Overview of annual Shetland Inshore Fish Survey (SIFS) data (2011 - 2022)

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Executive summary

An overview of results from the Shetland Inshore Fish Survey (SIFS) conducted by UHI Shetland (formerly NAFC Marine Centre) from 2011 - 2022 in the coastal waters around Shetland is presented. The purpose of the survey is to provide independent information on the distribution, relative abundance, and population structure of fish species in local waters. Key results from the available data are reported here with a focus on commercially important species. This report is intended for a general audience with information presented in a concise and non-technical format.

The survey has been carried out annually using the 12 m MFV *Atlantia II* (LK 502) during August and September, using a standardised survey trawl fitted with a small-mesh (20 mm) cod-end. The original annual inshore fish survey involves hauls from 27 pre-defined locations within 12 nautical miles of Shetland. Since 2017, a concurrent shallow fish survey has also been undertaken with up to 25 hauls targeting potential nursery grounds around the coast of Shetland. Catch rate results are used to investigate the relative abundance of commercial species by considering catch per unit effort (CPUE). Length data are used to further interpret variations in population structure and recruitment.

Results are presented for the most significant commercially important demersal fish species sampled throughout the surveys. Key findings from the 2022 surveys include:

- Haddock (*Melanogrammus aeglefinus*) was the main component of catches, and catch rates continue to be relatively high this year following the record levels observed in 2021. The 2022 length data were characterised by a large number of marketable haddock on inshore grounds and a distinct age-0 peak in shallow areas.
- In contrast, cod (*Gadus morhua*) and whiting (*Merlangius merlangus*) relative abundance was low this year compared to previous years, except for cod in shallow areas.
- Squid (*Loligo* spp.) were a much higher proportion of overall catches in 2022 than in previous years and the mean catch rate for squid this year were the highest yet recorded in the survey timeseries.
- Catches of flatfish and skate from inshore hauls were at the lower end of observed catch rates for these species, while results from shallow areas were more mixed.
- The data from shallow hauls suggests that some nearshore grounds around the coastline of Shetland are nursery areas for a variety of commercial species, for example plaice (*Pleuronectes platessa*) and monkfish (*Lophius* spp.).

Final points of this report include suggestions for further analyses and the recommendation that the annual inshore and shallow fish surveys are continued.

1 Introduction

The provision of accurate data for analyses makes effective field sampling essential for understanding marine environments. The management of demersal fisheries resources requires data on the distribution and relative abundance of the fish species present on or just above the seabed. Understanding the population ecology of target species also requires further biological information.

Data from commercial fisheries are key components of stock assessments for many locally important species. However, the behaviour of individual fishing vessels targeting specific species and using different gear configurations can bias commercial data. Such effects must be considered when interpreting fisheries dependent data. Therefore, independent data from scientific fisheries surveys are an important additional source of information and annual surveys can be used to build valuable timeseries for investigating the dynamics of fish communities and for informing the management of fish stocks.

On a broad scale, the International Bottom Trawl Survey Working Group (IBTSWG) coordinates international survey programmes for the International Council for the Exploration of the Sea (ICES). These programmes include annual fisheries-independent surveys in the North Sea and Northeast Atlantic which use a fleet of large research vessels from multiple countries to collect data from hundreds of hauls. However, the spatial resolution of these surveys is limited by the large areas that require to be covered and as a result usually only two 30 minute hauls are undertaken in each approximately 30 x 30 nautical mile statistical rectangle. Consequently, a smaller-scale survey using a vessel capable of sampling nearshore areas is beneficial for monitoring local temporal and spatial trends.

An annual fish survey has been undertaken in the waters around Shetland by the NAFC Marine Centre and now UHI Shetland since 2011. This survey was originally initiated in response to fishermen reporting high abundances of small cod on inshore fishing grounds (inside 12 nautical miles and approximately 50 - 150 m depth). Standardised scientific trawling gear and fishing methods have been used to provide an independent index of the nearshore distribution and relative abundance of demersal fish species. By repeating the survey each year, the resulting data have become increasingly valuable for determining the inter-annual variability of nearshore fish catch rates. Since 2017, these data have been further enhanced by an extended survey design which targets potential nursery grounds in shallow areas (approximately 20 - 50 m) to collect additional information on juvenile fish (those smaller and younger fish yet to reach sexual maturity).

The catch from each haul provides information on which species are present at that location and in what quantities, as well as the size compositions of key species. Size information is used to infer population structure and to indicate the strength of particular year-classes (those fish born in any one year) which can reveal variations in recruitment (the number of

fish surviving to enter the commercial fishery). Young individuals yet to be recruited to the fishery can be captured using scientific trawl gear utilising small mesh sizes. Consequently, scientific trawl data provide important information on juvenile abundances which is not available from commercial landings due to the commercial restrictions on landing sizes and gear design.

The use of standardised survey methods is essential to ensure that any changes in catches through time accurately reflects variability in the composition of demersal fish communities. The efficiency of trawling gear at catching fish is species-dependent, and so trawl surveys typically provide relative estimates rather than information on absolute abundances. Multiple hauls across a range of areas enables more robust estimates to be made and the variability of results to be quantified.

This report provides an overview of key results from the available survey data collected from 2011 to 2022. The focus of this report is on information for marketable demersal species which are most significant to the local mixed whitefish fishery. Results are presented in a concise and non-technical format aimed at being accessible to all those involved in fisheries and the general public. The purpose of this report is to: (1) provide an up-to-date and independent source of information on the present relative abundance and recruitment of commercially important fish species in the nearshore waters around Shetland; and (2) to contextualise these results within the inter-annual trends in catch rate and size composition from the previous 11 continuous years of survey data.

2 Materials and methods

2.1 Survey design

The Shetland Inshore Fish Survey (SIFS) has been carried out each year since 2011 during August and September around the coast of Shetland up to 12 nautical miles from shore. Initially the survey was designed to target known fishing grounds over a range of depths (approximately 50 – 150 m). In the first year, the locations of 21 survey tows were defined. In subsequent years, a further six tows were added giving 27 set inshore locations (Figure 1). In 2017, a shallow fish survey targeting potential nursery areas was added, sampled concurrently to the original inshore fish survey, and has been undertaken annually since. The 25 additional shallow water tows were chosen to follow a similar coverage around Shetland as the existing inshore survey but to extend coverage onto comparatively shallow grounds of approximately 20 – 50 m (Figure 1). Tow duration is variable in the shallow tows, ranging from approximately 0.17 – 0.60 hr (average is 0.39 hr), due to the limited suitable ground available in most shallow areas. The survey was carried out under a derogation granted by Marine Scotland and with survey hauls in protected areas approved following input from NatureScot.

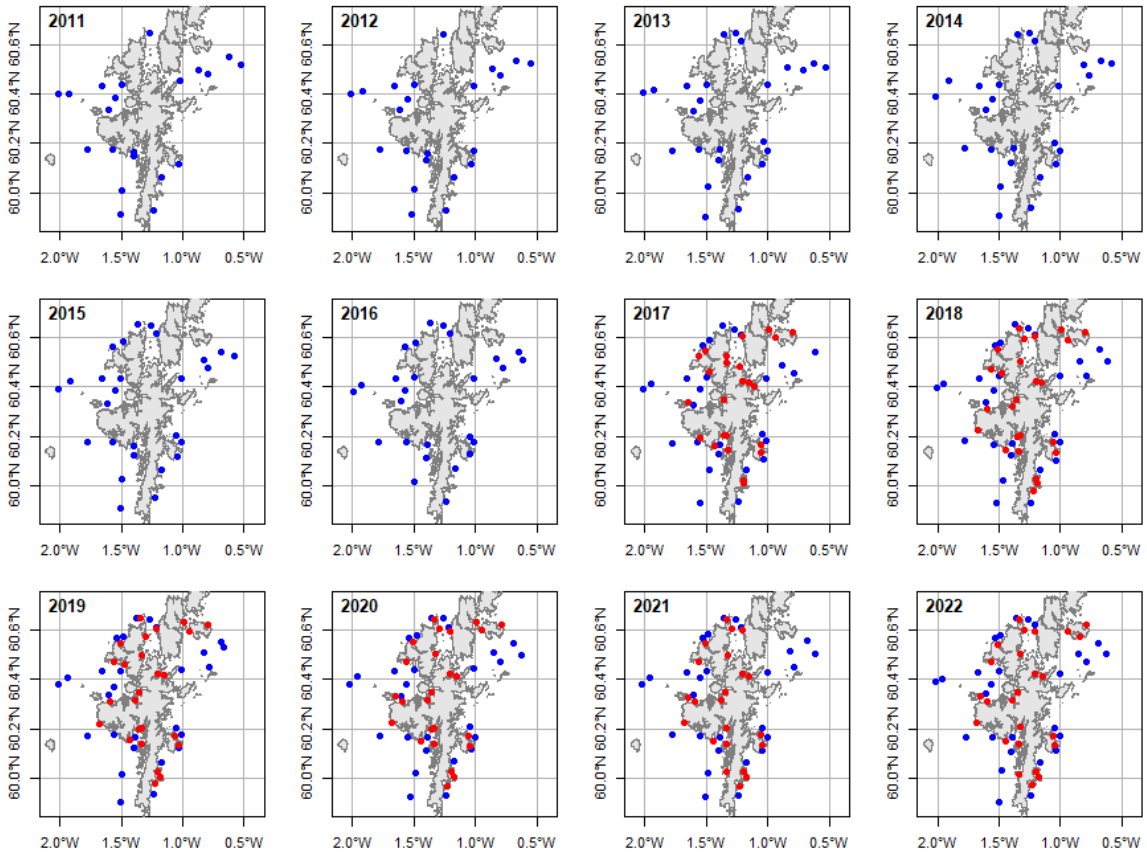

Figure 1. The locations of inshore (blue) and shallow (red) haul locations shown by year. Each location shows the approximate mid-point of each valid haul.

2.2 Trawl data

Survey work was conducted by UHI Shetland staff aboard the 12 m MFV *Atlantia II* (LK 502). The survey gear was based on a standard four-panel box trawl fitted with a small-mesh (20 mm) inner net. The gear was towed at approximately 2.5 knots with tow duration defined by the time from when the doors and net were on the seabed until when the trawl winch was engaged to haul the gear. Door spread and trawl headline height were monitored using a Notus net monitoring system. At each location, a towing duration of 1 hr was used whenever operationally possible. The presence of static fishing gear and other obstructions results in some variation in the locations and durations of survey tows from year to year.

The catch from each haul was first sorted then weighed by species. For commercially important species the individual fish total lengths were measured. Length data were also collected for flapper skate (*Dipturus intermedius*) but are not presented here. Subsampling for length measurements was necessary in some hauls for species caught in particularly high abundances, in which case a random subsample was taken and its weight measured. Hauls which were potentially affected by damage to the gear or operational problems were invalidated and excluded from analysis. Invalidated hauls were repeated when possible.

2.3 Data analysis and interpretation

The analysis presented here is restricted to the main commercially important demersal fish species present throughout the surveys:

- Haddock (*Melanogrammus aeglefinus*)
- Plaice (*Pleuronectes platessa*)
- Whiting (*Merlangius merlangus*)
- Cod (*Gadus morhua*)
- Monkfish (*Lophius* spp.)
- Squid (*Loligo* spp.)
- Lemon sole (*Microstomus kitt*)
- Thornback ray (*Raja clavata*)
- Cuckoo ray (*Raja naevus*)
- Spotted ray (*Raja montagui*)
- Saithe (*Pollachius virens*)
- Megrim (*Lepidorhombus whiffiagonis*)
- Witch (*Glyptocephalus cynoglossus*)
- Ling (*Molva molva*)
- Turbot (*Scophthalamus maximus*)
- Hake (*Merluccius merluccius*)

Data are shown separately for the inshore and shallow elements of the survey due to both the difference in timeseries of the data (only since 2017 for the shallow hauls) and due to the differences in catches from shallow hauls compared to those from the established inshore hauls.

In order to provide an index of relative abundance for each species the catch rate was considered. Catch rate is expressed as the catch per unit effort (CPUE) which is calculated per species for each haul by dividing the catch by the tow duration. While catch is generally quantified in terms of weight, this approach is less sensitive to hauls with high numbers of undersize fish which may be of interest when considering future recruitment to the fishery. Consequently, CPUE was considered both in terms of weight (kg / hr) and in terms of the number of individual fish (number / hour). Only weight data are available for squid. The average CPUE was calculated across all hauls in each year, and the variability between hauls was quantified by the standard error of the mean.

The size compositions of catches were investigated in more detail by considering length frequency distributions. For the above species, the total number (count) of individual fish in each 1 cm length class was calculated for each haul and corrected for sub-sampling when necessary, then summed over each year. Peaks in length frequency distributions can indicate a specific year-class, the age of which was inferred by using established age-length relationships for the species.

3 Results

Results are arranged by species in order of overall contribution by weight or number to inshore survey catch data. Results from both the inshore and shallow survey elements are coloured and superimposed to aid comparisons. From some species, low abundances (for example turbot) or very high variability between hauls (for example saithe) limit the scope for meaningful analyses but these results are included for completeness and to form a baseline of data for future studies.

3.1 Catch rates by weight

CPUE results by weight are presented in Figure 2. The primary overall components of the 2022 marketable inshore catches were haddock, plaice, and whiting; followed by cod, monkfish, squid, and lemon sole. Skate species also formed a substantial portion of catches, particularly thornback and cuckoo rays. Other commercial demersal species formed a relatively small component of overall catches.

For most species, catch rates in the shallow hauls were less than those from the inshore hauls. Some species which were regularly present in inshore hauls were absent in the 2022 shallow hauls (witch and ling). In contrast, catch rates of plaice, thornback ray, and spotted ray were markedly higher in the 2022 shallow hauls compared to the inshore hauls. While in other cases, such as cuckoo ray, CPUE by weight results were more similar between the inshore and shallow hauls.

Haddock catches in 2022 follow a similar pattern in both inshore and shallow hauls, with a decrease in catch rate by weight observed since the record high catches last year. However, inshore haddock catches this year were still relatively high compared to the overall timeseries. In contrast, whiting catch rate this year was at a relatively low level in both the inshore and shallow elements of the survey.

The 2022 cod catch rate was very similar to last year in the inshore hauls and was still well below the survey average. Mean cod catch rate results for the inshore and shallow hauls followed a very similar trend between 2019-2021; however, this year they have diverged with the results indicating the highest mean cod CPUE by weight recorded so far in the shallow surveys.

Inshore catches of plaice and lemon sole this year are very similar to last year and at the lower end of observed catch rates for these species, while shallow catches are at approximately average levels in both cases.

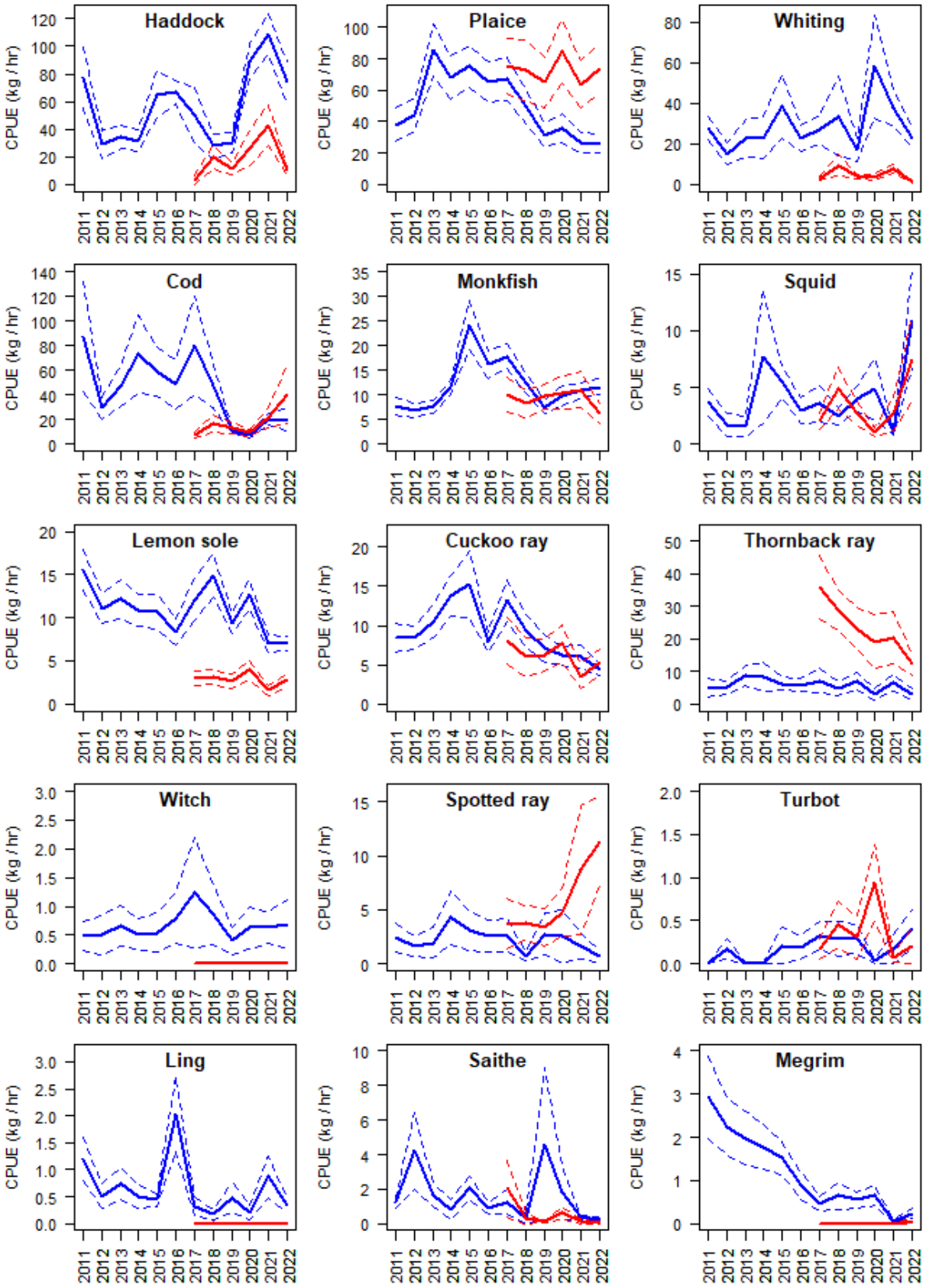

Figure 2. Catch per unit effort (CPUE) by weight for the inshore (blue) and shallow (red) elements of the fish survey. Presented species are selected and ordered by overall contribution to 2022 inshore CPUE by weight. For each year of available data the mean result for all valid hauls is shown (solid lines) with the variability between hauls indicated by the standard error (dashed lines). **How to interpret: these results show how the average catch rates in weight (y-axis) have changed over time from 2011 to 2022 (x-axis) for each selected species.**

Squid formed a much higher proportion of overall catches in 2022 than in previous years. Mean catch rate results for squid this year were the highest yet recorded in both the shallow (7.46 kg / hr) and inshore surveys (10.93 kg / hr), exceeding previous record years in 2014 (for inshore hauls) and 2018 (for shallow hauls). For context, the overall average squid CPUE over the preceding years was 2.68 kg / hr in shallow hauls and 3.56 kg / hr in inshore hauls.

Inshore catches of skate species were at a low level this year compared to previous years; while shallow catches were more mixed with a declining trend indicated by the thornback ray results contrasting with the increasing trend observed for spotted ray.

For many other species, catch rates in 2022 were within the range and standard errors of results from previous years. Large standard errors indicate high variability between hauls, which was observed in species such as spotted ray and often coincided with years of higher average catch rates.

When considering catch results by weight the potential contribution of smaller fish in nursery grounds is more likely to be obscured, and so these results are investigated in more detail by considering CPUE results by number in the following section.

3.2 Catch rates by number

Catch rates by number of fish caught per hour are presented in Figure 3. The general patterns of these catch rates are similar to the results in Figure 2 in most cases, for example the skate and flatfish species. Where there is a divergence in trends between Figure 2 and Figure 3 it indicates a substantial change in the overall size composition of that species.

For most species, the 2022 CPUE by number fluctuates within the range and standard errors of results from previous years. For example, the inshore whiting catch rate (by number) in 2022 is down from the previous couple years but were very similar to results in 2013 and 2019. However, the whiting catch rate from the shallow hauls is at the lowest level so far recorded. Shallow catch rates by number for cod and haddock are also well below peak levels, for example as recorded in 2018. Similarly, substantially fewer numbers of monkfish were observed on shallow grounds this year compared to the relatively high numbers observed in 2021. Some species are characterised by high variability between hauls, for example inshore witch results and shallow spotted ray results.

To understand how the size composition of species has varied in more detail, length frequency distributions are examined in the following section.

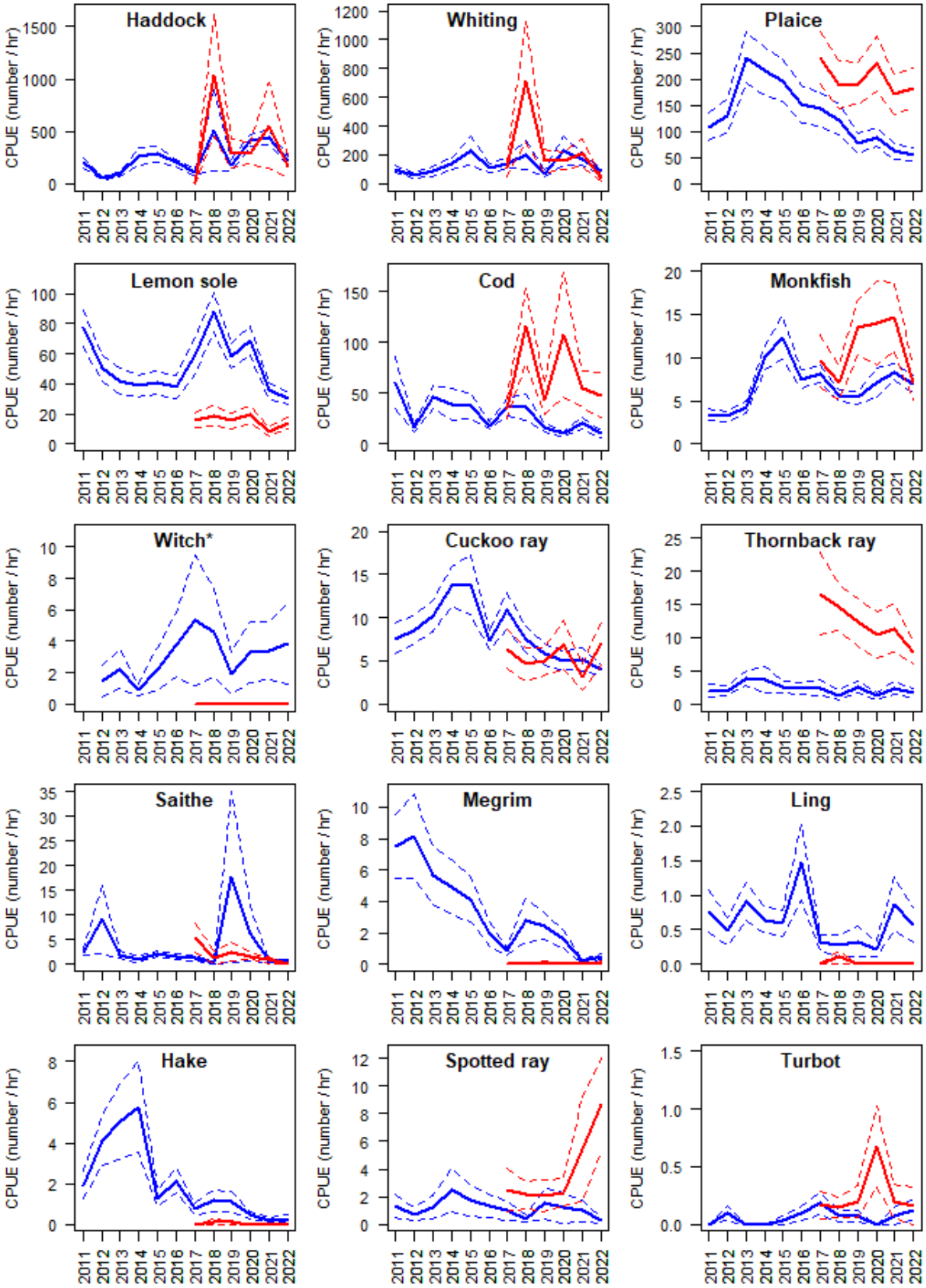

Figure 3. Catch per unit effort (CPUE) by number for the inshore (blue) and shallow (red) elements of the fish survey. For each year of available data the mean result for all valid hauls is shown (solid lines) with the variability between hauls indicated by the standard error (dashed lines). *Note that results for witch in 2011 are omitted due to unrecorded data. **How to interpret: these results show how the average catch rates in weight (y-axis) have changed over time from 2011 to 2022 (x-axis) for each selected species.**

3.3 Size compositions

The length-frequency distributions for each year are presented in Figure 4 to Figure 8. These results are interpreted in relation to changes in the population structure of the selected species in the shallow and inshore areas. Note that for simplicity of display these count data have not been standardised to survey effort (CPUE) and consequently the reader should not use these figures for making comparisons between quantities of catches in different areas and years.

The size composition of haddock catches (Figure 4) in both the inshore and shallow hauls continues to indicate strongly intermittent patterns in recruitment. Strong haddock year-classes can be followed over successive years, such as in 2014 where the clear peak in small haddock centred at 13 cm (age-0) can be followed to 26 cm (age-1) in 2015 and then at 35 cm (age-2) in 2016. Inshore haddock catches this year have a clearly defined dominant peak at 32 cm, likely associated with the peak at 24 cm observed last year and leading to relatively large numbers of marketable haddock in 2022. The presence of age-0 haddock is again visible in the data this year, particularly in the shallow hauls and centred around 13 cm.

Whiting length data (Figure 4) from inshore hauls in 2022 follow a similar pattern to the previous three years and is characterised by a single peak at 30 cm. There is very little indication of younger whiting year classes in inshore haul data from this year, and limited data from shallow hauls showing a peak of age-0 whiting at approximately 11 cm.

Cod length distributions demonstrate a relatively high variability in size composition over time (Figure 4). Inshore cod catches in 2022 were mostly composed of marketable length classes but spanned a relatively wide size range (7 - 92 cm) and with little evidence of some dominant peak as observed in previous years. Shallow haul results indicate a small peak of age-0 cod at around 12 cm and a larger peak centred at 35 cm, a similar general pattern to last year but with higher average length.

Plaice length distribution results continue to indicate a relatively stable size structure over time, this year peaking at approximately 33 cm in inshore hauls and 30 cm in shallow hauls (Figure 5). The 2022 plaice data from shallow hauls have a higher proportion of undersize fish but spans a wider range than the corresponding inshore data.

The lemon sole data (Figure 5) also show a relatively stable size composition in recent years, with little indication of distinct year classes. Inshore lemon sole length data indicate a broad peak centred at 27 cm this year, while the limited lemon sole catches in shallow hauls were composed of generally smaller fish peaking at 23 cm.

The monkfish length data (Figure 5) indicate a variable pattern through time and the presence of outliers over a relatively wide length range. Similar to that in previous years, the 2022

monkfish results indicate a relatively higher proportion of small fish on the shallow grounds compared to inshore areas with a peak at approximately 31 cm in the shallow hauls compared to 44 cm in inshore hauls.

Length data for thornback ray in 2022 was recorded over a wide length range (Figure 6), with the smallest specimen so far recorded observed this year (17 cm) in an inshore haul. Cuckoo ray results (Figure 6) show an asymmetric distribution, peaking in the inshore hauls at around 60 cm as in previous years. The high abundance of spotted ray observed this year in shallow grounds (Figure 6) is related to increased numbers across a broad size range and an overall relatively stable size structure.

Saithe and megrim were observed infrequently this year, predominately in inshore tows, yet spanned a considerable length range (Figure 7). Similarly, a limited number of ling were observed in inshore tows only, in abundances too low to enable much interpretation of population structure (Figure 7).

Witch results from inshore hauls in 2022 indicate a broad peak centred at 28 cm (Figure 8), similar to as in previous years. In the case of hake (Figure 8), some particularly small (down to 8 cm) examples were recorded this year. Turbot in 2022 were present again in limited numbers (Figure 8) in both shallow and inshore grounds, with the smallest individuals observed this year on the shallow grounds.

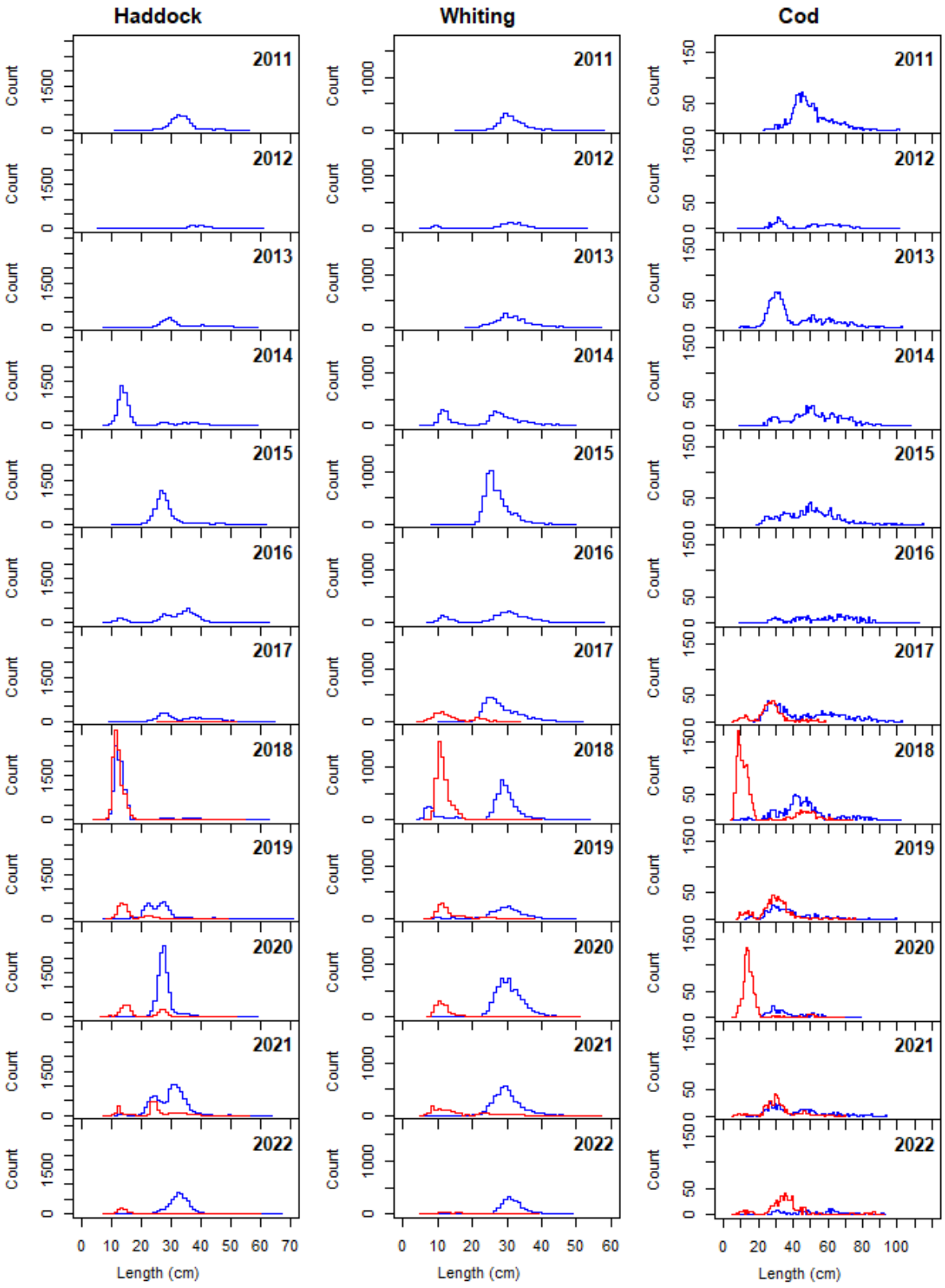

Figure 4. Length distribution results showing the total number (count) of individual fish in each 1 cm length class caught during the inshore (blue) and shallow (red) elements of the survey. **How to interpret: these results show the numbers of individual fish (y-axis) of each species in every 1 cm size category (x-axis) during each survey year. Note that these data are not standardised to survey effort.**

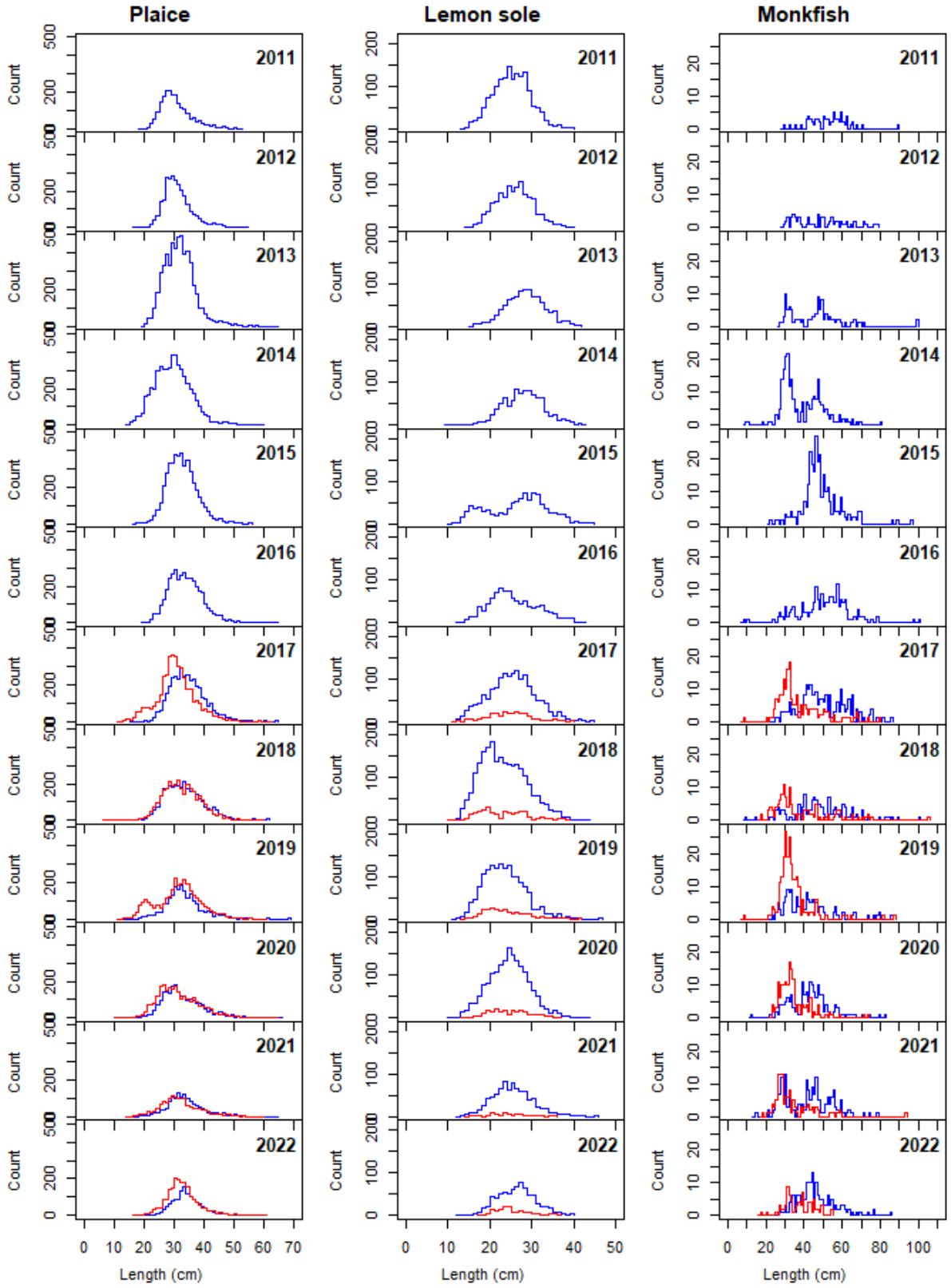

Figure 5. Length distribution results showing the total number (count) of individual fish in each 1 cm length class caught during the inshore (blue) and shallow (red) elements of the survey.

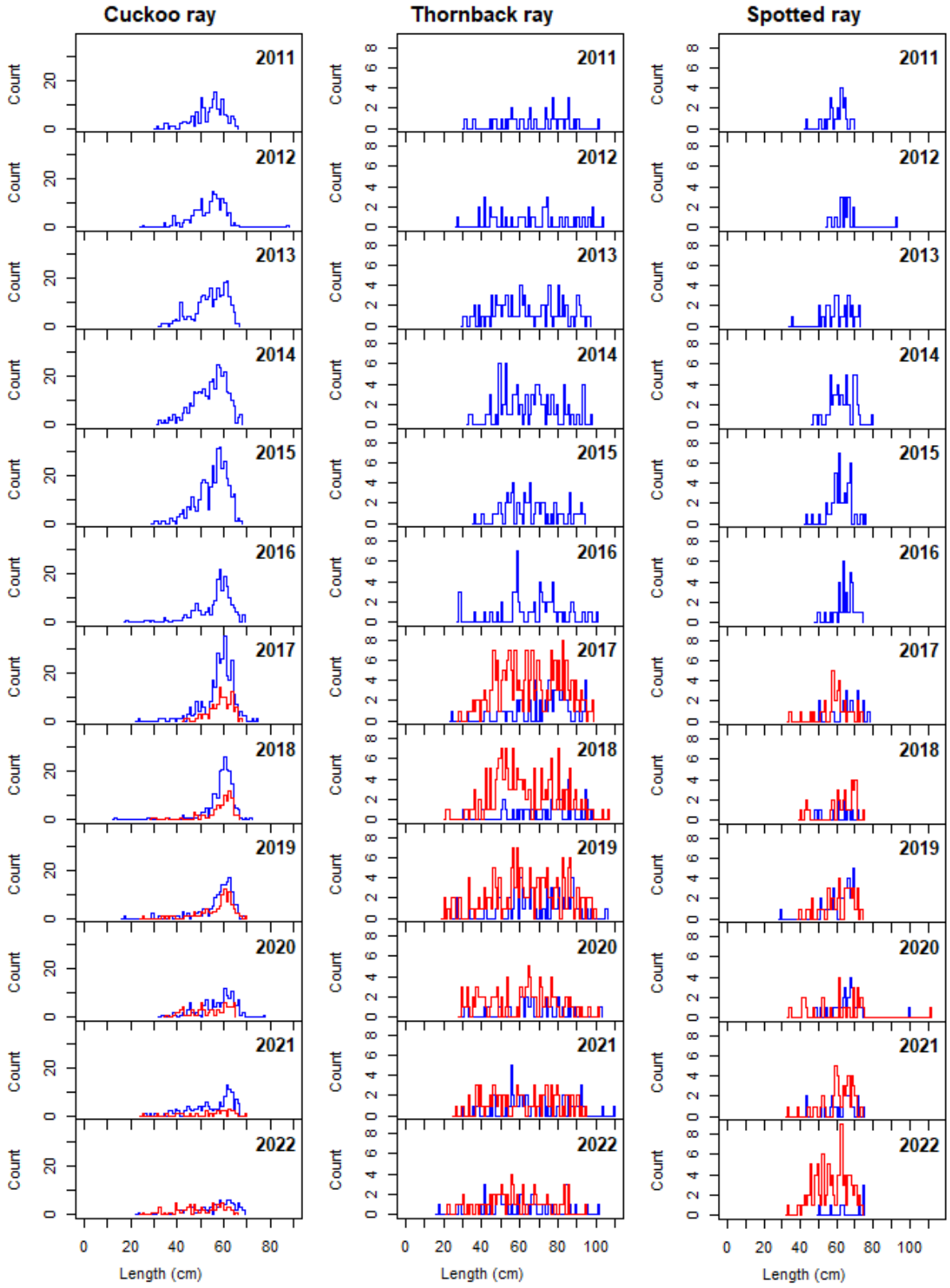

Figure 6. Length distribution results showing the total number (count) of individual fish in each 1 cm length class caught during the inshore (blue) and shallow (red) elements of the survey.

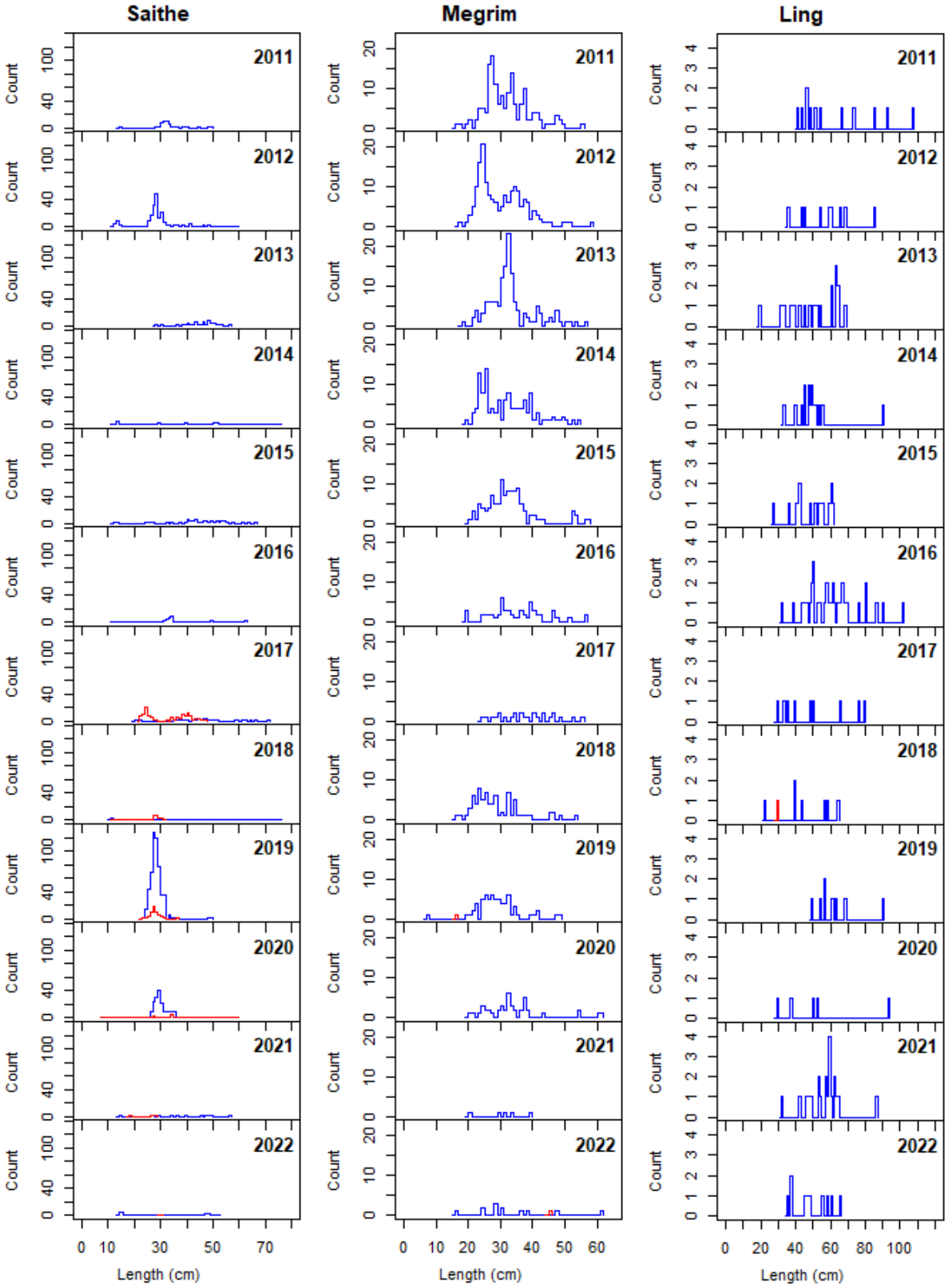

Figure 7. Length distribution results showing the total number (count) of individual fish in each 1 cm length class caught during the inshore (blue) and shallow (red) elements of the survey.

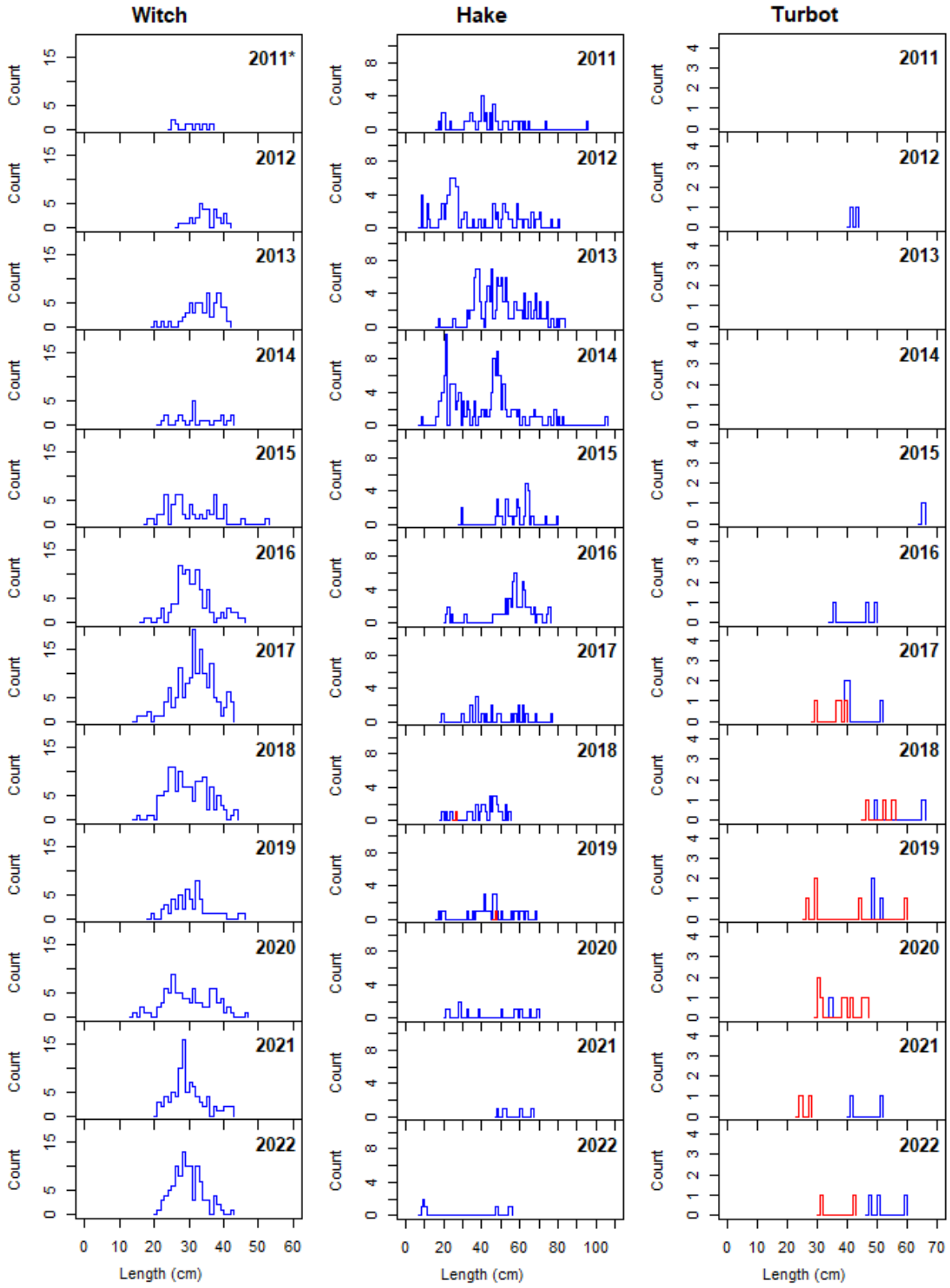

Figure 8. Length distribution results showing the total number (count) of individual fish in each 1 cm length class caught during the inshore (blue) and shallow (red) elements of the survey. *Note that length data for witch in 2011 were unrecorded for some hauls.

4 Discussion

Variations in the catch rates and size structure of commercial fish species around Shetland have been presented which summarise the 12 continuous years of annual survey data now available. As the temporal and spatial coverage of survey data has improved, trends and patterns in the relative abundance and distribution of locally important fish species can be investigated in increasing detail.

The main species contributing to the overall 2022 catches continues to be haddock, with inshore haddock catches this year characterised by a peak at 32 cm and strong numbers of marketable size classes. Haddock results also indicate a distinct age-0 peak in this year's shallow data, which follows similar previous observations that precede high levels of recruitment. In contrast, there was very little indication of juvenile whiting year classes in inshore haul data from this year, and limited data from shallow hauls corresponding to the lowest overall catch rate (by number) so far recorded. The 2022 cod catch rate results continue to be well below the survey average for the inshore hauls, but encouragingly in shallow areas the highest mean cod CPUE by weight was recorded this year.

The recruitment of gadoid species (which includes haddock, whiting, and cod) is known to be highly sensitive to random variations in environmental conditions and other factors. Haddock stocks in particular are well known to oscillate significantly in year-class abundances with periods of very good recruitment associated with significant increases to the overall stock. The available data here show that high catches of marketable fish follows evidence in the preceding years of the development of a strong year class, for example in the case of haddock over the last year and in 2015-2016. Such results indicate the utility of a survey of this scale and provides evidence that the methods used here can detect the strength of incoming recruitment from juvenile year-classes which can be followed through subsequent years. Although the future survival rates of undersize fish are unknown, given the results from previous years it seems likely that further recruitment to the local commercial fishery will be observed for species such as haddock and that strong relative abundances may again be detectable in larger length classes in future surveys.

The availability of survey data from shallow waters since 2017 has provided further valuable insights into the spatial distribution and population structure of some key species. In particular, the catch rates (by number) of cod and plaice in the 2022 shallow data exceeds catch rates in the inshore data which suggests that shallow areas around the coast of Shetland may be important nursery areas for these commercially important species. Shallow areas were also shown to have greater commercially exploitable abundances of some species, for example thornback ray. In contrast, the shallow data show that some species are recorded in relatively low abundances in shallow areas (for example lemon sole) or are completely absent (for example witch) which highlights the variation in environmental preferences among the selected species.

For many of the species considered here, this year's results were within the range of previous observations. However, the 2022 results indicate the highest catch rates (by weight) so far recorded for squid; corresponding to squid catch rates in inshore hauls which were over three times the average observed in preceding years. Squid length data are unavailable from these surveys; however, unlike the other species considered here squid are known to have a relatively simple population structure as they are short-lived and breed only once. Consequently, squid fisheries are often characterised by substantial interannual fluctuation in landings as annual stock size depends almost entirely on recruitment success and therefore is strongly affected by environmental conditions.

For some other species, this year's results showed relatively low catches on inshore grounds. For example, catch rates (by weight) for flatfish and skate species were less this year compared to previous years and seem to be related to a general decrease in relative abundance across all length classes. Similarly, some other species such as saithe and hake were observed in relatively low numbers in this year's inshore survey.

The overview presented here is intended to provide a short summary for key commercial species, and so there remains a wide range of opportunities for further analysis and interpretation of the SIFS dataset. For example, an analysis of non-commercial fish species is beyond the scope of this report but could provide additional insights on various important prey species and the overall local marine ecosystem. Similarly, further statistical tools could be applied to enable the significance of results to be investigated in more detail. An analysis of spatial distributions could be considered to explore trends with area and depth in more detail. The annual survey provides scope for further sampling efforts, for example the collection of fish diet samples. The increasing temporal coverage of the SIFS data provides additional opportunities for comparison to data from international surveys and local studies to investigate the interactions of species and associations with environmental characteristics.

The timely reporting of the data presented here should support the value and practicality of the SIFS to fisheries management organisations and local industry bodies. Future continuity of the annual trawl surveys around Shetland is recommended which would add value to the extensive dataset already collected and contribute to a comprehensive long-term understanding of the dynamics of inshore demersal fish communities.

5 Acknowledgements

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