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Assessment of Scallop stock status for selected waters around the English Coast 2017/2018

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Executive Summary

King Scallop fisheries around English coasts represent the most valuable single species in the region. The stocks are internationally exploited primarily by the UK and France using towed dredges. These fisheries are not governed by EU or national TACs and the stocks have not been subject to routine monitoring or formal assessment prior to 2017.

This report describes the assessment of the status of some of these stocks undertaken in 2017 and 2018 by the Centre for the Environment, Fisheries and Aquaculture Science (Cefas) during a collaborative project with the UK fishing industry, Defra (Department for Environment, Farming and Rural affairs) and Seafish. The results from the 2017 surveys are included for context and have been updated for this report to account for improvements in the methods used to analyse the data. This includes the correction of an error in the code covering the stocks in 27.7.e which over-estimated the stock area by approximately 30%. The estimates of harvest rates in the 2017 assessment used the 2017 surveys and the fishery data from the previous 12 months as a proxy for what might be taken from the stock in the 12 months subsequent to the survey. Full international landings data for 2017 have not been collated by the International Council for the Exploration of the sea (ICES) or the Scientific, Technical and Economic Committee for Fisheries (STECF), so landings for the 12 months after the 2017 survey have been estimated by taking the UK landings for that period and adjusting by the historic ratio of UK to International landings. The 2017 harvest rates are presented as the realised harvest rates, i.e. the landings in the 12 months following the survey. These changes (improvements, error correction and the realised landings) combine to give harvest rates that are substantially different to those estimated in 2017.

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

This report assesses the status of the dredged portion of stocks in 27.7.d.N, 27.7.e.I, 27.7.e.L, 27.7.e.O, 27.7.f.I and 27.4.b.S using dredge surveys and with additional estimates of unfished biomass in some parts of 27.7.e.L and 27.7.e.I. There is likely to be biomass of scallops outside those areas surveyed but for which there are no data to make any estimates. The biomass and exploitation rate of the fished portion of stock in the Bay de Seine part of 27.d.S is routinely estimated by scientists from The French Research Institute for the Exploration of the Sea (IFREMER) in a robust process. In 2018 we surveyed a small bed in 27.7.d.S that is not covered by the IFREMER assessment, the results of which are presented, however there is no further analysis of 27.7.d.S in this report

Three data streams were used for the assessments described in this report; dredge surveys, underwater TV surveys and a biological sampling programme. Dredge surveys in the main fished beds of 27.7.d.N, 27.7.e.I, 27.7.e.L, 27.7.e.O, 27.7.f.I and 27.4.b.S were used to estimate harvestable biomass available to the dredge fishery (converting survey catch rates to absolute biomass via a gear-efficiency coefficient). The scallop biomass in some un-dredged regions of assessment areas 27.7.e.I and 27.7.e.L was estimated from underwater TV surveys in the first year (2017); no underwater TV survey was undertaken in 27.7.d.N, 27.7.e.O, 27.7.f.I or 27.4.b.S.

A biological sampling programme will provide a time series of age structure of the removals, but these data are under review and only size distributions are presented. Estimates of harvestable biomass (i.e. biomass above minimum size and in areas in which dredgers can operate) and the exploitation rate experienced by those scallops are covered by this assessment, however the assessments presented here are not able to fully estimate the impact of the fishery on the wider stock as we were unable to estimate the scallop biomass in all un-dredged areas. Dredge surveys and catch sampling only cover the portions of stock found on the main fished grounds, as identified by density of Vessel Monitoring System data (VMS). Harvest rate estimates from dredge surveys or commercial sampling therefore only apply to the fished portion of the stock. In situations where there are significant portions of un-dredged stock that are contributing offspring to the fished areas, any estimates of MSY harvest rates will, in future, need to be adjusted to compensate for this.

The potential harvest rates experienced by the surveyed portion of stocks were estimated by comparing a proxy for international landings to the available biomass estimates, either dredged area only or including the biomass from un-dredged areas from the available UWTV surveys.

The estimates of harvest rate from dredge survey and UWTV are given below, note that the 2018 harvest rate estimates use some landing data prior to the survey being undertaken and will be updated when the full landings from the 12-month period after the survey are known.

	Provisional harvest rate on dredged portion of stock (dredge survey only, %)		**Provisional harvest rate for wider stock where UWTV available*** (not 100% coverage, %)**		**MSY Candidate (%)**
	2017*	2018**	2017*	2018**	
27.7.d.N	74.3	62.4	NA	NA	21
27.7.e.I	38.0	24.7	24.0	16.7	25
27.7.e.L	55.2	67.4	33.2	41.7	21
27.7.e.O	11.2	18.3	NA	NA	24
27.7.f.I	NA	10.2	NA	NA	NA
27.4.b.S	NA	42.2	NA	NA	NA

* assumes historic International landing ratio applied in 2017
** to be revised in 2019 once the true 2018 landings are known
*** assumes stock in UWTV areas is contributing a proportionate level of recruits to dredged portion of stock.

This is the second attempt at stock assessments undertaken for scallops in this region. A few points of data are always more uncertain than when a time series are available, so the results of this assessment should be viewed with some caution. These results represent the start of a long-term monitoring and assessment programme and there is likely to be some evolution of processes and methodologies. As the time series of data develops and increases in comprehensiveness, this will in turn contribute to a more robust determination of stock status of King Scallop in this region.

Assessment caveats and assumptions

- At the time of this report international landings since 2016 were not available. Harvest rates were calculated using an estimate of international landings based on the UK share of historic reported international landings. As such harvest rates presented in this report are provisional. If the UK share of the total international landings has changed then realised harvest rates can be higher or lower than our provisional estimates. Harvest rates will be retrospectively updated in future reports as data become available.
- Dredge surveys and catch sampling only cover the portions of stock found on the main fished grounds. Harvest rate estimates from dredge surveys or commercial sampling only apply to the fished portion of the stock.
- The gear-efficiency factor used to convert dredge survey data to total harvestable biomass used unpublished Cefas data. These data came from depletion experiments which although broadly in line with some similar studies remain uncertain. Further refinement/data for this parameter is required including the testing of key assumptions. Revised efficiency factors could have a large influence on the estimates of stock status.
- UWTV surveys detected biomass of scallop on grounds not exploited by dredgers and not all un-dredged grounds were surveyed with UWTV.
- Studies of larval connection between beds indicate incomplete interchange of larvae but the main dredged areas appear to have a degree of larval retention (i.e. self-

perpetuating). Incorporation of the un-dredged area biomass into harvest rate calculations assumes complete interchange. Restricting the biomass estimate to the dredged beds assumes no interchange.

- Once complete coverage of un-dredged beds is achieved, these two biomass estimates would be the basis for the maximum and minimum harvest rates experienced in an assessment area.

Contents

1 Introduction

1.1 Fishery Overview

The fishery for the scallop *Pecten maximus* in the Channel (ICES sub-divisions 27.7.d and 27.7.e) is the most valuable single species fishery in the region with around 35,000 tonnes of international landings reported in 2016. An additional 3,000 tonnes were reported for the fisheries off the English coasts in the North Sea and approaches to the Bristol Channel. The stocks are exploited principally by the UK and France, with additional activity from Ireland, the Netherlands and Belgium. Targeted fisheries predominantly use towed dredges although some commercial dive fisheries exist, particularly around Lyme Bay. *Pecten maximus* fisheries lie outside the EU TAC and quota regime and fishery management measures are largely under the control of the member states. EU regulations stipulate the minimum size of scallop that can be retained by vessels and also caps the level of effort that vessels ≥15m can utilise in area 27.7.

There is a distinct contrast between the UK and French fisheries, with the UK fisheries comprising a mix of large (≥15m) nomadic vessels and smaller (10-15m) vessels with a more localised range. Scallop fishery management for UK vessels consists of licence conditions (for vessels over 10m) and gear restrictions, with some spatial differentiation in vessel access in inshore (<6 nautical miles) areas. The French fishery is dominated by smaller vessels fishing much more inshore (on the French side of the Channel), and 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 the member states, the fisheries are in fact quite international, with multiple member states fishing upon the same stock units. The lack of agreements and coordination of fishery management measures at an official level has led to tension between fishers from the UK and France when some vessels are seen to be operating in places and at times that other fishers are prevented by their own national rules (i.e. UK vessels fishing during the French closed season). A voluntary seasonal closure harmonisation has existed since 2013 between the majority of the UK scalloping industry and the French industry.

1.2 Stock Unit Assessment Areas

Investigations into the transport and distribution of scallop larvae (ICES 2015, Catherall *et al.,* 2014) indicate that scallops within ICES subdivisions 27.7.d and 27.7.e are likely to compromise at least two biological populations, when viewed at the scale of multiple generations. However, given the fact that a) larval interchange appears to be only sporadic (rather than regular) b) there are distinct regional differences in growth rates and fishery management and c) post-larval scallops exhibit largely sessile behaviour, more regional stock assessments are appropriate.

Two stock assessment areas have been designated for ICES subdivision 27.7.d split along the 50-degree North line termed 27.7.d.N and 27.7.d.S. This division, dictated by the resolution of the landings data, allows a separation of the faster growing Baie de Seine stock from the rest of the eastern Channel, appropriate for stock assessment purposes. Three stock assessment areas have been designated for ICES subdivision 27.7.e to reflect slow-growing inshore areas around Cornwall (27.7.e.I), faster growing areas around Lyme Bay (27.7.e.L), and offshore scallop beds (27.7.e.O). Additional stock areas in the Approaches to the Bristol Channel (27.7.f.I) and North Sea (27.4.b.S) were introduced in 2018, as indicated in Figure 1.1. The ICES rectangles that sit within the assessment areas are listed in Table 1.1.

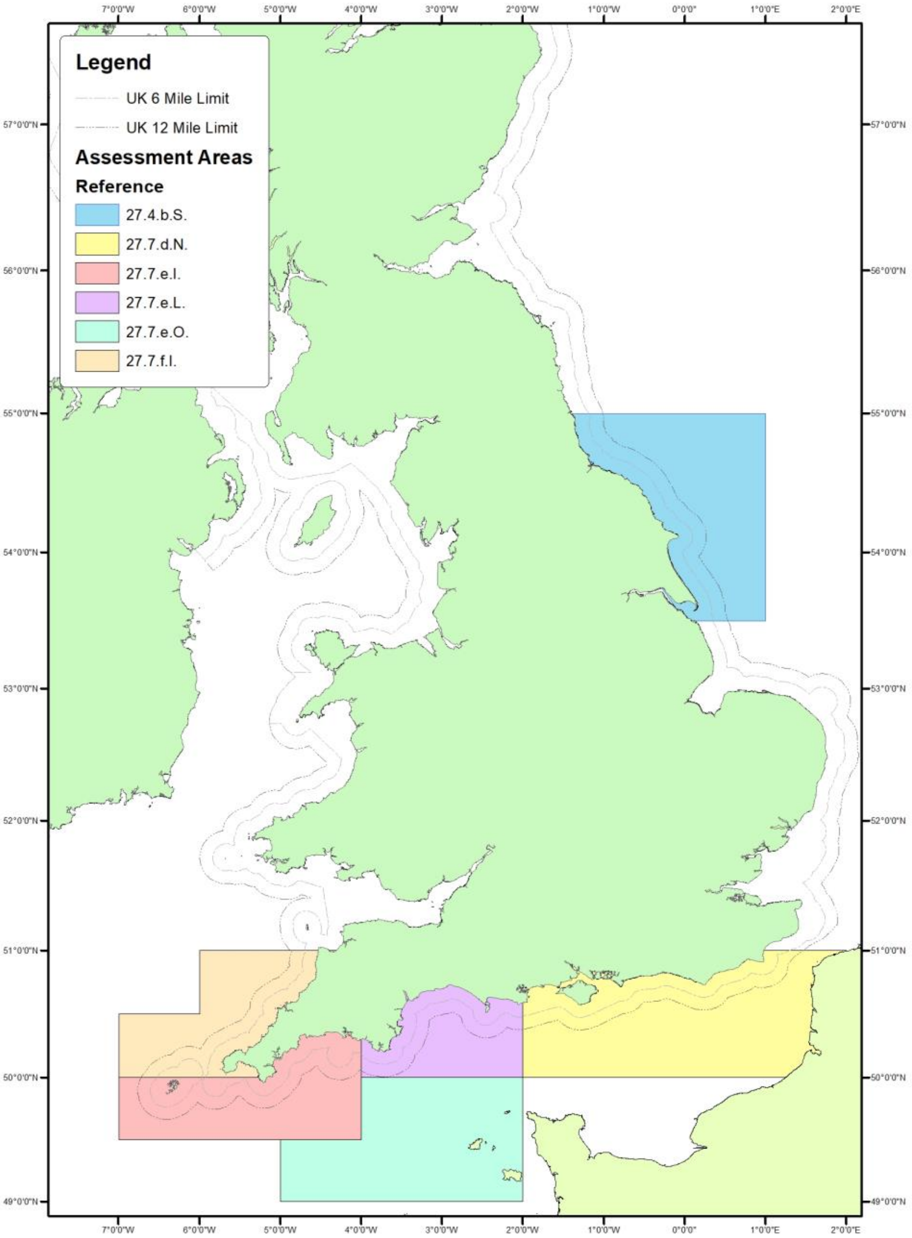


Figure 1.1. Stock unit assessment areas defined in the English Channel, Celtic and North Sea

Table 1.1: Assessment areas by ICES rectangle

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

* area within boundaries of division 27.7.e, $^+$ area within boundaries of division 27.7.f. Scallop fisheries in the remaining ICES rectangles in 27.7.e are dominated by French coastal activity and therefore beyond the scope of this assessment. The area of 27.7.d.S representing the majority of landings is covered by a survey operated by IFREMER (France) and is also not covered by this assessment report.

1.3 Biology

1.3.1 Range and habitat

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

1.3.2 Reproduction

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 1-5mm they then detach and settle onto the sea-bed where they take up their normal habit, recessed into the substrate.

1.3.3 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 (so called 'growth checks') occur when animals are stressed (such as after damage caused by interaction with scallop dredges) or sudden climactic changes. Age determination of scallops is performed by reading the annual growth rings on the upper (flat) shell; however, care must be taken not to confuse stress induced growth checks with annual patterns. Growth rates are extremely variable between areas and even between adjacent beds with the time required to reach the local Minimum Landing Size (MLS) varying between 2 to more than 5 years.

1.4 Fishery Management

EU legislation sets a MLS of 100mm shell length except for Irish Sea (107A) and Eastern Channel (107D) where it is 110mm. Prior to 2019 there was a limit on retained fish by-catch of 5% of the total retained catch, the remaining 95% being bivalve molluscs. This changed in 2019 to permit compliance with the Landing Obligation and now retained bycatch of non-quota species should be no greater than 5% of total retained catch. The Western Waters effort regime places an upper ceiling on the number of kilowatt days (KWdays) fished by vessels ≥15m towing dredges for scallops. Within the UK this pool of effort 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 being revised on a quarterly basis. In recent years this effort cap has been limiting, however the French fishery limits are not considered to be restrictive on their activity.

National legislation limits the number of licenses for scallop vessels >10m. The English Scallop Order applies in England to British vessels and places spatial restrictions on number of dredges that can be employed at any one time and specifies technical measures defining the type of dredge that can be used.

2 Stock Assessment for surveyed areas of 27.7.d.N

2.1 Area Definition

As described in Section 1.2, the stock area for 27.7.d.N covers the northern half of ICES subdivision 27.7.d with the main fishery covering a large bed which stretches across the mid-eastern part of the Channel, straddling the midline between UK and France. The perimeter of the bed was defined using VMS data (see Figure 2.1 and Annex 2). Using VMS data does mean that the bed represents only those grounds used by vessels >12m, however as vessels >12m land 93% of scallops from 27.7.d.N this designation captures the vast majority of landings. Recent expansion of the fishery to the south of bed 7.d.1 has led to the definition of a second bed (7.d.2) in area 27.7.d.S (Section 3 of this report).

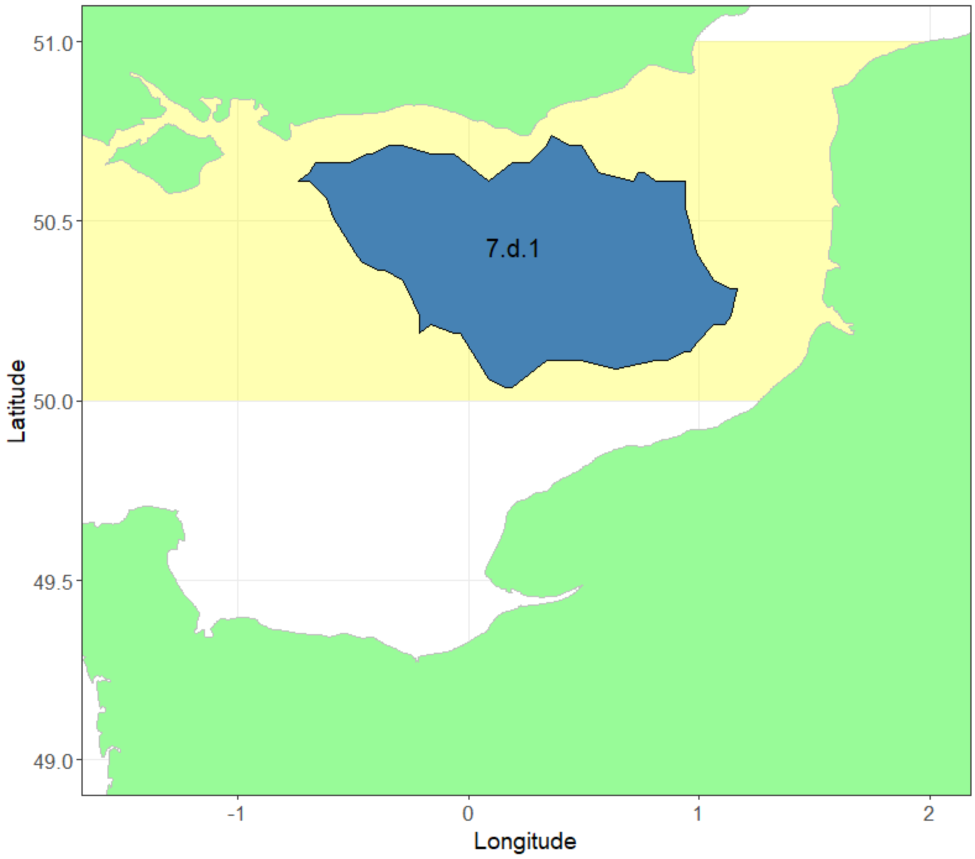


Figure 2.1 – Surveyed dredge area (Bed 7.d.1) within Assessment Area 27.7.d.N

2.2 Data Available 27.7.d.N

2.2.1 Catch and survey data

Landings by country as reported to STECF for the rectangles in assessment area 27.7.d.N are given in Table 2.1. Note that Belgian data are likely to be missing prior to 2012 although the tonnages are small. International landings after 2016 are not yet available.

Table 2.1 Landings (tonne) by country (STECF) in assessment area 27.7.d.N

	BEL	FRA	NLD	IRL	GBG	GBJ	IOM	UK	International total
2009	-	7375	299	-	-	-	15	5888	13577
2010	-	6701	148	-	-	-	-	9509	16359
2011	-	6792	-	5	-	-	-	8077	14874
2012	214	5747	-	-	-	-	-	3061	9023
2013	271	13190	-	14	-	-	-	3178	16653
2014	576	4190	-	232	-	-	-	4163	9160
2015	354	2983	-	7	-	-	-	1590	4935
2016	354	4323	-	86	-	-	-	1896	6659

The proportion of international landings, by quarter, that are generated by the UK fleet are given in Table 2.2. The landings (tonne) by country and by quarter are shown below (Figure 2.2) with grouped UK data. Winter seasons tend to show the greatest activity with the least landings occurring in the summer months (during which there is a voluntary closure by part of the UK fleet).

Table 2.2 UK fleet proportion of international landings by quarter

	Q1	Q2	Q3	Q4
2012	38.6%	16.3%	97.5%	23.1%
2013	36.4%	53.4%	67.6%	12.8%
2014	45.4%	43.5%	59.1%	44.5%
2015	24.8%	27.1%	82.8%	51.2%
2016	11.8%	8.5%	44.0%	38.1%
mean	31.4%	29.7%	70.2%	33.9%

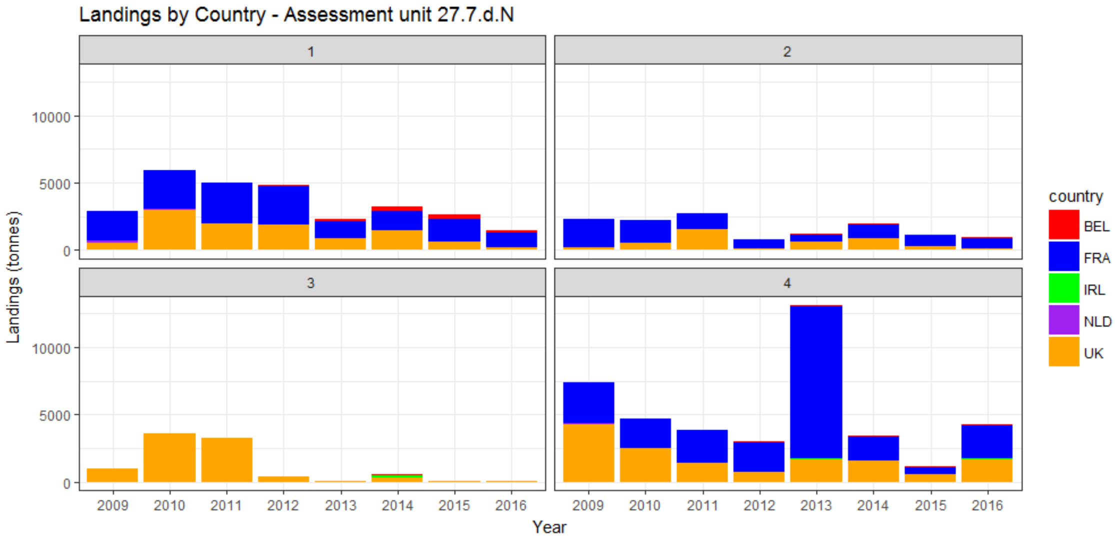


Figure 2.2 Assessment Area 27.7.d.N. Landings by country and by quarter (NB. Isle of Man, Guernsey and Jersey landings <1t per annum. Belgian landings only recorded since 2012)

There is also a lag interval in the collation of landings data within the UK; at the time of report writing (January 2019), landings data to the end of September (Q3, 2018) are considered reliable.

The fishery tends to be more active during the autumn and winter, therefore an appropriate way of viewing the landings data is by sampling season, in which a season comprises Q4 of the preceding year. UK landings data for area 27.7.d.N by quarter are summarised in Table 2.3 and indicate a large increase in 2009 compared to earlier in the time series, peaking in 2010, followed by a decline in recent years back to more typical values. This sudden increase in landings appears to have resulted from an increase in catch rates which drew in additional effort from the nomadic fleet at a time when access to other waters was becoming limited.

*Table 2.3 UK Landings (tonne) for 27.7.d.N by quarter. * provisional*

	1	2	3	4	Annual Total	Sampling Season Total (Q4, Q1, Q2, Q3)
2001	653	96	24	201	974	
2002	380	220	63	647	1310	864
2003	1228	111	6	487	1832	1992
2004	889	107	6	383	1385	1489
2005	553	133	18	529	1234	1088
2006	749	305	30	475	1559	1614
2007	653	152	51	1559	2414	1330
2008	686	479	51	606	1823	2776
2009	533	174	962	4242	5911	2275
2010	2947	514	3591	2458	9509	11294
2011	1922	1509	3256	1397	8083	9144
2012	1872	131	368	690	3061	3768
2013	831	620	40	1688	3179	2182
2014	1463	850	310	1541	4163	4310
2015	644	306	59	584	1594	2551
2016	168	78	21	1629	1897	851
2017	426	174	410	2419	3429	2639
2018	1337	1389	1581	1849*	6153*	6723

2.2.2 Discards

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 omission of discard data does not affect the estimation of fishable biomass. Scallops are assumed to have a high survival rate and therefore discard induced mortality is considered to be low.

2.2.3 Size composition

An extensive biological sampling program was started in 2017 and is described in Annex 1. The program collected both length and age samples with a higher sample collection rate on lengths than ages as is standard for fishery data collection programs. Age determination for this year has highlighted some inconsistencies between the two years of data that were not picked up during routine quality control and which will require further investigation. As such only size compositions are presented in this report.

Length samples for individual vessels were raised to UK landings on a quarterly basis before summation to total landings during each sampling season.

The number of samples collected for both years of the programme is shown (Table 2.4) below along with the number of age samples collected during the dredge survey. Age samples will be an important part of any future assessment process and are included for completeness.

Table 2.4 Sampling programme summary for stock assessment area 27.7.d.N

	Commercial Landings				Dredge Survey	
Sampling Season	**Length samples**	**Animals measured**	**Age samples**	**Shells aged**	**Age samples**	**Shells aged**
2017	10	1594	1	24	9	335
2018	41	6161	14	416	17	717

The landed numbers at size, raised to the landings data are show in Figure 2.3. There are significantly more animals at size groups above MLS in 2018 compared to 2017.

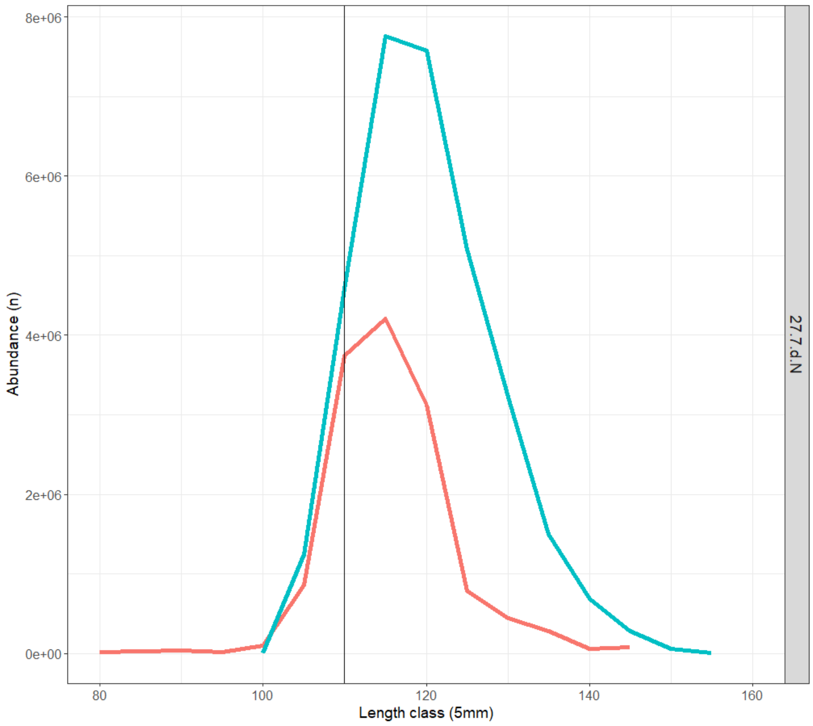


Figure 2.3. Estimated numbers by size group landed in 27.7.d.N. during 2017 (red) and 2018 (blue) sampling seasons. MLS shown

2.3 Biological Parameters and Dredge Efficiency

2.3.1 Natural mortality

Predation is the likely cause of most of the natural mortality, with brown crab and starfish being the most significant predator 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 but 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).

2.3.2 Size at maturity

Animals above Minimum Landing Size (MLS, 110 mm shell length) are almost exclusively found to be mature. Maturity is assumed to be knife-edged at 80mm shell height (based on Cefas data, unpublished).

2.3.3 Growth

Methodology for ageing at Cefas is based on work carried out by Dare and Deith (1989). Oxygen isotope assay was used to validate traditional ring counting methods and to produce von Bertalanffy growth parameters. A review of historic growth estimates including different grounds in the English Channel by Dare and Palmer provided von Bertalanffy growth parameters for assessment area 27.7.d.N (Cefas unpublished, 2001).

The von Bertalanffy model was used to estimate size at age:

$$\boldsymbol{Shell\ ht = H\infty\ (1 - exp(-k(age - t0)))}$$

where $\boldsymbol{H\infty}$ = shell height of an infinitely old scallop, $\boldsymbol{k}$ =growth rate and $\boldsymbol{t0}$ is the time at zero size.

2.3.4 Shell metric conversions

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 shell height (perpendicular to the hinge) as this axis has the least potential for damage. The minimum landing size for scallop is, however, determined using the shell length (parallel to the hinge across the widest point). As one purpose of the stock assessment is to estimate fishable 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.

The linear relationships between round shell length and both flat shell height and round shell height was investigated using an Analysis of Covariance. In this report we specifically state which size metric is used.

2.3.5 Weight – length relationship

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

The relationship between live weight and shell length is defined by:

$$\boldsymbol{Live\ wt = a.Shell\ length^{b}}$$

2.3.6 Dredge efficiency

Pecten maximus inhabits substrates from fine sand through to coarse sand and gravels 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 the fishing gear. 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 such variations in gear performance. Any biomass estimates resulting from the dredge surveys used for this assessment are sensitive to the choice of substrate specific efficiency parameters. The efficiency of spring-loaded dredges has been studied using diver observations, mark recapture methods and depletion studies (Chapman *et al*, 1977, Jenkins *et al* 2001 and Dare *et al* 1993 and 1994). However, it is a subset of results from a more recent depletion study carried out in the English Channel by Palmer *et al* (Cefas, unpublished data) that have been used for the basis of the stock abundance estimates presented here. The efficiency is defined as the percentage of scallops in the path of the dredge that are captured.

The biological and dredge efficiency parameters used in this assessment are presented in Table 2.5.

Table 2.5 Assessment parameters

Parameter	Description	Ground Type	Source
30%	Gear efficiency	Clean or clean becoming stony	Cefas (Palmer: 2001, unpublished data)
43%	Gear efficiency	Flint cobbles	Cefas (Palmer: 2001, unpublished data)
a= 1.55×10^{-3} b=2.45609	Weight – shell length	NA	IFREMER (unpublished data)
a=1.208916 b=-5.386429	Shell metric conversion - Flat height to round length	NA	Eastern Channel dredge survey 2017
80mm shell hgt (~90 length)	Size at maturity	NA	Cefas (unpublished data)
0.15 all ages	Natural mortality	NA	Cook *et al.*, 1990
h_∞=119.3, k=0.516, t0=0.692	von Bertalanffy Growth	NA	Cefas (unpublished review)

2.4 Dredge Surveys

2.4.1 Survey design description

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

2.4.2 2018 survey

The 2018 survey is the second dredge survey carried out it in this region as part of this programme.

In 2017 the survey was restricted to the UK Exclusive Economic Zone (EEZ) whereas the survey in 2018 included tows in the French EEZ. For 2018 four additional tows were carried out in a small recently defined bed (7.d.2) in the 27.7.d.S assessment area to the south of bed 7.d.1.

A chartered commercial fishing vessel was used to survey a grid of fishing stations as defined in the survey design (Annex 2) and shown in Figure 2.4. The commercial fishing vessel used for the survey this year was a 24m scallop dredger which usually fishes 20 “Newhaven” type dredges each side, and which facilitates short tow durations for effective sampling. A larger vessel was used in the first survey carried out in 2017 (details in first report). The vessel deploys a conveyor system to take catch down from the main deck to the factory deck for sorting.

The starboard side used 4 modified dredges and 6 standard dredges, and a wooden marker was used to keep the catch from the two gear types separate on the conveyor belt (see Figure 2.5). The port side beam used a standard 10 commercial dredge configuration. The beams were deployed synchronously for 15 minutes at approximately 2.5-3 knots (kts). The inclusion of the modified dredges was to allow for sampling of smaller size scallops that would otherwise be under-sampled using the standard commercial gear. N.B. The length distributions from the 4 modified dredges have been used for exploratory purposes only and are not included in this assessment.

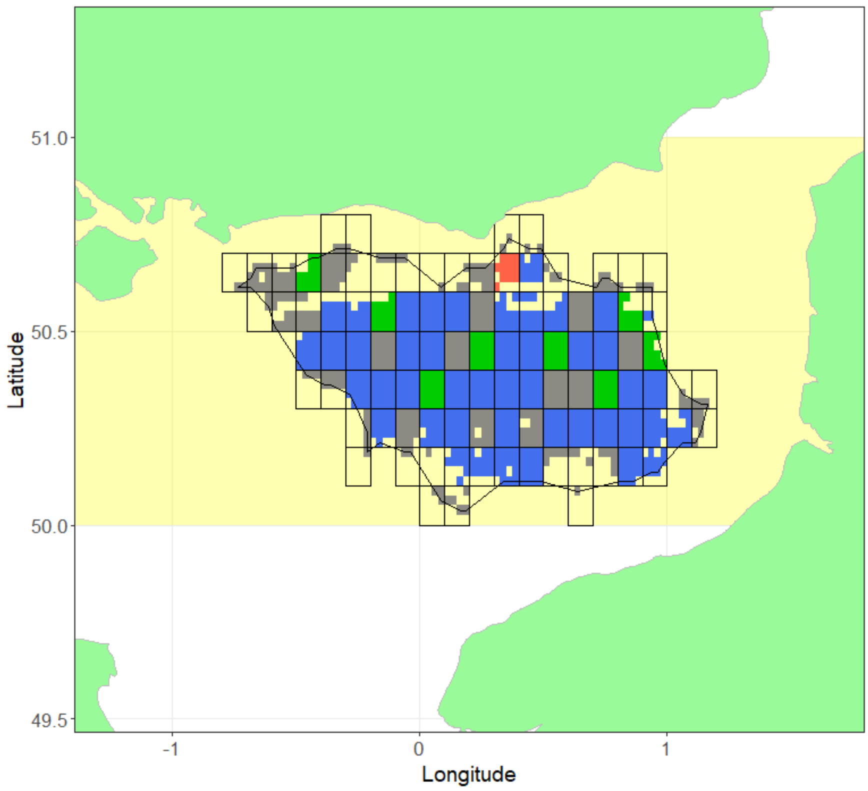


Figure 2.4. Sampled blocks in Bed 7.d.1, 27.7.d.N. Block shading indicates the total number of stations within each block 0 =grey, 1=blue, 2=green and 3=red

Forty-four randomly selected tows were surveyed in the UK part of bed 7.d.1 between 5th – 7th September and twenty-one tows in the French EEZ of bed 7.d.1 between 30th – 31st October 2018.

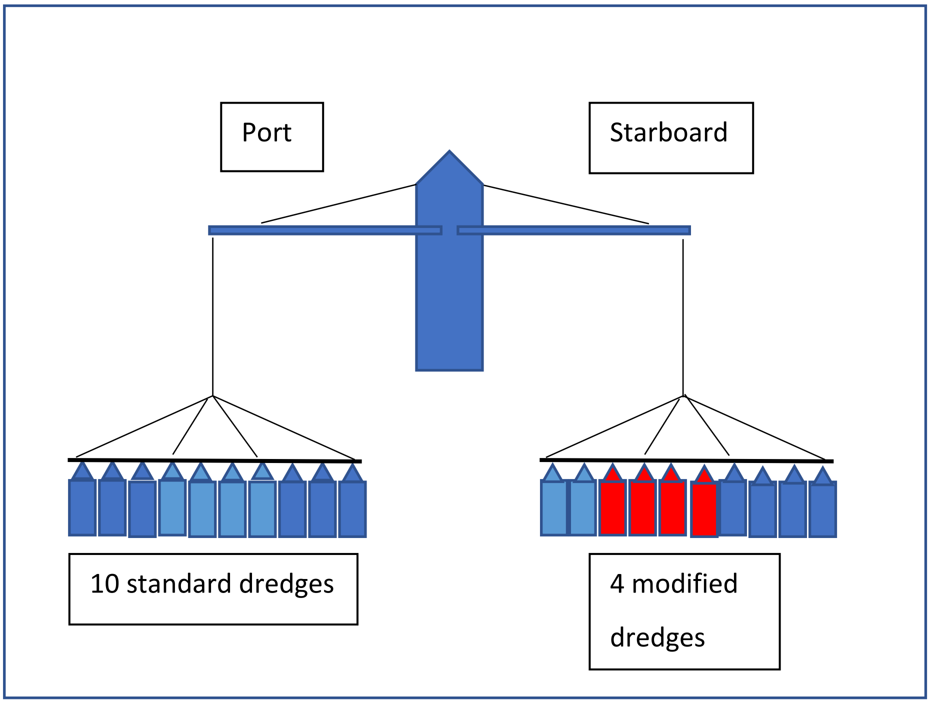


Figure 2.5 Gear configuration on survey vessel

The standard gear (Newhaven type dredges) were 75cm wide and fitted with 85-mm ring bellies and 8-teeth swords (tooth bars). The modified dredges were 75cm 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, shell length measured to the nearest mm. The numbers of scallop in each length sample and each sampled component of the catch were recorded to provide raising factors.
- Five individuals per 5mm size bin were retained for age determination at selected sites within each bed.

2.5 Survey Processing

The processing of the dredge survey data is detailed in Annex 3. The essence of the approach is to determine the swept area of the gear and then calculate the relative biomass density of caught scallops above MLS from the swept area and catch of scallop >MLS. These densities are then converted to absolute densities using the gear efficiency parameter appropriate to the ground type (Table 2.5). An arithmetic approach was taken to raise the survey data, as per last year, with the observed cells of randomly selected stations first being raised to the valid surface area of the block the cell was in. Cells within unsampled blocks were assumed to have the same density as the median sample density from randomly selected stations; the median density was taken to account for the skewed distribution of the station densities. This year all tow positions were randomly selected negating the need to apply appropriate procedures to industry selected tows to maintain statistical integrity.

2.5.1 Raised biomass estimates and uncertainty

The estimated biomass of harvestable scallop (>110mm) raised to each block is presented for 2017 and 2018 in Figure 2.6. Biomass estimates for the small Bed 7.d.2 are included in section 3.

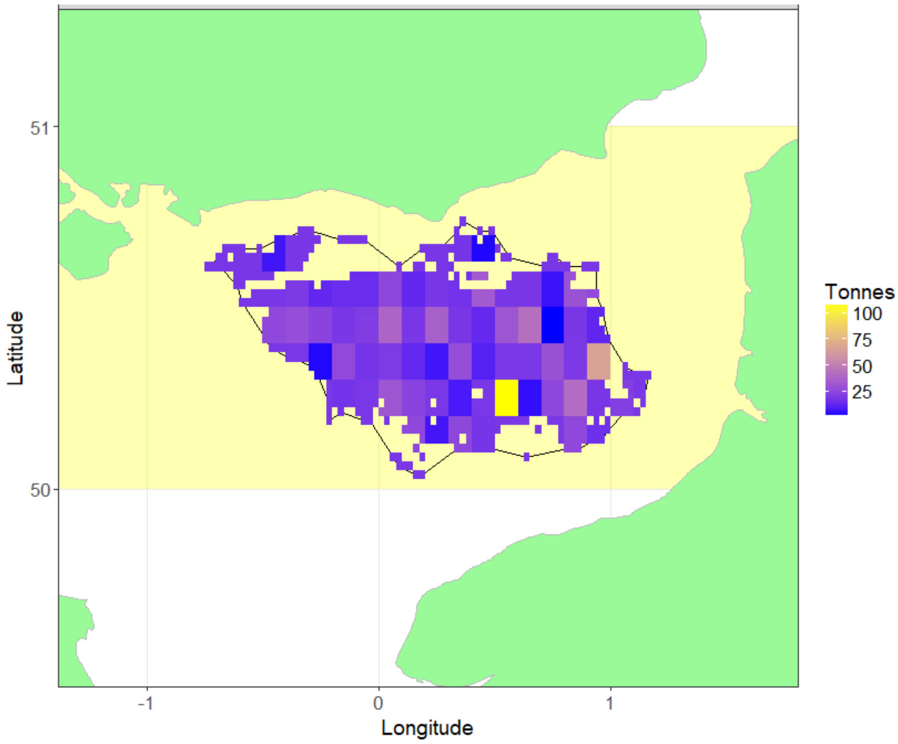


Figure 2.6 – Biomass (Tonnes) of harvestable (above 110mm length) scallops in Bed 7.d.1, Assessment Area 27.7.d.N (yellow)

In order to estimate the uncertainty around the estimate of harvestable biomass, the samples for each bed were bootstrapped 5000 times with replacement (Figure 2.7). For each iteration, the same raising procedure was used as for the main biomass estimation routine. The point estimate, along with median, 25th and 75th percentiles are given in Table 2.6. As the point estimate utilises all available data it is considered the most appropriate value for the biomass estimates.

In 2017 tows in the French EEZ were not surveyed and a bed mean density was used to estimate biomass in this unsampled area. In 2018 the French EEZ was surveyed allowing actual densities to be raised to this area.

Table 2.6 Median biomass, point estimate and percentiles dredged areas of 27.7.d.N for 2017 and 2018

Gear	Year	25th Centile (Tonnes)	Median Biomass (Tonnes)	Point Estimate (Tonnes)	75th Centile (Tonnes)
Commercial	2017	20876	22732	22981	24602
Commercial	2018	23506	24965	25047	26332

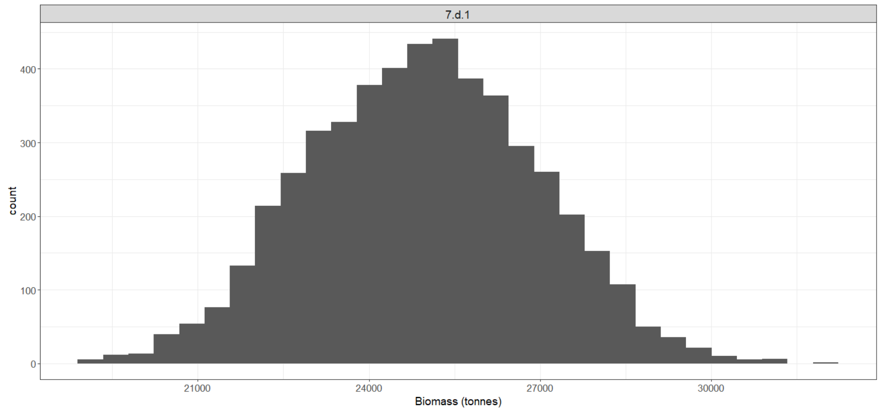


Figure 2.7 Distribution of biomass estimates for Bed 7.d.1 in 2018 from bootstrapping procedure

2.5.2 Size composition from dredge survey

From the size frequencies taken at each station, a total length frequency was derived and raised to the total population estimate (biomass). A larger portion (53%) of the 2018 survey catch in Bed 7.d.1 was below the MLS, compared to 36% in the 2017 survey.

The size distributions of the survey catches do not compare directly to those from the commercial landings as they are raised to total estimated biomass as opposed to reported removals (Figure 2.8). There is evidence of a pulse of smaller scallop below MLS in the survey size distributions not retained in those generated from the commercial samples. This is understandable given the large proportion of catch that was below the minimum landing size in the surveys. There is significantly more scallop in the 110mm size group in the 2018 survey compared to the 2017 survey.

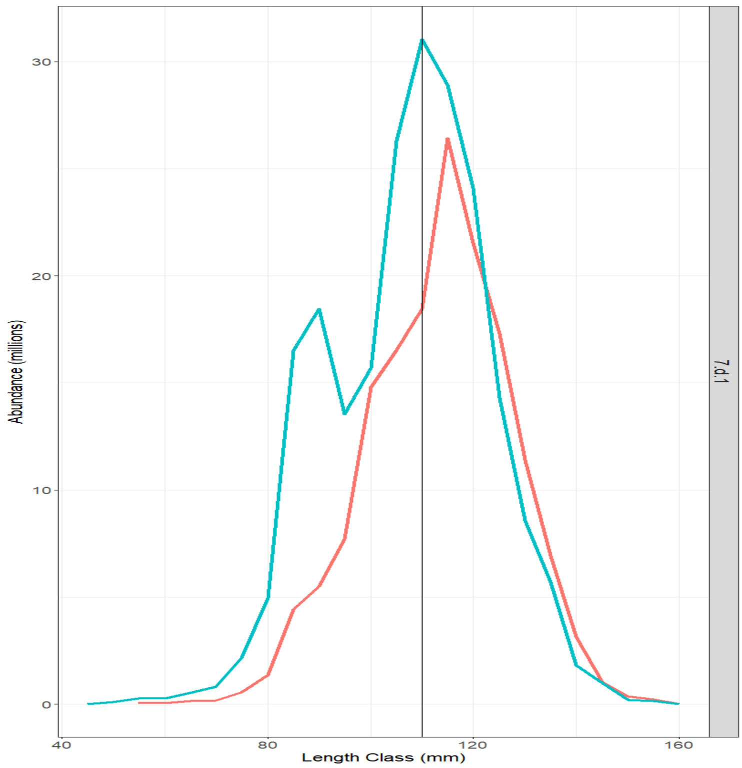


Figure 2.8 – Dredge survey: Length distributions of the scallop population in surveyed areas of Assessment Area 27.7.d.N for 2017 (red) and 2018 (blue)

2.6 Harvest Rate Estimation

The harvest rate (i.e. the ratio of landings to total harvestable biomass) is proposed to give a proxy for the fishing mortality experienced by this stock area. Ideally this will be constructed from the biomass immediately prior to the fishery and then compared to the removals from the observed biomass. However, international landings for the two most recent years were not available at the time of this assessment. Instead, for those rectangles which intersect bed 7.d.1, we used the UK landings as reported on the national database, raised by the average ratio of the UK component of the international landings (2009-2016) reported to STECF (Table 2.7). This assumes that the UK share of the international landings has been consistent in recent times. For the 2017 assessment year we have used landings for the 12-month period subsequent to the completion of the dredge survey (October-December 2017 and January-September 2018). Reported landings for the 2017 calendar year and corresponding estimate of harvest rate are included for comparison. For the 2018 assessment year we have used landings for the calendar year only, to provide a provisional harvest rate estimate. All harvest rate estimates are provisional at the time of this report and will be revised when data become available.

The best estimate of harvest rate uses the point estimate from all data, the range uses the 25th and 75th centile from the bootstraps (resampling exercise).

Biomass estimates for un-dredged areas of 27.7.d.N were not assessed using video survey in 2018 (or 2017), and as such harvest rate estimates only covers the fished part of the stock. There is additional stock outside the area surveyed with dredges but for which there are currently no data on either their biomass or ability to contribute recruitment to the main areas of fished stock.

Table 2.7 Biomass and Provisional harvest rate estimate for dredged areas of 27.7.d.N for 2017 and 2018

Year	Biomass Removed (tonnes)	Harvestable Biomass Estimate in Dredged Area (tonnes)	Provisional Harvest Rate on Dredged Portion Of Stock (%)	Provisional Harvest Rate Range (%, from resampling exercise)
2017*	17078	22981	74.3	69.4-81.8
2017+	8708	22981	37.9	35.4-41.7
2018*	NA	25047	NA	NA
2018+	15630	25047	62.4%	59.4-66.5

** biomass removal during 12-month period after survey. + removals during calendar year and provisional harvest rate estimates. All harvest rate estimates are provisional, to be updated. See explanation in text*

2.6.1 Landings size compositions – cohort modelling

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

In the first assessment (2018 report) we used an age-based cohort model to determine fishing mortality assuming the populations had been at equilibrium ("steady-state"), that is that fishing effort, recruitment and growth have all been constant. Deviations from this assumption will cause the model to give unreliable answers.

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

The Provisional harvest rate for the dredged portion of the stock and a candidate harvest rate consistent with MSY and estimated using the cohort method is presented in Table 2.8.

Table 2.8 Provisional harvest rate estimates for dredged areas of 27.7.d.N and an MSY candidate

Year	Provisional harvest rate on dredged portion of stock (Dredge Survey Only, %)	MSY Candidate Harvest Rate (%)
2017*	74.3	21
2018+	62.4	21

* biomass removal during 12-month period after survey. + removals during calendar year and provisional harvest rate estimates. All harvest rate estimates are provisional, to be updated (See explanation in text).

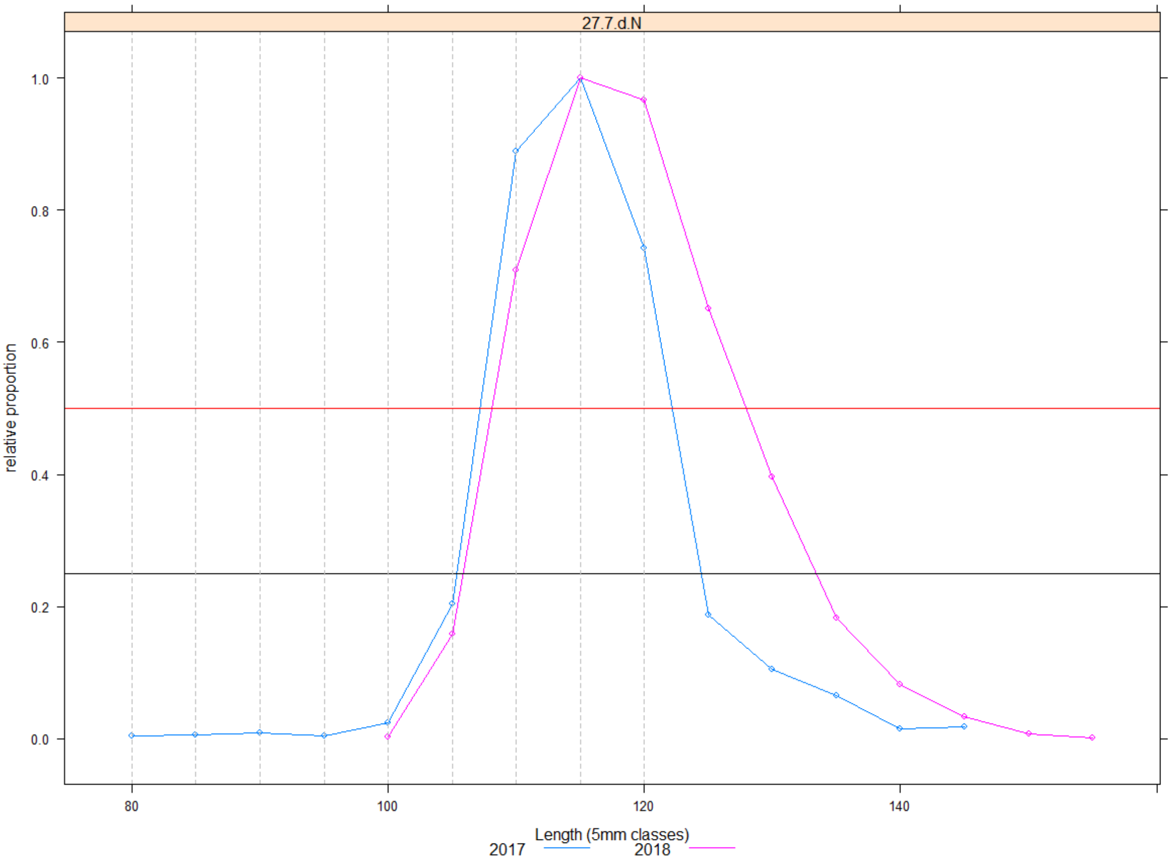


Figure 2.9 - Scaled landed size distributions as a proportion of highest mode. Horizontal reference lines at 25% (blue) and 50% (red)

Age compositions are being reviewed and are not presented in this report.

2.7 MSY Reference Point Estimation

Full estimation of the fishing mortality that generates maximum sustainable yield (MSY) requires a full analytical assessment and an estimate of the stock-recruitment relationship. Clearly this is not yet possible as is the case with many stocks assessed by ICES. In such cases, ICES 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, both within ICES and more widely around the globe. Fmax, the fishing mortality which gets the maximum yield from each recruited individual is also sometimes used as a proxy for the fishing mortality which provides the maximum sustainable yield (Fmsy), but is unlinked to spawning potential, is more uncertain in its estimation and in some circumstances, suggests fishing rates which are highly risky for the stock size.

A simple yield -per recruit model was constructed using selection-at-size and maturity-at-size parameters estimated in this assessment. This model estimates that in order to achieve F35%SpR, a harvest rate in the vicinity of 21% would be required. The Fmax estimate for this stock is very high (because there is relatively little growth potential after the MLS has been reached compared to expected losses through natural mortality). Following the Fmax estimate for this stock would remove ~66% of the harvestable stock in each year and reduce the spawning potential to ~15% of its virgin state is therefore considered to be highly risky strategy. The recommended FMSY reference point for this stock is therefore F35%SpR.

2.8 Conclusions

This is the second stock assessment undertaken for scallops in this region. This year the assessment includes biomass estimates and provisional harvest rates from the dredge survey.

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

Length structured modelling provides context for the harvest rate estimates. Presently the provisional harvest rate for this area is over 3.5 times higher than the harvest rate consistent with MSY. We note that if we had assumed that foreign landings were the same as in 2016, as opposed to proportional to UK landings, then the estimated harvest rate would be reduced to 50% (2.4 times higher than MSY). This highlights the importance of having access to the most recent international landings data.

The large variation in reported landings between 2017 and 2018, combined with a potential pulse in incoming recruitment suggests that the population in this area is not at equilibrium. The assumption of equilibrium is fundamental to the cohort models and yield per recruit estimates investigated in the 2017 report. As a result of these concerns, a modelling method which utilises scaled length samples was considered more appropriate than the age-based method used for the first assessment.

This year a change to a smaller survey vessel deploying less dredges was unavoidable. Both survey vessels deploy very similar gear and catches of scallop are standardised to area swept but no comparative tow work was carried out to confirm there was no change in catchability. As such caution should be used when comparing the 2017 and 2018 survey results.

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

It should be noted that the assessment of scallops in 27.7.d.N only covers the fished part of the stock and there is known to be additional stock outside the area surveyed but for which there are currently no data on either their biomass or ability to contribute recruitment to the fished stock. Future surveys of un-dredged areas are planned and, provided that there is evidence that scallops in un-dredged areas make significant contributions to those in dredge areas, proportionate inclusion of biomass from un-dredged areas is likely to revise the estimates of realised harvest rate downwards.

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.

3 Dredge survey of bed 7.d.2 in 27.7.d.S

3.1 Area Definition

VMS data from 2009 to 2016 were used to define the original beds in all assessment areas, but reported and recent expansion of the fishery to the south of bed 7.d.1 led to further investigation of these data. Inclusion of 2017 VMS data (the latest available at the time) enabled the definition of a second bed (7.d.2) in the Eastern English Channel. This bed falls almost exclusively within area 27.7.d.S but as it lies between the area in the Baie de Seine assessed by French scientists and Bed 7.d.1 assessed as part of this project it was deemed appropriate to survey this area.

3.1.1 2018 dredge survey

Results from four dredge tows carried out in a new bed (7.d.2) are presented below. Bed 7.d.2 comprises an area of 140km^2 and was defined at the request of industry colleagues using the latest VMS data available at that time (defined early in 2018 and includes 2017 data).

The sampling summary is presented in Table 3.1 and the number of sampled blocks in Figure 3.1.

Table 3.1 Sampling summary from dredge survey in bed 7.d.2 in 2018

Bed	Number of stations	Number of length samples	Number measured	Number aged
7.d.2	4	4	238	46

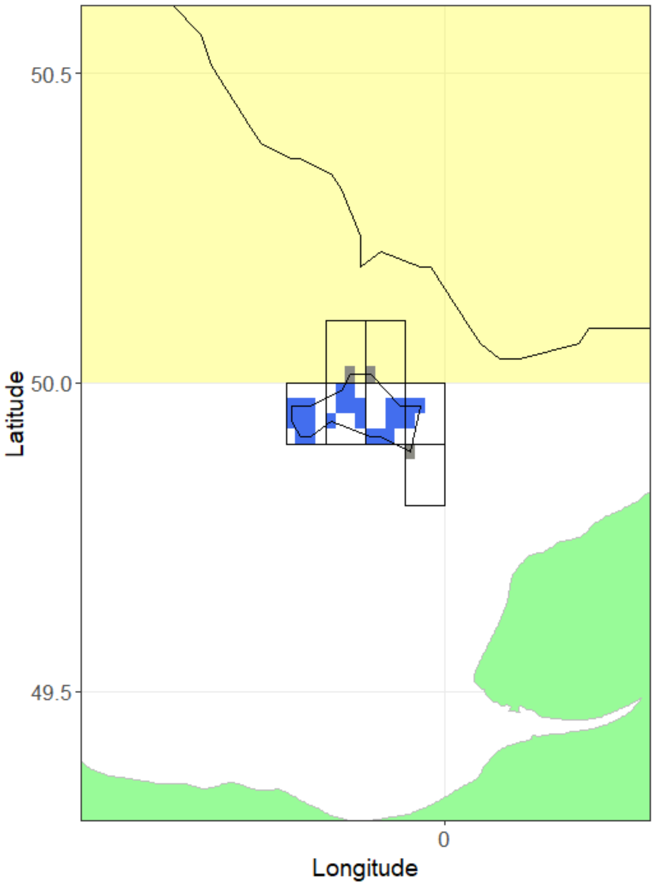


Figure 3.1 Sampled blocks in Bed 7.d.2, in assessment area 27.7.d.S in 2018. Block shading indicates the total number of stations within each block 0 =grey, 1=blue

3.1.2 Raised biomass estimates and uncertainty

The estimated harvestable biomass of harvestable scallop (>110mm) raised to each block is presented in Figure 3.2.

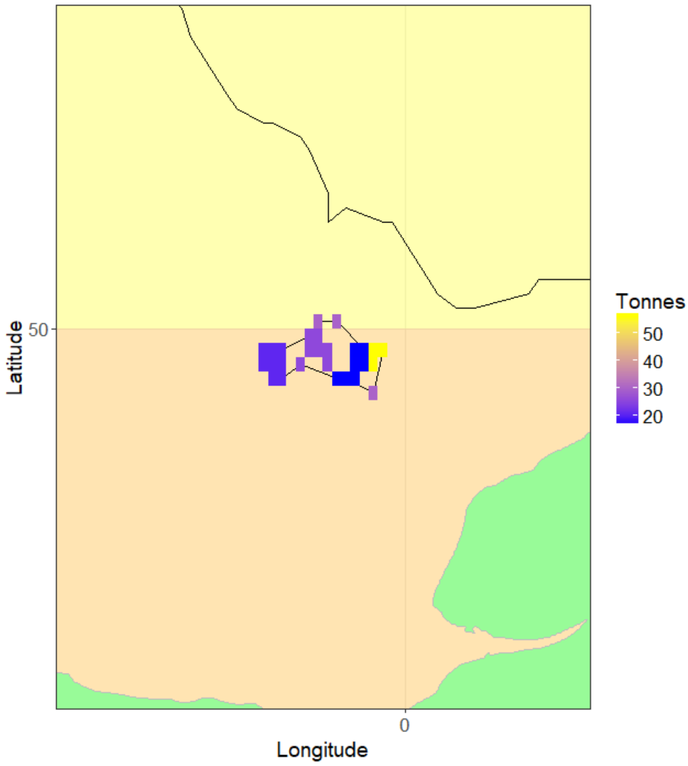


Figure 3.2 - Biomass (Tonnes) of harvestable (above 110mm length) scallops in the surveyed areas within bed 7.d.2, assessment area 27.7.d.S in 2018

In order to estimate the uncertainty around the estimate of harvestable biomass, the samples for each bed were bootstrapped 5000 times with replacement. For each iteration, the same raising procedure was used as for the main biomass estimation routine. The median, 25th and 75th percentiles and point estimates are given for each assessment area in Table 3.2.

Table 3.2 Biomass estimation for the dredge surveyed bed 7.d.2 for 2018

Bed	25th centile (tonnes)	Median harvestable biomass tonnes	Point estimate (tonnes)	75th centile (tonnes)
7.d.2	628	738	721	833

3.1.3 Size composition from dredge survey

From the size frequencies taken at each station, a total length frequency was pooled to the total population estimate for the bed (Figure 3.3).

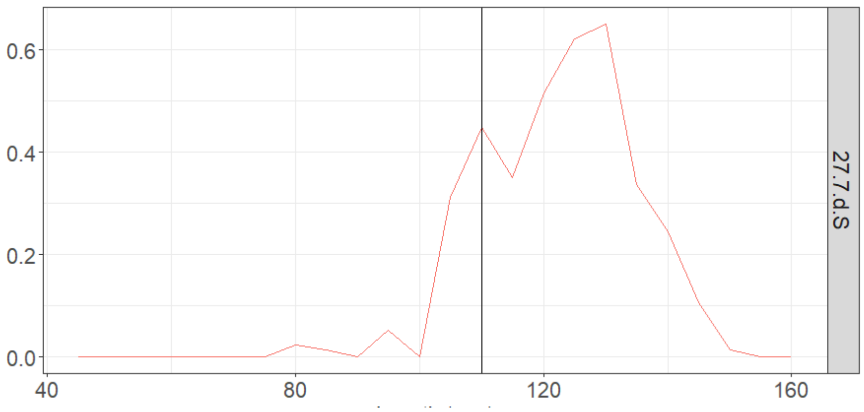


Figure 3.3 – Dredge survey: Numbers (millions) per length class (mm) for the scallop population in surveyed areas of 7.d.2 in 2018

3.2 Conclusions

This bed was defined following recent spatial expansion of fishing activity by both UK and French fleets and is the first dredge survey undertaken for scallops in this bed. This bed is positioned between 7.d.1 in assessment area 27.7.d.N and survey areas in the Baie de Seine carried out in 27.7.d.S by IFREMER. There is scope for assessment area 27.7.d.S to be internationally assessed.

Only four tows were carried out in this small bed and as such the biomass estimates are only indicative.

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

4 Stock Assessment in surveyed areas of 27.7.e and 27.7.f

4.1 Area Definitions

As described in Section 1.2, three scallop assessment areas which encompass the majority of areas fished by UK vessels have been defined within ICES division 27.7.e; 27.7.e.I (Inshore Cornwall), 27.7.e.L (Lyme Bay) and 27.7.e.O (Offshore). Within these there are eight scallop beds; two scallop beds are within 27.7.e.I, three within 27.e.L, and three within 27.7.e.O. Two of the beds (4 and 5) straddle two of the assessment areas; these beds have been assigned to the assessment area into which the majority of it lies (Figure 4.1). Beds 7 and 8 lie predominantly in the EEZ of Guernsey with a small part of bed 8 lying over the median line with France. In 2018 a new bed was created and surveyed in assessment area 27.7.f.I (Inshore). 27.7.f.I is within ICES division 27.7.f and located off the North Cornish coast.

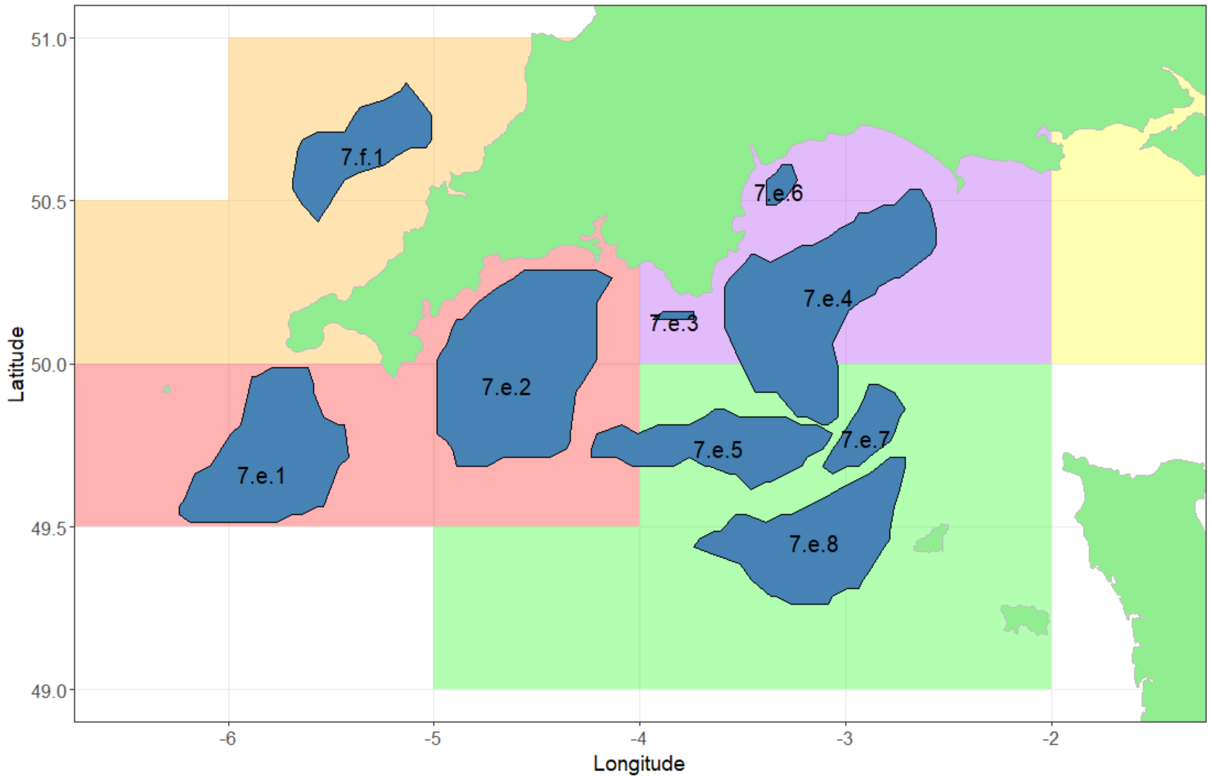


Figure 4.1– Beds 7.e.1 and 7.e.2 within Assessment Area 27.7.e.I (red), Beds 7.e.3, 7.e.4 and 7.e.6 in 27.7.e.L (purple), Beds 7.e.5, 7.e.7 and 7.e.8 in 27.7.e.O (green), and bed 7.f.1 in 27.7.f.I (orange)

4.2 Data Available 27.7.e and 27.7.f

4.2.1 Catch, and survey data

Landings by country as reported to STECF for the three assessment areas in 27.7.e and the one assessment area in 27.7.f are given in Table 4.1. Note that Belgian data are likely to be missing prior to 2012 although the tonnages are generally small. Rectangle 29E4 contains waters in both 27.7.e and 27.7.f. It is assumed that non-UK landings from 29E4 are from the 27.7.f area because all the 27.7.e waters lie inside 6 nautical miles where non-UK vessels are not entitled to fish.

Table 4.1. STECF Landings by for the three assessment areas in 27.7.e and f

27.7.e.l

	BEL	FRA	NLD	IRL	GBG	GBJ	IOM	UK	International
2009	-	36	181	-	-	-	-	2261	2478
2010	-	37	107	-	-	-	-	1029	1173
2011	-	55	-	1	-	-	-	1790	1846
2012	55	7	-	2	-	-	-	2502	2565
2013	1	34	-	1	-	-	-	2372	2409
2014	79	0	-	4	-	-	-	1667	1751
2015	102	0	-	33	-	-	-	3711	3846
2016	71	4	-	28	-	-	0	2836	2938
27.7.e.L	**BEL**	**FRA**	**NLD**	**IRL**	**GBG**	**GBJ**	**IOM**	**UK**	**International**
2009	-	37	47	-	0	-	-	1725	1809
2010	-	30	16	-	-	-	-	2554	2600
2011	-	40	-	-	-	-	-	3720	3761
2012	13	3	-	-	0	-	-	2953	2969
2013	4	35	-	-	-	-	-	2351	2390
2014	24	0	-	-	-	-	-	1834	1858
2015	10	1	-	-	-	-	-	1246	1257
2016	5	1	-	-	-	-	-	1416	1422
27.7.e.O	**BEL**	**FRA**	**NLD**	**IRL**	**GBG**	**GBJ**	**IOM**	**UK**	**International**
2009	-	828	66	-	-	-	-	2054	2948
2010	-	808	-	-	0	1	-	3140	3949
2011	-	671	-	-	-	0	-	1638	2309
2012	171	635	-	-	0	-	-	2643	3449
2013	14	817	-	2	-	-	-	3032	3866

2014	104	1141	-	1	-	-	-	1352	2597
2015	47	717	-	3	0	-	-	1055	1823
2016	58	764	-	-	0	-	0	891	1713

27.7.f.I	BEL	FRA	NLD	IRL	GBG	GBJ	IOM	UK	International
2009	-	-	-	0	-	-	-	203	203
2010	-	-	-	32	-	-	-	541	573
2011	-	-	-	143	-	0	-	140	284
2012	125	-	-	15	-	-	-	159	299
2013	135	-	-	47	-	-	-	393	575
2014	137	-	-	21	-	-	-	161	320
2015	78	-	-	-	-	-	-	35	114
2016	61	-	-	81	-	-	0	109	250

International landings data since 2016 are not yet available. There is also a lag in the collation of landings data within the UK. At the time of writing (January 2019), landings data to the end of September (Q3, 2018) are considered reliable. A sampling season is defined as quarter 4 in the preceding year and quarters 1 to 3 in the current calendar year

There is a seasonal pattern within the three areas, with Lyme Bay tending towards a year-round fishery, Inshore Cornwall being more of a Q2-3 fishery and offshore being more a Q3. UK data for the three assessment areas in 27.7.e and the one in 27.7.f by quarter are given in Table 4.2.

Table 4.2. Quarterly landings UK data by assessment area in 27.7.e and f

27.7.e.I	Q1	Q2	Q3	Q4	Annual	Sampling Season (Q4, Q1, Q2, Q3)
2001	222	1063	1071	145	2523	
2002	145	613	1182	95	2045	2086
2003	186	811	1169	207	2380	2261
2004	208	1050	1390	132	2901	2856
2005	441	1330	1388	162	3331	3292
2006	385	1280	1486	126	3286	3314
2007	207	551	684	82	1557	1567
2008	85	259	760	161	1357	1187
2009	219	791	1150	110	2281	2321

2010	92	461	401	80	1053	1063
2011	96	738	893	65	1869	1806
2012	240	1299	856	115	2553	2460
2013	194	823	1250	107	2508	2380
2014	81	578	890	119	1710	1655
2015	173	2255	1113	171	3823	3660
2016	320	1414	877	234	2879	2783
2017	245	912	1029	210	2398	2381
2018	269	1009	719	110	2107	2208

Table 4.2. Quarterly landings UK data by assessment area in 27.7.e and f continued

27.7.e.I	Q1	Q2	Q3	Q4	Annual	Sampling Season (Q4, Q1, Q2, Q3)
2001	515	423	176	361	1475	
2002	518	490	284	176	1468	1652
2003	131	330	276	236	973	913
2004	325	511	385	553	1775	1458
2005	626	721	465	977	2788	2365
2006	860	777	194	455	2286	2808
2007	521	740	268	482	2011	1984
2008	332	450	414	542	1737	1677
2009	544	539	395	343	1821	2019
2010	697	695	302	939	2633	2037
2011	1168	934	839	865	3807	3880
2012	964	591	558	915	3029	2979
2013	871	591	493	452	2408	2871
2014	504	611	416	354	1896	1988
2015	293	336	421	321	1371	1410
2016	385	278	408	493	1564	1391
2017	410	534	331	427	1703	1770
2018	304	397	563	625	1890	1699

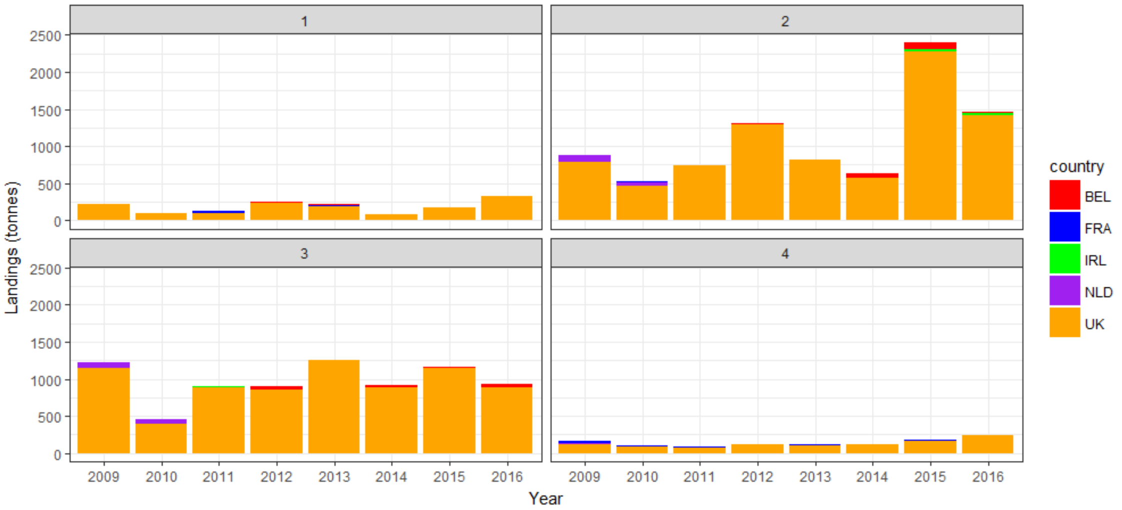
27.7.e.O	Q1	Q2	Q3	Q4	Annual	Sampling Season (Q4, Q1, Q2, Q3)
2001	183	350	35	11	578	
2002	116	450	118	37	720	695
2003	138	572	296	133	1139	1043
2004	205	318	72	105	700	728

2005	90	179	91	22	381	465
2006	150	140	147	122	559	458
2007	417	1108	817	65	2407	2464
2008	94	1022	411	81	1609	1593
2009	428	1299	314	13	2054	2121
2010	418	2251	465	7	3141	3147
2011	350	1116	158	13	1638	1631
2012	939	1488	120	114	2662	2561
2013	449	1351	1165	68	3032	3078
2014	184	427	695	45	1352	1375
2015	133	313	589	20	1055	1080
2016	130	272	480	11	892	902
2017	44	307	192	57	600	553
2018	91	367	431	429	1319	947

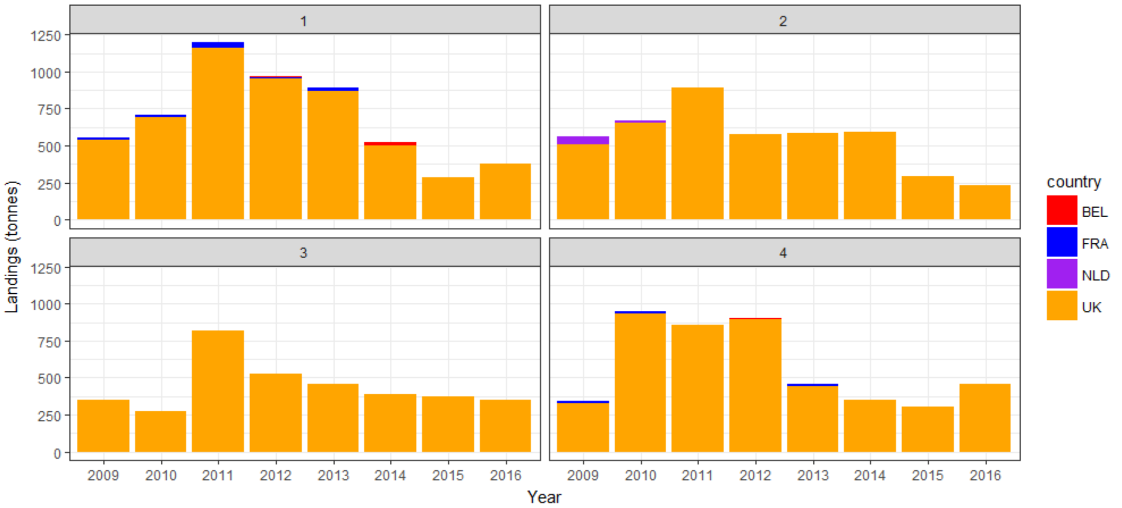
Table 4.2. Quarterly landings UK data by assessment area in 27.7.e and f continued

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

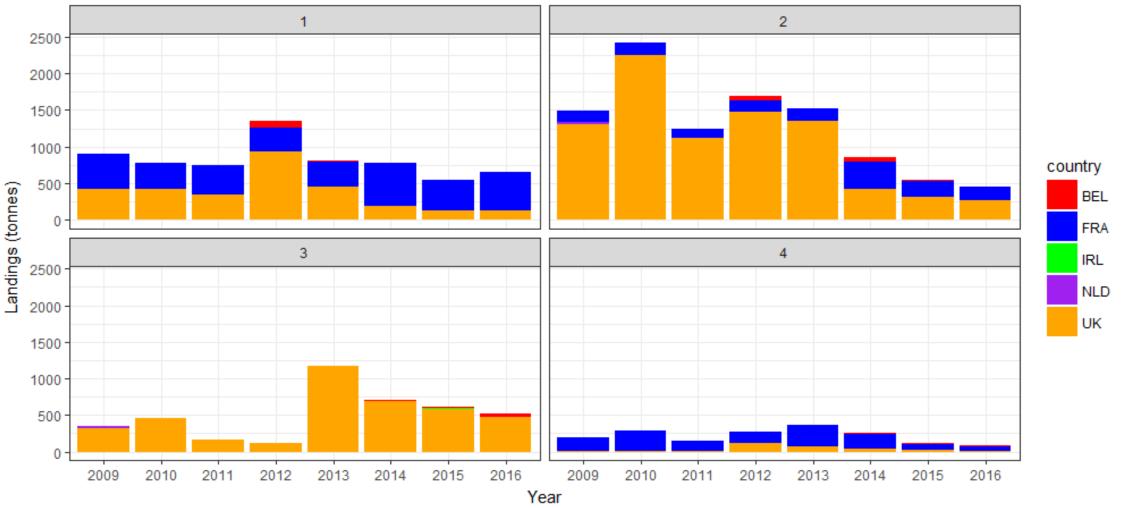
Landings by Country - Assessment unit 27.7.e.I



Landings by Country - Assessment unit 27.7.e.L



Landings by Country - Assessment unit 27.7.e.O



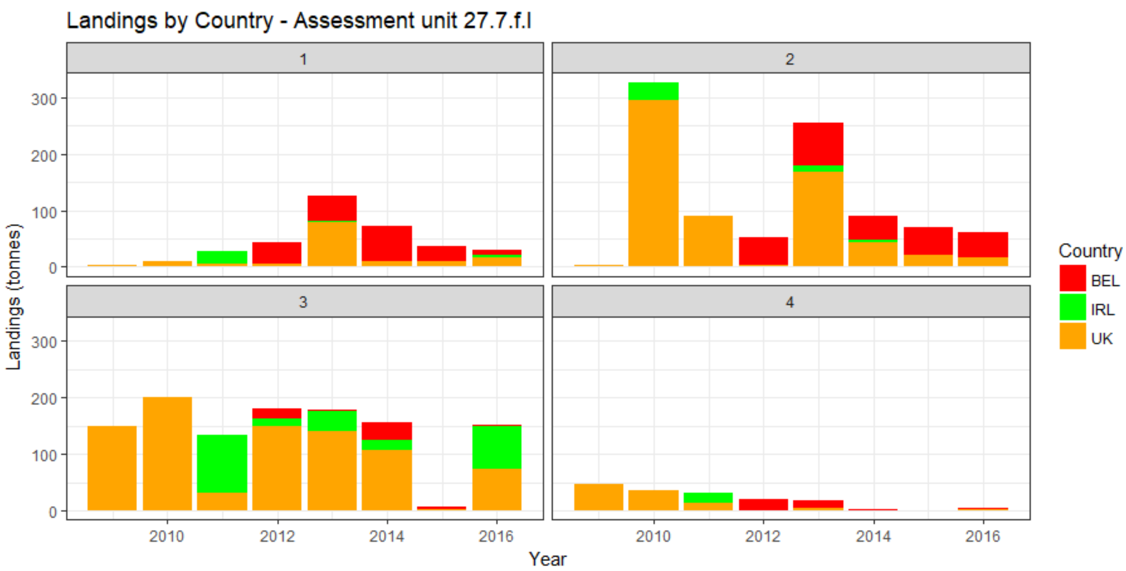


Figure 4.2. Assessment 27.7. Landings by country and by quarter (NB. Isle of Man, Guernsey and Jersey landings <1t per annum. Belgian landings only recorded since 2012)

Figure 4.2 shows the landings by country and quarter within the assessment areas in 27.7.e and 27.7.f. Annual landings in 7e inshore and Lyme Bay assessment regions are almost exclusively UK landings, with small tonnages in both areas from France, Belgium and the Netherlands. UK landings are most prevalent in 7e offshore with the exception of quarter 4 and the last three years in quarter 1, where French landings are higher. Landings from area 7f are small.

4.2.2 Discards

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 omission of discard data does not affect the estimation of harvestable biomass. Scallops are assumed to have a high survival rate and therefore discard induced mortality is considered to be low.

4.2.3 Size composition

An extensive biological sampling program was started in 2017 and is described in Annex 1. The program collected both length and age samples with a higher sample collection rate on lengths than ages as is standard for fishery data collection programs. Age determination for this year has highlighted some inconsistencies between the two years of data that were not picked up during routine quality control and which will require further investigation. As such only size compositions are presented in this report.

Length samples for individual vessels were raised to UK landings on a quarterly basis before summation to total landings during each sampling season.

The number of samples collected for both years of the programme is shown (Table 4.3) below along with the number of age samples collected during the dredge survey. Age samples will be an important part of any future assessment process and are included for completeness.

Table 4.3 Sampling programme summary

		Commercial Landings				Dredge Survey	
Assessment Area	**Sampling season**	**Length samples**	**Animals measured**	**Age samples**	**Shells aged**	**Age samples**	**Shells aged**
27.7.e.I	2017	25	4472	9	237	8	330
	2018	24	4353	9	243	16	506
27.7.e.L	2017	19	3502	7	271	3	141
	2018	23	4544	9	283	5	134
27.7.e.O	2017	8	1340	3	85	6	260
	2018	8	1237	6	178	14	475
27.7.f.I	2017	2	404	-	-	-	-
	2018	1	173	1	26	3	100

The landed numbers at size, raised to the landings data by each assessment area are shown in Figure 4.3. The size distribution for 27.7.e.I and 27.7.e.O indicates an increase in scallop at MLS in 2018 compared to 2017. This effect is not as evident in 27.7.e.L. The length distributions for 27.7.f.I were not adequately sampled in this assessment season and are not presented.

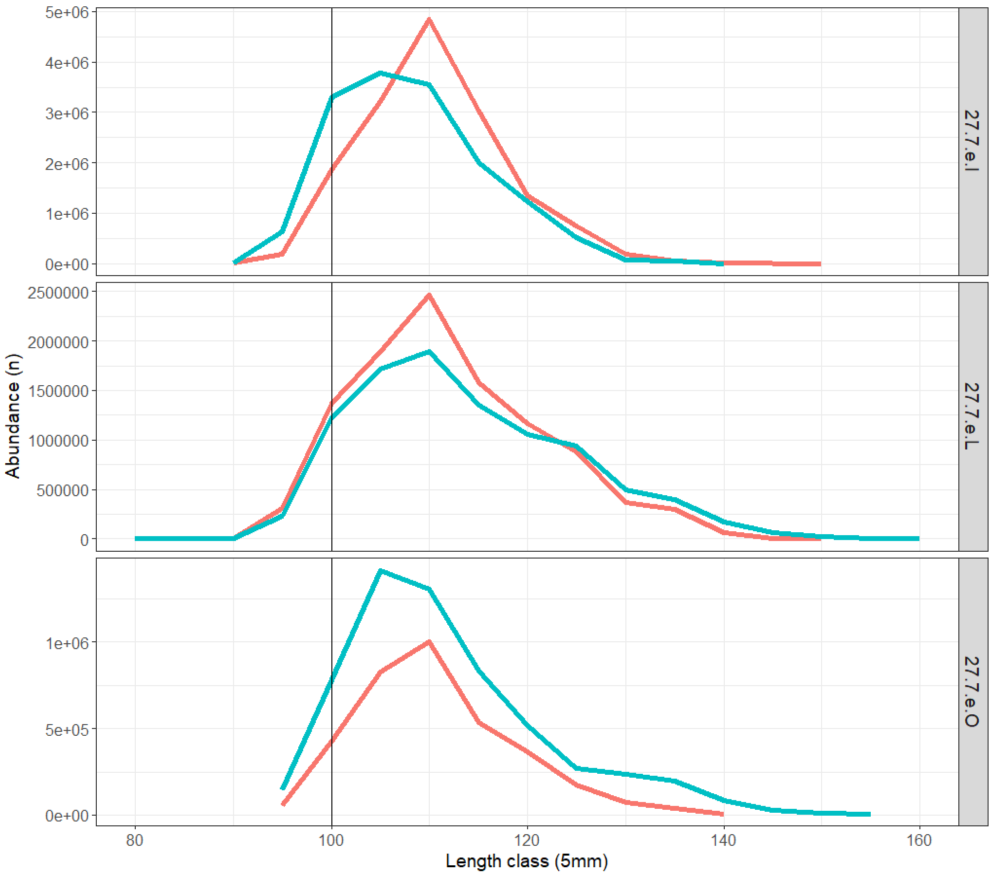


Figure 4.3 Estimated numbers in size group landed in 27.7.e.I, L and O during the 2017 (red) and 2018 (blue) sampling seasons. MLS shown

4.3 Biological Parameters and Dredge Efficiency

4.3.1 Natural mortality

Predation is the likely cause of most of the natural mortality, with the brown crab and starfish being the most significant predator 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 but 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).

4.3.2 Size at maturity

Animals above MLS (100 mm shell length) are almost exclusively found to be mature. Maturity is assumed to be knife-edged at 80mm shell height (based on Cefas data, unpublished).

4.3.3 Growth

Methodology for ageing at Cefas is based on work carried out by Dare and Deith (1989). Oxygen isotope assay was used to validate traditional ring counting methods and to produce von Bertalanffy growth parameters. A review of historic growth estimates including different grounds in the English Channel by Dare and Palmer (1994) was available but more recent estimates by Palmer *(*Cefas, unpublished data*)* are used for assessment areas in 27.7.e and 27.7.f.

The von Bertalanffy model was used to estimate size at age:

$$\boldsymbol{Shell\ ht} = \boldsymbol{H\infty}\ (\mathbf{1} - \boldsymbol{exp}(-\boldsymbol{k}(\boldsymbol{age} - \boldsymbol{t0})))$$

where $\boldsymbol{H\infty}$ = shell height of an infinitely old scallop, $\boldsymbol{k}$ =growth rate and $\boldsymbol{t0}$ is the time at zero size.

4.3.4 Shell metric conversions

The growing edge of scallop shells is the most fragile part of the shell and prone to damage. Scientific shell measurements are always taken on shell height (perpendicular to the hinge) as this axis has the least potential for damage, however the minimum landing size for scallop is set on the length (parallel to the hinge across the widest point). 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.

The linear relationships between round shell length and both flat shell height and round shell height was investigated using an Analysis of Covariance. In this report we specifically state which size metric is used.

4.3.5 Weight – length relationship

Scallops were not individually weighed as part of this project but an earlier Cefas project weighed component parts which when combined provide total weight of individuals (Cefas, 2012 unpublished report). Samples were collected from 5 sea areas in the English Channel, described as; 1. East of the Eddystone, 2. West of the Eddystone, 3. Scillies, 4. Offshore, 5. Lyme Bay (348 samples, 10,680 scallops).

The relationship between live weight and shell length is defined by:

$$\boldsymbol{Live\ wt} = \boldsymbol{a}.\boldsymbol{Shell\ length}^{\mathbf{b}}$$

4.3.6 Dredge efficiency

Pecten maximus inhabits substrates from fine sand through to coarse sand and gravels 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 the fishing gear. 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 such variations in gear performance. Indeed, the harvestable biomass estimates from the dredge surveys used for this assessment are sensitive to the choice of substrate specific efficiency parameters. The efficiency of spring-loaded dredges has been studied using diver observations, mark recapture methods and depletion studies (Chapman *et al.*, 1977, Jenkins *et al.,* 2001 and Dare *et al* 1993 and 1994). However, it is a subset of results from a more recent depletion study carried out in the English Channel by Palmer *et al* (Cefas, unpublished data) that we use for the basis of our estimates. The efficiency is defined as the percentage of scallops in the path of the dredge that are captured.

The parameters, biological and dredge efficiency, used in this assessment are presented in Table 4.4.

Table 4.4. Assessment parameters

Parameter	Description	Stock Area	Ground Type	Source
30%	Gear efficiency	27.7.e.I, O and L and 27.7.f.I	Clean or clean becoming stony	Cefas (Palmer, 2001, unpublished)
43%	Gear efficiency	27.7.e.I, O and L and 27.7.f.I	Flint cobbles	Cefas (Palmer, 2001 unpublished)
a= 1.189x10^{-3} b=2.488354	Weight – shell length	27.7.e.I and 27.7.f.I	NA	Cefas 2012 (unpublished)
a= 0.808x10^{-4} b=2.573519	Weight – shell length	27.7.e.O	NA	Cefas 2012 (unpublished)
a= 1.326x10^{-3} b=2.478189	Weight – shell length	27.7.e.L	NA	Cefas 2012 (unpublished)
a=1.209837 b=-4.904044	Shell metric conversion - flat height to round length	27.7.e.O, I and L, and 27.7.f.I	NA	Western channel dredge survey 2017
80mm shell hgt (~90 length)	Size at maturity	27.7.e.I, O and L, and 27.7.f.I	NA	Cefas (unpublished data)
0.15 all ages	Natural mortality	27.7.e.I, O and L, and 27.7.f.I	NA	Cook *et al*., 1990
h∞=116.5, k=0.584, t0=0.715	Von Bertalanffy Growth	27.7.e. L	NA	Cefas (unpublished data)
h∞=106.3, k=0.518, t0=0.921	Von Bertalanffy Growth	27.7.e. O	NA	Cefas (unpublished data)
h∞=105.5, k=0.437, t0=0.682	Von Bertalanffy Growth	27.7.e. I and 27.7.f.I	NA	Cefas (unpublished data)

4.4 Dredge and Underwater TV Surveys

4.4.1 2018 dredge survey

The survey design was essentially the same as that for the survey in 27.7.d and described in Annex 2. The commercial scallop vessel outlined in survey description for 27.7.d (Section 2.3) was used for dredge surveys in 27.7.e and 27.7.f.

Data available for analysis are described in Table 4.5.

Table 4.5. Sampling summary from dredge surveys in 2018

Bed	Number Of Stations	Number Of Length Samples	Number Of Age Samples	Number Measured	Number Aged
7.e.1	21	21	6	1564	191
7.e.2	31	31	10	3548	315
7.e.3	0	0	0	0	0
7.e.4	31	31	6	3388	175
7.e.5	20	19	3	1384	43
7.e.6	0	0	0	0	0
7.e.7	8	8	2	824	60
7.e.8	19	19	7	3320	302
7.f.1	14	13	3	1312	100

One hundred and forty-four randomly selected stations were carried out in the English and approaches to the Bristol Channel between 19-27th May 2018 and operated from the Devon ports of Brixham and Plymouth (Figure 4.4). Of the 144 stations 14 were carried out in 27.7.f and 130 in 27.7.e.

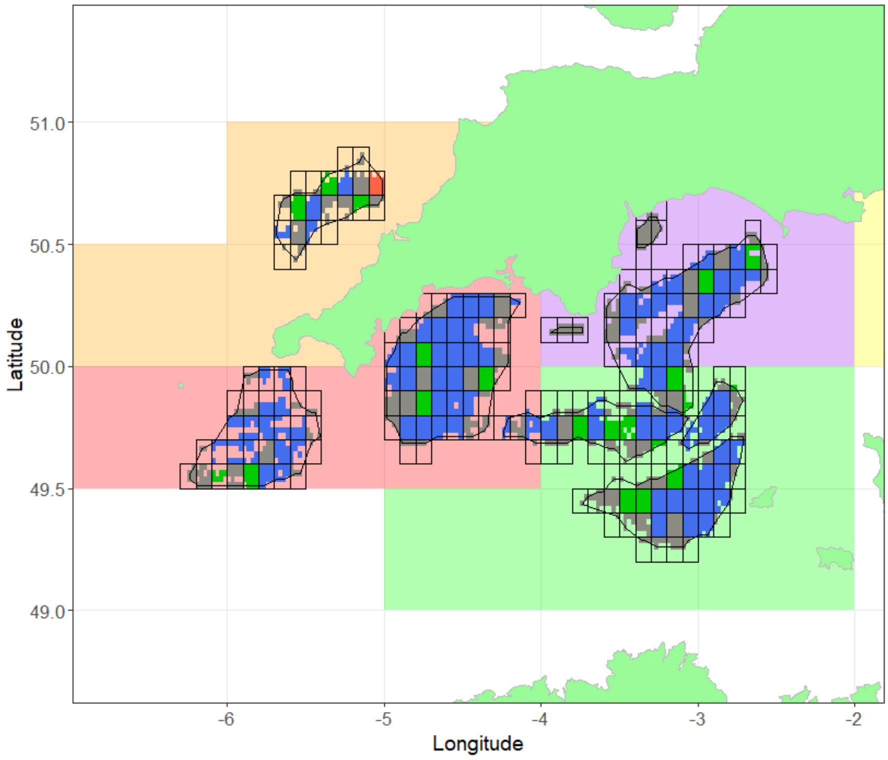


Figure 4.4 Sampled blocks in Beds 7.e.1-8 and 7.f.1, in assessment areas 27.7.e.I, O, L, and 27.7.f.I. Block shading indicates the total number of stations within each block 0 =grey, 1=blue, 2=green and 3=red

4.4.2 Video survey

In 2017 underwater TV (UWTV) surveys were used to determine the distribution and relative abundance of scallops in selected areas inaccessible to fishing gear including Marine Protected Areas (MPA) and areas with unsuitable ground types. No video surveys were undertaken in 2018 as research resources were used to progress technical and methodological advances for both underwater TV survey and other scallop research requirements. The methods for the 2017 video survey are included in annex 4.

4.5 Survey Processing

The processing of the dredge survey data is detailed in Annex 3. The essence of the approach is to determine the swept area of the gear and then determine the relative biomass density of caught scallops above MLS from the swept area and catch of scallop >MLS. These densities are then converted to absolute densities using the gear efficiency parameters in Table 4.4. An arithmetic approach was taken, with the observed cells of randomly selected stations first being raised to the valid surface area of the block the cell was in. Cells within unsampled blocks were assumed to have the same density as the median sample density from randomly selected stations; the median density was taken to account for the skewed distribution of the station densities. This year all tow positions were randomly selected negating the need to apply appropriate procedures to industry selected tows to maintain statistical integrity.

Information on video survey processing is presented in Annex 4.

4.5.1 Raised biomass estimates and uncertainty

Comparison with the first-year assessment highlighted a problem with survey area estimation of ~30% and resulting in an overestimation of the biomass in 2017 by the same proportion. This particular issue only affected the 27.7.e assessments and not those in 27.7.d. This report presents revised estimates for 2017 as well as those from the 2018 survey.

The estimated harvestable biomass of harvestable scallop (>100mm) raised to each block is presented in Figure 4.5.

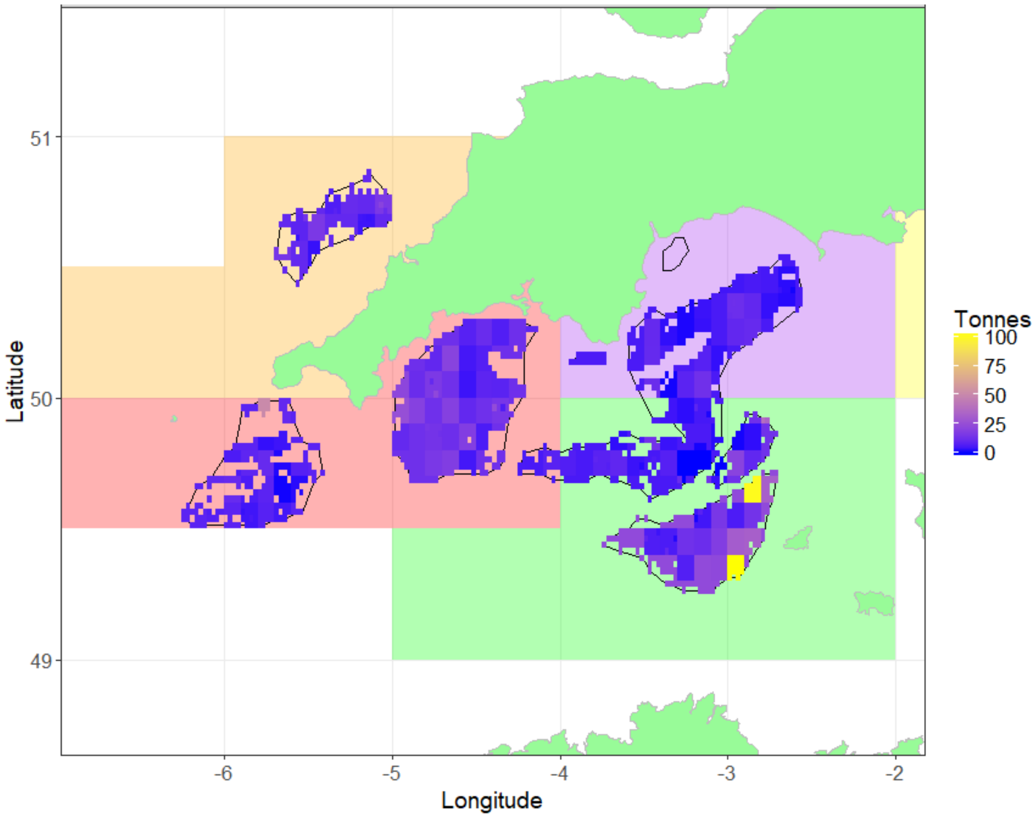


Figure 4.5 - Biomass (Tonnes) of harvestable (above 100mm length) scallops in the surveyed areas within 27.7.e.I (red), 27.7.e.L (purple), 27.7.e.O (green), and 27.7.f.I (orange)

In order to estimate the uncertainty around the estimate of harvestable biomass, the samples for each bed were bootstrapped 5000 times with replacement (Figure 4.6). For each iteration, the same raising procedure was used as for the main biomass estimation routine. The median, 25th and 75th percentiles and point estimates for both the 2017 (revised) and 2018 surveys are given in Table 4.6. As the point estimate utilises all available data it is considered the most appropriate value for the biomass estimates. The point estimates of biomass for 7.e.I, 7.e.L and 7.e.O were higher in 2018 compared to the reworked estimates for 2017 (22.3%, 13.7% and 23.9%).

Table 4.6 Biomass estimation for the dredge surveyed areas in 27.7.e.I, L, O and 27.7.f.I in 2017 and 2018

Assessment Area	Year	25th Centile (Tonnes)	Median Harvestable Biomass Tonnes	Point Estimate (Tonnes)	75th Centile (Tonnes)
27.7.e.I	2017	6417	7045	7337	7608
	2018	8585	9059	8971	9518
27.7.e.L	2017	2449	2563	2636	2722
	2018	2593	2792	2849	2995
27.7.e.O	2017	6919	8469	8673	9401
	2018	9119	10403	10746	11809
27.7.f.I	2018	1532	1674	1687	1815

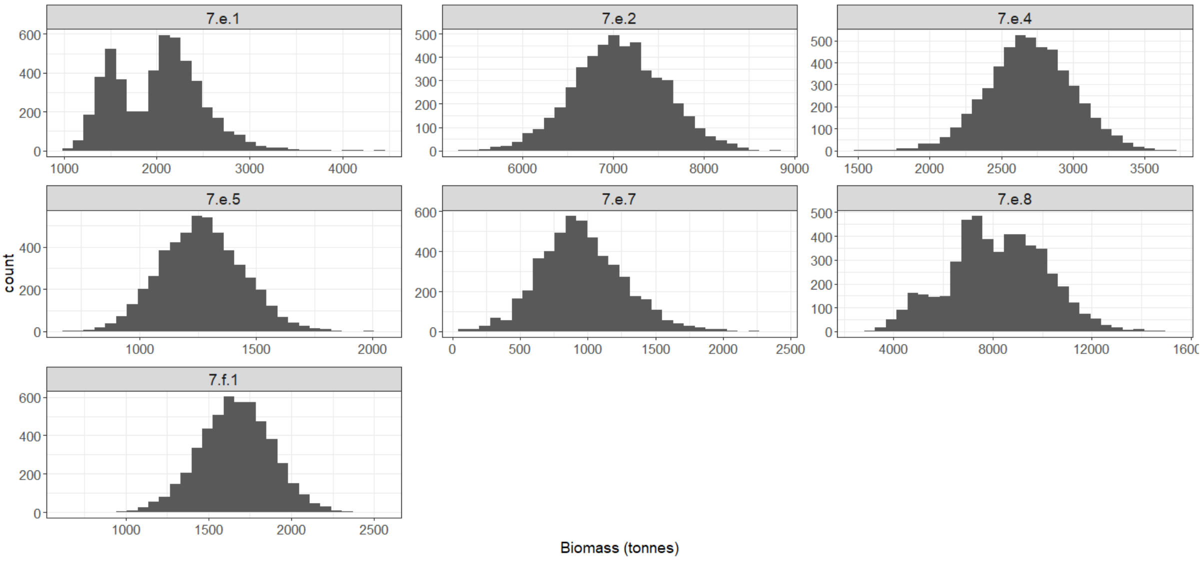


Figure 4.6 Distribution of 2018 biomass estimates for beds 7.e.1-7.e.8 and 7.f.1 from the bootstrapping procedure

4.5.2 Size composition from dredge survey

From the size frequencies taken at each station, a total length frequency was first derived by Bed (Figure 4.7), which were then pooled to the total population estimate for each assessment area (Figure 4.8). A significant portion of the catch from assessment areas in 27.7.e and 27.7.f were below the MLS (Table 4.7).

Table 4.7. Assessment in 27.7.e and 27.7.f. Proportion of scallops below the MLS in the commercial dredges from the dredge survey 2018

Assessment area	2017 (%)	2018 (%)
27.7.e.I	21	23
27.7.e.O	32	32
27.7.e.L	16	52
27.7.f.I		24

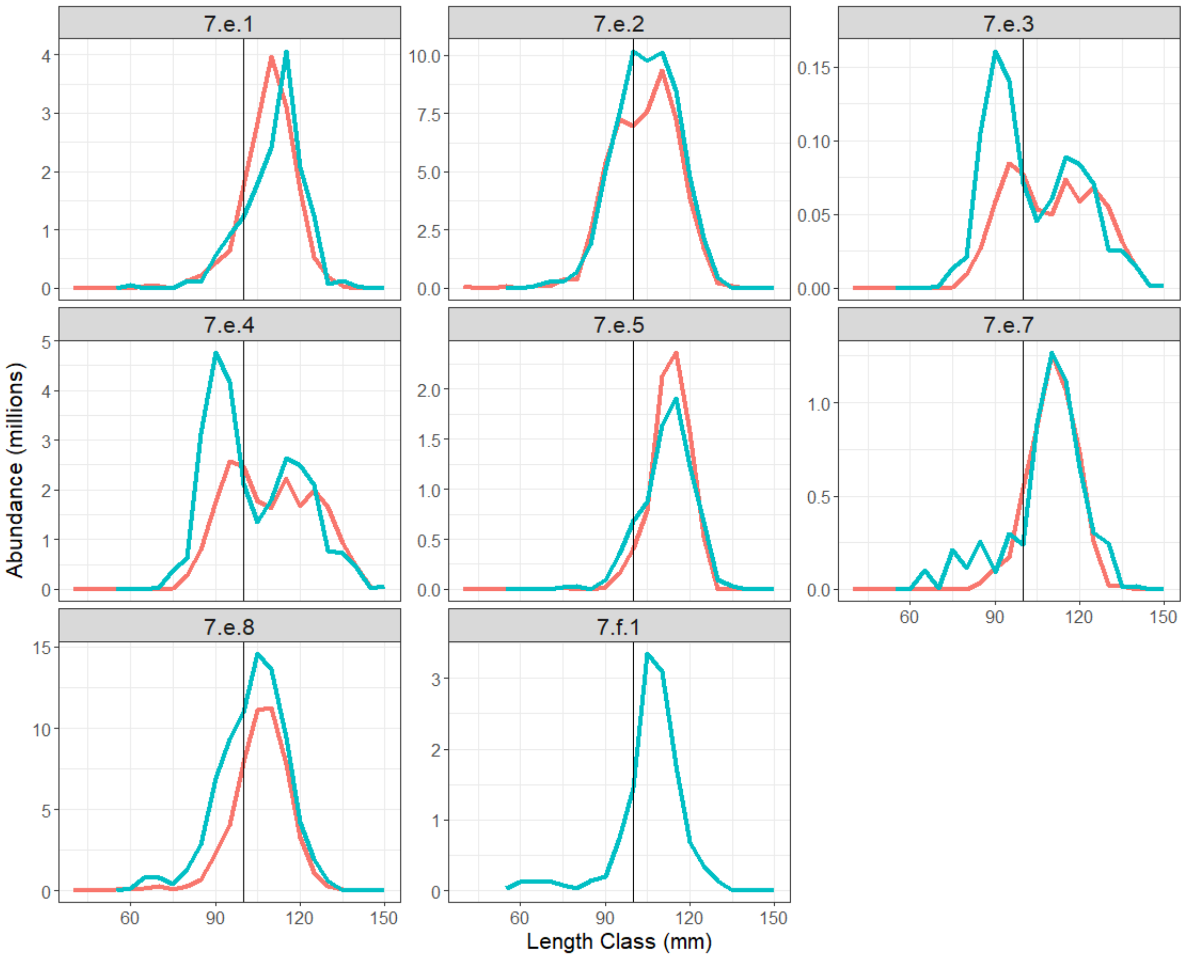


Figure 4.7 – Dredge survey: Bed raised length distributions for Beds 7.e.1-8 (2017, red and 2018, blue) and 7.f.1 (2018 only)

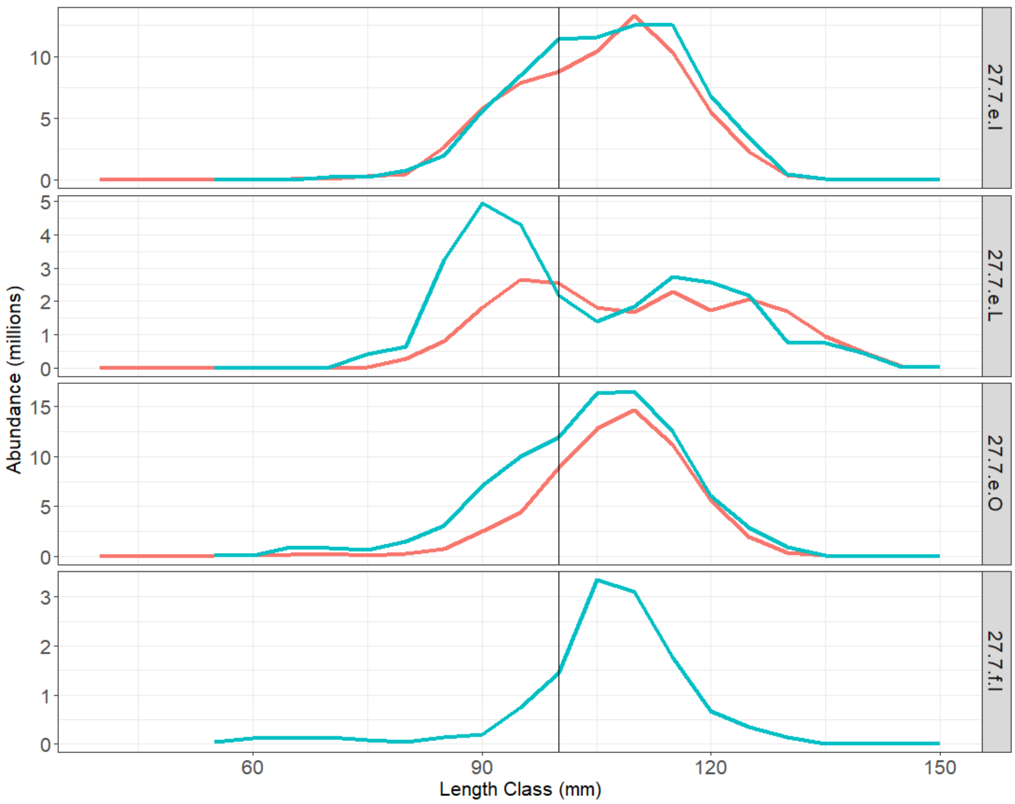


Figure 4.8 – Dredge survey: Length distributions of the scallop population in surveyed areas of 27.7.e.I, 27.7.e.L, 27.7.e.O (2017, red and 2018, blue) and 27.7.f.I (2018 only)

4.5.3 Relative abundance from video survey

Video survey work was not carried out in 2018. The 2017 video survey observed scallops to be distributed on the seabed in the un-dredged zones at low density. The survey carried out 11-minute tows to optimise coverage in the survey grid with the ship time available, and in line with similar underwater surveys. The camera drop frame required a slow tow speed and these limited the transect length to a little over 100m. As such, a significant proportion of the transects gave zero counts and the highest observed number scallops observed was 7.01 scallops per 100m^2. This has given rise to some data distribution anomalies resulting in greater uncertainty in the bootstraps (e.g. the point estimate of biomass lies outside the 75th centile of bootstrapped distributions). Although zero densities are not uncommon in surveys where target species are aggregated on the sea bed, further development of the camera deployment platform and subsequent data processing was carried out in 2018 and is planned for 2019.

For comparison, 9 video transects were carried out in fished Bed 4 at sites subsequently surveyed as part of the dredge survey a week later. The low densities observed on the video survey were typically consistent with scallop densities taken by the dredges on the dredge survey.

Video survey was not carried out in un-dredged areas of assessment area 27.7.e.O in the initial year (2017).

Further results from the 2017 UWTV survey are reproduced in Annex 5.

4.6 Harvest Rate Estimation

The harvest rate (i.e. the ratio of landings to total harvestable biomass) is proposed to give a proxy for the fishing mortality experienced by this stock area. Ideally this will be constructed from the biomass immediately prior to the fishery and then compared to the removals from the observed biomass, however international landings for the two most recent years were not available at the time of this assessment. Instead, for those rectangles which intersect beds in 27.7.e and 27.7.f, we used the UK landings as reported on the national database, raised by the average ratio of the UK component of the international landings (2009-2016) reported to Scientific, Technical and Economic Committee for Fisheries (STECF) (Table 4.9). This assumes that the UK share of the international landings has been consistent in recent times. For assessment areas in 27.7.e in assessment year 2017 we have used landings for the 12-month period after completion of the survey (July 2017 to June 2018). Reported landings for the 2017 calendar year and corresponding estimate of harvest rate are included for comparison. For the 2018 assessment year we have used landings for the calendar year only, to provide a provisional harvest rate estimate. All harvest rate estimates are provisional at the time of this report and will be revised when data become available.

The best estimate of harvest rate uses the point estimate from all data, the range uses the 25th and 75th centile from the bootstraps (resampling exercise).

Biomass estimates for un-dredged areas of 27.7.e and f were not assessed using video survey in 2018 (or 27.7.e.O and 27.7.f.I in 2017), and as such harvest rate estimates only covers the fished part of the stock. There is additional stock outside the area surveyed with dredges but for which there are currently no data on either their biomass or ability to contribute recruitment to the main areas of fished stock. Harvest rates estimated using biomass from un-dredged areas (UWTV, where available) added to that from dredged areas are included for reference (Table 4.9). Un-dredged areas are assumed to be at carrying capacity with no fishing mortality and the biomass estimates from 2017 video surveys have been included in both 2017 and 2018 estimates. These harvest rates are applicable only when connectivity between dredged and un-dredged populations is complete.

Table 4.8 Harvestable biomass estimates and provisional harvest rates for dredged areas of 27.7.e and 27.7.f for 2017 and 2018

Assessment Area	Year	Biomass Removed (tonnes)	Harvestable Biomass Estimate in Dredge Area (tonnes)	Provisional Harvest Rate on Dredged Portion of Stock (%)	Provisional Harvest Rate Range (%, from resampling excercise)
27.7.e.I	**2017**	**2790***	**7337**	**38.0**	**36.7-43.5**
	2017	2480+	7337	33.8	32.6-38.7
	2018	2218+	8971	24.7	23.3-25.8
27.7.e.L	**2017**	**1455***	**2636**	**55.2**	**53.4-59.4**
	2017	1730+	2636	65.6	63.5-70.6
	2018	1920+	2849	67.4	64.1-74
27.7.e.O	**2017**	**973***	**8673**	**11.2**	**10.4-14.1**
	2017	893+	8673	10.3	9.5-12.9
	2018	1964+	10746	18.3	16.6-21.5
27.7.f.I	**2017**	**358***	**-**	**-**	**-**
	2017	573+	-	-	-
	2018	172+	1686	10.2	9.5-11.3

** biomass removal during 12-month period after survey. + removals during calendar year and provisional harvest rate estimates.* All harvest rate estimates are provisional, to be updated. *See explanation in text*

Table 4.9 Removals (tonnes), estimated harvestable biomass (tonnes) and provisional harvest rate (%) incorporating biomass estimate from dredge and 2017 TV survey by assessment area in 2017 and 2018

Assessment Area	Year	Biomass Removed (tonnes)	Estimated Harvestable Biomass from Dredge Survey Areas (tonnes)	Estimated Harvestable Biomass from 2017 TV Survey Areas [Not 100%] (*tonnes*)	Estimated Total Harvestable Biomass (tonnes*)*	Provisional Harvest Rate inc. UWTV (%)
27.7.e.I	2017	2790*	7337	4291	11628	24.0
	2017	2480+	7337	4291	11628	21.3
	2018	2218+	8971	4291	13262	16.7
27.7.e.L	2017	1455*	2636	1751	4387	33.2
	2017	1730+	2636	1751	4387	39.4
	2018	1920+	2849	1751	4600	41.7
27.7.e.O	2017	973*	8673	-	-	-
	2017	893+	8673			
	2018	1964+	10746	-	-	-
27.7.f.I	2017	358*	-	-	-	-
	2017	573+	-	-	-	-
	2018	172+	1686	-	-	-

** biomass removal during 12-month period after survey. + removals during calendar year and provisional harvest rate estimates. All harvest rate estimates are provisional, to be updated(See explanation in text).*

4.6.1 Landings size compositions - cohort modelling

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

In the first assessment (2018 report) we used an age-based cohort model to determine fishing mortality assuming the populations had been at equilibrium, that is that fishing effort, recruitment and growth have all been constant. Deviations from this assumption will cause the model to give unreliable answers.

Marked differences in the reported landings between the two assessment years in some assessment areas have highlighted that the populations are not at equilibrium and for this report a method that is less susceptible to fluctuations in recruitment and fishing rate has been used. Scaled length distributions were used to determine gear selection parameters (L25 and L50) to facilitate a length-based method (Figure 4.9). Length based methods are routinely used for shellfish assessments where only size structure of the removals is available, typical for many shellfish species where age determination is problematic. The length-based assessment uses growth parameters to determine the time spent in each size class, often called pseudo-cohorts. As the relationship between stock and recruitment is unknown a yield per recruit model was used to determine parameter outputs relative to a single recruit.

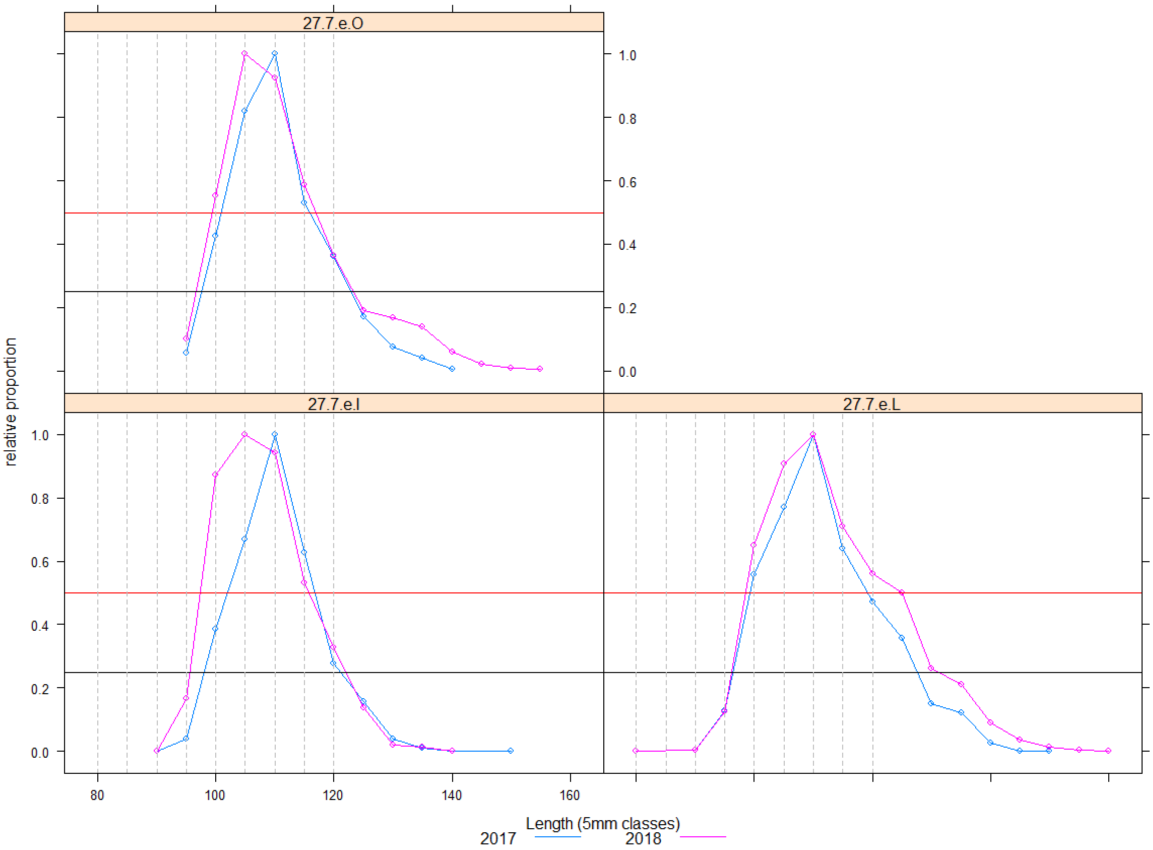


Figure 4.9. Landed size distributions as a proportion of the highest mode. Horizontal reference lines at 0.25 (blue) and 0.50 (red)

The provisional harvest rates for the dredged portion of the stocks and candidate harvest rates consistent with MSY and estimated using the cohort method are presented in Table 4.10.

Table 4.10 Provisional harvest rate estimates for dredged and wider areas and MSY candidates by assessment area and year

Assessment Area	Year	Provisional Harvest Rate on Dredged Portion of Stock (Dredge Survey Only, %)	Provisional Harvest Rate on Wider Stock (Inc. UWTV Survey [Not 100%], %)	MSY Candidate Harvest Rate (%)
27.7.e.I	2017*	38.0	24.0	25
	2018+	24.7	16.7	25
27.7.e.L	2017*	55.2	33.2	21
	2018+	67.4	41.7	21
27.7.e.O	2017*	11.2	-	24
	2018+	18.3	-	24

** based on biomass removal during 12-month period after survey. + based on removals during calendar year and provisional harvest rate estimates.* All harvest rate estimates are provisional, to be updated. *See explanation in text*

Lack of sampling opportunities led to inadequate sampling for 27.7.f.I and as such no size-based modelling was undertaken for this assessment area.

Age compositions are currently being reviewed and are not presented in this report.

4.7 MSY Reference Point Estimation

Full estimation of the fishing mortality that generates maximum sustainable yield (MSY) requires a full analytical assessment and an estimate of the stock-recruitment relationship. Clearly this is not yet possible as is the case with many stocks assessed by ICES. In such cases, ICES 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, both within ICES and more widely around the globe. Fmax, the fishing mortality which gets the maximum yield from each recruited individual is also sometimes used as a proxy for Fmsy, but is unlinked to spawning potential, is more uncertain in its estimation and in some circumstances, suggests fishing rates which are highly risky for the stock size.

A simple yield -per recruit model was constructed using selection-at-size and maturity-at-size parameters estimated in this assessment. The Fmax estimates for these areas are high (because there is relatively little growth potential after the MLS has been reached compared to expected losses through natural mortality). Following the Fmax estimate for these stocks would remove all spawning stock in one year and is therefore highly risky. The recommended FMSY reference point for this stock is therefore F35%SpR.

4.8 Conclusions

This is the second stock assessment undertaken for scallops in this region, although the first for 27.7.f. This year the assessment includes biomass estimates from the dredge surveys and the UWTV survey carried out in selected areas in 2017.

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

Variation in reported landings between 2017 and 2018 suggests that the populations in this region are not at equilibrium. The assumption of equilibrium is fundamental to the cohort models and yield per recruit estimates investigated in the 2017 report. As a result of these concerns, a modelling method which utilises scaled length samples was considered more appropriate than the age-based method used in the first assessment.

Provisional harvest rates are presented, and length structured modelling provided estimates of harvest rate corresponding to MSY for assessment areas in 27.7.e. for context. The provisional harvest rate for assessment area 27.7.e.I is higher than the harvest rate consistent with MSY (HRmsy) in the 2017 assessment season, but just below in 2018. Provisional harvest rates for 27.7.e.L (both assessment seasons) are higher than those consistent with HRmsy, whilst the harvest rates for 27.7.e.O are below HRmsy.

This year a change to a smaller survey vessel deploying less dredges was unavoidable. Both survey vessels deploy very similar gear and catches of scallop are standardised to area swept but no comparative tow work was carried out to confirm there was no change in catchability. As such caution should be used when comparing the 2017 and 2018 survey results.

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

It should be noted that the estimates of harvest rate for 27.7.e.O and 27.7.f.I are for the fished portion of the stocks only, unfished portions of stock were not surveyed in these areas. For areas 27.7.e.I and 27.7.L biomass estimates are available from the 2017 video surveys. It is known that additional stock outside the area surveyed but for which there are currently no data on either their biomass or ability to contribute recruitment to the fished stock. Future surveys of un-dredged areas are planned and are likely to revise the estimates of realised harvest rate downwards, provided that un-dredged areas are considered to contribute to the recruitment in the dredged areas.

5 Stock Assessment in surveyed areas of 27.4.b

5.1 Area Definitions

As described in Section 1.2, an additional scallop assessment area has been defined within ICES division 27.4.b, this encompasses the scallop fishing activity within English waters in the North Sea by UK vessels >=12m length. Within this division there are two scallop beds; 4.b.1 and 4.b.2 (Figure 5.1). These beds were defined in 2018 using VMS data (includes 2017 data) and first surveyed in 2018.

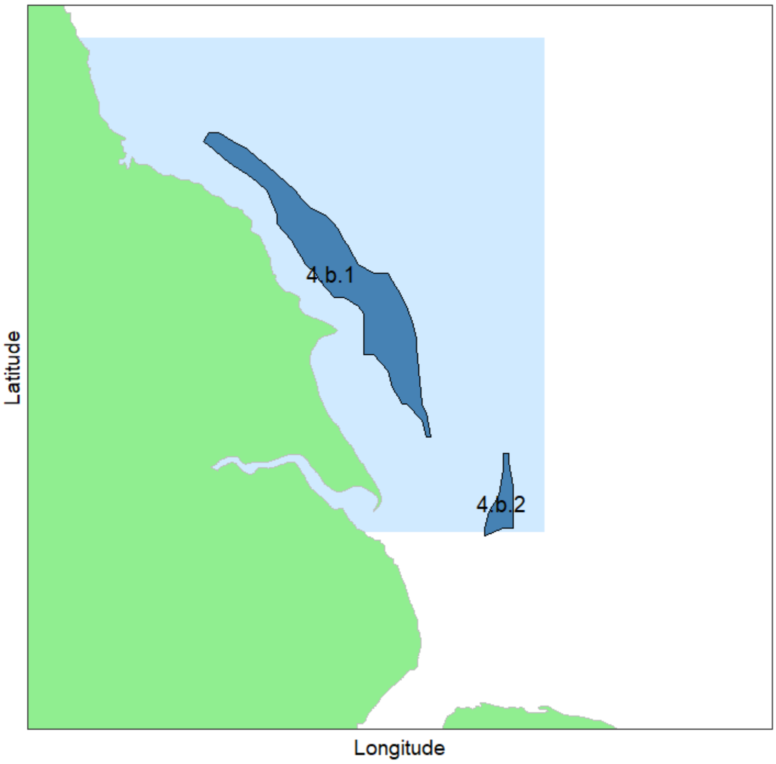


Figure 5.1– Beds 4.b.1 and 4.b.2 within Assessment Area 27.4.b.S (light blue)

5.2 Data Available 27.4.b.S

5.2.1 Catch and survey data

Landings by country as reported to STECF for the one assessment area in 27.4.b is given in Table 5.1. This fishery is exploited almost exclusively by UK registered vessels. International landings data for 2017 are not yet available.

Table 5.1. STECF Landings (tonne) by country (STECF) in assessment area in 27.4.b.S

	BEL	FRA	IRL	IOM	UK	International
2009	-	-	-	-	394	394
2010	-	-	-	-	361	361
2011	-	-	-	-	699	699
2012	0	-	-	6	985	991
2013	0	-	-	1	352	353
2014	0	0	-	-	2300	2301
2015	0	-	-	-	3172	3172
2016	0	-	0	-	1047	1047

Figure 5.2 shows the landings by country and quarter within the assessment areas in 27.4.b. Annual landings in the 4b South assessment regions are almost exclusively UK landings, with small tonnages from Isle of Man in 2012.

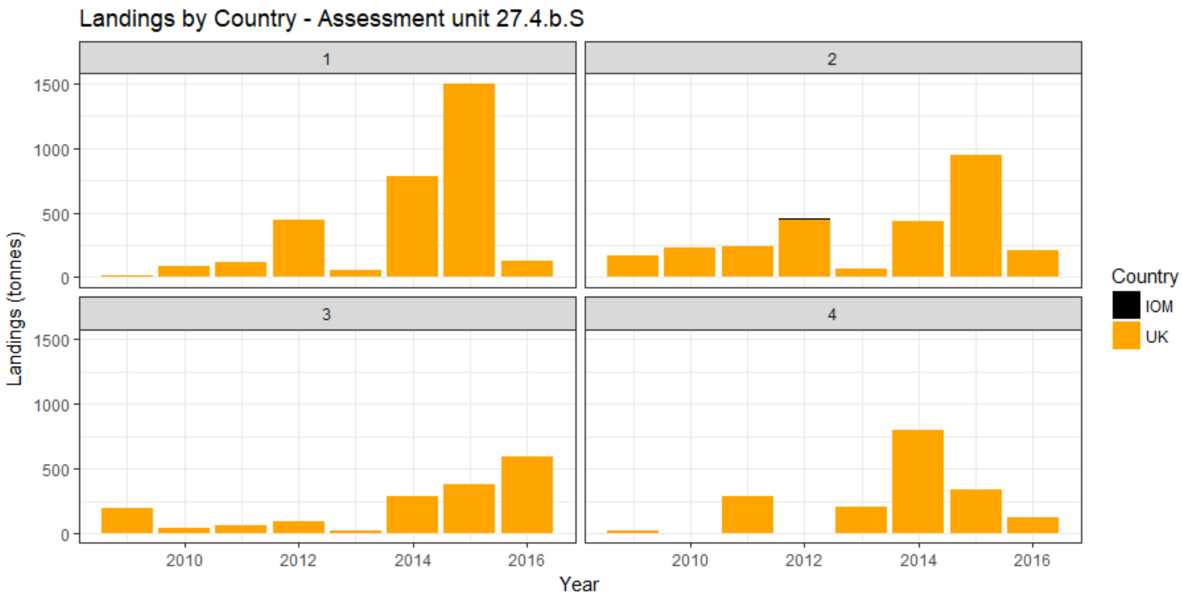


Figure 5.2. Landings by country and by quarter in assessment area 27.4.b.S

UK data for the assessment area in 27.4.b by quarter are given in Table 5.2. There is a lag in the collation of landings data within the UK. At the time of writing (January 2019), landings data to the end of September (Q3, 2018) are considered reliable. A sampling season is defined as quarter 4 of the preceding year and quarters 1 to 3 of the current calendar year.

Table 5.2. Quarterly landings UK data by assessment area in 27.4.b.S

27.4.b.S	Q1	Q2	Q3	Q4	Annual	Sampling Season (Q4, Q1, Q2, Q3)
2001	12	1	0	762	775	
2002	417	610	11	30	1068	1800
2003	434	112	3	6	554	579
2004	34	68	2	0	103	109
2005	161	0	0	121	282	161
2006	141	41	26	49	258	330
2007	21	119	144	1	285	333
2008	36	165	169	1	370	371
2009	18	166	190	20	394	375
2010	88	227	44	1	361	379
2011	117	239	57	286	699	414
2012	441	453	95	2	991	1275
2013	60	70	18	204	353	150
2014	786	435	283	797	2300	1708
2015	1506	951	377	340	3173	3630
2016	129	215	591	118	1054	1275
2017	936	886	385	297	2503	2325
2018	689	838	366	431*	2325*	2190

5.2.2 Discards

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 omission of discard data does not affect the estimation of harvestable biomass. Scallops are assumed to have a high survival rate and therefore discard induced mortality is considered to be low.

5.2.3 Size composition

An extensive biological sampling program started in 2017 in the English Channel was expanded to include this assessment area in 2018 and is described in Annex 1. The program collected both length and age samples with a higher sample collection rate on lengths than ages as is standard for fishery data collection programs. Age determination for this year has highlighted some inconsistencies between the two years of data that were not picked up during routine quality control and which will require further investigation. As such only size compositions are presented in this report.

Length samples for individual vessels were raised to UK landings on a quarterly basis before summation to total landings during each sampling season.

The number of samples collected in this the first year of the programme in this area is shown (Table 5.3) below along with the number of age samples collected during the dredge survey. Age samples will be an important part of any future assessment process and are included for completeness.

Table 5.3 Sampling programme summary

	Commercial landings				Dredge survey	
Sampling Season	**Length samples**	**Animals measured**	**Age samples**	**Shells aged**	**Age samples**	**Shells aged**
2018	7	875	10	385	7	288

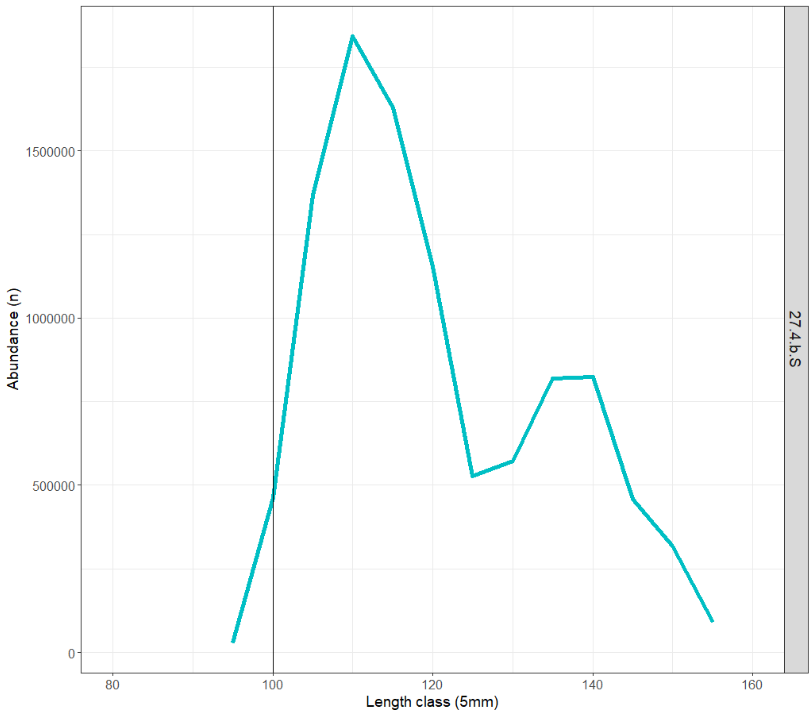


Figure 5.3 Estimated numbers in size groups landed from 27.4.b.S during 2018 sampling season. MLS shown

5.3 Biological Parameters and Dredge Efficiency

5.3.1 Natural mortality

Predation is the likely cause of most of the natural mortality, with the brown crab and starfish being the most significant predator 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 but 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).

5.3.2 Size at maturity

Animals above MLS (100 mm shell length) are almost exclusively found to be mature. Maturity is assumed to be knife-edged at 80mm shell height (based on Cefas data, unpublished).

5.3.3 Growth

Methodology for ageing at Cefas is based on work carried out by Dare and Deith (1989). Oxygen isotope assay was used to validate traditional ring counting methods and to produce von Bertalanffy growth parameters. A review of historic growth estimates including different grounds in the English Channel by Dare and Palmer (1994) was available but the more recent estimates by Palmer *(*Cefas, unpublished data*)* for assessment area 27.7.d are used for 27.4.b until more local estimates become available.

The von Bertalanffy model was used to estimate size at age:

$$\boldsymbol{Shell\ ht} = \boldsymbol{H\infty}\ (\mathbf{1} - \boldsymbol{exp}(-\boldsymbol{k}(\boldsymbol{age} - \boldsymbol{t0})))$$

where $\boldsymbol{H\infty}$ = shell height of an infinitely old scallop, $\boldsymbol{k}$ =growth rate and $\boldsymbol{t0}$ is the time at zero size.

5.3.4 Shell metric conversions

The growing edge of scallop shells is the most fragile part of the shell and prone to damage. Scientific shell measurements are always taken on shell height (perpendicular to the hinge) as this axis has the least potential for damage, however the minimum landing size for scallop is set on the length (parallel to the hinge across the widest point). 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.

The linear relationships between round shell length and both flat shell height and round shell height was investigated using an Analysis of Covariance. In this report we specifically state which size metric is used.

5.3.5 Weight – length relationship

Scallops were not individually weighed as part of this project but parameters for a weight-length relationship for 27.7.d was used for the North Sea. These estimates will be revised when more specific data become available.

The relationship between live weight and shell length is defined by:

$$\boldsymbol{Live\ wt} = \boldsymbol{a}.\boldsymbol{Shell\ length}^{\mathbf{b}}$$

5.3.6 Dredge efficiency

Pecten maximus inhabits substrates from fine sand through to coarse sand and gravels 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 the fishing gear. 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 such variations in gear performance. Indeed, the harvestable biomass estimates from the dredge surveys used for this assessment are sensitive to the choice of substrate specific efficiency parameters. The efficiency of spring-loaded dredges has been studied using diver observations, mark recapture methods and depletion studies (Chapman *et al.*, 1977, Jenkins *et al.,* 2001 and Dare *et al* 1993 and 1994). However, it is a subset of results from a more recent depletion study carried out in the English Channel by Palmer *et al* (Cefas, unpublished data) that we use for the basis of our estimates. The efficiency is defined as the percentage of scallops in the path of the dredge that are captured.

The parameters, biological and dredge efficiency, used in this assessment are presented in Table 5.4.

Table 5.4. Assessment parameters

Parameter	Description	Ground Type	Source
30%	Gear efficiency	Clean or clean becoming stony	Cefas (Palmer: 2001, unpublished data)
43%	Gear efficiency	Flint cobbles	Cefas (Palmer: 2001, unpublished data)
a= 1.55×10^{-3} b=2.456095	Weight – shell length	NA	IFREMER (unpublished data)
a=1.208916 b=-5.386429	Shell metric conversion - Flat height to round length	NA	Eastern Channel dredge survey 2017
80mm shell hgt (~90 length)	Size at maturity	NA	Cefas (unpublished data)
0.15 all ages	Natural mortality	NA	Cook *et al.*, 1990
h_∞=119.3, k=0.516, t0=0.692	von Bertalanffy Growth	NA	Cefas (unpublished review)

5.4 Dredge Survey

5.4.1 2018 dredge survey

The survey design was essentially the same as that for the surveys in the English Channel, and is described in Annex 2. This was the first dredge survey in assessment area 27.4.b.S and was carried out on the same vessel and during the same trip as that for 27.7.d.N.

Twenty-seven randomly selected stations were carried out in 27.4.b.S between 3rd-4th September 2018 and operating from Hartlepool. Of the 27 stations 23 were carried out in Bed 4.b.1 and 4 in the smaller bed, 4.b.2. Data available for analysis are described in Table 5.5.

Table 5.5. Sampling summary from dredge survey

Bed	Number of stations	Number of length samples	Number of age samples	Number measured	Number aged
4.b.1	23	23	5	2490	220
4.b.2	4	4	2	275	68

The same gear deployment configuration and sampling procedure outlined in survey description for 27.7.d was used. N.B. The length distributions from the 4 modified dredges have been used for exploratory purposes only and are not included in this assessment. The number of stations per block is shown in figure 5.4.

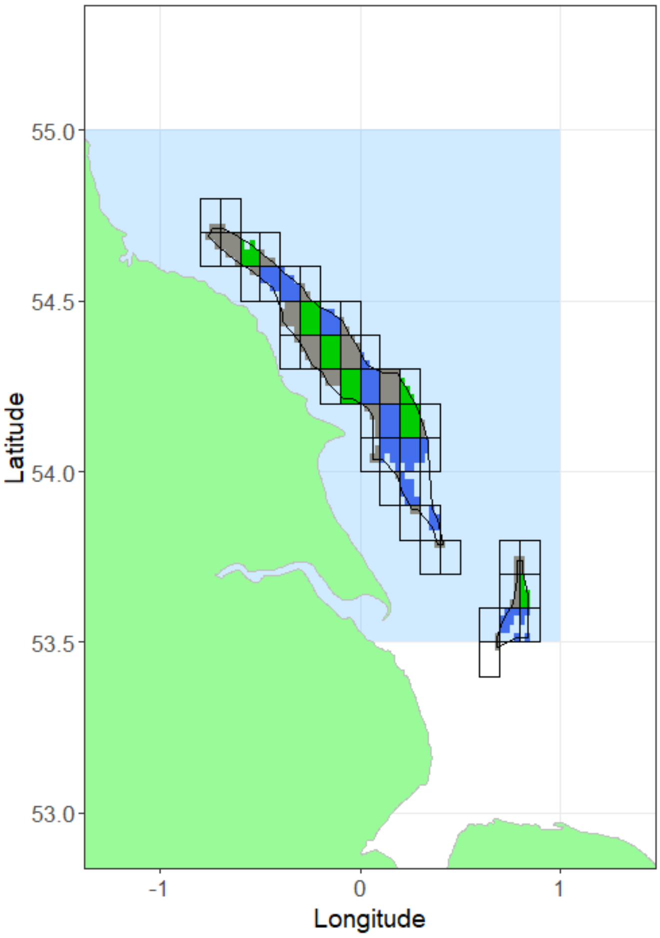


Figure 5.4 Sampled blocks in Beds 4.b.1 and 4.b.2, in assessment area 27.4.b.S. Block shading indicates the total number of stations within each block 0 =grey, 1=blue and 2=green

5.5 Survey Processing

The processing of the dredge survey data is detailed in Annex 3. The essence of the approach is to determine the swept area of the gear and then determine the relative biomass density of caught scallops above MLS from the swept area and catch of scallop >MLS. These densities are then converted to absolute densities using the gear efficiency parameters in Table 5.4. An arithmetic approach was taken, with the observed cells of randomly selected stations first being raised to the valid surface area of the block the cell was in. Cells within unsampled blocks were assumed to have the same density as the median sample density from randomly selected stations, the median density (rather than mean density) was used as it is statistically more appropriate for the skewed distribution of the station densities. All tow positions were randomly selected.

5.5.1 Raised biomass estimates and uncertainty

The estimated harvestable biomass of harvestable scallop (>100mm) raised to each block is presented in Figure 5.5.

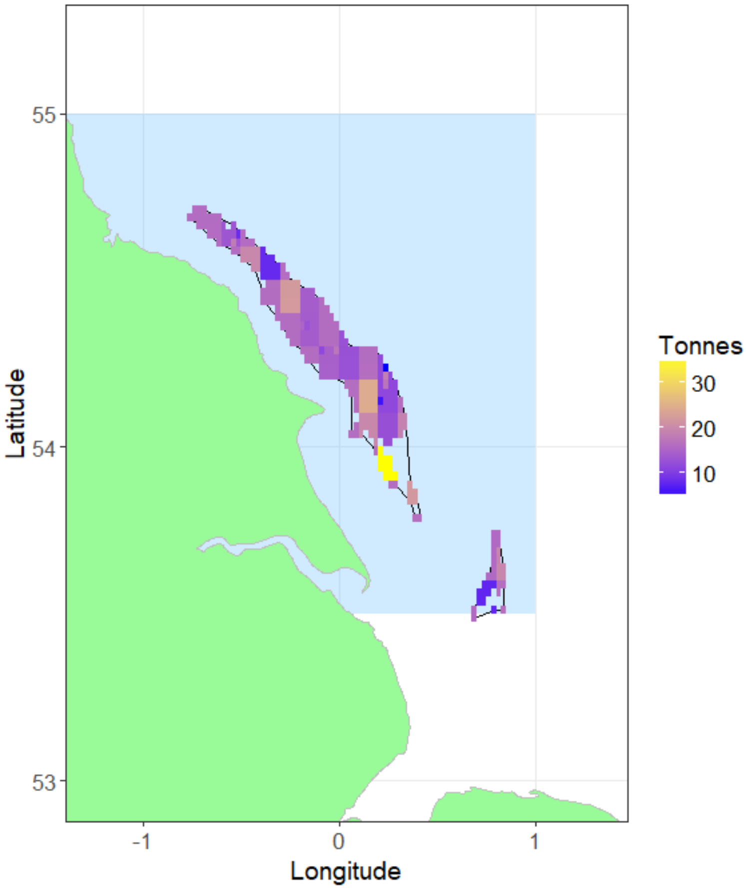


Figure 5.5 - Biomass (Tonnes) of harvestable (above 100mm length) scallops in the surveyed areas within 27.4.b.S (light blue)

In order to estimate the uncertainty around the estimate of harvestable biomass, the samples for each bed were bootstrapped 5000 times with replacement (Figure 5.6). For each iteration, the same raising procedure was used as for the main biomass estimation routine. The median, 25th and 75th percentiles and point estimates are given for each assessment area in Table 5.6. The bootstrap estimates for 4.b.2 gave a noisy histogram, this is owing to the low sampling rate of the small area.

Table 5.6 Biomass estimation for the dredge surveyed areas in 27.4.b.S (two beds combined) for 2018

Assessment area	25th centile (tonnes)	Median harvestable biomass (tonnes)	Point estimate (tonnes)	75th centile (tonnes)
27.4.b.S	5219	5483	5517	5739

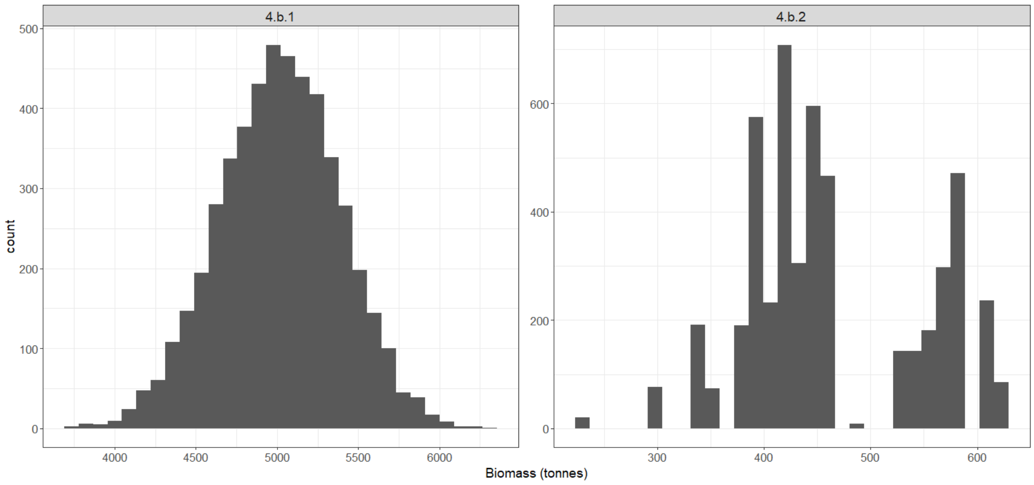


Figure 5.6 Distribution of 2018 biomass estimates for beds 4.b.1 and 4.b.2 from the bootstrapping procedure

5.5.2 Size composition from dredge survey

From the size frequencies taken at each station, a total length frequency was first derived by Bed (Figure 5.7), which were then pooled to the total population estimate for each assessment area (Figure 5.8). Thirty-nine percent of the catch from assessment area in 27.4.b was below the MLS.

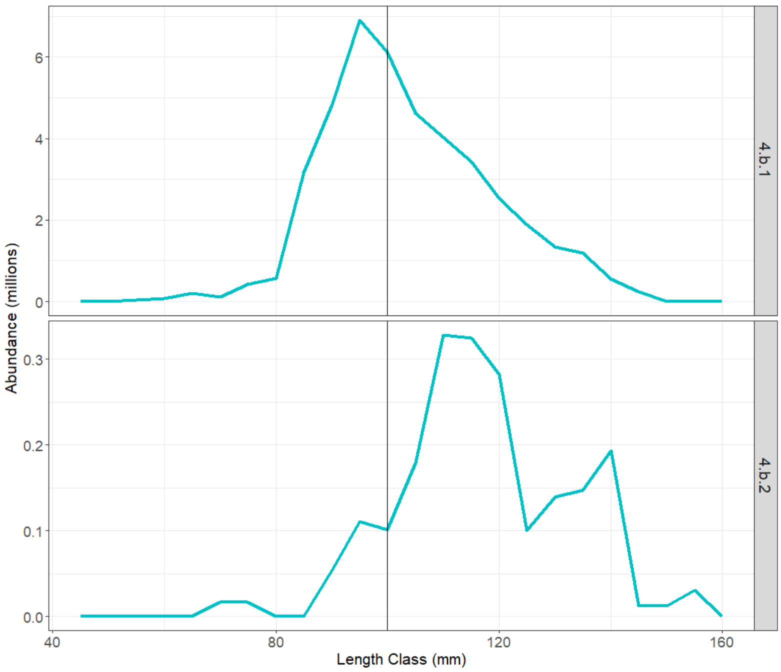


Figure 5.7 – Dredge survey: Bed raised length distributions for Beds 4.b.1 and 4.b.2 in 2018

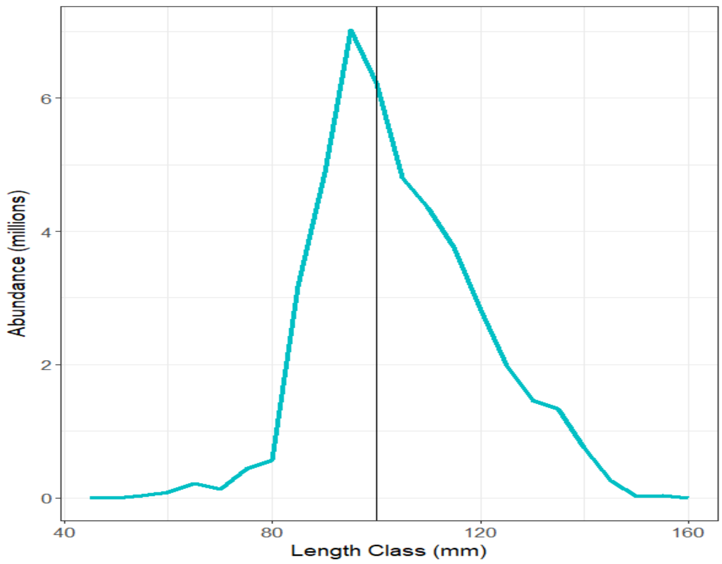


Figure 5.8 – Dredge survey: Length distribution for the scallop population in surveyed areas of 27.4.b.S in 2018

5.6 Harvest Rate Estimation

The harvest rate (i.e. the ratio of landings to total harvestable biomass) is proposed to give a proxy for the fishing mortality experienced by this stock area. Ideally this will be constructed from the biomass immediately prior to the fishery and then compared to the removals from the observed biomass during the subsequent 12-month period. For the 2018 assessment year we have used landings for the calendar year to provide a provisional harvest rate estimate, as

12 months have not elapsed since the survey was completed and the time of this report. International landings were also not available at the time of this assessment. Instead, for those rectangles which intersect beds 4.b.1 and 4.b.2, we used the UK landings as reported on the national database, raised by the average ratio of the UK component of the international landings (2009-2016) reported to Scientific, Technical and Economic Committee for Fisheries (STECF) (Table 5.7). The provisional harvest rate will be updated as data become available.

The best estimate of harvest rate uses the point estimate from all data, the range uses the 25th and 75th centile from the bootstraps (resampling exercise). Biomass estimates for un-dredged areas of 27.4.b were not assessed using video survey in 2018 and as such harvest rate estimates only covers the fished part of the stock. There is additional stock outside the area surveyed with dredges but for which there are currently no data on either their biomass or ability to contribute recruitment to the main areas of fished stock.

Table 5.7 Harvestable biomass estimates and harvest rates for the areas covered by the dredge survey in 2018

Year	Biomass Removed (tonnes)	Harvestable Biomass Estimate in Dredged Area (tonnes)	Harvest Rate on Dredged Portion of Stock (%)	Harvest Rate Range (%, from resampling exercise)
2018	2327+	5517	42.2	40.5-44.6

+ removals during calendar year and provisional harvest rate estimates. Harvest rate estimates are provisional. See explanation in text

5.6.1 Fishing mortality estimates from the landings size composition

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

This is the first year the biological sampling was carried out in this area and sampling opportunities only provided seven samples totalling eight hundred and seventy-five scallops. We have considered this sampling level to be below that required to enable a reliable length-based analysis at this time.

5.7 Conclusions

This is the first stock assessment undertaken for scallops in this region. The assessment in this area is dependent on the results of the dredge survey and is restricted to the biomass estimates and implied harvest rate. A single year of data is always more uncertain than when a time series are available, so the results of this assessment should still be viewed with some caution.

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

It should be noted that the estimates of harvest rate for 27.4.b is for the fished portion of the stocks only; unfished portions of stock were not surveyed in this area. It is known that additional stock outside the area surveyed but for which there are currently no data on either their biomass or ability to contribute recruitment to the fished stock.

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

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

6 Future Developments

These assessments mark the second in what is expected to be an ongoing series of assessments for scallop stocks around the English coast. The assessment techniques employed are 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:

- Gear efficiency (dredge and UWTV) estimates
- UWTV relate counts to biomass and size structure

- Greater understanding of the recruitment linkage between dredged scallop beds and un-dredged areas.

Annex 6 describes progress and current status of these issues.

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