Centre for Environment Fisheries & Aquaculture Science

Cefas

Assessment of king scallop stock status for selected waters around the English coast 2020/2021

A Defra and Industry Funded Project

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Executive Summary

This report details the status and development of selected king scallop stocks around England in 2021. King scallops (*Pecten maximus*) around the English coast are one of the most commercially valuable marine species (MMO, 2020). The stocks in the English Channel and approaches to the Bristol Channel are 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 over time. In 2017, five stocks within the English Channel were assessed. Two further stocks were added in 2018, one in the Bristol Channel and one in the North Sea. In 2021, a new assessment area covering the Dogger Bank was established, in response to the increase in fishing activity in that area during the previous year.

The five stock assessment areas identified in 2017 as being of importance to UK fisheries were: 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). The two additional assessment areas defined in 2018 were: 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). The Dogger Bank assessment area added in 2021 was labelled 27.4.b.D. These assignments are based on regional differences in growth and fishery exploitation patterns. Commercial landings data are available at the spatial resolution of statistical rectangles (1 degree in longitude, 0.5 degrees in latitude), as defined by the International Council for the Exploration of the Sea (ICES). The spatial extent of assessment areas is therefore defined based on statistical rectangles.

Three data streams were used for the assessments described in this report: dredge surveys using a commercial fishing vessel, underwater television (UWTV) surveys from RV Cefas Endeavour, and a biological sampling programme including commercial and survey catches. Dredge surveys have been carried out in the commercially fished parts of all assessed areas, and were used to estimate scallop biomass available to the dredge fishery. Based on UWTV surveys, estimates were obtained of the unfished biomass in some parts of most assessed areas during at least one year. The only exception is the recently established Area 27.4.b.D covering the Dogger Bank. The biological sampling programme provides information about the size and age structure of commercial landings. However, sampling during 2020 and 2021 was significantly impacted by the Covid-19 pandemic, especially the ageing of shells, which is more time-consuming and requires specialist training. Therefore, only size distributions are presented here.

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 are unable to estimate the scallop biomass in all un-dredged areas. There is likely to be biomass of scallops outside those areas surveyed, for which there are no data to make any estimates. 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 therefore only apply to the commercially 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 harvest rates experienced by the surveyed portion of stocks were estimated by comparing total international landings to the harvestable biomass estimates, either for the dredged area only, or including also the biomass from un-dredged areas. For this year's revision of the report, for the first time, we were able to obtain international landings through the data call of the ICES scallop working group (WGScallop). In 2021, this data call included all landings that were recorded until the end of 2020. This allowed us to determine the total international landings that were taken from the assessment areas during 12-month periods following the dredge surveys in 2017 – 2019. For the 12-month period following the dredge surveys in 2020, we extracted all UK landings from the MMO database iFish. Where UK landings exceeded the international landings from the previous year, we used them as a temporary estimate. Otherwise, we used the international landings from the previous year. 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 surveys. For the 12-month periods following the dredge surveys in 2021, even UK landings will only become available in May 2022 for the western English Channel, and in September 2022 for the eastern Channel and the North Sea.

The evolution of the harvestable biomass of the dredged portions of six of the assessment areas (excluding Areas 27.7.d.S and 27.4.b.D) is shown in Figure 1. 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 dredge-surveyed a small bed in 27.7.d.S that is not covered by the IFREMER assessment. These results were presented in the annexes of the previous reports. Also for Area 27.4.b.D, there has only been one dredge survey so far, the results of which are presented in this main part of the report.

The evolution of the harvest rates on the dredged portions of the same six assessment areas is listed in Table 1 and shown in Figures 2 and 3. Revision of international landings data, compared to the information available at the time of publication of the previous report, has reduced the 2020 harvest rate estimate for Area 27.7.f.I (30.8% from 35.4%). There has also been a small decrease in Area 27.7.e.O (5.5% from 6.4%). However, in other areas, the estimated harvest rate for 2020 has increased; most notably in Area 27.7.e.L (42.9% from 30.6%), and in Area 27.4.b.S (27.5% from 11.7%). Of the four

assessment areas for which MSY candidates have been determined, the harvest rate of the dredge portion of the stock exceeds the sustainable level in Area 27.7.e.I, and especially in Area 27.7.e.L, where the latest estimate of the realised harvest rate exceeds the MSY proxy by a factor of two.

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 available data increase in comprehensiveness, they will allow a more robust determination of king scallop stock status around the English coast.

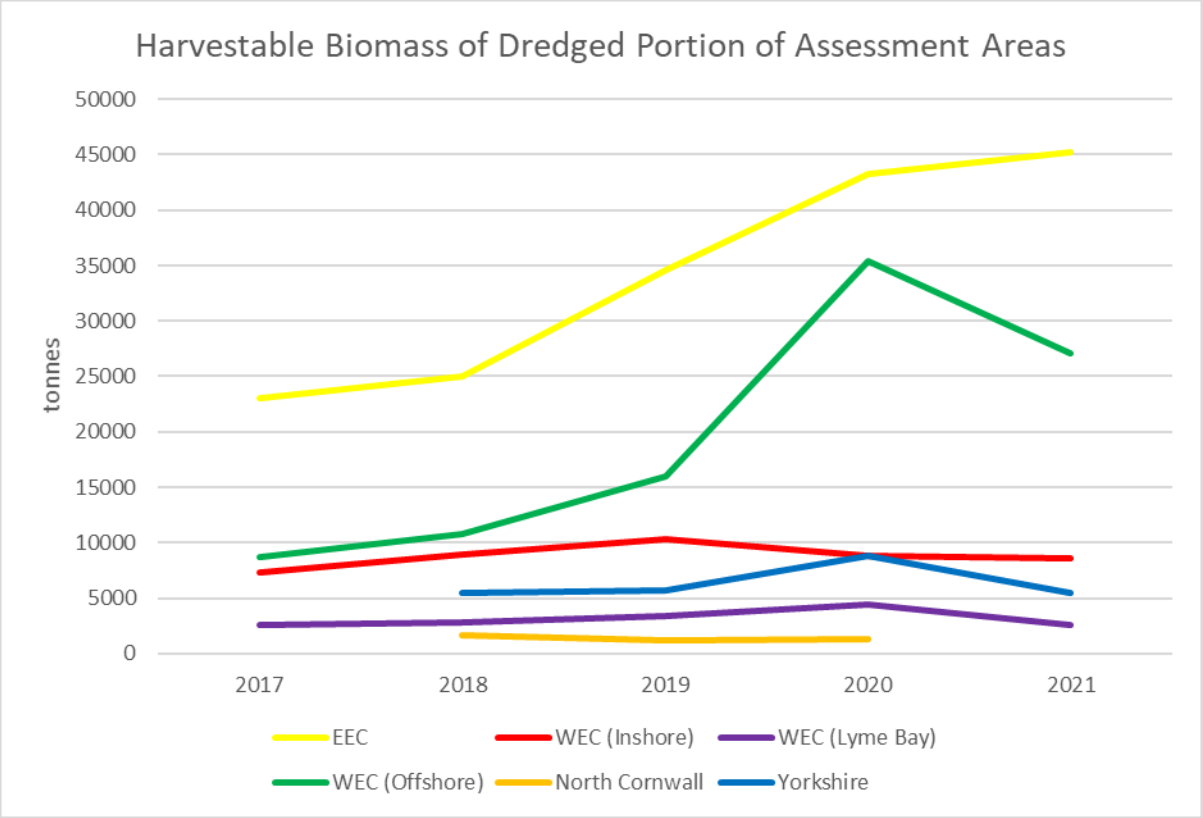

Figure 1: Harvestable biomass in the dredged parts of the king scallop assessment areas: Eastern English Channel (EEC, 27.7.d.N), Western English Channel (WEC) Inshore (27.7.e.I), Lyme Bay (27.7.e.L), Offshore (27.7.e.O), North of Cornwall (27.7.f.I), and Yorkshire\Durham (27.4.b.S). Years refer to 12-month periods starting from the dredge survey during that year.

Table 1: Estimates of harvest rate from dredge and UWTV surveys, together with a candidate for MSY. Years refer to 12-month periods starting from the dredge survey during that year.

Assessment Area	Harvest Rate on Dredged Portion of Stock (Dredge Survey Only, %)				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	56.1	24.4	19.5	48.9	56.0	24.3	19.5	21.5
27.7.e.I	37.8	16.8	17.4	20.5	23.1	11.0	12.0	13.4	19.5
27.7.e.L	55.0	76.9	37.9	42.9	27.4	39.9	21.3	26.9	21.0
27.7.e.O	11.0	13.6	11.7	5.5	10.3	12.8	11.2	5.4	20.9
27.7.f.I	-	8.0	34.6	30.8	-	6.5	26.0	23.8	-
27.4.b.S	-	47.0	15.5	27.5	-	-	-	-	-

* estimated from UK landings or international landings of previous year, whichever is higher (to be revised)

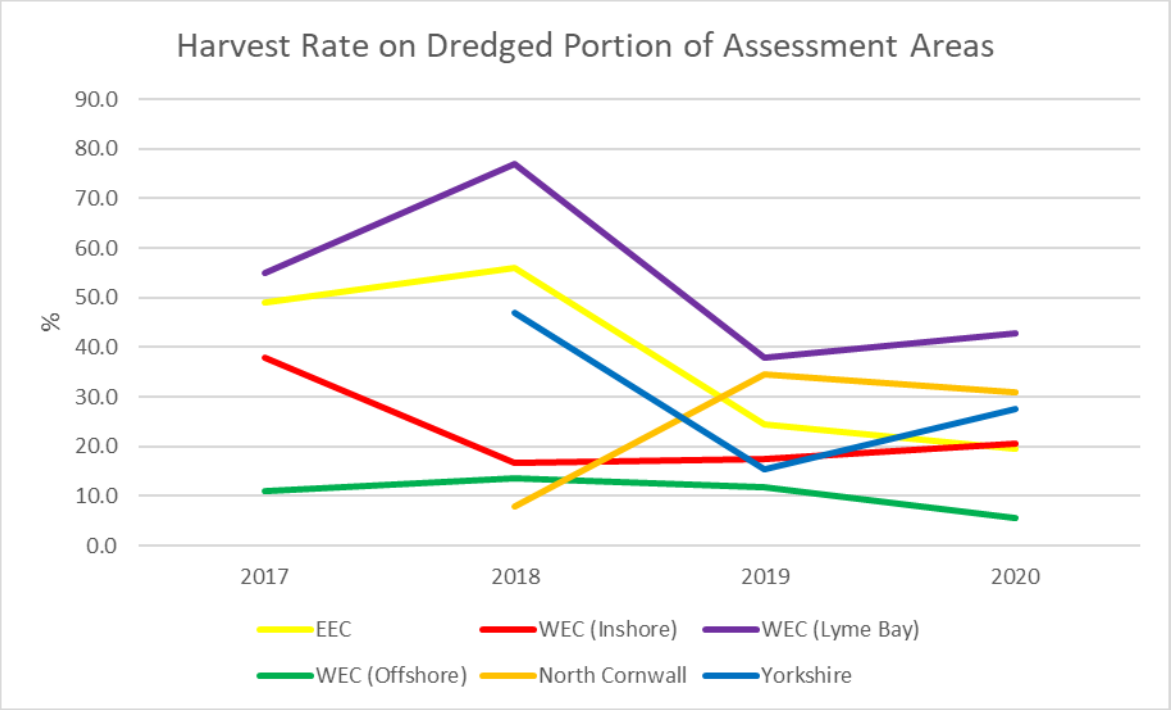

Figure 2: Realised harvest rate on the dredged portion of the king scallop assessment areas: Eastern English Channel (EEC, 27.7.d.N), Western English Channel (WEC) Inshore (27.7.e.I), Lyme Bay (27.7.e.L), Offshore (27.7.e.O), North of Cornwall (27.7.f.I), and Yorkshire\Durham (27.4.b.S). Years refer to 12-month periods starting from the dredge survey during that year.

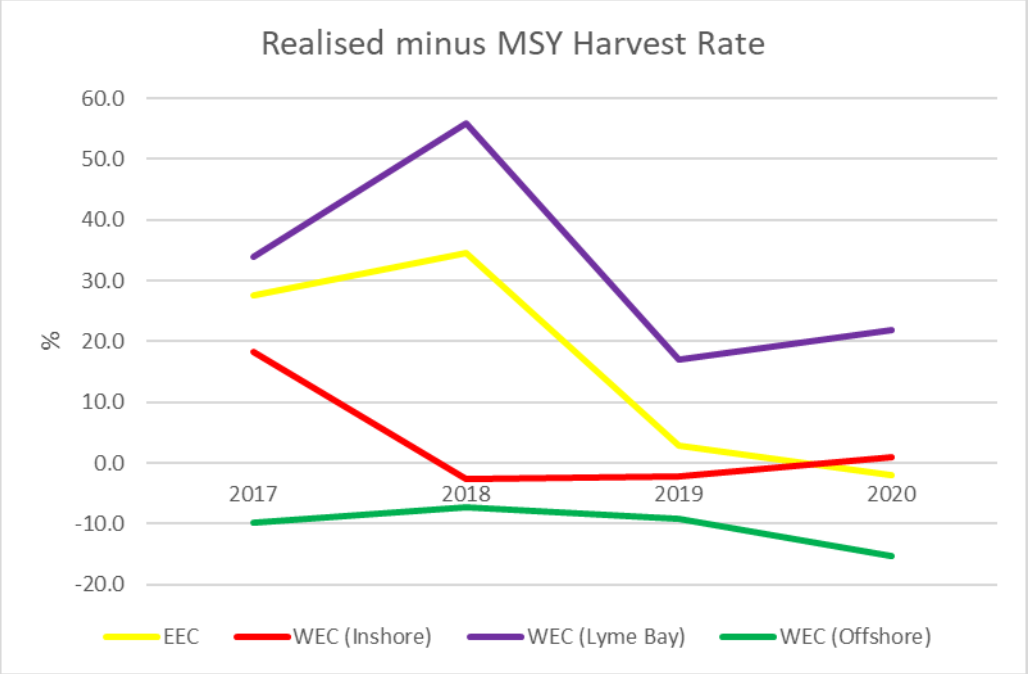

Figure 3: Realised minus maximum sustainable yield (MSY) harvest rate on the dredged portion of the king scallop assessment areas: Eastern English Channel (EEC, 27.7.d.N), Western English Channel (WEC) Inshore (27.7.e.I), Lyme Bay (27.7.e.L), and Offshore (27.7.e.O). Due to limited availability of sampling data, MSY harvest rates have not been determined for North of Cornwall (27.7.f.I) and Yorkshire\Durham (27.4.b.S). Years refer to 12-month periods starting from the dredge survey during that year.

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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 uses oxygen isotope assay to validate traditional ring counting methods and to estimate von Bertalanffy growth parameters (Dare, et al., 1989).

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.

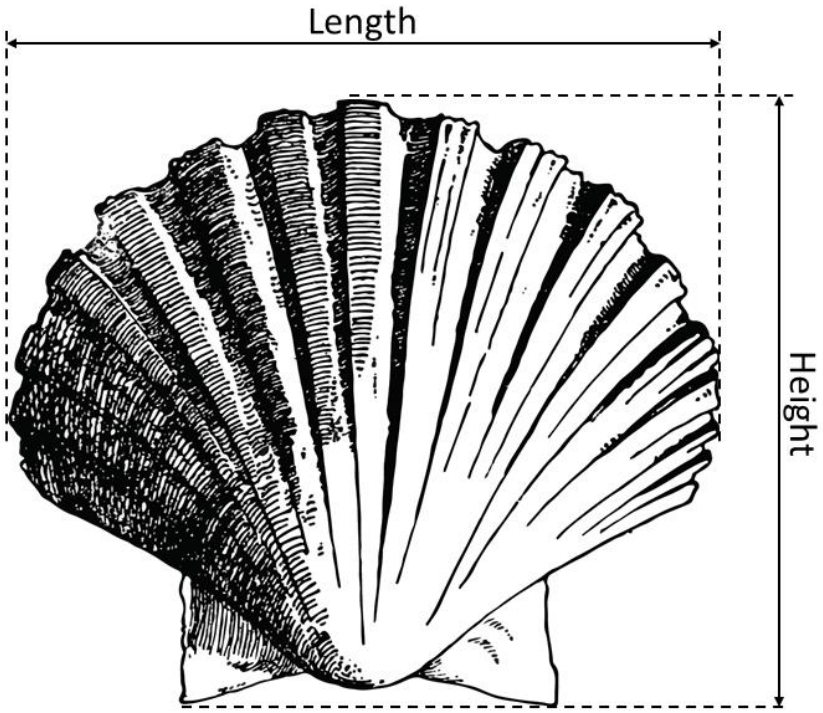

Figure 1.1: Scallop shell length and height illustrated based on the round (lower) valve.

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, L, can be calculated from flat height, H, 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

$$\mathrm{W} = \mathrm{c}\,L^{p}\ ,$$

where c and p 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 king scallop (*Pecten maximus*) is one of the most valuable shellfish species in the UK (MMO, 2020), with 7,078 tonnes of international landings reported to ICES as originating from our assessment area in the eastern English Channel (ICES Division 27.7.d) in 2020 (down from 11,413 tonnes in 2019), and 4,763 tonnes from our assessment areas in the western English Channel (ICES Division 27.7.e) in 2020 (down from 5,507 tonnes in 2019) (ICES, 2021). An additional 843 tonnes of international landings were reported to ICES as originating from our assessment area along the English coast in the North Sea (ICES Division 27.4.b) in 2020 (down from 2,333 tonnes in 2019), and 317 tonnes from the assessment area in the approaches to the Bristol Channel (Division 27.7.f) in 2020 (up from 272 tonnes in 2019).

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.

In UK waters, the minimum landing size (MLS) at which scallop may be retained 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. These values originate from EU legislation but are now retained in the corresponding UK legislation.

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.

The UK fleet comprises 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 Section 1 of the annexe. 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.

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. Currently, shells are aged up to year ten. However, from age eight onwards, as growth slows down almost completely, growth rings become difficult to distinguish along the edges of shells. An age eight plus group is therefore proposed for future modelling.

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. 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 not included in this report.

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). Scallop fisheries in the remaining ICES rectangles in Division 27.7.e are dominated by French coastal activity and are therefore beyond the scope of this report.

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.

In 2021, a new assessment area covering the Dogger Bank was established, in response to the increase in fishing activity in that area during the previous year.

The ICES statistical rectangles that define all our assessment areas are listed in Table 1.1.

Two finer grids than statistical rectangles 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.

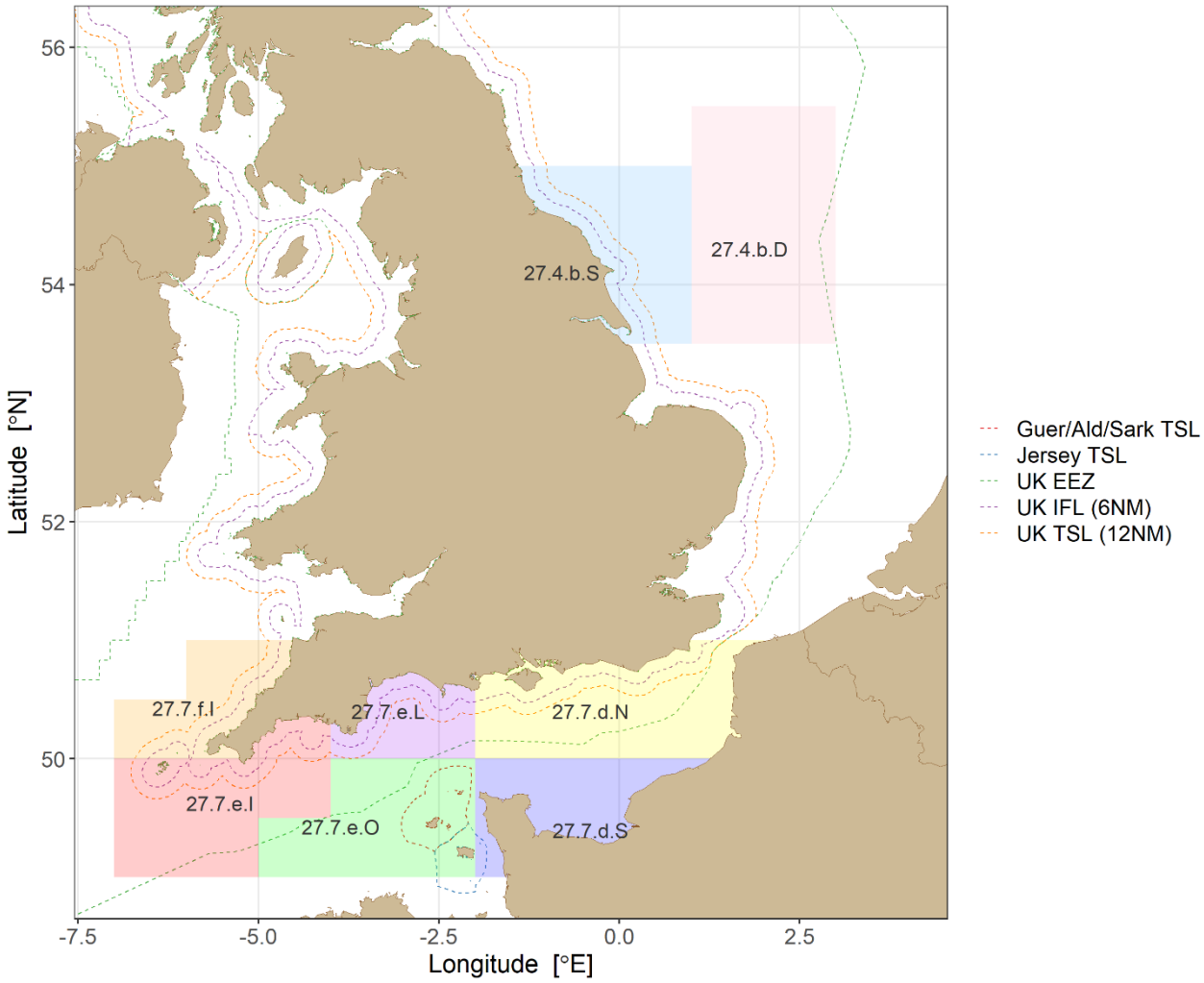

Figure 1.2: King scallop stock unit assessment areas defined in the English Channel, the Celtic and North Sea. The dashed lines indicate the Territorial Sea Limits (TSLs) of the UK and the Channel Islands, the UK Economic Exclusion Zone (EEZ), and the UK Inshore Fisheries Limit (IFL).

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		
27.4.b.D	36F1	36F2	37F1	37F2	38F1	38F2	39F1	39F2

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

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 Section 3 of the annexe. 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 2.3). 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.

1.6. Dredge survey gear type and configuration

A chartered commercial fishing vessel was used to survey a grid of fishing stations as defined in the survey design (Section 2 of the annexe). 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 1.3). 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 was 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.

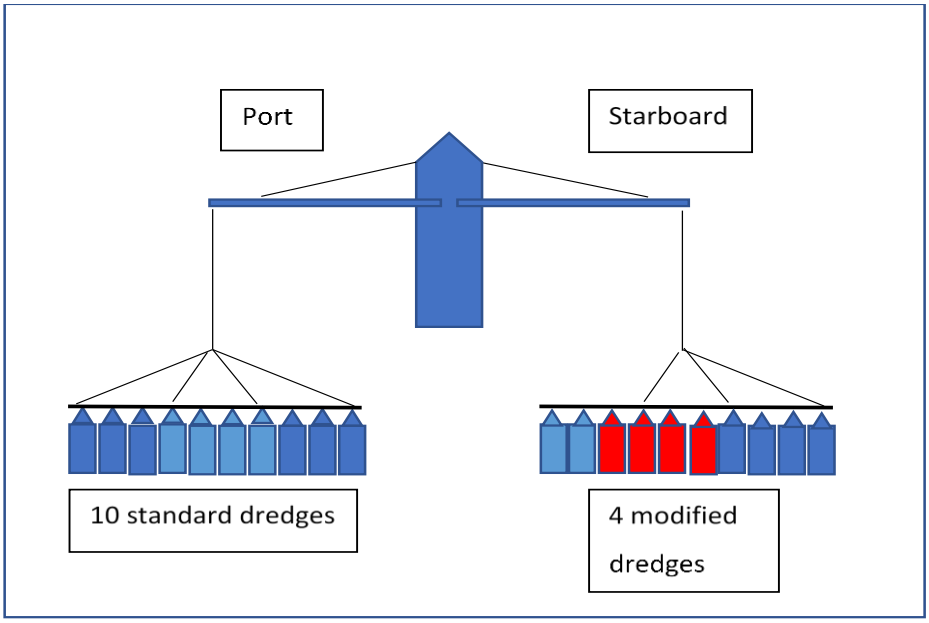

Figure 1.3: Gear configuration on the survey vessel.

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 Section 2 of the annexe). Using VMS data does mean that the bed represents only those grounds fished by vessels ≥ 12 m, however as these large vessels land more than 90% of scallops from 27.7.d.N, VMS-recorded activity captures the vast majority of landings. An 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. However, this area was only surveyed once in 2018 and is therefore not included in this assessment (see the annexes of the previous reports for a summary of the results).

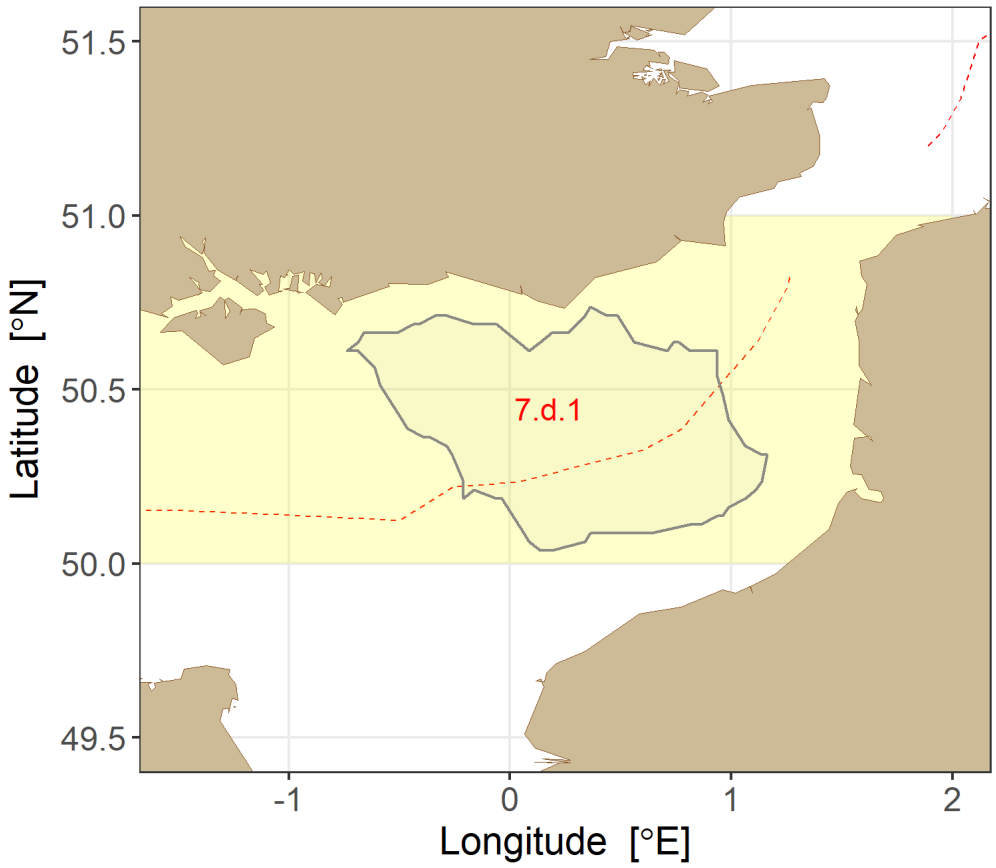

Figure 2.1: Dredge-surveyed part (Bed 7.d.1) of Area 27.7.d.N (yellow shading). The dashed red line indicates the boundary of the UK EEZ.

2.2. Commercial landings and sampling data

Total annual landings by country, originating from Area 27.7.d.N during the 2000 – 2020 period, are listed in Table A3 of the latest report of the ICES Scallop Working Group (ICES, 2021).

Due to the delay in the collation of commercial landings and sampling data within the UK, an appropriate way of analysing fisheries data is by season, in which a season comprises Q1 – Q3 of the current calendar year, and Q4 of the preceding year.

UK quarterly landings from Area 27.7.d.N are listed in Table 2.1. At the time of report writing (January 2022), landings data to the end of Q3 of 2021 are considered reliable. A large increase in landings, compared to previous years, occurred in 2009, peaking in 2010, and declining back to more typical values by 2012. 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. Since

2015, landings have increased again, the only exception being the relatively low landings in 2020. In 2021, landings were close to the value in 2011.

Table 2.1: 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	1389	1591	1849	6168	6737
2019	1814	1790	168	2587	6359	5622
2020	974	273	918	2507	4673	4753
2021	2566	1841	168	3218*	7793*	7083

* provisional

The number of samples collected each season through the biological sampling programme is shown in Table 2.2, 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. The listed number of samples, and number of shells measured or aged, only includes samples that have at least 70 size measurements, or at least 20 determined ages. Smaller samples are considered unreliable and are not included in the assessment.

Table 2.2: Biological sampling programme summary for Area 27.7.d.N. Number of age samples and shells aged are provisional and will be updated as more data become available.

	Commercial Landings				Dredge Survey	
Sampling Season	**Length Samples**	**Shells Measured**	**Age Samples**	**Shells Aged**	**Age Samples**	**Shells Aged**
2017	11	1773	1	24	22	829
2018	52	8122	19	555	12	498
2019	85	13991	30	856	16	632
2020	29	4163	5	139	8	320
2021	40	7070	-	-	-	-

Length distributions from the industry sampling programme, raised to the UK commercial landings, are show in Figure 2.2. Length samples for individual vessels were raised to monthly landings, before aggregation to total landings during each sampling season.

With the exception of 2018, when an unusually large number of animals with lengths above 120 mm were landed, the highest number of landed animals have lengths between 115 and 120 mm.

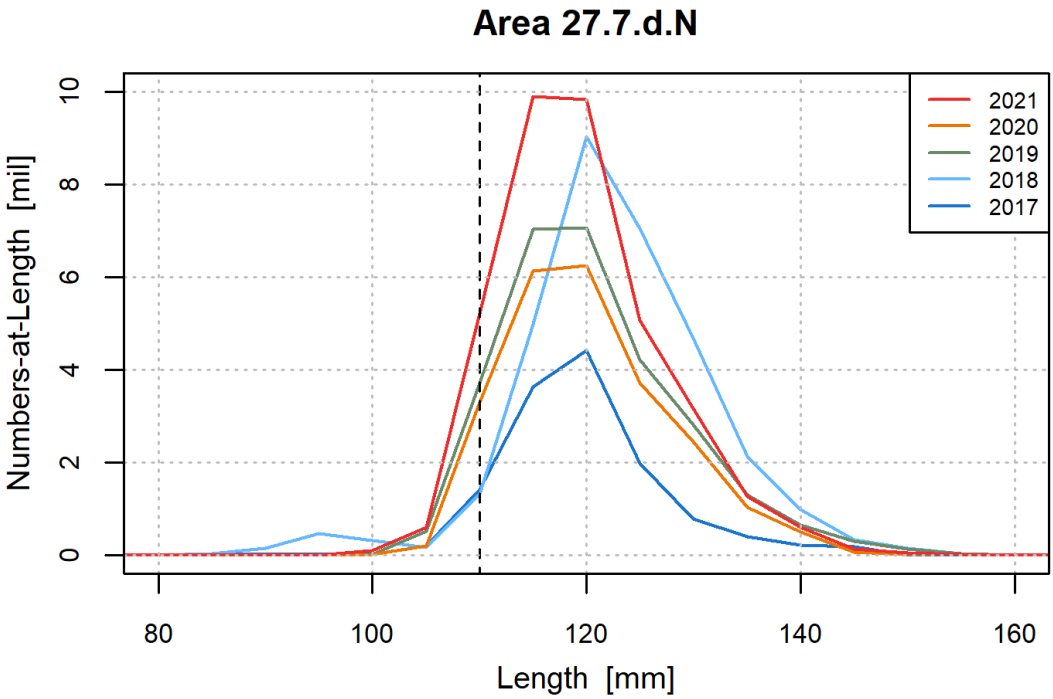

Figure 2.2: UK landed numbers in 5-mm size bins from Area 27.7.d.N during individual sampling seasons (Q1 – Q3 of current calendar year, plus Q4 of previous year). The vertical dashed line indicates MLS.

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 were obtained from IFREMER.

Table 2.3: 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 surveys

2.4.1. Dredge survey methodology

The dredge survey design and station selection procedure are described in Section 2 of the annexe. The commercial scallop vessel, the gear type and deployment configuration, as well as the sampling procedure are described in Section 1.6.

The surveys in 2017, 2020, and 2021 were restricted to the UK Exclusive Economic Zone (EEZ), whereas the surveys in 2018 and 2019 also included tows in the French EEZ. In 2018, four additional tows were carried out in a small bed (7.d.2) in the 27.7.d.S assessment area to the south of Bed 7.d.1. However, no dredge surveys have been carried out in this bed since then.

Between 13 – 16 September 2021, 47 randomly selected tows were surveyed in Bed 7.d.1, resulting in the sampled blocks shown in Figure 2.3.

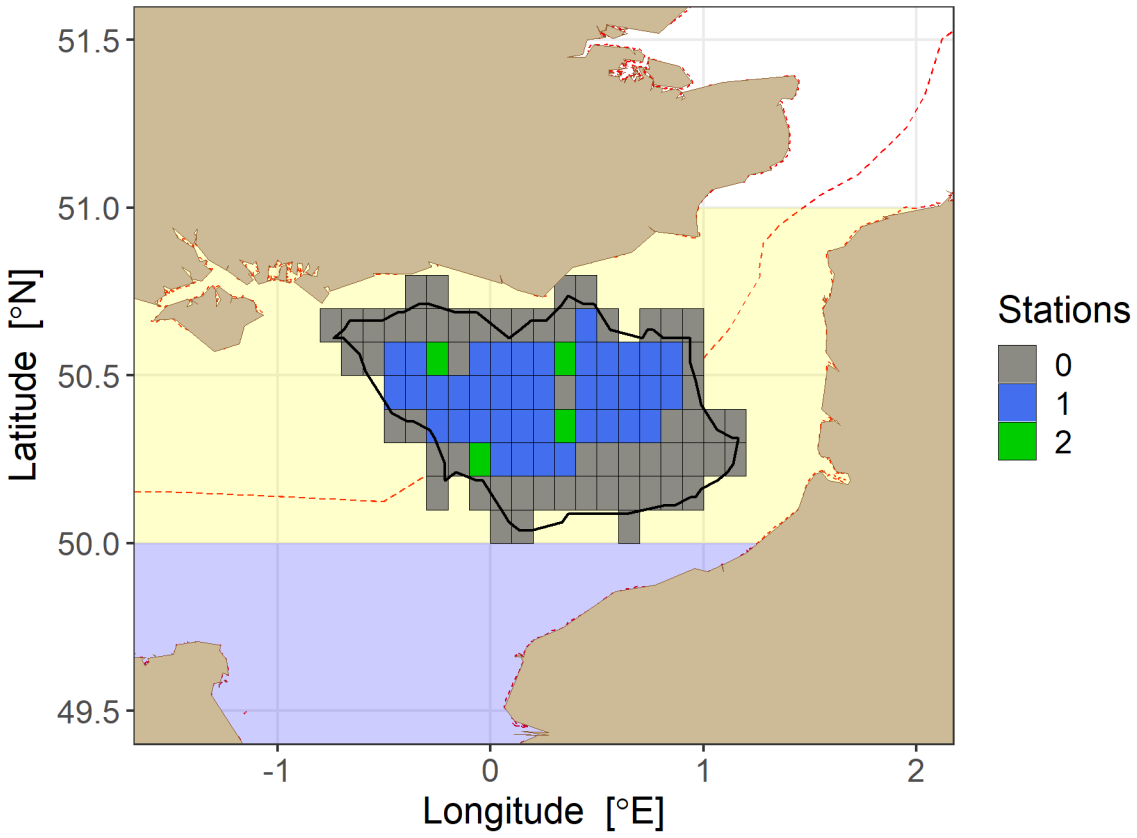

Figure 2.3: Number of stations visited during the 2021 dredge survey within each sampled block of Bed 7.d.1 (Area 27.7.d.N). The dashed red line indicates the boundary of the UK EEZ.

2.4.2. Underwater television survey methodology

For the first time in 2019, an underwater television (UWTV) survey was carried out to determine the spatial distribution and abundance of scallops in selected parts 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 surveys have been carried out in this area since then. The spatial coverage and methods of UWTV surveys are described in Section 4 of the annexe.

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 and 2021, the dredge surveys were 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 2021 is shown in Figure 2.4. Due to the absence of survey stations in the French EEZ, a constant bed average biomass was assumed for all valid grid cells in the un-surveyed area. The variability in biomass aggregated by the larger grid blocks within the French EEZ is due to differences in the number of valid grid cells within each block.

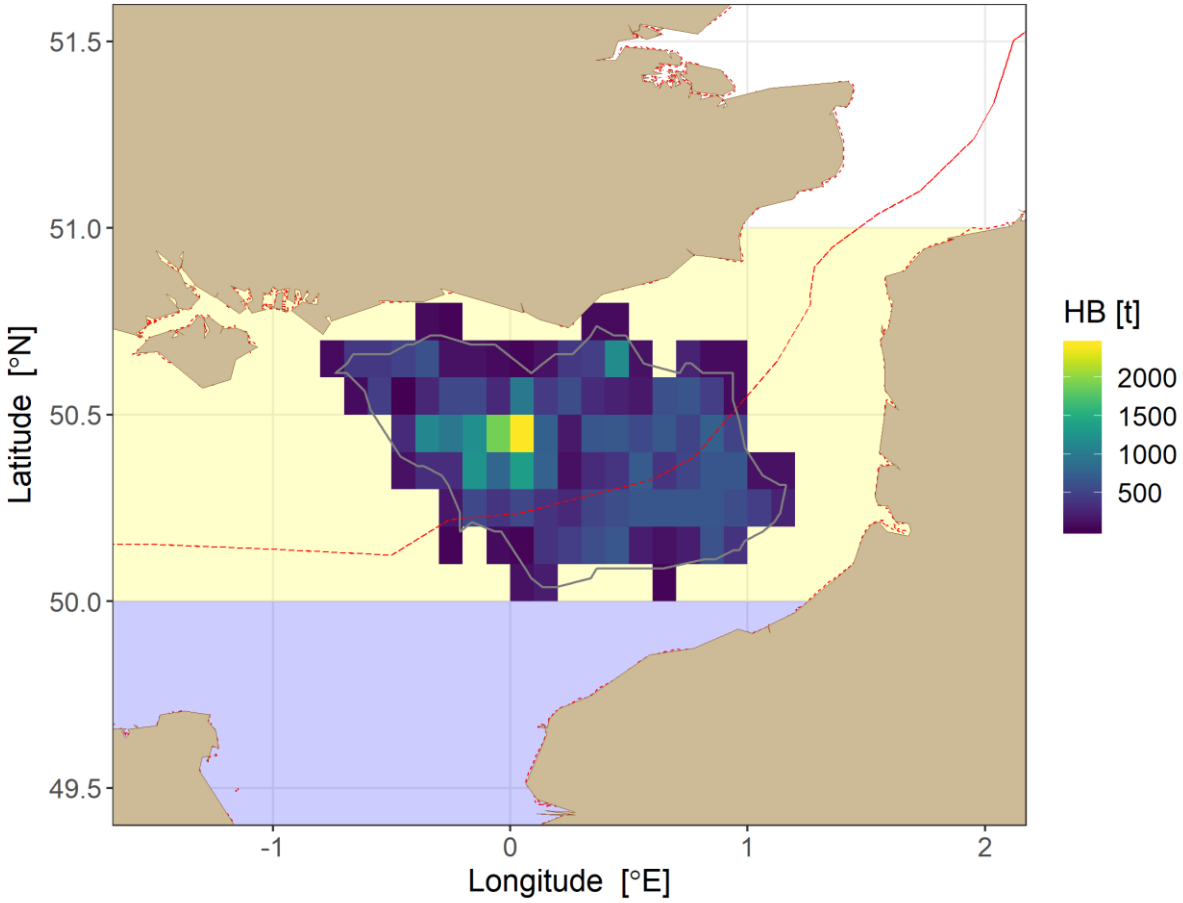

Figure 2.4: Harvestable biomass (tonnes) of scallops of at least MLS (110 mm round shell length) in Bed 7.d.1 (Area 27.7.d.N) during 2021. The dashed red line indicates the boundary of the UK EEZ.

To establish a measure of uncertainty around the harvestable biomass based on all survey stations ("survey estimate"), the values for individual stations within the same bed were randomly resampled with replacement ("bootstrapped") 5000 times. For each iteration, the same analysis procedure was used as for the survey estimate. The resulting distribution of harvestable biomass during 2021 is shown in Figure 2.5. The survey estimate, along with the median and quartile range from bootstrapping, are given in Table 2.4, together with the results for the previous years. As the survey 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 – 2021 period.

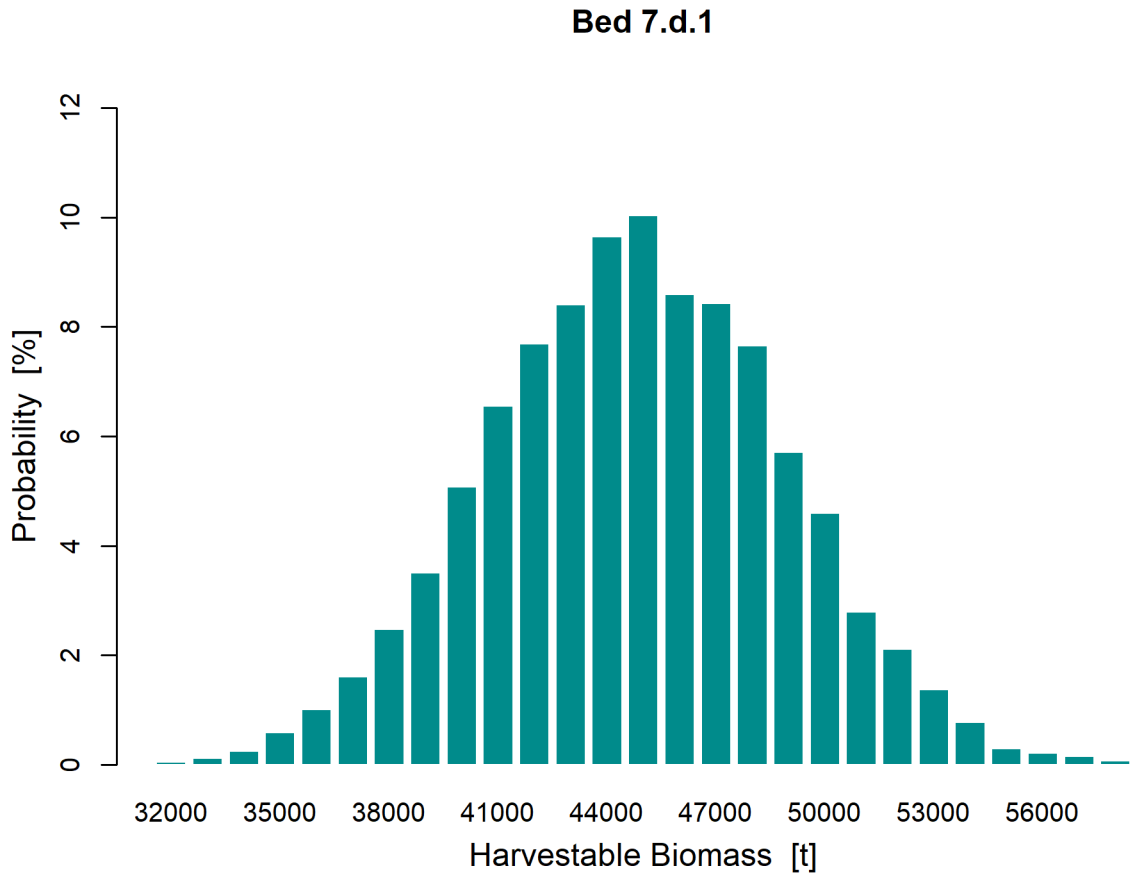

Figure 2.5: Distribution of harvestable biomass in Bed 7.d.1 (Area 27.7.d.N) during 2021 from random resampling ("bootstrapping").

Table 2.4: Harvestable biomass (tonnes) in Bed 7.d.1 (Area 27.7.d.N): survey estimate (using all station values), median, and quartile range from random resampling ("bootstrapping").

	25th Percentile	Median	Survey	75th Percentile
2017	20876	22732	22981	24602
2018	23506	24965	25047	26332
2019	33157	34752	34612	36477
2020	40192	43149	43216	45872
2021	42012	44791	45278	47610

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 2021 was 26%, which is lower than in previous years (36% in 2017, 53% in 2018, 29% in 2019, 35% in 2020). The below-MLS proportion of survey catches from the modified dredges in 2021 was 25%.

In 2018, there was evidence of a pulse of smaller scallops with round lengths between 85 – 90 mm. In 2019, there was an indication of a group of below-MLS animals with round lengths of around 100 mm. Since then, there have not been pre-recruit maxima in the area-aggregated length distributions.

The significant increase in harvestable biomass from 2019 to 2020 (Table 2.4) is reflected in an increase in numbers-at-length across the size spectrum, not just for above-MLS round lengths. The smaller increase from 2020 to 2021 is associated with a slight shift in the above-MLS size distribution towards larger round lengths. However, the number of survey-caught animals at and below MLS has noticeably decreased since the previous year. Future dredge surveys in that area will hopefully establish whether this is a sampling issue, or indicative of weaker recruitment.

The area-aggregated size distributions derived from survey catches (Figure 2.6) do not compare directly to those from commercial landings (Figure 2.2), as they are raised to total estimated biomass by means of an assumed dredge efficiency, as opposed to being raised to reported landings. Additionally, the survey samples are only restricted by technical limitations, i.e., reduced gear efficiency towards smaller shells. The industry samples are furthermore restricted by legal limitations and are therefore biased towards sizes above MLS.

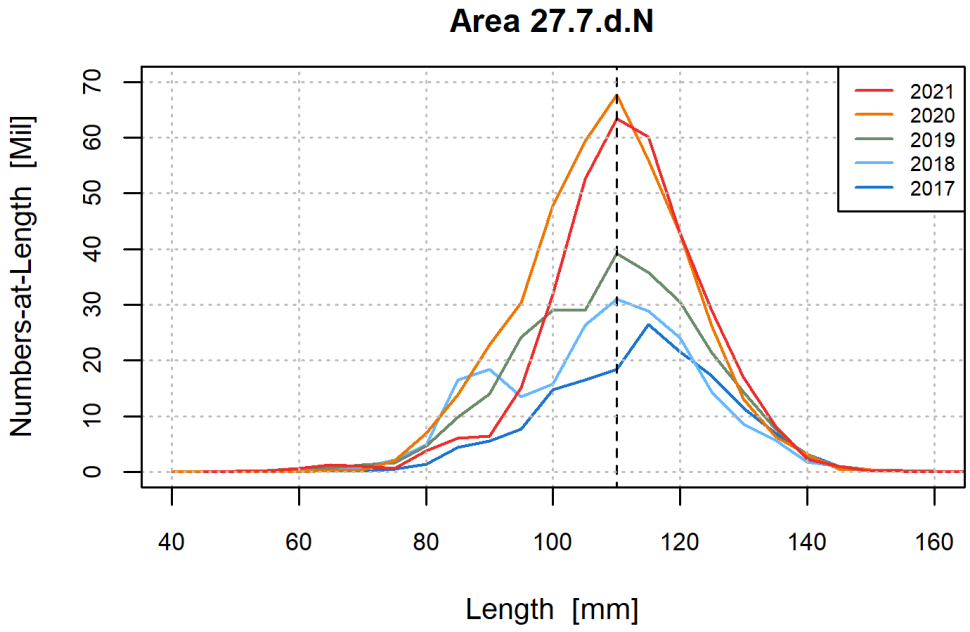

Figure 2.6: Annual population length distributions in 5-mm size bins from annual dredge surveys in Area 27.7.d.N. The vertical dashed line indicates MLS.

2.7. Relative abundance from UWTV survey

An UWTV survey was carried out in 2019 and details are given in Section 4 of the annexe. 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 Section 4 of the annexe. 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 a later 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 hope that these areas will be the subject of future UWTV surveys.

2.8. MSY reference point estimation

Estimation of the fishing mortality that generates maximum sustainable yield (MSY) requires a full analytical assessment, including an estimate of the stock-recruitment relationship. As is the case with many stocks assessed by ICES, this is not yet possible for king scallops. 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.

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. These data sources are not yet available for scallops along the English coast. Instead, scaled length distributions were used to determine gear selection parameters (L25 and L50 of a selection ogive) to facilitate a length-based cohort method. 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 model 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).

This model estimates that in order to achieve F35%SpR in Area 27.7.d.N, a harvest rate in the vicinity of 21.5% would be required (Table 2.5). 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.

Table 2.5: Fishing mortality, harvest rate, spawner-per-recruit, and average fishing mortality Fbar at reference points F0.1, FSpR35% and Fmax for Area 27.7.d.N.

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

2.9. Harvest rate estimation

The harvest rate (i.e. the ratio of landings to total harvestable biomass, assuming no dead discards) 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. At the time of writing of this assessment report (January 2022), international landings for 2017 – 2020 were available from the latest ICES Scallop Working Group (ICES, 2021). International landings for the 12-months following the two most recent dredge surveys in 2020 and 2021 were not available. Instead, for the 2020 survey, the international landings from the previous survey year were used. However, international landings and associated harvest rates presented here are provisional and will be revised when required data become available.

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 values are the survey estimates from Table 2.4. The range of harvest rate is based on the inter-quartile range of the harvestable biomass estimate from random resampling.

The harvest rates listed in Table 2.7 are based on biomass estimates that also include un-dredged zones that have been surveyed by UWTV. As such, harvest rate estimates include the fished part of the stock, together with small amounts of 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 estimate from the 2019 UWTV survey has been included for the other years. These harvest rates are applicable only when connectivity between dredged and un-dredged populations is complete.

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 described in the previous section, are listed in Table 2.8.

Table 2.6: International landings over 12-month periods following annual dredge surveys in the stated years, and harvest rate estimates for the dredged parts of Area 27.7.d.N.

	International Landings (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	14041	25047	56.1	53.3	59.7
2019	8429	34612	24.4	23.1	25.4
2020	8429*	43216	19.5	18.4	21.0

* estimate from previous year, to be revised when 2021 international landings have been reported

Table 2.7: International landings over 12-month periods following annual dredge surveys in the stated years, and harvest rate estimates for Area 27.7.d.N, combining harvestable biomass estimates from the dredge and UWTV surveys.

	International Landings (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	14041	25047	29	25076	56.0
2019	8429	34612	29	34641	24.3
2020	8429*	43216	29	43245	19.5

* estimate from previous year, to be revised when 2021 international landings have been reported

Table 2.8: 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	56.1	56.0	21.5
2019*	24.4	24.3	21.5
2020*	19.5	19.5	21.5

* estimate from previous year, to be revised when 2021 international landings have been reported

2.10. Conclusion

This is the fifth 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 and 2021 were restricted. As a result, the planned UWTV surveys in these years could not be carried out. Therefore, this assessment includes biomass estimates and provisional harvest rates based on the 2021 dredge survey, together with modest amounts of biomass estimated based on the 2019 UWTV survey in selected un-dredged zones.

The large variation in reported annual landings and 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). This 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 steadily increasing estimates of harvestable biomass. Since the 2020 dredge survey, the provisional harvest rate has been just below the MSY reference. However, harvest rate estimates for 2020 are provisional, as international landings for the 12 months following the 2020 dredge survey have not yet been reported. Projecting international landings two years in advance, i.e., from 2019 to 2021, was deemed too unreliable. Therefore, the 2021 realised harvest rate has not been calculated for this assessment.

In 2018, a change to a smaller survey vessel deploying fewer dredges was unavoidable. Both survey vessels deploy very similar gear, and scallop catches 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 using 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 gear-efficiency, and even relatively small changes to this value would have a significant impact upon the estimated harvestable biomass and realised 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 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.

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

3.1. Area definition

As described in Section 1.4, three scallop assessment areas which encompass the majority of areas fished by UK vessels of at least 12 m in length 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, two entirely within 27.7.e.L, and two entirely within 27.7.e.O. Two 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 6 nm of the coast and are no longer accessible to larger vessels, including our survey vessel. They are therefore not part of the dredge survey any more 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.

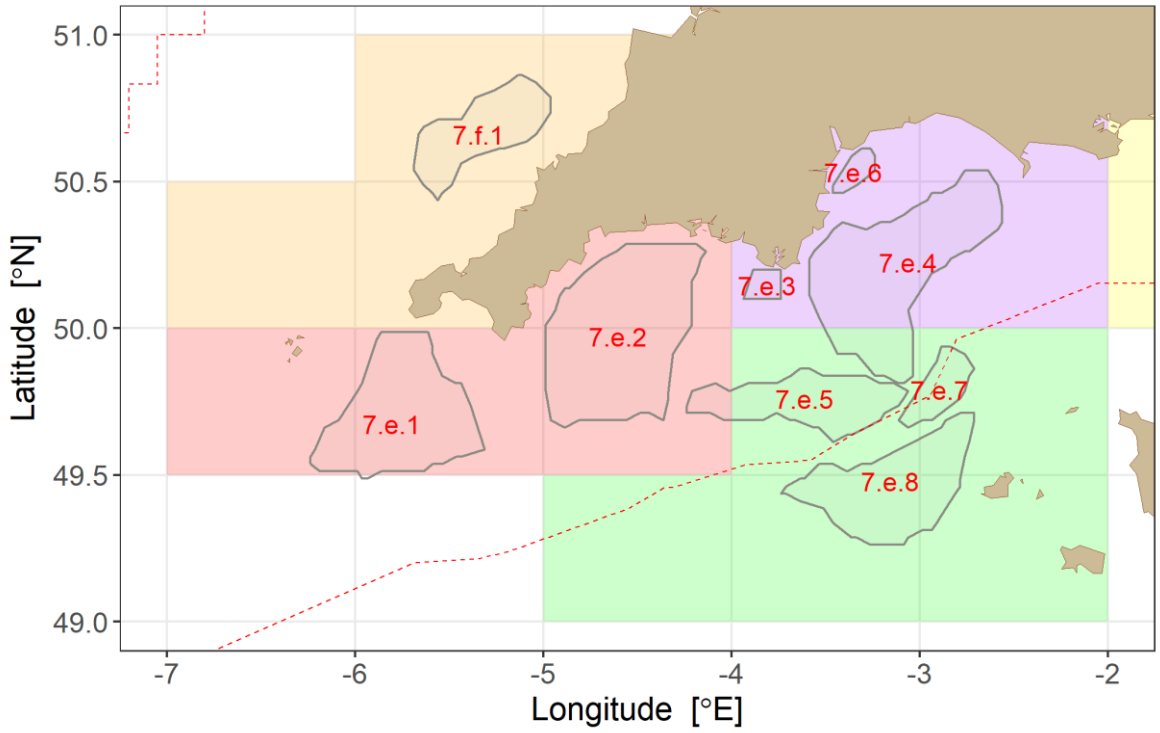

Figure 3.1: Dredge-surveyed parts of ICES Divisions 27.7.e and 27.7.f: Beds 7.e.1 and 7.e.2 within Area 27.7.e.I (red), Beds 7.e.3, most of 7.e.4 and 7.e.6 within Area 27.7.e.L (purple), Beds 7.e.5, 7.e.7 7.e.8, and part of 7.e.4 within Area 27.7.e.O (green), and Bed 7.f.1 with Area 27.7.f.I (orange).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

3.2. Commercial landings and sampling data

Total annual landings by country, originating from the assessment areas in Divisions 27.7.e and 27.7.f during the 2000 – 2020 period, are listed in Table A3 of the latest report of the ICES Scallop Working Group (ICES, 2021). These area totals are aggregated from fisheries data recorded with a spatial resolution of ICES statistical rectangles. 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.

Due to the delay in the collation of commercial landings and sampling data within the UK, an appropriate way of analysing fisheries data is by season, in which a season comprises Q1 – Q3 of the current calendar year, and Q4 of the preceding year.

UK quarterly landings for the assessment areas in Divisions 27.7.e and 27.7.f are listed in Table 3.1 to Table 3.4. At the time of report writing (January 2022), landings data to the end of Q3 of 2021 are considered reliable. There is a seasonal pattern within the three assessment areas of Division 27.7.e, 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 .

Table 3.1: UK quarterly landings (tonnes) from Area 27.7.e.I.

	Q1	Q2	Q3	Q4	Annual	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	219	897	1022	181	2319	2369
2018	262	1007	393	108	1770	1844
2019	189	574	1218	83	2063	2088
2020	124	395	287	116	922	890
2021	293	665	833	138*	1929*	1907

* provisional

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

	Q1	Q2	Q3	Q4	Annual	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	409	535	340	429	1713	1777
2018	304	399	575	628	1906	1707
2019	519	463	293	418	1693	1902
2020	316	171	459	543	1488	1364
2021	619	457	317	535*	1928*	1936

* provisional

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

	Q1	Q2	Q3	Q4	Annual	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	45	324	203	57	629	582
2018	106	415	444	429	1394	1022
2019	51	583	896	15	1544	1958
2020	60	521	1356	20	1957	1953
2021	96	1050	2540	87*	3773*	3706

* provisional

Table 3.4: UK quarterly landings (tonnes) from Area 27.7.f.l.

	Q1	Q2	Q3	Q4	Annual	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	117	103	228	31	478	456
2018	9	74	47	7	137	161
2019	42	57	211	13	323	316
2020	40	73	92	7	211	218
2021	30	26	28	3*	87*	91

* provisional

The number of samples collected each season through the biological sampling programme is shown in Table 3.5, 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. The listed number of samples, and number of shells measured or aged, only includes samples that

have at least 70 size measurements, or at least 20 determined ages. Smaller samples are considered unreliable and are not included in the assessment.

Table 3.5: Biological sampling programme summary for assessment areas in ICES Divisions 27.7.e and 27.7.f. Number of age samples and shells aged are provisional and will be updated as more data become available.

	Commercial Landings				Dredge Survey	
Sampling Season	Length Samples	Shells Measured	Age Samples	Shells Aged	Age Samples	Shells Aged
27.7.e.I						
2017	26	4623	9	237	8	330
2018	28	5131	10	266	17	524
2019	20	3728	8	244	13	601
2020	-	-	-	-	8	278
2021	-	-	-	-	-	-
27.7.e.L						
2017	21	3891	7	271	3	141
2018	33	6664	10	317	7	212
2019	19	3472	11	363	3	138
2020	5	1273	-	-	6	214
2021	-	-	-	-	-	-
27.7.e.O						
2017	8	1340	3	85	6	260
2018	12	2187	7	204	14	487
2019	10	1507	1	24	3	118
2020	-	-	-	-	7	254
2021	11	1757	-	-	-	-
27.7.f.I						
2017	2	404	-	-	-	-
2018	1	173	1	26	3	100
2019	2	295	1	30	4	279
2020	-	-	-	-	4	116
2021	-	-	-	-	-	-

Length distributions from the industry sampling programme, raised to the UK commercial landings, are show in Figure 3.2. Length samples for individual vessels were raised to UK monthly landings, before aggregation to total landings during each sampling season.

The size distributions for Area 27.7.e.I show large qualitative differences between years, with a shift towards smaller animals between 2017 and 2018, and a shift back to larger animals between 2018 and 2019. Unfortunately, length sampling in that area was interrupted in 2020 and 2021 due to the Covid-19 pandemic.

Length distributions in Area 27.7.e.L were fairly consistent between 2017 and 2019. In 2020, the number of sampled animals larger than 110 mm significantly decreased. However, this was based on only five samples.

In Area 27.7.e.O, the dramatic increase in UK seasonal landings over the survey period (by more than a factor of six between 2017 and 2021) is reflected in the large increase in the number of landed animals across the size spectrum, with a maximum at 105 mm in 2019 and 2021. This has decreased from the previous maximum at 115 mm in 2017, and 110 mm in 2018.

The length distributions for 27.7.f.I are only based on one or two samples every year between 2017 and 2019, and do not allow an analysis of significant changes over time.

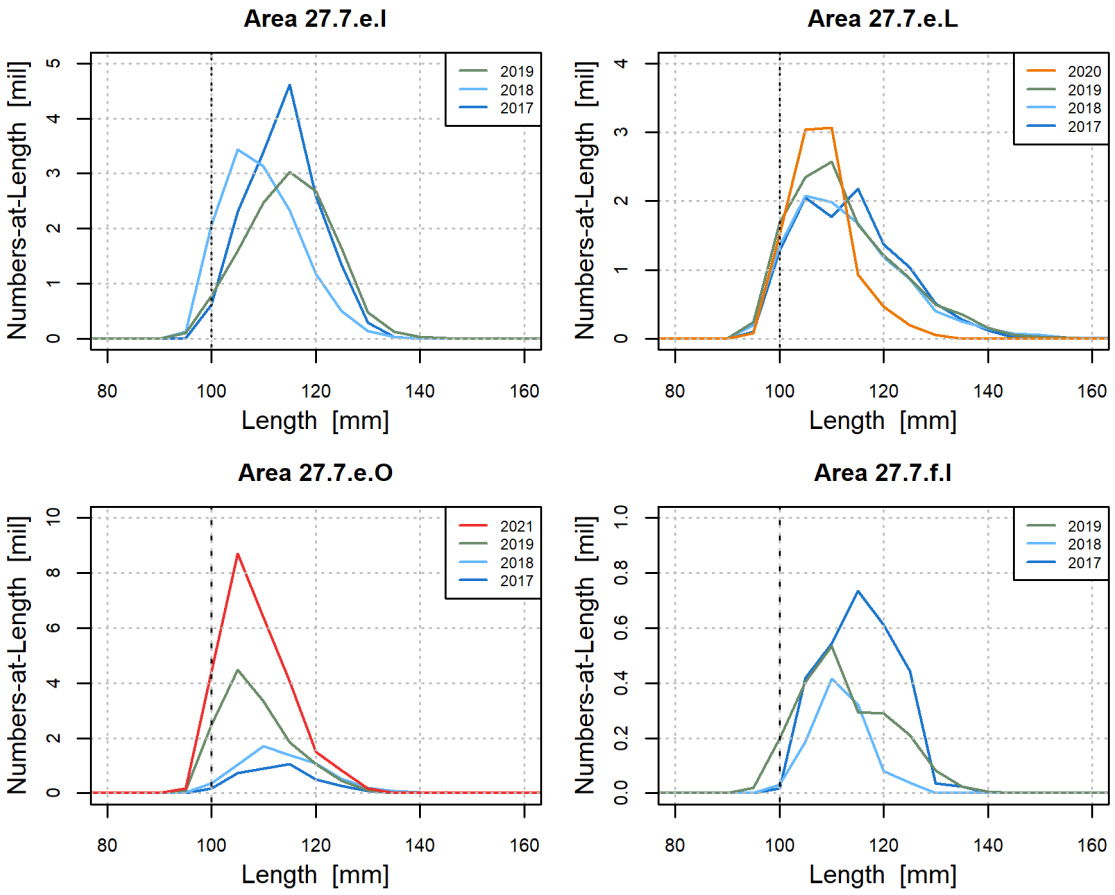

Figure 3.2: UK landed numbers in 5-mm size bins from assessment areas in ICES Divisions 27.7.e and 27.7.f during individual sampling seasons (Q1 – Q3 of current calendar year, plus Q4 of previous year). The vertical dashed line indicates MLS.

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 western English Channel: 1. East of the Eddystone, 2. West of the Eddystone, 3. Scillies, 4. Offshore, 5. Lyme Bay.

Table 3.6: 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 Section 2 of the annexe. The commercial scallop vessel, the gear type and deployment configuration, as well as the sampling procedure are described in Section 1.6.

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. In 2021 – with the exception of Beds 7.e.3 and 7.e.6, which have been excluded from the dredge survey, as described above – the beds in Division 27.7.e could be surveyed without any restrictions. However, due to poor weather conditions, the dredge survey in Division 27.7.f could not be carried out.

Between 14 – 28 May 2021, a total of 132 randomly selected stations were surveyed in Division 27.7.e, resulting in the sampled blocks shown in Figure 3.3. Availability by bed of length sampling data from the dredge survey is summarised in Table 3.7.

Table 3.7: Sampling summary of the 2021 dredge survey in the assessment areas of ICES Division 27.7.e.

Bed	Number of Stations	Number of Length Samples	Number Measured	Average Round Length [mm]	Range of Round Length [mm]
7.e.1	23	23	394	80.1	68 - 140
7.e.2	33	33	876	99.8	65 - 146
7.e.4	32	31	561	104.4	65 - 147
7.e.5	16	14	178	99.4	83 - 141
7.e.7	7	6	478	102.4	61 - 134
7.e.8	21	21	1859	102.7	56 - 131

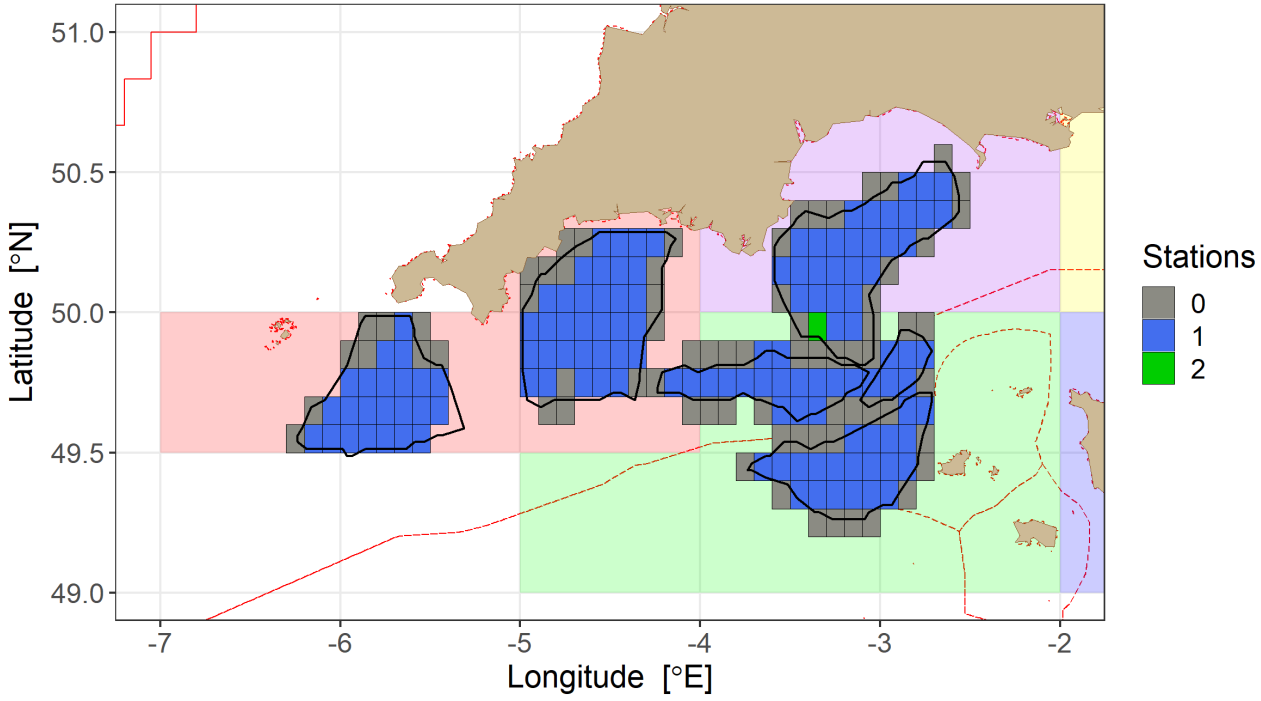

Figure 3.3: Number of stations visited during the 2021 dredge survey within each sampled block of Beds 7.e.1 – 8 and 7.f.1 within the assessment areas of ICES Divisions 27.7.e and 27.7.f. The dashed red lines indicate the boundary of the UK EEZ, as well as those of the Channel Islands.

3.4.2. Underwater television survey methodology

For the first time in 2017, an underwater television (UWTV) survey was 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 surveys were carried out since then. The spatial coverage and methods of UWTV surveys are described in Section 4 of the annexe.

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. 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 2021, unrestricted dredge surveying was possible in all beds of Division 27.7.e.

The estimated biomass of harvestable scallops (≥ 100 mm MLS) within 0.1-by-0.1 degree blocks in 2021 is shown in Figure 3.4.

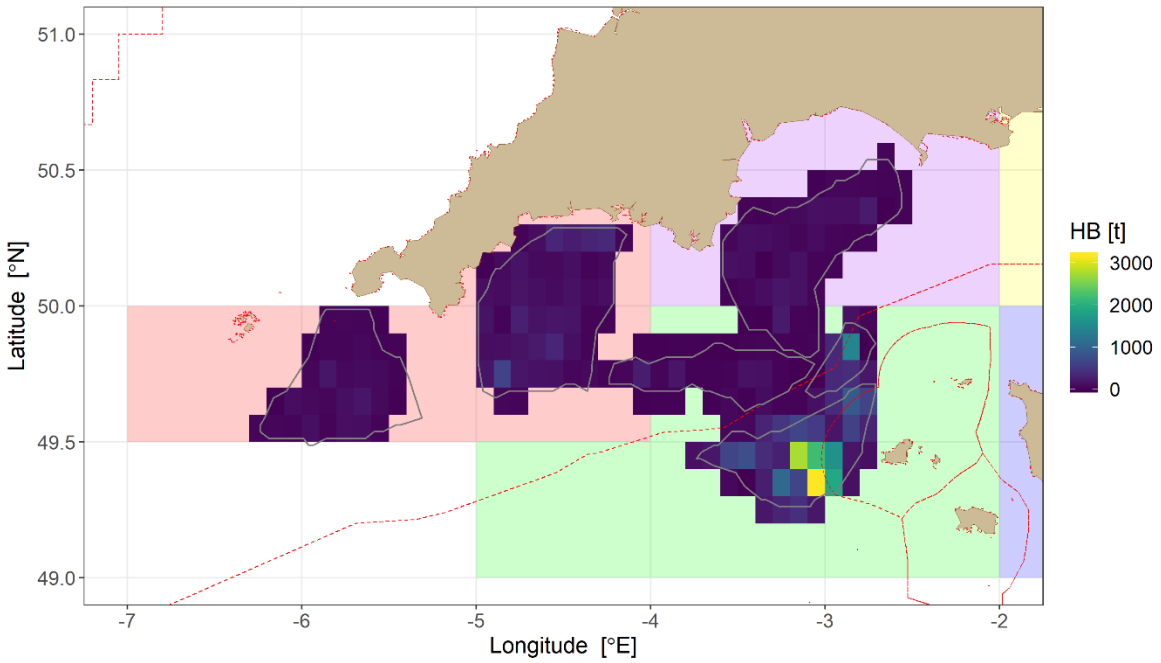

Figure 3.4: Harvestable biomass (tonnes) of scallops of at least MLS (100 mm round shell length) within the dredge surveyed parts of Areas 27.7.e.I (red), 27.7.e.L (purple), and 27.7.e.O (green) during 2021. The dashed red line indicates the boundary of the UK EEZ, as well as those of the Channel Islands.

To establish a measure of uncertainty around the harvestable biomass based on all survey stations ("survey estimate"), the values for individual stations within the same bed were randomly resampled with replacement ("bootstrapped") 5000 times. For each iteration, the same analysis procedure was used as for the survey estimate. The resulting distribution of harvestable biomass during 2021 is shown in Figure 3.5.

In Bed 7.e.7, the density of scallops on the ground varied greatly between different stations. This is reflected in a bimodal distribution of harvestable biomass based on random resampling. A longer time-series of survey results, and a higher number of stations, would be required to better establish the abundance of scallops in that bed.

The survey estimate, along with the median and quartile range from bootstrapping, are given in Table 3.8, together with the results for the previous years. As the survey 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 has decreased since. It is currently at a level between 2017 and 2018. In Area 27.7.e.L, estimates of harvestable biomass steadily increased from 2017 to 2020. However, the survey estimate in 2021 established a sudden decline to a level around that in 2017. Similarly, in Area 27.7.e.O, the increasing trend between 2017 and 2020 was reversed in 2021, with a current level between the 2019 and 2020 values.

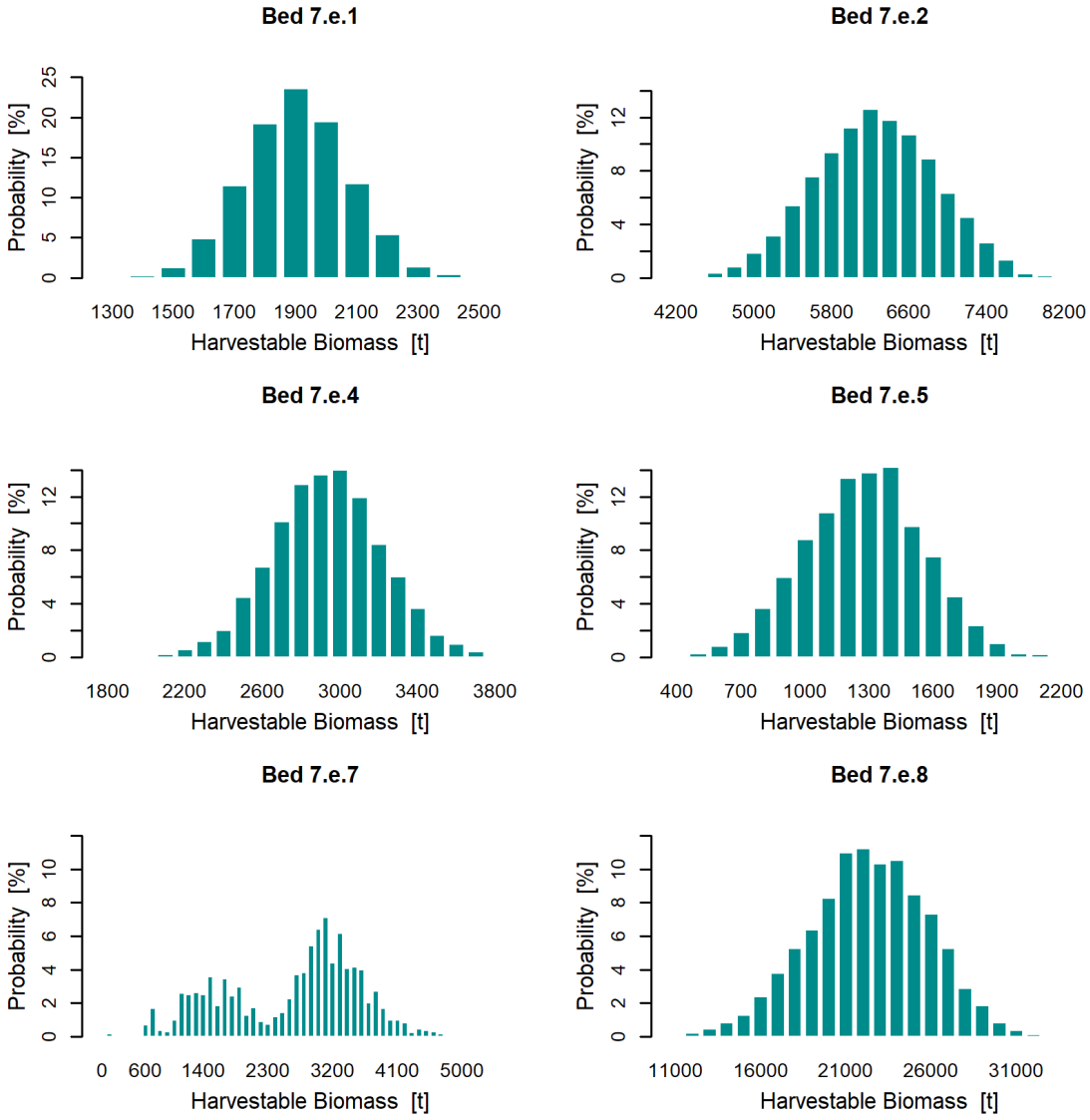

Figure 3.5: Distribution of harvestable biomass in Beds 27.7.e.1 – 8 (Division 27.7.e) during 2021 from random resampling ("bootstrapping").

Table 3.8: Harvestable biomass (tonnes) in dredged parts of the assessment areas in ICES Division 27.7.e: survey estimate (using all station values), median, and quartile range from random resampling ("bootstrapping").

	25th Percentile	Median	Survey	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
2021	7389	8350	8576	9412
27.7.e.L				
2017	2449	2563	2636	2722
2018	2593	2792	2849	2995
2019	3056	3362	3384	3664
2020	4028	4404	4470	4777
2021	2384	2602	2622	2813
27.7.e.O				
2017	6919	8469	8673	9401
2018	9119	10403	10746	11809
2019	13382	14877	15987	19868
2020	31772	35158	35370	38362
2021	20226	25292	27027	30767
27.7.f.I				
2017	-	-	-	-
2018	1532	1674	1687	1815
2019	945	1104	1143	1283
2020	1132	1280	1283	1420
2021	-	-	-	-

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 Division 27.7.e were derived. From these, total population numbers and biomasses could be estimated.

Between 2017 and 2019, a significant proportion by weight of survey catches from these assessment areas were below MLS (Table 3.9). In 2020, the below-MLS component of survey catches decreased significantly, which is reflected in the area-aggregated size distributions derived from survey catches by a shift towards larger sizes (Figure 3.6). In 2021, size distributions were similar to those in the previous year in Areas 27.7.e.I and 27.7.e.O. However, in Area 27.7.e.L, the size distribution shifted towards smaller animals and was similar to that in 2017, which is also shown in an increase in the below-MLS catch component.

The area-aggregated size distributions derived from survey catches (Figure 3.6) do not compare directly to those from commercial landings (Figure 3.2), as they are raised to total estimated biomass by means of an assumed dredge efficiency, as opposed to being raised to reported landings. Additionally, the survey samples are only restricted by technical limitations, i.e., reduced gear efficiency towards smaller shells. The industry samples are furthermore restricted by legal limitations and are therefore biased towards sizes above MLS.

The bed-aggregated size distributions derived from survey catches are shown in Figure 3.7. Population numbers in Beds 7.e.1 and 7.e.2 remain low compared with the 2017 – 2019 period. In Bed 7.e.4, a significant reduction in population numbers was observed between 2020 and 2021. However, in Beds 7.e.7 and 7.e.8, population numbers remain high compared with the 2017 – 2019 period.

Table 3.9: 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
2021	8	24	15	-

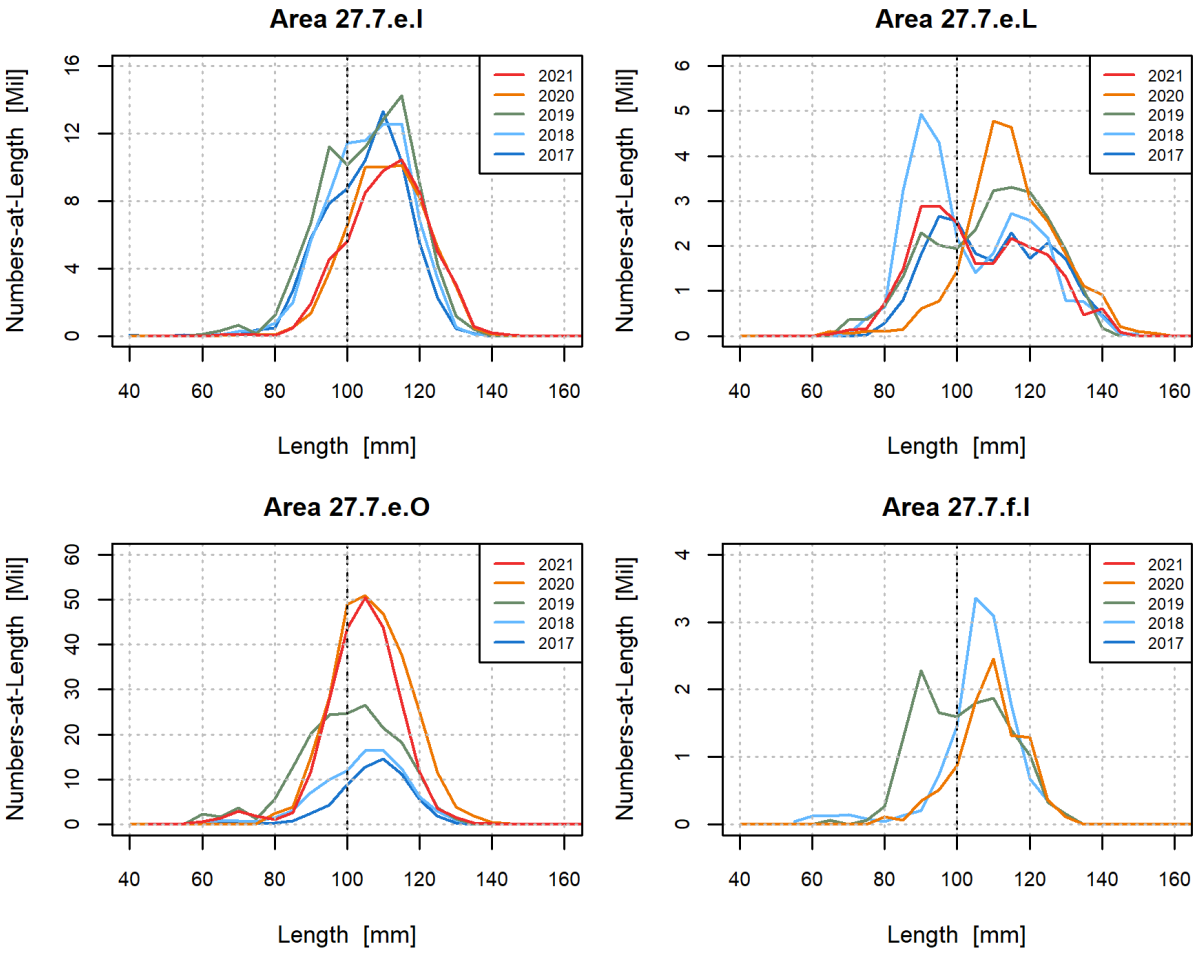

Figure 3.6: Annual population length distributions in 5-mm size bins from annual dredge surveys in the assessment areas of ICES Divisions 27.7.e and 27.7.f. The vertical dashed lines indicate MLS.

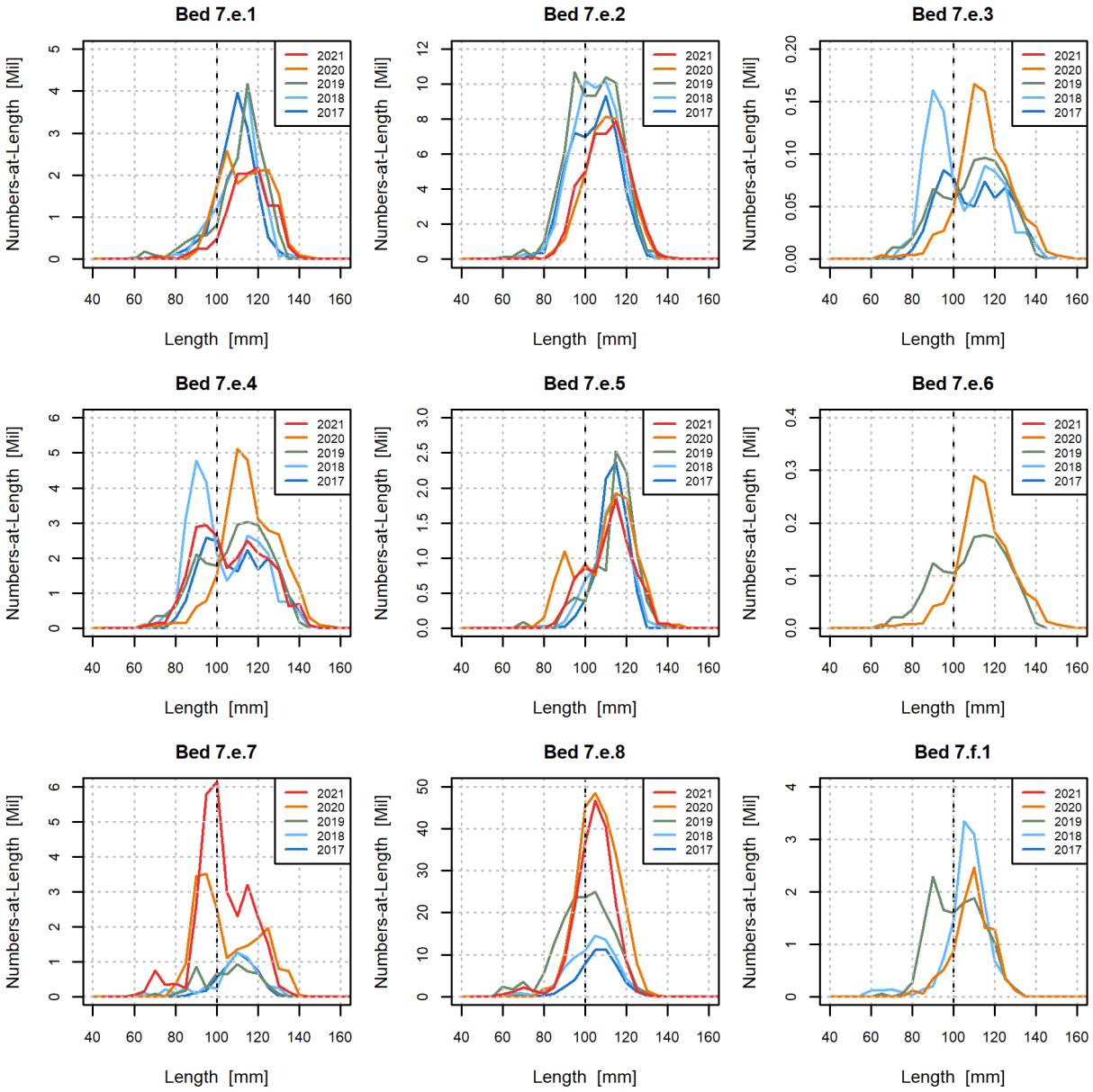

Figure 3.7: Annual population length distributions in 5-mm size bins from annual dredge surveys in Beds 7.e.1 – 8 and 7.f.1. The vertical dashed lines indicate MLS.

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 Section 4 of the annexe. Biomass estimates for the surveyed un-dredged zones in these assessment areas are included in the estimation of harvest rates in a later section.

3.8. MSY reference point estimation

Estimation of the fishing mortality that generates maximum sustainable yield (MSY) requires a full analytical assessment, including an estimate of the stock-recruitment relationship. As is the case with many stocks assessed by ICES, this is not yet possible for king scallops. 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.

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. These data sources are not yet available for scallops along the English coast. Instead, scaled length distributions were used to determine gear selection parameters (L25 and L50 of a selection ogive) to facilitate a length-based cohort method. 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 model 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).

The model estimates of harvest rates compatible with F35%SpR in the assessment areas of Division 27.7.e are listed in Table 3.10.

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.

Table 3.10: 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

3.9. Harvest rate estimation

The harvest rate (i.e. the ratio of landings to total harvestable biomass, assuming no dead discards) is proposed to give a proxy for the fishing mortality experienced by these assessment areas. 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. At the time of writing of this assessment report (January 2022), international landings for 2017 – 2020 were available from the latest ICES Scallop Working Group (ICES, 2021). International landings for the 12-months following the two most recent dredge surveys in 2020 and 2021 were not available. Instead, for the 2020 survey, the international landings from the previous survey year were used, unless UK landings recorded on a national database during the 12-month period following the 2020 survey already exceed those of the previous survey. This was the case in Areas 27.7.e.L and 27.7.e.O. However, international landings and associated harvest rates presented here are provisional and will be revised when required data become available.

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 values are the survey estimates from Table 3.8. The range of harvest rate is based on the inter-quartile range of the harvestable biomass estimate from random resampling.

The harvest rates listed in Table 3.12 are based on biomass estimates that also include un-dredged zones that have been surveyed by UWTV. 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 the 2017 UWTV survey have been included for later years. These harvest rates are applicable only when connectivity between dredged and un-dredged populations is complete.

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 described in the previous section, are listed in Table 3.13.

Table 3.11: International landings over 12-month periods following annual dredge surveys in the stated years, and harvest rate estimates for the dredged parts of ICES Divisions 27.7.e and 27.7.f.

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvest Rate on Dredged Portion of Stock (%)	Harvest Rate Range (%)	
27.7.e.I					
2017	2773	7337	37.8	36.4	43.2
2018	1507	8971	16.8	15.8	17.6
2019	1801	10378	17.4	16.6	18.9
2020	1801*	8791	20.5	19.3	21.5
27.7.e.L					
2017	1450	2636	55.0	53.3	59.2
2018	2192	2849	76.9	73.2	84.5
2019	1284	3384	37.9	35.0	42.0
2020	1916*	4470	42.9	40.1	47.6
27.7.e.O					
2017	956	8673	11.0	10.2	13.8
2018	1460	10746	13.6	12.4	16.0
2019	1868	15987	11.7	9.4	14.0
2020	1933*	35370	5.5	5.0	6.1
27.7.f.I					
2017	251	-	-	-	-
2018	135	1687	8.0	7.4	8.8
2019	395	1143	34.6	30.8	41.8
2020	395*	1283	30.8	27.8	34.9

* estimate from previous year, to be revised when 2021 international landings have been reported

Table 3.12: International landings over 12-month periods following annual dredge surveys in the stated years, and harvest rate estimates for assessment areas in ICES Divisions 27.7.e and 27.7.f, combining harvestable biomass estimates from the dredge and UWTV surveys.

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UWTV Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
27.7.e.l					
2017	2773	7337	4683	12020	23.1
2018	1507	8971	4683	13654	11.0
2019	1801	10378	4683	15061	12.0
2020	1801*	8791	4683	13474	13.4
27.7.e.L					
2017	1450	2636	2649	5286	27.4
2018	2192	2849	2649	5498	39.9
2019	1284	3384	2649	6033	21.3
2020	1916*	4470	2649	7119	26.9
27.7.e.O					
2017	956	8673	620	9293	10.3
2018	1460	10746	620	11366	12.8
2019	1868	15987	620	16607	11.2
2020	1933*	35370	620	35990	5.4
27.7.f.l					
2017	251	-	-	-	-
2018	135	1687	375	2062	6.5
2019	395	1143	375	1518	26.0
2020	395*	1283	375	1658	23.8

* estimate from previous year, to be revised when 2021 international landings have been reported

Table 3.13: 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	37.8	23.1	19.5
2018	16.8	11.0	19.5
2019	17.4	12.0	19.5
2020*	20.5	13.4	19.5
27.7.e.L			
2017	55.0	27.4	21.0
2018	76.9	39.9	21.0
2019	37.9	21.3	21.0
2020*	42.9	26.9	21.0
27.7.e.O			
2017	11.0	10.3	20.9
2018	13.6	12.8	20.9
2019	11.7	11.2	20.9
2020*	5.5	5.4	20.9

* estimate from previous year, to be revised when 2021 international landings have been reported

3.10. Conclusion

This is the fifth stock assessment undertaken for king scallops in the western English Channel (assessment areas of ICES Division 27.7.e). Due to poor weather conditions, the planned dredge survey within Area 27.7.f.I had to be cancelled. Furthermore, due to the Covid-19 pandemic, scientific surveys and commercial catch sampling in 2020 and 2021 were restricted. As a result, the planned UWTV surveys in these years could not be carried out. Therefore, this assessment includes biomass estimates and provisional harvest rates based on the 2021 dredge survey in Division 27.7.e, together with the biomass estimated based on the 2017 and 2019 UWTV surveys in selected un-dredged zones.

The large variation in reported annual landings and estimated harvestable biomass 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). This 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 fell below that value in 2018 and 2019. Based on provisional international landings during the 12-month period following the 2020 dredge survey, the realised harvest rate during that period has increased again to just above the MSY reference. Including biomass in selected un-dredged zones reduces the estimated harvest rate to below the MSY reference since 2018. However, ecological significance of the combined dredged and un-dredged parts of the assessment area requires complete connectivity between the different populations, which has not yet been demonstrated.

In the dredged part of Area 27.7.e.L, the estimated realised 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. In 2019, due to a combination of an increased estimate of harvestable biomass and reduced international landings, the realised harvest rate fell to about half the value of the previous year. In 2020, despite an increase in the estimate of harvestable biomass, the harvest rate in the dredged part of the assessment area increased again, due to an increase in international landings. Even with the inclusion of biomass in selected un-dredged zones, the estimated realised harvest rate remains above the reference value. However, harvest rate estimates for 2020 are provisional, as international landings for the 12 months following the 2020 dredge survey have not yet been reported. Projecting international landings two years in advance, i.e., from 2019 to 2021, was deemed too unreliable. Therefore, the 2021 realised harvest rates in this and the other assessment areas have not been calculated.

The realised harvest rate in the dredged part of Area 27.7.e.O has been consistently below the MSY reference value of 20.9% since 2017, and was particularly low in 2020, due to a large increase in the estimated harvestable biomass. However, harvestable biomass has decreased again from 2020 to 2021, and the longer-term evolution of the stock will have to be monitored through future surveys.

Due to insufficient sampling data, no size-based modelling was carried out for Area 27.7.f.I. The estimated realised harvest rate increased significantly from 2018 to 2019 and has been between 20 – 30% since then.

In 2018, a change to a smaller survey vessel deploying fewer dredges was unavoidable. Both survey vessels deploy very similar gear, and scallop catches 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 using 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 gear-efficiency, and even relatively small changes to this value would have a significant impact upon the estimated harvestable biomass and realised 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 areas, 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 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.

4. Stock assessment for surveyed areas of ICES Division 27.4.b

4.1. Area definition

As described in Section 1.4, two scallop assessment areas which encompass the majority of areas fished by UK vessels of at least 12 m in length within ICES Division 27.4.b have been defined: 27.4.b.S (inshore Yorkshire and Durham), and 27.4.b.D (Dogger Bank) (Figure 4.1). Within Area 27.4.b.S, two scallop beds were defined in 2018 based on 2009 – 2017 VMS data, and were first surveyed in 2018. Due to the intense fishing activity in the Dogger Bank area during spring and early summer of 2020, five beds were defined within Area 27.4.b.D, which were first surveyed in 2021. All beds in Division 27.4.b are within the UK EEZ. However, there may be future restrictions imposed on towed gear within Area 27.4.b.D, as it is within the Dogger Bank SAC, which is partly proposed to protect seabed features.

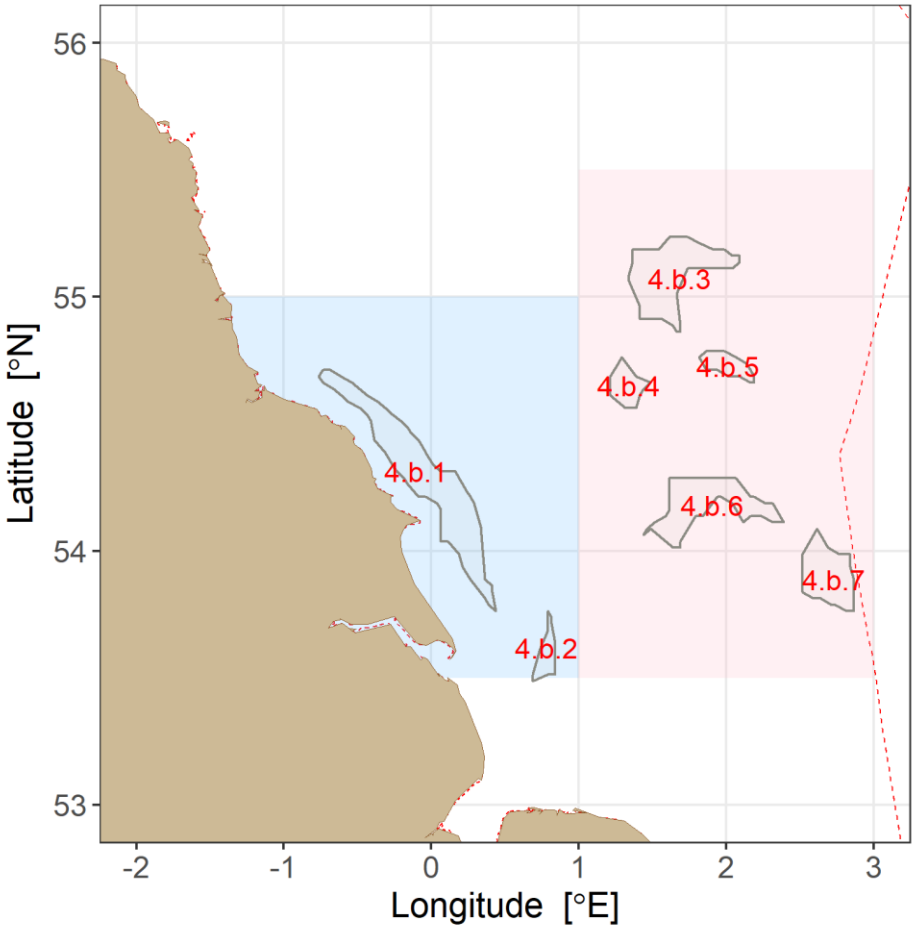

Figure 4.1: Dredge-surveyed parts of ICES Division 27.4.b: Beds 4.b.1 and 4.b.2 within Area 27.4.b.S (light blue), and Beds 4.b.3 – 7 within Area 27.7.b.D (pink). The dashed red line indicates the boundary of the UK EEZ.

4.2. Commercial landings and sampling data

Total annual landings by country, originating from the assessment areas in Division 27.4.b during the 2000 – 2020 period, are listed in Table A3 of the latest report of the ICES Scallop Working Group (ICES, 2021). This fishery is exploited almost exclusively by UK registered vessels.

Due to the delay in the collation of commercial landings and sampling data within the UK, an appropriate way of analysing fisheries data is by season, in which a season comprises Q1 – Q3 of the current calendar year, and Q4 of the preceding year.

UK quarterly landings for the assessment areas in Division 27.4.b are listed in Table 4.1 and Table 4.2. At the time of report writing (January 2022), landings data to the end of Q3 of 2021 are considered reliable. There is no consistent seasonal pattern in UK fishing

activity within Area 27.4.b.S, and within the last few years, the fishing activity in the Dogger Bank area has been limited primarily to Q2 and Q3 of 2020.

Table 4.1: 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	888	385	297	2505	2326
2018	689	842	366	434	2331	2194
2019	1020	842	304	158	2323	2600
2020	500	132	81	131	844	871
2021	1365	867	24	185*	2440*	2387

* provisional

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

	Q1	Q2	Q3	Q4	Annual	Sampling Season (Q4, Q1, Q2, Q3)
2017	0	5	15	0	20	20
2018	0	0	1	1	2	1
2019	0	1	4	7	11	5
2020	50	1612	551	1	2214	2219
2021	0	38	35	0*	73*	75

* provisional

The number of samples collected each season 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. The listed number of samples, and number of shells measured or aged, only includes samples that have at least 70 size measurements, or at least 20 determined ages. Smaller samples are considered unreliable and are not included in the assessment.

Table 4.3: Biological sampling programme summary for assessment areas in ICES Division 27.4.b. Number of age samples and shells aged are provisional and will be updated as more data become available.

	Commercial Landings				Dredge Survey	
Sampling Season	Length Samples	Shells Measured	Age Samples	Shells Aged	Age Samples	Shells Aged
			27.4.b.S			
2018	10	1494	12	439	7	288
2019	6	965	3	106	5	225
2020	2	290	-	-	3	94
2021	-	-	-	-	-	-
			27.4.b.D			
2020	5	638	5	215	-	-
2021	1	114	-	-	-	-

Length distributions from the industry sampling programme, raised to the UK commercial landings, are show in Figure 4.2. Length samples for individual vessels were raised to UK monthly landings, before aggregation to total landings during each sampling season.

On the basis of the few samples available for Area 27.4.b.S, there is an indication that the number of landed animals in the 100 – 120 mm range have declined significantly between 2019 and 2020. However, the 2020 size distribution is only based on two samples and may therefore not be representative. Unfortunately, no samples are available for 2021 to verify whether the reduced abundance of animals with lengths below 125 mm is a persistent phenomenon or the result of artificial variability due to low sampling.

On the basis of one sampling season in 2020, most of the landed animals had lengths of around 140 mm, compared with the maximum between 125 – 130 mm along the Yorkshire and Durham coast. If commercial activity in the Dogger Bank area continues, future sampling will establish whether increased exploitation levels lead to a shift in the catch size distribution towards smaller animals.

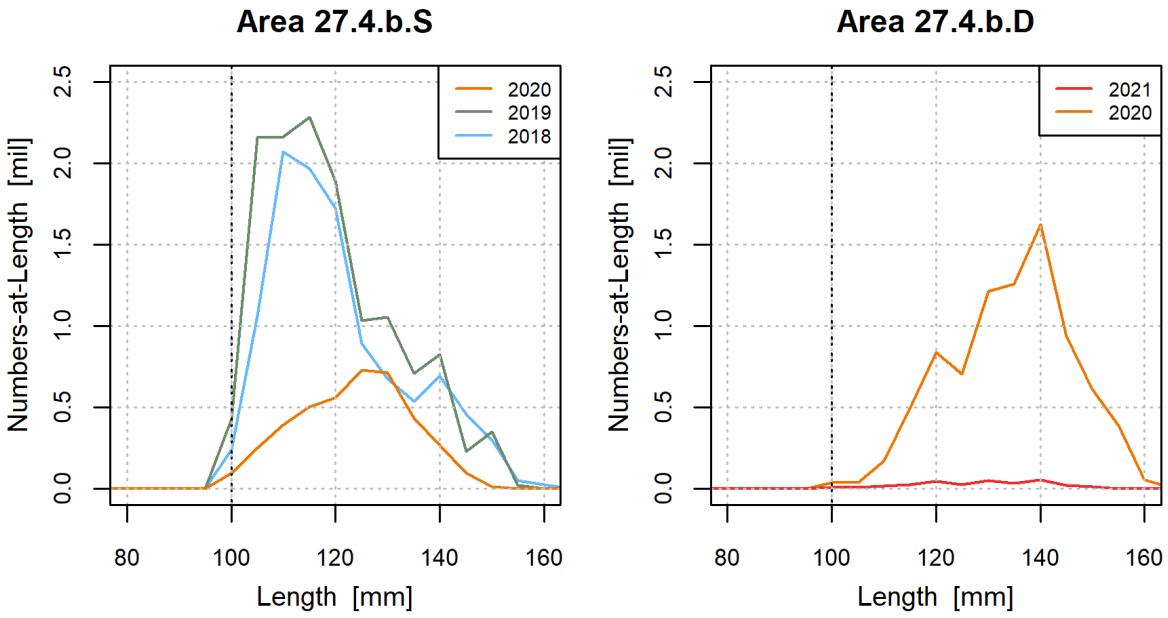

Figure 4.2: UK landed numbers in 5-mm size bins from assessment areas in ICES Division 27.4.b during individual sampling seasons (Q1 – Q3 of current calendar year, plus Q4 of previous year). The vertical dashed line indicates MLS.

4.3. Biological parameters and dredge efficiency

No area-specific growth parameters and weight-length relationships are available for Areas 27.4.b.S and 27.4.b.D. 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 the assessment areas in the North Sea. Similarly, the weight-length relationship for Area 27.7.d.N (obtained from IFREMER) will be used for the North Sea areas until more specific data become available.

Table 4.4: Biological and dredge efficiency parameters used for assessment areas in ICES Division 27.4.b.

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 and underwater television surveys

4.4.1. Dredge survey methodology

The dredge survey design and station selection procedure are described in Section 2 of the annexe. The commercial scallop vessel, the gear type and deployment configuration, as well as the sampling procedure are described in Section 1.6.

Between 11 – 18 September 2021, a total of 19 randomly selected stations were surveyed in Area 27.4.b.S. In Area 27.4.b.D, at total of 30 randomly selected stations were surveyed

between 9 – 11 September 2021. This resulted in the sampled blocks shown in Figure 4.3. Availability by bed of length sampling data from the dredge survey is summarised in Table 4.5.

Table 4.5: Sampling summary of the 2021 dredge survey in the assessment areas of ICES Division 27.4.b.

Bed	Number of Stations	Number of Length Samples	Number Measured	Average Round Length [mm]	Range of Round Length [mm]
4.b.1	17	17	638	115.3	71 - 149
4.b.2	2	2	135	114.1	66 - 143
4.b.3	11	11	279	97.5	70 - 156
4.b.4	3	3	99	132.3	87 - 160
4.b.5	2	2	199	118.7	61 - 147
4.b.6	9	6	69	98.3	84 - 151
4.b.7	5	3	158	127.3	84 - 159

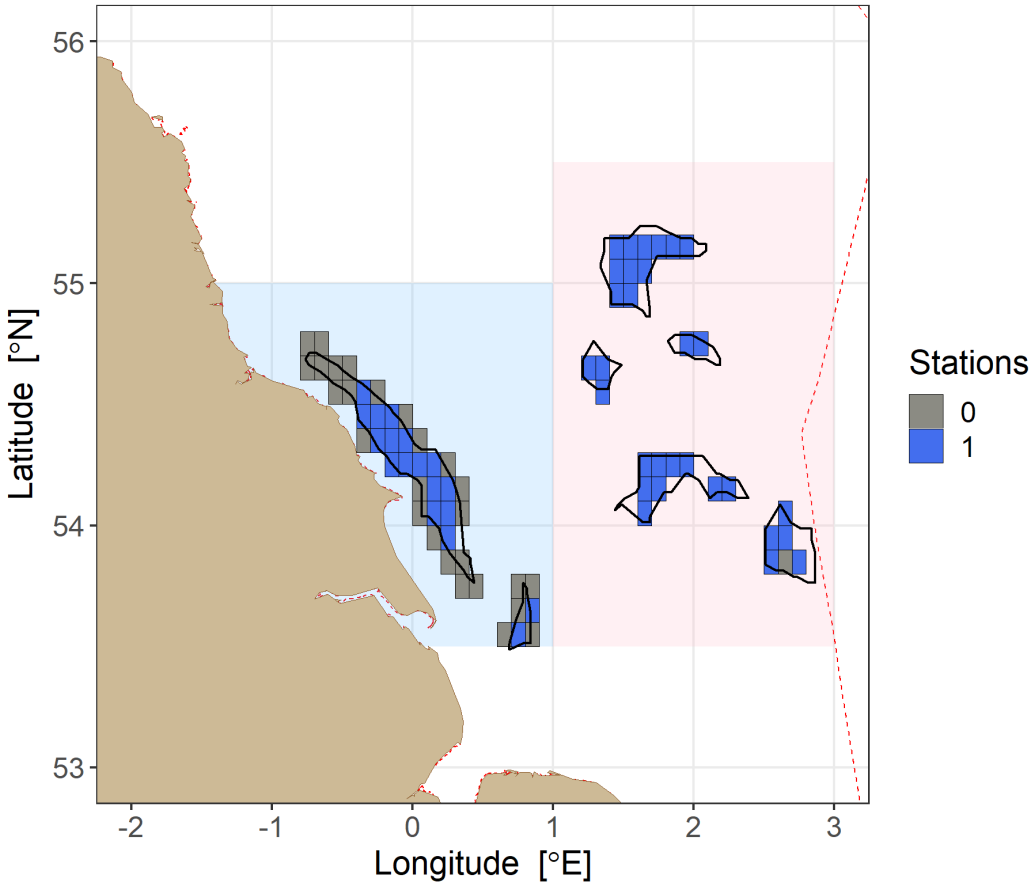

Figure 4.3: Number of stations visited during the 2021 dredge survey within each sampled block of Beds 4.b.1 – 7 within the assessment areas of ICES Division 27.4.b. The dashed red line indicates the boundary of the UK EEZ.

4.4.2. Underwater television survey methodology

For the first time in 2021, an underwater television (UWTV) survey was carried out to determine the spatial distribution and abundance of scallops in selected parts of Area 27.4.b.S that are inaccessible to fishing gear, including Marine Protected Areas (MPAs), and areas with unsuitable ground types. The spatial coverage and methods of UWTV surveys are described in Section 4 of the annexe.

4.5. Raised biomass estimates and uncertainty

The estimated biomass of harvestable scallops (≥ 100 mm MLS) within 0.1-by-0.1 degree cells in 2021 is shown in Figure 4.4.

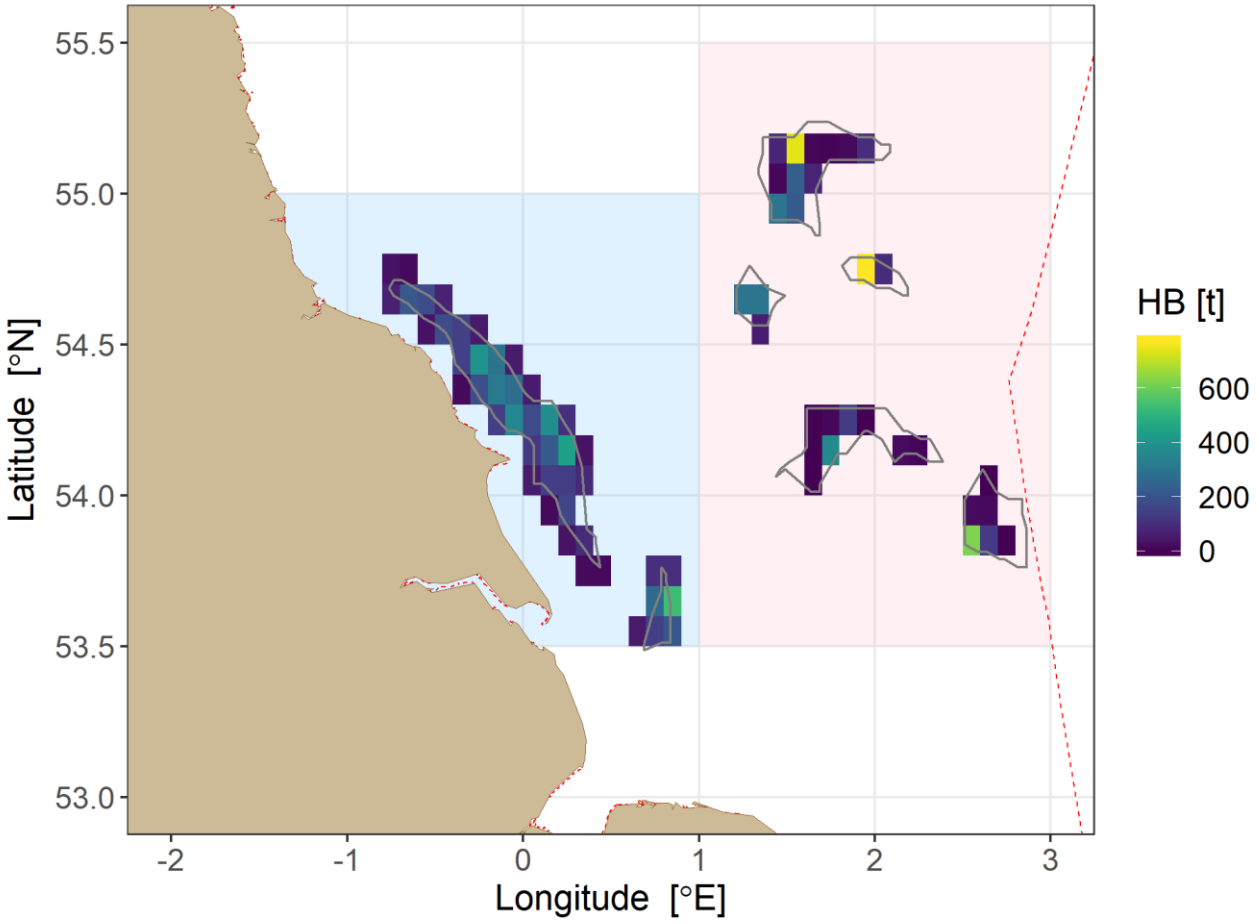

Figure 4.4: Harvestable biomass (tonnes) of scallops of at least MLS (100 mm round shell length) within the dredge surveyed parts of Areas 27.4.b.S (light blue), and 27.4.b.D (pink) during 2021. The dashed red line indicates the boundary of the UK EEZ.

To establish a measure of uncertainty around the harvestable biomass based on all survey stations ("survey estimate"), the values for individual stations within the same bed were randomly resampled with replacement ("bootstrapped") 5000 times. For each iteration, the same analysis procedure was used as for the survey estimate. The resulting distribution of harvestable biomass during 2021 is shown in Figure 4.5. The survey estimate, along with the median and quartile range from bootstrapping, are given in Table 4.6, together with the results for the previous years. As the survey estimate utilises all available data, it is

considered the most accurate value. As in previous years, no bootstrap distribution was generated for Bed 4.b.2 (Area 27.4.b.S), as only two tows were carried out during the 2021 survey due to the presence of static gear. Similarly, in Area 27.4.b.D, a randomised harvestable biomass distribution was only generated in the bed with the highest number of stations, i.e., Bed 4.b.3.

Compared with the previous two years, the estimated harvestable biomass in Bed 4.b.1 significantly increased in 2020, a change well outside the annual inter-quartile ranges. However, in 2021, the harvestable biomass decreased again to just below the level in 2018.

In Bed 4.b.3, the density of scallops on the ground varied greatly between different stations. This is reflected in a bimodal distribution of harvestable biomass based on random resampling. A longer time-series of survey results, and a higher number of stations, would be required to better establish the abundance of scallops in that bed, and in the wider assessment area.

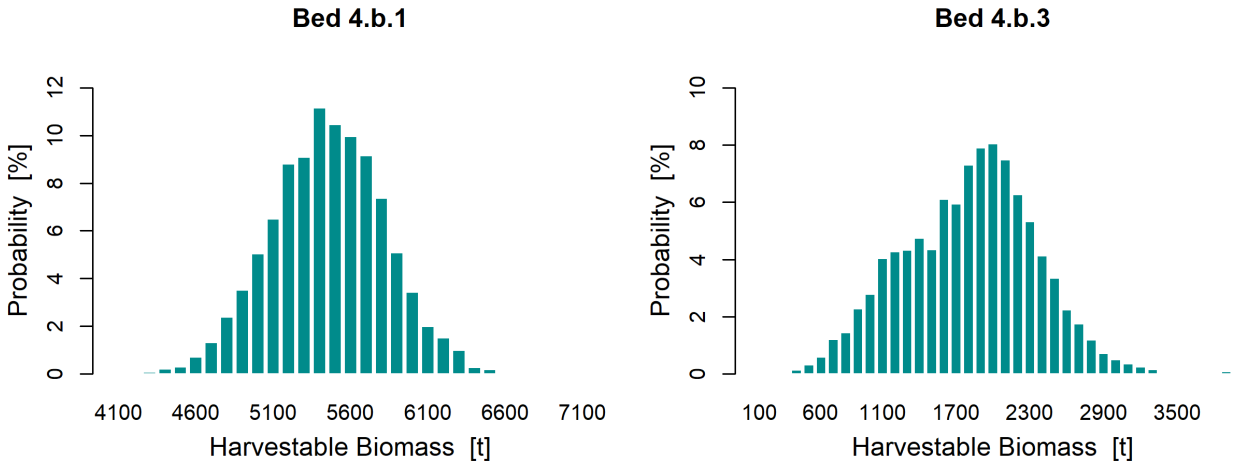

Figure 4.5: Distribution of harvestable biomass in Beds 4.b.1 (Area 27.4.b.S) and 4.b.3 (Area 27.4.b.D) during 2021 from random resampling ("bootstrapping").

Table 4.6: Harvestable biomass (tonnes) in Beds 4.b.1 (Area 27.4.b.S) and 4.b.3 (Area 27.4.b.D): survey estimate (using all station values), median, and quartile range from random resampling ("bootstrapping").

	25th Percentile	Median	Survey	75th Percentile
		4.b.1		
2018	5219	5483	5517	5739
2019	5392	5797	5754	6142
2020	8406	8797	8774	9198
2021	5204	5458	5470	5704
		4.b.3		
2021	1424	1849	1783	2171

4.6. Size composition from dredge survey

From the size samples taken at each station, total (pooled) length frequency distributions within assessment areas of ICES Division 27.4.b were derived. From these, total population numbers and biomasses could be estimated.

In 2021, the gradual upward shift in the above-MLS size distribution in Bed 4.b.1 continued from previous years (Figure 4.6). As this bed makes the largest contribution to the assessment area, this is also true for the area-aggregated size distributions (Figure 4.7). However, in contrast with the previous year, there was a distinct secondary maximum at sizes just below MLS in 2021, both in bed- and area-aggregated size distributions. Due to that, the below-MLS proportion by weight of survey catches from standard gear in Bed 4.b.1 increased from 4% in 2020 to 6% in 2021, but remains well below the values of 39% in 2018, and 21% in 2019.

In Bed 4.b.2, the density of scallops on the ground was unusually high during the 2021 survey, particularly due to a large number of animals with round shell lengths just above MLS.

In Area 27.4.b.D, the aggregated population size distribution has a maximum between 135 – 140 mm, which is close to the maximum of the landed size distribution at 140 mm that was found based on the industry sampling programme (Figure 4.2).

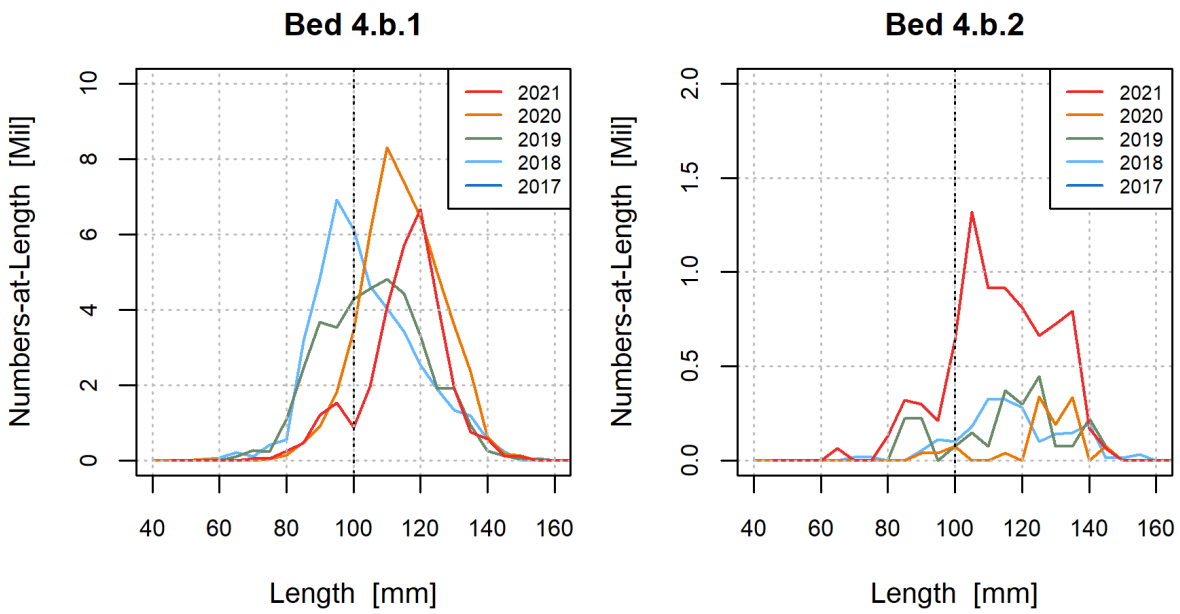

Figure 4.6: Annual population length distributions in 5-mm size bins from annual dredge surveys in Beds 4.b.1 and 4.b.2 of Area 27.4.b.S. The vertical dashed lines indicate MLS.

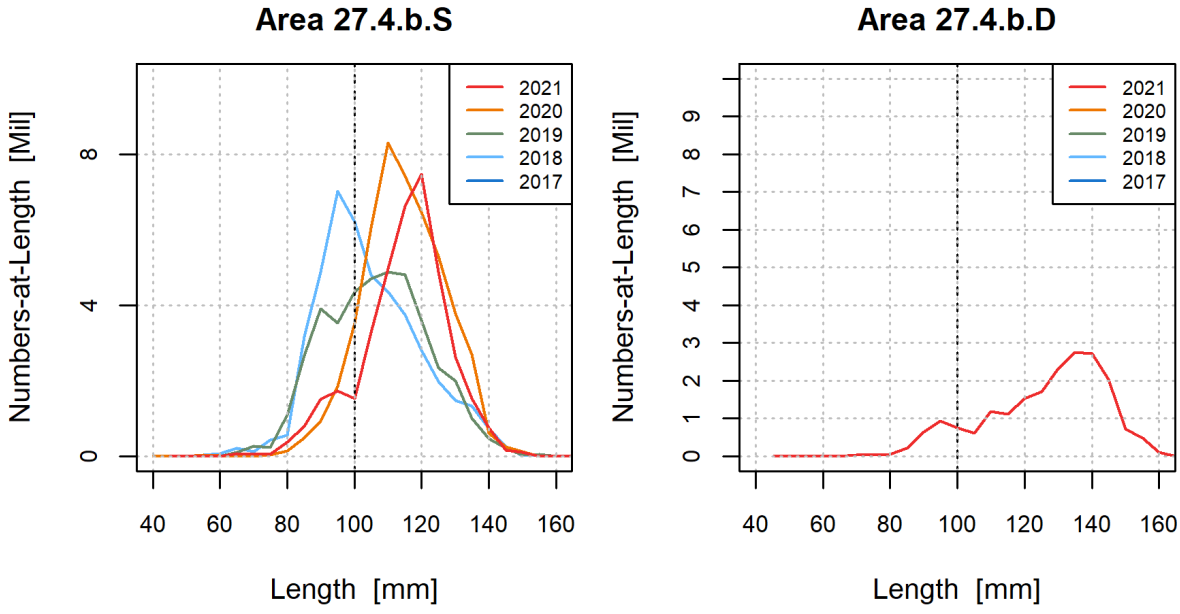

Figure 4.7: Annual population length distributions in 5-mm size bins from annual dredge surveys in Areas 27.4.b.S and 27.4.b.D. The vertical dashed lines indicate MLS.

4.7. Relative abundance from UWTV survey

The first UWTV survey in Area 27.4.b.S was carried out in September 2021. The three surveyed beds are: TV.4.b.A with 16 stations (17 – 18 May 2021), TV.4.b.B with 10 stations (14 – 15 May 2021), and TV.4.b.C with 31 stations (15 – 18 May 2021). The tow duration was consistently 20 minutes, with average track lengths between 240 m (TV.4.b.B) and 248 m (TV.4.b.A).

The UWTV survey established that scallops are distributed at low density on the seabed in the un-dredged zones. The zero count percentage was between 70% (TV.4.b.B) and 88% (TV.4.b.A), and the density was between 1.3 (TV.4.b.A) and 4.4 (TV.4.b.C) scallops per 1000 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 2021 UWTV survey are reproduced in Section 4 of the annexe. The total biomass estimate for the surveyed un-dredged zones in Area 27.4.b.S is included in the estimation of harvest rates in a later section.

4.8. MSY reference point estimation

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 been carried out for Area 27.4.b.S since 2018 and has provided a total of 18 length samples (Table 4.3). Sampling has been severely impacted by the Covid-19 pandemic, with only two samples in 2020 and none in 2021. We still consider this sampling level to be below that required to enable a reliable analysis using a length-based cohort model. Therefore, an MSY harvest rate cannot be established for this assessment area.

4.9. Harvest rate estimation

The harvest rate (i.e. the ratio of landings to total harvestable biomass, assuming no dead discards) is proposed to give a proxy for the fishing mortality experienced by these assessment areas. 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. At the time of writing of this assessment report (January 2022), international landings for 2017 – 2020 were available from the latest ICES Scallop Working Group

(ICES, 2021). International landings for the 12-months following the two most recent dredge surveys in 2020 and 2021 were not available. Instead, for the 2020 survey, the UK landings recorded on a national database during the 12-month period following the survey were used. However, international landings and associated harvest rates presented here are provisional and will be revised when required data become available.

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 values are the survey estimates from Table 4.6. The range of harvest rate is based on the inter-quartile range of the harvestable biomass estimate from random resampling.

A harvest rate estimate for Area 27.4.b.D is not possible at this moment, as we only have reported international landings until the end of 2020, and only have a harvestable biomass estimate from the dredge survey in 2021.

The harvest rates listed in Table 4.8 are based on biomass estimates that also include un-dredged zones that have been surveyed by UWTV. 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 estimate from the 2021 UWTV survey has been included for earlier years. These harvest rates are applicable only when connectivity between dredged and un-dredged populations is complete.

Table 4.7: International landings over 12-month periods following annual dredge surveys in the stated years, and harvest rate estimates for the dredged parts of Area 27.4.b.S.

	International Landings (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	889	5754	15.5	14.5	16.5
2020	2413*	8774	27.5	26.2	28.7

* estimate based on 2020-2021 UK landings, to be revised when 2021 international landings have been reported

Table 4.8: International landings over 12-month periods following annual dredge surveys in the stated years, and harvest rate estimates for Area 27.4.b.S, combining harvestable biomass estimates from the dredge and UWTV surveys.

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UWTV Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
2018	2594	5517	1745	7262	35.7
2019	889	5754	1745	7499	11.9
2020	2413*	8774	1745	10519	22.9

* estimate based on 2020-2021 UK landings, to be revised when 2021 international landings have been reported

4.10. Conclusion

This is the fourth stock assessment undertaken for king scallops in the assessment areas of ICES Division 27.4.b, and the first time that an UWTV survey in selected un-dredged zones could be carried out. Therefore, this assessment includes biomass estimates and provisional harvest rates based on the 2021 dredge and UWTV surveys.

Due to the limited number of available length samples in these assessment areas, a reliable analysis using a length-based cohort model has not yet been possible. Therefore, an MSY harvest rate cannot be established for this assessment area, as a reference point for observed harvest rates.

So far, harvest rates could only be estimated for the 2018 – 2020 period, with a significant decrease observed from 2018 to 2019, and an increase to an intermediate value in 2020. However, harvest rate estimates for 2020 are provisional, as international landings for the 12 months following the 2020 dredge survey have not yet been reported. Projecting international landings two years in advance, i.e., from 2019 to 2021, was deemed too unreliable. Therefore, the 2021 realised harvest rate has not been calculated for this assessment.

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 gear-efficiency, and even relatively small changes to this value would have a significant impact upon the estimated harvestable biomass and realised 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 Division 27.4.b only covers the fished part of the stock and selected un-dredged zones. Additional stock is known to exist outside the surveyed areas, 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 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, 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 fifth 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.
- Continue to improve understanding of the recruitment linkage between dredged scallop beds and un-dredged areas.

Section 5 of the annexe describes the progress made 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 writing this report (January 2022), international landings were only available until the end of 2020. Therefore, the harvest rates for 2020 had to be estimated either from the previous year or from UK landings, if these exceed the international landings during the previous year. Harvest rates will be retrospectively updated in future reports as data become available. Projecting international landings two years in advance, i.e., from 2019 to 2021, was deemed too unreliable. Therefore, the 2021 realised harvest rate has not been calculated for this assessment.
- 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 data for this parameter are 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, but not all un-dredged grounds were surveyed with UWTV.
- Studies of larval drift between beds indicate incomplete connectivity, whereby 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.

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