Centre for Environment Fisheries & Aquaculture Science

Cefas

Assessment of king scallop stock status for selected waters around the English coast 2023

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 2023. King scallops (*Pecten maximus*) around the English coast are one of the most commercially valuable marine species, and the most valuable of the wild-caught mollusc species (MMO, 2022). The stocks in the English Channel and approaches to the Bristol Channel are exploited primarily by the UK and France using towed dredges while those in the Central North Sea are almost exclusively UK fisheries. These fisheries are not managed 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. However, with the introduction of a dredge ban inside the Dogger Bank MPA, the area was dropped from the survey in 2022.

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 scallop growth rates 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 video system (UVS) surveys from the 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 UVS 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 which has not been surveyed in this

way. The biological sampling programme provides information about the size and age structure of commercial landings.

These assessments establish estimates of harvestable biomass (i.e., the combined biomass of all scallops at or 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 establish the impact of the fishery on the wider stock, as we are unable to estimate the scallop biomass in all un-dredged areas. Dredge surveys and catch sampling only cover the portions of stock found on the main fished grounds, as identified by the areal density of Vessel Monitoring System (VMS) pings. Harvest rate (i.e. the reported annual landings from each assessed area as a percentage of the harvestable biomass, assuming no dead discards) estimates from dredge surveys therefore only apply to the commercially fished portion of the stock. So far, UVS surveys have not encountered any patch of scallops at a density that would be comparable to the density within the main fishing grounds. Should that become the case, outside areas from which significant portions of un-dredged stock contribute offspring to the fished areas, any estimates of maximum sustainable yield (MSY) harvest rates will be adjusted accordingly.

The harvest rates experienced by the surveyed portion of stocks were estimated by comparing total international landings to the harvestable biomass estimates for the dredged areas. International landings are obtained through the data call of the ICES scallop working group (WGScallop). In 2023, this data call included all landings that were recorded until the end of 2022. However, at the time of finalising this report (March 2024), the results for 2022 had not been published. We are therefore using international landings that were taken from the assessment areas during 12-month periods following the dredge surveys in 2017 – 2020. For the 12-month periods following the dredge surveys in 2021 and 2022, we extracted all UK landings from the MMO database iFish and used them as a temporary estimate. The reported harvest rates for 2021 and 2022 are therefore provisional. For the 12-month periods following the dredge surveys in 2023, even UK landings will only become available in May 2024 for the western English Channel and the Bristol Channel, and in September 2024 for the eastern English Channel and the North Sea.

Following the survey strategy agreed with the Project Steering Board at the start of the king scallop assessment project, at the end of the first 5-year period, 2017 – 2021, we updated the survey design based on the most recent 10 years of VMS data. This update only affects the surveyed regions within the established assessment areas, rather than the assessment areas themselves. Updating the survey design every 5 years is seen as a good compromise between year-to-year consistency and flexibility to allow the dredge surveys to adjust to shifting commercial exploitation patterns. For comparability with the new survey design, the 2017 – 2021 survey data were reanalysed by associating the

previous survey locations with the new dredge bed outlines, and by interpolating scallop abundances at individual stations throughout the revised beds.

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 at the northern edge of 27.7.d.S that is not covered by the IFREMER assessment. These results were presented in the annexes of the report published in 2020, covering the 2018-19 survey season. With the new survey design, starting in 2022, we will routinely survey another small bed at the northern edge of 27.7.d.S. This bed is too small to be representative of the entire 27.7.d.S assessment area. We therefore analyse it as an extension of the larger bed in 27.7.d.N. For Area 27.4.b.D, there has also only been one dredge survey so far, in 2021, the results of which were presented in the main part of the report published in 2022.

The evolution of the harvest rates on the dredged portions of the six regularly assessed areas is listed in Table 1 and shown in Figures 2 and 3. The Lyme Bay area (27.7.e.L) continues to experience the highest exploitation levels, consistently above the MSY target since 2017, and increasing since 2019. In the eastern English Channel (27.7.d.N) the exploitation rate has generally been at or below the MSY target. The only exception is 2018, when an unusually low harvestable biomass estimate combined with unusually high international landings. Exploitation rates in the inshore (27.7.e.I) and offshore (27.7.e.O) areas of the western English Channel have consistently been below the respective MSY target since 2017. In Area 27.4.b.S, the exploitation rate has generally been close to or below the MSY target. The exception is 2018, when international landings were unusually high, combined with a low harvestable biomass. In Area 27.7.f.I, due to the combination of unusually low harvestable biomass and high international landings, the harvest rate in 2019 was a few percent above the MSY target. During the other years, harvest rates were below the reference point.

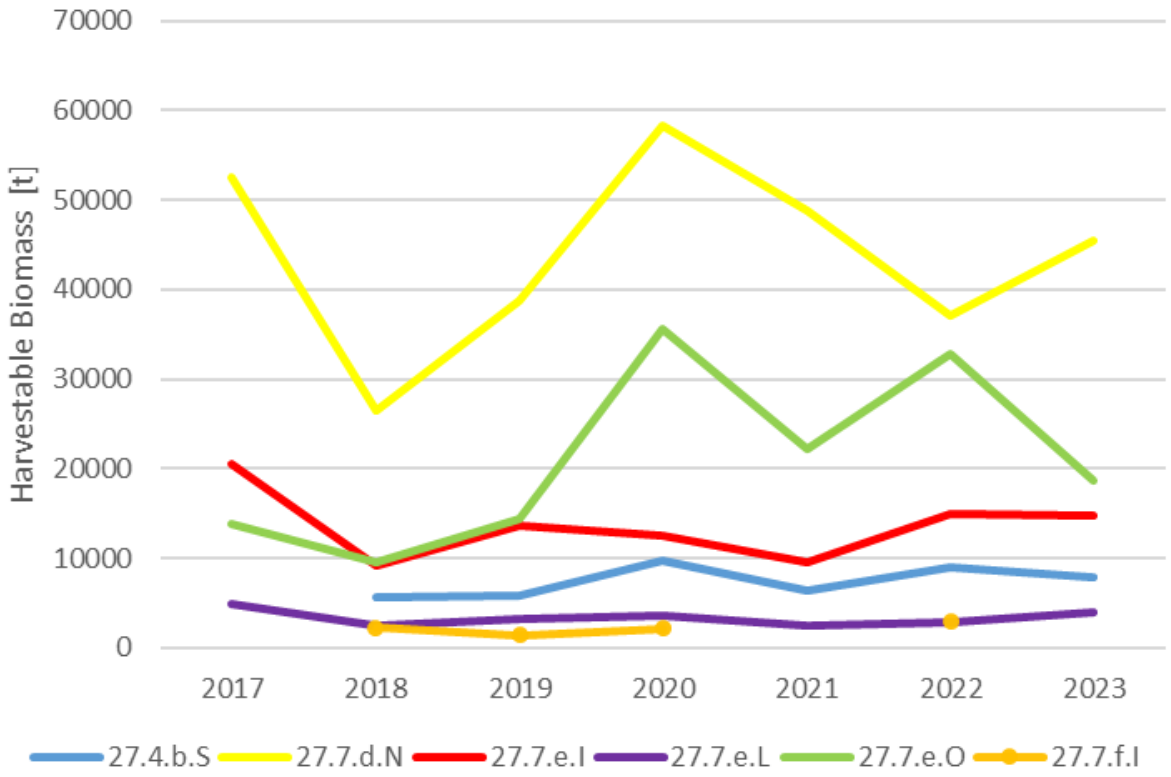

Figure 1: Harvestable biomass in the dredged parts of the king scallop assessment areas: Eastern English Channel (EEC, 27.7.d.N), Western English Channel (WEC) Inshore (27.7.e.I), Lyme Bay (27.7.e.L), Offshore (27.7.e.O), North of Cornwall (27.7.f.I), and Yorkshire\Durham (27.4.b.S).

Table 1: Estimates of harvest rate from dredge surveys, together with MSY target reference points. 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, %)					MSY Target (%)
	2018	2019	2020	2021*	2022 *	
27.4.b.S	46.9	15.3	25.2	23.7	13.9	23.0
27.7.d.N	53.1	21.7	20.2	17.6	16.3	23.4
27.7.e.I	16.3	13.3	10.5	18.1	10.6	24.2

Assessment Area	Harvest Rate on Dredged Portion of Stock (Dredge Survey Only, %)					MSY Target (%)
	2018	2019	2020	2021*	2022 *	
27.7.e.L	92.1	39.5	55.2	70.4	71.9	24.4
27.7.e.O	15.2	12.9	7.6	18.5	15.5	26.5
27.7.f.I	6.1	27.9	8.7	-	1.0	23.4

* estimated from UK landings (to be revised)

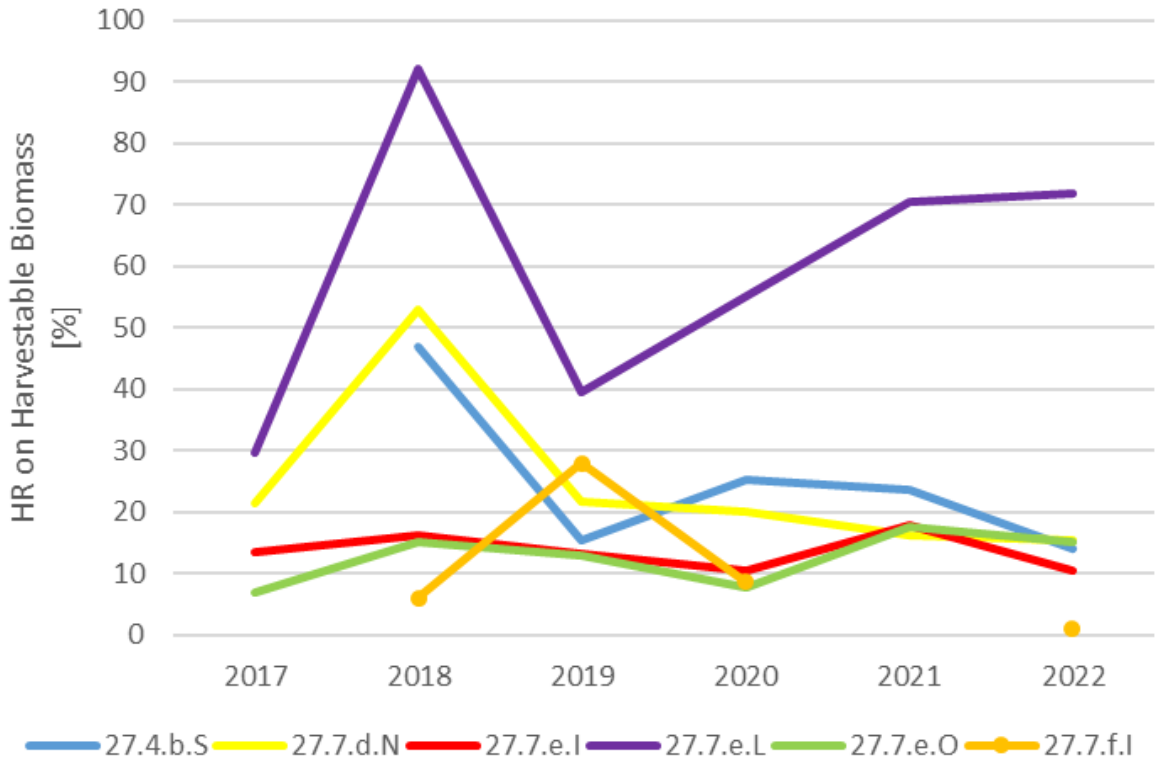

Figure 2: Realised harvest rate on the dredged portion of the king scallop assessment areas: Eastern English Channel (EEC, 27.7.d.N), Western English Channel (WEC) Inshore (27.7.e.I), Lyme Bay (27.7.e.L), Offshore (27.7.e.O), North of Cornwall (27.7.f.I), and Yorkshire\Durham (27.4.b.S). Years refer to 12-month periods starting from the dredge survey during that year. Values in 2021 and 2022 are provisional, based on UK landings.

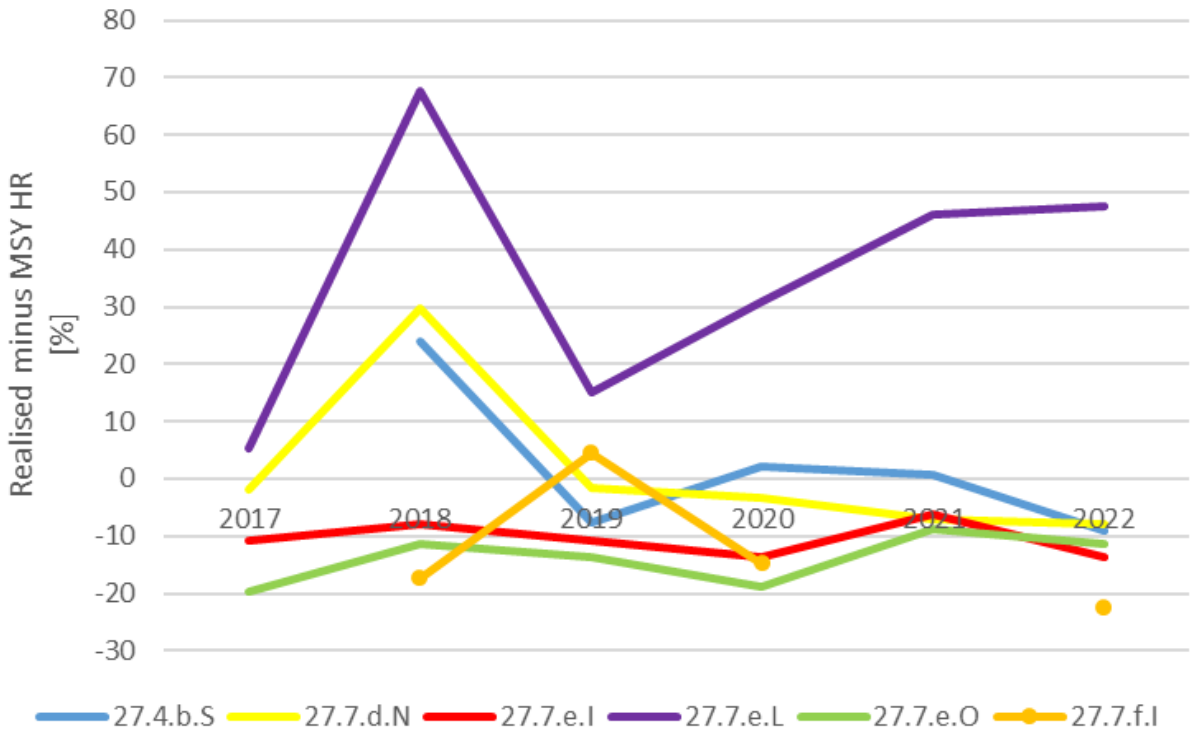

Figure 3: Realised minus maximum sustainable yield (MSY) harvest rate on the dredged portion of the king scallop assessment areas: Eastern English Channel (EEC, 27.7.d.N), Western English Channel (WEC) Inshore (27.7.e.I), Lyme Bay (27.7.e.L), Offshore (27.7.e.O), North of Cornwall (27.7.f.I), and Yorkshire\Durham (27.4.b.S). Years refer to 12-month periods starting from the dredge survey during that year. Values in 2021 and 2022 are provisional, based on UK landings.

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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 changes in water temperature. 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 traditional ring counting methods, which have been validated using oxygen isotope assays (Dare & Deith, 1989). Due to financial and time constraints, an isotope analysis for age determination is not possible on a routine basis.

On the basis of the distribution of height-at-age values, we are able to estimate growth parameters by fitting the von Bertalanffy model to the observational data,

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

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.

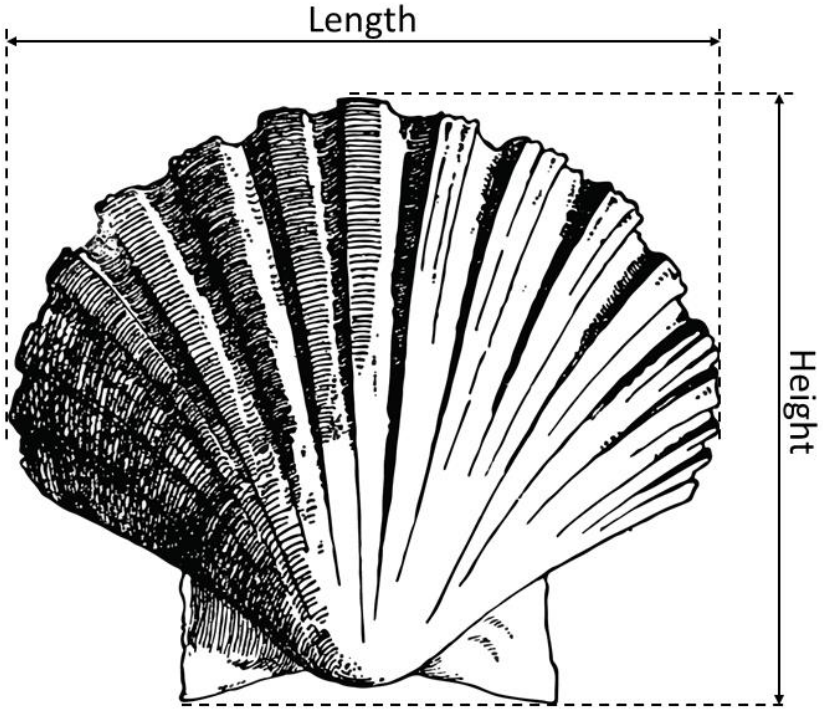

Figure 1.1: Scallop shell length and height illustrated based on the round (lower) valve.

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

King scallops (*Pecten maximus*) around the English coast are one of the most commercially valuable marine species, and the most valuable of the wild-caught mollusc species in UK waters (MMO, 2022).

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 did not form part of the EU Total Allowable Catch (TAC) and quota regime. Therefore, scallops were never regarded as shared stocks, and fishery management measures have remained 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 corresponding UK legislation.

Other EU legislation, also retained in corresponding UK legislation, caps the effort that large vessels can utilise in UK waters of ICES Subarea 27.7. This Western Waters effort regime places an upper limit on the number of kilowatt days fished by vessels with lengths in excess of 15 m and 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. In the past, 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 were 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 existed from 2013 to 2020 between the majority of the UK scalloping industry and the French industry. From 2021, mandatory seasonal closures in UK waters of Division 27.7.d have been in place, with changing closure periods from one year to the next. In 2023, the closure period ran from 1 July to 30 September, with a matching closure period in the Lyme Bay area of Division 27.7.e, to prevent effort displacement from the east. During that year, the EU introduced a seasonal closure for EU and UK scallop dredgers in EU (French) waters of Division 27.7.d and some parts of 27.7.e (North Finistère), during the period from 15 May to 30 September 2023 (with an extension until 15 October in the Baie de Seine area of 27.7.d). A consultation is ongoing for the UK closure period in 2024.

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. On 14 December 2023, a newly developed Fisheries Management Plan (FMP) for king scallops in English and Welsh waters was published by the UK Government (https://www.gov.uk/government/publications/king-scallop-fisheries-management-plan-fmp). I lays the foundation for improved data acquisition on the state of king scallop stocks to allow a transition of fisheries management away from a precautionary approach to a robust estimation of maximum sustainable yield.

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 and has been retained in corresponding UK legislation.

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, Mason, & Kinnear, 1977; Dare, Key, Darby, & Connor, 1993; Dare, Palmer, Howell, & Darby, 1994; Jenkins, Beukers-Stewart, & Brand, 2001). However, for these stock assessments, we are currently using unpublished results from a depletion study carried out by Cefas in the English Channel in 2001.

Recent work at Cefas to determine a methodology for estimating dredge efficiency using Radio Frequency Identification (RFID) and Underwater Video Systems (UVS) has made some progress but has not yet provided alternative efficiency coefficients to those used in previous years. Research efforts are expected to continue with a focus on UVS, rather than RFID. For RFID, the system has proven to be too fragile for deployment from a commercial scallop dredger.

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 at least 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.

The age determination of scallop shells is time-consuming and needs to be carried out by sufficiently experienced readers. It is temporarily on hold due to staff limitations. Size sampling, including the measurement of individual annual growth increments, continues but at a reduced rate. At the time of finalising this report, we were still processing samples from 2023. We have therefore not been able to present results from the sampling programme for 2023. Collected samples are stored for measuring and age reading when the necessary staff become available.

1.4. Stock units and assessment areas

Investigations into the transport and distribution of scallop larvae (Catherall, Hold, Murray, & Bell, 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 (27.4.b.D) was established in response to the increase in fishing activity in that area during the previous year. However, with the introduction of a dredge ban inside the Dogger Bank MPA, the area was dropped

from the routine survey in 2022. The results from 2021 are shown in Section 4 of the annexe but are not further discussed in the main part of this report. Future surveys of this area may resume on a less frequent cycle.

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.

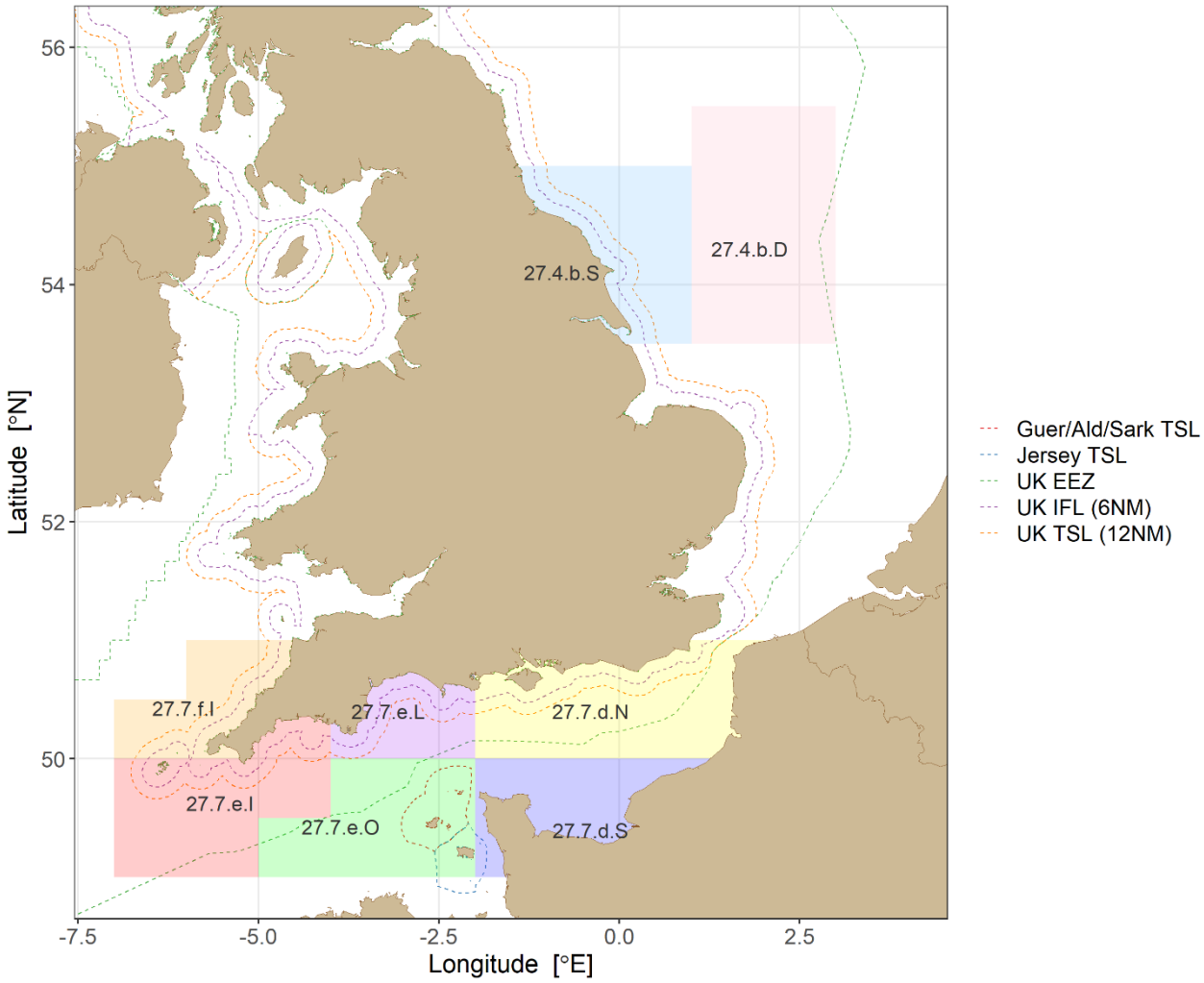

Figure 1.2: King scallop stock unit assessment areas defined in the English Channel, the Celtic and North Sea. The dashed lines indicate the Territorial Sea Limits (TSLs) of the UK

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.

27.4.b.D	36F1	36F2	37F1	37F2	38F1	38F2	39F1	39F2
27.4.b.S	36E9	36F0	37E9	37F0	38E8	38E9	38F0	
27.7.d.N	29E8	29E9	29F0	29F1	30E8	30E9	30F0	30F1
27.7.d.S	27E8	27E9	27F0	28E8	28E9	28F0	28F1	
27.7.e.I	27E3	27E4	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				

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

1.5. Dredge surveys

1.5.1. Design

Following the survey strategy agreed with the Project Steering Board at the start of the king scallop assessment project, at the end of the first 5-year period, 2017 – 2021, we updated the survey design based on the most recent 10 years of Vessel Monitoring System (VMS) data. This update only affects the surveyed regions within the established assessment areas (Figure 1.2), rather than the assessment areas themselves (for a detailed description of the new survey design, see Section 2 of the annexe). Updating the survey design every 5 years is seen as a good compromise between year-to-year consistency and flexibility, to allow the dredge surveys to adjust to shifting commercial exploitation patterns.

We have taken the opportunity to also make changes to the way we analyse survey data. In the past, we have used a fixed track length for all stations without GPS and DST track data. Instead, we are now using the median track length for each individual bed in a given survey year. This is necessitated by the fact that actual track lengths are considerably

shorter than the track length calculated based on tow duration and speed, due to the time it takes for the fishing gear to reach the seabed (see Section 3.3 of the annexe for details).

For comparability with the new survey design, we have reanalysed the 2017 – 2021 survey data by associating the previous survey locations with the new dredge bed outlines, and by interpolating scallop abundances at individual stations throughout the revised beds.

1.5.2. Data

The stock unit assessment areas described above are surveyed by dredging and underwater video system. 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 2.2). As described in more detail in the first assessment report (Bell, Lawler, Masefield, & McIntyre, 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.

1.5.3. 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 has been a 21-m scallop dredger. A larger vessel was used for the 2017 survey (Bell, Lawler, Masefield, & McIntyre, 2018). During the survey, ten “Newhaven” type dredges were deployed on each side (Figure 1.3). On the sampling (starboard) side, six standard king scallop dredges and four queen scallop dredges with smaller ring diameters were deployed, with ten standard dredges on the non-sampling side for compensation. A conveyor system took catch down from the main to the factory deck for sorting, and a wooden marker was used to keep the catch from the two different gear types separate on the conveyor belt. The two beams were deployed synchronously for 15 minutes at a speed of approximately 2.5 – 3.0 knots. Where the commercial dredges were observed to have filled (with 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 gears (Newhaven type dredges) were 75 cm wide and fitted with 85-mm ring bellies and 8-teeth swords (tooth bars). The queen scallop 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.

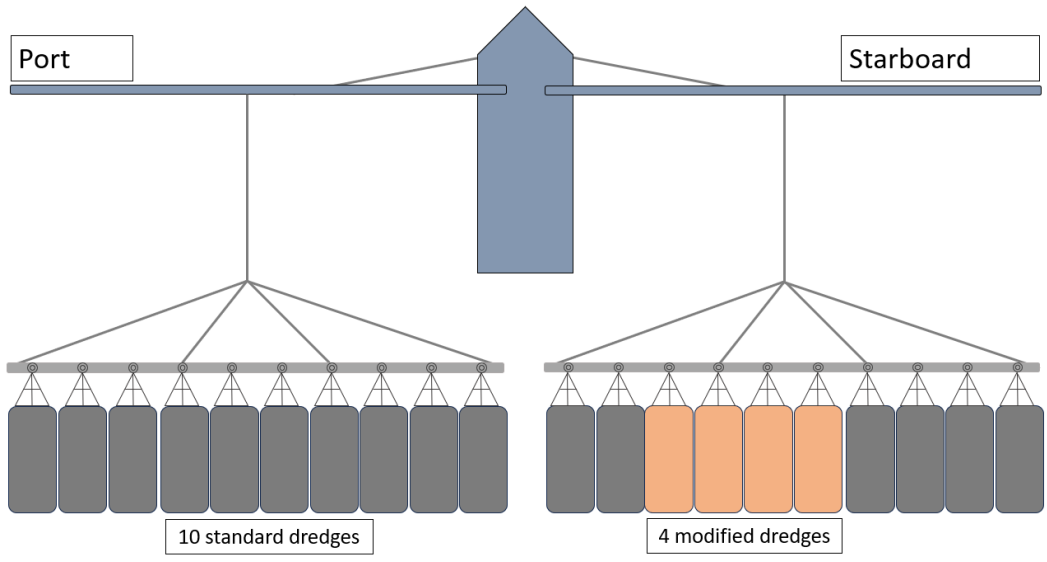

Figure 1.3: Gear configuration on the survey vessel.

2. Stock assessment for surveyed parts of Areas 27.7.d.N and 27.7.d.S

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, and extending into Area 27.7.d.S (Figure 2.1). The perimeter of the bed was defined using Vessel Monitoring System (VMS) data (see Section 2 of the annexe). Using this approach 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 Division 27.7.d, VMS-recorded activity captures the vast majority of landings.

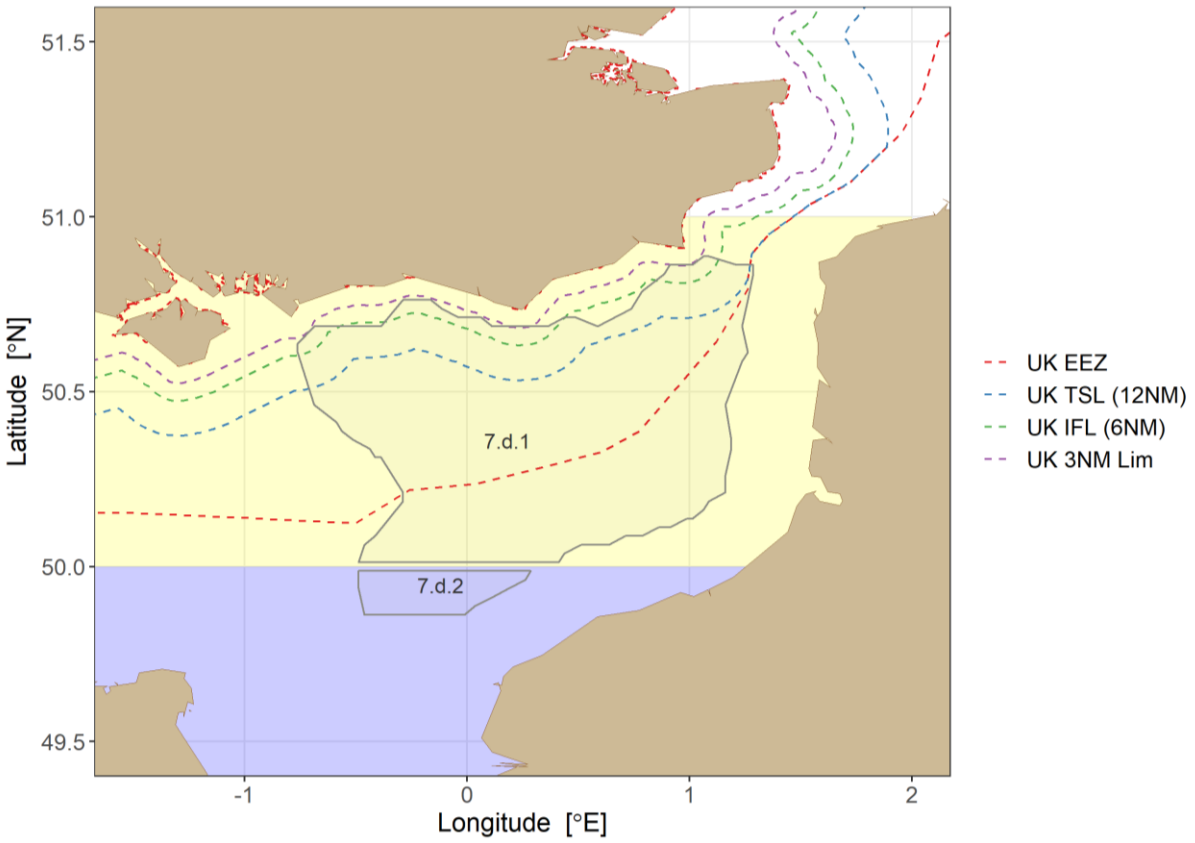

Figure 2.1: Dredge-survey Bed 7.d.1 of Area 27.7.d.N (yellow), and Bed 7.d.2 of Area 27.7.d.S (blue).

2.2. Commercial landings and sampling data

UK quarterly landings from Area 27.7.d.N are listed in Table 2.1. This includes all landings by UK vessels, as well as all landings by international vessels into the UK. At the time of finalising this report (March 2024), landings data to the end of Q3 of 2023 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. From 2015 to 2019, landings steadily increased, followed by relatively low landings in 2020, during the first year of the COVID-19 pandemic. In 2021, landings increased again, reaching the highest value since 2010, despite a two-month (August and September) regional closure in the UK EEZ, in addition to the 15 May to 30 September closure in the French EEZ. Since 2021, UK landings have decreased. The UK share of international landings has fluctuated greatly over the past two decades. Since 2019, it has been consistently above 50%.

Table 2.1: UK quarterly landings (tonnes) from Area 27.7.d.N. UK landings share is calculated relative to total international landings as reported to ICES.

	Q1	Q2	Q3	Q4	Annual	Landings Share
2001	653	96	24	201	974	22%
2002	380	220	63	647	1310	20%
2003	1228	111	6	487	1832	26%
2004	889	107	6	383	1385	21%
2005	553	133	18	529	1234	21%
2006	749	305	30	475	1559	24%
2007	653	152	51	1559	2414	27%
2008	686	479	51	606	1823	22%
2009	533	174	962	4242	5911	46%
2010	2947	514	3591	2458	9509	56%
2011	1922	1509	3256	1397	8083	53%
2012	1872	131	368	690	3061	34%

	Q1	Q2	Q3	Q4	Annual	Landings Share
2013	831	620	40	1688	3179	27%
2014	1463	850	310	1541	4163	45%
2015	644	306	59	584	1594	32%
2016	168	78	21	1629	1897	29%
2017	426	174	410	2419	3429	43%
2018	1338	1389	1591	1849	6168	43%
2019	1814	1790	168	2587	6359	56%
2020	974	273	918	2507	4673	66%
2021	2758	2087	404	3570	8819	58%
2022	2839	1958	205	2363	7365	
2023	2224	1429	0	2727*	6380*	

* provisional

Length distributions from the industry sampling programme, raised to the UK commercial landings of king scallop dredgers, are show in Figure 2.2. Length samples for individual vessels were raised to monthly vessel landings, before aggregation to total annual UK landings.

Unlike in the other assessment areas, there is a strong interannual consistency in the relative frequency-at-length distribution in Area 27.7.d.N, with the highest number of landed animals at lengths between 115 and 120 mm.

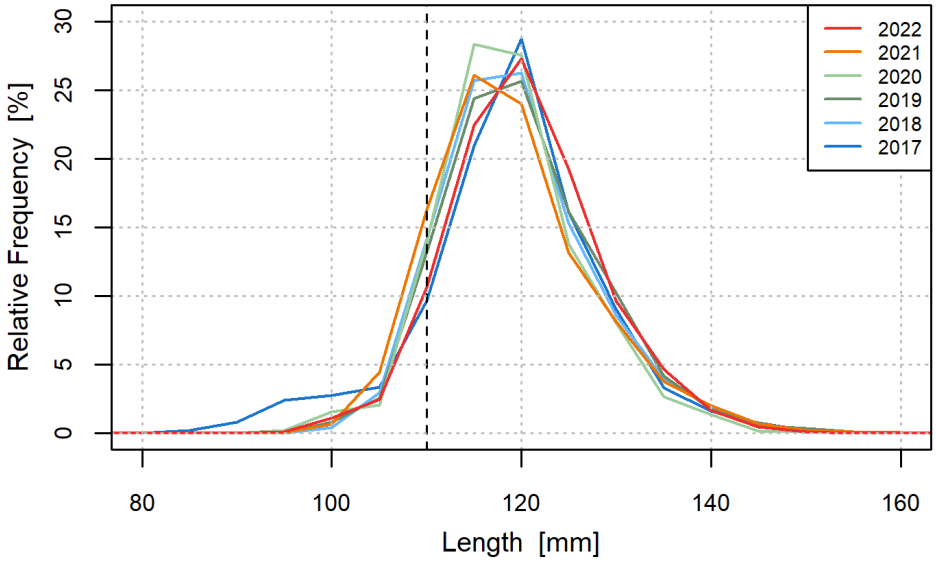

Figure 2.2: Annual relative frequency-at-length distributions (round shell length in 5-mm size bins) in commercial landings of UK king scallop dredgers from Area 27.7.d.N. The vertical dashed line indicates MLS.

2.3. Biological parameters and dredge efficiency

A review of historic growth estimates, based on an unpublished study by Cefas in the English Channel in 2001, 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 2.2: 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 (based on an unpublished depletion study in 2001)
Gear efficiency – ground type flint cobbles	43%	Cefas (based on an unpublished depletion study in 2001)
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

Parameter	Value	Source
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_∞ = 119.3 k = 0.516 t_0 = 0.692	Cefas (based on an unpublished fine-mesh dredge study in 2001); see Section 1.1.3 for functional relationship

2.4. Dredge and underwater video system surveys

2.4.1. Dredge survey methodology

The updated 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 1.5.

The surveys in 2017, 2020, and 2021 were restricted to the UK Exclusive Economic Zone (EEZ), whereas the surveys in 2018, 2019, 2022 and 2023 also included tows in the French EEZ. Most of the survey effort is focussed on Bed 7.d.1 (Figure 2.1). In 2018, four additional tows were carried out in a small bed in the 27.7.d.S assessment area to the south of Bed 7.d.1. With the new survey design, starting in 2022, we will routinely survey another small bed, 7.d.2, at the northern edge of 27.7.d.S. This bed is too small to be representative of the entire 27.7.d.S assessment area. We therefore analyse it as an extension of the larger bed in 27.7.d.N. However, the abundance in 7.d.2 is not added to the area abundance in 27.7.d.N.

During 5 – 10 September 2023, 74 randomly selected stations were surveyed in Bed 7.d.1, resulting in the sampled blocks shown in Figure 2.3. In total, 7662 shells from the standard gear were measured, with a median round length of 110 mm, equal to the MLS in this area. Of these shells, 49.5% were below MLS and would have to be discarded during commercial fishing.

During 6 – 7 September 2023, 4 tows were surveyed in Bed 7.d.2, resulting in 86 length measurements from the standard gear, with a median round length of 126 mm (above the MLS of 110 mm). Of these shells, 11.6% were below MLS.

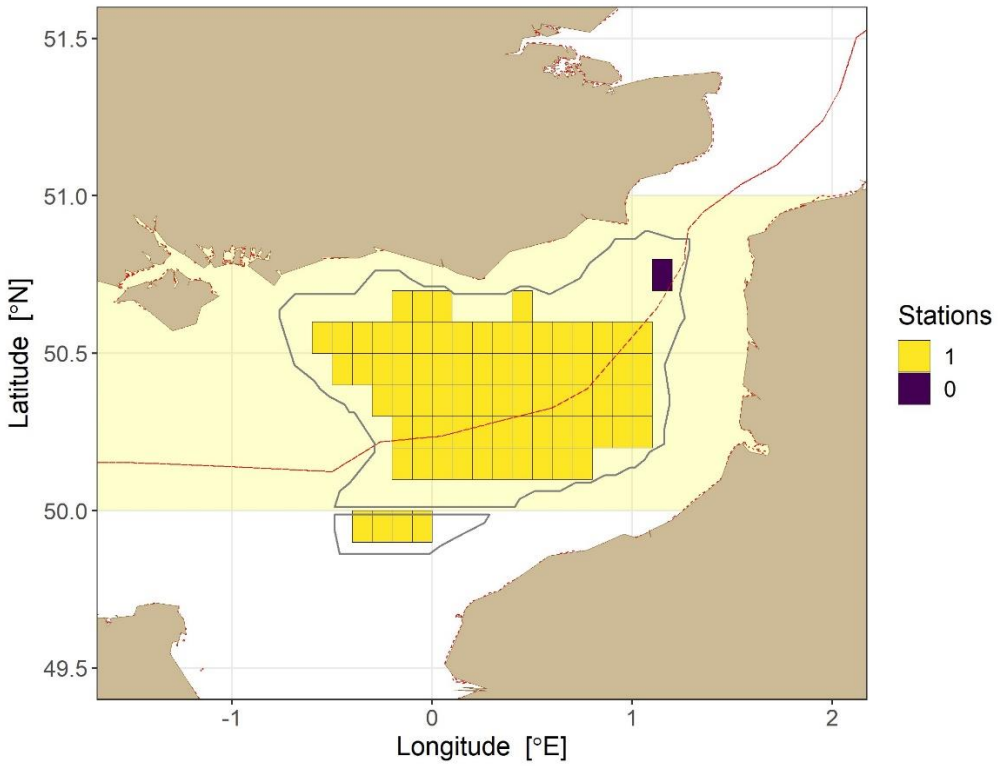

Figure 2.3: Number of stations visited during the 2023 dredge survey within each sampled block of Beds 7.d.1 and 7.d.2. The red line indicates the boundary of the UK EEZ.

2.4.2. Underwater video system survey methodology

For the first time in 2019, an underwater video system (UVS) survey was carried out to determine the spatial distribution and abundance of scallops in the northern parts of Area 27.7.d.N that are inaccessible to the commercial fishing fleet, either due to conservation measures, or due to the presence of ground types that are unsuitable for the deployment of dredges. In 2022, a further UVS survey was carried out to the southwest of the dredged area. The spatial coverage and methods of UVS surveys are described in Section 4 of the annexe.

2.5. Raised biomass estimates and uncertainty

From the size samples taken at each station, total (pooled) length frequency distributions within Beds 7.d.1 and 7.d.2 were derived. From this, the total population number and biomass, as well as the biomass of harvestable scallops (round shell lengths ≥ 110 mm MLS), could be estimated. The harvestable biomass within 0.1-by-0.1 degree grid cells in 2023 is shown in Figure 2.4.

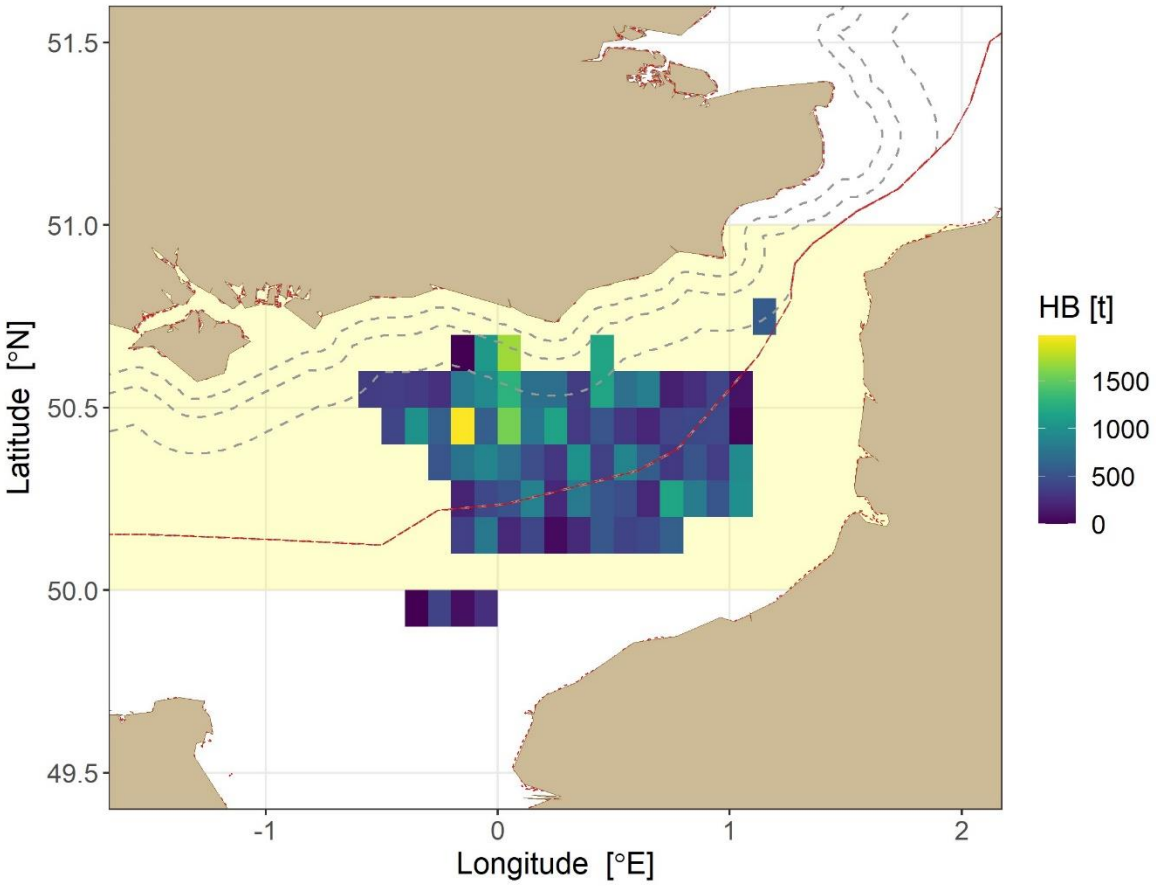

Figure 2.4: Harvestable biomass (tonnes) of scallops of at least MLS (110 mm round shell length) in Beds 7.d.1 and 7.d.2 during 2023. The red line indicates the boundary of the UK EEZ. The three black dashed lines indicate the outer limits of the 3-, 6-, and 12-nm zones.

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 in Bed 7.d.1 during 2023 is shown in Figure 2.5. The number of stations in Bed 7.d.2 is insufficient for bootstrapping. The survey estimate for harvestable biomass in that bed in 2023 was 727 tonnes.

The survey estimate for Bed 7.d.1, along with the median and quartile range from bootstrapping, are given in Table 2.3. As the survey estimate utilises all available data, it is considered the most accurate value.

The harvestable biomass in Bed 7.d.1 has fluctuated by more than a factor of two since 2017, with high values in 2017 and 2020, and the lowest value in 2018.

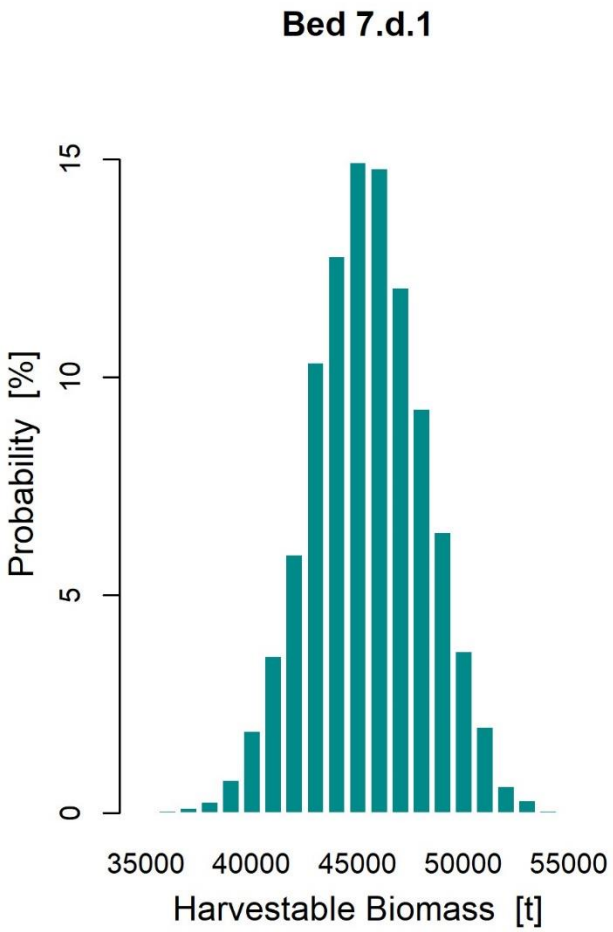

Figure 2.5: Distribution of harvestable biomass in Bed 7.d.1 (Area 27.7.d.N) during 2023 from random resampling ("bootstrapping").

Table 2.3: 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	51173	54139	52580	57330
2018	24690	26427	26455	28051
2019	37245	39146	38794	41030
2020	53764	57450	58378	60871
2021	45984	48919	48908	51946
2022	35368	37007	37025	38671
2023	43567	45341	45411	47199

2.6. Size composition from dredge survey

The relative abundance of scallops above and below MLS (110 mm) in Area 27.7.d.N since 2017 is shown in Table 2.4 and Figure 2.6.

At 120 mm and above, the size distribution changes little from one year to the next. The most significant changes are at the smaller sizes. This can either be due to a genuine temporal change in the population size distribution, indicative of a particularly strong cohort of pre-recruits, or due to the random station selection, in connection with the patchy distribution on scallops, as some tows fall onto ground with an unusually high proportion of juveniles.

In 2018, there was evidence of a high proportion of smaller scallops with round lengths between 85 – 90 mm. In 2022, there was again an indication of a group of below-MLS animals with round lengths within the 85 – 95 mm size range, which is a significant change from 2021, when the relative abundance of pre-recruits in survey catches was unusually low. From 2022 to 2023, the abundance of undersized animals increased further.

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 further restricted by legal limitations and are therefore biased towards sizes above MLS.

Table 2.4: Proportion in percent by number of scallops below MLS (110 mm) in the standard commercial dredges from dredge surveys.

	27.7.d.N
2017	36.6
2018	44.3
2019	37.7
2020	46.7
2021	40.7
2022	46.9
2023	49.5

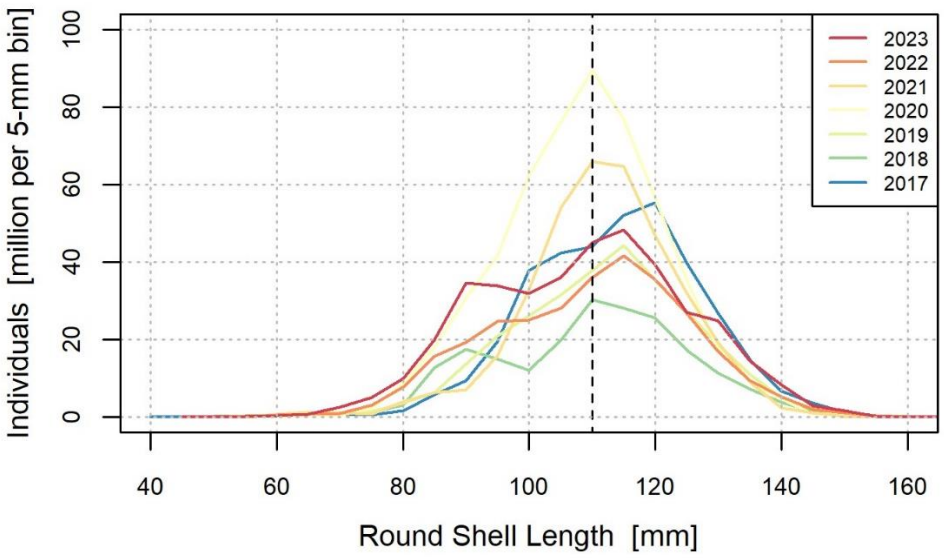

Figure 2.6: Annual population length distributions in 5-mm size bins from annual dredge surveys in Area 27.7.d.N. The vertical dashed line indicates MLS.

2.7. Relative abundance from UVS survey

A UVS 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 250 m. 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. The highest density observed in Area 27.7.d.N was 0.30 scallops per 100 m^2 in zone TV.7.e.E (of which only a small part is in Area 27.7.d.N). The 29 tonnes of harvestable biomass estimated for that part of TV.7.e.E that is within area 27.7.d.N are included in the estimation of harvest rates in Section 2.9.

In 2022, a further UVS survey was carried out in TV.7.d.C, to the southwest of the dredged area. At 3.20 scallops per 100 m^2, the density there was about ten times higher than in the previously surveyed un-dredged part of Area 27.7.d.N. The 966 tonnes of harvestable biomass estimated for that part of TV.7.d.C that is within area 27.7.d.N are also included in the estimation of harvest rates.

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%VSpR) is a commonly used reference point within ICES advisory areas (ICES, 2022).

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 stock 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; for more details, see Section 6 of the annexe).

Based on the data that were available at the start of the scallop assessment project, the model estimated that in order to achieve F35%VSpR, a harvest rate (i.e. the ratio of landings to total harvestable biomass, assuming no dead discards) in the vicinity of 21.5% would be required in Area 27.7.d.N. On the basis of the first five years of survey data (2017 – 2021) and the updated survey design, we have updated the MSY reference points in all assessed areas. Using the same model as before, we now estimate that a harvest rate of 23.4% would be an appropriate proxy for an MSY reference point in Area 27.7.d.N.

2.9. Harvest rate estimation

Harvest rate is a measure of the fishing mortality within a given area. Ideally it 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 finalising this report (March 2024), international landings for calendar years 2017 – 2021 were available from the ICES Scallop Assessment Working Group.[1] International landings for the 12-month periods following the two most recent dredge surveys in 2021 and 2022 were not available. Instead, for the 2021 and 2022 surveys, UK landings recorded on a national database were used. International landings and associated harvest rates presented here for these two years will be revised when required data become available.

Harvest rates for the dredged parts of Area 27.7.d.N are listed in Table 2.5. The corresponding estimates of harvestable biomass are based on the results from dredge surveys. The harvestable biomass values are the survey estimates from Table 2.3. 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 2.6 are based on biomass estimates that also include un-dredged zones that have been surveyed by UVS. 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 UVS, for which there is currently no information about the biomass, or its ability to contribute to recruitment to the main areas of the fished stock. Un-dredged areas are assumed to be at carrying capacity with no fishing mortality, and the sum of the biomass estimates from the 2019 and 2022 UVS surveys have also been included for the other

[1] See the latest published report on the ICES WGScallop website: https://www.ices.dk/community/groups/Pages/WGScallop.aspx.

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 2.7.

Table 2.5: 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	52580	21.4	19.6	22.0
2018	14041	26455	53.1	50.1	56.9
2019	8429	38794	21.7	20.5	22.6
2020	11797	58378	20.2	19.4	21.9
2021	8584*	48908	17.6	16.5	18.7
2022	6021*	37025	16.3	15.6	17.0

* estimate based on UK landings, to be revised when 2022 and 2023 international landings have been reported

Table 2.6: 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 UVS surveys.

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UVS Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
2017	11260	52580	995	53575	21.0
2018	14041	26455	995	27450	51.2
2019	8429	38794	995	39789	21.2

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UVS Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
2020	11797	58378	995	59373	19.9
2021	8584*	48908	995	49903	17.2
2022	6021*	37025	995	38020	15.8

* estimate based on UK landings, to be revised when 2022 and 2023 international landings have been reported

Table 2.7: Harvest rate estimates for Area 27.7.d.N, with MSY reference point.

	Harvest Rate on Dredged Portion of Stock (Dredge Survey Only, %)	Harvest Rate on Wider Stock (Incl. UVS Survey, %)	MSY Reference Point Harvest Rate (%)
2017	21.4	21.0	23.4
2018	53.1	51.2	23.4
2019	21.7	21.2	23.4
2020	20.2	19.9	23.4
2021*	17.6	17.2	23.4
2022*	16.3	15.8	23.4

* estimate based on UK landings, to be revised when 2022 and 2023 international landings have been reported

2.10. Conclusion

This assessment includes biomass estimates and provisional harvest rates based on the 2023 dredge survey, together with modest amounts of biomass estimated based on the 2019 and 2022 UVS surveys 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, Lawler, Masefield, & McIntyre, 2018). This length-structured cohort modelling provides context for harvest rate estimates by establishing an assessment-area-specific MSY reference value.

The estimated harvest rate for Area 27.7.d.N in 2018 was more than twice the MSY reference value of 23.4%. This was due to a low harvestable biomass estimate, rather than unusually high international landings. During the other years, the harvest rate in 27.7.d.N has been at or below the MSY target.

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.

A presentation of the assessment approach to the ICES Scallop Assessment Working Group (WGScallop) 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. 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 has been carried out for the North Sea and the English Channel. Two Cefas reports are currently under review.

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. Bed 7.e.3 is within a Marine Protected Area and bed 7.e.6 is positioned in a sensitive area within 6 nm of the coast. These two beds are no longer accessible to larger vessels, including our survey vessel. They are therefore not part of the dredge survey anymore but have been surveyed using UVS 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.

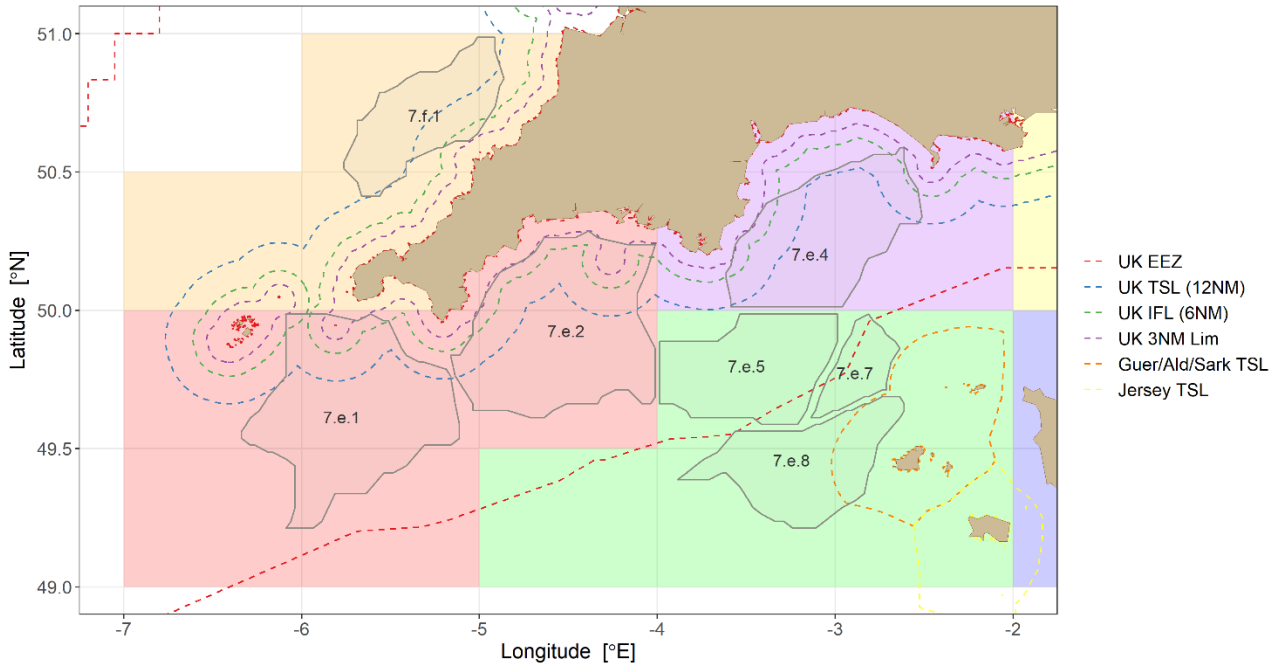

Figure 3.1: Dredge-surveyed parts of ICES Divisions 27.7.e and 27.7.f: Beds 7.e.1 and 7.e.2 within Area 27.7.e.I (red), Bed 7.e.4 within Area 27.7.e.L (purple), Beds 7.e.5, 7.e.7 7.e.8 within Area 27.7.e.O (green), and Bed 7.f.1 with Area 27.7.f.I (orange).

3.2. Commercial landings and sampling data

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. This includes all landings by UK vessels, as well as all landings by international vessels into the UK. At the time of finalising this report (March 2024), landings data to the end of Q3 of 2023 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.

The UK share of international landings in the inshore assessment areas of Division 27.7.e is generally high, above 80% in 27.7.e.I, and above 90% in 27.7.e.L. In the offshore assessment area, 27.7.e.O, the UK landings share has fluctuated between 37% and 78% over the past two decades. In the assessment area north of Cornwall, 27.7.f.I, the UK landings share over the same time period has fluctuated between 22% and 86%.

Table 3.1: UK quarterly landings (tonnes) from Area 27.7.e.I. UK landings share is calculated relative to total international landings as reported to ICES.

	Q1	Q2	Q3	Q4	Annual	Landings Share
2001	222	1063	1071	145	2523	97%
2002	145	613	1182	95	2001	95%
2003	186	812	1169	208	2374	86%
2004	208	1050	1390	132	2780	82%
2005	441	1330	1389	162	3321	87%
2006	385	1280	1486	126	3277	99%
2007	207	550	684	82	1524	90%
2008	85	259	760	161	1265	91%

	Q1	Q2	Q3	Q4	Annual	Landings Share
2009	219	791	1150	110	2271	91%
2010	92	461	401	80	1033	87%
2011	96	737	892	65	1791	95%
2012	241	1299	856	114	2509	97%
2013	194	822	1250	107	2372	99%
2014	81	578	890	119	1667	92%
2015	173	2255	1113	171	3711	96%
2016	321	1414	878	235	2847	96%
2017	219	897	1022	181	2319	99%
2018	262	1007	393	108	1770	96%
2019	189	574	1218	83	2063	99%
2020	124	395	287	116	922	96%
2021	303	688	859	140	1992	98%
2022	147	401	891	85	1524	
2023	200	588	1381	43*	2212*	

* provisional

Table 3.2: UK quarterly landings (tonnes) from Area 27.7.e.L. UK landings share is calculated relative to total international landings as reported to ICES.

	Q1	Q2	Q3	Q4	Annual	Landings Share
2001	515	423	176	361	1475	95%
2002	518	490	284	176	1468	100%
2003	131	330	276	236	973	99%
2004	325	511	385	553	1775	99%
2005	626	721	465	977	2788	97%
2006	860	777	194	455	2286	100%
2007	521	740	268	482	2011	98%

	Q1	Q2	Q3	Q4	Annual	Landings Share
2008	332	450	414	542	1737	99%
2009	544	539	395	343	1821	96%
2010	697	695	302	939	2633	98%
2011	1168	934	839	865	3807	98%
2012	964	591	558	915	3029	100%
2013	871	591	493	452	2408	100%
2014	504	611	416	354	1896	99%
2015	293	336	421	321	1371	99%
2016	385	278	408	493	1564	100%
2017	409	535	340	429	1713	100%
2018	304	399	575	628	1906	99%
2019	519	463	293	418	1693	99%
2020	316	171	459	543	1488	100%
2021	632	457	350	598	2037	100%
2022	417	496	457	472	1842	
2023	549	608	112	859*	2128*	

* provisional

Table 3.3: UK quarterly landings (tonnes) from Area 27.7.e.O. UK landings share is calculated relative to total international landings as reported to ICES.

	Q1	Q2	Q3	Q4	Annual	Landings Share
2001	183	350	35	11	578	37%
2002	116	450	118	37	720	48%
2003	138	572	296	133	1139	56%
2004	205	318	72	105	700	42%

	Q1	Q2	Q3	Q4	Annual	Landings Share
2005	90	179	91	22	381	38%
2006	150	140	147	122	559	49%
2007	417	1108	817	65	2407	61%
2008	94	1022	411	81	1609	54%
2009	428	1299	314	13	2054	68%
2010	418	2251	465	7	3141	78%
2011	350	1116	158	13	1638	71%
2012	939	1488	120	114	2662	77%
2013	449	1351	1165	68	3032	73%
2014	184	427	695	45	1352	49%
2015	133	313	589	20	1055	57%
2016	130	272	480	11	892	50%
2017	45	324	203	57	629	64%
2018	106	415	444	429	1394	74%
2019	51	583	896	15	1544	66%
2020	60	521	1356	20	1957	75%
2021	96	1154	2671	87	4008	75%
2022	97	1037	3541	83	4758	
2023	347	1113	1848	73*	3381*	

* provisional

Table 3.4: UK quarterly landings (tonnes) from Area 27.7.f.l. UK landings share is calculated relative to total international landings as reported to ICES.

	Q1	Q2	Q3	Q4	Annual	Landings Share
2001	10	14	20	2	46	40%
2002	6	6	15	2	29	86%
2003	15	10	31	2	58	39%
2004	78	23	32	6	138	77%
2005	12	33	3	0	49	83%
2006	5	16	80	55	156	47%
2007	6	39	16	2	62	22%
2008	10	116	18	12	156	50%
2009	9	7	150	47	214	84%
2010	15	309	203	36	563	86%
2011	11	137	53	18	218	39%
2012	10	22	173	1	205	55%
2013	85	173	259	12	529	68%
2014	15	59	124	7	204	50%
2015	35	46	59	9	149	32%
2016	19	21	97	4	141	43%
2017	117	103	228	31	478	86%
2018	9	74	47	7	137	60%
2019	42	57	211	13	323	81%
2020	40	73	92	7	211	58%
2021	31	28	35	3	98	28%
2022	26	4	9	5	44	
2023	7	25	11	0*	43*	

* provisional

Length distributions from the industry sampling programme, raised to the UK commercial landings of king scallop dredgers, are show in Figure 3.2. Length samples for individual

vessels were raised to monthly vessel landings, before aggregation to total annual UK landings. Length sampling in all four assessment areas was impacted by the COVID-19 pandemic. In 2020, we were only able to obtain one sample for the Lyme Bay area (27.7.e.L). In the area north of Cornwall (27.7.f.I), we were also not able to obtain any samples in 2021. Although we obtained four samples from that area in 2022, we were not able to link any of them with reported landings and were therefore not able to use them to determine a raised length distribution during that year.

In comparison with Area 27.7.d.N in the eastern English Channel, the size distributions in the western Channel show large qualitative differences between years. In Area 27.7.e.I, the most significant interannual change is a shift towards unusually small landed animals in 2022, compared with the previous year. In Area 27.7.e.L, the raised length distribution for 2020 is only based on one sample and therefore not representative. However, there is a noticeable shift towards larger landed animals in 2022, compared with the previous year. In Area 27.7.e.O, the most noticeable change over time is the reduced number of landed animals with lengths of 120 mm and larger in 2021 and 2022, compared with the 2017 – 2019 period. 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.

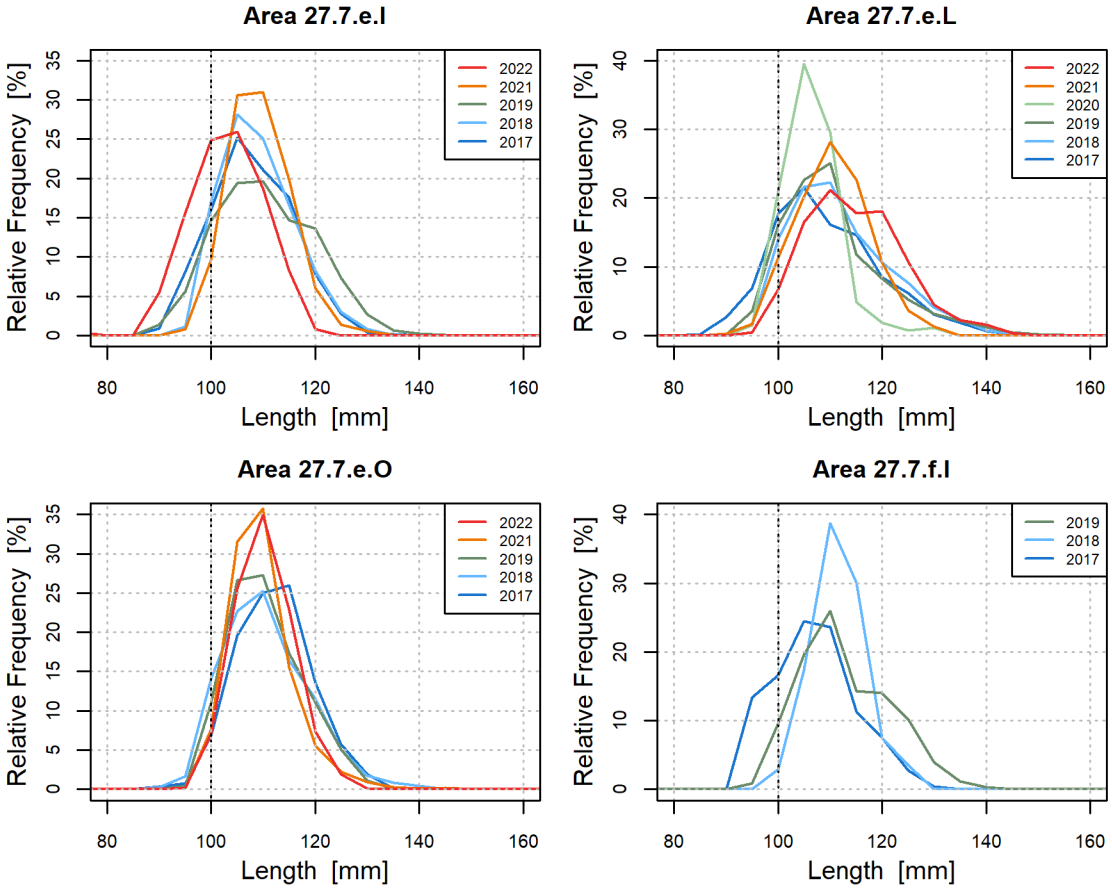

Figure 3.2: Annual relative frequency-at-length distributions (round shell length in 5-mm size bins) in commercial landings of UK king scallop dredgers from assessment areas in ICES Divisions 27.7.e and 27.7.f. The vertical dashed lines indicate MLS.

3.3. Biological parameters and dredge efficiency

A review of historic growth estimates, based on an unpublished study by Cefas in the English Channel in 2001, provided von Bertalanffy growth parameters for the assessment areas in ICES Divisions 27.7.e and 27.7.f. Parameters for weight- length relationships were obtained from an unpublished study by Cefas in 2012, during which 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 3.5: 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 (based on an unpublished depletion study in 2001)
Gear efficiency – ground type flint cobbles	43%	All	Cefas (based on an unpublished depletion study in 2001)
Round length to weight	$a = 1.189 \times 10^{-3}$ $b = 2.488354$	27.7.e.I and 27.7.f.I	Cefas (based on an unpublished study in 2012); see Section 1.1.5 for functional relationship
	$a = 1.326 \times 10^{-3}$ $b = 2.478189$	27.7.e.L	Cefas (based on an unpublished study in 2012)
	$a = 8.08 \times 10^{-5}$ $b = 2.573519$	27.7.e.O	Cefas (based on an unpublished study in 2012)
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 (based on an unpublished fine-mesh dredge study in 2001); see Section 1.1.3 for functional relationship
	$H_\infty = 116.5$ $k = 0.584$ $t_0 = 0.715$	27.7.e.L	Cefas (based on an unpublished fine-mesh dredge study in 2001)
	$H_\infty = 106.3$ $k = 0.518$ $t_0 = 0.921$	27.7.e.O	Cefas (based on an unpublished fine-mesh dredge study in 2001)

3.4. Dredge and underwater video system surveys

3.4.1. Dredge survey methodology

The updated 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 1.5.3.

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, due to sensitivities associated with EU-exit, 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 – with the exception of Beds 7.e.3 and 7.e.6, which have been excluded from the dredge survey, as described above – unrestricted dredge surveying was possible in all beds of Division 27.7.e. However, due to poor weather conditions, the dredge survey in Division 27.7.f could not be carried out. In 2023, we were able to dredge survey all beds in Divisions 27.7.e. However, again due to poor weather conditions, the dredge survey in Division 27.7.f could not be carried out.

During 4 – 12 May 2023, a total of 120 randomly selected stations were surveyed in Division 27.7.e. No stations were surveyed in Area 27.7.f.I. This resulted in the sampled blocks shown in Figure 3.3. Availability by bed of length sampling data from the dredge survey is summarised in Table 3.6.

Table 3.6: Sampling summary of the 2023 dredge survey in the assessment areas of ICES Divisions 27.7.e, based on catches in the standard king scallop gear.

Bed	Number of Stations	Number Measured	Median Round Length [mm]	Percent by number below MLS
7.e.1	30	731	115	9.4
7.e.2	25	758	117	4.4
7.e.4	20	577	104	37.3
7.e.5	19	306	119	3.3
7.e.7	6	335	110	11.6
7.e.8	20	1989	102	40.0

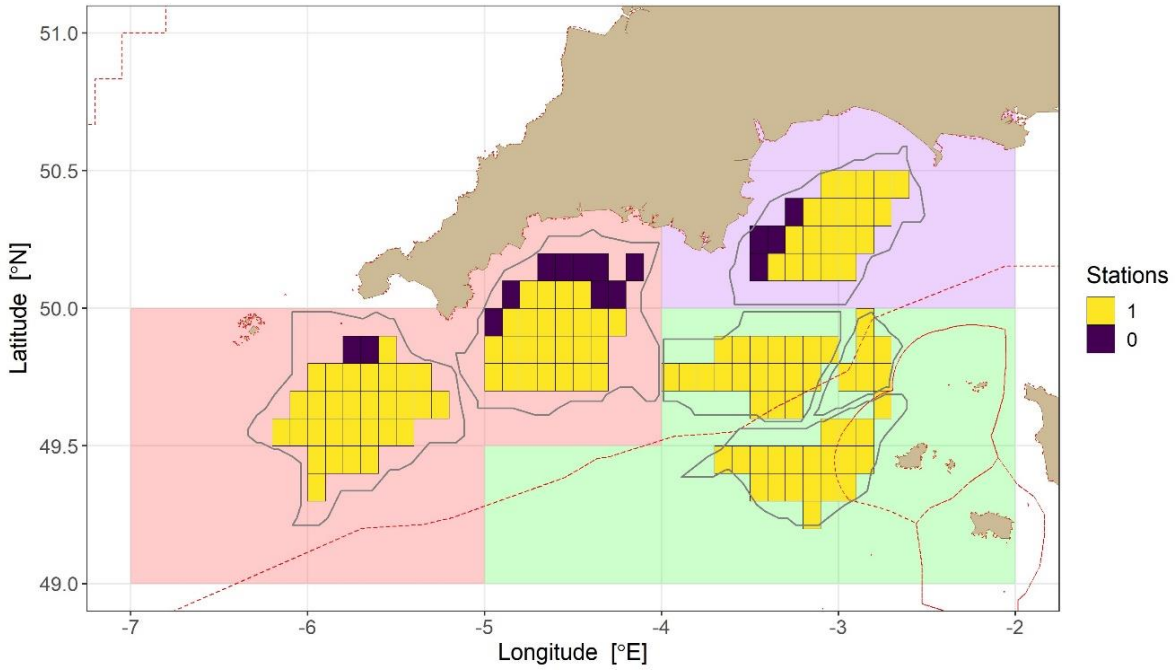

Figure 3.3: Number of stations visited during the 2023 dredge survey within each sampled block of Beds 7.e.1 – 8. The red lines indicate the boundary of the UK EEZ, as well as those of the Channel Islands.

3.4.2. Underwater video system survey methodology

For the first time in 2017, an underwater video system (UVS) survey was carried out to determine the spatial distribution and abundance of scallops in selected parts (TV.7.e.A, C and D) of ICES Division 27.7.e that are inaccessible to the commercial fishing fleet, either due to conservation measures, or due to the presence of ground types that are unsuitable for the deployment of dredges. In June 2019, UVS surveys covered two further un-dredged zones that lie within Division 27.7.e (TV.7.e.B and TV.7.e.E). In 2022, further UVS surveys in Division 27.7.e were planned. In most of the planned areas, surveying had to be abandoned due to bad weather. In Bed TV.7.e.C, 7 stations were surveyed. However, due to the rough sea state, visibility was too poor to analyse the video footage. In 2023 a UVS survey was carried out in TV.7.e.F. However, due to technical issues with cables, the western third of the area could not be surveyed. It is hoped that this part of the survey area will be completed in 2024. The spatial coverage and methods of UVS surveys are described in Section 4 of the annexe.

3.5. Raised biomass estimates and uncertainty

From the size samples taken at each station, total (pooled) length frequency distributions within the beds of Division 27.7.e and 27.7.f were derived. From this, the total population number and biomass, as well as the biomass of harvestable scallops (round shell lengths ≥ 100 mm MLS), could be estimated. The harvestable biomass within 0.1-by-0.1 degree grid cells in 2023 is shown in Figure 3.4.

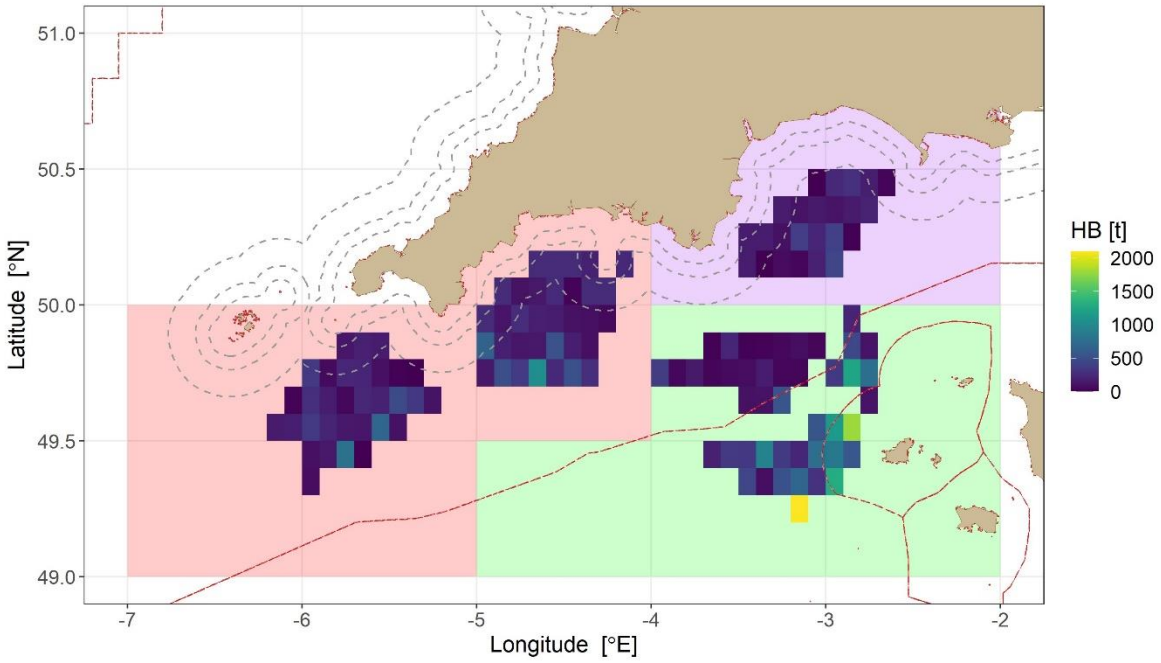

Figure 3.4: Harvestable biomass (tonnes) of scallops of at least MLS (100 mm round shell length) within the dredge surveyed parts of Areas 27.7.e.I (red), 27.7.e.L (purple) and 27.7.e.O (green) during 2023. The red line indicates the boundary of the UK EEZ. The three black dashed lines indicate the outer limits of the 3-, 6-, and 12-nm zones.

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 in Divisions 27.7.e during 2023 is shown in Figure 3.5.

The survey estimates for the assessment areas in Divisions 27.7.e, along with the medians and quartile ranges from bootstrapping, are given in Table 3.7. As the survey estimate utilises all available data, it is considered the most accurate value.

In the two inshore areas 27.7.e.I and 27.7.e.L, harvestable biomass has fluctuated without any overall trends between 2017 and 2023. In the offshore area, 27.7.e.O, where abundance is highest, the harvestable biomass generally increased from 2017 to 2022, with values below 20k tonnes before 2020 to above 20k tonnes since then and until 2022. In 2023, harvestable biomass was below 20k tonnes again, but still above the values from 2017 to 2019.

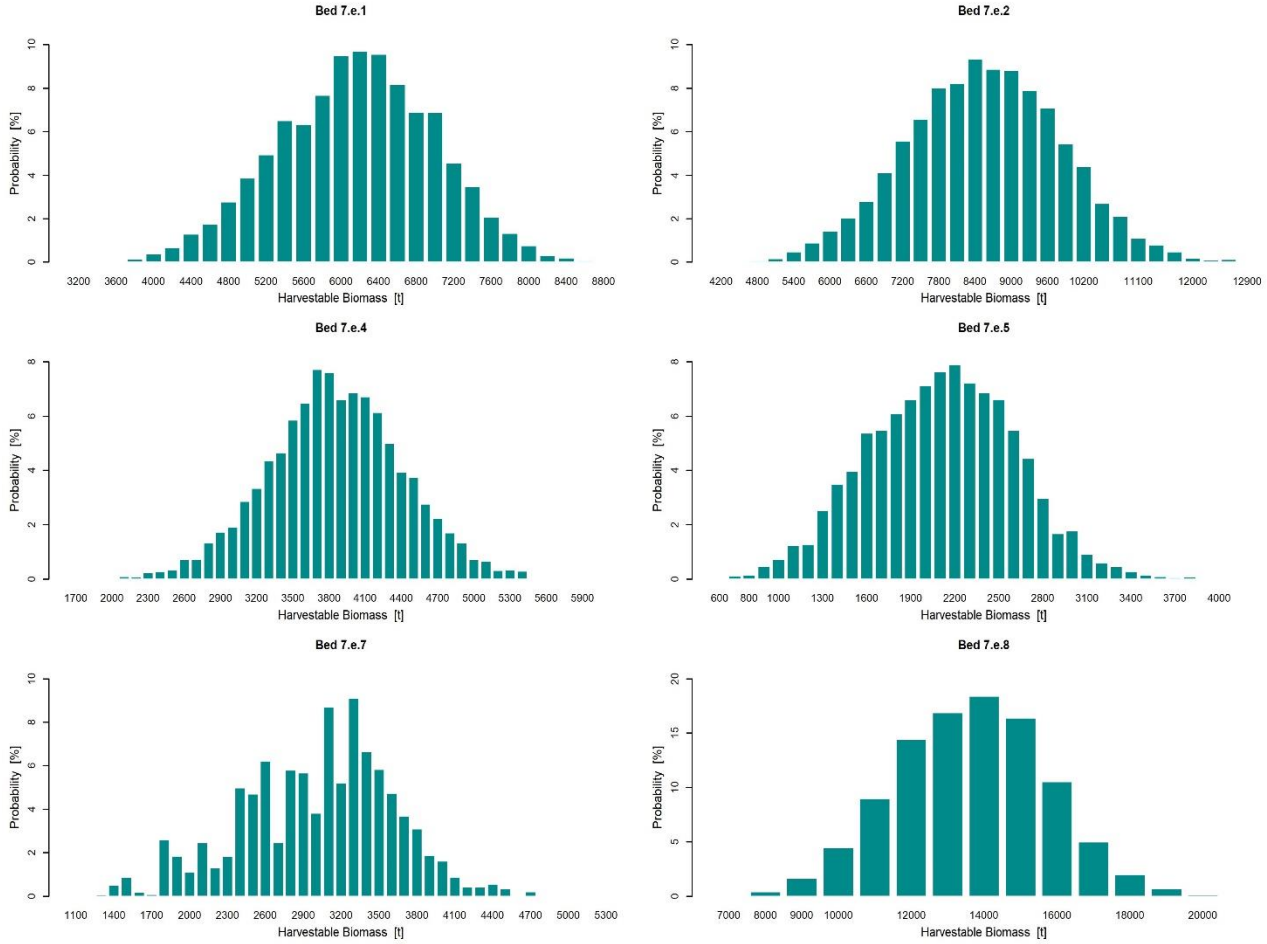

Figure 3.5: Distribution of harvestable biomass in the beds of Divisions 27.7.e during 2023 from random resampling (“bootstrapping”).

Table 3.7: Harvestable biomass (tonnes) in dredged parts of the assessment areas in ICES Divisions 27.7.e and 27.7.f: survey estimate (using all station values), median, and quartile range from random resampling ("bootstrapping").

	25th Percentile	Median	Survey	75th Percentile
27.7.e.l				
2017	19749	20600	20586	21417
2018	8826	9175	9237	9500
2019	12699	13407	13555	14135
2020	11558	12412	12425	13229
2021	8958	9425	9443	9882
2022	14195	14957	14994	15708
2023	13673	14713	14740	15779
27.7.e.L				
2017	4765	5044	4888	5340
2018	2215	2391	2381	2571
2019	2901	3171	3252	3432
2020	3250	3604	3632	3947
2021	2460	2643	2500	2837
2022	2533	2806	2808	3065
2023	3455	3841	3880	4236
27.7.e.O				
2017	13084	13815	13847	14523
2018	8412	9585	9605	10840
2019	11810	14331	14444	16078
2020	30964	34674	35517	38453
2021	19747	21884	22123	23909
2022	29023	31902	32813	34782
2023	17228	18773	18736	20245
27.7.f.l				
2017	-	-	-	-

	25th Percentile	Median	Survey	75th Percentile
2018	2063	2245	2216	2440
2019	1180	1426	1415	1672
2020	1828	2147	2148	2449
2021	-	-	-	-
2022	2496	2784	2828	3071
2023	-	-	-	-

3.6. Size composition from dredge survey

The relative abundances of scallops above and below MLS (100 mm) in the assessment areas of Divisions 27.7.e and 27.7.f since 2017 are shown in Table 3.8 and Figure 3.6.

In the two assessment areas with the highest number of stations, 27.7.e.I and 27.7.e.O, the locations of peaks in annual size distributions fluctuate between 105 and 115 mm round shell length, without any clear indication of significant pulses of undersized scallops. By contracts, in Lyme Bay (Area 27.7.e.L), size distributions had dominant peaks below MLS (100 mm) in 2018 and 2021. In 2023, an unusually high number of scallops with sizes at MLS were caught. In the Bristol Channel (Area 27.7.f.I), the size distribution had a dominant peak below MLS in 2019. Unfortunately, to date, only four surveys have been carried out in that area.

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 further restricted by legal limitations and are therefore biased towards sizes above MLS.

Table 3.8: Percent by number 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	14.6	20.3	14.1	-
2018	22.8	47.8	23.4	15.6
2019	26.3	23.1	34.8	42.7
2020	12.8	10.2	27.7	12.7
2021	14.2	42.6	33.1	-
2022	14.5	26.0	35.0	18.6
2023	6.9	37.3	32.1	-

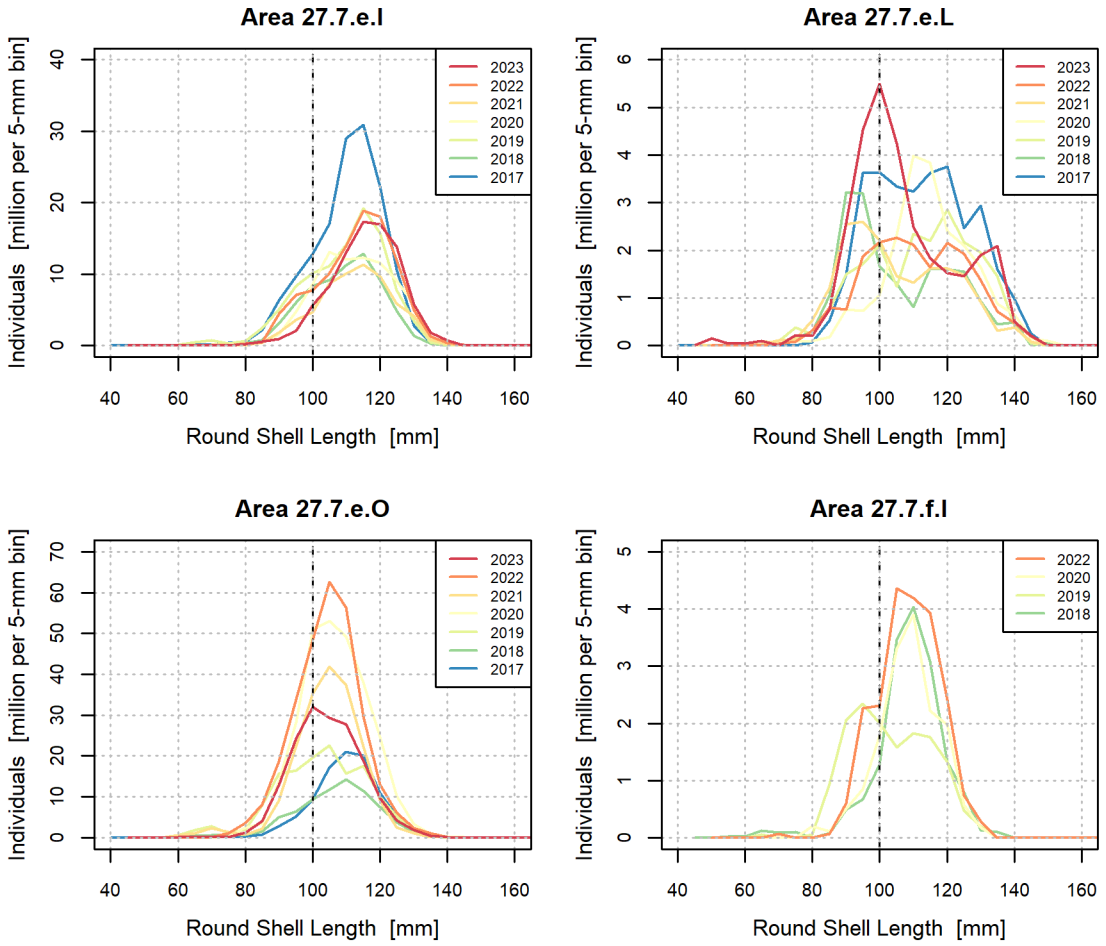

Figure 3.6: Annual population length distributions in 5-mm size bins from annual dredge surveys in the assessment areas of ICES Divisions 27.7.e and 27.7.f. The vertical dashed lines indicate MLS.

3.7. Relative abundance from UVS survey

UVS surveys were carried out in 2017, 2019, and 2023. 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. From 2019, tow speed and duration were increased to provide a transect length of just under 250 m.

The UVS surveys established that scallops are distributed at relatively low densities on the seabed in the un-dredged zones, in comparison with the main dredged areas (see 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 Section 3.9.

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 within ICES advisory areas (ICES, 2022).

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 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; for more details, see Section 6 of the annexe).

Based on the data that were available at the start of the scallop assessment project, this model estimated that in order to achieve F35%VSpR, a harvest rate (i.e. the ratio of landings to total harvestable biomass, assuming no dead discards) in the vicinity of 19.5% would be required in Area 27.7.e.I, of 21.0% in Area 27.7.e.L, and 20.9% in Area 27.7.e.O. At that time, 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.

Together with the update of the survey design, on the basis of the first five years of survey data (2017 – 2021), we have updated the MSY reference points in all assessed areas. Using the same model as before, we now estimate that a harvest rate of 24.2% would be an appropriate proxy for an MSY reference point in Area 27.7.e.I, of 24.4% in Area 27.7.e.L, 26.5% in Area 27.7.e.O, and 23.4% in Area 27.7.f.I.

3.9. Harvest rate estimation

Harvest rate is a measure of the fishing mortality within a given area. Ideally it 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 finalising this report (March 2024), international landings for calendar years 2017 – 2021 were available from the ICES Scallop Assessment Working Group.[2] International landings for the 12-month periods following the two most recent dredge surveys in 2021 and 2022 were not available. Instead, for the 2021 and 2022 surveys, UK landings recorded on a national database were used. International landings and associated harvest rates presented here for these two years will be revised when required data become available.

Harvest rates for the dredged parts of assessment areas in Divisions 27.7.e and 27.7.f are listed in Table 3.9. The corresponding estimates of harvestable biomass are based on the results from dredge surveys. The harvestable biomass values are the survey estimates from Table 3.7. 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 3.10 are based on biomass estimates that also include un-dredged zones that have been surveyed by UVS. 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 UVS, for which there is currently no information about their biomass, or their ability to contribute to recruitment to the main areas of the fished stock. Un-dredged areas are assumed to be at carrying capacity with no fishing mortality, and the combined biomass estimates from the non-overlapping successful UVS surveys have been included for all 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 3.11.

[2] See the latest published report on the ICES WGScallop website: https://www.ices.dk/community/groups/Pages/WGScallop.aspx.

Table 3.9: 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	20586	13.5	12.9	14.0
2018	1507	9237	16.3	15.9	17.1
2019	1801	13555	13.3	12.7	14.2
2020	1309	12425	10.5	9.9	11.3
2021	1710*	9443	18.1	17.3	19.1
2022	1588*	14994	10.6	10.1	11.2
27.7.e.L					
2017	1450	4888	29.7	27.2	30.4
2018	2192	2381	92.1	85.2	98.9
2019	1284	3252	39.5	37.4	44.3
2020	2004	3632	55.2	50.8	61.7
2021	1761*	2500	70.4	62.1	71.6
2022	2020*	2808	71.9	65.9	79.7
27.7.e.O					
2017	956	13847	6.9	6.6	7.3
2018	1460	9605	15.2	13.5	17.4
2019	1868	14444	12.9	11.6	15.8
2020	2717	35517	7.6	7.1	8.8
2021	4097*	22123	18.5	17.1	20.7
2022	5095*	32813	15.5	14.6	17.6
27.7.f.I					
2017	251	-	-	-	-
2018	135	2216	6.1	5.5	6.5
2019	395	1415	27.9	23.6	33.5

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvest Rate on Dredged Portion of Stock (%)	Harvest Rate Range (%)	
2020	187	2148	8.7	7.6	10.2
2021	73*	-	-	-	-
2022	28*	2828	1.0	0.9	1.1

* estimate based on UK landings, to be revised when 2022 and 2023 international landings have been reported

Table 3.10: 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 UVS surveys.

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UVS Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
27.7.e.I					
2017	2773	20586	5629	26215	10.6
2018	1507	9237	5629	14866	10.1
2019	1801	13555	5629	19184	9.4
2020	1309	12425	5629	18054	7.3
2021	1710*	9443	5629	15072	11.3
2022	1588*	14994	5629	20623	7.7
27.7.e.L					
2017	1450	4888	2151	7039	20.6
2018	2192	2381	2151	4532	48.4
2019	1284	3252	2151	5403	23.8
2020	2004	3632	2151	5783	34.7
2021	1761*	2500	2151	4651	37.9

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UVS Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
2022	2020*	2808	2151	4959	40.7
27.7.e.O					
2017	956	13847	2742	16589	5.8
2018	1460	9605	2742	12347	11.8
2019	1868	14444	2742	17186	10.9
2020	2717	35517	2742	38259	7.1
2021	4097*	22123	2742	24865	16.5
2022	5095*	32813	2742	35555	14.3
27.7.f.I					
2017	251	-	-	-	-
2018	135	2216	375	2591	5.2
2019	395	1415	375	1790	22.1
2020	187	2148	375	2523	7.4
2021	73*	-	-	-	-
2022	28*	2828	375	3203	0.9

* estimate based on UK landings, to be revised when 2022 and 2023 international landings have been reported

Table 3.11: Harvest rate estimates for assessment areas in ICES Divisions 27.7.e and 27.7.f, with MSY reference points.

	Harvest Rate on Dredged Portion of Stock (Dredge Survey Only, %)	Harvest Rate on Wider Stock (Incl. UVS Survey, %)	MSY Reference Point Harvest Rate (%)
27.7.e.I			
2017	13.5	10.6	24.2

	Harvest Rate on Dredged Portion of Stock (Dredge Survey Only, %)	Harvest Rate on Wider Stock (Incl. UVS Survey, %)	MSY Reference Point Harvest Rate (%)
2018	16.3	10.1	24.2
2019	13.3	9.4	24.2
2020	10.5	7.3	24.2
2021*	18.1	11.3	24.2
2022*	10.6	7.7	24.2
27.7.e.L			
2017	29.7	20.6	24.4
2018	92.1	48.4	24.4
2019	39.5	23.8	24.4
2020	55.2	34.7	24.4
2021*	70.4	37.9	24.4
2022*	71.9	40.7	24.4
27.7.e.O			
2017	6.9	5.8	26.5
2018	15.2	11.8	26.5
2019	12.9	10.9	26.5
2020	7.6	7.1	26.5
2021*	18.5	16.5	26.5
2022*	15.5	14.3	26,5
27.7.f.I			
2017	-	-	-
2018	6.1	5.2	23.4
2019	27.9	22.1	23.4
2020	8.7	7.4	23.4
2021*	-	-	-
2022*	1.0	0.9	23.4

* estimate based on UK landings, to be revised when 2022 and 2023 international landings have been reported

3.10. Conclusion

This assessment includes biomass estimates and provisional harvest rates based on the 2022 dredge survey in Divisions 27.7.e and 27.7.f, together with the biomass estimated based on the 2017, 2019 and 2023 UVS 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, Lawler, Masefield, & McIntyre, 2018). This length-structured cohort modelling provides context for harvest rate estimates by establishing assessment-area-specific MSY reference values.

The Lyme Bay area (27.7.e.L) continues to experience the highest exploitation levels, consistently above the MSY target since 2017, and increasing since 2019. Exploitation rates in the inshore (27.7.e.I) and offshore (27.7.e.O) areas of the western English Channel have consistently been below the respective MSY target since 2017.

In the assessment area to the north of Cornwall (27.7.f.I), due to the combination of unusually low harvestable biomass and high international landings, the harvest rate in 2019 was a few percent above the MSY target. In the other surveyed years (2018, 2020 and 2022), harvest rates were below the reference point.

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.

A presentation of the assessment approach to the ICES Scallop Assessment Working Group (WGScallop) 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 is currently no information about 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 has been carried out for the North Sea and the English Channel. Two Cefas reports are currently under review.

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 first defined in 2018, and revised in 2022. 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 surveyed once in 2021. All beds in Division 27.4.b are within the UK EEZ. However, there are now 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. Dredge surveys have therefore not been carried out in that area since 2021.

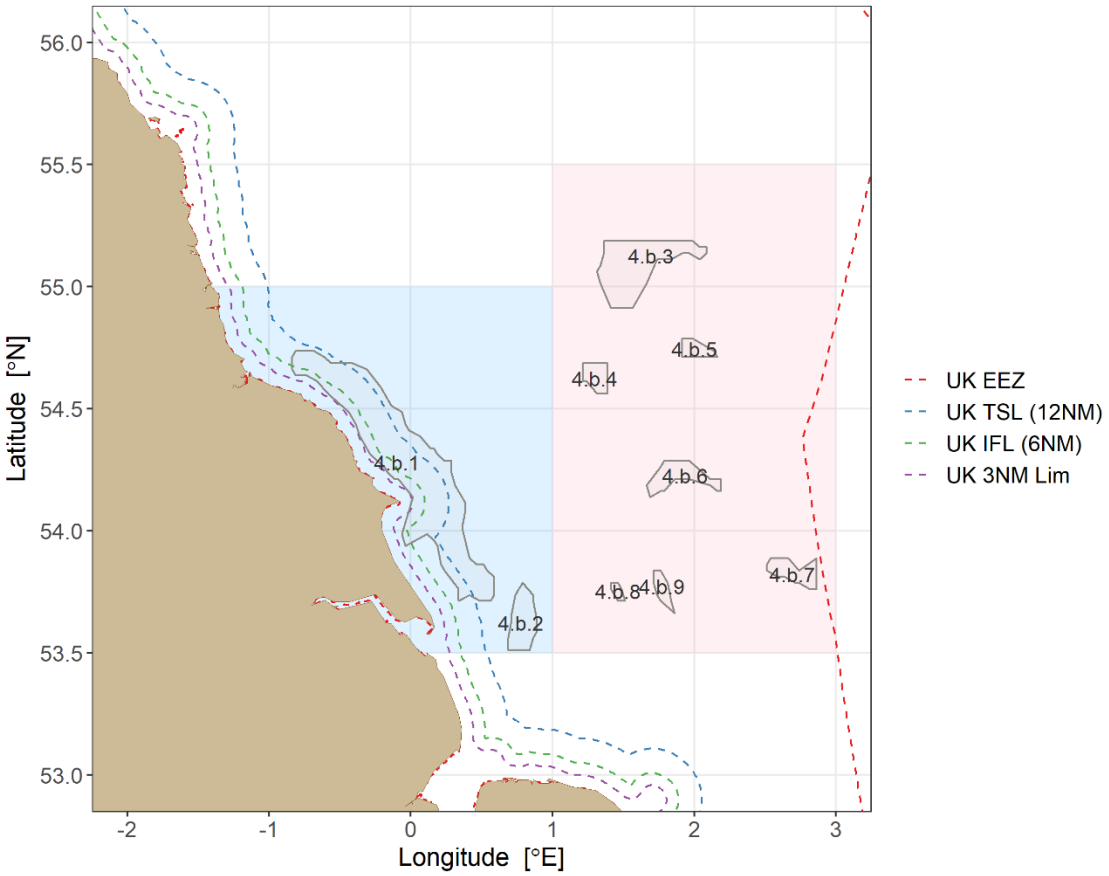

Figure 4.1: Dredge-surveyed parts of ICES Division 27.4.b: Beds 4.b.1 and 4.b.2 within Area 27.4.b.S (light blue), and Beds 4.b.3 – 9 within Area 27.7.b.D (pink).

4.2. Commercial landings and sampling data

UK quarterly landings from Area 27.4.b.S are listed in Table 4.1. This includes all landings by UK vessels, as well as all landings by international vessels into the UK. At the time of finalising this report (March 2024), landings data to the end of Q3 of 2023 are considered reliable. Scallop fishing in that area is conducted almost exclusively by UK vessels. There is no consistent seasonal pattern in UK fishing activity. On average, annual landings since 2014 have been more than four times higher than during the 2001 – 2013 period.

Table 4.1: UK quarterly landings (tonnes) from Area 27.4.b.S. UK landings share is calculated relative to total international landings as reported to ICES.

	Q1	Q2	Q3	Q4	Annual	Landings Share
2001	12	1	0	762	775	100%
2002	417	610	11	30	1068	100%
2003	434	112	3	6	554	100%
2004	34	68	2	0	103	100%
2005	161	0	0	121	282	100%
2006	141	41	26	49	258	99%
2007	21	119	144	1	285	99%
2008	36	165	169	1	370	100%
2009	18	166	190	20	394	100%
2010	88	227	44	1	361	100%
2011	117	239	57	286	699	100%
2012	441	453	95	2	991	100%
2013	60	70	18	204	353	100%
2014	786	435	283	797	2300	100%
2015	1506	951	377	340	3173	100%
2016	129	215	591	118	1054	100%
2017	936	888	385	297	2505	100%
2018	689	842	366	434	2331	100%
2019	1020	842	304	158	2323	100%
2020	500	132	81	131	844	100%
2021	1425	870	25	185	2506	100%
2022	887	401	33	96	1417	
2023	572	305	301	85*	1263*	

* provisional

Length distributions from the industry sampling programme, raised to the UK commercial landings of king scallop dredgers, are show in Figure 4.2. Length samples for individual

vessels were raised to monthly vessel landings, before aggregation to total annual UK landings.

The high interannual variability in the relative frequency-at-length distribution in Area 27.4.b.S is likely to be the result of the low sampling levels (only about a tenth of the industry samples available for the Eastern English Channel), rather than genuine shifts in the population size distribution or changes in gear selectivity. The shifting locations of peaks cannot be reconciled with known growth rates for this area.

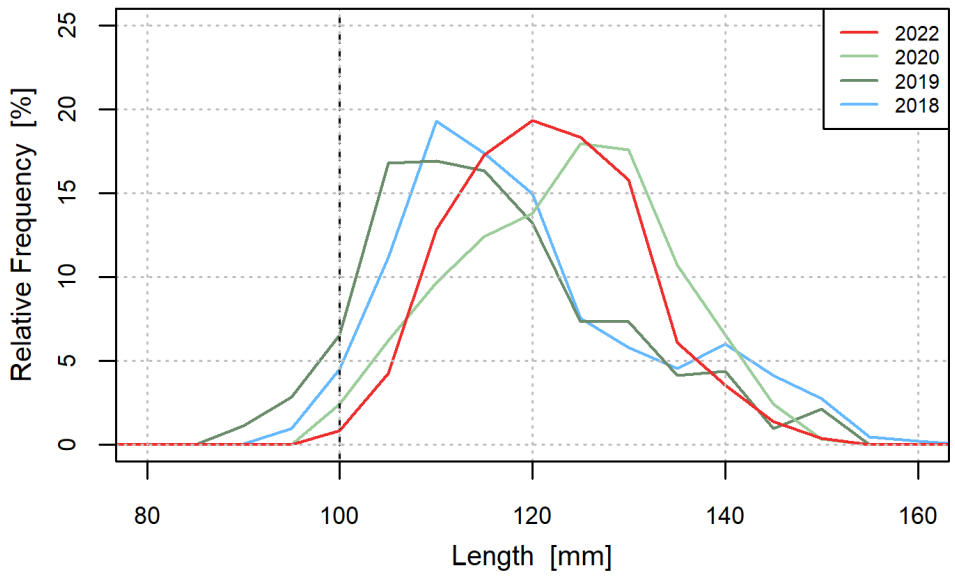

Figure 4.2: Annual relative frequency-at-length distributions (round shell length in 5-mm size bins) in commercial landings of UK king scallop dredgers from Area 27.4.b.S. The vertical dashed line indicates MLS.

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, based on an unpublished study by Cefas in the English Channel in 2001, 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 4.2: 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 (based on an unpublished depletion study in 2001)
Gear efficiency – ground type flint cobbles	43%	Cefas (based on an unpublished depletion study in 2001)
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 (based on an unpublished fine-mesh dredge study in 2001); see Section 1.1.3 for functional relationship

4.4. Dredge and underwater video system surveys

4.4.1. Dredge survey methodology

The updated 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 1.5.3.

During 3 – 4 September 2023, 19 randomly selected stations were surveyed in Bed 4.b.1, resulting in the sampled blocks shown in Figure 4.3. In total, 1151 shells from the standard gear were measured, with a median round length of 115 mm. Of these shells, 18.7% were below MLS and would have to be discarded during commercial fishing.

On 4 September 2023, one further station was surveyed in Bed 4.b.2. Among the 46 measured shells, the median round length was 113 mm, and 17.4% were below MLS.

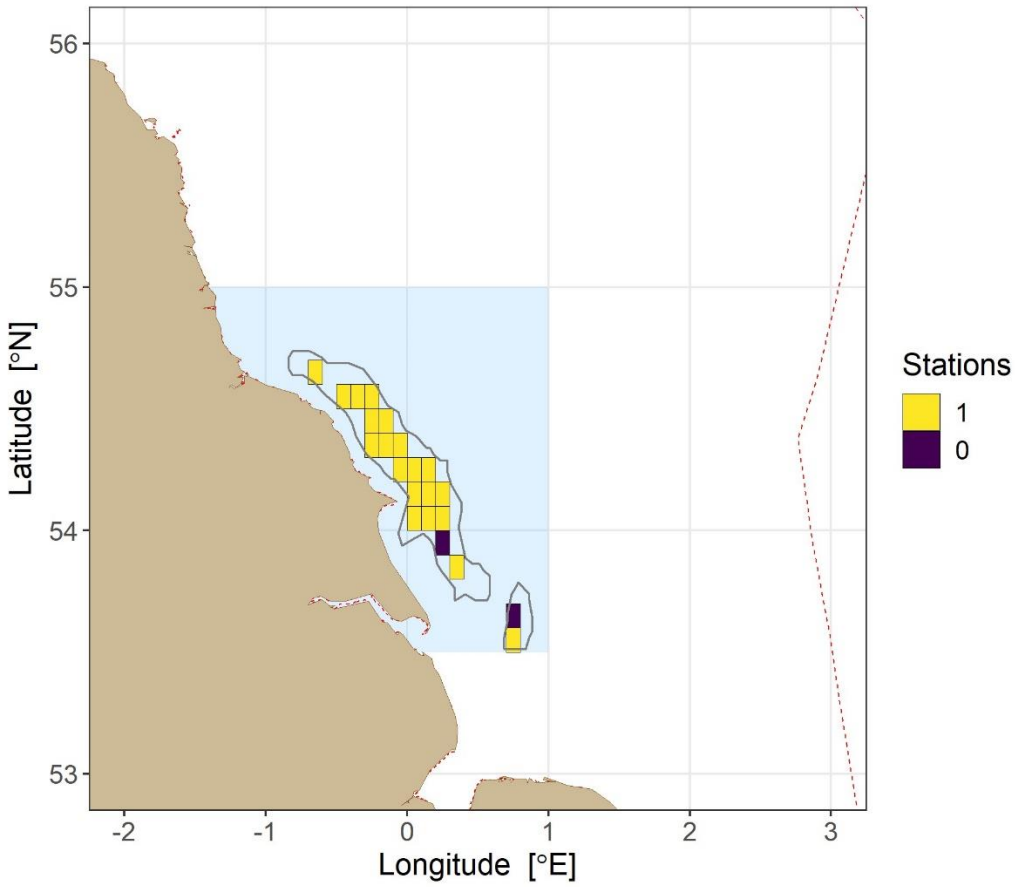

Figure 4.3: Number of stations visited during the 2023 dredge survey within each sampled block of Beds 4.b.1 and 4.b.2. The red line indicates the boundary of the UK EEZ.

4.4.2. Underwater video system survey methodology

For the first time in 2021, an underwater video system (UVS) 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 the commercial fishing fleet, either due to conservation measures, or due to the presence of ground types that are unsuitable for the deployment of dredges. The spatial coverage and methods of UVS surveys are described in Section 4 of the annexe.

4.5. Raised biomass estimates and uncertainty

From the size samples taken at each station, total (pooled) length frequency distributions within Beds 4.b.1 and 4.b.2 were derived. From this, the total population number and biomass, as well as the biomass of harvestable scallops (round shell lengths ≥ 100 mm MLS), could be estimated. The harvestable biomass within 0.1-by-0.1 degree grid cells in 2023 is shown in Figure 4.4.

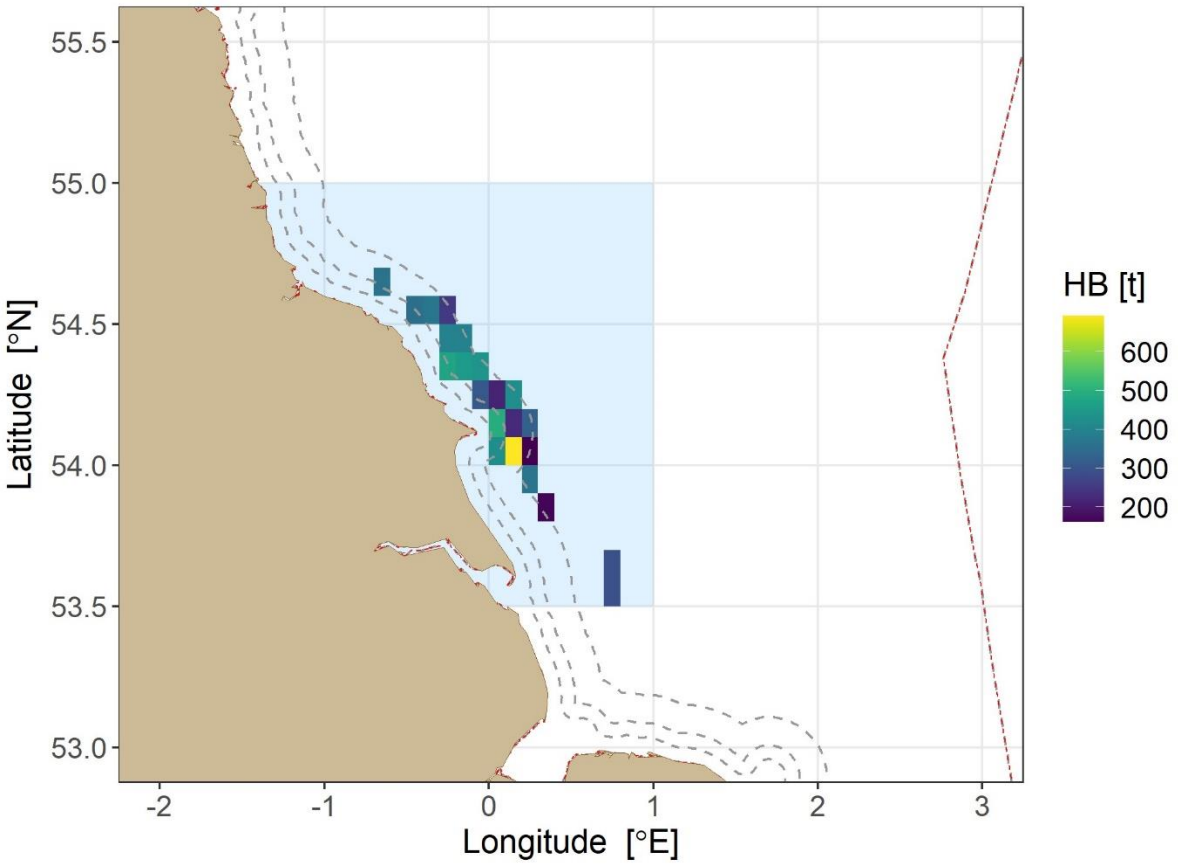

Figure 4.4: Harvestable biomass (tonnes) of scallops of at least MLS (100 mm round shell length) in Beds 4.b.1 and 4.b.2 during 2023. The red line indicates the boundary of the UK EEZ. The three black dashed lines indicate the outer limits of the 3-, 6-, and 12-nm zones.

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 in Bed 4.b.1 during 2023 is shown in Figure 4.5. As there is only one station in Bed 4.b.2, random resampling of these data is not possible.

The survey estimate for Area 27.4.b.S (Beds 4.b.1 and 4.b.2 combined), along with the median and quartile range from bootstrapping, are given in Table 4.3. As the survey estimate utilises all available data, it is considered the most accurate value.

The harvestable biomass in Area 27.4.b.S has fluctuated between 5k and 10k tonnes since 2018. However, it has generally increased, from below 6k tonnes before 2020 to above 6k tonnes since then.

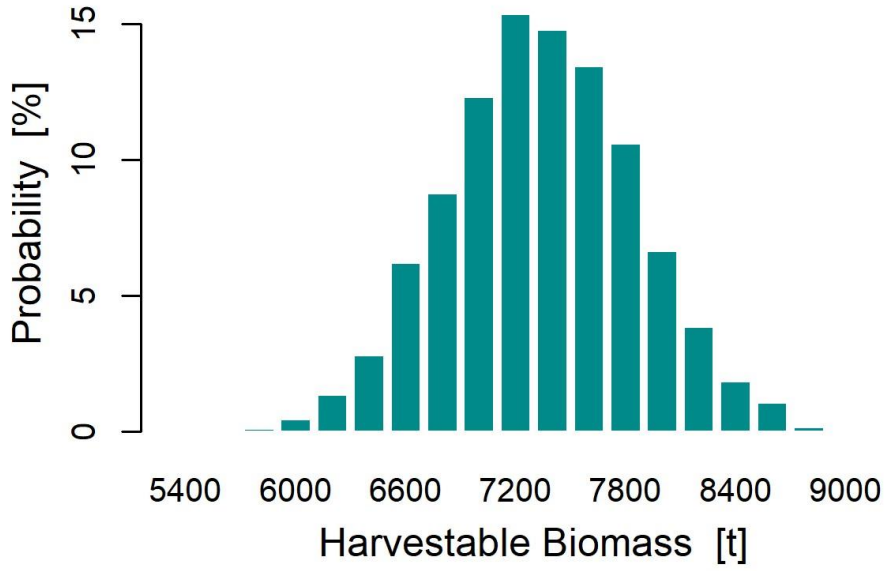

Figure 4.5: Distribution of harvestable biomass in Bed 4.b.1 (Area 27.4.b.S) during 2023 from random resampling ("bootstrapping").

Table 4.3: Harvestable biomass (tonnes) in Area 27.4.b.S: survey estimate (using all station values), median, and quartile range from random resampling ("bootstrapping").

	25th Percentile	Median	Survey	75th Percentile
2017	-	-	-	-
2018	5170	5456	5533	5735

	25th Percentile	Median	Survey	75th Percentile
2019	5513	5749	5803	5984
2020	9176	9667	9732	10139
2021	5979	6388	6375	6800
2022	7659	8405	8911	9111
2023	7559	7917	7872	8263

4.6. Size composition from dredge survey

The relative abundance of scallops above and below MLS (100 mm) in Area 27.4.b.S since 2018 is shown in Table 4.4 and Figure 4.6.

Until 2022, there was a gradual upward shift in the combined Area 27.4.b.S size distribution. Due to that, the below-MLS proportion by number of survey catches from standard gear significantly decreased between 2018 and 2022. However, from 2022 to 2023, the undersized proportion increased again.

Changes in the relative abundance of small animals can either be due to a genuine temporal change in the population size distribution, indicative of a particularly strong cohort of pre-recruits, or due to the random station selection, in connection with the patchy distribution on scallops, as some tows fall onto ground with an unusually high proportion of juveniles.

The area-aggregated size distributions derived from survey catches (Figure 4.6) do not compare directly to those from commercial landings (Figure 4.2), 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 further restricted by legal limitations and are therefore biased towards sizes above MLS.

Table 4.4: Percent by number of scallops below MLS (100 mm) in the standard commercial dredges from dredge surveys.

	27.4.b.S
2017	-
2018	33.1
2019	27.7
2020	10.8
2021	13.5
2022	10.4
2023	18.6

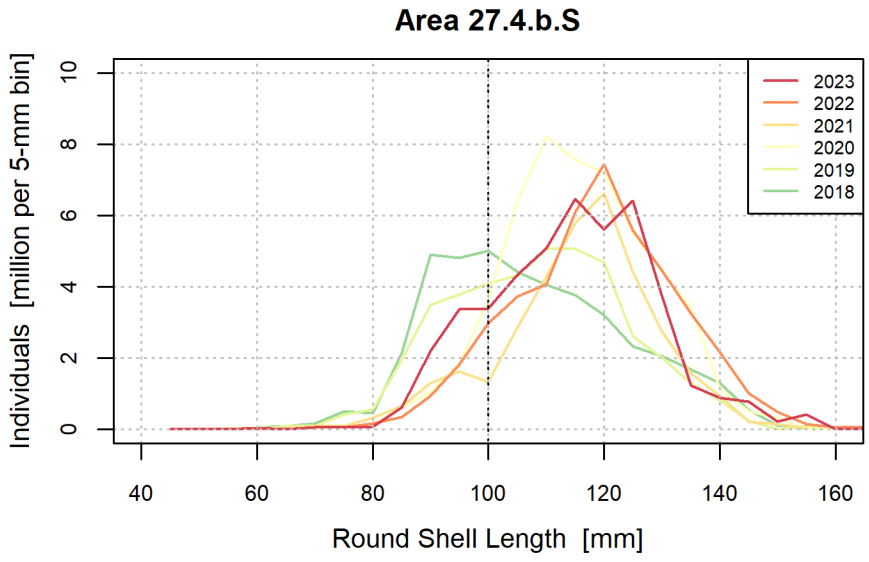

Figure 4.6: Annual population length distributions in 5-mm size bins from annual dredge surveys in Area 27.4.b.S. The vertical dashed line indicates MLS.

4.7. Relative abundance from UVS survey

The first UVS 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 UVS surveys established that scallops are distributed at relatively low densities on the seabed in the un-dredged zones, in comparison with the main dredged areas (see 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 Section 4.9.

4.8. 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%VSpR) is a commonly used reference point within ICES advisory areas (ICES, 2022).

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 stock 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; for more details, see Section 6 of the annexe).

Based on the limited sampling data that were available for Area 27.4.b.S at the start of the scallop assessment project, it was not possible to determine a biological reference point that is consistent with MSY. However, on the basis of the first five years of survey data

(2017 – 2021), the spawner per recruit model estimates that in order to achieve F35%VSpR, a harvest rate (i.e. the ratio of landings to total harvestable biomass, assuming no dead discards) in the vicinity of 23.0% would be required in Area 27.4.b.S.

4.9. Harvest rate estimation

Harvest rate is a measure of the fishing mortality within a given area. Ideally it 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 finalising this report (March 2024), international landings for calendar years 2017 – 2021 were available from the ICES Scallop Assessment Working Group.[3] International landings for the 12-month periods following the two most recent dredge surveys in 2021 and 2022 were not available. Instead, for the 2021 and 2022 surveys, UK landings recorded on a national database were used. International landings and associated harvest rates presented here for these two years will be revised when required data become available. Since fishing in this area is conducted almost exclusively by UK vessels, the anticipated revisions for the North Sea assessment area are minor compared with the assessment areas in the English Channel.

Harvest rates for the dredged parts of Area 27.4.b.S are listed in Table 4.5. The corresponding estimates of harvestable biomass are based on the results from dredge surveys. The harvestable biomass values are the survey estimates from Table 4.3. 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 4.6 are based on biomass estimates that also include un-dredged zones that have been surveyed by UVS. 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 UVS, for which there is currently no information about their biomass, or their 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 also been included for other years. These harvest rates are applicable only when connectivity between dredged and un-dredged populations is complete.

[3] See the latest published report on the ICES WGScallop website: https://www.ices.dk/community/groups/Pages/WGScallop.aspx.

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 4.7.

Table 4.5: 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 (%)	
2017	2186	-	-	-	-
2018	2594	5533	46.9	45.2	50.2
2019	889	5803	15.3	14.9	16.1
2020	2450	9732	25.2	24.2	26.7
2021	1511*	6375	23.7	22.2	25.3
2022	1242*	8911	13.9	13.6	16.2

* estimate based on UK landings, to be revised when 2022 and 2023 international landings have been reported

Table 4.6: 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 UVS surveys.

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UVS Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
2017	2186	-	-	-	-
2018	2594	5533	856	6389	40.6

	International Landings (tonnes)	Harvestable Biomass in Dredged Area (tonnes)	Harvestable Biomass from UVS Survey (tonnes)	Total Harvestable Biomass (tonnes)	Total Harvest Rate (%)
2019	889	5803	856	6659	13.4
2020	2450	9732	856	10588	23.1
2021	1511*	6375	856	7231	20.9
2022	1242*	8911	856	9767	12.7

* estimate based on UK landings, to be revised when 2022 and 2023 international landings have been reported

Table 4.7: Harvest rate estimates for Area 27.4.b.S, with MSY reference point.

	Harvest Rate on Dredged Portion of Stock (Dredge Survey Only, %)	Harvest Rate on Wider Stock (Incl. UVS Survey, %)	MSY Reference Point Harvest Rate (%)
2017	-	-	-
2018	46.9	40.6	23.0
2019	15.3	13.4	23.0
2020	25.2	23.1	23.0
2021*	23.7	20.9	23.0
2022*	13.9	12.7	23.0

* estimate based on UK landings, to be revised when 2022 and 2023 international landings have been reported

4.10. Conclusion

This assessment includes biomass estimates and provisional harvest rates based on the 2022 dredge, together with biomass estimated based on UVS surveys 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, Lawler, Masefield, & McIntyre, 2018). This length-structured cohort modelling provides context for harvest rate estimates by establishing an assessment-area-specific MSY reference value.

In the Yorkshire/Durham area (27.4.b.S), the exploitation rate was significantly above the MSY target in 2018. This was the result of unusually high total landings, combined with a relatively low harvestable biomass. Since then, harvest rate has fluctuated around the MSY reference value.

A presentation of the assessment approach to the ICES Scallop Assessment Working Group (WGScallop) 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 27.4.b.S 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 is currently no information about 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 has been carried out for the North Sea and the English Channel. Two Cefas reports are currently under review.

5. Future developments

This report summarises the results of 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 UVS) estimates for different ground types.
- Relate UVS counts to size and biomass structure.
- Continue to improve understanding of the recruitment linkage between dredged scallop beds and un-dredged areas and incorporate this information into stock assessments and management advice.

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 finalising this report (March 2024), international landings were only available until the end of 2021. Therefore, the harvest rates for survey years 2021 and 2022 had to be estimated from UK landings. Harvest rates will be updated in future reports as data become available.
- Dredge surveys and catch sampling only cover the portions of stock found on the main fished grounds. Harvest rate estimates from dredge surveys or commercial sampling only apply to the fished portion of the stock.
- The gear-efficiency factor used to convert dredge survey data to total harvestable biomass used unpublished Cefas data. These data came from depletion experiments which, although broadly in line with some similar studies, remain uncertain. Further 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.
- UVS surveys detected biomass of scallop on grounds not exploited by dredgers, but not all un-dredged grounds were surveyed with UVS.
- Studies of larval drift between beds indicate incomplete connectivity, whereby the main dredged areas appear to have a degree of larval retention (i.e., they are 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.

- Basic biological parameters that are used in this assessment – such as growth rates, size at maturity, and natural mortality -- are derived from unpublished studies that were conducted more than 20 years ago. Natural mortality is difficult to determine, especially for a species that is heavily commercially exploited. Cefas does not determine maturity stages anymore, as part of the sampling programme.

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