ICES WGSCALLOP REPORT 2018

ECOSYSTEM PROCESSES AND DYNAMICS STEERING GROUP

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Report of the Scallop Assessment Working Group (WGScallop)

10–12 October 2018

York, UK

ICES
International Council for the Exploration of the Sea

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Contents

Executive summary

The ICES Scallop Assessment Working Group (WGScallop) met in Aberdeen (2016), Belfast (2017) and York (2018) with an average of 16 participants from 8 countries. The main terms of reference for the working group were to update and provide data and exchange knowledge on the various scallop fisheries in the Northeast Atlantic region. This included the compilation of available scallop fisheries data and the production of maps to better identify stock boundaries and inform spatial management.

The WG also considered the various assessments for scallop stocks and reviewed the recent developments in the English Channel. The scallop stocks in the Baie ds Seine have experienced extremely large recruitment events over the past few years and the group has discussed the fisheries management measures in this region.

Over the last few years, the English Channel has also seen the re-introduction of a scallop data collection programme, a cooperative industry survey and stock assessment. The WG reviewed the approaches and made recommendations on the methodologies which were accepted and included in the most recent assessment.

A main focus of the group has been understanding the scallop ecosystem and the impacts of fishing. A number of work areas have been delivered which examined marine spatial planning and potential benefits of seasonal closures, Marine Protected Area's and European marine sites as conservation zones and possible recruitment supply areas for scallop populations. A number of projects have recently been established through the EU Interreg programme and the WG is keen to see how these develop over the next few years.

The WG has made significant progress in terms of establishing an international scientific forum where resources, knowledge, experience and insights can be exchanged. This is evident in the recent advances in the use of use of camera systems to complement existing survey work. Image surveys are expanding due to information exchange; presently they are being conducted in Canada, Iceland and the United States; further cameras are increasingly being used to examine dredge performance and habitat and are used or being trialled in various UK surveys.

The overall objective of the group continues to be providing scientific advice on scallops and defining a common approach to the assessment of scallop stocks. In 2018, for the first time all stocks were assessed using an independent fisheries survey. The WG understands there are still limitations and uncertainties surrounding future funding sources for surveys and are also considering fishery dependent indicators and their possible uses to inform stock status.

The growing need for global assessment and advice of scallops is becoming increasing apparent and the group plans to use the Baie Des Seines/English Channel and the Irish Sea/Isle of Man fisheries as case studies to explore possible management frameworks and to continue with the progress of assessments for all scallop stocks.

1 Administrative details

Working Group name

Scallop Assessment Working Group (WGScallop)

Year of Appointment within current cycle

2016

Reporting year within current cycle (1, 2 or 3)

3

Chair(s)

Kevin Stokesbury, USA

Meeting dates and venues

3–7 October 2016, Aberdeen, Scotland, UK (16 participants)

10–12 October 2017, Belfast, Northern Ireland, UK (14 participants)

10–12 October 2018, York, England, UK (18 participants)

2 Terms of Reference

The focus of the first 3-year working group (2013 to 2015) was to provide scientific advice on scallops and define a common approach to the assessment of scallop stocks. The workshop focussed ICES areas: IIa, IVa, IVb, V, VIa, VIa and IVb, VIIa, VIId, VIIe/h, VIIg, and VIII. Scallop species and biological stocks were identified in each of the ICES areas. The ToR for this 3-year period (2016 to 2018) were:

1. Compile and present data on landings and fishing effort that enables the following data products to be produced at as high a spatial resolution as the available data allows in ICES areas IV, VI and VII. Refer to WGScallop 2015 for methodologies
    a. maps of fishing pressure, fishing effort and landings
    b. GLM/GAM standardised LPUE indicators of stock status
    c. maps of relative abundance of scallop
    d. best estimates of absolute abundance using available habitat specific gear efficiency estimates
    e. estimates of area of stock distribution exposed to fishing each year
2. Identify larval source sink patterns to
    a. Inform managers of MPAs and European Marine Sites (EMS) of the potential value of protected areas as sources of scallop recruitment
    b. Identify populations that are important sources of larval supply, A) Review of current research underway on scallops, focusing on population

dynamics, stock structure, life history and habitat impact of fisheries. B) Compare basic models derived from landings and effort to more complex models where they are available. (link to WKLife)

3. By-catch fish, discard scallop mortality – compile data, see if we can create a universal data base (observer trips).

For the 2017 and 2018 meetings these ToR were expanded upon based on needs identified by the group to include:

4. Estimate scallop discard mortality
5. Review the scallop aging experiment and determine best-practises for further aging work
6. Review the scallop stock assessment approach and methodologies developed for stock in English waters and comment on the appropriateness of the approaches to deliver metrics of stock biomass and exploitation rate suitable for use in a management context.

3 Summary of Work plan

To complete compilation of landings, effort, fishing distribution data and to derive basic indicators of stock status. Evaluate how stock assessment methods proposed by WKLife can be applied to scallop stocks. Evaluate the potential benefit of MPAs and European marine sites as sources of scallop recruitment. Evaluate and report on bycatch species composition and also on discard mortality rates of undersize scallops with reference to the EU landings obligation

4 Summary of Achievements of the WG during 3-year term

Overview

- The first benefit of ICES Scallop working group is the gathering of the group of scientists working on the **King, Queen and Icelandic scallop fisheries** together to exchange knowledge, experience and insights.
- To address questions **globally** as well as locally by sharing and expanding resources and knowledge.
- Focused on understanding the scallop within its ecosystem and the impacts of fishing.
- Work includes examining effects of the environment on life history and the impacts of fishing on benthic communities.
- Examined marine spatial planning and potential benefits of MPA's and European marine sites as conservation zones and recruitment supply areas for scallop populations.

Presentations of Working group products

- Stokesbury, K.D.E. Overview of ICES scallop working group 2013 to 2016. South Western Fish Producer Organization Ltd, Brixham, England, 11 Oct 2016.
- Stokesbury, K.D.E. ICES Scallop Working Group Overview. International Pectinid Workshop, Portland, Maine, April 2017
- Numerous presentations at the pectinid Workshop from members of the WGScallop.

Data products and methodological developments

- In 2018 for the first time all stocks were assessed using an independent fisheries survey.
- Image surveys are expanding due to information exchange; presently they are being conducted in Canada, Iceland and the United States; further cameras are increasingly being used to examine dredge performance and habitat.
- Technology exchange including electronic observer data collection (Nestform), video technology and automatic processing, VMS and GIS mapping including google map open access video catalogues.

Advisory products

- Review and revision of the industry cooperative scallop survey of the English Channel.
- Development of volunteering rotational plan accepted by French fishermen in the Baie des Seine to improve harvest of a large recruiting year-class in 2018, based on examples from rotation management in the Gulf of Maine USA.
- Although not a direct product of the WG during the six years of its existence we have identified, observed and reported on four of the largest recruitment events ever observed in scallop populations; the stocks are in the France (Baie des Seine), Canada (Georges Bank and Browns Bank), Isle of Man, and the United States. This would seem an unusual opportunity for a WG, which we would like to follow up with further study of the potential drivers.

5 Final report on ToRs, work plan and Science Implementation Plan

5.1 In response to ToR 1

Compile and present data on landings and fishing effort that enables the following data products to be produced at as high a spatial resolution as the available data allows in ICES areas IV, VI and VII. Refer to WGScallop 2015 for methodologies

a) maps of fishing pressure, fishing effort and landings

b) GLM/GAM standardised LPUE indicators of stock status

c) maps of relative abundance of scallop

d) best estimates of absolute abundance using available habitat specific gear efficiency estimates e) estimates of area of stock distribution exposed to fishing each year

The working group has established information on the location of fishing effort, methods of surveying, population dynamics, biological parameters, fishery reference points and habitat impacts for the King, Queen and Icelandic scallops in ICES areas: IIa, IVa, IVb, V, VIa, VIa and IVb, VIIa, VIId, VIIe/h, VIIg, and VIII, as outlined by the ToR's, as they stand now based on the research of individual groups and organizations. Some information is sparse or lacking such as population dynamics and reference points by stock. Each meeting, updates on the stock assessments from different areas are presented (refer to summaries below). VMS data is being compiled and examined that includes kilowatt days, and VMS hours by ICES rectangle or on a finer scale, and the WG has reached out to the WG? For example an overview of VMS data was presented by Bryce Stewart on the King scallop fleet activity in 2015 (Figure 1). However, effort from the southern Irish Sea is missing. There is a continuing difficulty in compiling these data from different countries, particularly for near shore populations, fished by smaller vessels.

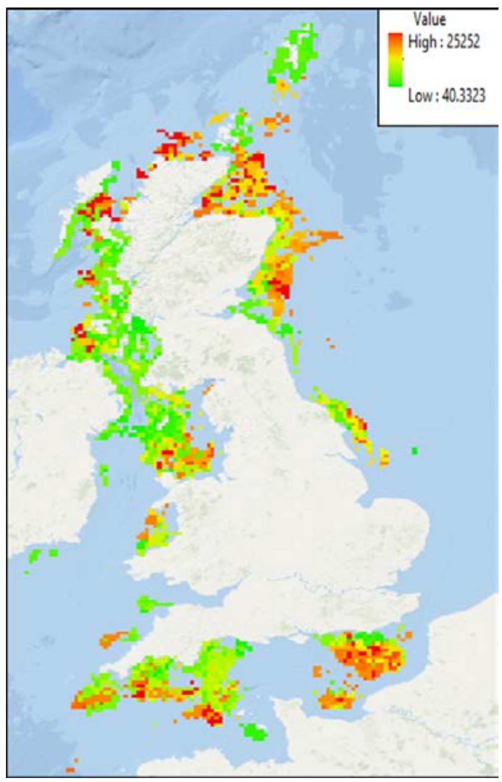


Figure 1. King scallop fleet activity in 2015 by J Holden, A Caeen, B. Lart and B. Stewart.

In 2018 for the first time all the scallop stocks in the ICES area had independent stock assessment surveys. Gear type and configuration vary by country and agency, but each were detailed at the working group. Experiments examining the selectivity and efficiency of the sampling gear continue and turning these relative estimates of abundance in to absolute estimates is still a huge challenge. On-going research to better understand dredge efficiency includes outreach to fishermen on best fishing practises, high resolution depletion studies and camera work, both examining how the dredge fishes underwater and comparisons between different high-resolution density estimates. Work is also underway comparing different stock assessment models such as the CASA to examine different approaches given our present data limitations.

A continuing concern is the cost of funding independent surveys. Although this year all stocks had an independent survey, continuing support of surveys in the Isle of Man, the Celtic Sea, Northern Ireland and Cardigan Bay are all in question. A continual debate within the working group is the use of dependent verses independent data for stock assessment somewhat reflective of the larger discussion being held in a number of fisheries (for example "Does catch reflect abundance? Nature 2013, vol 494: 304–306).

5.2 In response to ToR 2

Identify larval source sink patterns to

a) Inform managers of MPAs and European Marine Sites (EMS) of the potential value of protected areas as sources of scallop recruitment

b) Identify populations that are important sources of larval supply

In the previous 3 year report (2013–2015) results were presented on a large scale effort from France entitled the "COMANCHE Project: Ecosystem interaction and anthropogenic impacts on king (*Pecten maximus*) populations in the English Channel" (presented by E Foucher at the 21st pectinid Workshop). This project detailed connectivity between different scallop populations highlighting three major functional units (Bay of Seine, Normand-Breton Gul and South-western coast of England). Work is also continuing on connectivity with a focus in the Celtic Sea where there seems to be a good deal of genetic structure within the populations of King scallop.

5.3 In response to ToR 3

By-catch fish, discard scallop mortality - compile data, see if we can create a universal database (observer trips)

By-catch and discard mortality are two major issues facing this fishery and have direct impacts on its classification of sustainability. Presently a number of countries are collecting detailed information on by-catch in their fishery independent surveys. There also have been several studies on discard mortality (i.e. Scotland, the Isle of Man, and Wales). Plans are underway to develop a uniform by-catch database compiling the information from these different independent surveys and this work will continue at the next meeting.

5.4 In response to ToR 4

Review the scallop aging experiment and determine best-practises for further aging work

In 2013, WGScallop first discussed and compiled information on available data and stock assessment methods for scallops. Many institutes rely heavily on ageing methods but there are no common methodologies or protocols and this issue has been highlighted and discussed at previous meetings. In 2017, WGScallop agreed to implement a scallop (*Pecten maximus*) exchange between the institutes. A random sample size of 20 scallops from each institute was agreed and an excel template designed. All institutes were requested to provide information on the time of year caught, area/bed, first ring, and time of spawning for their submitted scallops. There are no agreed protocols or methodology but it was agreed that all scallops should be aged independently and the group also agreed that height measurements of each ring would be useful. Institutes uploaded documents to the share point detailing their own methodology and standard operating procedures, but the understanding was that each institute was going to implement their own methods to age the scallops received.

A total of 111 scallops from six institutes were circulated. Results have been received for 1200 scallops aged by 20 different readers from six institutes. Scallops have recently been received from another institute who wishes to participate; and other institutes have reported that they are in the process of entering and collating their data and will send shortly. Data will be analysed over the next year and results presented to the WG next year.

5.5 In response to ToR 5

Review the scallop stock assessment approach and methodologies developed for stock in English waters and comment on the appropriateness of the approaches to deliver metrics of stock biomass and exploitation rate suitable for use in a management context

'Scallop wars' highlight the need for improved international co-operation in fisheries management

The recent 'scallops wars' in the English Channel saw scallop fisheries hitting the headlines around the UK, France, and indeed the world. The dispute was largely between British and French ships over access to scallop fishing grounds in the Bay of Seine off the coast of Normandy in northern France. Tensions have existed for over a decade, but the most recent conflict in September 2018 saw 40 small French boats try to chase off five larger British boats. Stones were thrown and boats collided, but there were no injuries or sinkings.

The scallop wars have two underlying, root causes. The first is that there are two groups of fishermen, targeting the same species in the same area but under different rules. A local regulation prohibits French boats from targeting scallops in the Bay of Seine until October each year. But this French regulation does not apply to British or other nations boats.

In previous years, the French fishermen have persuaded the larger UK boats to stay away until October by transferring extra European fishing allocation to them, so they can fish in other areas. This year, with Brexit looming, and after increased numbers of under 15 m British boats fished the area in 2017, this "gentleman's agreement" broke down.

Although it is legal for boats from Britain, Ireland and other countries to fish in the area before October, the frustration of the French fishermen is understandable. Over a decade ago, France instigated highly progressive management measures for its scallop fishery (see below), including limits on licences, reductions in boat and gear size, time restrictions, and increases in dredge mesh size.

Now scallop stocks in the Bay of Seine are at near record levels, but vessels from other countries are catching them before the French are allowed to go fishing themselves. In comparison, although there are now efforts to improve the sustainability of the scallop fishery around the UK, catch rates are declining overall, while the the number of scallop fishing boats has increased from 135 a decade ago to more than 200 now.

The second root cause is that nomadic boats from the UK and other countries have no links to the local community that depends upon the scallops in the Bay of Seine. Small boats, such as the French use, have a limited range and depend entirely on what they can catch in the area. In such situations where there are extensive kin ties and shared communities, fishermen are much more likely to develop informal agreements with regard to who fishes where.

Of course, such tensions work both ways. For many years the French trawled for sea bass in the English channel, disadvantaging UK fishers who were banned due to concerns they would catch too many dolphins by mistake. The French fishery was only stopped by the EU when sea bass stocks collapsed.

It has been suggested that this is just a skirmish before the 'battle of Brexit'. Ships from elsewhere in the EU take more fish from UK waters than the British fleet does and many in the UK fishing community would like to see reform that addresses what they see as an injustice. The problem is that most fish are not scallops, which rarely move, but instead undergo annual migrations across international boundaries. Therefore preventing fishing in one area may not necessarily reduce access to stocks.

In the absence of robust international agreements that manage stocks rather than areas, and respect the fact that neither fish nor shellfish care about human boundaries, the North Sea could become the new Mediterranean, where poor regulation and disagreement between EU and non-EU states has resulted in a steady decline in stocks. Climate change induced shifts in abundance and distribution will likely further complicate matters.

In the face of Brexit we should be aiming to improve international relations, not damage them. Otherwise fish and shellfish stocks and the wider marine environment are likely to suffer most – at which point everyone loses.

* *Adapted from the original article in The Conversation: https://theconversation.com/scallop-wars-between-britain-and-france-are-just-a-pre-brexit-skirmish-102588*

Initial assessment of Scallop (*Pecten maximus*) stock status for selected waters within the Channel 2016/2017 – UK Cefas

At the 2017 meeting, a detailed description of the cooperative industry survey for the English Channel was presented and reviewed by the working group. An update of the success of that first field season is presented below. The advice of the Working Group was followed and the survey was modified to improve the precision by increasing the number of stations in the stratified random design. Refer to the summary below provided by CEFAS.

A review of the sampling design of the newly developed English Channel cooperative dredge survey conducted by Cefas and the fishing Industry was completed (ToR 6, 2017, Belfast). This survey came together very quickly resulting from a great deal of work and coordination between the scientific agency and the industry. Surveys began in May and were conducted into September 2017. Data from the summer's surveys were not available at this meeting but the sampling design, assumptions and possible statistical procedures were presented and discussed.

The beds in the English Channel were defined by examining 8 years of VMS data. Two grids of different scales were laid over the VMS data. A course grid of 0.1^0 divided the beds into blocks (each approx. $80km^2$) and a 2nd finer grid of 0.025^0 divided each block into 16 cells (each approx. $5km^2$). One cell was randomly selected within each block, the midpoint of which was used as a tow position. The number of random tows was reduced by 25% to enable the fishing industry partners to contribute to tow location selection. The randomly selected tows were used to estimate the density/abundance of each block within a bed but blocks where no random tow was available the bed median density was used. Where the density from a non-random industry provided tow was available this was used for the cell estimate only. This process was necessary as the industry tows were not randomly assigned and their influence therefore had to be restricted to a local effect only. Biomass in each block was estimated from the size distribution and a bed specific length weight relationship and these estimates were summed to provide estimates for each bed.

Substrate specific efficiency was previously estimated by depletion tow experiments. Estimates suggested higher efficiency for this gear compared to some other studies, but those used were thought to be more relevant. We suggested that continuing and expanding these efficiency experiments, maybe add a camera to dredge (useful in other areas i.e. Isle of Man).

Permission was not obtained to sample in French waters for the 2017 sampling year and bed median densities were applied to those areas within the French EEZ.

Drop camera surveys are being conducted in non-fished areas (non-contact ~0.5m altitude); these worked well but covered only small area given the low scallop density (~1 scallop to $100m^2$). We suggested conducting some drop camera samples in the fished areas where dredge survey tows are taken, could add to the estimates of dredge efficiency.

Addressing the 3 primary questions on design put forward by the research scientists conducting the survey the WG suggested:

1) The definitions of the beds using the VMS and a polygon tool

This is a sound approach that clearly defines the beds based on the fishing effort.

2) The stratification on rectangles characterizing the bed

Habitat map might improve precision and accuracy by enabling stratification by substrate type. The basis for stratification could be further developed.

Re-randomize stations annually? Examine the data collected in 2017 by post-stratifying by habitat to see if re-stratification is required.

3) The inclusion of the industry survey stations in the sampling design.

The inclusion of the industry tows complicates the estimate of the variance associated with the survey design, probably a bootstrap technique will be required.

Need to conduct analysis of the industry vs random tows on actual data. Does the reduction of 25% of the random tows result in a significant increase in variance? The survey could be improved possibly by randomly assigning (within strata) 100% of the tows. Industry LPUE data in the previous year could be used to assign industry tows.

Explore different interpolations, different smoothers, geostatistical procedures etc.

The monitoring programme started in 2017 includes two other data streams: The use of UWTV to estimate abundance in non-dredged areas and an industry scallop sampling scheme to provide the age structure of removals.

Assessment of Scallop (*Pecten maximus*) stock status for selected waters within the Channel 2017/2018 – UK Cefas

The first assessment of scallop stocks in the English Channel was carried out towards the end of 2017 and the report presented to the meeting. Partial presentation of the executive summary is included below:

The report describes the initial assessment of the status of some of these stocks undertaken in 2017 by the Centre for the Environment, Fisheries and Aquaculture Science (Cefas) during a collaborative project with the UK fishing industry, Defra and Seafish.

Five stock assessment areas have been 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). These assignments are based on regional differences in growth and fishery exploitation patterns. Fisheries data are available at the spatial resolution of ICES Rectangle and their boundaries are used to describe the extent of the assessment areas. The fished stock in the Bay de Seine part of 27.7.d.S is assessed by France whose scientists carry out an assessment of biomass and exploitation rate on fished grounds in this region.

This report assesses the status of the dredged portion of stocks in 27.7.d.N, 27.7.e.I, 27.7.e.L and 27.7.e.O 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 in this initial year but for which there are no data to make any estimates. This report does not cover scallop stock in area 27.7.d.S. 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 IFREMER in a robust process.

Three data streams were used for the assessments described in this report. Dredge surveys in the main fished beds of 27.7.d.N, 27.7.e.I, 27.7.e.L and 27.7.e.O 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 non-dredged regions of assessment areas 27.7.e.I and 27.7.e.L was estimated from underwater TV surveys; no underwater TV survey was undertaken in 27.7.d.N or 27.7.e.O. 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 VMS data. 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 non-dredged stock that are contributing offspring to the fished areas, the MSY harvest rate 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 the international landings to the available biomass estimates, either dredged area only or including the biomass from un-dredged areas from the available UWTV surveys. Finally, the age compositions of the landings were used in a cohort model to obtain alternative estimates of harvesting rates.

In order to put the estimates of biomass and harvest rate into context, candidate harvest rates for maximum sustainable yield have been estimated.

This is the first attempt at stock assessments undertaken for scallops in this region. Single 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. The estimates of harvest rate from the different data streams are given below.

	HARVEST RATE ON DREDGED PORTION OF STOCK (DREDGE SURVEY ONLY)	HARVEST RATE FOR WIDER STOCK WHERE UWTV AVAILABLE (NOT 100% COVERAGE)	HARVEST RATE ON DREDGED PORTION OF STOCK (COHORT MODEL)	MSY CANDIDATE
27.7.D.N.	35.5%	NA	48.0%	25.0%
27.7.E.I.	27.4%	17.3%	35.3%	24.5%
27.7.E.L.	36.5%	22.0%	32.5%	21.0%
27.7.E.O.	13.6%	NA	28.6%	32.8%

We consider this project to be 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.

Researchers are still filling data gaps and improving parameter estimates and as such have included a list of caveats and assumptions in the report which can be found at:

https://www.gov.uk/government/publications/aseessment-of-scallops-stocks-201617

Further evolution of survey design, assessment methodology and refinement of parameter estimates is likely to address these issues.

Updates in 2018

Cefas and their industry collaborators have taken on board WG recommendations regarding use of industry selected tow positions for the dredge surveys and from 2018 all tow positions will be randomly selected each year. Dredge survey beds will be reviewed at an appropriate frequency.

The researchers have released RFID tagged scallops and subsequently tried to recapture these and detect them with RFID readers mounted in front of the dredges to estimate efficiency. Results of this study were not available at the time of the 2018 meeting. The technology has been shown to work, but further surveys and testing are necessary to develop a system capable of being used on commercial fishing vessels. When developed the equipment will be deployed on the survey fishing vessel to enable estimation of efficiency and more robust density estimates from survey catch rates.

The sampling targets for the industry scallop sampling scheme have been revised from the original and nominal ones to a system where the number of samples per ICES rectangle and quarter are proportional to the reported landings. The ratio of age samples to length samples has been increased to provide a better interpretation of age structure.

Annual assessment survey of the Bay of Seine King Scallop stock: results of the survey COMOR2018

The survey took place from 2 to 18 July 2018. The main objective is to assess the King scallop (*Pecten maximus*) stock of the Bay of Seine (English Channel, ICES Division 7d, France), in the area located within the 12 miles limits (inside the French territorial waters) and also in the area located just in the north of the 12 miles limit, corresponding to the ICES rectangle 28E9, called "Proche Extérieur" (Figure x.1).

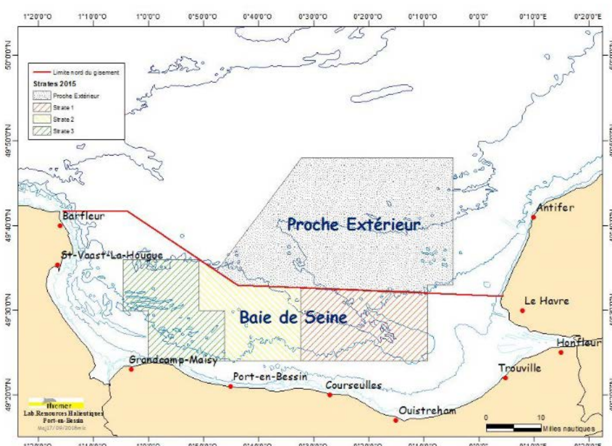


Figure x.1. Area of the Bay of Seine assessment survey.

The scientific protocol is based on a random stratified sampling; the employed gear is a 2 meter width French dredge with diving plate, one equipped with 72mm inside diameter rings, and the second one with 50mm inside diameter rings. Each tow is realized straight facing into the current; the length is ½ nautical mile, the speed of the R/V vessel 3 knots. This year, 160 tows have been done.

1) **Area "Extérieur baie de Seine"**

Abundance indexes (number of King Scallops per mile x dredge width) by ages have been processed, from age 1 to age 7+. The exploitable biomass in the Eastern Channel, and especially in the north of the Bay of Seine, is mainly composed by 2 and 3 years old individuals. Age 2 index (83.64) is in 2018 below the 3 previous year's indexes, and also below the average index for the last decade (around half of the mean index); (Table. x.1). Indexes for age 3 to 7 are similar to those observed last and previous years (Figure x.2).

Table x.1. Average abundance indexes in the "Proche Extérieur" for age 1 to 7+, for historical period 1992–2007 and the last decade 2008–2017.

	1 an	2 ans	3 ans	4 ans	5 ans	6 ans	7 ans
Moyenne 1992-2007	48.13	59.66	12.09	3.49	0.80	0.18	0.16
Moyenne 2008-2017	135.49	152.78	22.38	4.64	1.23	0.51	0.22

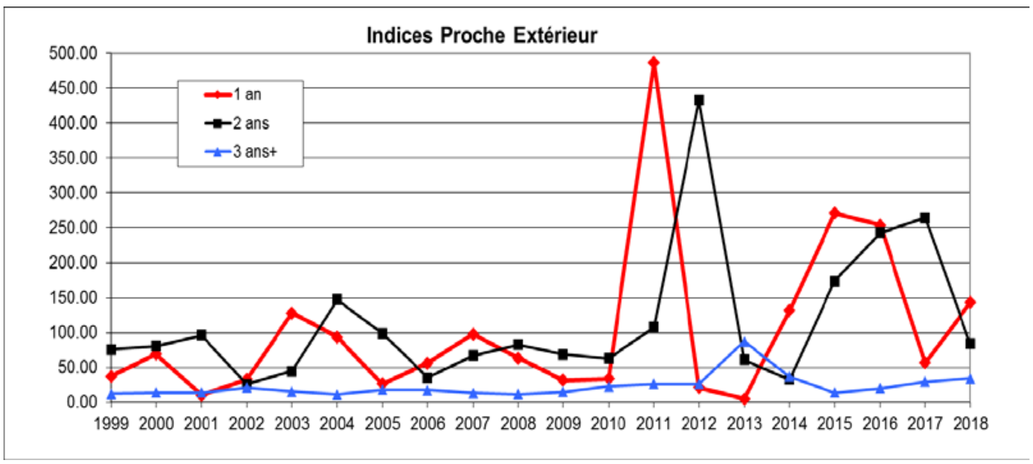


Figure x.2. Trends of abundance indexes in the area "Proche Extérieur" from 1999 to 2018.

The age 1 index is around 3 times better than last year, meaning the arrival of a new large cohort in the fishery in 2019. Globally, the situation of the stock is better now that it was historically; all indexes by age are around 3 times higher for the current decade than for the period from 1992 to 2007.

The exploitable biomass (King Scallops over the 110 mm MLS) is estimated to 7846 tonnes (Figure x.3). It is less than B_{2017} (18783 tonnes) and the average $B_{2008–2017}$ biomass (11 502 tonnes). Anyway, the status of the stock could not be considered in danger, because the exploitable biomass remains higher than the average biomass from 1998 to 2007 (5554 tonnes), and because the projected arrival of the new exploitable cohort in 2019 will be high again. The structure of the population shows that the stock is mainly composed by age 2 and 3 years old scallops (Figure x.4).

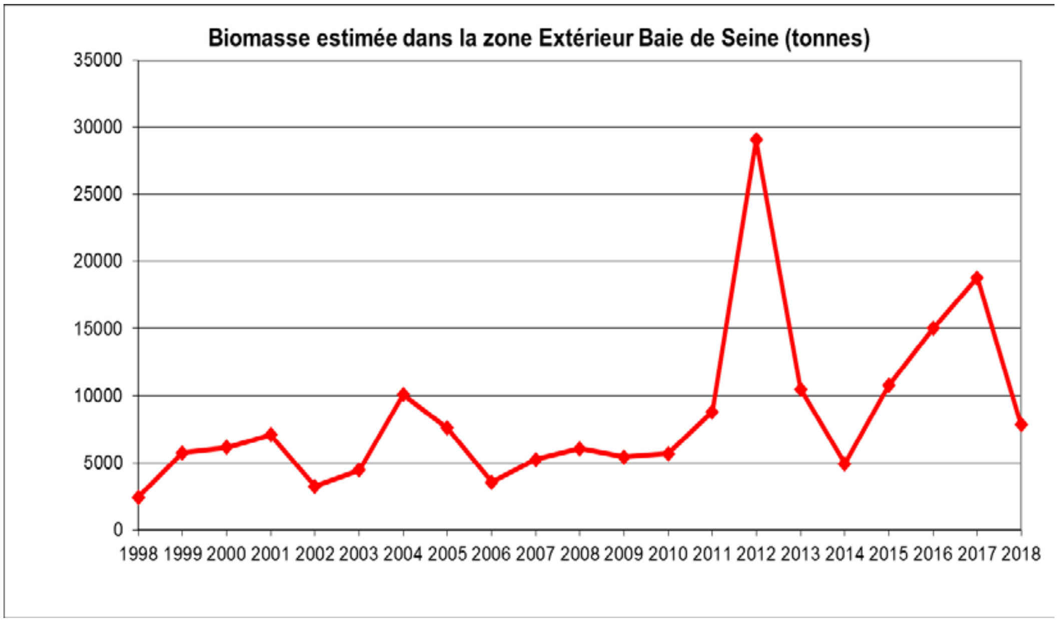


Figure x.3. Trends of estimated exploitable biomass in the area "Proche Extérieur" from 1998 to 2018.

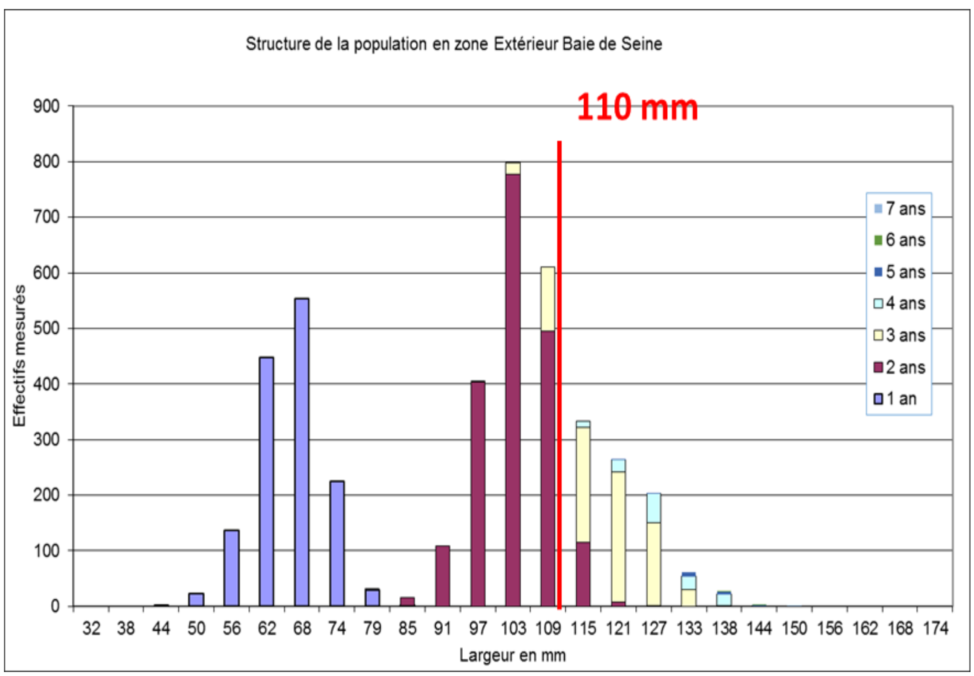


Figure x.4. Structure of the population of the "Proche Extérieur" in July 2018.

2) Bay of Seine

This area is located between the French coast of Normandy and the 12 nautical miles limit on the North. This King Scallop seabed is entirely into the French territorial waters.

The global status of the Bay of Seine stock is really good, it is the best situation ever seen from the beginning of the time series. Age 2 and age 3 indexes (respectively 789.08 and 175.63) are the two records of the time series. The age 2 index is approximatively 3 times and half above the average index of the last decade (218.66). The age 3 index, corresponding to King scallops already fished since one year, is 5 times better than the average. It results from the decision of French authorities and French fishermen Organizations to maintain closed during all the fishing season the Western part of the Bay of Seine (rotational closure). The improvement of the stock status in the bay of Seine could be observed on average indexes of historical period compared to average indexes of the last decade (Table. x.2). The age 1 index is one time again relatively high (394.33), above the average (Figure x.5).

Table x.2. Average abundance indexes in the "Bay of Seine" for age 1 to 7+, for historical period 1992–2007 and the last decade 2008–2017.

	1 an	2 ans	3 ans	4 ans	5 ans	6 ans	7 ans
Moyenne 1992-2007	57.85	66.69	13.26	4.26	1.22	0.29	0.13
Moyenne 2008-2017	256.55	218.66	34.24	9.45	2.78	0.91	0.59

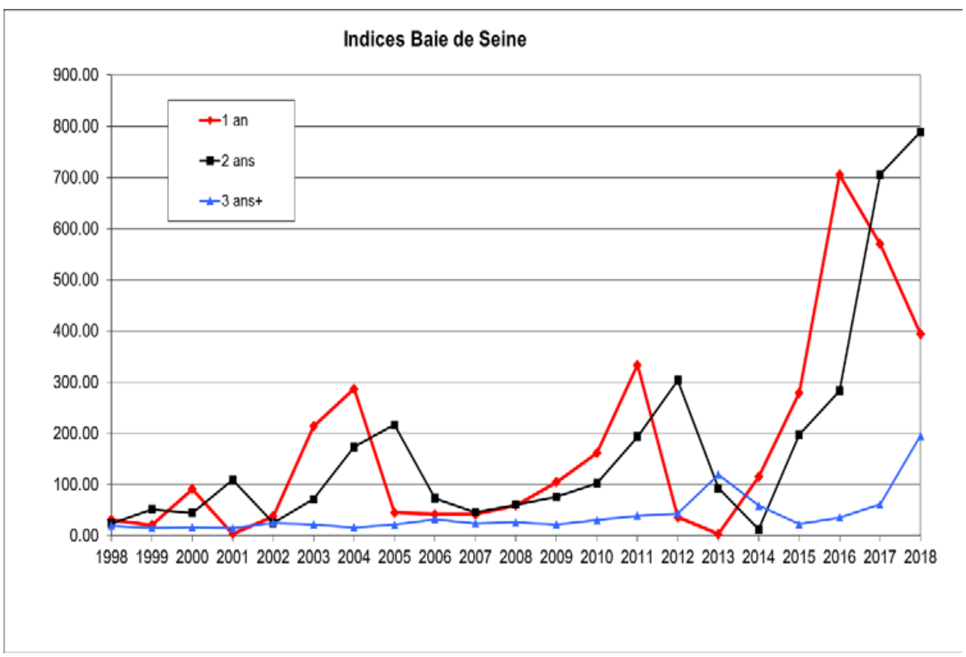


Figure x.5. Trends of abundance indexes in the area "Bay of Seine" from 1999 to 2018.

The exploitable biomass (King Scallops over the 110 mm MLS) is estimated to 63581 tonnes (Figure x.6), better than B_{2017} (48572 tonnes) and 3.5 times above the average $B_{2008–2017}$ biomass (17 233 tonnes).

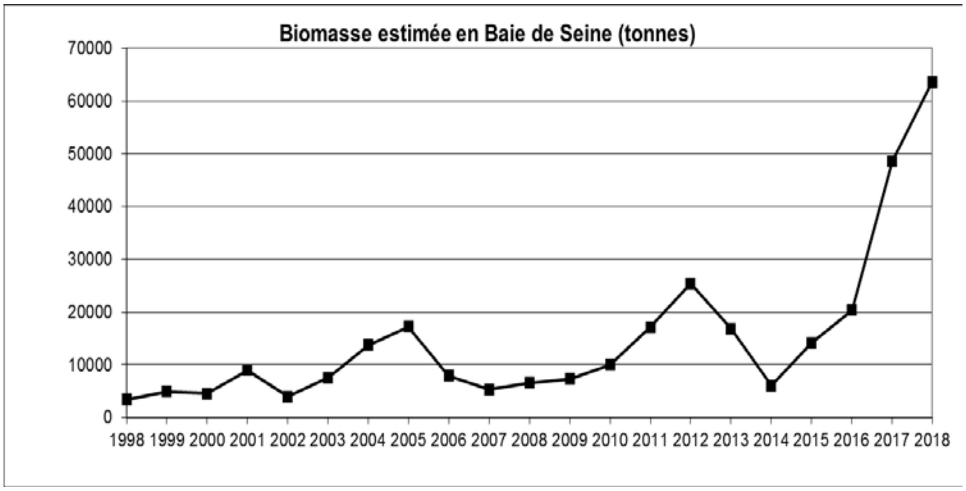


Figure x.6. Trends of estimated exploitable biomass in the area "Bay of Seine" from 1998 to 2018.

The structure of the population is the same as the "Proche Exterieur" and shows that the stock is mainly composed by age 2 and 3 years old scallops (Figure x.7).

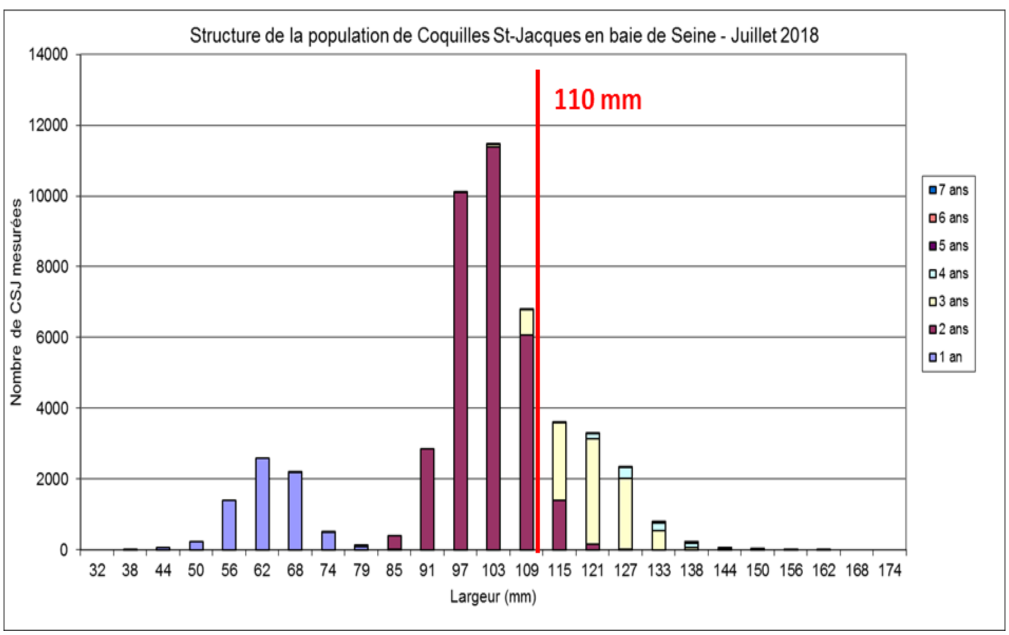


Figure x.7. Structure of the population of the "Bay of Seine" in July 2018.

The global situation off the coasts of Normandy (Eastern Channel) is good, but the most proportion of the exploitable biomass is located into the French territorial waters (Figure x.8).

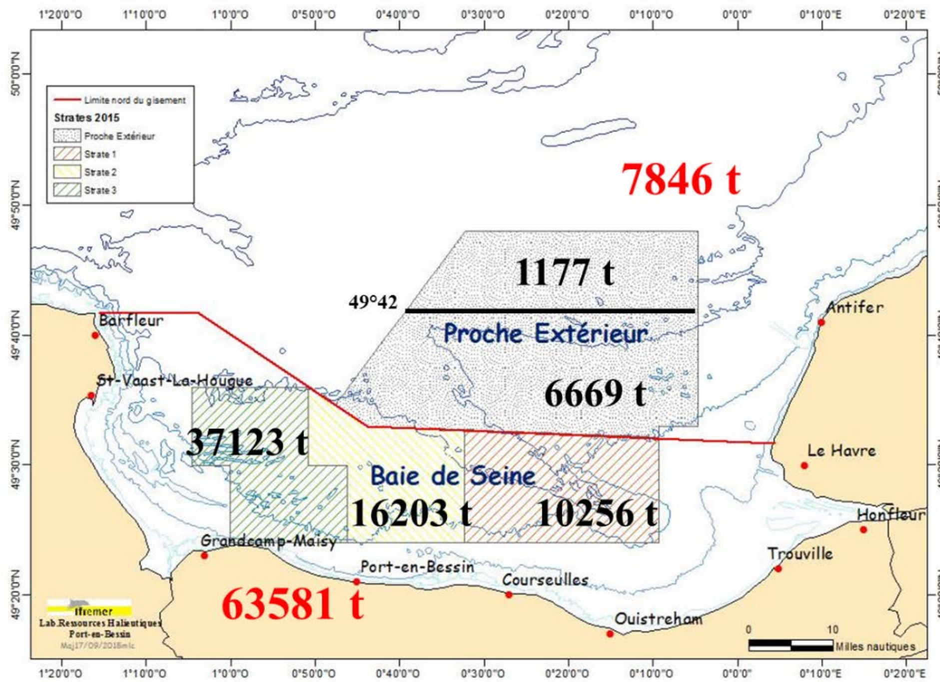


Figure x.8. Distribution of the exploitable biomass off the coasts of Normandy, Eastern Channel, France.

Recent French landings and trends 2000–2017 in the King Scallop fishery in Eastern Channel.

Almost all of the French King Scallop landings come from the English Channel, less than 2% have been caught in the Rade de Brest (Western end of Brittany) or small sea grounds in the Bay of Biscay (South of Brittany, Pertuis Charentais).

25 724 tons were caught during the fishing season 2016–2017 (from October to 15 May), 18 334 tons in Eastern Channel and 7390 tons in Western Channel, respectively 71% and 29% (Figure x.9).

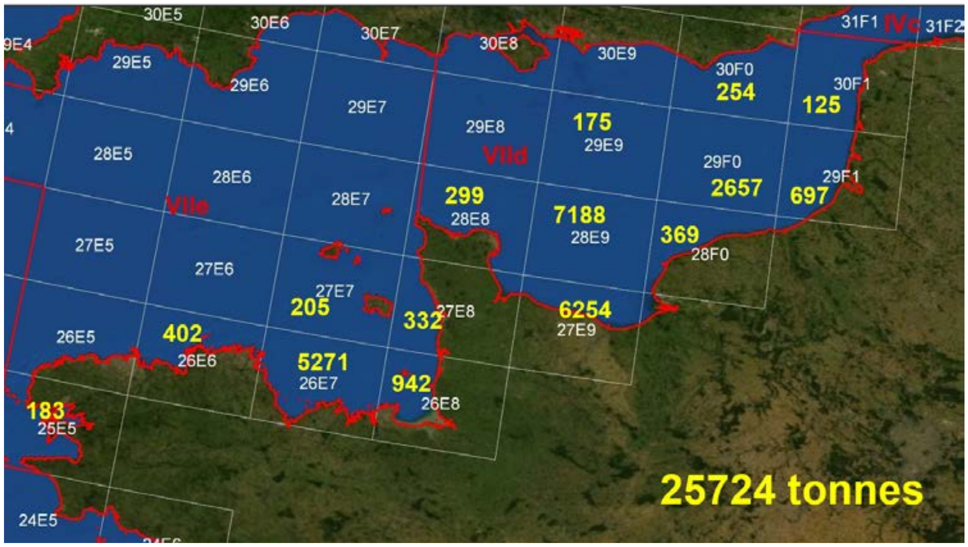


Figure x.9. French landings during the fishing season 2016–2017 in the Channel, by ICES rectangle (Source: Database SACROIS, French Ministry of Fisheries/Ifremer Système d'Information Halieutique).

In the Western Channel, 71% of the catches are coming from the Bay of Saint-Brieuc, inshore sea ground within the French territorial waters (ICES rectangle 26E7). In the Eastern Channel, the 3 ICES rectangles 27E9, 28E9 and 29F0 contribute to 88% of the total French landings in the Eastern Channel, and the 2 single rectangles 27E9 (entirely within the French territorial waters) and 28E9 (northern part in international waters, middle corresponding to the "Proche Extérieur" and southern part in French territorial waters) contribute to 73% of the total French landings. These 2 rectangles are so essential for the sustainability of the French King Scallop fishery in Eastern Channel.

For the last fishing season 2017–2018, the global landings in the English Channel is really stable (25 609 tons), but the repartition between Eastern and Western Channel slightly different. Indeed, 6420 tons (25%) have been caught in Western Channel (including 4820 tons in the Bay of Saint-Brieuc, 75% of Western landings) and 19189 tons (75%) in Eastern Channel (Figure x.10).

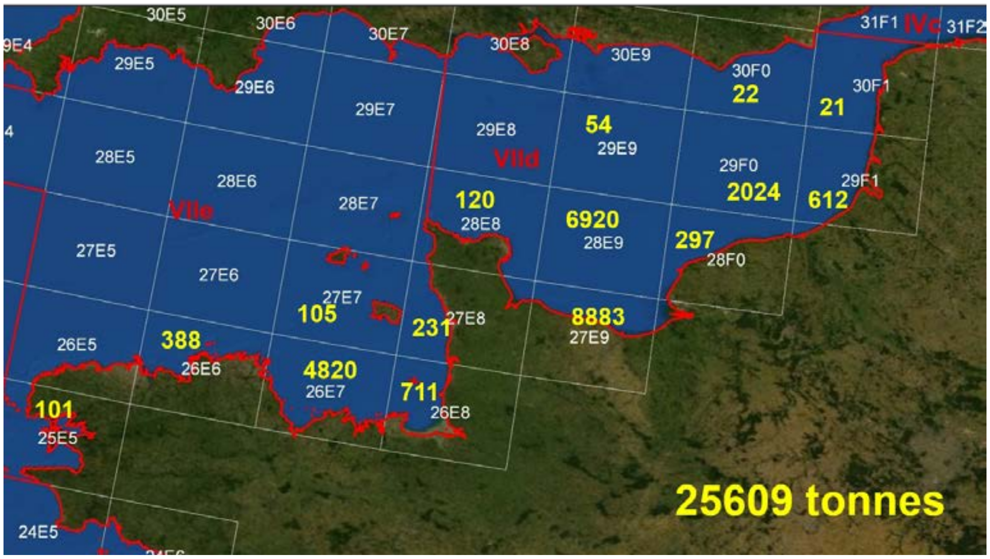


Figure x.10. French landings during the fishing season 2017–2018 in the Channel, by ICES rectangle (Source: Database SACROIS, French Ministry of Fisheries/Ifremer Système d'Information Halieutique).

In the Eastern Channel for the season 2017–2018, the 3 ICES rectangles 27E9, 28E9 and 29F0 contribute to 93% of the total French landings in the Eastern Channel, and the 2 single rectangles 27E9 (entirely within the French territorial waters) and 28E9 (northern part in international waters, middle corresponding to the "Proche Extérieur" and southern part in French territorial waters) contribute to 82% of the total French landings.

The global trends of King scallop landings in the Eastern Channel (ICES division VIId) present a continuous increase since 2000, from 8000 tons (6000t for France and 2000 for UK) to more than 24 000 tons in 2017 (18 000t for France and 6000t for UK); (Figure x.11).

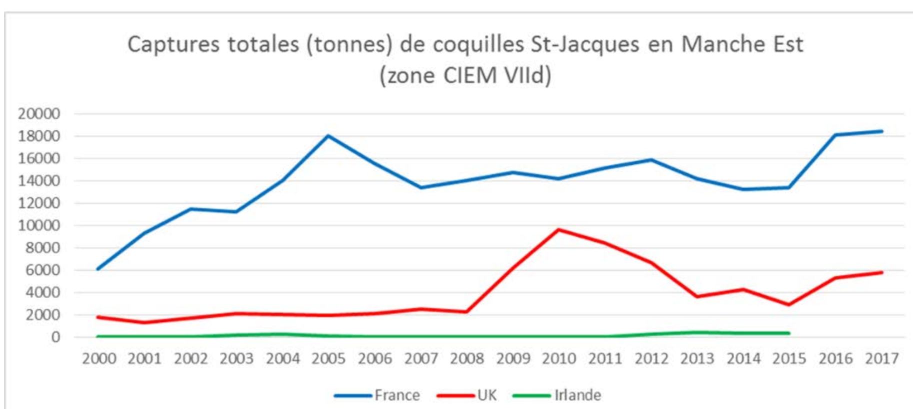
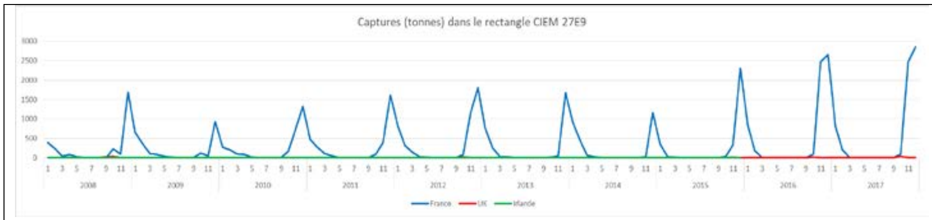
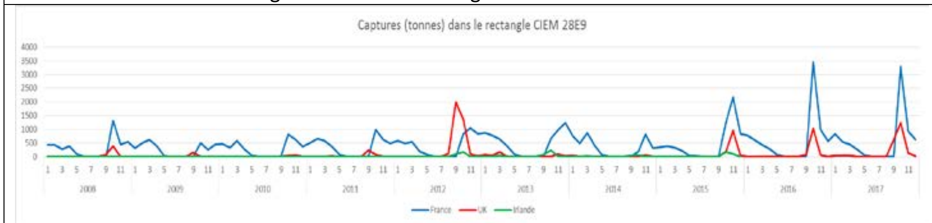


Figure x.11. King scallop landings trends in Eastern Channel, from 2000 to 2017.

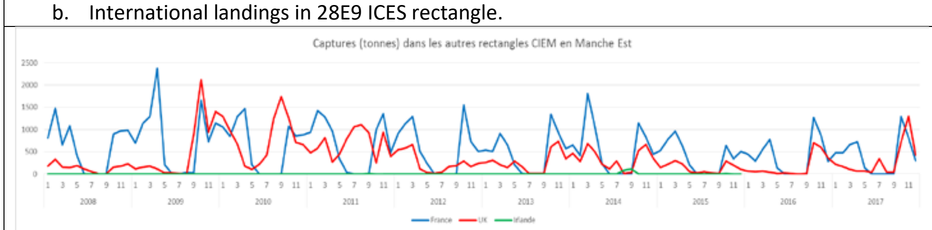
The trends of King scallop landings by month in the Eastern Channel from 2008 to 2017 are slightly different between France and UK, and also between the most important ICES rectangles (27E9, 28E9, 29F0 and the other rectangles of the VIId division). The seasonality of the fishing season in France is clearly shown (Figure x.12), in November and December in the Bay of Seine inshore fishery (entirely within the French territorial waters in 27E9, and from October to May in the other rectangles (Figure x.12b,c,d).



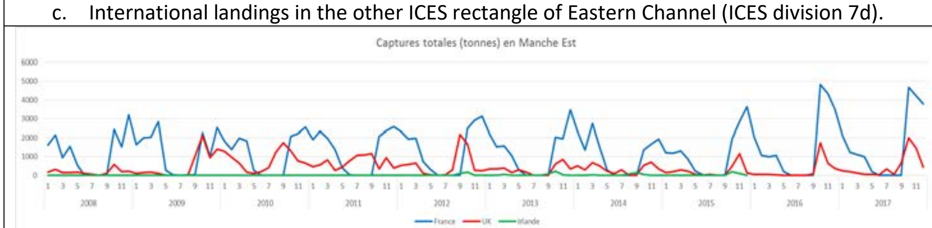
a. International landings in 27E9 ICES rectangle.



b. International landings in 28E9 ICES rectangle.



c. International landings in the other ICES rectangle of Eastern Channel (ICES division 7d).



d. International landings in Eastern Channel (ICES division 7d), all rectangles.

Figure x.12. Monthly trends of international King scallop landings in the ICES division 7d, from 2008 to 2017.

UK landings do not show such a seasonality and appear all over the year, especially in the middle and northern part of the Eastern English Channel. They appear in the Bay of Seine in the ICES rectangle 28E9 quite recently, the first year of important landings is 2012. Catches in this area, off the French coast, are opportunistic and concentrated during only 2 months, October and November. Anyway, ULK landings are representing during the all period around third of French landings.

The French LPUE (in Kg/hour) are constantly increasing from 2000 to 2017, in all areas in the Eastern Channel (Figure x.13). In the French territorial waters (ICES rectangle 27E9), where restrictive measures are in place since the middle of the 2000s (fishing season, limitation of hours per day and fishing days per week, individual quotas per boat, limitation of number of boats and number of dredges per boats, high selectivity of fishing gears…), LPUE have been raised from 60 Kg per hour in 2000 to nearly 250 Kg per hour in 2017.

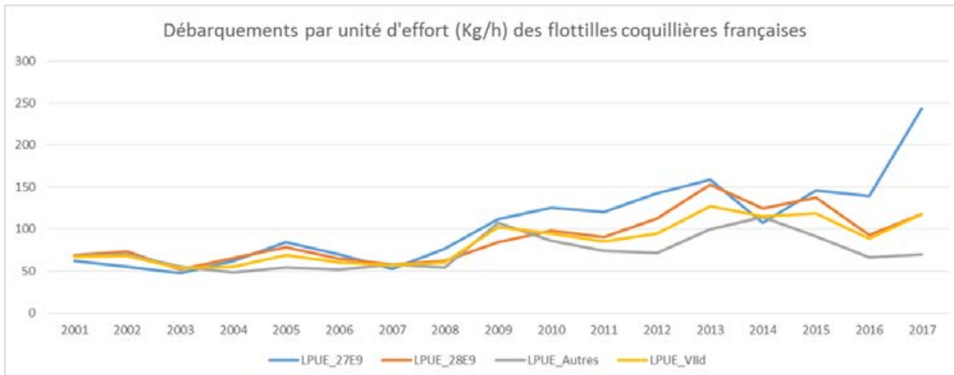


Figure x.13. Trends of French LPUE (in Kg per hour) in the ICES division 7d, from 2008 to 2017.

5.6 Science highlights

Northern Celtic Sea and Southern Irish Sea

Surveys

In 2017, and funded through the Interreg BLUEFISH Project, the Marine Institute completed the first dedicated scallop surveys took place in the northern Celtic Sea and southern Irish Sea since 2005. The aim of the survey was to investigate whether a relationship identified from previous surveys between scallop density (i.e. number of individuals caught per 100 m^2) and acoustic backscatter data, which is reflective of ground type, still existed in the scallop grounds of the northern Celtic Sea off the south-east coast of Ireland. Any shift in the distribution of sand or gravel patches would render the previous ground discrimination maps redundant. Seabed acoustic surveys are regularly carried out by the Marine Institute using a multibeam echo-sounder sonar system that provides information on the hardness and texture of the seabed. In the northern Celtic Sea there are two principal ground types dominated by either sand or gravel. No acoustic backscatter data is currently available for the scallop grounds of the southern Irish Sea.

The survey took place between 24 September and 2 October 2017 on board the RV Celtic Voyager, using four Newhaven spring-loaded dredges (commonly used by fishing vessels targeting scallops in Ireland) Due to bad weather, only 24 stations (three in the southwest Irish Sea and 21 in the northern Celtic Sea) were sampled. Scallop catches were measured and weighed throughout the survey, with tissue samples taken for genetic and biotoxin analysis. Bycatch was also recorded. The RV Prince Madog carried out dredging at 10 stations in the northern Celtic Sea at the same time.

Results of the survey indicate the linear relationship between scallop density and ground type still existed for the range of acoustic backscatter values in this area. Similar to survey results from 2001–2005, scallop abundance was highest on grounds comprised of gravel/coarse sediment, and substantially lower on sand sediments. A linear relationship was also observed from the stations sampled by the RV Prince Madog, although sampling was not carried out on stations covering the same range of acoustic backscatter values as the RV Celtic Voyager, with catches also lower when compared to the RV Celtic Voyager. This relationship suggests that *P. maximus* discriminate not only between sand and gravel sediments, but also between different grades of these sediments. From 2001–2005, relationships between abundance and ground type were also observed over fine spatial scales, indicating that spatial differences in larval supply was not a contributing factor to this relationship.

A 2018 survey is currently underway, and aims to survey some of the main beds fished by the offshore Irish scallop fleet (vessels >20 m), with their spatial extent identified using VMS data from 2014–2016. The survey areas are Cardigan Bay, the southern Irish Sea, and the inshore and offshore scallop grounds of the northern Celtic Sea. The 2018 survey is also funded through the BLUEFISH Project and will take place on board commercial fishing vessels as opposed to a research vessel. In the southern Irish Sea, where acoustic backscatter data is not available, the location of sampling stations has been allocated in proportion to the fishing activity of the Irish fleet from 2014–2016 in these areas. In the Celtic Sea, the location of sampling stations has been determined using classified acoustic backscatter data that identifies patches of seabed as being predominantly comprised of either sand or gravel sediments. Locations were randomly allocated based on where a 1500 m tow can be carried out on one of the predominant types of substrate, with approximately 80% of stations to take place on gravel based on the 2005 survey that identified scallop abundance as being approximately 80% greater on gravel sediments compared to sand. Successful surveys will allow for abundance estimates to be calculated for these areas that take into account dredge efficiency parameters, with geostatistical methods being employed to use the available acoustic backscatter data to inform the interpolation of the survey data (Co-Kriging) in the Celtic Sea.

The annual spawning cycle

Opportunistic sampling of shucked muscle and gonad samples submitted to the institute for biotoxin testing has taken place throughout 2018 in order to identify spawning times of scallop in the Celtic Sea. Variation in the macroscopic appearance of the gonad allows a spawning stage to be assigned, with a time-series of the proportions of developing, ripe and spent gonads allowing mass-spawning events to be identified. Data collected thus far indicates three main spawning events: mid-May, mid-July, and continuous spawning from mid-August through to mid-September. Sampling will continue throughout 2019. A good time-series of data would also allow the environmental variables that influence gonad development and spawning times to be identified. Knowledge of spawning times will also provide information for larval dispersal simulations investigating connectivity between scallop stocks in the southern Irish Sea and Celtic Sea.

Size distribution of the catch and landings

A port sampling programme has been in place since 2009 whereby random samples of scallop landings by ICES rectangle from the Irish fleet are opportunistically sampled for shell height at seafood processors. The programme provides a time-series of size data from the scallop stocks fished by the Irish fleet. Since 2009 through to September 2018, 237 samples from 33 ICES rectangles have been obtained, with 131 of these samples from the Celtic Sea (31E2, 31E3, 32E2, 32E3, 33E3 and 33E3). Less frequent samples from the English Channel, Irish Sea, and the North Channel between Northern Ireland and Scotland are also obtained Approximately 400 scallops are measured per sample. Port sampling in 2018 has increased compared to previous years as a result of involvement in the BLUEFISH Project.

Sampling on board commercial scallop vessels has been in place since 2011. Marine Institute observers measure the size distribution of the scallop catch and also record and measure bycatch species, Twenty seven trips have been completed from 2011–2017, with data collected from 793 individual hauls in ICES area VIIa, and 184 hauls in area VIIg. In area VIIa, spotted ray and plaice have been the most recorded bycatch species, and in area VIIg, white-bellied monkfish and megrim have been the most frequent. Elasmobranch species such as the cuckoo ray, lesser-spotted dogfish and thornback ray has also been more frequently recorded as a bycatch species in area VIIa compared to VIIg.

Catch and effort indicators

A 15 year time-series of logbook (landings) and VMS (effort) data from the Irish offshore scallop fleet (vessels > 15 m) is available. Although the VMS and Landings data are reported at different temporal and spatial resolutions they can be combined to link landings and fishing time, and calculations of nominal landings per unit effort (LPUEn) described as $kgs.dredge^{-1}.day^{-1}$, $kgs.dredge^{-1}.loggedhr^{-1}$ or $kgs.dredge^{-1}.VMShr^{-1}$. VMS data from scallop vessels has been used to map the historic distribution of scallop fishing. This has defined the known distributional extent of commercially viable scallop beds fished by the Irish fleet. The annual distribution of scallop fishing provides an estimate of the annual footprint or pressure to which the stock is exposed, although the footprint estimate is sensitive to the resolution (ping frequency) of the VMS data.

Temporal trends in LPUEn are different across areas. In the Celtic Sea, catch rates increased from approximately 50 $kgs.dredge^{-1}.day^{-1}$ from 2005–2007 to approximately 75 $kgs.dredge^{-1}.day^{-1}$ in 2011–2013, but has since steadily declined to 2007 levels in 2016. Since the Irish fleet began entering the eastern English Channel scallop fishery on an annual basis in 2011, catch rates reached 200 $kgs.dredge^{-1}.day^{-1}$ in 2012; more than double the LPUEn returned from any other area exploited by the fleet during our time-series. A subsequent decrease in catch rates followed in 2013 and 2014. Catch rates in 2015 once again increased to 200 $kgs.dredge^{-1}.day^{-1}$, and in 2016 reached 240 $kgs.dredge^{-1}.day^{-1}$, making this area a very efficient and lucrative fishery for the Irish fleet.

LPUEn can be standardised (LPUEs) to remove trends that may be due to factors other than changes in the abundance of scallop. Likely factors to consider are fishing season (month), location (e.g. ICES rectangle within stock), ground type, vessel power, gear type, vessel plotting systems, wind speed and tidal strength. Information to supplement this work will be gathered directly from skippers of the fleet through questionnaires and interviews, with the aim of identifying the environmental factors & gear settings the fleet consider important for maintaining gear efficiency & catch rates.

Increased frequency of VMS and catch reporting, as implemented in some inshore VMS systems for smaller vessels, potentially allows reconstruction of precise vessel track information and the landings associated with that track. As the number of dredges can be predicted from vessel length the swept-area associated with a given catch could be estimated. Accounting for gear efficiency would then allow absolute estimates of the abundance of the component of the stock above the minimum landing size to be estimated and provide survey type information based on a much higher volume of data than can be achieved from a dedicated survey. Changes in biomass could then be tracked seasonally and be used to inform near real time management.

Connectivity across scallop beds in the Irish and Celtic Seas

Larval dispersal simulations were undertaken in the Irish and Celtic Seas by the Marine Institute to assess the level of connectivity between scallop beds in the area. The work is ongoing. Connectivity across five scallop beds (north east Celtic Sea, south Irish Sea, Cardigan Bay and Liverpool Bay) was estimated annually for years 2011–2015.

The Ichthyop model was used to interface with archived ROMS model output files which contain arrays of current vectors and temperature and salinity data at 3 hour intervals at resolutions of 1.2–1.5km in the horizontal and with up to 40 vertical layers. Current vectors, from ROMS output, integrated the effects of coastal topography, depth, wind forcing, freshwater inflows and solar heating on current strengths and direction within grid cells in the model. ROMS output faithfully reproduced salinity and temperature fields observed from satellite data.

Simulated larvae were introduced to Ichthyop by subsampling vessel monitoring system (VMS) data. The VMS data were assumed to be a proxy for the distribution and relative abundance of adult scallop and therefore represented locations from which larvae would be introduced to the water column during spawning events.

Larvae were treated either as passive particles with neutral buoyancy or particles which migrated vertically on a 24hr period between near-surface waters (night) and 20m depth (day). This, on average, retained larvae above the thermocline in areas of stratified water.

Simulations were initiated on 1 June of each year and ran for a maximum of 40 days but the total amount of heat (degree hours/days) experienced by larvae was calculated for each larvae during the model runs and larvae were deemed to be competent to settle after a given number of degree days identified from published temperature development rate functions. Physiological rather than chronological age was therefore used to identify the point at which settlement could occur. Spawning was presumed to occur during June throughout the area and in all years 2011–2015.

Outputs from Ichthyop are in the form of NETcdf files. R scripts were developed to extract and report the outputs including conversion to shape file format for use within GIS, reporting of depth distributions of larvae during simulation, tracking individual larvae and drawing polygons describing the distribution of dispersal.

Results indicate that there is limited connectivity across the 5 scallop beds studied with a high level of self-recruitment. There is no exchange of larvae from the eastern Irish Sea south to other beds. There is no exchange of larvae from the Celtic Sea north into the Irish Sea. Larvae may be transported from the south Irish Sea into the Celtic Sea. There is some east west exchange of larvae between the south Irish Sea and Cardigan Bay. The south Irish Seabed is at highest risk of limited larval supply. Interannual differences in the level of larval exchange across beds are evident. The findings are consistent with information on stock structure from genetic work undertaken at the University of Aberystwyth (N. McKeown and P. Shaw) which shows significant genetic differentiation between Celtic Sea and Cardigan Bay stocks.

Future developments

Spawning season may vary annually and the most suitable time(s) to initiate the dispersal simulation should therefore consider the gonad development and readiness to spawn. As the simulations are necessarily done retrospectively on archived ROMS files a retrospective set of seasonal gonad development indices would ideally also be available to inform the timing of the simulations. This work is ongoing as described above.

Larval vertical migratory behaviour has a significant effect on dispersal; this is likely to be either tidally timed or occur on a diel cycle in response to changes in light intensity. Studies to identify larval depth distributions and behaviour would be important to inform future simulations.

Correlations between the expected regularity of larval supply to different beds and age class structure of scallops on these beds could be investigated when a time-series of larval supply estimates have been produced. This would indicate whether or not variability of larval supply is a significant contribution to recruitment variability. In that respect there is now evidence from survey data and from genetic information that recruitment can be very irregular and infrequent in areas such as the south Irish Sea where the larval dispersal simulations show poor retention and supply of larvae. Furthermore, genetic variability in these areas is reduced and negatively correlated with age indicative of small closed populations experiencing sequential mortality. These areas are in proximity to the Celtic Sea Front the position of which may control the delivery of larvae to these areas.

Isle of Man King Scallops: 2018 fishery and stock assessment

The annual spring scallop stock assessment survey was undertaken from 4–17 April 2018. The survey uses a set of four king and queen scallop dredges to sample fixed stations around the Isle of Man's territorial sea. Currently 11 historical survey stations that cover the extent of the main king scallop fishing grounds, and which have been surveyed since 1992, have been used for the stock assessment. An age based stock assessment approach (a4a/FLR) has been developed with assistance from the EU Joint Research Council at ISPRA who designed the methodology. This preliminary assessment has been used alongside the ICES Category 3 approach for TAC calculation. Following declines in both the survey abundance index and the estimated biomass from the stock assessment model a 20% reduction of the previous year's TAC has been agreed for the 2018/2019 fishing season (2562 t). Dredge cameras continue to be used on the survey and have been useful for assessing the sediment and habitat characteristics of a site along with validating tow data. A validation trial was undertaken during the survey with Sonardyne and 2G Robotic to test the feasibility of using laser scanning equipment to identify scallops on the seabed. Successful validation was achieved and further analysis is being undertaken. In terms of the fishery, following a period of steady incline in landings there was a sharp reduction in landings (tonnes/calendar year) from a peak in 2016 (5714 t) to 2017 (3515 t) calendar year. New electronic data collection techniques for both the king and queen scallop fishery have improved both the speed and resolution of industry dependent data that is collected within the Isle of Man's territorial waters.

Isle of Man Queen Scallops: 2018 fishery and stock assessment

The annual spring scallop stock assessment survey was undertaken from 4–17 April 2018. The survey uses a set of four king and queen scallop dredges to sample fixed stations around the Isle of Man's territorial sea. We continue to use CSA (Catch Survey Analysis) for the queen scallop stock assessment with data from any site with 3 or more years of data where queen scallops are historically present. There continues to be a decline in post-recruit (over 55 mm) and recruit (under 55 mm) abundance index for queen scallops and a corresponding decline in estimated biomass from the model. Following ICES Category 3 protocol for TAC calculations the decline in survey abundance led to a 20% (capped) reduction in the TAC relative to the previous season (794 t).

For the 2018 Isle of Man queen scallop fishery the quota was split into trawl (697 t) and dredge (97 t) in line with the relative number of eligible vessels prosecuting each metier. Spatial distribution of landings in the 2018 fishing season was significantly different from the three previous seasons with 2018 landings split among all of the four main fishing grounds rather than a single fishing ground dominating the landings as in 2017 (EDG), 2016 (TAR) and 2015 (TAR). LPUE for the main fished grounds was significantly lower in 2018 than the previous three seasons. The scientific advice continues to recommend a reduction in fishing effort for this fishery to allow recovery.

King Scallop (*Pecten maximus*) in the Bay of Saint-Brieuc (VIIe, 26e7)

Survey COSB 2018 (August 26th-September 7th). Results and management projections. Work undertaken under financial support from the European project FEAMP 28 (years 2017–2019).

Introduction and historical context

Ifremer carried out the yearly directed stock assessment for the inshore King Scallop fishery of the Saint-Brieuc Bay (VIIe, 26e7) extended to 634 km² of total surface divided in six spatial strata (survey COSB2018; French R/V "Thalia"; Figure 1).

The on board operations usually undertaken in the late summer involve in sampling 115 stations by dredging on constant distances of 200 m using an experimental dredge of 2 m width equipped with a pressure plate (Breton dredge), teeth of 8.5 cm length and belly and back ring diameter of 50 mm. The dredge efficiency is calibrated owing to previous references (Fifas and Berthou, 1999; Fifas *et al.*, 2004; Figure 2). Caught individuals are exhaustively aged and a LFD by age group and by tow is obtained.

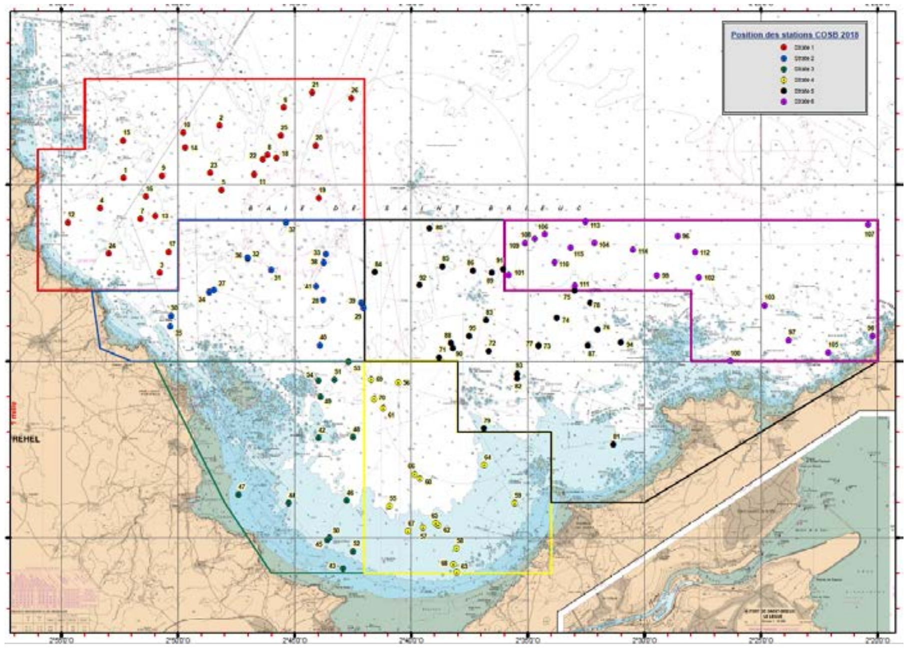


Figure 1. Survey COSB 2018. 115 sampling units in the Saint-Brieuc Bay (realised by Didier Le Roy).

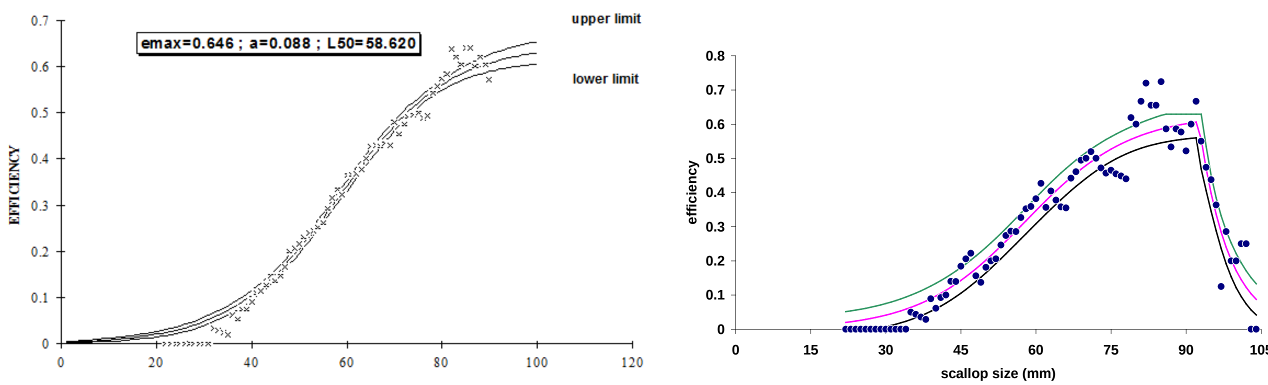


Figure 2. Efficiency model *vs.* scallop size (height, mm) for experimental dredge (with a pressure plate) used in COSB survey. Left: teeth length of 9–13 cm; right: teeth length of 7.5 cm.

The inshore King Scallop fishery of the Saint-Brieuc Bay is probably represented by the highest density levels in European scale. For the period 1962–2018, landings usually oscillated in a range of 4000–6000 t with some extreme values as 12 500 t (season 1972/73) and 1300 t (season 1989/90). In recent years, the exploitation has been undertaken by 220–230 vessels (99% dredgers, 1% divers) whereas the maximum numbers of vessels was reached in the mid-70s (466). Many historical stages throughout more than a half century of exploitation (from the early 60's onwards) show the vanguard position of this stock for the scallop French fisheries.

1965: The first regulations aiming to control the fishing effort occurred in this fishery. As consequence of the severe winter 1963 the LPUEs steeply decreased two years later. As the collapse of the Bay of Brest stock was recent, managers decided to stop fishing activity. The first scallop survey was also carried out the same year.

1973–1974: The first licences system by couple skipper/vessel was initiated in this fishery.

1976: A quota/TAC for a national fishery in France was firstly adopted aiming to stabilise volume of catches between fishing seasons 1975/76 and 1976/77 (enormous cohort 1973, very poor cohort 1974).

1978: Sales at auction became compulsory for the first time in France.

1985, 1996, 2017: Diameter of dredge rings increased from 72 mm to 85 mm, then to 92 mm and finally to 97 mm for the first time on a King scallop stock.

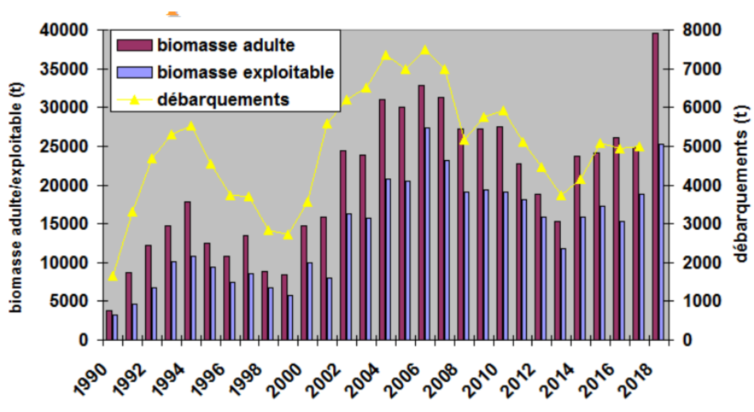
1990: For the first time, it was implicitly accepted that the engine power affects the individual catch capacity (the maximum allowed limit of 292 kW was drastically reduced at 185 kW).

Results

Adult and exploitable biomass

The adult biomass includes all age groups 2 and +, it provides an index of the potential fecundity of the stock. The exploitable biomass corresponds to individuals larger than 102 mm (MLS in VIIe French waters), thus it is a fraction of the adult one (Figure 3). Table 1 gives many indices such as biomasses of the recruited year class (GR 2) and of the remaining year classes (GR 3+).

Those indices show cyclical pattern with a downwards trend in the period 2006–2013 (respectively –53% and –57% for adult and exploitable biomass). Afterward, an increasing phase is obvious. In 2018, the historically highest level (respectively +59% and +35% for adult and exploitable biomass compared to 2017) is reached. Comparing year 2018 vs. maximum level for 2000s (year 2006) gives +21% for the adult biomass, although –7% for the exploitable one.



YEAR 2018	
AGE	numbers (10^6)
1	318.80 ± 19.1%
2	130.59 ± 17.8%
3	54.77 ± 17.9%
4	86.64 ± 19.1%
5	41.49 ± 16.9%
6+	17.84 ± 24.9%

Figure 3. Left: Adult (yrs 2+) and exploitable biomass (L≥102 mm) in the Saint-Brieuc Bay King Scallop stock. Yellow curve provides nominal landings by season. Right: estimates from COSB 2018 survey by age group and relative precision.

Table 1. Biomass (t) for the recruited year class (GR 2), for the remaining year classes (GR 3+), adult biomass, exploitable biomass, proposed and actually harvested quotas.

Year	GR 2	GR 3 +	Adult biomass	Exploitable biomass	Proposed quota	Nominal landings	Δ	Δ (%)
2008	6880	20320	27200	19030	4800	5152(3)	352	7 %
2009	6880	20310	27190	19330	5200	5766	566	11 %
2010	7350	20170	27520	19060	5000	5923	923	18 %
2011	3640	19030	22680	18100	4500	5095	595	15 %
2012	1880	16980	18860	15860	3500	4456	956	27 %
2013	2880	12490	15370	11790	3000	3744	744	25 %
2014	7020	16630	23650	15910	3550	4163	613	17 %
2015	6610	17470	24080	17240	3800	5086	1286	34 %
2016	8210	17930	26140	15300	3550	4935	1385	39 %
2017	4010	20860	24870	18780	3850	4986	1136	30 %
2018	11520	28130	39640	25310				

Information by age group

Recruitment (cohort 2016)

The survey 2018 revealed an exceptionally strong level for age 2: 131 million individuals corresponding to 11 520 t of total biomass (figure 4a; against 43 million and 4010 t for the same age group in the last year's survey). This has been the highest abundance for this age group since the cohort 1973 although with no possibility of direct comparison as the method was different in previous decades. The arithmetic and geometric means for years 1991–2017 (cohorts 1989–2015) are respectively 61 and 54 million scallops. The mean size (length) is equal to 93 mm (against 94 mm a year ago). A fraction of 6.5% reached the MLS=102 mm in September 2018 (otherwise 1030 t, 7680 t in January under average growth conditions).

Remaining year classes (yrs 3+).

The management policy consists to preserve more than one significantly present age groups in the order to reduce fluctuations between yearly total abundance as more as possible independently of the annual recruitment variability. Four age groups are significantly abundant in the fishery: 3–6 years (respectively 6670 t, 11 840 t, 6470 t, 3140 t). The total remaining biomass was estimated at 28 130 t (20 160 t in 2017). The cohort 2015 (Figure 4b) is represented by a total abundance of 55 million, among them 64% reached the MLS=102 mm (4730 t on a total biomass of 6670 t).

Juveniles (cohort 2017).

In September 2018, the age group 1 was estimated equal to 319 million individuals (figure 4c; this abundance should provide a total one of 135 in the next year's survey; see below). This is the second range of strength since the cohort 1973. It is noticeable that the majority of historically high reproductions (cohorts 1973, 1999, 2005, 2016, 2017) occurred during the last two decades of the stock history. The arithmetic mean for years 1991–2017 (cohorts 1990–2016) is equal to 129 million and the geometric one to 108 million. The mean size of this year class was 61 mm (length) against 68 mm a year ago for the cohort 2016.

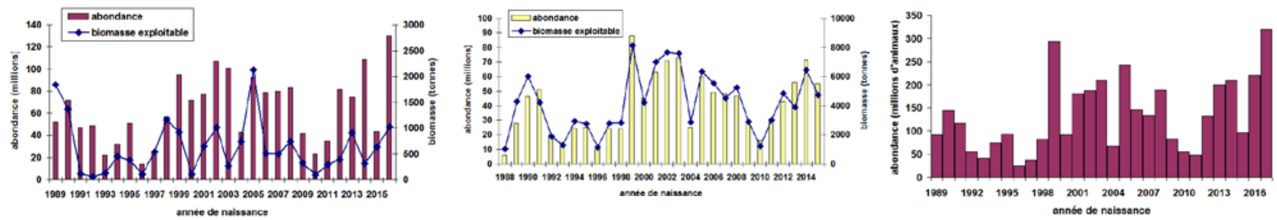


Figure 4. The 2018 status for (a) the age group 2 (cohort 2016); (b) the age group 3 (cohort 2015) and (c) the age group 1 (cohort 2017).

Projections and inputs

The entry in the fishery of five abundant cohorts during the last six years (apart from the class 2015), and among them the exceptionally high level of two consecutive reproductions (2016 and 2017) allowed to totally invert the downwards trend of the period 2006–2013. In 2018, the potential fecundity represented by the adult biomass reached a record value (+59% compared to 2017, even more, +21% compared to the maximum level of 2006). If the immediately exploitable biomass (+35% from the 2017 value) is slightly lower (-7%) than that of 2006, this bodes well for the future as the current population age structure is younger. Nevertheless, the scallop stock is subject to cyclical fluctuations (Figure 2). The steep upwards trend of recent years followed a downwards cycle (2006–2013) which was the longest in the stock history.

Relationship GR1/GR2

The strong correlation (R^2=0.87; Figure 5a) of abundance at age 2 *vs.* age 1 by cohort between two consecutive years allows to accurately estimate abundance of cohort 2017 in 2019 ≈ 135 million scallops for a total biomass equal to 12 960 t (319 million at age 1 for the 2018s survey).

Components of fishing mortality

The biological module of the bio-economic model (project IAM, years 2009–2011; Figure 5b) allows to integrate in the harvested scallops not only the nominal ones landed and sold at auction but furthermore other sources of fishing mortality such as mortality by discarding (low values: 2–5%), by damaging (harmed scallops by the action of towed dredges on the bottom, low values: 5–10%) and mortality corresponding to illicit catches either during the opened fishing season (November to April) or during the closed one (mainly by bottom trawling). The third component seems to have been reduced in the more recent years (Figure 6).

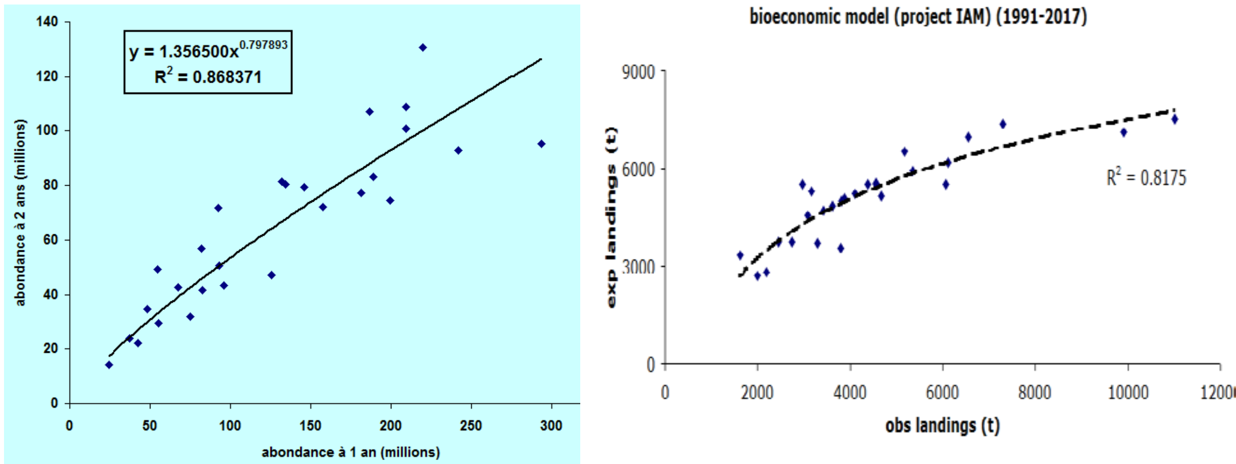


Figure 5. (a) Relationship between abundance for age 2 vs. age 1 by cohort (b) Bio-economic model (project IAM): expected total landings vs. observed ones.

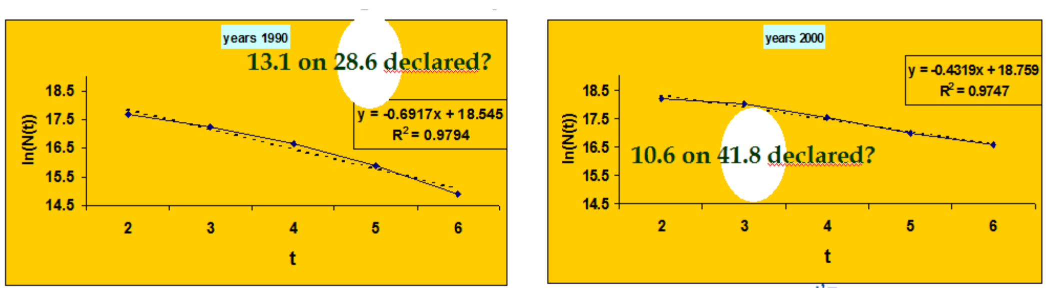


Figure 6. Estimates of not declared harvested quantities of scallops. Processed data by pseudo-cohort averaged by decade (1990's and 2000's) input in the biological module of the project IAM (see above).

Probabilistic S/R relationships

The year class abundances (2018–2020) are not currently known. The 2018's cohort abundance will be reliably estimated not before the late summer 2019 as the spat collectors used in summer 2018 provide a minor part of explanation for the future class strength. The input values for those three classes will be simulated. The simulation takes into account that a Ricker S/R model explains a very low ($\varrho^2 \approx .115$) part of the predicted cohort abundance. The uncertainty in this relationship can be expressed by a log-normal probability. On this basis, recruitments for cohorts 1989–2017 (surveys 1990–2018) are assigned to probability levels against the spawning biomass[1] of the birth year (Fig; 7a).

The Figure 7a may suggest the existence of a cyclical pattern for the probability values. Moreover, the smoothed values for those probabilities against year provide a satisfactory precision of a periodic function with a cycle on 15 years (Figure 7b). The 2018–2020 year classes' abundances are input by two ways:

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[1] The spawning biomass differs from the adult one because it is calculated by weighing accordingly to the number of eggs potentially produced which is a function of the scallop size.

1) Simulation by using a constant probability of 0.5 (in this case, the abundances for cohorts 2018–2020 fluctuate in the range 59–75 million).

2) Simulation accordingly to the periodicity as described by Figure 7b (in this case, abundances for cohorts 2018–2020 fluctuate in the range 126–197 million).

There is no incidence on three years projections for nominal landings as the classes 2018–2020 will not yet contribute in the exploitable fraction in this time scale. At the opposite, for the spawning biomass the option (2) causes more reactivity of the stock as it seems to be currently located on the upper part of the cyclical pattern.

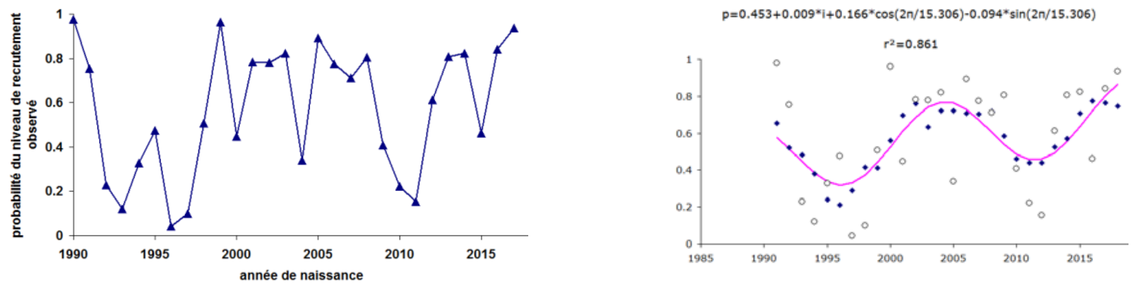


Figure 7. (a) Log-normal probability for the observed recruitments (year classes 1990–2016) vs. observed spawning biomass. (b) Fitting of the probabilities (smoothed values on 5 years).

Scenarios for the projections.

Three projection options are computed:

1) Stability for nominal landings between seasons 2017/18 and 2018/19 (4986 t).

2) Status quo for fishing effort between seasons 2017/18 and 2018/19.

3) Minimization of the nominal landings variations for fishing seasons comprised between 2017/18 and 2020/21 as regards the already known future increase of catches due to the recent year classes strength.

All three scenarios are performed under the new ring diameter for dredges (97 mm instead of 92). The basis for that is the biological module (project IAM; summed up in § 3.1) and also developed for the National Research French project ANR COMANCHE (years 2011–2014). The Table 2 provides numerical application for the three approaches above.

Table 2. Numerical application for the 2018/19 season's proposed quota. 1st column: proposed quota(t); 2nd column: actual nominal landings (t); 3rd column: Δf=% variation for fishing effort between 2017/18 and 2018/19; 4th to 6th columns: ΔY1, ΔY2, ΔY3=% variation of landings between subsequent fishing seasons; 7th to 9th columns: ΔBf1, ΔBf2, ΔBf3=% variation of spawning biomasses between springs/summers of subsequent years.

		Δf	ΔY1	ΔY2	ΔY3	ΔBf1	ΔBf2	ΔBf3	E[Y]	σ[Y]	comb(Y)	E[Bf]	σ[Bf]
3500	4372	-18.3%	-12.3%	34.0%	14.1%	20.6%	3.7%	-10.3%	7.52%	18.97%	26.49%	9.82%	12.7%
3550	4424	-17.2%	-11.3%	33.7%	13.9%	20.4%	3.6%	-10.5%	7.91%	18.39%	26.30%	9.64%	12.6%
3600	4476	-16.1%	-10.2%	33.4%	13.8%	20.2%	3.4%	-10.6%	8.30%	17.82%	26.12%	9.46%	12.6%
3650	4529	-15.0%	-9.2%	33.0%	13.6%	20.0%	3.2%	-10.8%	8.69%	17.25%	25.93%	9.28%	12.6%
3700	4581	-13.9%	-8.1%	32.7%	13.4%	19.8%	3.1%	-10.9%	9.07%	16.69%	25.76%	9.10%	12.5%
3750	4633	-12.7%	-7.1%	32.4%	13.2%	19.6%	2.9%	-11.1%	9.46%	16.12%	25.58%	8.92%	12.5%
3800	4685	-11.6%	-6.0%	32.1%	13.0%	19.4%	2.8%	-11.2%	9.84%	15.57%	25.42%	8.74%	12.5%
3850	4737	-10.5%	-5.0%	31.8%	12.8%	19.2%	2.6%	-11.4%	10.23%	15.02%	25.25%	8.56%	12.5%
3900	4789	-9.4%	-4.0%	31.5%	12.6%	18.9%	2.5%	-11.5%	10.61%	14.48%	25.09%	8.38%	12.4%
3950	4840	-8.3%	-2.9%	31.2%	12.4%	18.7%	2.3%	-11.6%	10.99%	13.95%	24.94%	8.21%	12.4%
4000	4891	-7.2%	-1.9%	30.9%	12.2%	18.5%	2.2%	-11.8%	11.38%	13.42%	24.79%	8.03%	12.4%
4050	4943	-6.0%	-0.9%	30.6%	12.1%	18.3%	2.0%	-11.9%	11.76%	12.90%	24.66%	7.85%	12.4%
4100	4994	-4.9%	0.2%	30.2%	11.9%	18.1%	1.9%	-12.1%	12.14%	12.38%	24.52%	7.68%	12.3%
4150	5045	-3.8%	1.2%	29.9%	11.7%	17.9%	1.7%	-12.2%	12.52%	11.88%	24.40%	7.50%	12.3%
4200	5097	-2.7%	2.2%	29.6%	11.5%	17.7%	1.6%	-12.3%	12.90%	11.38%	24.29%	7.33%	12.3%
4250	5148	-1.5%	3.2%	29.3%	11.3%	17.5%	1.4%	-12.5%	13.28%	10.90%	24.19%	7.15%	12.2%
4300	5198	-0.4%	4.3%	29.0%	11.1%	17.3%	1.3%	-12.6%	13.66%	10.44%	24.10%	6.98%	12.2%
4350	5250	0.7%	5.3%	28.7%	11.0%	17.1%	1.1%	-12.7%	14.04%	9.98%	24.02%	6.81%	12.2%
4400	5301	1.9%	6.3%	28.4%	10.8%	16.9%	1.0%	-12.9%	14.42%	9.54%	23.96%	6.63%	12.2%
4450	5351	3.0%	7.3%	28.1%	10.6%	16.7%	0.9%	-13.0%	14.79%	9.13%	23.92%	6.46%	12.1%
4500	5401	4.1%	8.3%	27.8%	10.4%	16.5%	0.7%	-13.1%	15.17%	8.73%	23.90%	6.29%	12.1%
4550	***5452***	***5.3%***	***9.3%***	***27.5%***	***10.2%***	***16.3%***	***0.6%***	***-13.3%***	***15.55%***	***8.36%***	***23.91%***	***6.12%***	***12.1%***
4600	5502	6.4%	10.3%	27.2%	10.1%	16.1%	0.4%	-13.4%	15.92%	8.01%	23.93%	5.95%	12.0%
4650	5552	7.5%	11.4%	26.9%	9.9%	15.9%	0.3%	-13.5%	16.30%	7.70%	23.99%	5.78%	12.0%
4700	5603	8.7%	12.4%	26.6%	9.7%	15.7%	0.2%	-13.7%	16.68%	7.41%	24.09%	5.61%	12.0%
4750	5653	9.8%	13.4%	26.3%	9.6%	15.5%	0.0%	-13.8%	17.05%	7.17%	24.22%	5.44%	12.0%
4800	5703	11.0%	14.4%	26.0%	9.4%	15.3%	-0.1%	-13.9%	17.42%	6.97%	24.39%	5.27%	11.9%
4850	5753	12.1%	15.4%	25.7%	9.2%	15.1%	-0.3%	-14.1%	17.79%	6.81%	24.60%	5.10%	11.9%
4900	5803	13.3%	16.4%	25.4%	9.0%	14.9%	-0.4%	-14.2%	18.17%	6.70%	24.86%	4.93%	11.9%
4950	5853	14.4%	17.4%	25.1%	8.9%	14.7%	-0.5%	-14.3%	18.54%	6.63%	25.18%	4.77%	11.8%
5000	5902	15.6%	18.4%	24.8%	8.7%	14.5%	-0.7%	-14.4%	18.91%	6.62%	25.53%	4.60%	11.8%

							Log-normal p=0.5			Cyclical log-nc	
	Quota	Landings	Δf	ΔY1	ΔY2	ΔY3	ΔBf1	ΔBf2	ΔBf3	ΔBf1	ΔBf2
Option 1	4092	4986	-5%	0%	30%	12%	18%	2%	-12%	18%	6%
Option 2	4320	5219	0%	5%	29%	11%	17%	1%	-13%	17%	6%
Option 3	4550	5452	5%	9%	28%	10%	16%	1%	-13%	16%	5%

Conclusions

There is no other surveyed species or stocks in French fisheries with possibility of reliable projections on three years. The partnership scientists/fishing industry (project FEAMP 28 on years 2017–2019 with possibility of extension for 2020–2022) consists to guarantee the durability of the whole study. In this partnership, the survey at sea provides accurate estimates for GR1+ whereas the age-size structured stratified biological sampling on landings allows to calculate all fishing mortality components for GR2+ and the spat collectors for GR0 gives the first semi-quantitative estimate by cohort.

The management regulations allow to smooth decreasing patterns when the unavoidable weak cohorts arrive although the cannot completely change neither cyclical phenomena nor the global warming trend.**References.**

Fifas S., Berthou P., 1999. An efficiency model of a scallop (*Pecten maximus*, L.) experimental dredge: Sensitivity study. *ICES Journal of Marine Science*, *56*: 489–499.

Fifas S., Vigneau J., Lart W., 2004. Some aspects of modelling scallop (*Pecten maximus*, L.) dredge efficiency and special reference to dredges with depressor plate (English Channel, France). *J. Shell. Res., Aug. 2004; 23 (2)*: 611–620.

Iceland (*Chlamys islandica*)

Moratorium was put in place in 2003 on the scallops grounds in Iceland. Since 2014 the annual dredge survey targeting Iceland scallops (*Chlamys islandica*) on the main beds in Breiðafjöður was substituted by a drop frame camera survey/mapping. During the last years of the dredge survey there was a reduction in number of days at sea and in 2012 and 2013 only southern and northern part of the main scallop areas in Iceland, Breiðafjörður were surveyed respectively. The full dredge survey index between 2006–2011 had dropped down to between 11–14 % of the average index of the years 1993–2000, prior to collapse of the stock. In the last two dredge surveys old scallops (~10 year) were dominant in the catches but recruitment was also evident in several areas.

In 2014 a co-operation was established between the stakeholders and the Marine and Freshwater Research Institute in regards to increase the research activities (partly funded by the industry in form of vessel time) and conduct experimental fishing. Two drop frame surveys were conducted in 2014, 146 camera stations were conducted in April and 43 stations in December after a spell of experimental fishing. In 2015, 80 drop frame stations were carried out, 150 in 2016, 241 in 2017 and 222 in 2018 (still being analyzed). The scope of the drop frame survey was to get an absolute abundance estimate on the common grounds and also to search for new beds and get a better coverage of known scallop beds (Fig X). Few new beds and scallops in fishable densities in the inner part of the old grounds have been detected in the drop frame surveys. A link to the drop frame surveys can be found here: http://www.hafro.is/~jonasp/

In the experimental fishing of 2014, 280 tonnes were fished in an area in southern part of the fjord. During the winter of 2015–2016, 630 tonnes were fished on four distinct areas. During the winter of 2016–2017, 575 tonnes were fished on five distinct areas, but due to a fisherman strike that lasted 8 weeks, the season was cut short. During the autumn of 2017, 945 tonnes were fished on six areas. Each experimental area was split up further into roughly 1 km^2 rectangles. The fishing effort varied between areas, but proposed harvest ratio was between 4–8% . On almost all rectangles within an area a decline in LPUE was observed during the fishing season. It is proposed to fish one more year with this experimental setup, but first result suggest that harvest ratio over 5% is too high for this fishery, based on current estimation of areas and abundance.

Scottish Scallop Dredge Survey 2016-2018 overview

Marine Scotland Science (MSS) has been carrying out dredge surveys for king scallops (*Pectin Maximus*) since the late 1980s, formerly using commercial boats, but more recently its own research vessel which since 2008 has been the MRV Alba na Mara. The aim of these surveys is to collect catch rate data for use in the stock assessment process. MSS conducts three scallop surveys per year, covering the east coast of Scotland, the west coast and Shetland with a possible 332 fixed stations. The station positions are based on historical fishing patterns and areas of suitable sediment from British Geological Survey sediment maps. Additional stations have been recently added using Vessel Monitoring Systems (VMS) data from the commercial fishing fleet to ensure coverage representative of industry fishing areas.

Spring loaded Newhaven type dredges are used on the surveys, with a total fishing width of 9 m. The starboard side has 6 x 9 tooth bar and 80 mm belly rings, similar to commercial king scallop dredges and the port side has sampling gear made up of 6 x 11 tooth bar and 60 mm belly rings, similar to that used for Queen scallop fishing. The latter sampling gear is utilised to catch undersized scallops and smaller bycatch.

At each station, the dredges are towed at a speed of about 2.5 knots for approximately 30 minutes, and all king scallops caught are aged and measured. Other objectives for the surveys have included: assessing scallop shell damage, identification and length measurements of bycatch, underwater filming of dredges using a Go-pro camera, record and retain marine litter (monitoring as part of the Marine Strategy Framework Directive), collection of scallop samples for genetics , toxin analysis and parasite research, and recently the collection of frozen scallops for heavy metal testing as part of the OSPAR assessment of hazardous substances in the marine environment .

In 2016 a total 210 stations were sampled and 28 900 scallops caught, 2017 saw 221 stations sampled with 26 801 scallops caught and in 2018, 30 549 scallops from 236 stations; with every scallop measured, aged and assessed for damage.

Number of bycatch individuals caught and sampled over the last 3 years was consistent in 2016 and 2017 at 14 532 and 14 648 individuals sampled respectively; mostly starfish species. There was an increase in 2018 to 19 695 individuals, due to a large increase in the number of Queen scallops caught in Shetland and on the west coast surveys.

Camera trials have progressed slowly over the last two years because of the limited time available on the surveys, but advances in the design of the housing and lighting have been made. Three styles of housing in various positions have been trialled to protect the Go-pro camera, one situated on the bar and two raised off the bar. The raised steel housing has proven to be the best so far in terms of durability and clarity of the footage; but adjustments are required to improve the angle of the camera to obtain an improved view of the dredges. Currently a dive torch is the light source but a stronger light source may be required in future trials if a greater view of the dredge is required.

Northern Ireland update

King scallops, *Pecten maximus*

In 2017, 1028 tonnes of scallops were landed into NI ports (down from 1294 tonnes in 2016) by 57 vessels (47 from NI, 7 Scottish, 2 English and 1 Irish). Commercial landings per unit effort (LPUE) has showed a downward trend from 2015.

AFBI carry out an annual scallop survey concentrating on the Northern Ireland territorial sea (ICES rectangles 36E4, 37E4, 38E4, 39E3 and 39E4). The survey, which has a time series extending from 1985, collects data on scallops length, breadth, total weight, muscle and gonad weight, scallop ages and bycatch number and weight. Genetic samples are also collected for future analysis. Analysis of survey catches between 1992 and 2018 shows that whilst there was an increase in catch rate up to 2014, from 2015 there had been a decrease (Figure 1).

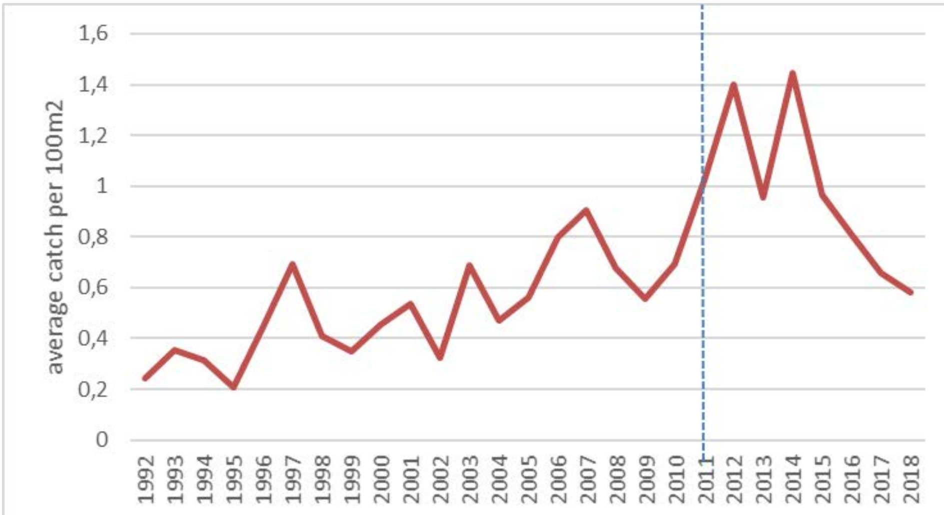


Figure 1. Catches of scallops per 100m² reported from the AFBI scallop survey between 1992 and 2018 (the blue line represents the year at which the survey was extended from the County Down area only, to the full Northern Ireland territorial seas).

During the survey, all bycatch species are counted and weighed. In the 2018 survey, 58 bycatch species were recorded. Analysis of bycatch from 2001–2018 shows a total of 10 Phyla, 22 classes, 51 orders and 111 families have been reported during this period. The characterising bycatch species along the north coast of Northern Ireland is the queen scallop, *Aequipecten opercularis*, whilst along the East Antrim and County Down coasts it is the common starfish, *Asterias rubens*.

Queen scallops, *Aequipecten opercularis*

In 2017, 9 vessels landed 117 tonnes of queenies into Northern Ireland. There has been a dramatic decrease in landings of queenies into Northern Ireland from peak landings in 2011 (Figure 2).

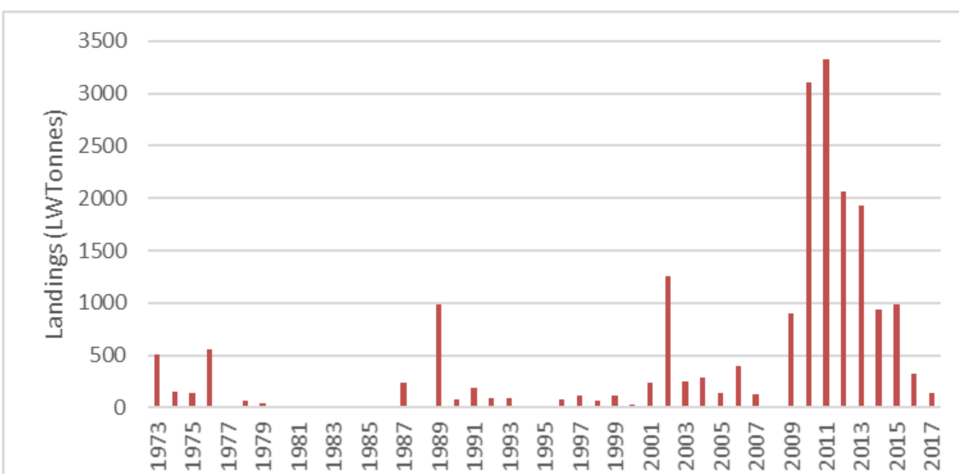


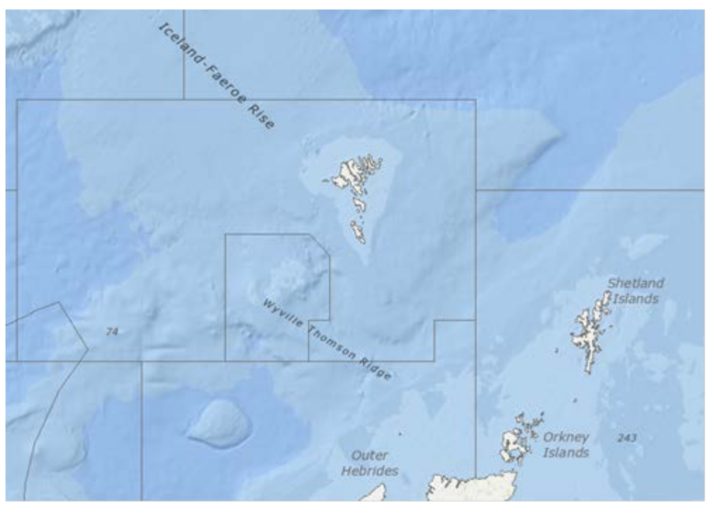
Figure 2. Landings of queenies into Northern Ireland between 1973 and 2017.

AFBI have been carrying out an annual queen scallop survey since 2013. The survey covers areas VIa and VIIa. Stations are selected randomly from a fixed survey grid. At each selected station a camera sled is deployed and towed for 15 minutes. The camera footage is analysed and all queenies are counted each minute by two separate readers (if counts are out with a determined range then a third counter analyses the footage and so on). This provides information on the density of queenies. Based on the counts, stations are selected for fishing (to collect biological information on the queenies). Fishing is by a queen scallop net or a dredge bar, which is fitted with two king scallop dredges, one of which is fitted with a fine mesh liner, and two queen scallop dredges.

In June-July 2018, 52 camera stations were carried out along the Northern Ireland north coast (area VIa) along with 18 exploratory camera tows (to look for stock boundaries). For fishing purposes, seven queenie net tows were carried out as well as eight dredge tows. Results from the VIa survey showed an increase in estimated abundance compared to 2017, but this is still lower than the estimated abundance reported during the first survey in 2013.

Within the Irish Sea (area VIIa) 46 camera stations and 13 dredge tows were completed. The survey results showed a continuation in the decrease of the estimated queenie biomass.

Queen scallops (*Aequipecten opercularis*) Faroe Islands Update



The commercial dredge fishery for queen scallops (*Aequipecten opercular*i) within the Faroe islands territorial waters (ICES 5b) began in the early 1970s in the eastern area (E) relatively close to shore, about 1–15 nm from the coast on sandy, rocky or soft bottom habitats (Figure 3) Marine specimen such as whelks, mussels, starfishes, brittle-stars, sea urchins, and crabs are present in the main habitats of scallops. The fishery expanded to the northern coast (N) in the 1990s but pressure from the traditional longline fishing for gadoids resulted in the interruption of further exploitation of the resource in this area. In recent years the northern fishing grounds have been exploited along a narrow fjord situated in the north-west (DJ) of the islands with limited success.

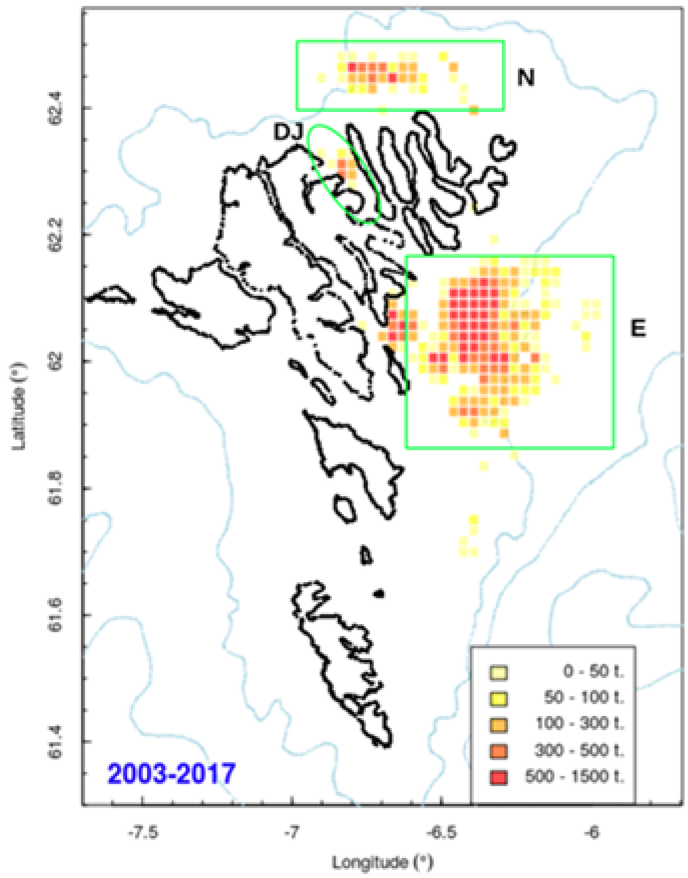


Figure 3. Main fishing grounds for queen scallops in Faroe waters.

The fleet consists of a domestic vessel of around 30 m long and 170 t. using a double 12-feet dredge. There are indications of increases in gear efficiency but evidence is poorly documented.

The fishing grounds cover around 400 km² and 100 km² in the east and north respectively. The fishery operates at depths ranging from 60 m to 110 m in the east and 90 m to 110 m in the north (Figure 4) whereas the north-west fjord is slightly deeper than the latter.

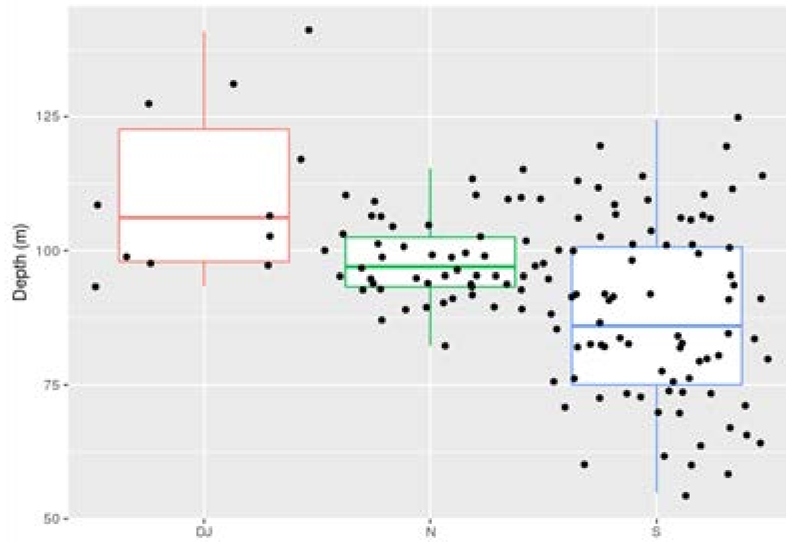


Figure 4. Depths of the north-west fjord (DJ, left), north (N, middle) and east (E, right) fishing areas.

Initially the scallop fishery was highly seasonal (August till January) but at present it has extended until the beginning of the summer season (Figure 5).

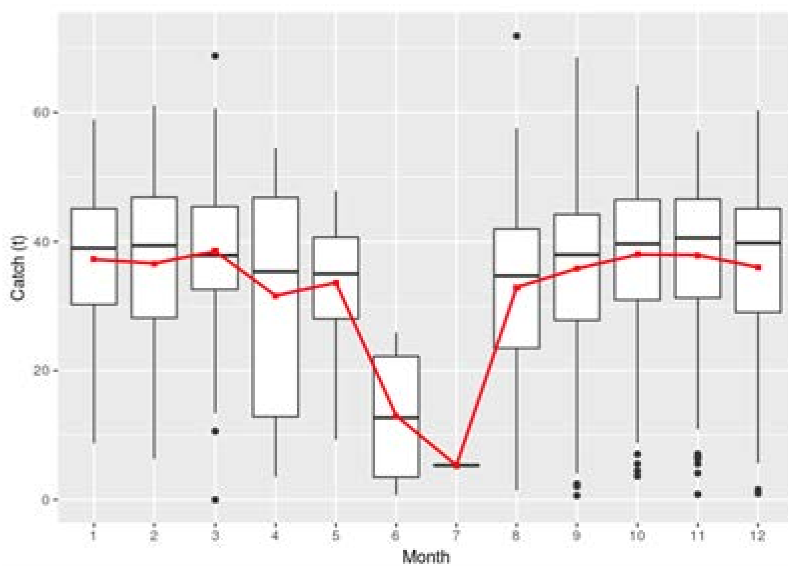


Figure 5. Seasonal development of queen scallop fishery (monthly average catch in the 2003–2017 period)

No assessments for scallops are carried out and therefore estimates of recruitment and fishing pressure are not available. The historical fishing grounds (E) are managed through licenses issued annually whereas both the north (N) and north-east (DJ) are managed with TAC allocations. A swept area survey was carried out in 1991 in the east and north coast. In 2012 and 2013, similar surveys were conducted in the northern area as well as in the north-west ford respectively. Size and age samples were taken to investigate growth patterns (Figure 6). Average height of 1-year old scallop (recruits) in the DJ and N areas is estimated at around 50 mm and 40 mm respectively.

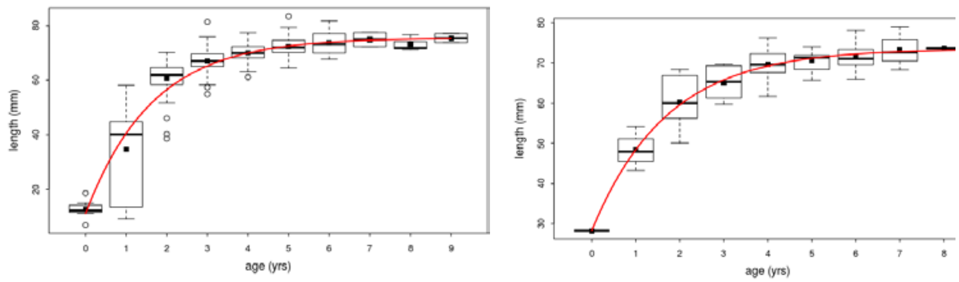


Figure 6. Von-Bertalanfy growth as a function of age (years) and shell height (mm) from the N (left) and DJ (right) areas. Data compiled from swept area surveys carried out in 2012 (N area) and 2013 (DJ area).

Although growth seems spatially and size-dependant the data suggest no substantial differences in mean size for older age groups between the two areas (Table 3). Small scallops tend to grow at rates of approximately 10–20 mm per year while larger individuals grow around 0–5 mm annually.

Table 3. Parameters of the von-Bertalanfy growth equation as a function of age (years) and shell height (mm) in the N and DJ areas.

Parameter	N area	DJ area
L_∞	81.1 mm	79.6 mm
k	0.589	0.538
t_0	0.78	0.206

Landings and effort data are available from official statistical sources and logbooks respectively. Since 1991, landings have fluctuated between 2300 and 6700 metric tonnes (Figure 7). After record high landings of more than 5000 t. from 2012 to 2014, reported catches decreased substantially to 3000 t in 2015 and 2016. The official catch for 2017 is estimated at 2500 t. and therefore well below the historical average (4100 t).

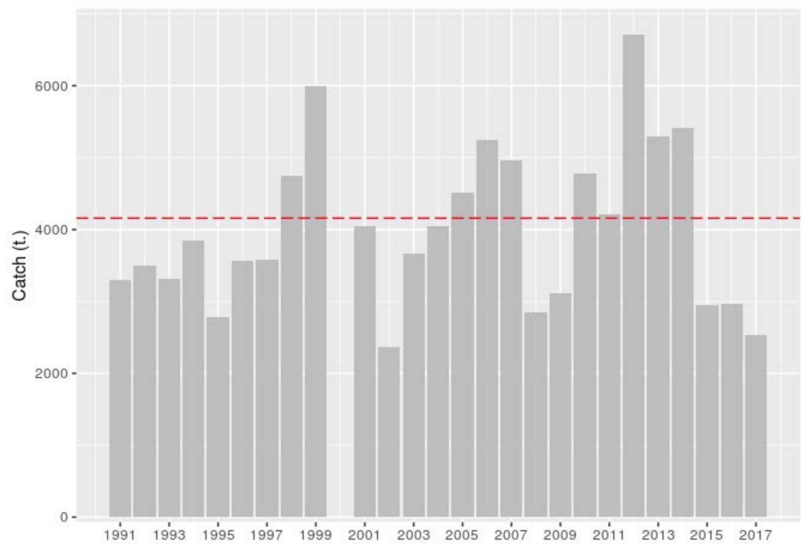


Figure 7. Historical development of landings for queen scallop in Faroe waters (1991–2017). Data for 2000 were not available from official sources. (Source: Faroese Statistical Office).

Series of catch rates (CPUE, catch per hour) are compiled from logbook data since 2003. The data are standardized with GLM (generalized linear models) and LMER (random effect models) to filter out potential confounding effects of annual and seasonal effects. The results suggest no long-term decline of the scallop fishery. The index fluctuates around 1500 kg/hour with no clear trend while fishing effort has decreased which may indicate an increase in dredge efficiency. Uncertainties in effort estimates prevented the compilation of reliable data in 2016 and 2017.

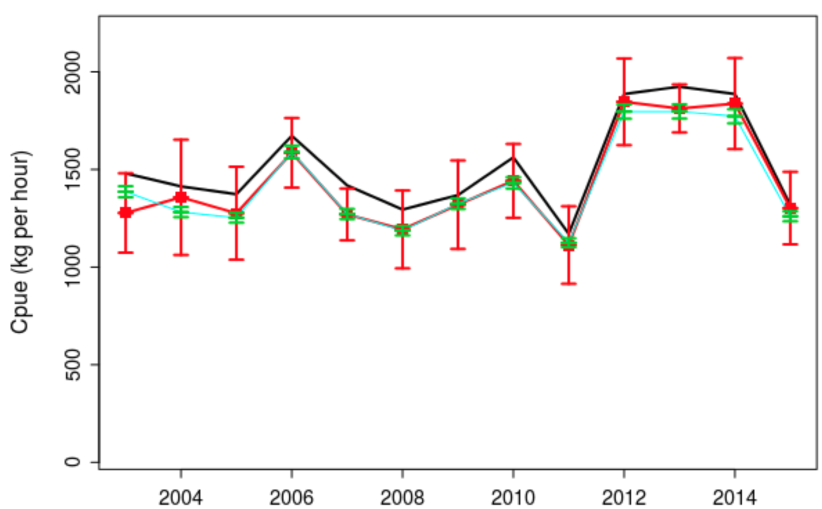


Figure 8. Series of catch per unit of effort (CPUE) from 2003 to 2015. Black line represents observed data while green (linear mixed effects model) and red lines (GLM model) show standardized series. The cpue series were not compiled in 2016 and 2017 due to uncertain estimates of effort.

Although age disaggregated data is sparse it suggests that growth is spatially dependant within and among the north and eastern areas (Figure 8).

In 2016, an experimental fishery with underwater camera was performed in both historical and undisturbed fishing grounds to assess the effect of dredging on the sea floor. The resolution of the footage is relatively poor and cannot be used quantitatively but rather as a visual indicator of effects of dredging in bottom habitats (Figure 9). The footage illustrates considerable contrasts of abundance in fishing grounds and the potential effects of dredging in scallop habitats.

Figure 9. Underwater snapshots of bottom habitats in queen scallop fishing grounds during an experimental underwater camera survey in 2017.

Wales. King scallops update

Scallop surveys have been conducted in Welsh waters since 2012 and as recently as 2018. However, the future of the surveys remains uncertain. The approach has been area-based, where points from a grid are randomly selected for each survey within pre-defined survey areas. The data gathered from these surveys is currently being used to implement stock assessment. At least three stock assessment models are currently being refined and fitted to the data. These models all behave differently in their mathematical and statistical calculations, but importantly all differ in the way they disaggregate the stock biomass. More specifically, there is a delay-difference model, splitting the stock in to pre- and post-recruits, an age-structured model and a length-structured model. The intention is to compare the outputs of these three models, as well as conducting sensitivity analyses, to determine the most appropriate model for the Welsh scallop fishery.

English and Western Channel Scallop (*Pecten maximus*) Fishery – UK Fisheries Improvement Program PUKFI, specific action "ACTION 7 – Habitat"

Funded by the European Maritime Fisheries Fund (EMFF) and supported by the Marine Stewardship Council, the project's Action Plan under Principle 2 of the MSC "To assess the environmental impact of fisheries entering into certification" addresses the need for determining the catch (as opposed to the landings) of primary and secondary species caught in the English Channel scallop dredge fishery. The Action Plan specifically also looks at reducing the impact of these fisheries on habitats, especially Vulnerable Marine Ecosystems (specific FIP Action 7).

The English Channel scallop fisheries are of significant economic importance on both sides of areas VII d and VII e, named "Unit of Assessment – UoA" in the framework of FIP project. During a pre-assessment exercise, this UoA was recognised as "highly likely to reduce structure and function of habitats to a point where there would be serious or irreversible harm".

In this context, Action 7 was defined to analyse and quantify the spatial scale, intensity and impact of the fishery on commonly encountered habitat and in particular, VMEs, inside the UoA (Action years 1 – 2). Based on this, future appropriate and more effective management approaches may be developed, in fact the Action 7 outcomes will be embedded in an on-going, risk-based habitat impact monitoring system (Actions years 3 – 4). During the first two years the action foreseen was to review existing information, produce a fishery foot-print analysis and habitat mapping (work in progress).

To address these goals three main approaches are being taken: 1. Placing cameras on board vessels to gather increased data on catches and bycatch; 2. Interviews with fishermen to collect more information on fishing activity; 3. Modelling the environmental impact of the fishery.

To date six cameras have been built. These are ready to be deployed with the support of the stakeholders in the project. Monitoring with cameras will allow us to record videos of the catch passing through the conveyor belts on board vessels. Lasers in the cameras will allow us, through a post processing step, to take measurement of the specimens. Data on the presence and potentially abundance of sensitive species will be recorded, and where possible size measurements will allow us to infer biomass. These data will be used to assess habitat status, quality and level of exploitation and related vulnerability in different areas.

Interviews with fishermen will consist of a set of 25 questions with a technical section on the vessels features and fishermen experience, and a second section to collect habitat data and fishing behaviour data. The interviews are designed to collect additional data on fishing ground habitats and fishing behaviours, to increase the data available to validate the modelling exercise.

Through the modelling exercise, VMS data / benthic dataset / GIS layers will be used to model sensitive species responses to fishing pressure (e.g. species distribution modelling), to identify any hot spots of vulnerability (also by overlapping fishing pressure footprint). A list of sensitive species has been defined (as from the current protection Acts and Directives in the areas; e.g. OSPAR), presence data have been downloaded by species database and will be integrated and validated with data from the cameras on board. Cameras will also measure size (length) of species as a proxy of longevity. Apart from abundance and presence absence data, all this set of data will be integrated into the modelling exercise. Environmental data layers will be used to further inform the modelling exercise.

To engage local fishermen in the project, we have employed various activities such as infographics and online communication tools (e.g. social media promotion).

6 Cooperation

The WG working Group has had few exchanges with other WG's in ICES, although many members serve on other Working Groups so information is shared through them.

7 Summary of Working Group self-evaluation and conclusions

A copy of the full Working Group self-evaluation is included in the report as Annex 4.

Annex 1: List of participants

Name	Institute	Country (of institute)	Email
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Annex 2: Recommendations

Recommendation	Adressed to
1. Request for spatial data layers for king and queen scallop fishing intensity/pressure for the Celtic Seas and Greater North Sea Ecoregions.	WGSFD
2. Investigate/suggest/conduct alternative assessment methodogies for data limited stocks which currently do not have an analystical assessment.	WKLIFE

Requests to other groups

WGSFD: Spatial data layers for scallop fishing intensity/pressure for the Celtic Seas and Greater North Sea Ecoregions. GIS layers preferably by month (or quarter) and separate layers for king and queen scallops.

Background: WGscallop has been working towards better defining stock boundaries and has utilised the layers produced by WGSFD in the past. However, the group had concerns that previous layers were for the DRB_MOL metier and that this might not accurately represent the footprint for the specific scallop (king and queen) fisheries in question (the group is aware that mussel dredging is prevalent in certain areas).

WKLIFE: Investigate/suggest/conduct alternative assessment methodologies for data limited scallop stocks which currently do not have an analytical assessment.

Background: A number of the scallop stocks are data limited in the sense they do not have a survey, or have a very limited survey time series, no commercial sampling data (or limited data where age readings may be unreliable). The group has discussed looking at other fishery dependant indicators and would like to know if these would be suitable to assess scallop stock status.

Annex 3: WGScallop draft resolution 2019–2021

The **Scallop Assessment Working Group** (WGScallop), chaired by Lynda Blackadder, Scotland, UK, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2019	7–11 October	Isle of Man	Interim report by 1 December	
Year 2020			Interim report by Date	
Year 2021			Final report by Date to SCICOM	

ToR descriptors

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
a	Compile and present data on scallop fisheries in ICES areas IV, VI and VII by collating available fishery statistics.	The fisheries are socio-economically important and there is a need to collate these data at a national level to ensure assessments can proceed.	5.1	Years 1,2,3	Landings, effort and commercial sampling data on listed species, from each country.
b	Review recent/current stock assessment methods of the main scallop species and explore other methodologies; including comparisons with fishery dependant indicators.	The aim is to assess the status of scallop stocks and contribute to Integrated Ecosystem Assessment and Management and descriptor 3 of the MSFD.	5.1, 6.3	Years 1,2,3	Report on alternative assessment methods. Link with WKLIFE.
c	Collate all available data and attempt to conduct a stock assessment for the north east Irish Sea.	The Isle of Man currently conducts stock assessments on their territorial seas. The aim is to assess the wider area.	5.1, 6.2	Years 1,2,3	Stock assessment for north east Irish Sea.
d	Review and report on current scallop surveys and share expertise, knowledge and technical advances.	Focus will be on reporting recent updates with regards to surveys and sampling, use of cameras, gear efficiency and selectivity, impact of scallop dredging, discard mortality, MPA's and closed areas, bycatch.	1.4, 1.5, 4.4, 5.2, 5.4	Years 1,2,3	WG report chapters. Exchange of scientific staff on surveys. Database to collate bycatch data.

e	Continue to refine stock structure using best available information on genetics and larval dispersal and look to improve current mapping of scallop stocks.	Knowledge on the genetic stock structure and extent of larval dispersal is still weak but a number of projects are underway.	1.4, 1.8	Years 1,2,3	WG report chapters and relevant maps. Link with WGSFD.
f	Keep current biological parameters under review and update when more information becomes available and report on all relevant aspects of: biology, ecology, physiology and behaviour, in field and laboratory studies.	Several biological parameters are important for analytical assessments and parameters may vary depending on the stock area.	5.1, 5.2	Years 1,2,3	Update knowledge on crucial stock parameters.
g	Compare age reading methodologies and attempt to develop common practices and determine precision and bias of scallop age reading data derived from different readers and methods.	Many institutes rely heavily on aging methods but there are no common methodologies or protocols.	4.4, 5.1	Years 1,2,3	Produce guidelines on agreed methodologies.

Summary of the Work Plan

Year 1	Annual standard outputs for ToR a,d,e, f. Collate lists of available data for Irish Sea (c). Age reading workshop (g), arrange scientific staff exchange on surveys (d) and knowledge exchange on current scallop stock assessment methods (b).
Year 2	Annual standard outputs for ToR a,d, f. Collate available data for Irish Sea (c). Age reading guidelines further discussed (g). Update and report on genetic and larval dispersal models and attempt to colloborate on further work (e). Review scallop stock assessments caried out by national institutess (b).
Year 3	Annual standard outputs for ToR a,d, f. Stock assessmnet for Irish Sea (c). Age reading guidelines produced (g). Produce maps on genetic stock structure and larval dispersal (e) Further develop scallop stock assessment methods (b).

Supporting information

Priority	The fisheries for scallops are socio-economically important and trans-national in Europe and North America. Management of stocks in Europe is primarily by technical measures and in most countries there are generally little or no management instruments to control fishing effort. This is currently the only scientific assessment forum for discussion and development of common assessment methods for scallops. Consequently,

	these activities are considered to have a very high priority.
Resource requirements	The research programmes, which provide the main input to this group, are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Group is normally attended by 16 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	There are no obvious direct linkages as the WG does not currently provide advice.
Linkages to other committee or groups	There are currently no direct linkages but the WG has made recommendations for WGSFD and WKLIFE.
Linkages to other organizations	None.

Annex 4: WGScallop self-evaluation 2016–2018

1) Name: Scallop Assessment Working Group (WGScallop)

2) Year of appointment: 2016

3) Current Chair: Kevin Stokesbury, USA

4) Meeting dates and venues:

Aberdeen, Scotland, 3-7 October 2016, 16 participants;

Belfast, Northern Ireland, 10-12 October 2017, 14 participants

York, England, 10-12 October 2018, 18 participants

WG Self-Evaluation

5) In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc. *

- The first benefit of ICES Scallop working group is the gathering of the group of scientists working on the **King, Queen and Icelandic scallop fisheries** together to exchange knowledge, experience and insights.

Data products and methodological developments

- In 2018 for the first time all stocks were assessed using an independent fisheries survey.
- Image surveys are expanding due to information exchange; presently they are being conducted in Canada, Iceland and the United States; further cameras are increasingly being used to examine dredge performance and habitat.
- Technology exchange including electronic observer data collection (Nestform), video technology and automatic processing, VMS and GIS mapping including google map open access video catalogues.

Advisory products

- Review and revision of the industry cooperative scallop survey of the English Channel.
- Development of volunteering rotational plan accepted by French fishermen in the Baie des Seine to improve harvest of a large recruiting year-class in 2018, based on examples from rotation management in the Gulf of Maine USA.

6) Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.

Had provided advice on the survey design of the DEFRA cooperative scallop survey in the English Channel (detailed above).

7) Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities.

- Stokesbury, K.D.E. Overview of ICES scallop working group 2013 to 2016. South Western Fish Producer Organization Ltd, Brixham, England. 11 Oct 2016.
- Stokesbury, K.D.E. ICES Scallop Working Group Overview. International Pectinid Workshop, Portland, Maine April 2017
- Numerous presentation at the pectinid Workshop from members of the WGScallop.

8) Please indicate what difficulties, if any, have been encountered in achieving the work plan.

- Continuing insecurity over funding of independent scallop surveys in all stock areas.

Future plans

9) Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)

Yes, definitely. Draft resolution included in report.

10) If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.

(*If you answered YES to question 10 or 11, it is expected that a new Category 2 draft resolution will be submitted through the relevant SSG Chair or Secretariat*.)

11) What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?

Interaction with WG addressing habitat/gear impacts, expertise in aging and using VPA's, expertise in automation of imagery data.

12) Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific)

The recent interactions between French and English vessels in the English Channel emphasise the importance of this Working Group. Scallops are an extremely important fishery to the ICES community and given the large number of different countries involved with fishing similar stocks a uniform approach and open communication will be critical.