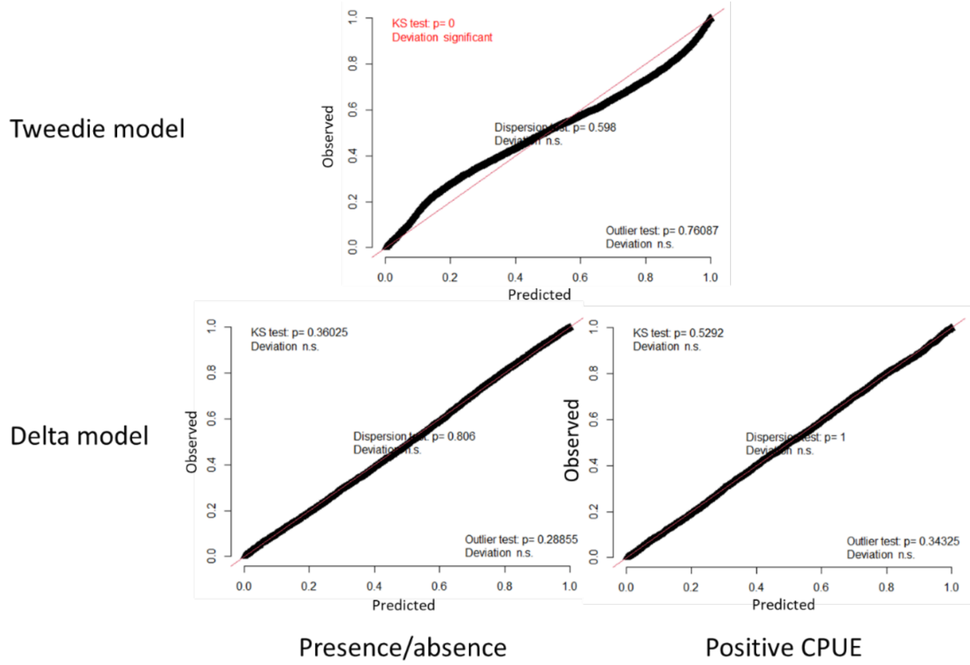



**Figure 9.8. CPUE model residual diagnostics. Top panel shows the residual pattern in the Tweedie model using the latest data and with the (1|vessel_year) random effect. Bottom panel shows the results from the delta model with the specification mentioned in the text.**

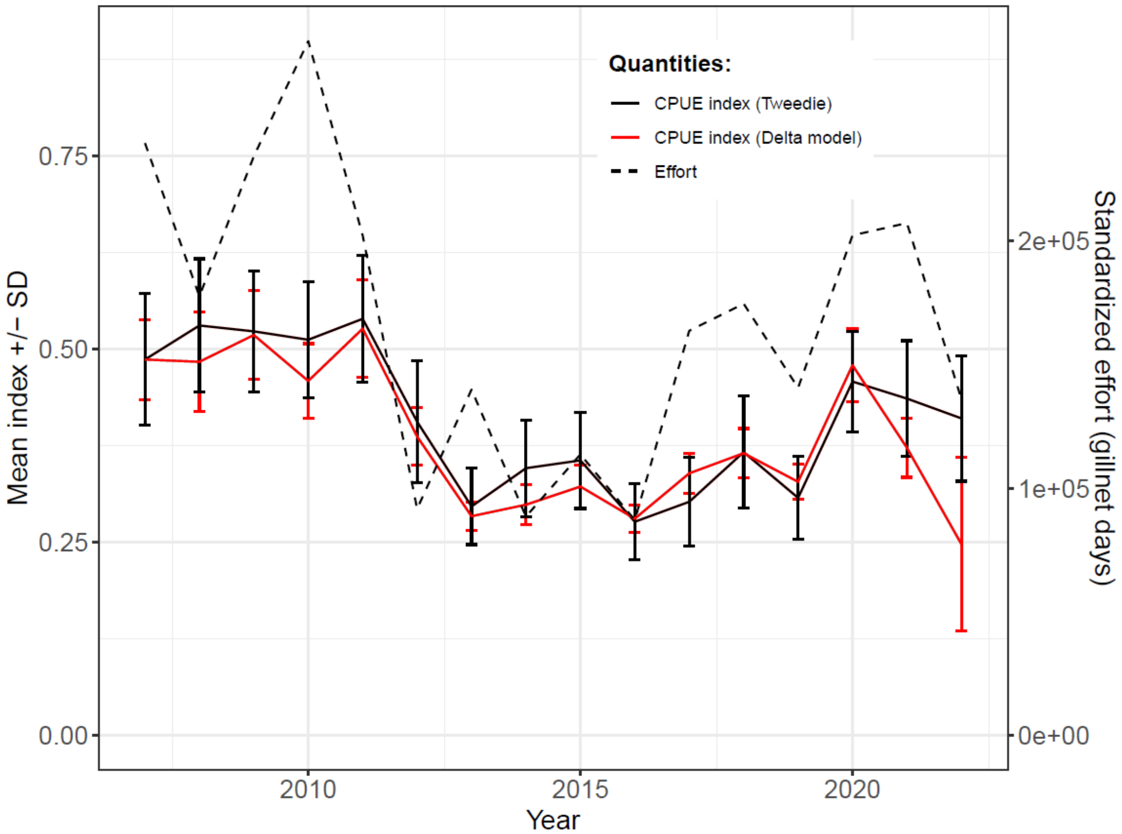



**Figure 9.9. Standardized CPUE (kg per gillnet day) +/- SD (solid black line with error bars for the original Tweedie model, and solid red line with error bars for the new delta model) and the corresponding standardized effort (dash line) for anglerfish based on the data from the Norwegian coastal reference fleet in ICES Subarea 2a, from vessels targeting anglerfish with large meshed gillnets.**

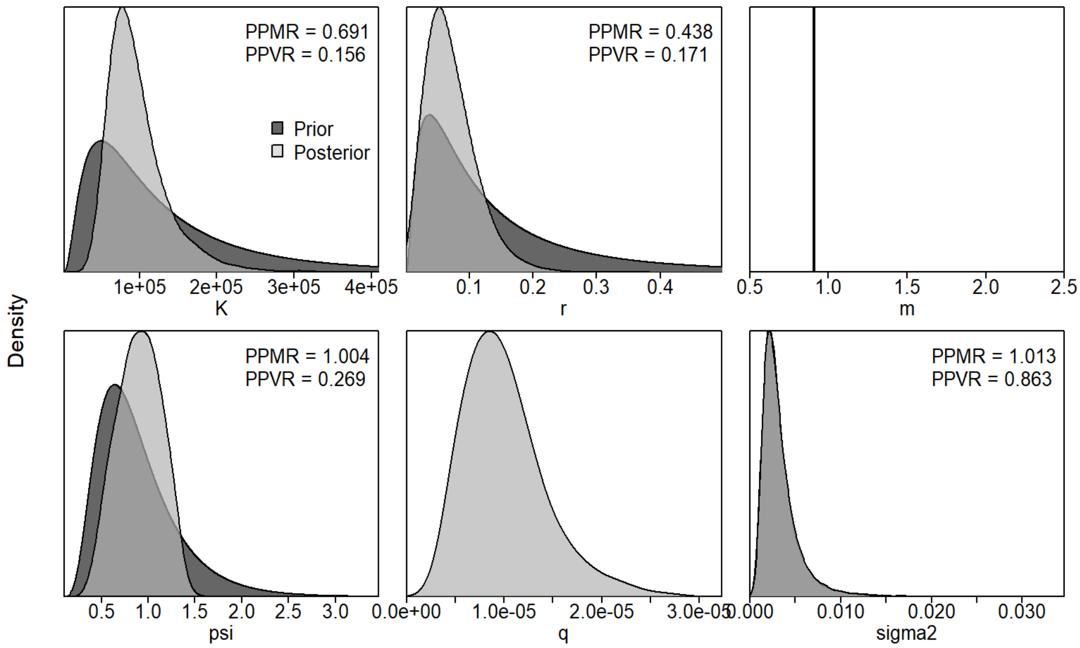



**Figure 9.10. Prior and posterior distributions of the JABBA model parameters for the anglerfish assessment.**

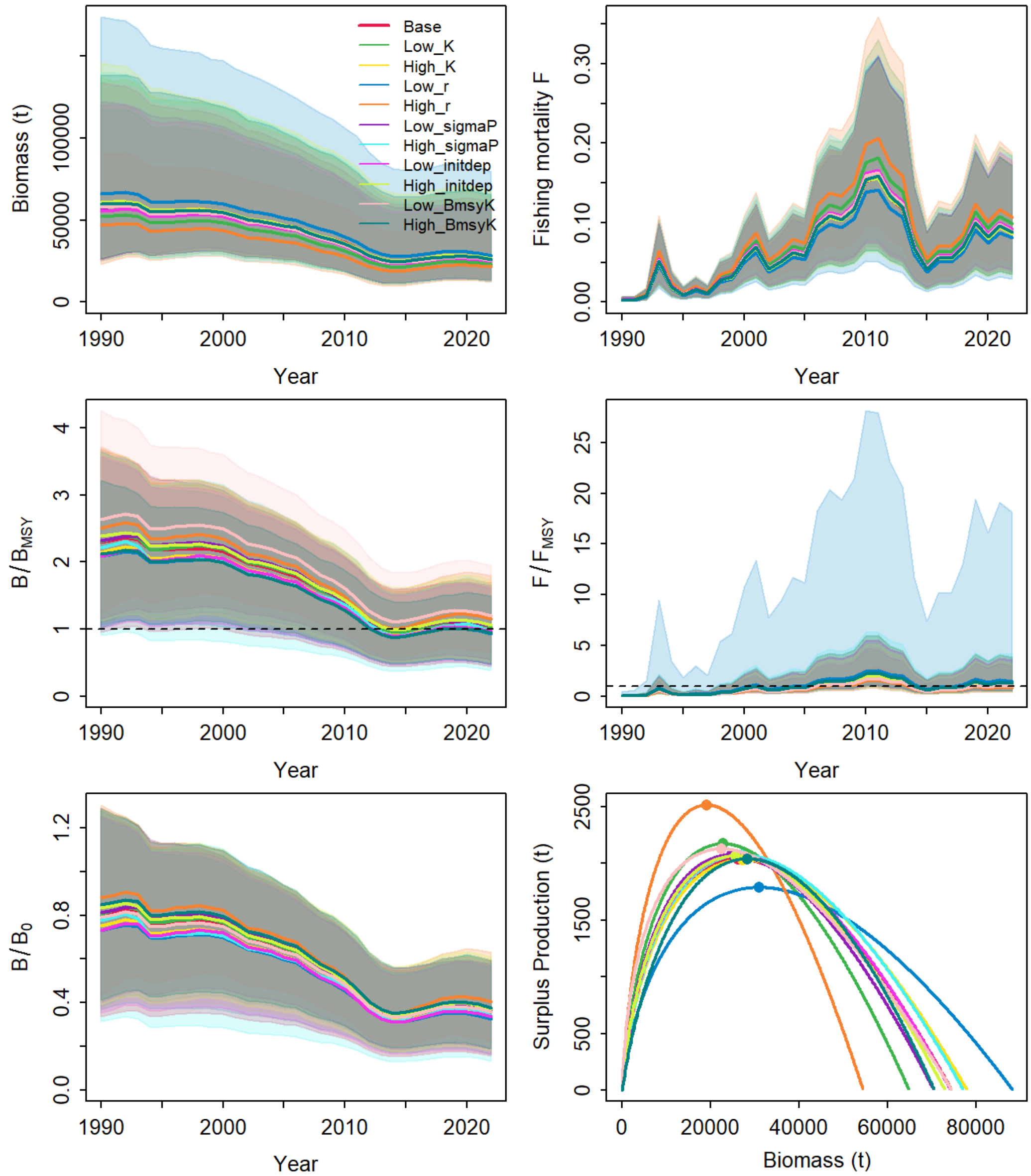
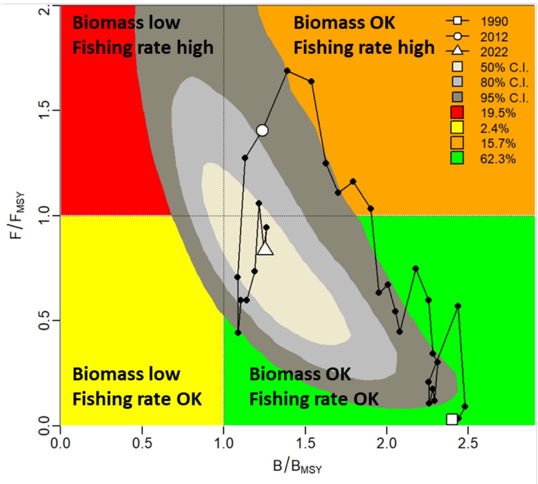
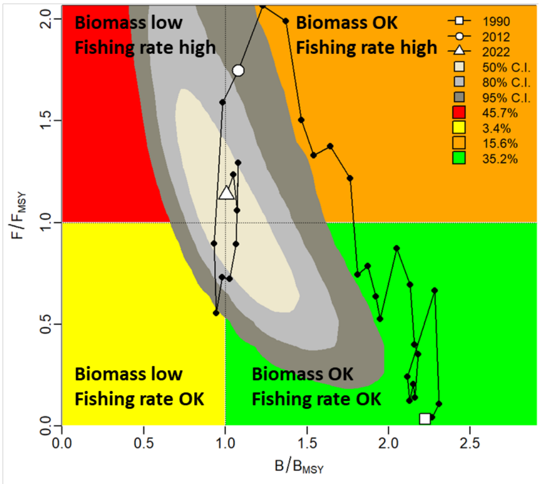



**Figure 9.11. Estimated trajectories for biomass, fishing mortality, B/BMSY, F/FMSY, B/B0, and surplus production for the ICES Subarea 1–2 anglerfish based on 11 JABBA scenarios (the name of scenario and the associated color is indicated in the figure). The lines show the mean trajectory, and the shaded areas denote 95% credibility intervals.**




**Using CPUE from Tweedie model**




**Using CPUE from delta model**

**9.12. Kobe plot for the JABBA base case scenario showing the estimated joint trajectories (1990–2021) of B/B$_{Msy}$ and F/F$_{MSY}$. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend. The figure on the left shows the results using the original Tweedie model when calculating the abundance index while the figure on the right uses the index derived from the delta model.**

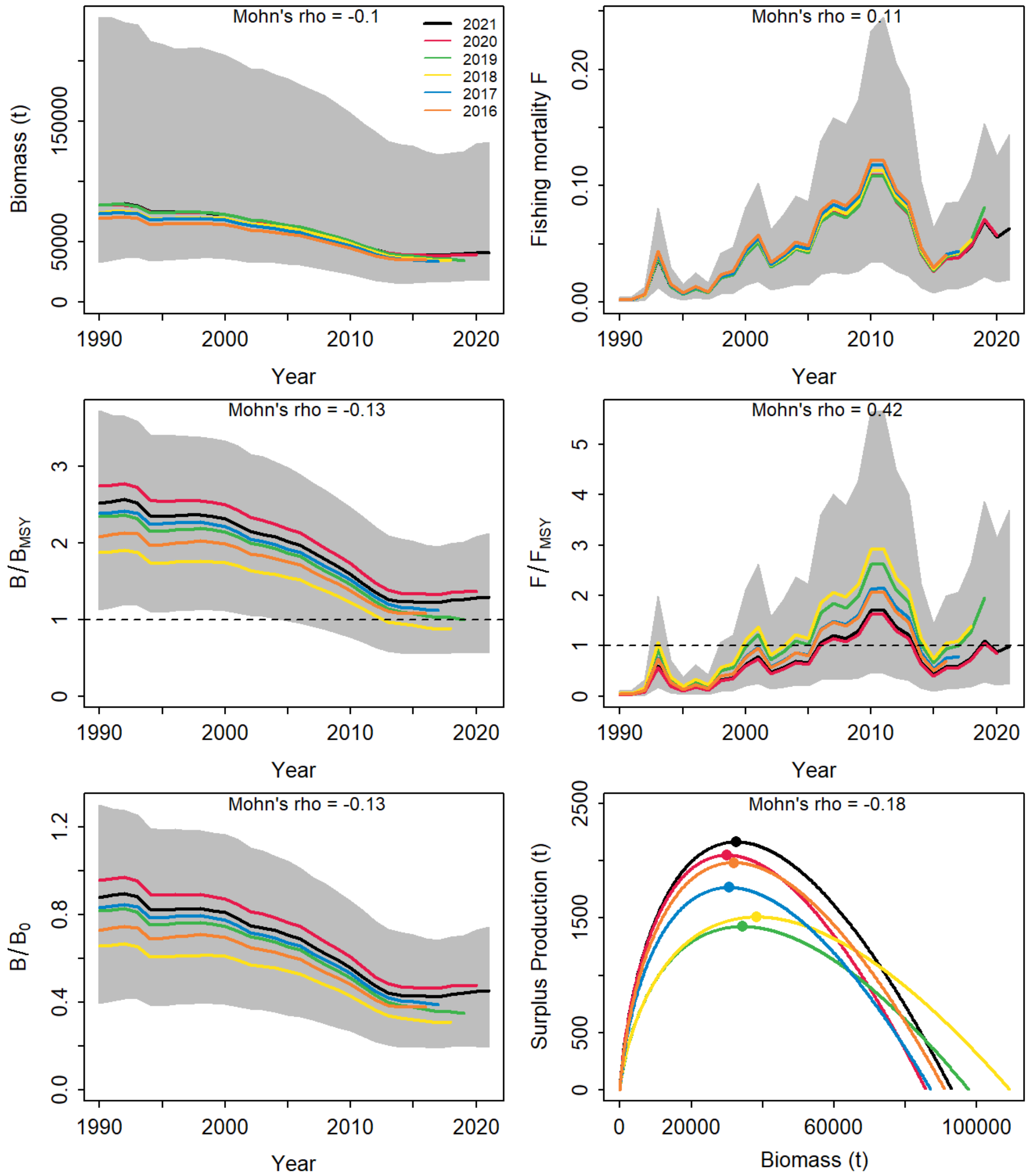



**Figure 9.13. Retrospective analysis from the JABBA base case scenario. Different colours illustrate the results from different peels (ref. Table 9.7).**

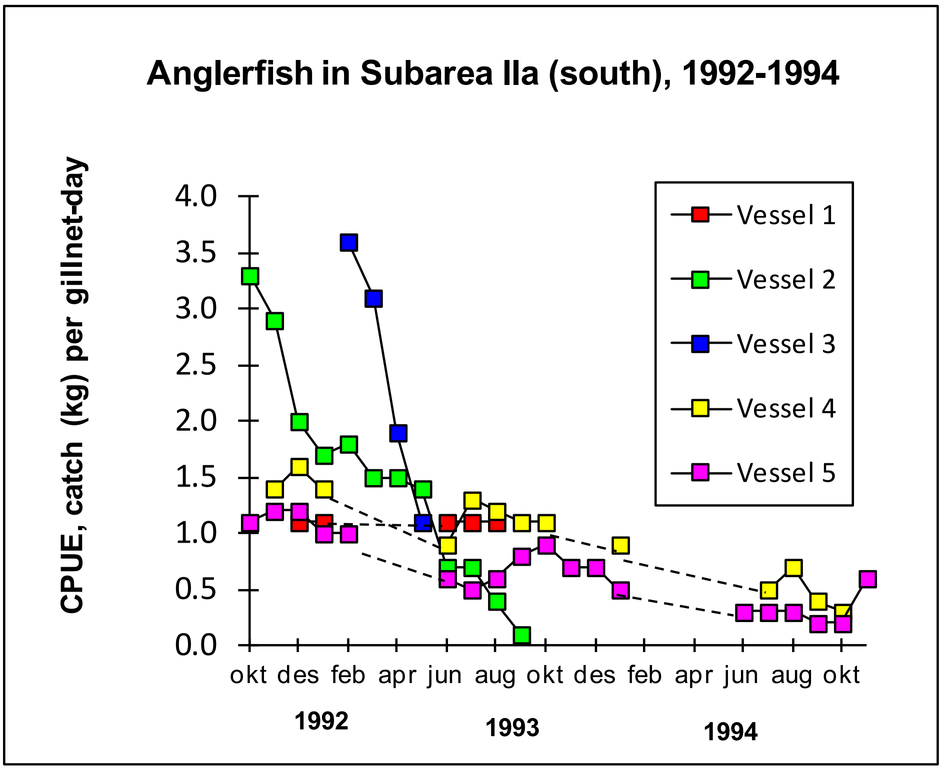



**Figure 9.14. Catch per unit effort for five boats in the gillnet fishery for anglerfish in Møre and Romsdal (between 62–63˚N) in the period October 1992 to October 1994. Boat 1 > 25m; Boat 2 ca. 20 m; Boat 3 ca. 10 m; Boat 4 and 5 ca. 16 m. Boats 1–4 were fishing with gillnet 360 mm nesh size, boat 5 with 300 mm mesh size. These data have been used as input to the JABBA assessment.**

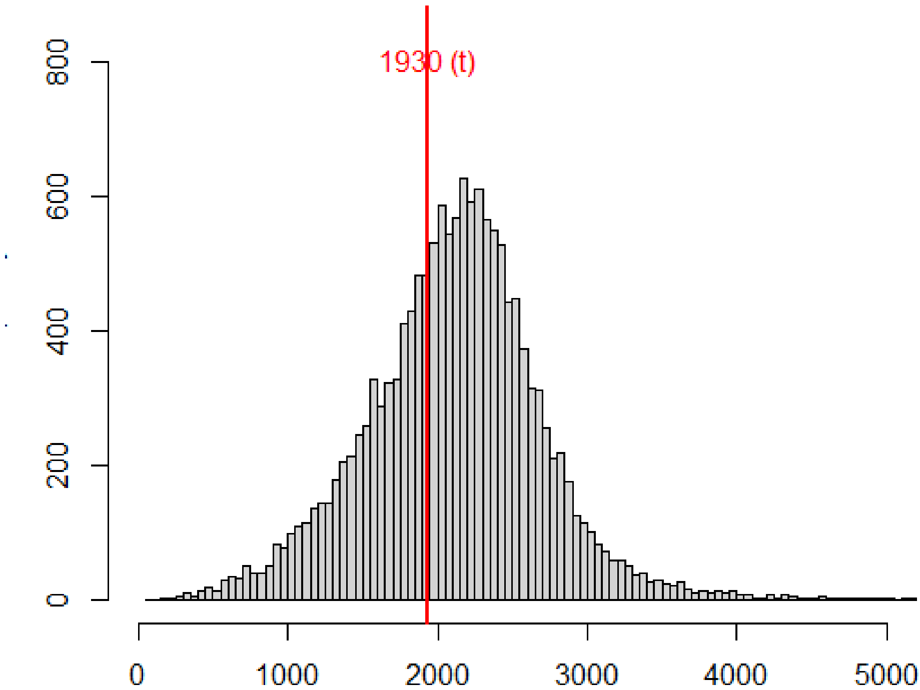



**Figure 9.15 Posterior distribution of the MSY from the base-case scenario along with the 35th quantile of the distribution highlighted with a red line.**

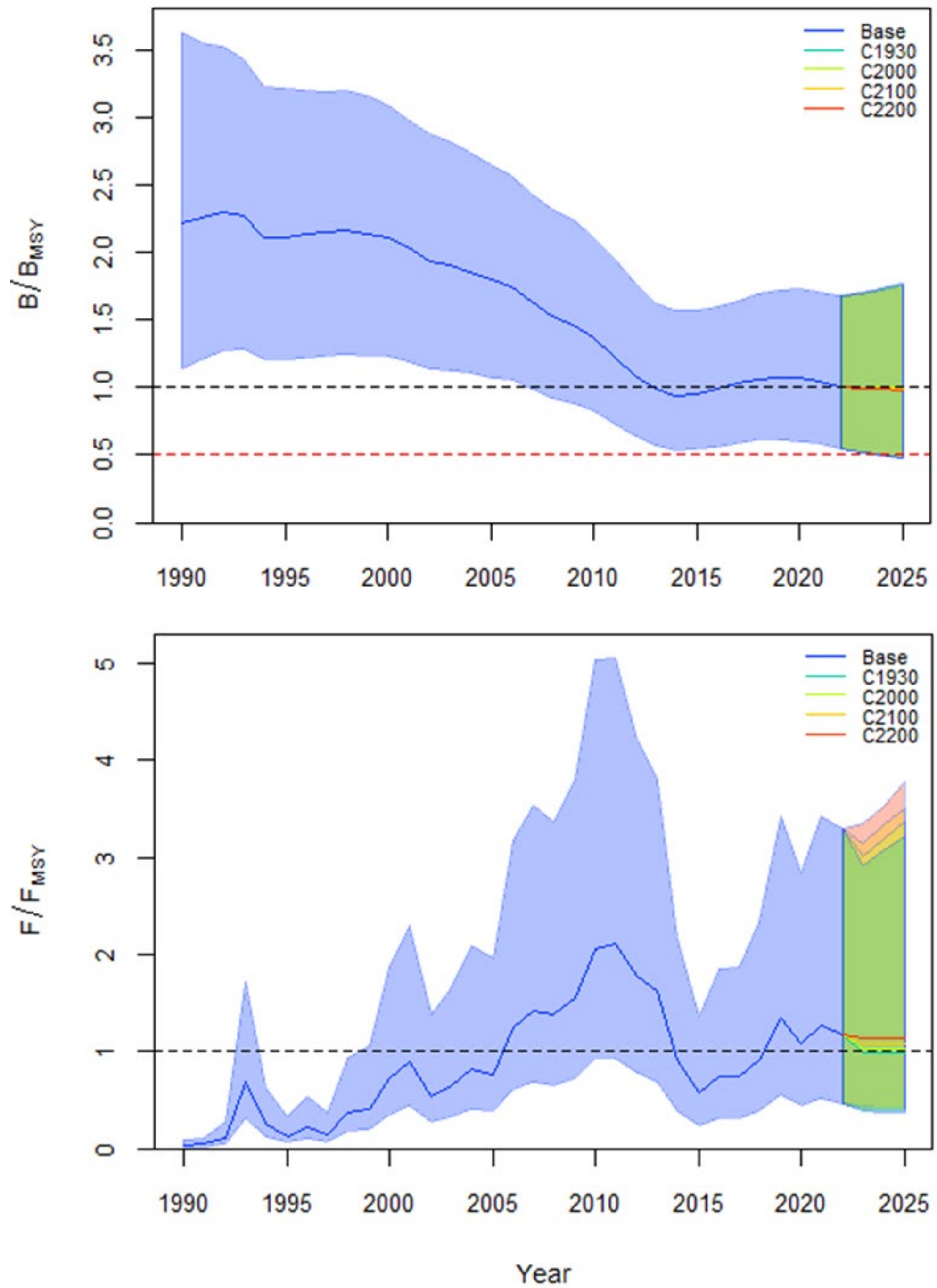
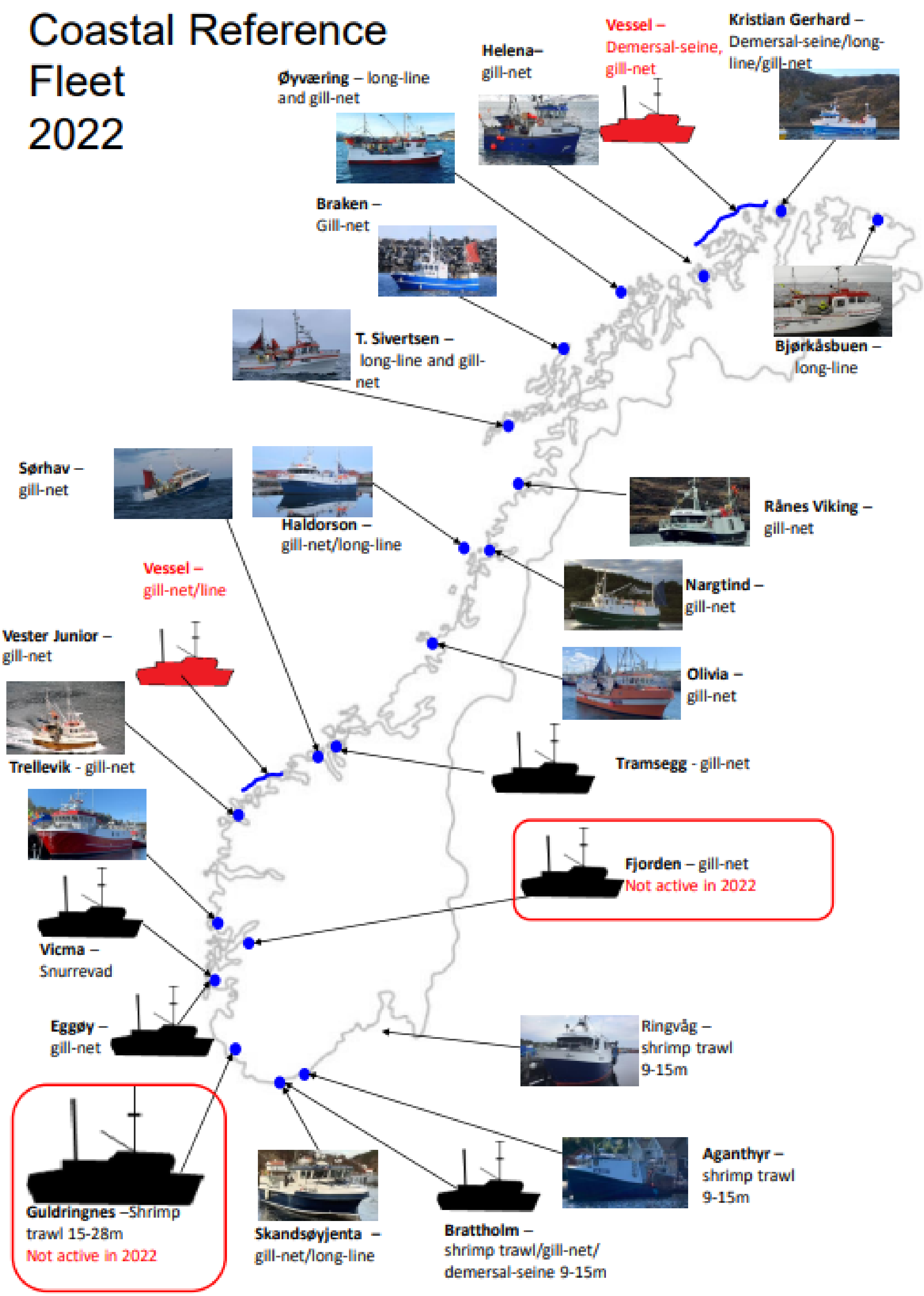
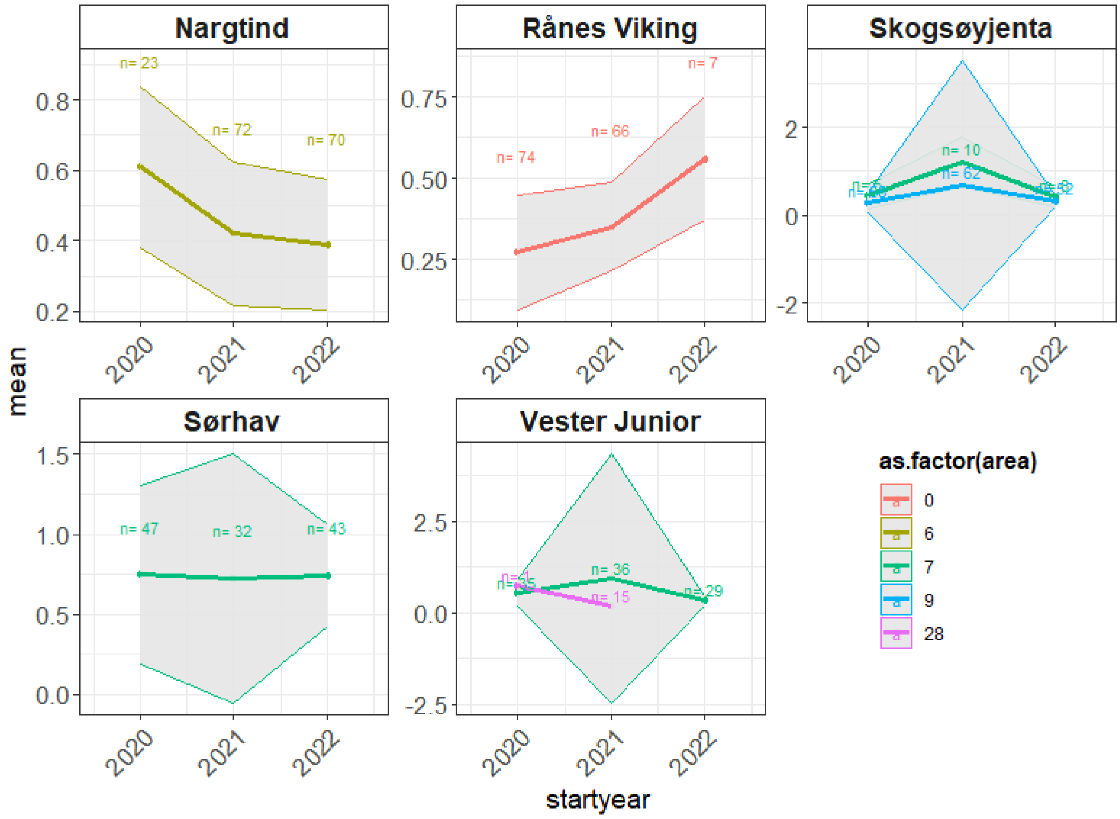



**Figure 9.16. Projected (2023–2025) biomass ($B/B_{MSY}$ - upper panel) and fishing mortality ($F/F_{MSY}$ - lower panel) trajectories for different levels of catch (color coded) using the base-case model.**

**Appendix figure H1.**



**Appendix figure H2. Mean +/- SD in the raw CPUE for the five vessels participating in the RF program during 2020–2022.**



**Appendix table H1. Data contribution (i.e. fishing events) from the various vessels participating into the coastal reference fleet program from 2007 to 2022.**

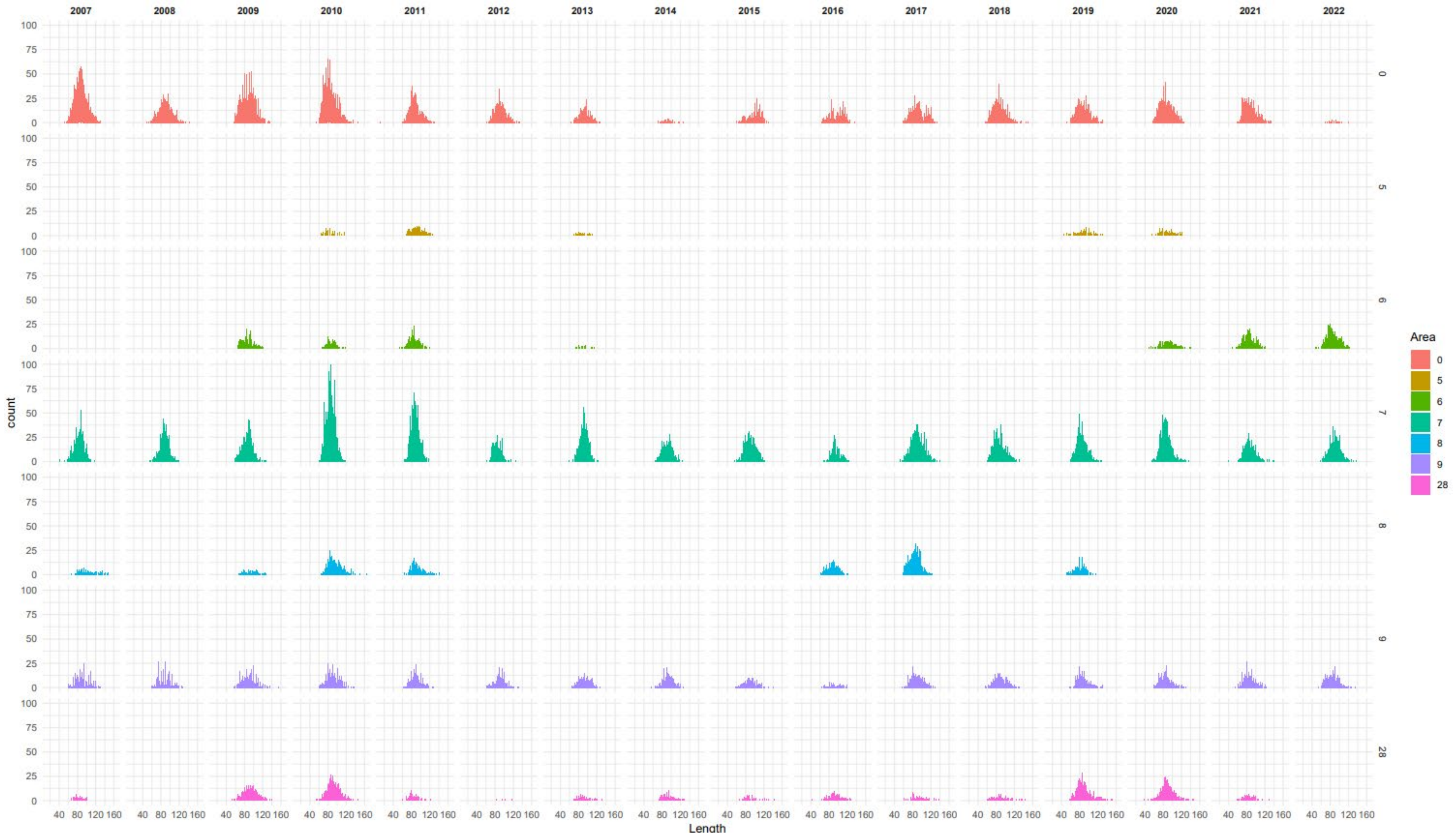
| Vessel | Year | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
| Ben Hur | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Braken | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 28 | 0 | 0 |
| Britt Evelyn | 0 | 0 | 0 | 0 | 0 | 10 | 23 | 32 | 17 | 20 | 37 | 26 | 33 | 36 | 0 | 0 |
| Eggøy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 |
| Eggumsværin | 0 | 0 | 22 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Elias | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fanøyvåg | 0 | 0 | 0 | 3 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fjorden | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 34 | 0 | 0 |
| Haaværbuen | 158 | 135 | 102 | 92 | 69 | 0 | 42 | 22 | 41 | 26 | 0 | 0 | 0 | 0 | 0 | 0 |
| Haldorson | 0 | 0 | 12 | 0 | 35 | 24 | 0 | 8 | 5 | 22 | 0 | 0 | 0 | 29 | 0 | 0 |
| Heimdal | 32 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hellskjær | 0 | 0 | 0 | 0 | 0 | 12 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nargtind | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 72 | 70 |
| Nimrod | 74 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Økssund | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 113 | 90 | 82 | 56 | 25 | 0 | 0 | 0 |
| Øygutt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ramona | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rånes Viking | 32 | 49 | 86 | 87 | 68 | 49 | 65 | 0 | 66 | 55 | 69 | 90 | 71 | 74 | 66 | 7 |
| Skogsøyjenta | 33 | 23 | 53 | 28 | 33 | 31 | 52 | 51 | 57 | 15 | 85 | 69 | 94 | 63 | 72 | 58 |
| Snarsetværin | 26 | 72 | 18 | 30 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Solgløtt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sommarøybue | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sørhav | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48 | 40 | 51 | 47 | 32 | 43 |
| Stording | 0 | 0 | 18 | 27 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| T.Sivertsen | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thema | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tom-Robert | 128 | 47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tramsegg | 122 | 37 | 73 | 51 | 48 | 21 | 39 | 55 | 35 | 1 | 1 | 3 | 4 | 24 | 21 | 0 |
| Trellevik | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 16 | 0 | 0 | 0 |
| Vågøybuen | 0 | 6 | 24 | 35 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vandsøyvåg | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vester Junior | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 20 | 18 | 43 | 41 | 12 | 36 | 51 | 29 |
| Vicma | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 53 | 151 | 0 | 0 | 0 | 0 | 0 |

**Appendix table H2. Input data to the JABBA assessment in the form of catch and abundance indices of anglerfish (L. piscatorius) in ICES subareas 1 and 2.**

| Year | Catch | CPUE (mean) | CPUE (SE) |
|---|---|---|---|
| 1990 | 151 | | |
| 1991 | 180 | | |
| 1992 | 488 | 0.5 | 0.3 |
| 1993 | 3042 | 1 | 0.2 |
| 1994 | 1024 | 0.5 | 0.1 |
| 1995 | 526 | | |
| 1996 | 887 | | |
| 1997 | 601 | | |
| 1998 | 1549 | | |

| Year | Catch | CPUE (mean) | CPUE (SE) |
|---|---|---|---|
| 1999 | 1743 | | |
| 2000 | 2999 | | |
| 2001 | 3624 | | |
| 2002 | 2071 | | |
| 2003 | 2477 | | |
| 2004 | 3001 | | |
| 2005 | 2735 | | |
| 2006 | 4348 | | |
| 2007 | 4591 | 0.49 | 0.06 |
| 2008 | 4151 | 0.48 | 0.07 |
| 2009 | 4458 | 0.52 | 0.06 |
| 2010 | 5515 | 0.46 | 0.05 |
| 2011 | 5112 | 0.53 | 0.07 |
| 2012 | 3765 | 0.39 | 0.05 |
| 2013 | 3103 | 0.28 | 0.03 |
| 2014 | 1657 | 0.30 | 0.04 |
| 2015 | 1043 | 0.32 | 0.04 |
| 2016 | 1435 | 0.28 | 0.04 |
| 2017 | 1484 | 0.34 | 0.05 |
| 2018 | 1903 | 0.37 | 0.05 |
| 2019 | 2809 | 0.33 | 0.04 |
| 2020 | 2280 | 0.48 | 0.06 |
| 2021 | 2601 | 0.37 | 0.05 |
| 2022 | 2293 | 0.25 | 0.15 |

**Appendix figure H3. Length distributions of anglerfish *(L. piscatorius)* caught and retained in large-meshed gillnets per year and Norwegian statistical areas. Areas 0, 5, 6 and 7 represent ICES Subarea 2. Note the different scale of the *y*-axis in App. figs H3-H5.**



**Appendix figure H4. Length distributions of anglerfish *(L. piscatorius)* caught as bycatch and retained in other gillnets per year and Norwegian statistical areas. Note the different scale of the *y*-axis in App. figs H3-H5.**

**Appendix figure H5. Length distributions of anglerfish (*L. piscatorius*) caught as bycatch and retained in other gears per year and Norwegian statistical areas. Note the different scale of the *y*-axis in App. figs H3-H5.**

# Section contents