Centre for Environment Fisheries & Aquaculture Science

Cefas

Assessment of king scallop stock status for selected waters around the English coast 2019/2020

A Defra and Industry Funded Project

Andrew Lawler and Nikolai Nawri

March 2021

This publication is available at www.gov.uk/government/publications

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Cefas Document Control

Submitted to:	Helen Hunter
Date submitted:	14th April 2021
Project Manager:	Nicki Hawkes
Report compiled by:	Andy Lawler and Nikolai Nawri
Quality control by:	Stuart Reeves
Approved by and date:	25th March 2021
Version:	V2.0
Recommended citation for this report:	Lawler, A. & Nawri, N., (2021). Assessment of king scallop stock status for selected waters around the English coast 2019/2020. Cefas Project Report for Defra,+ 89 pp.

Version control history

Version	Author	Date	Comment
V1.0	Lawler, A. & Nawri, N	25/01/21	1st draft
V2.0	Lawler, A. & Nawri, N	25/03/21	2nd draft

Executive Summary

This report details the status and development of selected king scallop stocks around England in 2020. King scallop (*Pecten maximus*) fisheries around English coasts represent the most valuable single marine species in the region. The stocks in the English Channel and approaches to the Bristol Channel are internationally exploited primarily by the UK and France using towed dredges. These fisheries are not governed by EU or national total allowable catches (TACs), and the stocks were not subject to routine monitoring or formal assessment prior to 2017. Annual assessments have been undertaken since 2017 by the Centre for Environment, Fisheries and Aquaculture Science (Cefas), as part of a collaborative project with the UK fishing industry, the UK Department for Environment, Food and Rural Affairs (Defra), and the UK Sea Fish Industry Authority (Seafish). The number of stocks assessed has increased through time. In 2017, five stocks within the English Channel were assessed and two further stocks were added in 2018, one in the Bristol Channel and one in the North Sea.

The report describes the results from scientific surveys and the biological sampling programme in 2020. The results for previous years have been updated to account for improvements in the data and are included to show stock development. International landings after 2019 were not available at the time of writing of this report meaning the reported harvest rates for 2020 are therefore provisional based on estimates of what will be taken from the stock over the 12 months following the survey.

In 2017, five stock assessment areas were identified as being of importance to UK fisheries: three in ICES Division 27.7.e (Inshore Cornwall, 27.7.e.I; Lyme Bay, 27.7.e.L; Offshore, 27.7.e.O) and two in Division 27.7.d (North, 27.7.d.N; South, 27.7.d.S). In 2018 two additional assessment areas were defined, one in the approaches to the Bristol Channel (27.7.f.I) and another in Division 27.4.b (North Sea South, 27.4.b.S). These assignments are based on regional differences in growth and fishery exploitation patterns. Commercial landings data are available at the spatial resolution of ICES statistical rectangle (1 degree in longitude, 0.5 degrees in latitude), and their boundaries are used to describe the extent of the assessment areas.

This report assesses the status of the dredged portion of stocks in 27.7.d.N, 27.7.e.I, 27.7.e.L, 27.7.e.O, 27.7.f.I and 27.4.b.S, using dredge surveys, with additional estimates of unfished biomass in some parts of 27.7.e.I, 27.7.e.L, 27.7.e.O and 27.7.d.N from underwater television (UWTV) surveys. There is likely to be biomass of scallops outside those areas surveyed, for which there are no data to make any estimates. The biomass and exploitation rate of the fished portion of stock in the Bay de Seine (part of 27.7.d.S) is routinely estimated by French institute IFREMER. In 2018 we surveyed a small bed in 27.7.d.S that is not covered by the IFREMER assessment. These results are presented in the annex of this report.

Three data streams were used for the assessments described in this report: dredge surveys, UWTV surveys, and a biological sampling programme. Dredge surveys in the

main fished beds of 27.7.d.N, 27.7.e.I, 27.7.e.L, 27.7.e.O, 27.7.f.I, and 27.4.b.S were used to estimate scallop biomass available to the dredge fishery. The scallop biomass in some un-dredged regions of assessment areas 27.7.e.I and 27.7.e.L was estimated from UWTV surveys in the first year (2017), and areas in 27.7.e.O, 27.7.f.I and 27.7.d.N in the third year (2019). No UWTV survey has so far been undertaken in 27.4.b.S. The UWTV surveys originally planned for 2020 could not be carried out as a result of the restrictions imposed due to the Covid-19 pandemic.

A biological sampling programme will provide a time series of age structure of the removals, but these data are currently under review, and only size distributions are presented here. The biological sampling programme was significantly impacted by the pandemic during 2020.

This assessment establishes estimates of harvestable biomass (i.e., biomass above minimum landing size and in areas in which dredgers can operate), and the exploitation rate experienced by harvestable scallops. However, the assessment is not able to fully estimate the impact of the fishery on the wider stock, as we were unable to estimate the scallop biomass in all un-dredged areas. Dredge surveys and catch sampling only cover the portions of stock found on the main fished grounds, as identified by the areal density of Vessel Monitoring System (VMS) pings. Harvest rate estimates from dredge surveys or commercial sampling therefore only apply to the fished portion of the stock. In situations where there are significant portions of un-dredged stock that are contributing offspring to the fished areas, any estimates of maximum sustainable yield (MSY) harvest rates will, in future, need to be adjusted to compensate for this, should more information become available.

The potential harvest rates experienced by the surveyed portion of stocks were estimated by comparing international landings, or a proxy for them, to the harvestable biomass estimates, either for the dredged area only, or including also the biomass from un-dredged areas. Revision of international landings data this year has significantly reduced harvest rate estimates compared to last year for areas 27.7.d.N in 2017 (49% from 74.4%) and 2019 (26.7% from 41.2%) and for 27.7.e.L in 2019 (40.4% from 65.4%).

Estimates of harvest rate from dredge and UWTV surveys, together with a candidate for MSY.

Assessment Area	Provisional Harvest Rate on Dredged Portion of Stock* (Dredge Survey Only, %)				Provisional Harvest Rate for Wider Stock where UWTV Available* (Not Complete Coverage, %)				MSY Candidate (%)
	2017	2018	2019*	2020**	2017	2018	2019*	2020**	
27.7.d.N	49.0	56.2	26.7	21.4	48.9	56.1	26.7	21.4	21.5

Assessment Area	Provisional Harvest Rate on Dredged Portion of Stock* (Dredge Survey Only, %)				Provisional Harvest Rate for Wider Stock where UWTV Available* (Not Complete Coverage, %)				MSY Candidate (%)
	2017	2018	2019*	2020**	2017	2018	2019*	2020**	
27.7.e.I	37.6	16.8	17.5	20.7	22.9	11.0	12.1	13.5	19.5
27.7.e.L	54.7	77.0	40.4	30.6	27.3	39.9	22.6	19.2	21.0
27.7.e.O	11.0	13.6	12.5	6.4	10.3	12.8	12.1	6.3	20.9
27.7.f.I	-	8.8	39.7	35.4	-	7.2	29.9	27.4	-
27.4.b.S	-	47.0	17.8	11.7	-	-	-	-	-

* estimated from UK removals and 2017-2019 UK market share, to be revised.
** estimated from UK removals and 2017-2019 UK market share, or estimate from previous year, whichever is higher, to be revised.

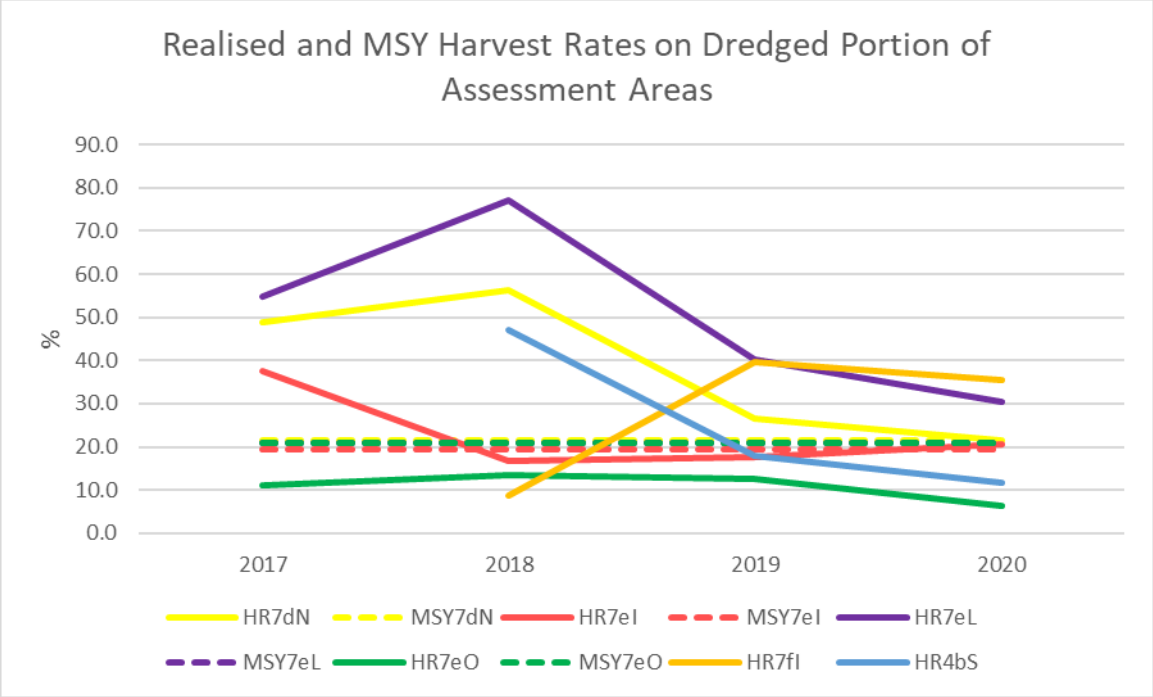

Figure 1: Comparison between realised and maximum sustainable yield (MSY) harvest rates in the dredged parts of the king scallop assessment areas.

With the short time period covered by our king scallop assessments, the results presented here are still preliminary. They are the start of a long-term monitoring and assessment programme, and processes and methodologies are likely to evolve in the future. As the

time series of data develops and increases in comprehensiveness, this will in turn contribute to a more robust determination of the stock status of king scallops in this region.

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1. Introduction

1.1. Biology

1.1.1. Range and habitat

The king scallop (*Pecten maximus*) is a large bivalve mollusc (up to 175 mm shell length, or 153 mm shell height) that is resident on the continental shelf of Northwest Europe. It is common at depths of 5 – 200 m, on substrates ranging from muddy sand to coarse gravel. The species ranges from northern Norway to Morocco, the Canaries and the Azores. Scallops are common around the British Isles.

1.1.2. Reproduction and settlement

Scallops are permanent hermaphrodites and are very fecund. A large scallop may produce 2 million eggs per spawning event. Spawning times vary from spring to autumn with some populations exhibiting two peaks of spawning over that period. Larvae remain in the plankton for around 30 days and may thus be dispersed over long distances. At metamorphosis, the larvae settle onto a primary site (often erect Hydrozoans and Bryozoans) to which they attach by means of byssus threads. On reaching a size of approximately 1-5 mm, they detach and settle onto the seabed, where they take up their normal habit, recessed into the substrate.

1.1.3. Growth

Growth in scallops is continuous with new material laid down along the outside edge of the shell in very fine ridges (striae). There is considerable seasonal variation in growth rates, and a compression of the growth ridges indicates periods of slower growth, usually associated with winter conditions. Other causes of slower growth (”growth checks”) occur when animals are stressed (such as after damage caused by interaction with scallop dredges), or due to sudden climatic changes. When determining the age of scallops by reading the annual growth rings on the upper (flat) shell, care must be taken not to confuse these stress induced growth checks with annual patterns. Growth rates are extremely variable even between adjacent beds, with the time required to reach the local minimum landing size (MLS) varying from 2 to more than 5 years.

Animals larger than the area-specific MLS are almost exclusively found to be mature. Based on unpublished data, Cefas assumes maturity to be knife-edged at 80 mm flat shell height in all assessment areas.

Methodology for ageing at Cefas is based on work carried out by (Dare, et al., 1989). Oxygen isotope assay was used to validate traditional ring counting methods and to produce von Bertalanffy growth parameters.

On the basis of these parameters, the von Bertalanffy model is used to estimate size at age,

$$H(t) = H_{\infty}\left(1 - \exp\left(-k(t - t_0)\right)\right) ,$$

where H_{∞} is asymptotic shell height, k is the growth rate, and t_0 is the time at zero size.

1.1.4. Shell size metric conversions

Two shell size metrics are specifically referred to in this report. The round shell is the lower curved valve, and its length is measured parallel to the hinge across the widest point. The flat shell is the top valve, and its height is measured perpendicular to the hinge.

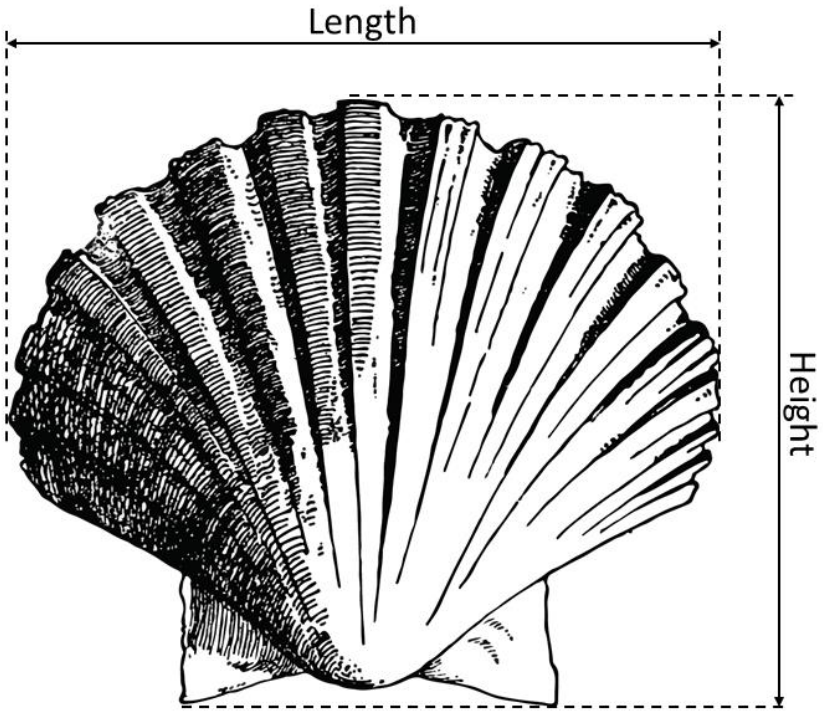

Figure 1.1: Scallop shell length and height illustrated based on the round (lower) valve.

The growing edge of scallop shells is the most fragile part of the shell and prone to damage. Scientific shell measurements are therefore generally taken on the flat shell height, as this axis has the least potential for damage. The MLS for scallop is, however, determined using the round shell length . As one purpose of the stock assessment is to estimate harvestable biomass, it is desirable to present results in length equivalents.

Consequently, parameters for converting shell metrics to the equivalent length of the round shell have been determined, such that round length can be calculated from flat height by means of a linear regression relationship,

$$L = a\,H + b\ .$$

1.1.5. Weight-length relationship

The relationship between live weight and round shell length is estimated by

$$W = a\,L^{b}\ ,$$

where a and b are area-specific positive constants, which are determined through regression analyses based on biological sampling data.

1.1.6. Natural mortality

Predation is the likely cause of most of the natural mortality (i.e., mortality not related to fishing activity), with brown crab and starfish being the most significant predators on scallops less than two years old. Scallops that reach sexual maturity are less vulnerable to predation due to the robustness of their shells.

Natural mortality is not precisely known. However, in common with other fish and shellfish stocks of similar longevity (up to 20 years), it is assumed to be 0.15 yr^{-1} for all ages and areas (Cook, et al., 1990).

1.2. Fishery

1.2.1. Overview

The fishery for the king scallop (*Pecten maximus*) in the English Channel (ICES Divisions 27.7.d (east) and 27.7.e (west)) is the most valuable single species fishery in the region with over 46,000 tonnes of international landings reported in 2019 (ICES, 2020). An additional 3,950 tonnes were reported for the fisheries off the English coasts in the North Sea and approaches to the Bristol Channel. The stocks are exploited principally by the UK and France, with additional activity from Ireland, the Netherlands and Belgium. Targeted fisheries predominantly use towed dredges although some commercial dive fisheries exist, particularly around Lyme Bay. *Pecten maximus* fisheries lie outside the EU total allowable catch (TAC) and quota regime, and fishery management measures are largely under the control of individual states.

EU regulations stipulate the minimum size of caught scallop that can be retained. In UK waters, this minimum landing size (MLS) is 100 mm round shell length, except for the Irish Sea (Division 27.7.a) and the Eastern Channel (Division 27.7.d), where it is 110 mm.

EU legislation also caps the effort that large vessels can utilise in ICES Subarea 27.7. This Western Waters effort regime places an upper limit on the number of kilowatt days fished by vessels with lengths > 15 m towing scallop dredges. Within the UK, this effort pool is administered by the Marine Management Organisation (MMO) in a system which sets a maximum number of days per quarter that any vessel with a scallop entitlement may fish. These limits are revised on a quarterly basis. In recent years, the Western Waters effort regime has been limiting for UK vessels, however the effort restrictions are not considered to be restrictive on French activity.

There is a distinct contrast between the UK and French fisheries, with the UK fisheries comprising a mix of large (> 15 m) nomadic vessels and smaller (10-15 m) vessels with a more localised range.

Scallop fishery management in the UK limits the number of licenses for scallop vessels longer than 10 m, and also introduces gear restrictions. The Scallop Fishing (England) Order 2012 applies to British vessels operating in English waters and places restrictions on the number of dredges that can be employed at any one time. It also specifies technical measures defining the type of dredge that can be used.

The French fishery is dominated by smaller vessels fishing much more inshore (on the French side of the Channel) and is concentrated in two zones: the Baie de Seine and the Baie de Saint Brieuc. The French management system is complex, with a range of quotas, and layers of temporal restrictions (seasonal and daily hours), with access and quota being determined at a local level.

Although the EU leaves scallop fishery management to its member states, the fisheries are in fact quite international, with multiple states fishing upon the same stock units. The lack of agreements and coordination of fishery management measures at an official level has led to tension between fishers from the UK and France when some vessels are seen to be operating in places and at times that other fishers are prevented by their own national rules (i.e. UK vessels fishing during the French closed season). A voluntary seasonal closure harmonisation has existed since 2013 between the majority of the UK scalloping industry and the French industry.

The UK left the EU on the 31st January 2020 and the transitional phase where the UK was still subject to EU laws expired 31st December 2020. The implications on fishery access, markets and management measures at the time of this report are still subject to further discussions . The Trade and Cooperation Agreements (TCA) between the EU and the UK includes conditions defining access of EU vessels to UK waters and UK vessels to EU waters. These are based on track record and are expected to replace existing arrangements. The details are not yet clear.

1.2.2. Discards and bycatch

Discards are known to occur in the fishery. However, no quantitative estimates have been made, and therefore this assessment does not include discards. As almost all discards are due to minimum size restrictions, the lack of discard data does not affect the estimation of harvestable biomass. Scallops are assumed to have a high discard survival rate.

Prior to 2019, there was a limit on retained fish bycatch in scallop dredges of 5% of the total retained catch of otherwise bivalve molluscs.

Since the complete phasing in of the EU Landing Obligation in 2019, scallop dredgers have been required to land all quota species (except skates and rays) regardless of catch component. However, for non-quota species the 5% bycatch rule applies as before.

1.2.3. Dredge efficiency

Pecten maximus inhabits substrates from fine sand through to coarse sand and gravel, in which it lies recessed into the seabed. However, such substrates may exist among varying amounts of rocks, stones, outcrops of bedrock and associated benthos, all of which will affect the efficiency of dredges. Gear efficiency is defined as the percentage of captured scallops in the path of the dredge. In order to assess the spatial distribution of the stock, whether from commercial catch per unit effort (CPUE) data, or from research surveys, it is important to be able to account for variations in gear performance. Any biomass estimates presented in this assessment are sensitive to the choice of substrate-specific efficiency parameters. The efficiency of spring-loaded dredges has been studied using diver observations, mark recapture methods and depletion studies (Chapman, et al., 1977; Dare, et al., 1993; Dare, et al., 1994; Jenkins, et al., 2001). However, it is a subset of unpublished results from a more recent depletion study carried out in the English Channel by Palmer and others at Cefas that have been used in this analysis.

Recent work at Cefas to determine a methodology for estimating dredge efficiency using novel technology (Radio Frequency Identification, RFID) has made significant progress but has not yet provided alternative efficiency coefficients to those used in previous years. Research with the aim of providing updated methodology and efficiency coefficients has been delayed due to restrictions imposed by the Covid-19 pandemic, but is ongoing.

1.3. Biological sampling programme

An extensive biological sampling programme was started in 2017 and is described in Annex 1. The programme collects both length and age samples with a higher collection rate for lengths than for ages, as is standard for fishery data collection programs. Sampling this year was significantly impacted by the pandemic. Age determination has highlighted some inconsistencies between the first two years of data that were not picked up during

routine quality control and required further investigation. These inconsistencies have been resolved but an ICES workshop was carried out in March 2020 to assist with development of ageing technique and to provide international contribution. A further ICES workshop is scheduled for October 2021. As such, although we continue to add to our valuable time-series of age data, only size compositions are presented in this report. We intend to carry out age structured assessments when longer time series of age data are available.

1.4. Stock unit assessment areas

Investigations into the transport and distribution of scallop larvae (Catherall, et al., 2014) indicate that scallops within ICES Divisions 27.7.d and 27.7.e are likely to compromise at least two biologically distinct populations, when viewed at the scale of multiple generations. This is due to the fact that a) larval interchange is considered to be only sporadic, b) there are distinct regional differences in growth rates and fishery management, and c) post-larval scallops exhibit largely sessile behaviour. Regional stock assessments are therefore appropriate.

Two stock assessment areas have been designated for ICES Division 27.7.d in the eastern English Channel, namely 27.7.d.N and 27.7.d.S, which are split along the 50ºN line (Figure 1.2). This split, dictated by the resolution of landings data, allows a separation of the faster growing Baie de Seine stock from the rest of the eastern Channel, and is considered appropriate for stock assessment purposes. Three stock assessment areas have been designated for ICES Division 27.7.e to reflect slow-growing inshore areas south of Cornwall (27.7.e.I), faster growing areas within Lyme Bay (27.7.e.L), and offshore scallop beds further to the south (27.7.e.O). Additional stock areas in the Approaches to the Bristol Channel (27.7.f.I) and in the North Sea (27.4.b.S) were introduced in 2018. The ICES statistical rectangles that define these assessment areas are listed in Table 1.1.

Two finer grids are defined for more detailed spatial analyses: a grid of 0.1-by-0.1 degree blocks, and a grid of 0.025-by-0.025 degree cells.

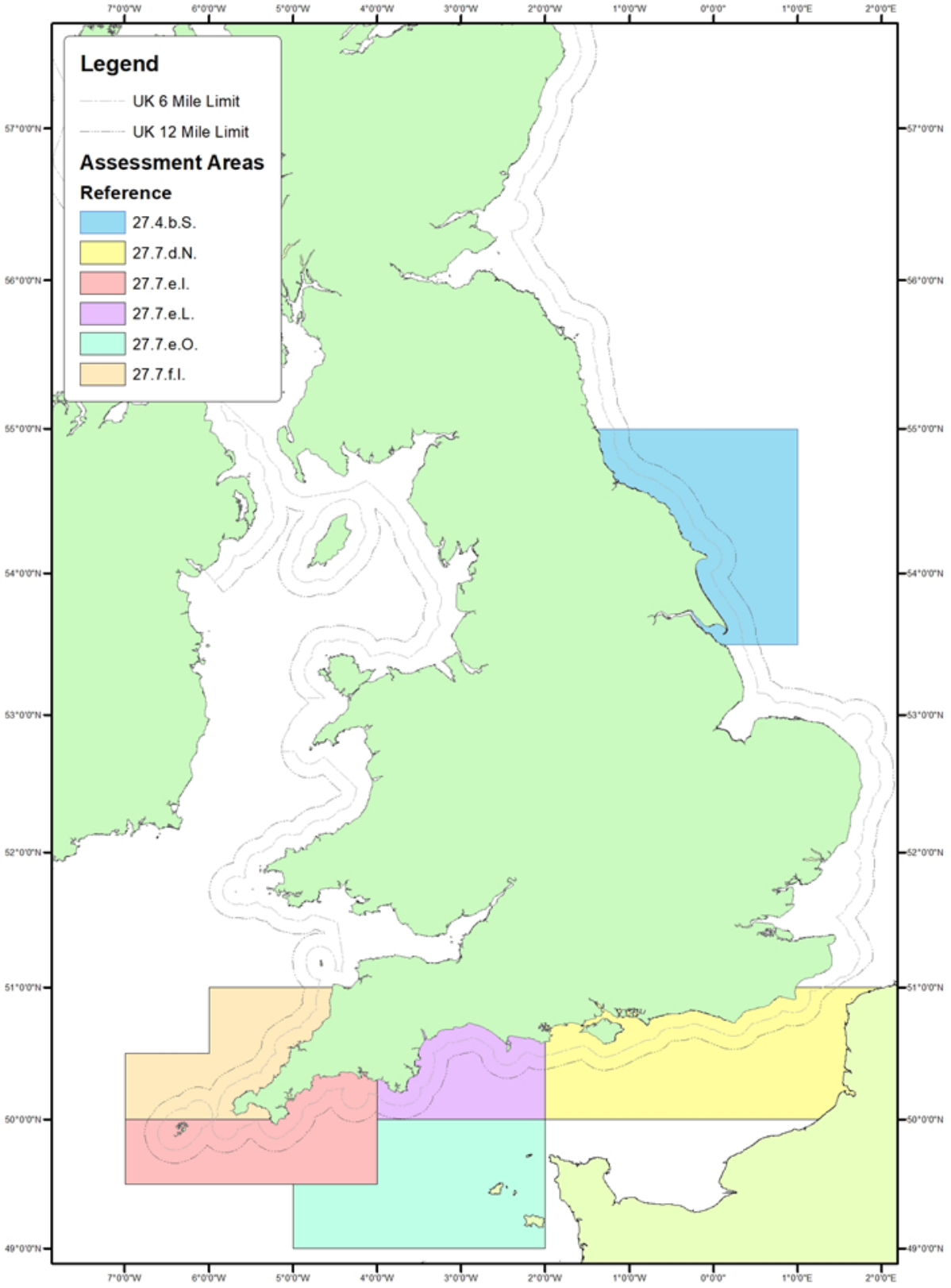

Figure 1.2: King scallop stock unit assessment areas defined in the English Channel, the Celtic and North Sea.

Table 1.1: Assessment areas by ICES statistical rectangle.

27.7.d.N	29E8	29E9	29F0	29F1	30E8	30E9	30F0	30F1
27.7.e.I	28E3	28E4	28E5	29E5	29E4*			
27.7.e.L	29E6	29E7	30E6	30E7				
27.7.e.O	27E5	27E6	27E7	28E6	28E7			
27.7.f.I	29E3	29E4+	30E4	30E5				
27.4.b.S	36F0	37E9	37F0	38E8	38E9	38F0		

* area within boundaries of Division 27.7.e.
+ area within boundaries of Division 27.7.f.

Scallop fisheries in the remaining ICES rectangles in Division 27.7.e are dominated by French coastal activity and therefore beyond the scope of this report. The majority of scallop landings in the English Channel are reported to originate from Area 27.7.d.S. It is covered by a survey conducted by IFREMER (France) and is therefore also not included in this report.

1.5. Survey data

The stock unit assessment areas described above are surveyed by dredging and underwater television. The processing of the dredge survey data is detailed in Annex 3. The essence of the approach is to determine the swept area of the gear and then calculate the harvestable biomass density and total catch of scallops at or above MLS from the area swept. Catch densities are then converted to population densities using the gear efficiency parameter appropriate for the particular ground type (Table 2.4). As described in more detail in the first assessment report (Bell, et al., 2018), an arithmetic approach was taken to raise the survey data, with the observed cells of randomly selected stations first being raised to the valid surface area of the containing block. Cells within unsampled blocks were assumed to have the same density as the average sample density from randomly selected stations. Since 2019, all tow positions have been randomly selected, negating the need to apply appropriate procedures to industry selected tows to maintain statistical integrity.

2. Stock assessment for surveyed parts of Area 27.7.d.N

2.1. Area definition

As described in Section 1.4, the 27.7.d.N assessment area covers the northern half of ICES Division 27.7.d, with the main fishery covering a large bed which stretches across the mid-eastern part of the Channel, straddling the border between UK and France (Figure 2.1). The perimeter of the bed was defined using Vessel Monitoring System (VMS) data (see Annex 2). Using VMS data does mean that the bed represents only those grounds fished by vessels ≥ 12 m, however as these large vessels land 93% of scallops from 27.7.d.N, VMS-recorded activity captures the vast majority of landings. Recent expansion of the fishery to the south of Bed 7.d.1 has led to the definition of a second bed (7.d.2) in Area 27.7.d.S (see Annex 6). However, this area was not surveyed in 2020 and is therefore not included in this assessment.

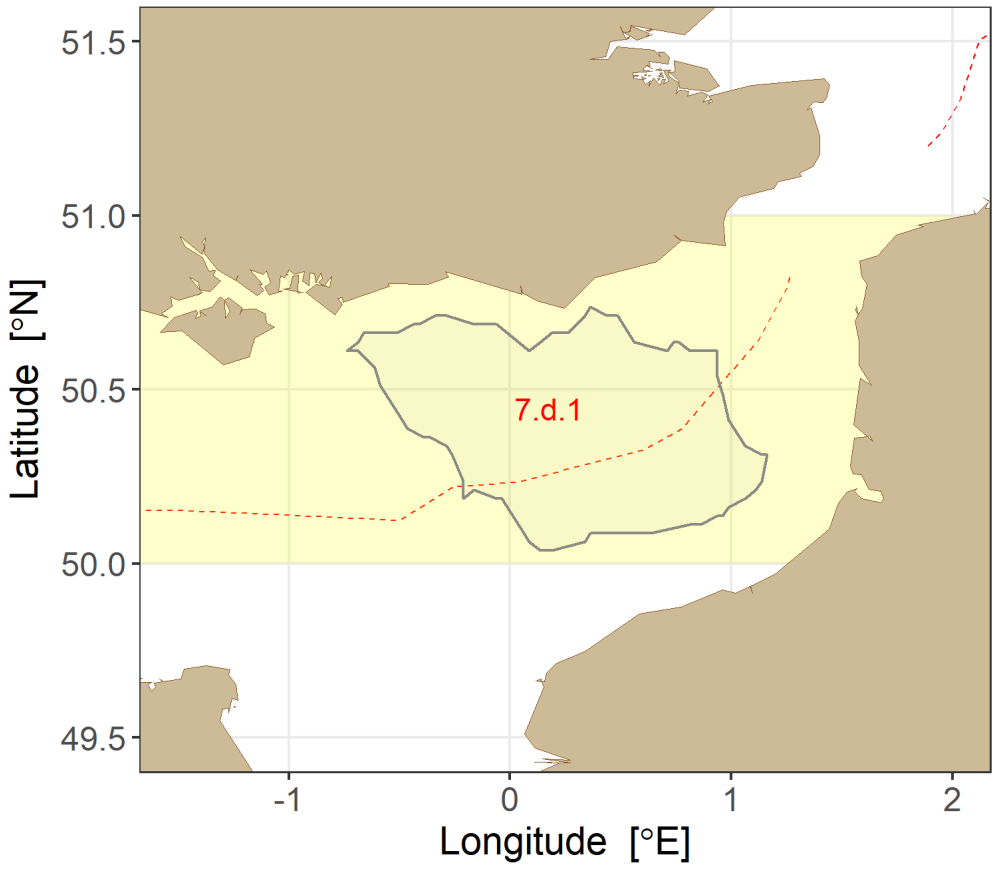

Figure 2.1: Dredge-surveyed part (Bed 7.d.1) of Area 27.7.d.N (yellow shading). The dashed red line indicates the boundary of the UK EEZ.

2.2. Available data

2.2.1. Catch and survey data

Annual landings by country for the 2009-2016 period, as reported to the EU Scientific, Technical and Economic Committee for Fisheries (STECF) for the rectangles in Area 27.7.d.N, are listed in Table 2.1. Note that Belgian data are likely to be missing prior to 2012, although tonnages since then have been small. International landings after 2016 are not yet available from STECF. Total international landings for 2017-2019 were obtained from the latest ICES Scallop Working Group (ICES, 2020).

Table 2.1: Annual landings (tonnes) by country (as reported to STECF and ICES) in Area 27.7.d.N.

	BEL	FRA	NLD	IRL	GBG	GBJ	IOM	UK	International
2009	-	7375	299	-	-	-	15	5888	13577
2010	-	6701	148	-	-	-	-	9509	16359
2011	-	6792	-	5	-	-	-	8077	14874
2012	214	5747	-	-	-	-	-	3061	9023
2013	271	13190	-	14	-	-	-	3178	16653
2014	576	4190	-	232	-	-	-	4163	9160
2015	354	2983	-	7	-	-	-	1590	4935
2016	354	4323	-	86	-	-	-	1896	6659
2017*	325	3952	-	228	-	-	-	3429	7934
2018*	277	7240	-	781	-	-	-	6160	14458
2019*	205	4260	-	596	-	-	-	6386	11448

* from (ICES, 2020).

Quarterly landings by country are shown in Figure 2.2. Quarter 4 tends to show the greatest activity, while the lowest landings occur in the summer months (quarters 2 and 3) during which there is a voluntary closure by part of the UK fleet.

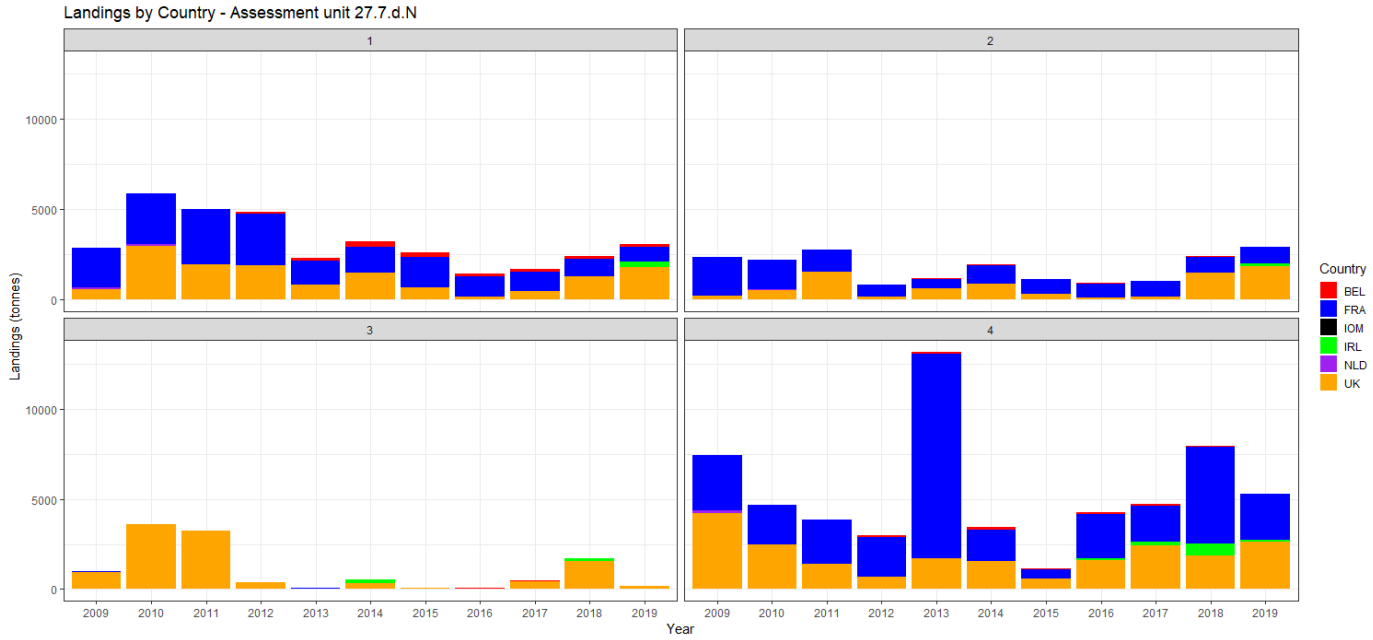

Figure 2.2: Quarterly landings by country in Area 27.7.d.N. (N.B. Isle of Man, Guernsey and Jersey landings < 1 t per annum. Belgian landings only recorded since 2012).

As the fishery tends to be more active during the autumn and winter, an appropriate way of analysing landings data is by sampling season, in which a sampling season comprises Q1-Q3 of the current calendar year and Q4 of the preceding year. Although there is a delay in the collation of landings data within the UK, at the time of report writing (January 2021), landings data to the end of Q3 2020 are considered reliable. UK quarterly landings for Area 27.7.d.N are listed in Table 2.2 and indicate a large increase in 2009 compared to previous years, peaking in 2010, and declining in recent years back to more typical values. This sudden increase in landings appears to have resulted from an increase in catch rates which drew in additional effort from the nomadic fleet at a time when access to other waters was becoming limited.

Table 2.2: UK quarterly landings (tonnes) from Area 27.7.d.N.

	Q1	Q2	Q3	Q4	Annual	Sampling Season (Q4, Q1, Q2, Q3)
2001	653	96	24	201	974	-
2002	380	220	63	647	1310	864
2003	1228	111	6	487	1832	1992
2004	889	107	6	383	1385	1489
2005	553	133	18	529	1234	1088
2006	749	305	30	475	1559	1614
2007	653	152	51	1559	2414	1330
2008	686	479	51	606	1823	2776
2009	533	174	962	4242	5911	2275
2010	2947	514	3591	2458	9509	11294
2011	1922	1509	3256	1397	8083	9144
2012	1872	131	368	690	3061	3768
2013	831	620	40	1688	3179	2182
2014	1463	850	310	1541	4163	4310
2015	644	306	59	584	1594	2551
2016	168	78	21	1629	1897	851
2017	426	174	410	2419	3429	2639
2018	1338	1387	1591	1849	6165	6735
2019	1814	1790	165	2016	5784	5617
2020	974	273	917	2417*	4582*	4752

* provisional.

2.2.2. Size composition

The number of samples collected each year through the biological sampling programme is shown in Table 2.3, along with the number of age samples collected during dredge surveys. As mentioned in Section 1.3, although not included at this point, age samples will be an important part of future assessments and are listed for completeness.

Table 2.3: Biological sampling programme summary for Area 27.7.d.N.

	Commercial Landings				Dredge Survey	
Sampling Season	Length Samples	Animals Measured	Age Samples	Shells Aged	Age Samples	Shells Aged
2017	10	1594	1	24	9	335
2018	47	7191	16	458	17	717
2019	67	10699	26	774	18	416
2020	27	3892	5	139*	12	320*

* awaiting update.

Sampling length distributions, raised to the commercial landings, are show in Figure 2.3. Length samples for individual vessels were raised to UK quarterly landings, before summation to total landings during each sampling season. There are significantly more animals above MLS (110 mm) in 2018-2020 compared to 2017.

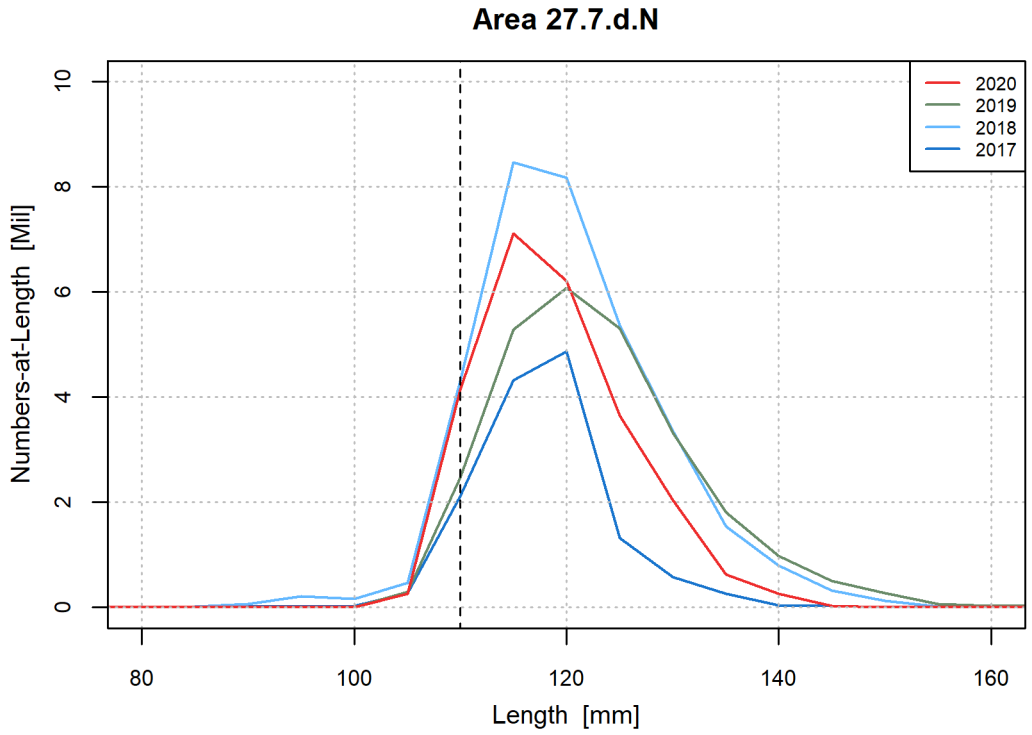

Figure 2.3: UK landed numbers in 5-mm size bins from Area 27.7.d.N during individual sampling seasons (Q1-Q3 of current calendar year, plus Q4 of previous year). The vertical dashed line indicates MLS. N.B. reduced sampling in 2020 season due to Covid pandemic.

2.3. Biological parameters and dredge efficiency

A review of historic growth estimates by Dare and Palmer (Cefas, 2001; unpublished), including different grounds in the English Channel, provided von Bertalanffy growth parameters for Area 27.7.d.N.

Scallops were not individually weighed as part of this project, but parameters for a weight-length relationship for ICES Division 27.7.d was obtained from IFREMER.

Table 2.4: Biological and dredge efficiency parameters used for Area 27.7.d.N.

Parameter	Value	Source
Gear efficiency – ground type clean or clean becoming stony	30%	Cefas (Palmer, 2001; unpublished)
Gear efficiency – ground type flint cobbles	43%	Cefas (Palmer, 2001; unpublished)
Round length to weight	$a = 1.55 \times 10^{-3}$ $b = 2.45609$	IFREMER (unpublished); see Section 1.1.5 for functional relationship
Flat height to round length	$a = 1.208916$ $b = -5.386429$	Eastern Channel dredge survey 2017; see Section 1.1.4 for functional relationship
Size at maturity	80 mm shell height (~90 mm length)	Cefas (unpublished)
Natural mortality	0.15 for all ages	(Cook, et al., 1990)
Von Bertalanffy growth	$H_\infty = 119.3$ $k = 0.516$ $t_0 = 0.692$	Cefas (Dare and Palmer, 2001; unpublished); see Section 1.1.3 for functional relationship

2.4. Dredge and underwater television survey

2.4.1. Dredge survey methodology

The dredge survey design and station selection procedure are described in Annex 2.

The 2020 dredge survey was the fourth that was carried out in Area 27.7.d.N as part of this programme.

The surveys in 2017 and 2020 were restricted to the UK Exclusive Economic Zone (EEZ), whereas the surveys in 2018 and 2019 also included tows in the French EEZ. For 2018, four additional tows were carried out in a small recently defined bed (7.d.2) in the 27.7.d.S

assessment area to the south of Bed 7.d.1. Surveying at these four tow sites was also intended for the 2019 and 2020 dredge surveys but was not achieved during these survey periods.

A chartered commercial fishing vessel was used to survey a grid of fishing stations as defined in the survey design (Annex 2). The commercial fishing vessel used for the surveys since 2018 was a 24 m scallop dredger. A larger vessel was used for the 2017 survey (Bell, et al., 2018). The current survey vessel deployed ten “Newhaven” type dredges on each side, which facilitated short tow durations for effective sampling (Figure 2.4). A conveyor system took catch down from the main deck to the factory deck for sorting. Four modified (queen scallop) dredges and six standard dredges were deployed on the starboard side, and a wooden marker was used to keep the catch from the two gear types separate on the conveyor belt. The port side beam had ten standard commercial dredges. The two beams were deployed synchronously for 15 minutes at a speed of approximately 2.5-3 knots. Where the commercial dredges were observed to have filled (biota and substrate) on recovery the tow was rejected, and a further 5-minute tow carried out at the same site. This was to avoid underestimation of scallop biomass at sites where dredges may have stopped fishing during the course of the tow.

The standard gear (Newhaven type dredges) were 75 cm wide and fitted with 85-mm ring bellies and 8-teeth swords (tooth bars). The modified dredges were 75 cm wide with 55-mm rings in the belly, nylon mesh backs and 13-teeth swords. Dredge spring tension was manually tested regularly by the crew throughout the survey, and the vessel’s usual schedule of gear refurbishment was carried out to maintain efficiency.

At each tow position catches of scallops were processed and measured as follows.

- Starboard side – scallop catch sorted into retained and discarded component for each of the two gear types (all dredges within gear type pooled). Numbers of each component was recorded, and components were then subsampled for length purposes, with round shell length measured to the nearest millimetre. The numbers of scallop in each length sample and each sampled component of the catch were recorded to provide raising factors.
- Five individuals per 5-mm size bin were retained for age determination at selected sites within each bed.

The inclusion of the four modified dredges was to allow for sampling of smaller size (pre-recruitment) scallops that would otherwise be under-sampled using the standard commercial gear. The length distributions from these modified dredges have been used for exploratory purposes only and are not included in this assessment.

Between 22-30 September 2020, 51 randomly selected tows were surveyed in Bed 7.d.1, resulting in the sampled blocks shown in Figure 2.5.

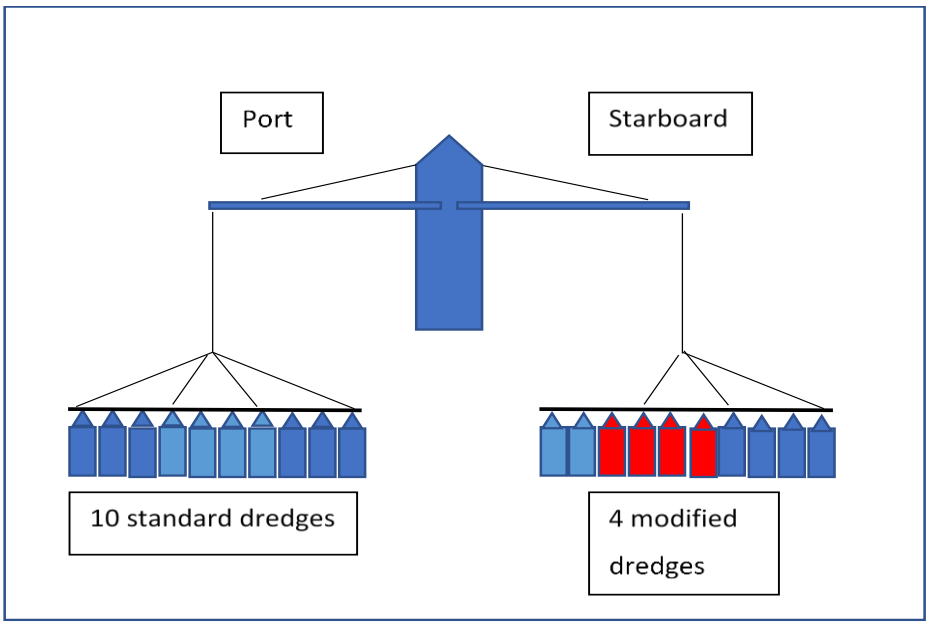

Figure 2.4: Gear configuration on the survey vessel.

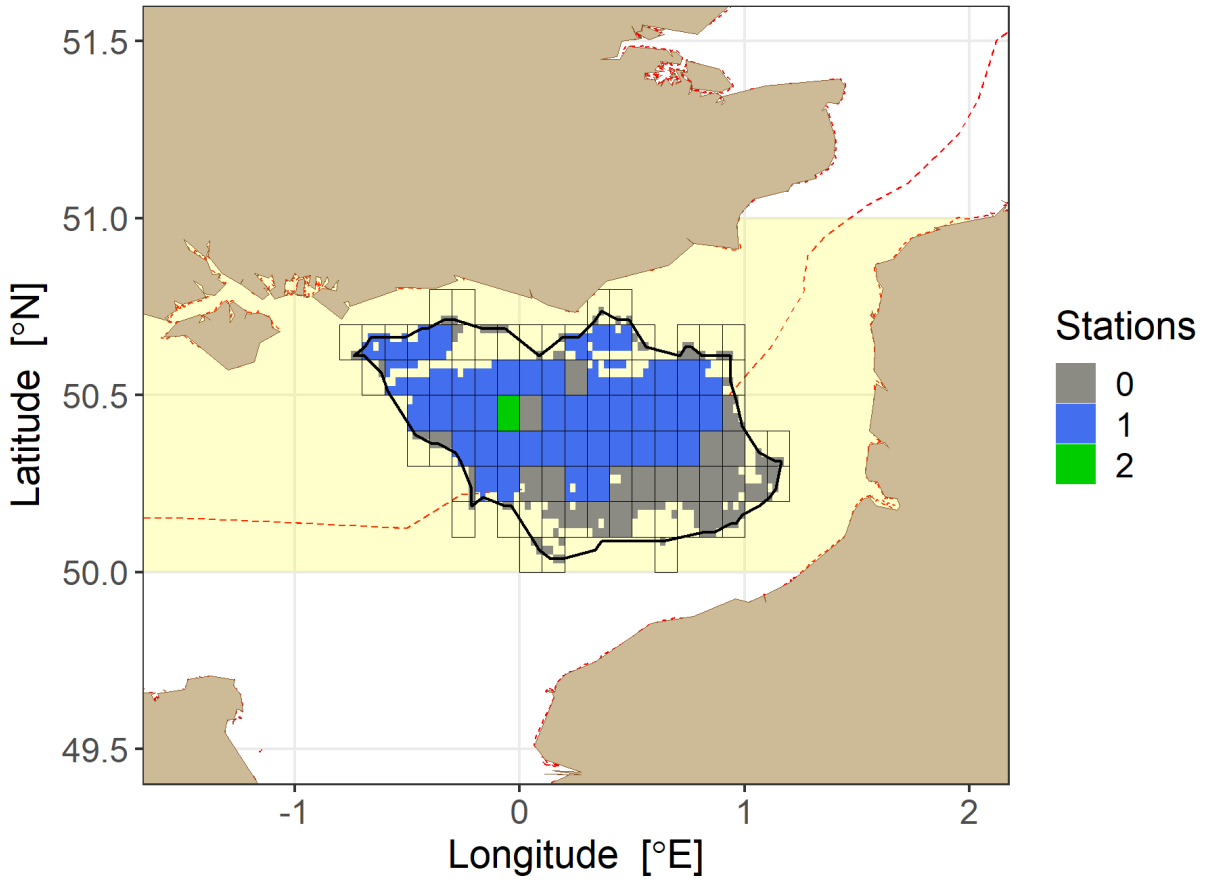

Figure 2.5: Number of stations visited during the 2020 dredge survey within each sampled block of Bed 7.d.1 (Area 27.7.d.N). The dashed red line indicates the boundary of the UK EEZ.

2.4.2. Underwater television survey methodology

In 2019, underwater television (UWTV) surveys were carried out to determine the spatial distribution and abundance of scallops in selected parts (TV.7.d.A and TV.7.e.E) of Area 27.7.d.N that are inaccessible to fishing gear, including Marine Protected Areas (MPAs), and areas with unsuitable ground types. No UWTV survey was carried out in 2020. The methods for UWTV surveys are described in Annex 4.

2.5. Raised biomass estimates and uncertainty

In 2017, no areas in the French EEZ were surveyed and a bed mean density was used to estimate biomass there. In 2018 and 2019, the French EEZ was surveyed allowing actual densities to be raised to this area. However, in 2020, the dredge survey was once again limited to the UK EEZ. This affected the southern part of Bed 7.d.1.

The estimated biomass of harvestable scallops (≥ 110 mm MLS) within 0.1-by-0.1 degree blocks in 2020 is shown in Figure 2.6.

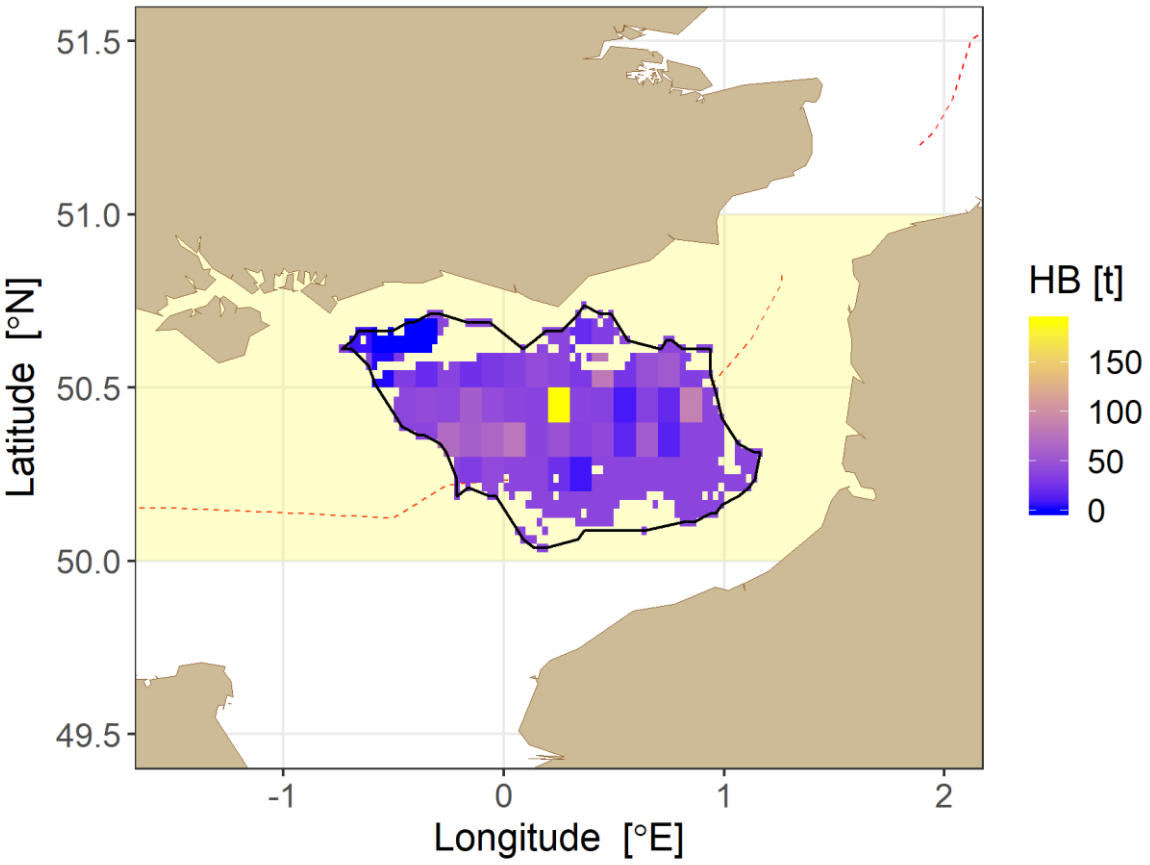

Figure 2.6: Harvestable biomass (tonnes) of scallops of at least MLS (110 mm round shell length) in Bed 7.d.1 (Area 27.7.d.N) during 2020. The dashed red line indicates the boundary of the UK EEZ.

To establish a measure of uncertainty around the estimate of harvestable biomass, the values for each bed were randomly resampled ("bootstrapped") 5000 times with replacement. For each iteration, the same analysis procedure was used as for the original estimate. The resulting distribution of harvestable biomass during 2020 is shown in Figure 2.7. The point estimate, along with the median and quantile range, are given in Table 2.5, together with the results for the previous years. As the point estimate utilises all available data, it is considered the most accurate value.

The harvestable biomass in Bed 7.d.1 has steadily increased (almost doubled) over the 2017-2020 period.

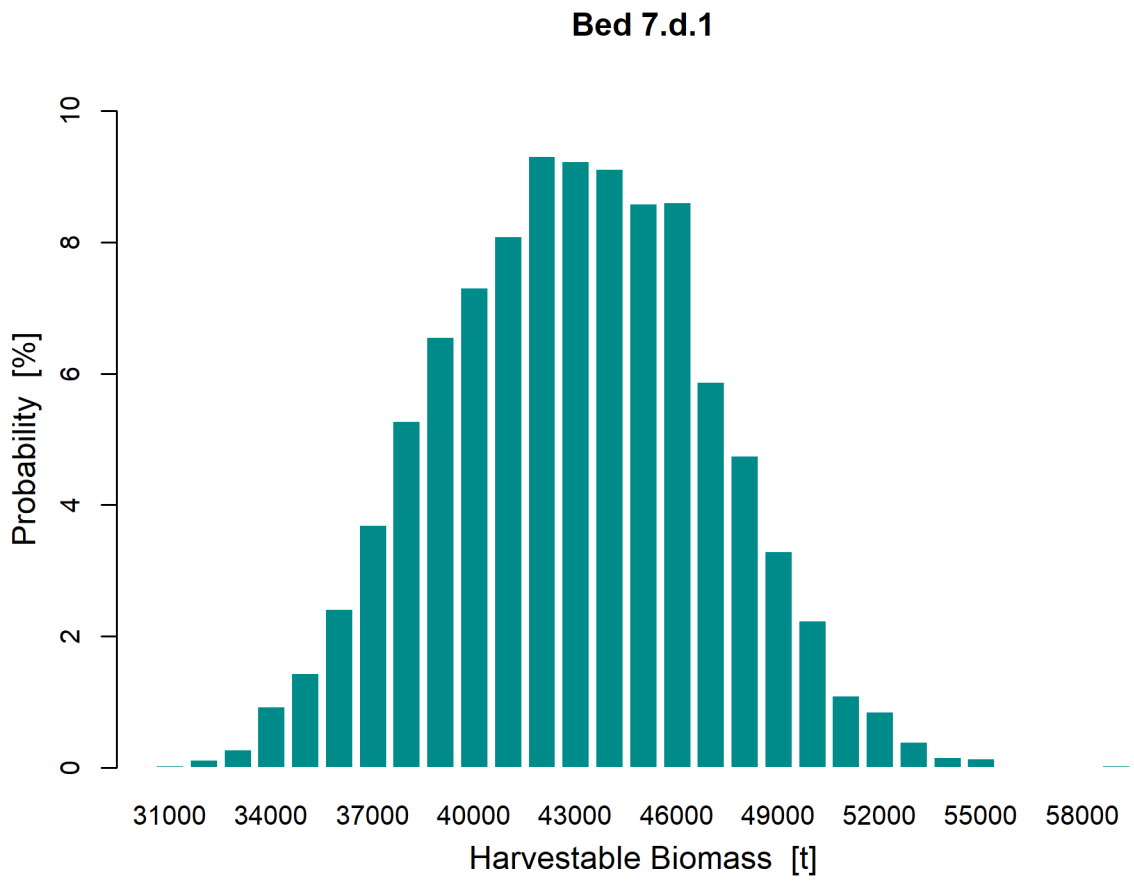

Figure 2.7: Distribution of harvestable biomass in Bed 7.d.1 (Area 27.7.d.N) during 2020 from random resampling ("bootstrapping").

Table 2.5: Estimates of biomass (tonnes), point value, median, and quartile range from bootstrapping, for Bed 7.d.1 (Area 27.7.d.N).

	25th Percentile	Median	Point Value	75th Percentile
2017	20876	22732	22981	24602
2018	23506	24965	25047	26332
2019	33157	34752	34612	36477
2020	40192	43149	43216	45872

2.6. Size composition from dredge survey

From the size samples taken at each station, a total (pooled) length frequency distribution within Area 27.7.d.N was derived. From this, the total population number and biomass could be estimated.

The proportion by weight of survey catches below MLS taken by the standard commercial gear in 2020 was 35%, which is towards the lower end of the range in previous years (36% in 2017, 53% in 2018, 29% in 2019).

The size distributions derived from survey catches (Figure 2.8) do not compare directly to those from commercial landings (Figure 2.3), as they are raised to total estimated biomass by means of an assumed dredge efficiency, as opposed to being raised to reported removals.

There was evidence of a pulse of smaller scallop below MLS in the 2018 survey size distributions, unlike in those generated from the commercial samples. There were significantly more scallops in the 110 mm size group in the 2018 and 2019 surveys compared to the 2017 survey. The significant increase in harvestable biomass from 2019 to 2020 (Table 2.5) is reflected in an increase in numbers-at-length across the size spectrum.

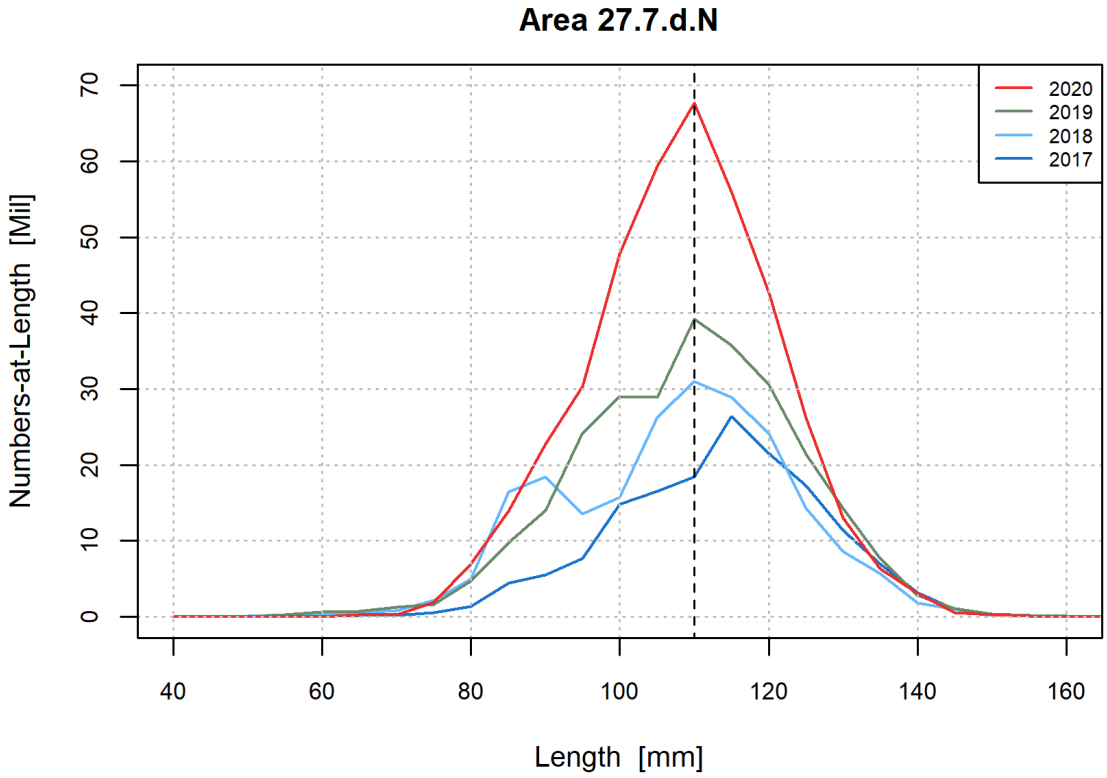

Figure 2.8: Annual population length distributions in 5-mm size bins from the annual dredge surveys in Area 27.7.d.N. The vertical dashed line indicates MLS.

2.7. Relative abundance from UWTV survey

An UWTV survey was carried out in 2019 and details are given in Annex 4. The tow speed was 0.4 knots, and tow duration was 20 minutes, which provided a transect length of just under 250m. It established that scallops are distributed at low density on the seabed in the un-dredged zones. All transects in zone TV.7.d.A. within Area 27.7.d.N gave zero counts, and the highest density observed was 0.30 scallops per 100 m^2 in zone TV.7.e.D (of which only a small part is in Area 27.7.d.N). Although zero densities are not uncommon in surveys where target species are aggregated on the seabed, further development of the camera deployment platform is expected to improve sampling coverage.

Further results from the 2019 UWTV survey are reproduced in Annex 4. The 29 tonnes of biomass estimated for the surveyed un-dredged zones in this assessment area are included in the estimation of harvest rates in the following section.

There is likely additional resource in other un-dredged zones already defined but yet to be surveyed (e.g.TV.7.d.C), and possibly in other un-dredged areas yet to be defined. We anticipate these areas will be the subject of future UWTV surveys.

2.8. Harvest rate estimation

The harvest rate (i.e. the ratio of landings to total harvestable biomass) is proposed to give a proxy for the fishing mortality experienced by this assessment area. Ideally this is calculated from the harvestable biomass immediately prior to the start of a particular fishing season, in relation to the total removals during that season. International landings for 2017 and 2018 were available from the latest ICES Scallop Working Group (ICES, 2020). Although these are considered much more reliable than the estimates based on UK share and presented in previous reports, they may be subject to further refinement. International landings for the 12-months following the two most recent dredge surveys (2019 and 2020) were not available at the time of writing of this assessment report. Instead, UK landings recorded on a national database were used, divided by the average ratio of the UK component of international landings during the 2017-2019 period (0.47). This assumes that the UK share of international landings has been stable since then. For the most recent survey, the estimated international landings for the 12-month period following the previous survey were used, unless landings during the incomplete 12-month period since the latest survey already exceed those of the previous survey. This is more likely to be indicative of future landings than an estimate based on incomplete landings data. However, international removals and associated harvest rates presented here are provisional and will be revised when required data become available.

Provisional harvest rates for the dredged parts of Area 27.7.d.N are listed in Table 2.6. The corresponding estimates of harvestable biomass are based on the results from dredge surveys. The harvestable biomass estimates are the point values from Table 2.5. The range of harvest rate is based on the inter-quartile range of the harvestable biomass estimate from random resampling.

The provisional harvest rates listed in Table 2.7 are based on biomass estimates that also include un-dredged zones that have been surveyed by UWTV. Biomass estimates for selected un-dredged zones of 27.7.d.N were assessed for the first-time using UWTV in 2019. As such, harvest rate estimates include the fished part of the stock, together with small amounts from un-dredged areas. There is additional stock outside the area surveyed with dredges and UWTV, for which there are currently no data on their biomass or ability to contribute to recruitment to the main areas of fished stock.

Table 2.6: Biomass removed during 12-month periods following annual dredge surveys, and provisional harvest rate estimate for the dredged parts of Area 27.7.d.N.

	Biomass Removed (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvest Rate on Dredged Portion of Stock (%)	Harvest Rate Range (%)	
2017	11260	22981	49.0	45.8	53.9
2018	14069	25047	56.2	53.4	59.9
2019	9233*	34612	26.7	25.3	27.8
2020	9233**	43216	21.4	20.1	23.0

* estimated from UK removals and 2017-2019 UK market share, to be revised.
** estimate from previous year, to be revised.

Table 2.7: Biomass removed during 12-month periods following annual dredge surveys, and provisional harvest rate estimate for Area 27.7.d.N, combining harvestable biomass estimates from the dredge and UWTV surveys.

	Biomass Removed (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UWTV Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
2017	11260	22981	29	23010	48.9
2018	14069	25047	29	25076	56.1
2019	9233*	34612	29	34641	26.7
2020	9233**	43216	29	43245	21.4

* estimated from UK removals and 2017-2019 UK market share, to be revised.
** estimate from previous year, to be revised.

2.9. Landings size composition – cohort modelling

Most fully analytical fish stock assessments use a time series of age composition of the landings (along with other data such as total landings or catches and a survey series) to estimate the rate at which the fishery is exploiting the stock.

In the first assessment for 2017 (Bell, et al., 2018) we used an age-based cohort model to determine fishing mortality, assuming the populations had been at equilibrium (“steady-state”), that is that fishing effort, recruitment and growth have all been constant. Deviations from this assumption will result in unreliable simulations.

Marked differences in the reported landings between different assessment years have highlighted that the populations are not at equilibrium, Therefore, for this report a method has been employed that is less susceptible to fluctuations in recruitment and fishing. Scaled length distributions were used to determine gear selection parameters (L25 and L50 of a selection ogive) to facilitate a length-based cohort method (Figure 2.9). Length-based methods are routinely used for shellfish assessments, where only size structure of the removals is available, and is typical for many shellfish species, where routine age determination is problematic. The length-based assessment uses growth parameters to determine the time spent in each size class and projects the spawning stock biomass and catch expected from a batch of recruits (a yield and spawner per recruit model).

Provisional harvest rates for the dredged portion of the assessment area, and a candidate harvest rate consistent with MSY, estimated using the length-based cohort method, are presented in Table 2.8.

Age compositions are not presented in this report for any of the assessment areas.

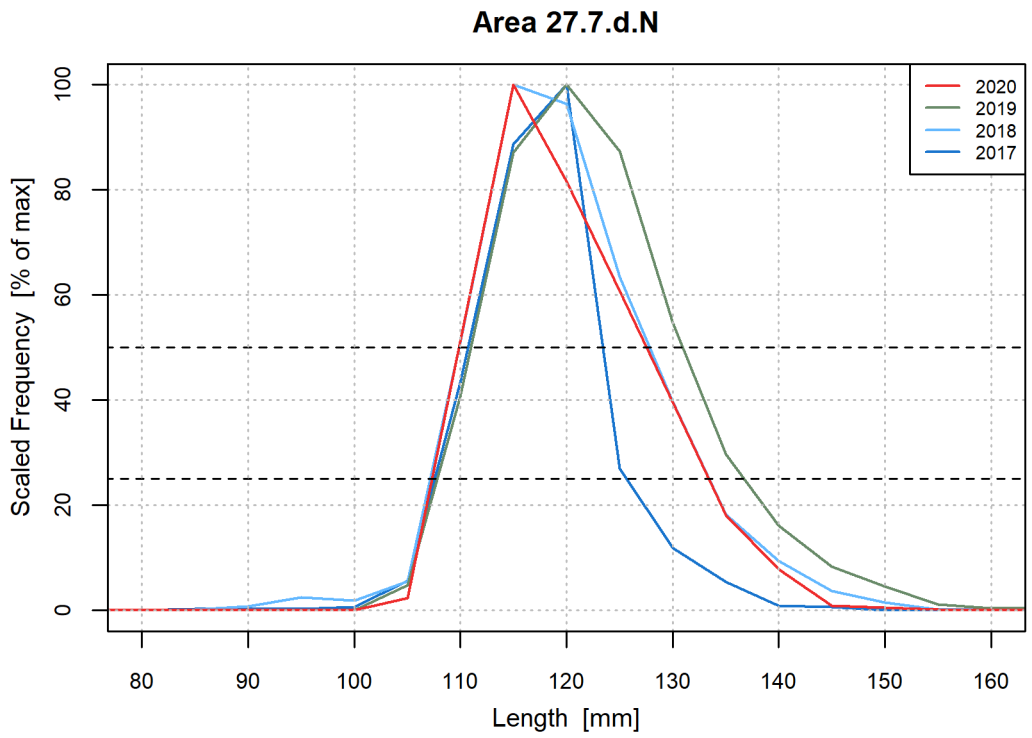

Figure 2.9: Scaled landed size distributions as a proportion of the mode. Horizontal lines indicate 25% and 50% levels. N.B. reduced sampling in 2020 season due to COVID-19 pandemic.

Table 2.8: Provisional harvest rate estimates for Area 27.7.d.N, with an MSY candidate.

	Harvest Rate on Dredged Portion of Stock (Dredge Survey Only, %)	Harvest Rate on Wider Stock (Incl. UWTV Survey, %)	MSY Candidate Harvest Rate (%)
2017	49.0	48.9	21.5
2018	56.2	56.1	21.5
2019*	26.7	26.7	21.5
2020**	21.4	21.4	21.5

* estimated from UK removals and 2017-2019 UK market share, to be revised.
** based on removals estimate from previous year, to be revised.

2.10. MSY reference point estimation

Full estimation of the fishing mortality that generates maximum sustainable yield (MSY) requires a full analytical assessment, including an estimate of the stock-recruitment relationship. Clearly, as is the case with many stocks assessed by ICES, this is not yet possible. For these stocks, ICES scientists use proxy reference points that have been found to be reasonable approximations to MSY reference points. The fishing mortality which generates 35% of the virgin spawning potential (F35%SpR) is a commonly used reference point, not only within ICES advisory areas, but also globally. F0.1, the fishing mortality where the increase in the yield-per-recruit per unit of fishing effort is 10% of that for an unexploited stock, is often close to F35%SpR. Fmax, the fishing mortality which gets the maximum yield from each recruited individual, is also sometimes used as a proxy for the fishing mortality which provides the maximum sustainable yield (FMSY). This, however, is unlinked to spawning potential, and is more uncertain in its estimation. In some circumstances, it suggests fishing rates which are highly risky for the stock size.

A simple yield-per-recruit model was constructed using selection-at-size and maturity-at-size parameters estimated in this assessment. The fishing mortality, harvest rate and spawner-per-recruit are presented for three reference points in Table 2.9.

This model estimates that in order to achieve F35%SpR, a harvest rate in the vicinity of 21.5% would be required. The F0.1 estimate (18.1%) is of a similar magnitude. The Fmax estimate for this stock is very high, because there is relatively little growth potential after the MLS has been reached, compared to expected losses through natural mortality. Exploitation at the Fmax estimate for this stock would remove about 66% of the harvestable stock in each year and reduce the spawning potential to about 18% of its virgin state. This is therefore considered to be a high-risk strategy. Instead, the recommended FMSY reference point for this stock is F35%SpR. The relationship between yield or spawner-per-recruit to fishing mortality is presented in Figure 2.10.

Table 2.9: Fishing mortality, harvest rate, spawner-per-recruit, and average fishing mortality Fbar at reference points F0.1, FSpR35% and Fmax.

Reference Point	Fishing Mortality	Harvest Rate (%)	Spawner-per-Recruit	Fbar
F0.1	0.210	18.1	0.392	0.106
FSpR35%	0.252	21.5	0.350	0.127
Fmax	0.680	51.9	0.178	0.342

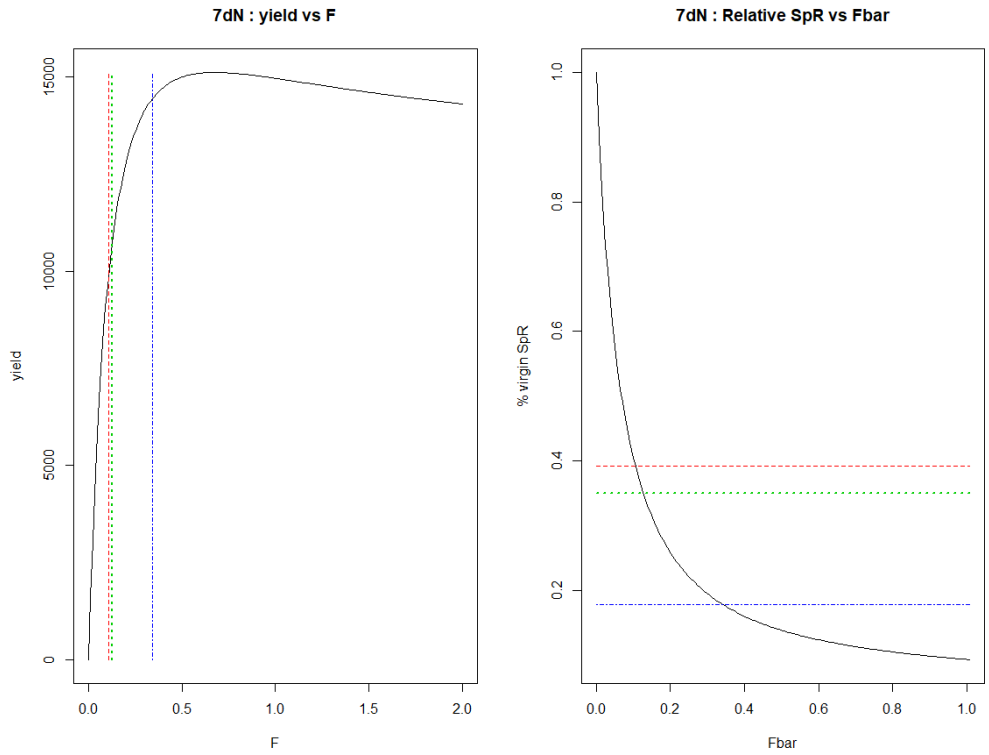

Figure 2.10: Yield (left) and relative spawner-per-recruit (right) against fishing mortality. Three reference points are indicated: F0.1 (red), FSpR35% (green), and Fmax (blue).

2.11. Conclusion

This is the fourth stock assessment undertaken for king scallops in the eastern English Channel (Area 27.7.d.N). Due to the Covid-19 pandemic, scientific surveys and commercial catch sampling in 2020 were restricted. As a result, the planned UWTV survey could not be carried out.

Therefore, this 2020 assessment includes biomass estimates and provisional harvest rates from the 2020 dredge survey, together with modest amounts of biomass estimated based on the 2019 UWTV survey in selected un-dredged zones.

Previous reports have highlighted the problems of using UK share to estimate international removals and harvest rates for those Assessment Areas with shared stocks. Harvest rate estimates for the latest two years should be viewed with caution. The large variation in estimated harvestable biomass suggests that the population in this assessment area is not at equilibrium. The assumption of equilibrium is fundamental to cohort modelling and yield-per-recruit estimates. As a result of these concerns, a modelling approach which utilises scaled length samples was considered more appropriate than the age-based method used for the first assessment for 2017 (Bell, et al., 2018).

Length-structured cohort modelling provides context for harvest rate estimates by establishing an MSY candidate reference value. The estimated harvest rate for Area 27.7.d.N in 2017-2018 was more than twice the MSY reference value of 21.5%, but has since then gone down considerably due to higher estimated harvestable biomass estimates, while estimates of international removals have been revised downward since the dredge survey in 2019. Revision of the removals has provided harvest rate estimates for 2017 and 2019 considerably lower than those presented in last year's report (2017, 49% from 74.4%; 2019, 26.7% from 41.2%). Presently, the provisional harvest rate is just below the MSY reference. However, the harvest rates presented here are provisional and need revision when more data become available. The size of this discrepancy may be due to the assumption that foreign landings are proportional to UK landings. This highlights the importance of having access to the most recent international landings data and retrospectively updating estimates with actual landings when they become available.

In 2018, a change to a smaller survey vessel deploying fewer dredges was unavoidable. Both survey vessels deploy very similar gear and catches of scallop are standardised to area swept. However, no comparative tow work was carried out to confirm that there was no change in catchability. As such, caution should be used when comparing the results from the 2017 survey with later surveys, which were carried out by the same vessel since 2018.

A presentation of the assessment approach to the ICES Scallop Working Group highlighted that there are several key areas of uncertainty that require further work to better understand their impact. With the swept area biomass assessment, the key parameter is the gear-efficiency estimate, and even relatively small changes to this estimate would have a significant impact upon the estimated harvestable biomass and harvest rate. Research to develop novel technology to resolve gear efficiency estimates is still ongoing.

It should be noted that the assessment of scallops in Area 27.7.d.N only covers the fished part of the stock and selected un-dredged zones. Additional stock is known to exist outside the surveyed area, for which there are currently no data on either biomass or the ability to contribute to recruitment to the fished stock. Further surveys of un-dredged areas are planned. Provided that there is evidence that scallops in un-dredged areas make significant contributions to the recruitment in dredge areas, proportionate inclusion of biomass from un-dredged areas is likely to revise the estimates of realised harvest rate downwards. Hydrographic and particle dispersal modelling to estimate the level of larval connectivity between exploited and unfished areas is planned.

We would hope that in future assessments we will be able to see weak and strong year-classes moving through the population structure to give confidence that the sampling scheme is able to adequately follow the population development. As a time-series of age compositions develops, the use of age structured assessment methods will be investigated. A time series as long as the number of year classes in the fishery is preferred, which in this case is eight years (8 year plus group).

3. Stock assessment for surveyed areas of ICES Divisions 27.7.e and 27.7.f

3.1. Area definitions

As described in Section 1.4, three scallop assessment areas which encompass the majority of areas fished by UK vessels within ICES Division 27.7.e have been defined: 27.7.e.I (Inshore Cornwall), 27.7.e.L (Lyme Bay) and 27.7.e.O (Offshore) (Figure 3.1). Within these areas, eight scallop beds have been identified: two within 27.7.e.I, three within 27.7.e.L, and three within 27.7.e.O. Two of the beds (7.e.4 and 7.e.5) straddle two of the assessment areas. Beds 7.e.3 is within a Marine Protected Area and 7.e.6 is positioned in a sensitive area within 6nm of the coast and are no longer accessible to larger vessels, including our survey vessel. They are therefore not part of the dredge survey anymore, but have been surveyed using underwater television in 2017 and 2019. Beds 7.e.7 and 7.e.8 lie predominantly in the French EEZ, with a small part of Bed 7.e.8 lying in the territorial waters of Guernsey, and a small part of Bed 7.e.7 lying in the UK EEZ. In 2018, a new bed, 7.f.1, was defined and surveyed in Area 27.7.f.I (Inshore). This area is within ICES Division 27.7.f, off the North Cornish coast.

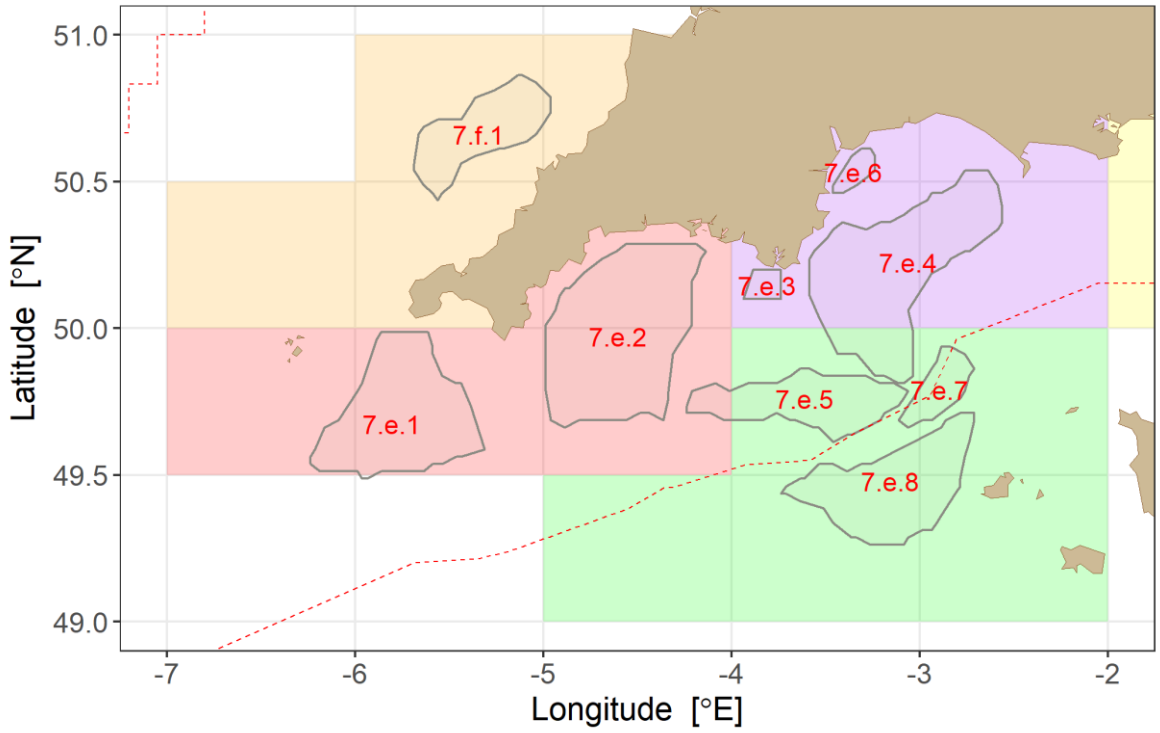

Figure 3.1: Dredge-surveyed parts of ICES Divisions 27.7.e and 27.7.f: Beds 7.e.1 and 7.e.2 within Area 27.7.e.I (red), Beds 7.e.3, most of 7.e.4 and 7.e.6 within Area 27.7.e.L (purple), Beds 7.e.5, 7.e.7 7.e.8, and part of 7.e.4 within Area 27.7.e.O (green), and Bed 7.f.1 with Area 27.7.f.I (orange). The dashed red line indicates the boundary of the UK EEZ.

3.2. Available data

3.2.1. Catch and survey data

Annual landings by country for the 2009-2016 period, as reported to STECF for the rectangles in the assessment areas in Divisions 27.7.e and 27.7.f are listed in Table 3.1. Note that Belgian data are likely to be missing prior to 2012, although tonnages since then have been small. Rectangle 29E4 contains waters in both Divisions 27.7.e and 27.7.f. It is assumed that non-UK landings from 29E4 are from Division 27.7.f, since all 27.7.e waters lie inside 6 nautical miles from the coast, where non-UK vessels are not entitled to fish. Total international landings for 2017-2019 were obtained from the latest ICES Scallop Working Group (ICES, 2020).

Table 3.1: Annual landings (tonnes) by country (as reported to STECF and ICES) in the four assessment areas in ICES Divisions 27.7.e and 27.7.f.

27.7.e.I	BEL	FRA	NLD	IRL	GBG	GBJ	IOM	UK	International
2009	-	36	181	-	-	-	-	2261	2478
2010	-	37	107	-	-	-	-	1029	1173
2011	-	55	-	1	-	-	-	1790	1846
2012	55	7	-	2	-	-	-	2502	2565
2013	1	34	-	1	-	-	-	2372	2409
2014	79	0	-	4	-	-	-	1667	1751
2015	102	0	-	33	-	-	-	3711	3846
2016	71	4	-	28	-	-	0	2836	2938
2017*	23	-	-	5	-	-	-	2397	2425
2018*	64	-	-	1	3	-	-	1809	1877
2019*	21	5	-	-	-	-	-	2054	2080
27.7.e.L	**BEL**	**FRA**	**NLD**	**IRL**	**GBG**	**GBJ**	**IOM**	**UK**	**International**
2009	-	37	47	-	0	-	-	1725	1809
2010	-	30	16	-	-	-	-	2554	2600
2011	-	40	-	-	-	-	-	3720	3761
2012	13	3	-	-	0	-	-	2953	2969
2013	4	35	-	-	-	-	-	2351	2390
2014	24	0	-	-	-	-	-	1834	1858
2015	10	1	-	-	-	-	-	1246	1257
2016	5	1	-	-	-	-	-	1416	1422
2017*	8	-	-	-	-	-	-	1704	1712
2018*	9	1	-	-	-	-	-	1908	1918
2019*	6	2	-	-	-	-	-	1691	1701
27.7.e.O	**BEL**	**FRA**	**NLD**	**IRL**	**GBG**	**GBJ**	**IOM**	**UK**	**International**
2009	-	828	66	-	-	-	-	2054	2948
2010	-	808	-	-	0	1	-	3140	3949
2011	-	671	-	-	-	0	-	1638	2309
2012	171	635	-	-	0	-	-	2643	3449

2013	14	817	-	2	-	-	-	3032	3866
2014	104	1141	-	1	-	-	-	1352	2597
2015	47	717	-	3	0	-	-	1055	1823
2016	58	764	-	-	0	-	0	891	1713
2017*	6	264	-	-	56+	-	-	573	899
2018*	15	193	-	-	215+	-	-	1179	1602
2019*	9	163	-	-	417+	-	-	1128	1717
27.7.f.I	**BEL**	**FRA**	**NLD**	**IRL**	**GBG**	**GBJ**	**IOM**	**UK**	**International**
2009	-	-	-	0	-	-	-	203	203
2010	-	-	-	32	-	-	-	541	573
2011	-	-	-	143	-	0	-	140	284
2012	125	-	-	15	-	-	-	159	299
2013	135	-	-	47	-	-	-	393	575
2014	137	-	-	21	-	-	-	161	320
2015	78	-	-	-	-	-	-	35	114
2016	61	-	-	81	-	-	0	109	250
2017*	45	-	-	5	-	-	-	310	360
2018*	55	-	-	2	-	-	-	86	143
2019*	51	-	-	-	-	-	-	221	272

* from (ICES, 2020). + Channel Islands combined

There is a seasonal pattern within the three assessment areas of Division 27.7.e (Figure 3.2), with Area 27.7.e.L (Lyme Bay) tending towards a year-round fishery, while in Area 27.7.e.I (Inshore Cornwall) and Area 27.7.e.O (Offshore) the highest landings are being recorded in Q2 and Q3.This is also the case in Area 27.7.f.I (Figure 3.3).Annual landings in Areas 27.7.e.I and 27.7.e.L are almost exclusively by UK vessels, with small tonnages in both areas from France, Belgium and the Netherlands. UK landings are most prevalent in Area 27.7.e.O, with the exception of Q4 and during some recent years in Q1, when French landings are higher. Quarterly landings from Area 27.7.f.I are consistently below 400 tonnes.


Landings by Country - Assessment unit 27.7.e.l
1
2
3
4
Landings (tonnes)
0
500
1000
1500
2000
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year
Country
BEL
FRA
IRL
NLD
UK


Landings by Country - Assessment unit 27.7.e.L
1
2
3
4
Landings (tonnes)
0
250
500
750
1000
1250
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year
Country
BEL
FRA
NLD
UK

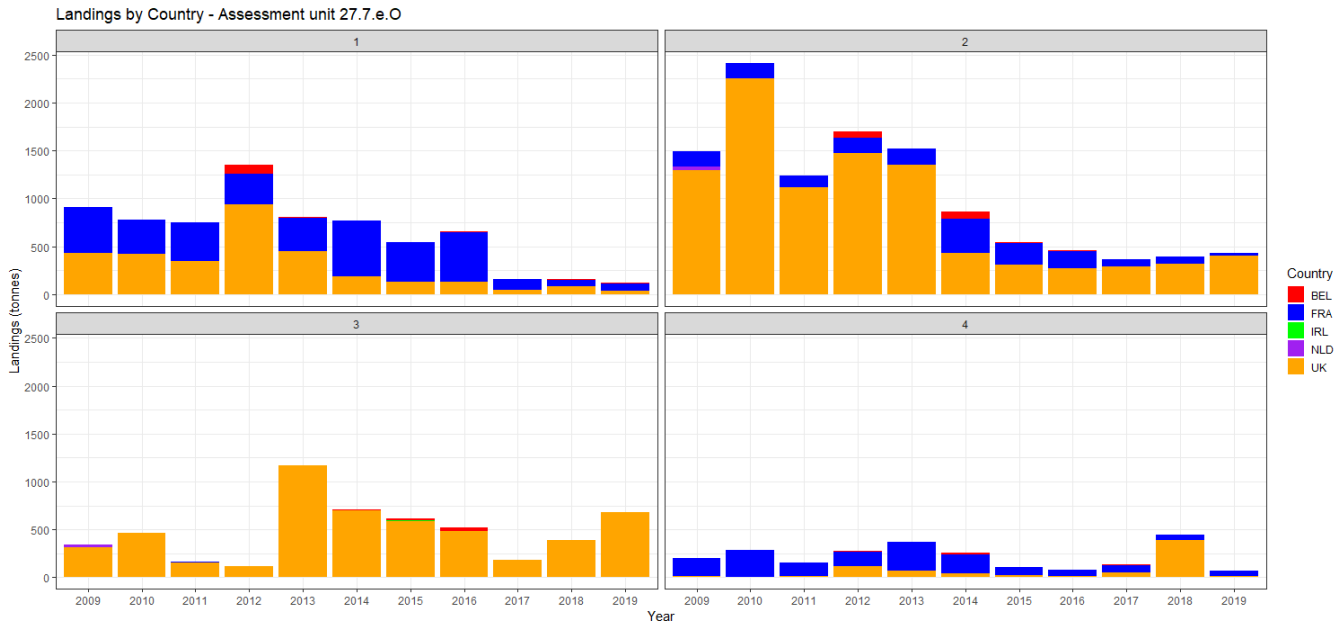

Figure 3.2: Quarterly landings by country in the assessment areas of Division 27.7.e. (NB. Isle of Man, Guernsey and Jersey landings <1t per annum. Belgian landings only recorded since 2012).

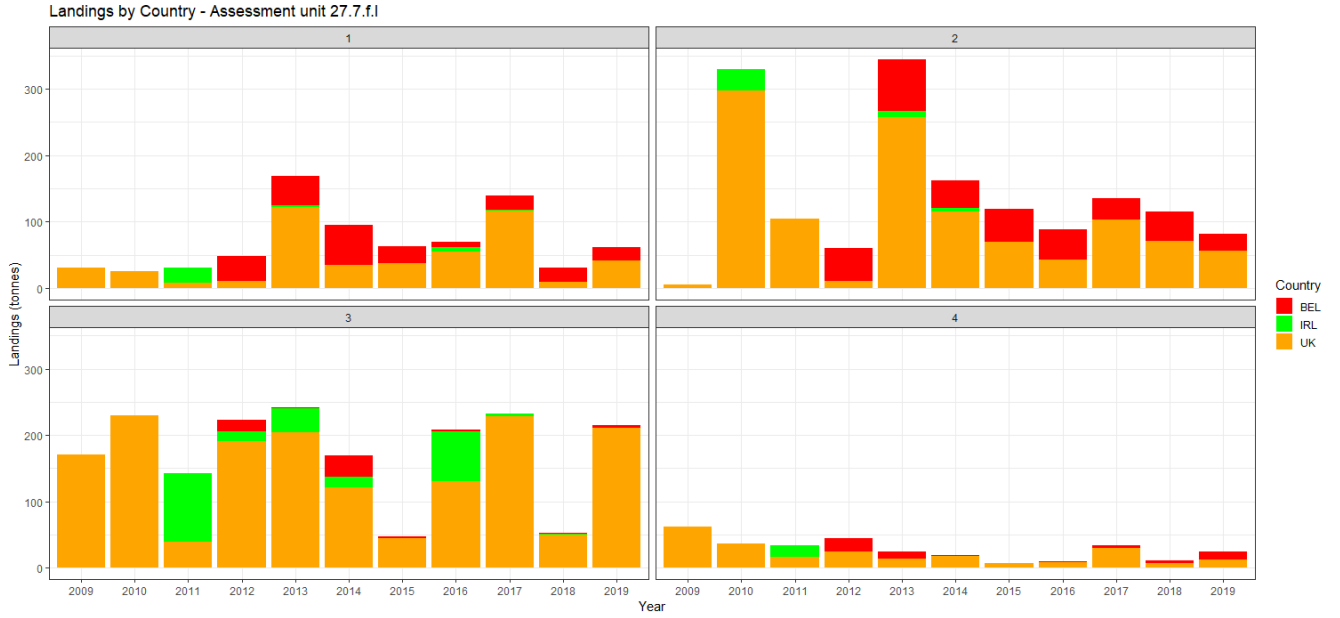

Figure 3.3: Assessment areas in 27.7.f. Landings by country and by quarter (NB. Isle of Man, Guernsey and Jersey landings <1t per annum. Belgian landings only recorded since 2012).

UK quarterly landings for the assessment areas in Divisions 27.7.e and 27.7.f are listed in Table 3.2 to Table 3.5. A sampling season comprises Q1-Q3 of the current calendar year and Q4 of the preceding year. Although there is a delay in the collation of landings data within the UK, at the time of report writing (January 2021), landings data to the end of Q3 2020 are considered reliable.

Table 3.2: UK quarterly landings (tonnes) from Area 27.7.e.I.

	Q1	Q2	Q3	Q4	Annual Total	Sampling Season Total (Q4, Q1, Q2, Q3)
2001	222	1063	1071	145	2523	
2002	145	613	1182	95	2001	2086
2003	186	812	1169	208	2374	2261
2004	208	1050	1390	132	2780	2856
2005	441	1330	1389	162	3321	3292
2006	385	1280	1486	126	3277	3314
2007	207	550	684	82	1524	1567
2008	85	259	760	161	1265	1187
2009	219	791	1150	110	2271	2321
2010	92	461	401	80	1033	1063
2011	96	737	892	65	1791	1806
2012	241	1299	856	114	2509	2460
2013	194	822	1250	107	2372	2380
2014	81	578	890	119	1667	1655
2015	173	2255	1113	171	3711	3660
2016	321	1414	878	235	2847	2783
2017	241	882	1023	210	2356	2381
2018	269	1017	395	110	1792	1892
2019	220	580	954	73	1827	1864
2020	123	391	285	113*	911*	881

* provisional.

Table 3.3: UK quarterly landings (tonnes) from Area 27.7.e.L.

	Q1	Q2	Q3	Q4	Annual Total	Sampling Season Total (Q4, Q1, Q2, Q3)
2001	515	423	176	361	1475	
2002	518	490	284	176	1468	1652
2003	131	330	276	236	973	913
2004	325	511	385	553	1775	1458
2005	626	721	465	977	2788	2365
2006	860	777	194	455	2286	2808
2007	521	740	268	482	2011	1984
2008	332	450	414	542	1737	1677
2009	544	539	395	343	1821	2019
2010	697	695	302	939	2633	2037
2011	1168	934	839	865	3807	3880
2012	964	591	558	915	3029	2979
2013	871	591	493	452	2408	2871
2014	504	611	416	354	1896	1988
2015	293	336	421	321	1371	1410
2016	385	278	408	493	1564	1391
2017	410	534	331	427	1703	1768
2018	304	399	575	630	1908	1705
2019	518	462	272	369	1622	1882
2020	313	160	457	507*	1437*	1348

* provisional.

Table 3.4: UK quarterly landings (tonnes) from Area 27.7.e.O.

	Q1	Q2	Q3	Q4	Annual Total	Sampling Season Total (Q4, Q1, Q2, Q3)
2001	183	350	35	11	578	
2002	116	450	118	37	720	695
2003	138	572	296	133	1139	1043
2004	205	318	72	105	700	728
2005	90	179	91	22	381	465
2006	150	140	147	122	559	458
2007	417	1108	817	65	2407	2464
2008	94	1022	411	81	1609	1593
2009	428	1299	314	13	2054	2121
2010	418	2251	465	7	3141	3147
2011	350	1116	158	13	1638	1631
2012	939	1488	120	114	2662	2561
2013	449	1351	1165	68	3032	3078
2014	184	427	695	45	1352	1375
2015	133	313	589	20	1055	1080
2016	130	272	480	11	892	902
2017	44	307	192	57	600	553
2018	91	368	431	429	1319	947
2019	49	514	827	14	1403	1818
2020	61	520	1348	18*	1946*	1944

* provisional.

Table 3.5: UK quarterly landings (tonnes) from Area 27.7.f.l.

	Q1	Q2	Q3	Q4	Annual Total	Sampling Season Total (Q4, Q1, Q2, Q3)
2001	10	14	20	2	46	
2002	6	6	15	2	29	29
2003	15	10	31	2	58	58
2004	78	23	32	6	138	134
2005	12	33	3	0	49	55
2006	5	16	80	55	156	101
2007	6	39	16	2	62	116
2008	10	116	18	12	156	146
2009	9	7	150	47	214	179
2010	15	309	203	36	563	574
2011	11	137	53	18	218	237
2012	10	22	173	1	205	222
2013	85	173	259	12	529	517
2014	15	59	124	7	204	210
2015	35	46	59	9	149	147
2016	19	21	97	4	141	146
2017	93	88	169	1	351	354
2018	2	61	40	3	106	103
2019	2	27	161	13	203	193
2020	40	73	92	7*	211*	218

* provisional.

3.2.2. Size composition

The number of samples collected each year through the biological sampling programme is shown in Table 3.6, along with the number of age samples collected during dredge surveys. As mentioned in Section 1.3, although not included at this point, age samples will be an important part of future assessments and are listed for completeness.

Table 3.6: Biological sampling programme summary for assessment areas in ICES Divisions 27.7.e and 27.7.f.

	Commercial Landings				Dredge Survey	
Sampling Season	Length Samples	Animals Measured	Age Samples	Shells Aged	Age Samples	Shells Aged
27.7.e.I						
2017	10	1594	1	24	9	335
2018	47	7191	16	458	17	717
2019	67	10699	26	774	11	446
2020	-	-	-	-	8	277*
27.7.e.L						
2017	19	3502	7	271	3	141
2018	24	5231	10	317	6	175
2019	14	2674	10	344	3	119
2020	4	1002	-	-	7	235*
27.7.e.O						
2017	8	1340	3	85	6	260
2018	9	1397	6	178	14	487
2019	8	1209	2	44	5	207
2020	-	-	-	-	6	222*
27.7.f.I						
2017	2	404	0	0	0	0
2018	1	173	1	26	3	100
2019	2	295	1	30	4	183
2020	-	-	-	-	4	116*

* awaiting update.

Sampling length distributions, raised to the commercial landings, are shown in Figure 3.4. Length samples for individual vessels were raised to UK quarterly landings, before summation to total landings during each sampling season. The size distributions for 27.7.e.L and 27.7.e.O indicate a significant increase in the numbers of scallop at MLS (100 mm) in 2019 compared to the previous two years (more than twice for 27.7.e.L and six times higher for 27.7.e.O). This effect is not evident in 27.7.e.I. The length distributions for 27.7.f.I do not suggest significant changes over time.

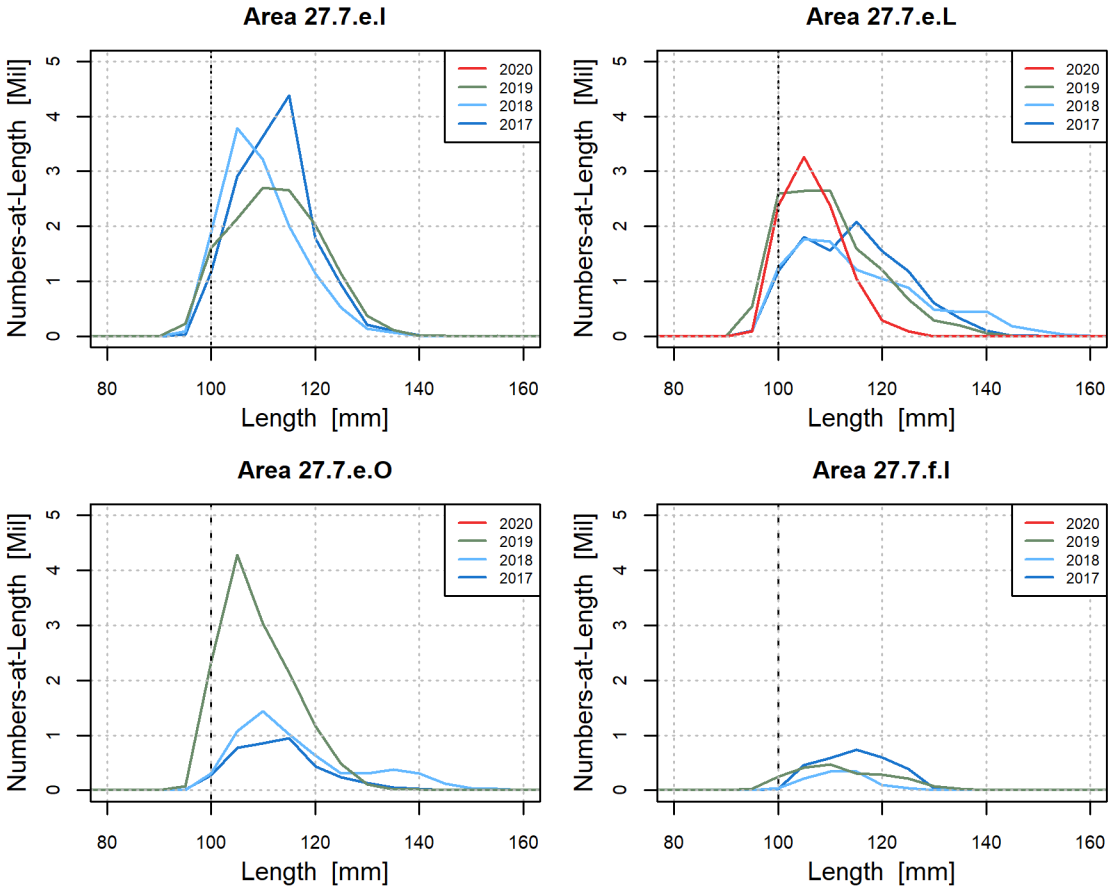

Figure 3.4: UK landed numbers in 5-mm size bins from assessment areas in ICES Divisions 27.7.e and 27.7.f during individual sampling seasons (Q1-Q3 of current calendar year, plus Q4 of previous year). The vertical dashed line indicates MLS. N.B. reduced sampling in 2020 season due to COVID-19 pandemic.

3.3. Biological parameters and dredge efficiency

Unpublished growth estimates by Palmer at Cefas provided von Bertalanffy growth parameters for the assessment areas in ICES Divisions 27.7.e and 27.7.f.

Component parts of scallops were weighed as part of an earlier project. When combined, they provide the total weight of individuals (Cefas, 2012; unpublished). A total of 348 samples (comprising 10,680 scallops) were collected from five areas in the English Channel: 1. East of the Eddystone, 2. West of the Eddystone, 3. Scillies, 4. Offshore, 5. Lyme Bay.

Table 3.7: Biological and dredge efficiency parameters used for assessment areas in ICES Divisions 27.7.e and 27.7.f.

Parameter	Value	Area	Source
Gear efficiency – ground type clean or clean becoming stony	30%	All	Cefas (Palmer, 2001; unpublished)
Gear efficiency – ground type flint cobbles	43%	All	Cefas (Palmer, 2001; unpublished)
Round length to weight	$a = 1.189 \times 10^{-3}$ $b = 2.488354$	27.7.e.I and 27.7.f.I	Cefas (2012; unpublished); see Section 1.1.5 for functional relationship
	$a = 1.326 \times 10^{-3}$ $b = 2.478189$	27.7.e.L	Cefas (2012; unpublished)
	$a = 8.08 \times 10^{-5}$ $b = 2.573519$	27.7.e.O	Cefas (2012; unpublished)
Flat height to round length	$a = 1.209837$ $b = -4.904044$	All	Eastern Channel dredge survey 2017; see Section 1.1.4 for functional relationship
Size at maturity	80 mm shell height (~90 mm length)	All	Cefas (unpublished)
Natural mortality	0.15 for all ages	All	(Cook, et al., 1990)
Von Bertalanffy growth	$H_\infty = 105.5$ $k = 0.437$ $t_0 = 0.682$	27.7.e.I and 27.7.f.I	Cefas (Dare and Palmer, 2001; unpublished); see Section 1.1.3 for functional relationship
	$H_\infty = 116.5$ $k = 0.584$ $t_0 = 0.715$	27.7.e.L	Cefas (Dare and Palmer, 2001; unpublished)
	$H_\infty = 106.3$ $k = 0.518$ $t_0 = 0.921$	27.7.e.O	Cefas (Dare and Palmer, 2001; unpublished)

3.4. Dredge and underwater television surveys

3.4.1. Dredge survey methodology

The dredge survey design and station selection procedure are described in Annex 2.

The same commercial scallop vessel, gear deployment configuration and sampling procedure outlined in the survey description for Area 27.7.d.N (Section 2.4.1) was used for the assessment areas in ICES Divisions 27.7.e and 27.7.f.

Between 3-12 August 2020, operating from Newlyn, a total of 128 randomly selected stations were surveyed in the Western English Channel and approaches to the Bristol Channel. Of these, 115 were carried out in Division 27.7.e and 13 in Division 27.7.f. As in 2019, because of sensitivities associated with Brexit, tow positions were not carried out in the French EEZ in 2020, resulting in lower tow numbers and samples for Beds 7.e.7 and 7.e.8 compared to previous years.

Data available for analysis are summarised in Table 3.8. The number of stations per block is shown in Figure 3.5.

Table 3.8: Sampling summary of the 2020 dredge surveys in the assessment areas of ICES Divisions 27.7.e and 27.7.f.

Bed	Number of Stations	Number of Length Samples	Number of Age Samples	Number Measured	Number Aged
7.e.1	19	19	3	503	120*
7.e.2	33	33	5	879	157*
7.e.3	0	0	0	0	0
7.e.4	31	31	7	599	246*
7.e.5	20	20	3	327	115*
7.e.6	0	0	0	0	0
7.e.7	4	4	1	288	40*
7.e.8	8	8	2	865	65*
7.f.1	13	13	4	276	116*

* awaiting update.

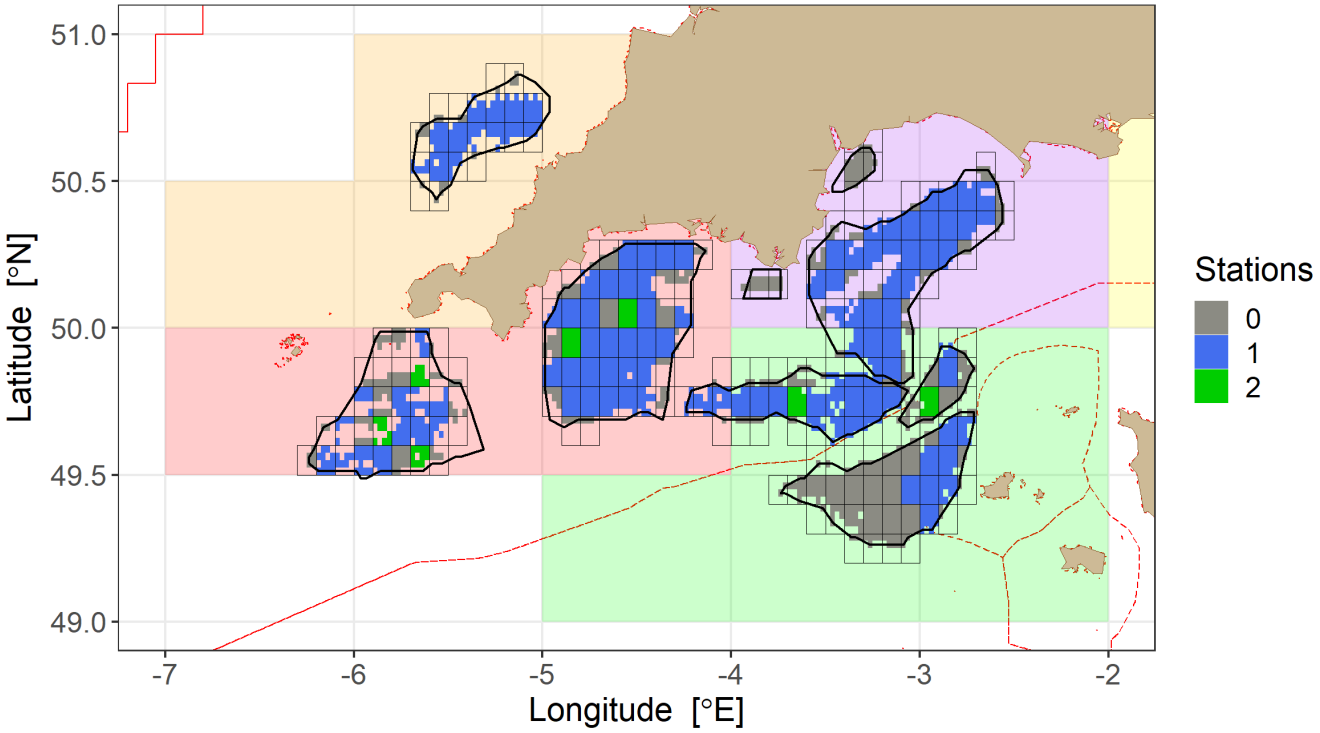

Figure 3.5: Number of stations visited during the 2020 dredge survey within each sampled block of Beds 7.e.1-8 and 7.f.1 within the assessment areas of ICES Divisions 27.7.e and 27.7.f. The dashed red line indicates the boundary of the UK EEZ, as well as those of the Channel Islands.

3.4.2. Underwater television survey methodology

In 2017, underwater television (UWTV) surveys were carried out to determine the spatial distribution and relative abundance of scallops in selected parts (TV.7.e.A, C and D) of ICES Division 27.7.e that are inaccessible to fishing gear, including Marine Protected Areas (MPAs), and areas with unsuitable ground types. In June 2019, UWTV surveys covered two further un-dredged zones that lie within Division 27.7.e (TV.7.e.B and TV.7.e.E). No UWTV survey was carried out in 2020. The methods for UWTV surveys are described in Annex 4.

3.5. Raised biomass estimates and uncertainty

In 2017, no areas in the French EEZ were surveyed and a bed mean density was used to estimate biomass there. In 2018, the French EEZ was surveyed allowing actual densities to be raised to this area. However, in 2019 and 2020, the dredge survey was once again limited to the UK EEZ. This affected the southern part of Bed 7.e.7 and the western part of

Bed 7.e.8. The northern part of Bed 7.e.7 is in the UK EEZ and the eastern part of Bed 7.e.8 is within the territorial waters around Guernsey.

In 2020, due to restrictions during the Covid-19 pandemic, the dredge surveys in the assessment areas of ICES Divisions 27.7.e and 27.7.f, which would normally have been conducted in May, were delayed until August. To make the 2020 survey results more comparable with previous years, the projected international commercial landings reported between 15 May and 15 August were added to the survey-derived biomass estimates. Since there are no publicly available databases with up-to-date landings from non-UK vessels, international landings were projected based on historic UK market shares (see Section 3.8 for a more detailed description).

The estimated biomass of harvestable scallops (≥ 100 mm MLS) within 0.1-by-0.1 degree blocks in 2020 is shown in Figure 3.6.

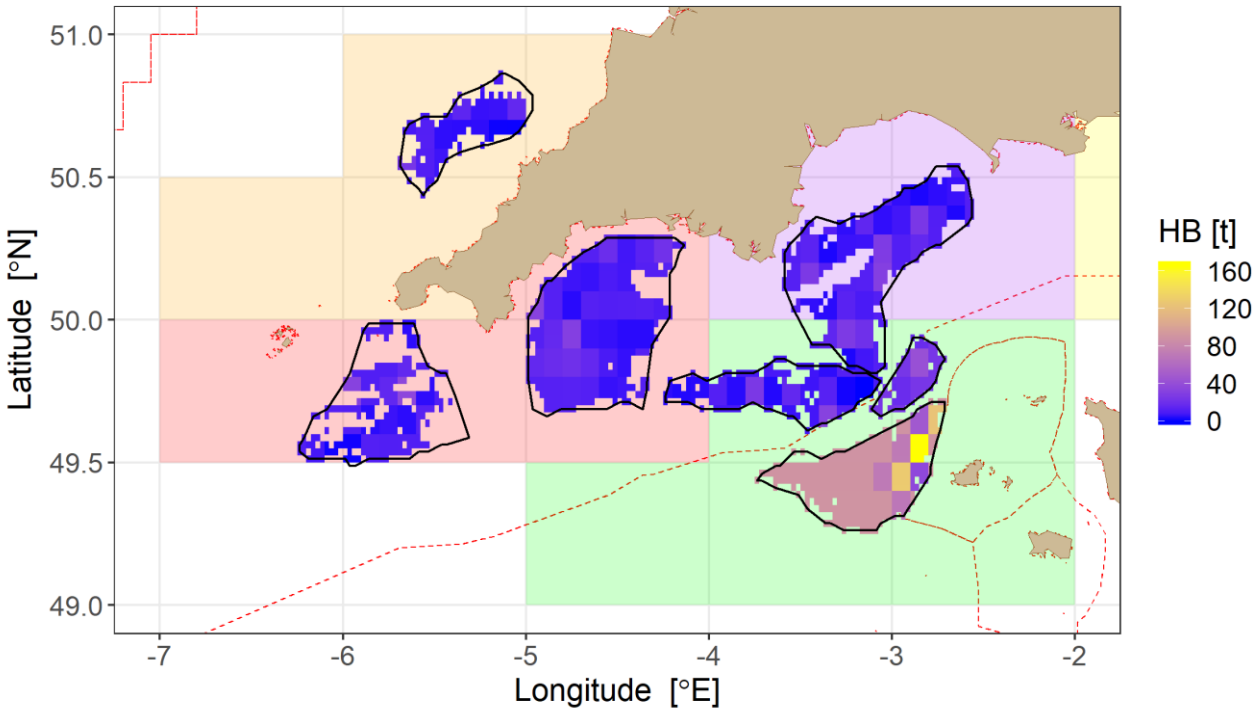

Figure 3.6: Harvestable biomass (tonnes) of scallops of at least MLS (100 mm round shell length) within the surveyed parts of Areas 27.7.e.I (red), 27.7.e.L (purple), 27.7.e.O (green), and 27.7.f.I (orange) during 2020. The dashed red line indicates the boundary of the UK EEZ, as well as those of the Channel Islands.

To establish a measure of uncertainty around the estimate of harvestable biomass, the values for each bed were randomly resampled ("bootstrapped") 5000 times with replacement. For each iteration, the same analysis procedure was used as for the original estimate. The resulting distribution of harvestable biomass during 2020 is shown in Figure 3.7.

The point estimate, along with the median and quantile range, are given in Table 3.9, together with the results for the previous years. As the point estimate utilises all available data, it is considered the most accurate value.

In Area 27.7.e.I, harvestable biomass increased during the 2017-2019 period, but decreased in 2020. In Areas 27.7.e.L and 27.7.e.O, the increasing trend has persisted into 2020. However, it remains to be seen whether the unusually large increase in biomass from 2019 to 2020 in Area 27.7.e.O is backed up by the 2021 survey. There are no indications of systematic changes over time in Area 27.7.f.I.

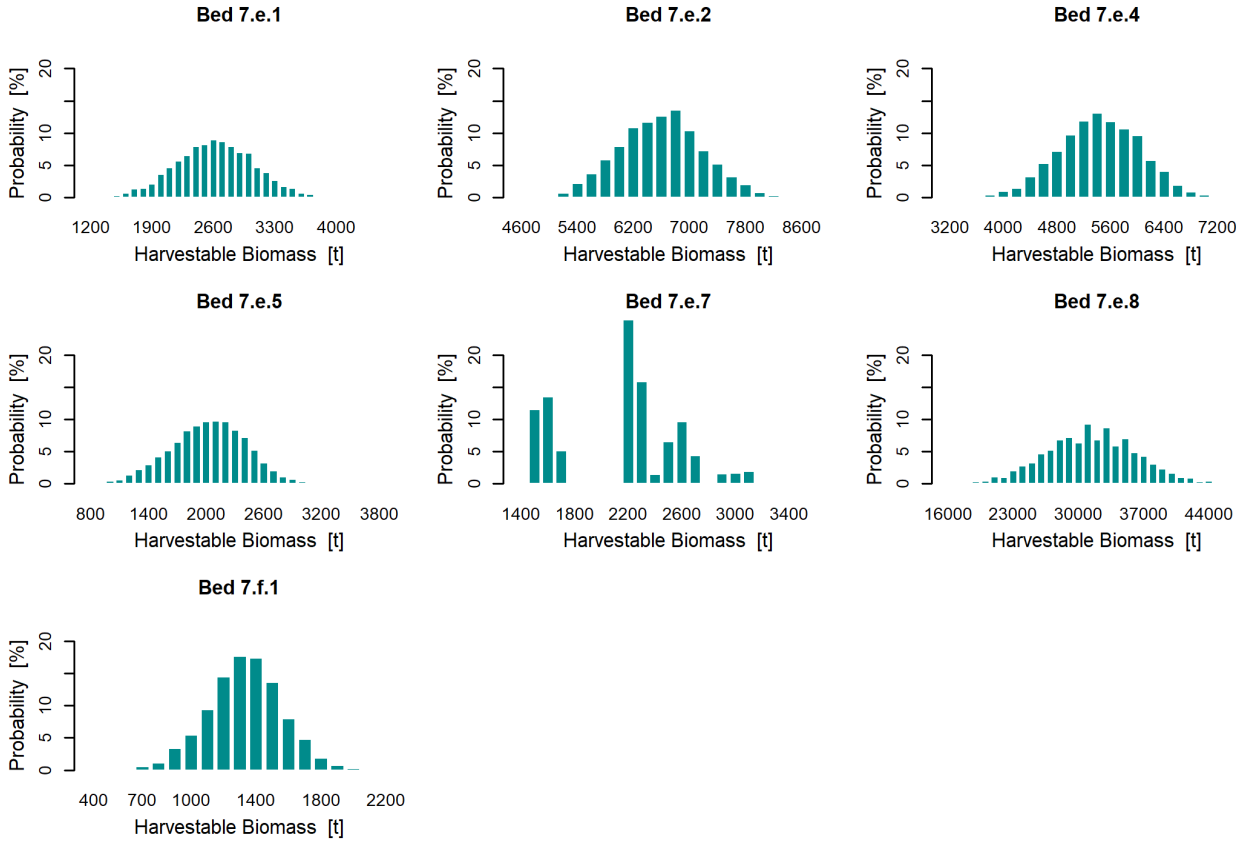

Figure 3.7: Distribution of harvestable biomass in Beds 27.7.e.1-8 and 27.7.f.1 during 2020 from random resampling (“bootstrapping”).

Table 3.9: Estimates of biomass (tonnes), point value, median, and quartile range from bootstrapping, for dredged parts of assessment areas in ICES Divisions 27.7.e and 27.7.f.

	25th Percentile	Median	Point Value	75th Percentile
27.7.e.I				
2017	6417	7045	7337	7608
2018	8585	9059	8971	9518
2019	9547	10286	10378	10864
2020	8373	8857	8791	9329
27.7.e.L				
2017	2449	2563	2636	2722
2018	2593	2792	2849	2995
2019	3056	3362	3384	3664
2020	4028	4404	4470	4777
27.7.e.O				
2017	6919	8469	8673	9401
2018	9119	10403	10746	11809
2019	13382	14877	15987	19868
2020	31772	35158	35370	38362
27.7.f.I				
2017	-	-	-	-
2018	1532	1674	1687	1815
2019	945	1104	1143	1283
2020	1132	1280	1283	1420

3.6. Size composition from dredge survey

From the size samples taken at each station, total (pooled) length frequency distributions within assessment areas of ICES Divisions 27.7.e and 27.7.f were derived. From these, total population numbers and biomasses could be estimated.

In previous years, a significant proportion by weight of survey catches from these assessment areas were below MLS (Table 3.10). With the exception of Bed 7.e.5 (mainly Area 27.7.e.O and partly Area 27.7.e.I) and Bed 7.e.7 (Area 27.7.e.O), the size distributions in 2020 have shifted upwards (Figure 3.8), leading to a significant reduction in

the undersized proportion of survey catches. This is also seen in size distributions aggregated within assessment areas (Figure 3.9).

The area-aggregated size distributions derived from survey catches (Figure 3.9) do not compare directly to those from commercial landings (Figure 3.4), as they are raised to total estimated biomass by means of an assumed dredge efficiency, as opposed to being raised to reported removals.

Table 3.10: Proportion by weight (percent) of scallops below MLS (100 mm) in the standard commercial dredges from dredge surveys.

	27.7.e.I	27.7.e.L	27.7.e.O	27.7.f.I
2017	21	16	32	-
2018	23	52	32	24
2019	17	17	31	45
2020	6	4	12	7

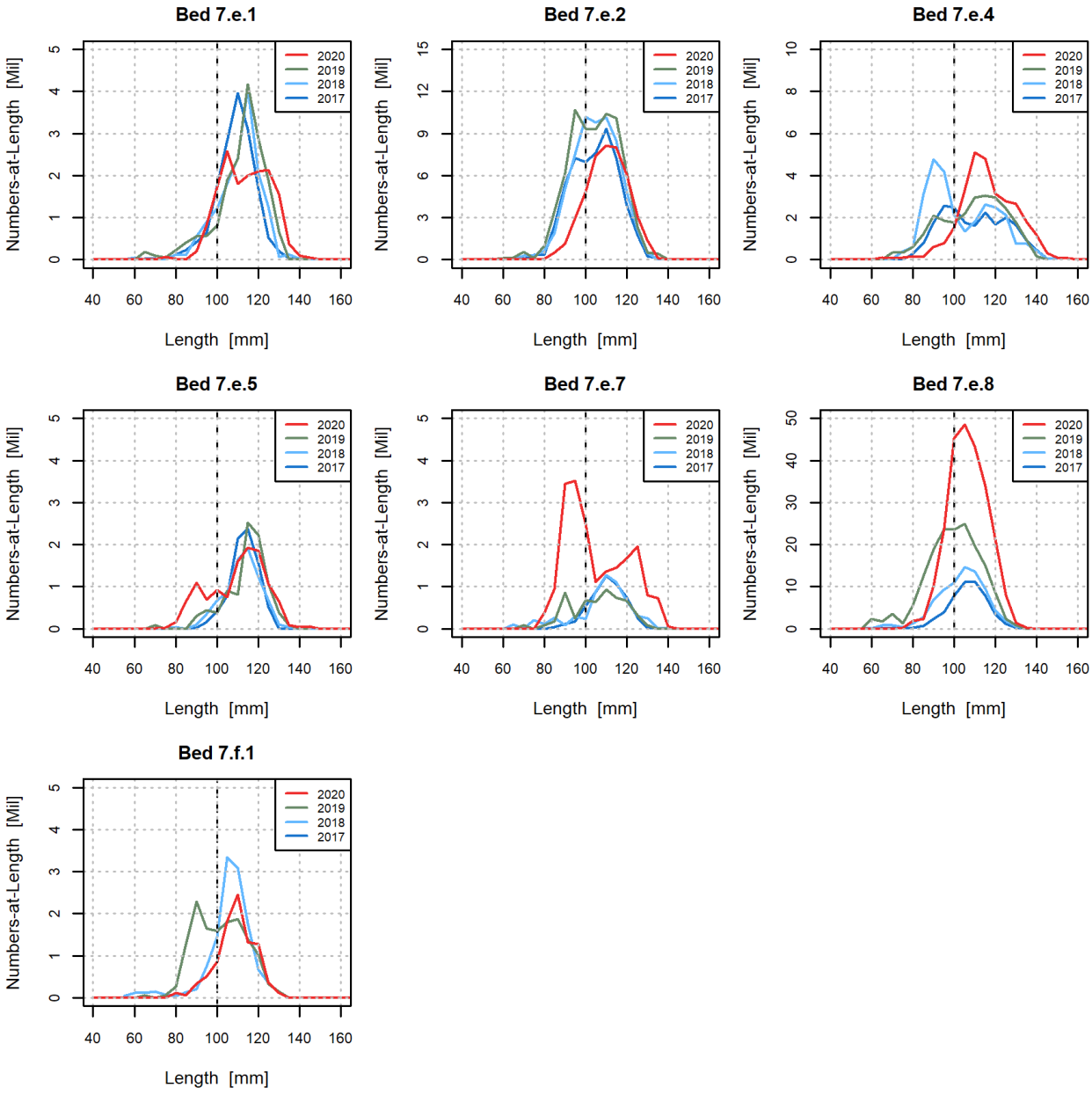

Figure 3.8: Annual population length distributions in 5-mm size bins from the 2020 dredge survey in Beds 7.e.1-8 and 7.f.1. The vertical dashed lines indicate MLS.

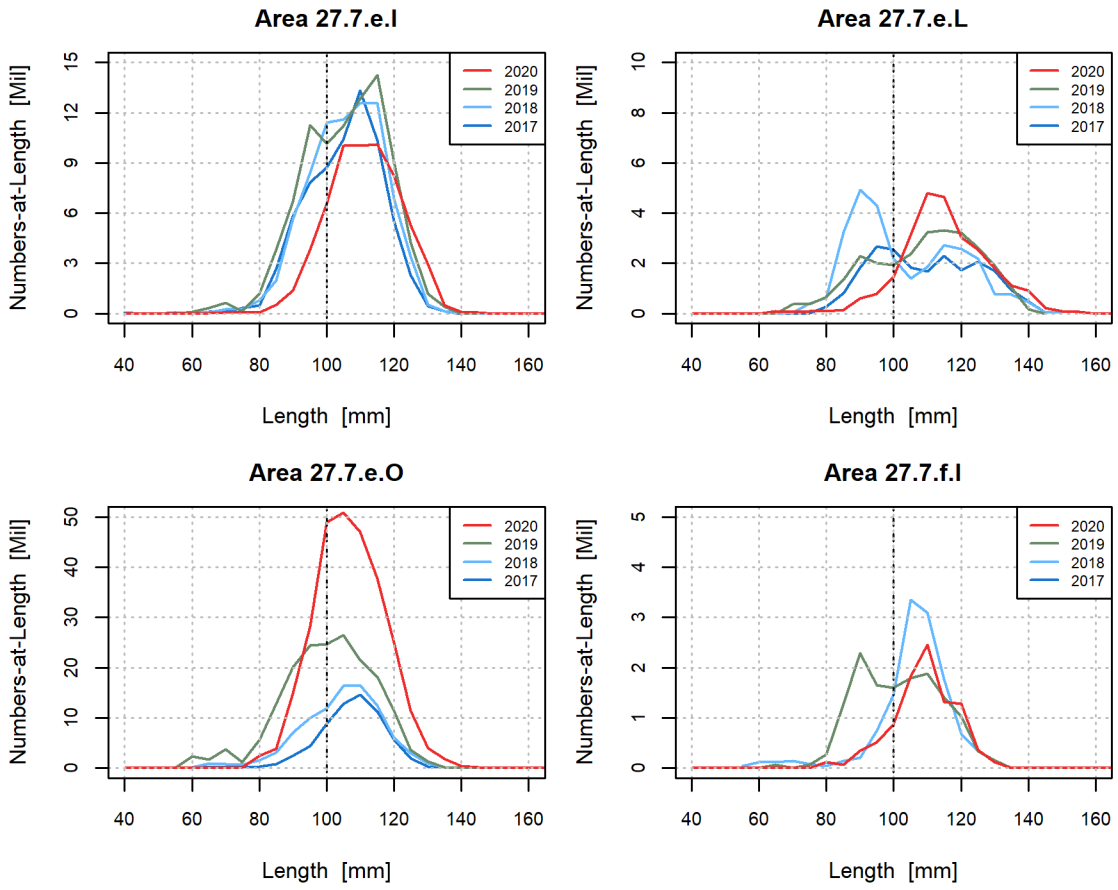

Figure 3.9: Annual population length distributions in 5-mm size bins from the 2020 dredge survey in in the assessment areas of ICES Divisions 27.7.e and 27.7.f. The vertical dashed lines indicate MLS.

3.7. Relative abundance from UWTV survey

UWTV surveys were carried out in 2017 and 2019. In 2017, tow duration was 11 minutes to optimise coverage during the limited ship time, and in line with similar video surveys. The camera drop frame required a slow tow speed, which limited the transect length to a little over 100 m. In 2019, tow speed and duration were increased to provide a transect length of just under 250 m.

The UWTV surveys established that scallops are distributed at low density on the seabed in the un-dredged zones. Despite the increase in ground coverage in the 2019 survey, a significant proportion of the transects gave zero counts, and the highest density observed during the 2019 survey was 0.94 scallops per 100 m^2. Although zero densities are not uncommon in surveys where target species are aggregated on the seabed, further development of the camera deployment platform is expected to improve sampling coverage.

Further results from the 2017 and 2019 UWTV surveys are reproduced in Annex 4. Biomass estimates for the surveyed un-dredged zones in these assessment areas are included in the estimation of harvest rates in the following section.

3.8. Harvest rate estimation

The harvest rate (i.e. the ratio of landings to total harvestable biomass) is proposed to give a proxy for the fishing mortality experienced by this assessment area. Ideally this is calculated from the harvestable biomass immediately prior to the start of a particular fishing season, in relation to the total removals during that season. International landings for 2017 and 2018 were available from the latest ICES Scallop Working Group (ICES, 2020). Although these are considered more reliable than the estimates based on UK share and presented in previous reports, they may be subject to further refinement. International landings for the 12-months following the two most recent dredge surveys were not available at the time of writing of this assessment report. Instead, for 2019 the UK landings recorded on a national database were used, divided by the average ratio of the UK component of international landings during the 2017-2019 period (27.7.e.I, 98%; 27.7.e.L, 99%; 27.7.e.O, 80%; 27.7.f.I, 76%). This assumes that the UK share of international landings has been stable since then. For the most recent survey, the estimated international landings for the 12-month period following the previous survey were used, unless landings in the incomplete 12-month period since the latest survey already exceed those of the previous period. This is more likely to be indicative of future landings than an estimate based on incomplete landings data. However, international removals and associated harvest rates presented here are provisional and will be revised when required data become available.

Provisional harvest rates for the dredged parts of assessment areas in ICES Divisions 27.7.e and 27.7.f are listed in

Table 3.11. The corresponding estimates of harvestable biomass are based on the results from dredge surveys. The harvestable biomass estimates are the point values from Table 3.9. The range of harvest rate is based on the inter-quartile range of the harvestable biomass estimate from random resampling.

The provisional harvest rates listed in Table 3.12 are based on biomass estimates that also include un-dredged zones that have been surveyed by UWTV. Biomass estimates for selected un-dredged zones of Division 27.7.e were assessed in 2017 and again in 2019 using UWTV (in addition to a small area in Division 27.7.f.). As such, harvest rate estimates include the fished part of the stock, together with biomass estimated for selected un-dredged areas. There is additional stock outside the area surveyed with dredges and UWTV, for which there are currently no data on their biomass or ability to contribute to recruitment to the main areas of fished stock. Un-dredged areas are assumed to be at carrying capacity with no fishing mortality, and the biomass estimates from 2017 UWTV surveys have been included in estimates for later years. These harvest rates are

applicable only when connectivity between dredged and un-dredged populations is complete.

Table 3.11: Biomass removed during 12-month periods following annual dredge surveys, and provisional harvest rate estimate for the dredged parts of ICES Divisions 27.7.e and 27.7.f.

	Biomass Removed (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvest Rate on Dredged Portion of Stock (%)	Harvest Rate Range (%)	
27.7.e.I					
2017	2757	7337	37.6	36.2	43.0
2018	1506	8971	16.8	15.8	17.5
2019	1821*	10378	17.5	16.8	19.1
2020	1821**	8791	20.7	19.5	21.7
27.7.e.L					
2017	1441	2636	54.7	52.9	58.8
2018	2195	2849	77.0	73.3	84.7
2019	1366*	3384	40.4	37.3	44.7
2020	1366**	4470	30.6	28.6	33.9
27.7.e.O					
2017	956	8673	11.0	10.2	13.8
2018	1460	10746	13.6	12.4	16.0
2019	2003*	15987	12.5	10.1	15.0
2020	2264*	35370	6.4	5.9	7.1
27.7.f.I					
2017	273	-	-		
2018	148	1687	8.8	8.2	9.7
2019	454*	1143	39.7	35.4	48.0
2020	454**	1283	35.4	32.0	40.1

* estimated from UK removals and 2017-2019 UK market share, to be revised.
** estimate from previous year, to be revised.

Table 3.12: Biomass removed during 12-month periods following annual dredge surveys, and provisional harvest rate estimate for assessment areas in ICES Divisions 27.7.e and 27.7.f, combining harvestable biomass estimates from the dredge and UWTV surveys.

	Biomass Removed (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UWTV Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
27.7.e.I					
2017	2757	7337	4683	12020	22.9
2018	1506	8971	4683	13654	11.0
2019	1821*	10378	4683	15061	12.1
2020	1821**	8791	4683	13474	13.5
27.7.e.L					
2017	1441	2636	2649	5286	27.3
2018	2195	2849	2649	5498	39.9
2019	1366**	3384	2649	6033	22.6
2020	1366**	4470	2649	7119	19.2
27.7.e.O					
2017	956	8673	620	9293	10.3
2018	1460	10746	620	11366	12.8
2019	2003*	15987	620	16607	12.1
2020	2264*	35370	620	35990	6.3
27.7.f.I					
2017	273	-	375	-	-
2018	148	1687	375	2062	7.2
2019	454*	1143	375	1518	29.9
2020	454**	1283	375	1658	27.4

* estimated from UK removals and 2017-2019 UK market share, to be revised.
** estimate from previous year, to be revised.

3.9. Landings size composition – cohort modelling

Most fully analytical fish stock assessments use a time series of age composition of the landings (along with other data such as total landings or catches and a survey series) to estimate the rate at which the fishery is exploiting the stock.

In the first assessment for 2017 (Bell, et al., 2018) we used an age-based cohort model to determine fishing mortality, assuming the populations had been at equilibrium (“steady-state”), that is that fishing effort, recruitment and growth have all been constant. Deviations from this assumption will result in unreliable simulations.

Marked differences in the reported landings between different assessment years have highlighted that the populations are not at equilibrium, Therefore, for this report a method has been employed that is less susceptible to fluctuations in recruitment and fishing. Scaled length distributions were used to determine gear selection parameters (L25 and L50 of an ogive curve) to facilitate a length-based cohort method (Figure 3.10). Length-based methods are routinely used for shellfish assessments, where only size structure of the removals is available, and is typical for many shellfish species, where routine age determination is problematic. The length-based assessment uses growth parameters to determine the time spent in each size class and projects the spawning stock biomass and catch expected from a batch of recruits (a yield and spawner per recruit model).

Provisional harvest rates for the dredged portion of the assessment areas, and candidate harvest rates consistent with MSY, estimated using the length-based cohort method, are presented in Table 3.13.

Lack of sampling opportunities led to inadequate size distributions for Area 27.7.f.I. Therefore, no size-based modelling was undertaken for this assessment area.

Age compositions are not presented in this report for any of the assessment areas.

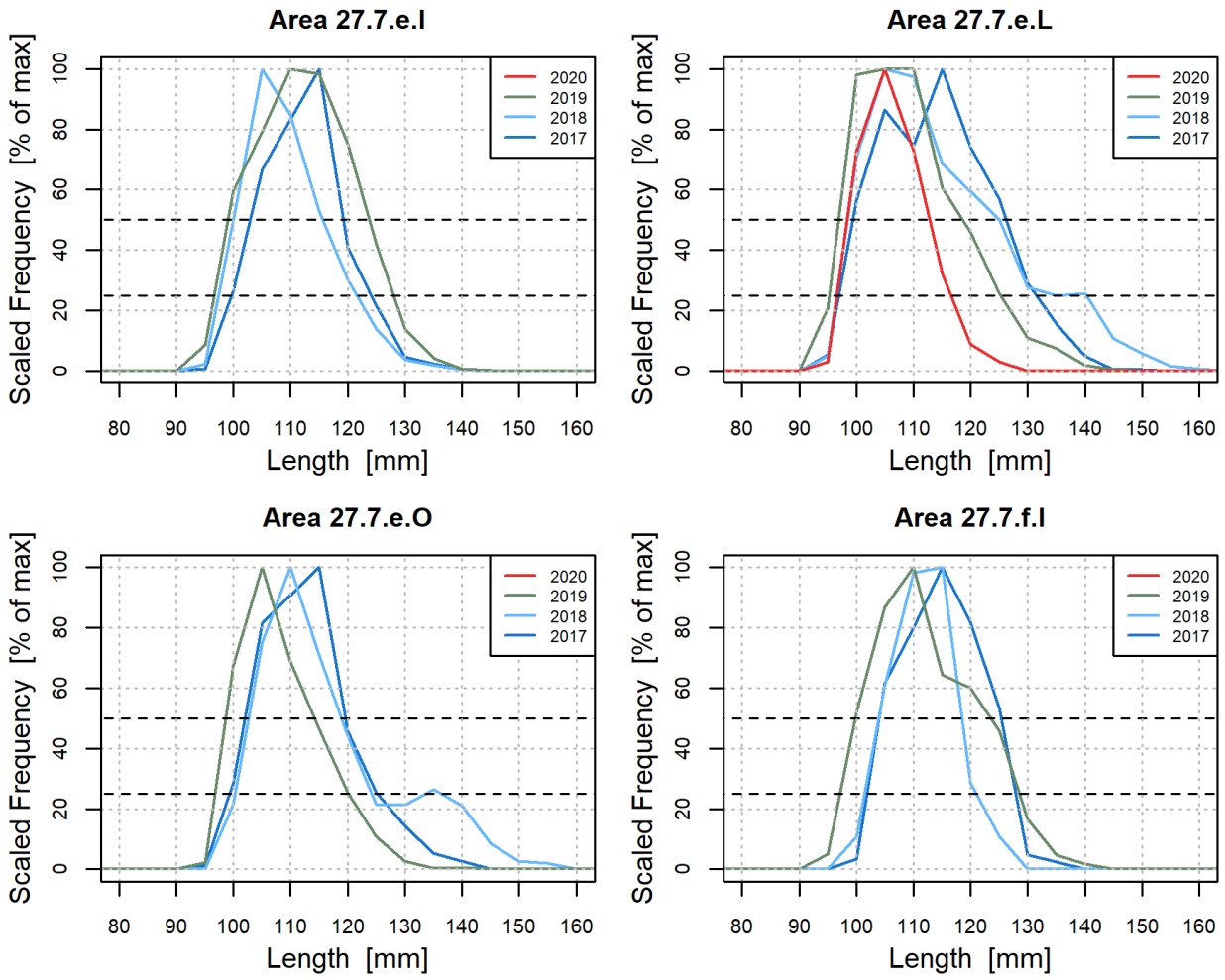

Figure 3.10: Scaled landed size distributions as a proportion of the mode. Horizontal lines indicate 25% and 50% levels. N.B. reduced sampling in 2020 season due to COVID-19 pandemic.

Table 3.13: Provisional harvest rate estimates for assessment areas in ICES Division 27.7.e, with MSY candidates.

	Harvest Rate on Dredged Portion of Stock (Dredge Survey Only, %)	Harvest Rate on Wider Stock (Incl. UWTV Survey, %)	MSY Candidate Harvest Rate (%)
27.7.e.I			
2017	37.6	22.9	19.5
2018	16.8	11.0	19.5
2019*	17.5	12.1	19.5
2020**	20.7	13.5	19.5
27.7.e.L			
2017	54.7	27.3	21.0
2018	77.0	39.9	21.0
2019*	40.4	22.6	21.0
2020**	30.6	19.2	21.0
27.7.e.O			
2017	11.0	10.3	20.9
2018	13.6	12.8	20.9
2019*	12.5	12.1	20.9
2020*	6.4	6.3	20.9

* estimated from UK removals and 2017-2019 UK market share, to be revised.
** based on removals estimate from previous year, to be revised.

3.10. MSY reference point estimation

Full estimation of the fishing mortality that generates maximum sustainable yield (MSY) requires a full analytical assessment, including an estimate of the stock-recruitment relationship. Clearly, as is the case with many stocks assessed by ICES, this is not yet possible. For these stocks, ICES scientists use proxy reference points that have been found to be reasonable approximations to MSY reference points. The fishing mortality which generates 35% of the virgin spawning potential (F35%SpR) is a commonly used reference point, not only within ICES advisory areas, but also globally. F0.1, the fishing mortality at which the slope of the yield-per-recruit curve is 10%, is often close to

F35%SpR. Fmax, the fishing mortality which gets the maximum yield from each recruited individual, is also sometimes used as a proxy for the fishing mortality which provides the maximum sustainable yield (Fmsy). This, however, is unlinked to spawning potential, and is more uncertain in its estimation. In some circumstances, it suggests fishing rates which are highly risky for the stock size.

A simple yield-per-recruit model was constructed using selection-at-size and maturity-at-size parameters estimated in this assessment. The fishing mortality, harvest rate and spawner-per-recruit are presented for three reference points in Table 3.14.This model estimates that in order to achieve F35%SpR, a harvest rate in the vicinity of 20% would be required. The Fmax estimates for these areas are high, because there is relatively little growth potential after the MLS has been reached compared to expected losses through natural mortality. Following exploitation at the Fmax estimates for these stocks would remove all or most of the spawning stock in one year and is therefore highly risky. The recommended FMSY reference point for this stock is therefore F35%SpR. The relationship between yield or spawner-per-recruit to fishing mortality is presented by assessment area in Figure 3.11.

Table 3.14: Fishing mortality, harvest rate, spawner-per-recruit, and average fishing mortality Fbar at reference points F0.1, FSpR35% and Fmax.

Reference Point	Fishing Mortality	Harvest Rate (%)	Spawner per Recruit	Fbar
27.7.e.I				
F0.1	0.235	17.1	0.382	0.120
FSpR35%	0.272	19.5	0.350	0.138
Fmax	0.995	52.3	0.146	0.506
27.7.e.L				
F0.1	0.230	19.1	0.372	0.117
FSpR35%	0.253	21.0	0.350	0.129
Fmax	0.760	56.2	0.158	0.388
27.7.e.O				
F0.1	0.245	18.2	0.383	0.126
FSpR35%	0.285	20.9	0.350	0.146
Fmax	1.170	62.2	0.139	0.602

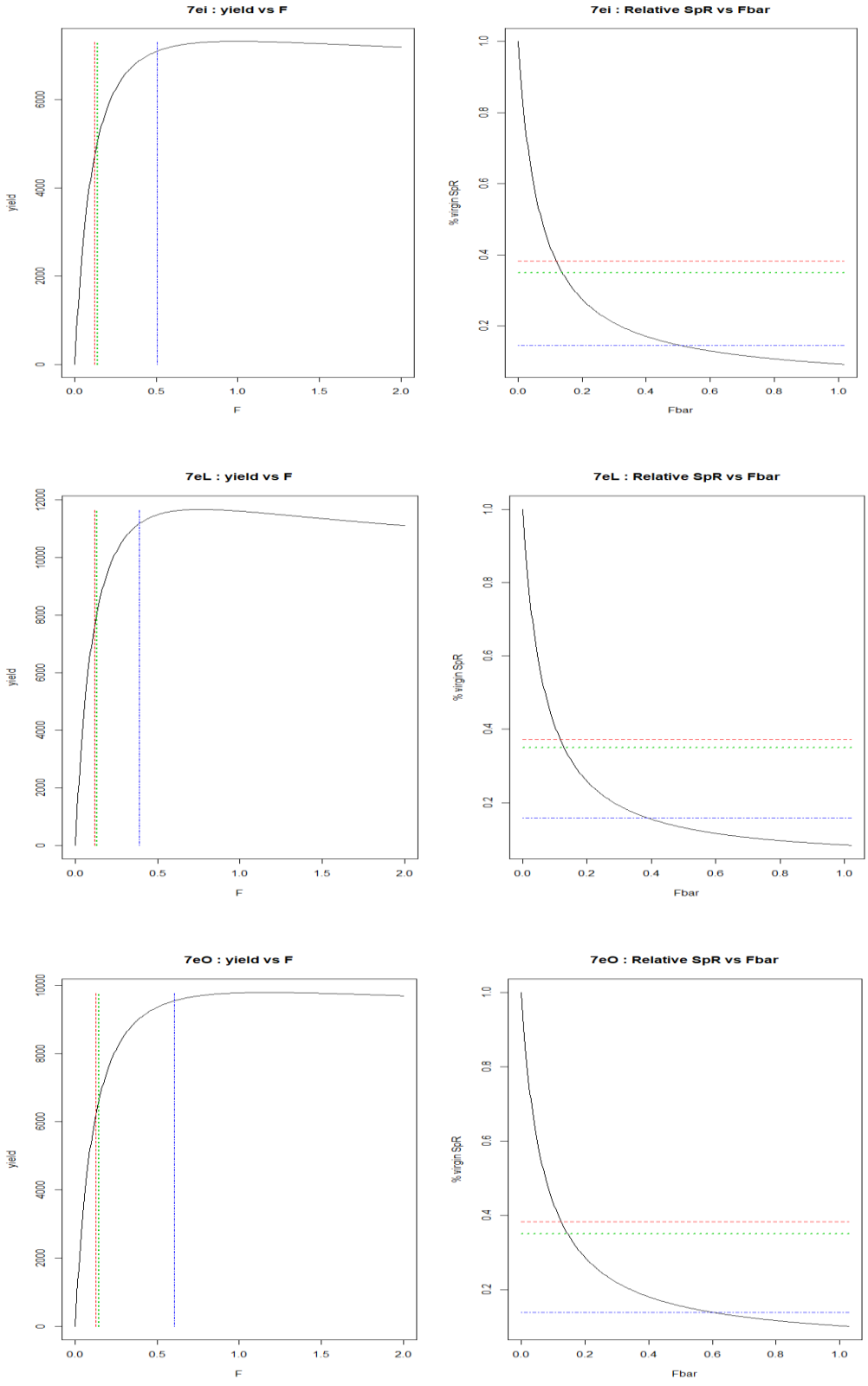

Figure 3.11: Yield (left) and relative spawner-per-recruit (right) against fishing mortality for assessment areas in ICES Division 27.7.e: Area 27.7.e.I (top), Area 27.7.e.L (middle), and Area 27.7.e.O (bottom). Three reference points are indicated: F0.1 (red), FSpR35% (green), and Fmax (blue).

3.11. Conclusion

This is the fourth stock assessment undertaken for king scallops in the western English Channel (assessment areas of ICES Division 27.7.e), and the third for the assessment area in Division 27.7.f. Due to the Covid-19 pandemic, scientific surveys and commercial catch sampling in 2020 were restricted. As a result, the planned UWTV survey could not be carried out.

Therefore, this 2020 assessment includes biomass estimates and provisional harvest rates from the 2020 dredge survey, together with the biomass estimated based on the 2017 and 2019 UWTV surveys in selected un-dredged zones.

Variation in reported annual landings suggests that the populations in these assessment areas are not at equilibrium. The assumption of equilibrium is fundamental to cohort modelling and yield-per-recruit estimates. As a result of these concerns, a modelling approach which utilises scaled length samples was considered more appropriate than the age-based method used for the first assessment for 2017 (Bell, et al., 2018)..

Length-structured cohort modelling provides context for harvest rate estimates by establishing an MSY candidate reference value.

In the dredged part of Area 27.7.e.I, the estimated harvest rate was significantly above the MSY reference value of 19.5% in 2017 but has since fallen to just above that value. Including biomass in selected un-dredged zones further reduces the estimated harvest rate.

In the dredged part of Area 27.7.e.L, the estimated harvest rate was above the MSY reference value of 21.0% in 2017 and 2018 by more than a factor of two and three, respectively. Due to the significant increase in the estimate of harvestable biomass in 2020, the harvest rate in the dredged part of the assessment area has decreased to 30.6%. Including biomass in selected un-dredged zones reduces the estimated harvest rate to just below the reference value.

The harvest rate in the dredged part of Area 27.7.e.O has been consistently below the MSY reference value of 20.9%.

Due to insufficient sampling data, no size-based modelling was carried out for Area 27.7.f.I.

Although international landings for the 12-month periods following the 2017 and 2019 dredge surveys are now considered reliable, all harvest rates presented here are provisional and may need revision when more data become available. Previous reports have highlighted the problems of using UK share to estimate international removals and harvest rates for those assessment areas with shared stocks. Harvest rate estimates for the latest two years should be viewed with caution.

In 2018, a change to a smaller survey vessel deploying fewer dredges was unavoidable. Both survey vessels deploy very similar gear and catches of scallop are standardised to area swept. However, no comparative tow work was carried out to confirm that there was no change in catchability. As such, caution should be used when comparing the results from the 2017 survey with later surveys, which have been carried out by the same vessel since 2018.

A presentation of the assessment approach to the ICES Scallop Working Group highlighted that there are several key areas of uncertainty that require further work to better understand their impact. With the swept area biomass assessment, the key parameter is the gear-efficiency estimate, and even relatively small changes to this estimate would have a significant impact upon the estimated harvestable biomass and harvest rate. Research to develop novel technology to resolve gear efficiency estimates is still ongoing.

It should be noted that the assessment of scallops in Divisions 27.7.e and 27.7.f only covers the fished part of the stock and selected un-dredged zones. Additional stock is known to exist outside the surveyed area, for which there are currently no data on either biomass or the ability to contribute to recruitment to the fished stock. Further surveys of un-dredged areas are planned. Provided that there is evidence that scallops in un-dredged areas make significant contributions to the recruitment in the dredged areas, proportionate inclusion of biomass from un-dredged areas is likely to revise the estimates of realised harvest rate downwards. Hydrographic and particle dispersal modelling to determine the level of larval connectivity between exploited and unfished areas is planned.

We would hope that in future assessments we will be able to see weak and strong year-classes moving through the population structure to give confidence that the sampling scheme is able to adequately follow the population development. As a time-series of age compositions develops, the use of age structured assessment methods will be investigated. A time series as long as the number of year classes in the fishery is preferred, which in this case is a minimum of eight years (8 year plus group).

4. Stock assessment for surveyed parts of Area 27.4.b.S

4.1. Area definition

As described in Section 1.4, an additional scallop assessment area has been defined within ICES Division 27.4.b, which encompasses the scallop fishing activity within English waters of the North Sea by UK vessels of at least 12 m in length. Within this division are two scallop beds, 4.b.1 and 4.b.2 (Figure 4.1). These beds were defined in 2018 based on 2009-2017 VMS data, and were first surveyed in 2018.

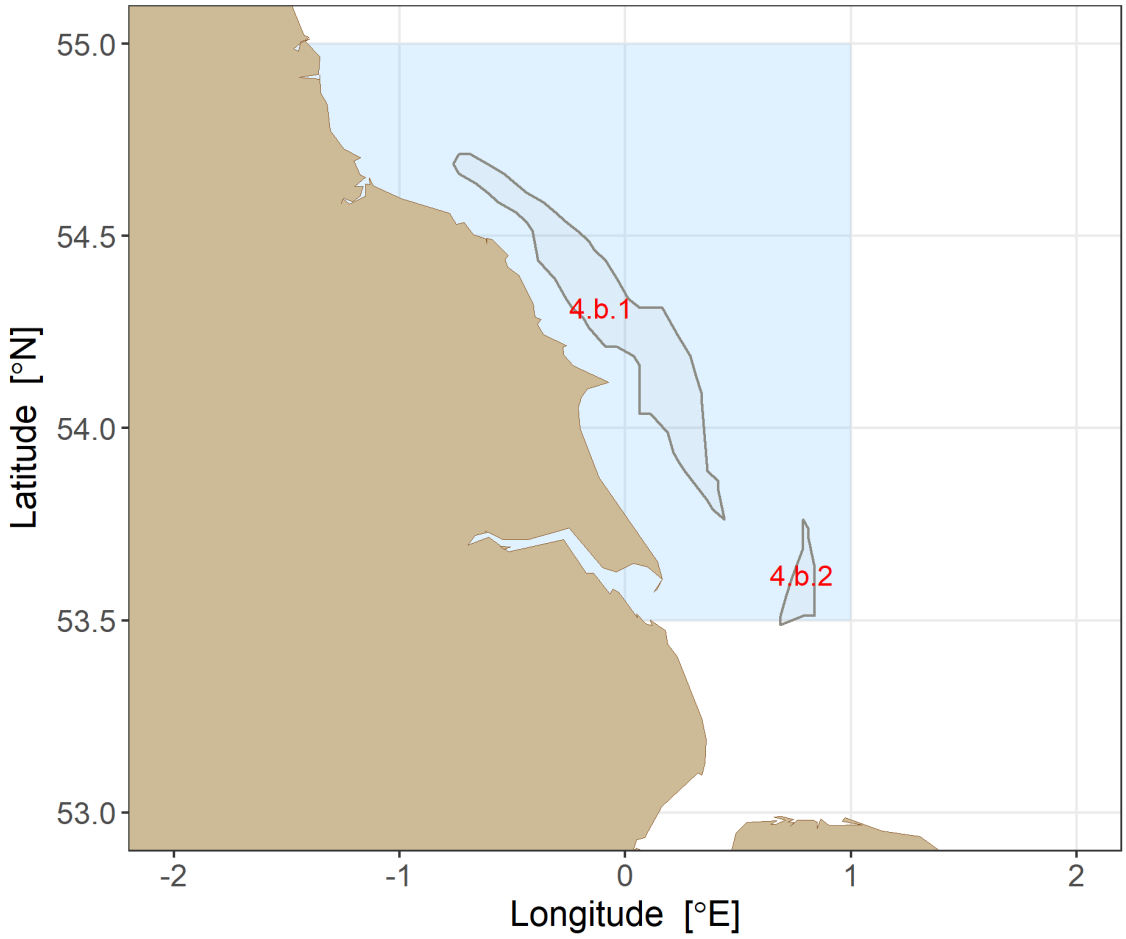

Figure 4.1: Dredge-surveyed parts (Beds 4.b.1 and 4.b.2) of Area 27.4.b.S (light blue shading).

4.2. Available data

4.2.1. Catch and survey data

Annual landings by country for the 2009-2016 period, as reported to STECF for the rectangles in Area 27.4.b.S, are listed in Table 4.1. Total international landings for 2017-2019 were obtained from the latest ICES Scallop Working Group (ICES, 2020). This fishery is exploited almost exclusively by UK registered vessels.

Table 4.1: Annual landings (tonnes) by country (as reported to STECF and ICES) in Area 27.4.b.S.

	BEL	FRA	NLD	IRL	GBG	GBJ	IOM	UK	International
2009	-	-	-	-	-	-	-	394	394
2010	-	-	-	-	-	-	-	361	361
2011	-	-	-	-	-	-	-	699	699
2012	0	-	-	-	-	-	6	985	991
2013	0	-	-	-	-	-	1	352	353
2014	0	0	-	-	-	-	-	2300	2301
2015	0	-	-	-	-	-	-	3172	3172
2016	0	-	-	0	-	-	-	1047	1047
2017*	9	-	-	-	-	-	-	2503	2512
2018*	-	-	-	-	-	-	-	2322	2322
2019*								2333	2333

* from (ICES, 2020).

Figure 5.2 shows international quarterly landings by country within Area 27.4.b.S. Landings in this assessment area are almost exclusively from UK vessels, with small contributions in 2012 from vessels registered to the Isle of Man.

Figure 4.2: Quarterly landings by country in Area 27.4.b.S.

UK quarterly landings for Area 27.4.b.S are listed in Table 4.2. A sampling season comprises Q1-Q3 of the current calendar year and Q4 of the preceding year. Although there is a delay in the collation of landings data within the UK, at the time of report writing (January 2021), landings data to the end of Q3 2020 are considered reliable.

Table 4.2: UK quarterly landings (tonnes) from Area 27.4.b.S.

	Q1	Q2	Q3	Q4	Annual	Sampling Season (Q4, Q1, Q2, Q3)
2001	12	1	0	762	775	-
2002	417	610	11	30	1068	1800
2003	434	112	3	6	554	579
2004	34	68	2	0	103	109
2005	161	0	0	121	282	161
2006	141	41	26	49	258	330
2007	21	119	144	1	285	333
2008	36	165	169	1	370	371
2009	18	166	190	20	394	375
2010	88	227	44	1	361	379
2011	117	239	57	286	699	414
2012	441	453	95	2	991	1275
2013	60	70	18	204	353	150
2014	786	435	283	797	2300	1708
2015	1506	951	377	340	3173	3630
2016	129	215	591	118	1054	1275
2017	936	886	385	297	2503	2325
2018	689	838	366	434	2328	2190
2019	998	839	294	87	2218	2565
2020	499	132	81	125*	836*	869

* provisional.

4.2.2. Size composition

The number of samples collected each year through the biological sampling programme is shown in Table 4.3, along with the number of age samples collected during dredge surveys. As mentioned in Section 1.3, although not included at this point, age samples will be an important part of future assessments and are listed for completeness.

Table 4.3: Biological sampling programme summary for Area 27.4.b.S.

	Commercial Landings				Dredge Survey	
Sampling Season	Length Samples	Animals Measured	Age Samples	Shells Aged	Age Samples	Shells Aged
2018	8	998	11	411	7	288
2019	6	965	4	124	6	225
2020	2	290	*	*	6	94*

* awaiting update.

Sampling length distributions, raised to the commercial landings, are show in Figure 4.3. Length samples for individual vessels were raised to UK quarterly landings, before summation to total landings during each sampling season. There is an indication that in 2018 the number of large animals above 130 mm length was higher than in 2019.

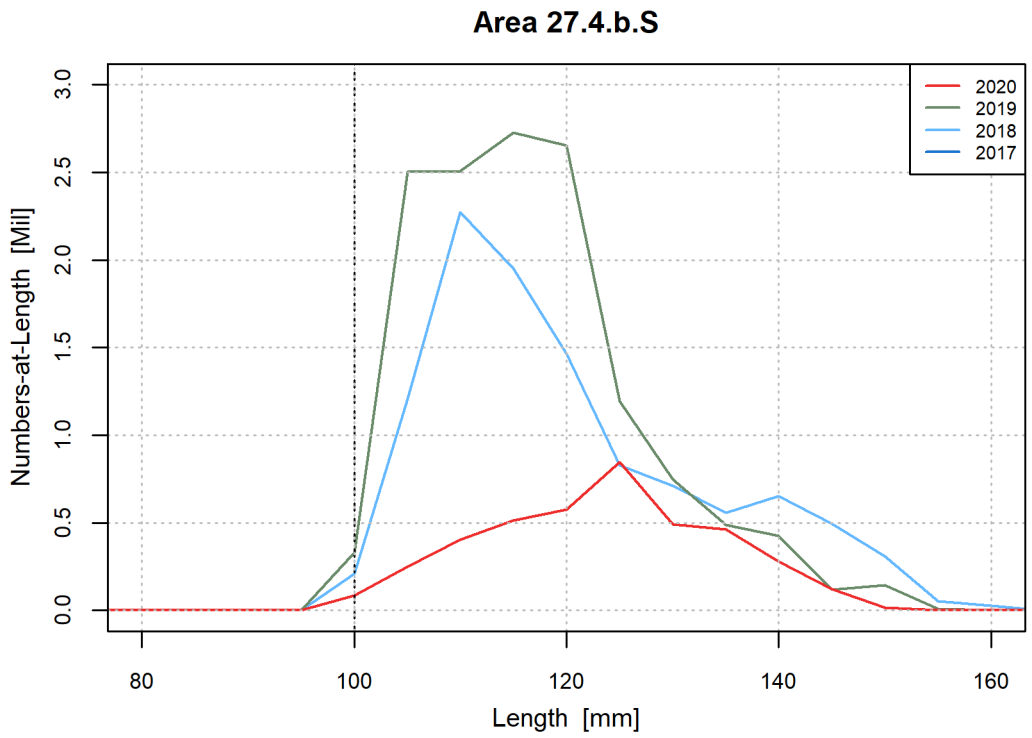

Figure 4.3: UK landed numbers in 5-mm size bins from Area 27.4.b.S during individual sampling seasons (Q1-Q3 of current calendar year, plus Q4 of previous year). The vertical dashed line indicates MLS. N.B. reduced sampling in 2020 season due to COVID-19 pandemic.

4.3. Biological parameters and dredge efficiency

No area-specific growth parameters and weight-length relationships are available for Area 27.4.b.S. A review of historic growth estimates by Dare and Palmer (Cefas, 2001; unpublished), including different grounds in the English Channel, provided von Bertalanffy growth parameters for Area 27.7.d.N. Until more local estimates become available, these will be used for Area 27.4.b.S. Similarly, the weight-length relationship for Area 27.7.d.N (obtained from IFREMER) will be used for Area 27.4.b.S until more specific data become available.

Table 4.4: The biological and dredge efficiency parameters used in this assessment.

Parameter	Value	Source
Gear efficiency – ground type clean or clean becoming stony	30%	Cefas (Palmer, 2001; unpublished)
Gear efficiency – ground type flint cobbles	43%	Cefas (Palmer, 2001; unpublished)
Round length to weight	$a = 1.55 \times 10^{-3}$ $b = 2.45609$	IFREMER (unpublished); see Section 1.1.5 for functional relationship
Flat height to round length	$a = 1.208916$ $b = -5.386429$	Eastern Channel dredge survey 2017; see Section 1.1.4 for functional relationship
Size at maturity	80 mm shell height (~90 mm length)	Cefas (unpublished)
Natural mortality	0.15 for all ages	Cook et al., 1990
Von Bertalanffy growth	$H_\infty = 119.3$ $k = 0.516$ $t_0 = 0.692$	Cefas (Dare and Palmer, 2001; unpublished); see Section 1.1.3 for functional relationship

4.4. Dredge survey methodology

The dredge survey design and station selection procedure are described in Annex 2.

The same commercial scallop vessel, gear deployment configuration and sampling procedure outlined in the survey description for Area 27.7.d.N (Section 2.4.1) was used for Area 27.4.b.S.

The 2020 dredge survey was the third that was carried out in Area 27.4.b.S as part of this programme, on the same vessel and during the same trip as that for 27.7.d.N.

Between 20-21 September 2020, operating from Hartlepool, 24 randomly selected stations (22 in Bed 4.b.1 and 2 in Bed 4.b.2) were surveyed in Area 27.4.b.S. Data available for analysis are summarised in Table 4.5. The number of stations per block is shown in Figure 4.4.

Table 4.5: Sampling summary of the 2020 dredge survey in Area 27.4.b.S.

Bed	Number of Stations	Number of Length Samples	Number of Age Samples	Number Measured	Number Aged
4.b.1	22	22	5	1190	94*
4.b.2	2	2	1	20	-*

* awaiting update.

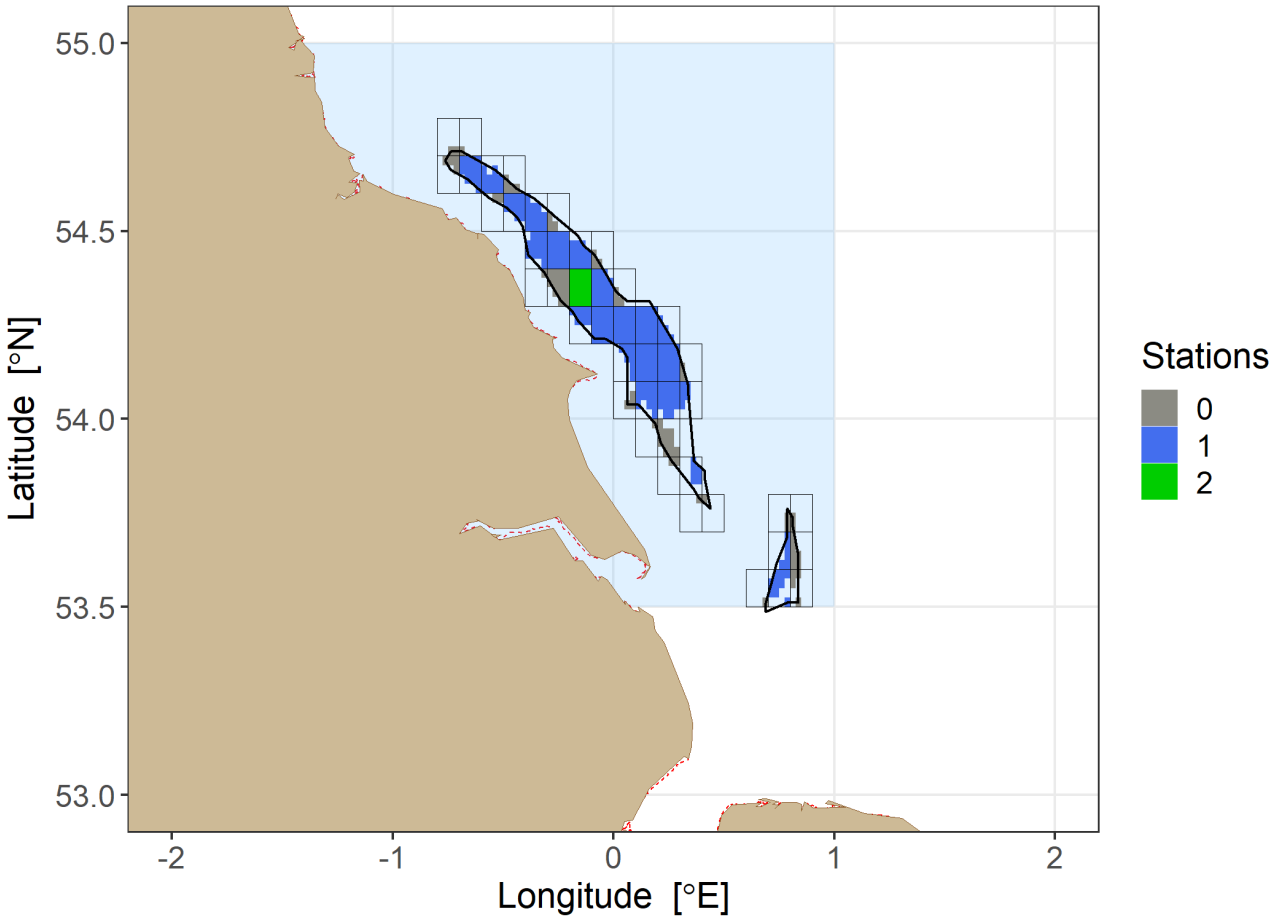

Figure 4.4: Number of stations visited during the 2020 dredge survey within each sampled block of Beds 4.b.1 and 4.b.2 (Area 27.4.b.S)

4.5. Raised biomass estimates and uncertainty

The estimated biomass of harvestable scallops (≥ 100 mm MLS) within 0.1-by-0.1 degree blocks in 2020 is shown in Figure 4.5.

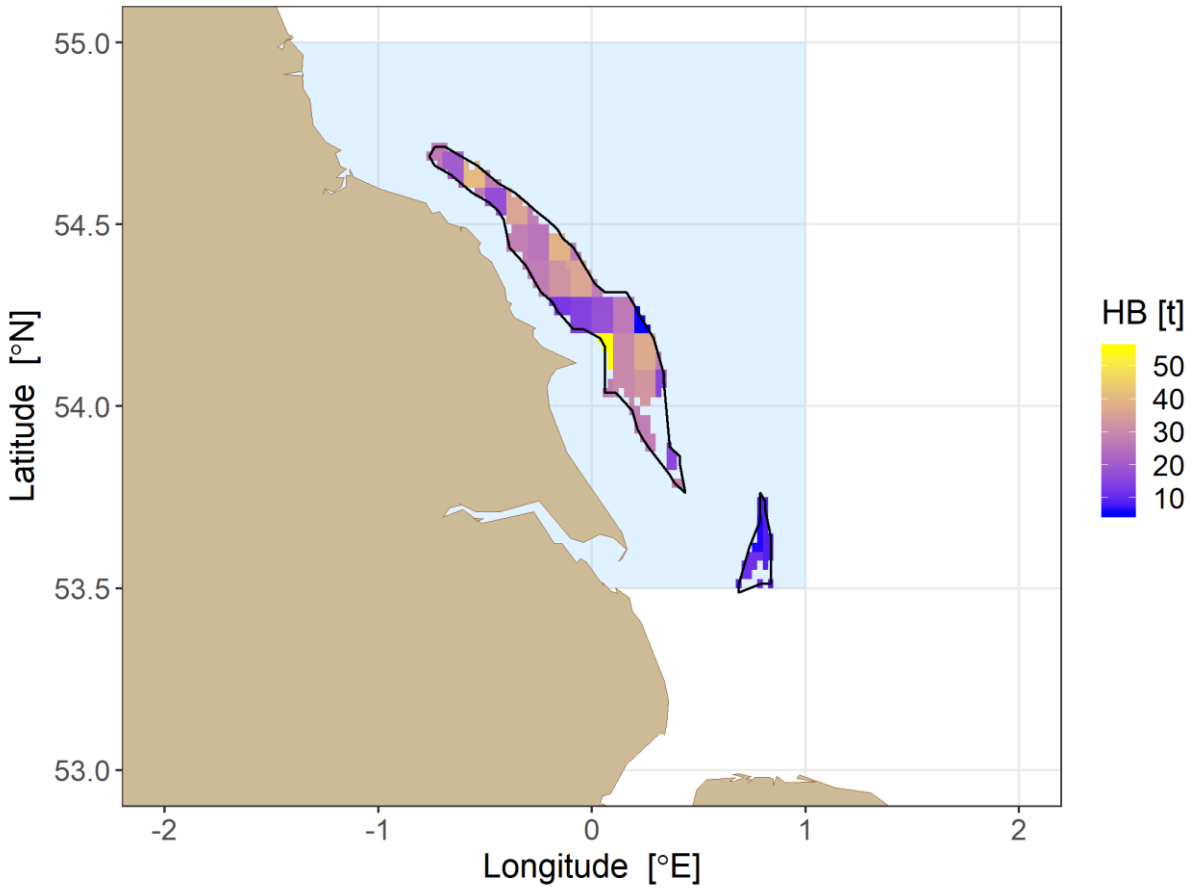

Figure 4.5: Harvestable biomass (tonnes) of scallops of at least MLS (100 mm round shell length) in Beds 4.b.1 and 4.b.2 (Area 27.4.b.S) during 2020.

To establish a measure of uncertainty around the estimate of harvestable biomass, the values for each bed were randomly resampled (“bootstrapped”) 5000 times with replacement. For each iteration, the same analysis procedure was used as for the original estimate. The resulting distribution of harvestable biomass during 2020 is shown in Figure 4.6. The point estimate, along with the median and quantile range, are given in Table 4.6, together with the results for the previous years. As the point estimate utilises all available data, it is considered the most accurate value.

As for 2019, no bootstrap distribution was generated for Bed 4.b.2, as only 2 tows were carried out during the 2020 survey due to the presence of static gear.

Compared with the previous two years, the harvestable biomass in Bed 4.b.1 has significantly increased in 2020, well outside the annual inter-quartile ranges. It remains to be seen whether this increase is backed up by the 2021 survey.

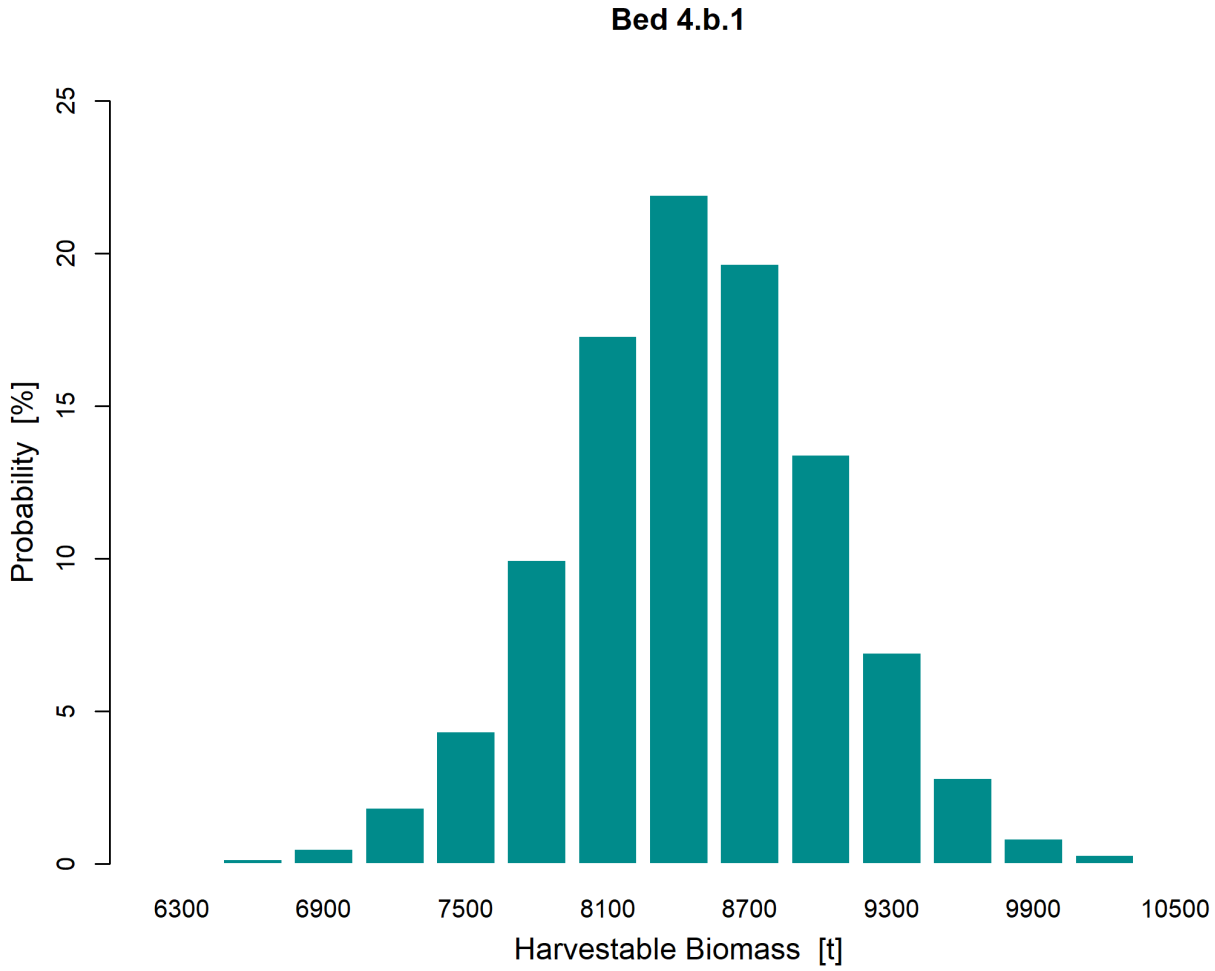

Figure 4.6: Distribution of harvestable biomass in Bed 4.b.1 during 2020 from random resampling ("bootstrapping").

Table 4.6: Estimates of biomass (tonnes), point value, median, and quartile range from bootstrapping, for Bed 4.b.1 (Area 27.4.b.S).

	25th Percentile	Median	Point Value	75th Percentile
2018	5219	5483	5517	5739
2019	5392	5797	5754	6142
2020	8406	8797	8774	9198

4.6. Size composition from dredge survey

From the size samples taken at each station, a total (pooled) length frequency distribution within Area 27.4.b.S was derived. From this, the total population number and biomass could be estimated.

Only 4% of the survey catch by weight taken in the standard commercial gear in 2020 was below MLS, compared to 39% in 2018, and 21% in 2019. This is reflected in a significant upward shift in the size distributions in Beds 4.b.1 and 4.b.2 (Figure 4.7), as well as in the area-aggregated size distributions (Figure 4.8).

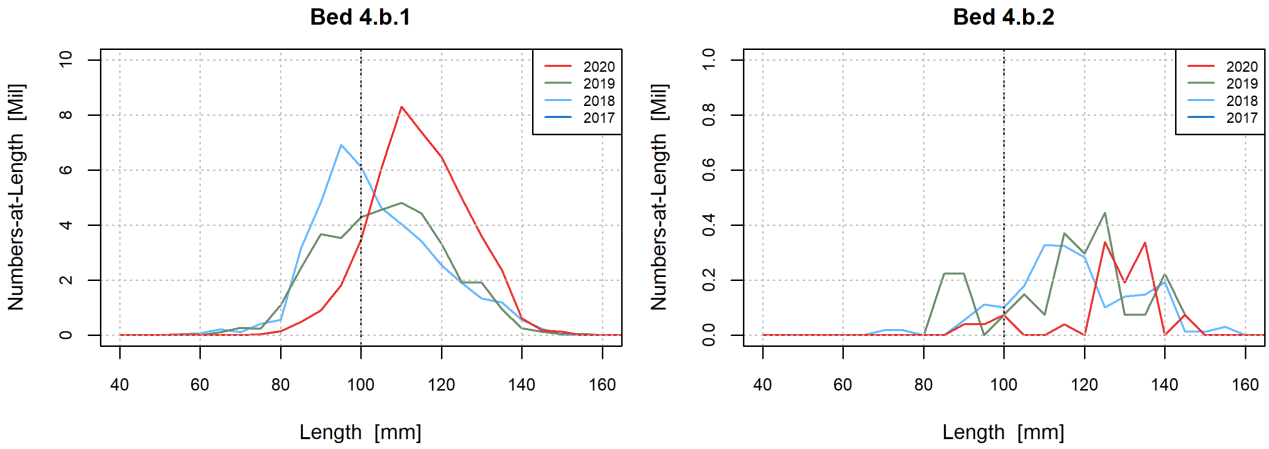

Figure 4.7: Annual population length distributions in 5-mm size bins from the 2020 dredge survey in Beds 4.b.1 and 4.b.2. The vertical dashed lines indicate MLS.

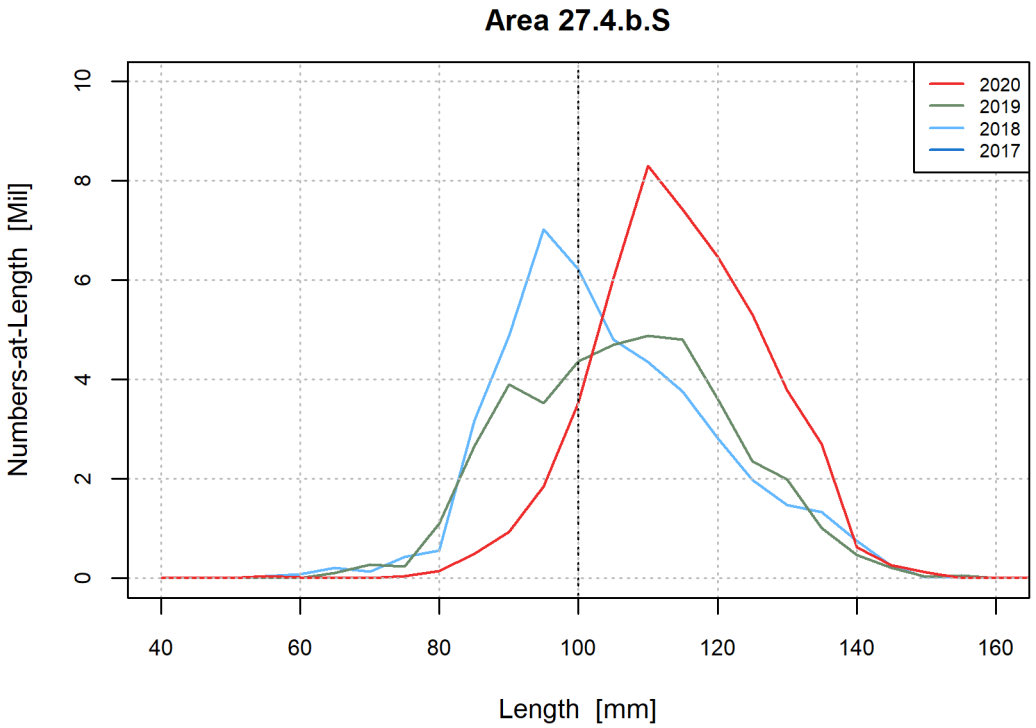

Figure 4.8: Annual population length distributions in 5-mm size bins from the 2020 dredge survey in Area 27.4.b.S.

4.7. Harvest rate estimation

The harvest rate (i.e. the ratio of landings to total harvestable biomass) is proposed to give a proxy for the fishing mortality experienced by this assessment area. Ideally this is calculated from the harvestable biomass immediately prior to the start of a particular fishing season, in relation to the total removals during that season. Total international landings for the 12-month period after the 2018 dredge survey was available from the ICES Scallop Working Group (ICES, 2020). Landings for the 2019 period are estimated using an average UK share 2017-2019 (99.9%), as per the other areas described in this report. Foreign landings from this area have been historically insignificant. The provisional harvest rate estimates are considered reliable with the exception of the very latest (2020), which is predicted.

Provisional harvest rates for the dredged parts of Area 27.4.b.S are listed in Table 4.7. The corresponding estimates of harvestable biomass are based on the results from dredge surveys. The harvestable biomass estimates are the point values from Table 4.6. The range of harvest rate is based on the inter-quartile range of the harvestable biomass estimate from random resampling.

Biomass estimates for un-dredged zones of Area 27.4.b.S have not been assessed using UWTV. As such harvest rate estimates only cover the fished proportion of the stock. There is additional stock outside the area surveyed with dredges, for which there are currently no data on either its biomass or ability to contribute recruitment to the main areas of the fished stock.

Table 4.7: Biomass removed and provisional harvest rate estimate for the dredged parts of Area 27.4.b.S.

	Biomass Removed (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvest Rate on Dredged Portion of Stock (%)	Harvest Rate Range (%)	
2018	2594	5517	47.0	45.2	49.7
2019	1027*	5754	17.8	16.7	19.0
2020	1027**	8774	11.7	11.2	12.2

* estimated from UK removals and 2017-2019 UK market share, to be revised.
** estimate from previous year, to be revised.

4.8. Landings size composition

Most fully analytical fish stock assessments use a time series of age composition of the landings (along with other data such as total landings or catches and a survey series) to estimate the rate at which the fishery is exploiting the stock.

Biological sampling of commercial landings has now been carried out for Area 27.4.b.S for three years and has provided a total of 16 length samples. We still consider this sampling level to be below that required to enable a reliable length-based analysis.

4.9. Conclusion

This is the third stock assessment undertaken for king scallops in Area 27.4.b.S. It is dependent on the results from the dredge survey and is restricted to harvestable biomass estimates and implied harvest rate on the dredged portion of the stock.

A few years of data are always more uncertain than an extended time-series, so the results of this assessment should still be viewed with some caution.

A presentation of the assessment approach to the ICES Scallop Working Group highlighted that there are several key areas of uncertainty that require further work to better understand their impact. With the swept area biomass assessment, the key parameter is the gear-efficiency estimate, and even relatively small changes to this estimate would have a significant impact upon the estimated harvestable biomass and harvest rate. Research to develop novel technology to resolve gear efficiency estimates is still ongoing.

It should be noted that the estimates of harvest rate for Area 27.4.b.S only consider the fished portion of the stocks. Unfished zones have not been surveyed in this area. Additional stock is known to exist outside the surveyed area, for which there are currently no data on either biomass or the ability to contribute to recruitment to the fished stock.

Future surveys of un-dredged areas are planned and are likely to revise the estimates of realised harvest rate downwards, provided that un-dredged areas are found to contribute to the recruitment in dredged areas.

We would hope that in future assessments, and as our sampling scheme becomes more comprehensive, we will be able to determine the harvest rate which is compatible with MSY using the same method used for the assessment areas in the English Channel.

5. Future developments

This report summarises the results of the fourth in what is expected to be an ongoing series of assessments of king scallop stocks around the English coast. The methodology employed is expected to evolve over the coming years as more data become available and data quality improves.

Key data issues to develop as resources permit include:

- Improve gear efficiency (dredge and UWTV) estimates for different ground types.
- Relate UWTV counts to size and biomass structure.
- Improve understanding of the recruitment linkage between dredged scallop beds and un-dredged areas.

Annex 5 describes the progress with these issues.

6. Assessment caveats and assumptions

- Landings data for the 12-month period post survey are required to provide a realised harvest rate. At the time of this report international landings since 2019 were not available. Instead harvest rates for 2019 and 2020 are estimated from UK landings and the UK historic share of the international landings. Harvest rates for the last assessment year are based on the previous estimate of removals if these are higher than those reported. Although harvest rates for 2017 and 2018 are considered reliable, they have been described as provisional (ICES, 2020), and they may undergo further refinement. As such all-harvest rates presented in this report are provisional. If the UK share of the total international landings has changed then realised harvest rates can be higher or lower than our provisional estimates. Harvest rates will be retrospectively updated in future reports as data become available.
- Dredge surveys and catch sampling only cover the portions of stock found on the main fished grounds. Harvest rate estimates from dredge surveys or commercial sampling only apply to the fished portion of the stock.
- The gear-efficiency factor used to convert dredge survey data to total harvestable biomass used unpublished Cefas data. These data came from depletion experiments which although broadly in line with some similar studies remain uncertain. Further refinement/data for this parameter is required including the testing of key assumptions. Revised efficiency factors could have a large influence on the estimates of stock status.
- UWTV surveys detected biomass of scallop on grounds not exploited by dredgers and not all un-dredged grounds were surveyed with UWTV.
- Studies of larval connection between beds indicate incomplete interchange of larvae but the main dredged areas appear to have a degree of larval retention (i.e. self-perpetuating). Incorporation of the un-dredged area biomass into harvest rate calculations assumes complete interchange. Restricting the biomass estimate to the dredged beds assumes no interchange.
- Once complete coverage of un-dredged beds is achieved, these two biomass estimates would be the basis for the maximum and minimum harvest rates experienced in an assessment area.

Acknowledgements

This project was co-funded by Defra and the UK scallop fishing industry.

We would like to thank the fishing industry for their considerable help towards the aims of this project which included but was not restricted to provision of scallop length data and biological samples and substantial contributions to the project steering board. We would also like to thank the crew of FV Evening Star for their expertise and hard work during the two dredge surveys.

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Pakefield Road, Lowestoft, Suffolk, NR33 0HT

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