Shellfish Stocks and Fisheries Review 2022

BIM Ireland's Seafood Development Agency

Foras na Mara
Marine Institute

Shellfish Stocks and Fisheries

Review 2022

An assessment of selected stocks

The Marine Institute and Bord Iascaigh Mhara

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Rialtas na hÉireann
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Cómhaoinithe ag an Aontas Eorpach

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Photographs on cover by Jonathan White (Whelk – Buccinum undatum), Jonathan White (Brown Crab – Cancer pagurus) and Owen O'Connell (Scallop Cultch)

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1 Introduction

This review presents information on the status of selected shellfish stocks in Ireland. In addition, data on the fleet and landings of shellfish species (excluding *Nephrops* and mussels) are presented. The intention of this annual review is to present stock assessment and management advice for shellfisheries that may be subject to new management proposals or where scientific advice is required in relation to assessing the environmental impact of shellfish fisheries especially in areas designated under European Directives. The review reflects the recent work of the Marine Institute (MI) in the biological assessment of shellfish fisheries and their interaction with the environment.

The information and advice presented here for shellfish is complementary to that presented in the MI Stock Book on demersal and pelagic fisheries. Separate treatment of shellfish is warranted as their biology and distribution, the assessment methods that can be applied to them and the system under which they are managed, all differ substantially to demersal and pelagic stocks.

Shellfish stocks are not generally assessed by The International Council for the Exploration of the Sea (ICES) and although they come under the competency of the Common Fisheries Policy they are generally not regulated by EU TAC and in the main, other than crab and scallop, are distributed inside the national 12 nm fisheries limit. Management of these fisheries is within the competency of the Department of Agriculture, Food and Marine (DAFM).

A co-operative management framework introduced by the Governing Department and BIM in 2005 (Anon 2005), and under which a number of fishery management plans were developed, was, in 2014, replaced by the National and Regional Inshore Fisheries Forums (NIFF, RIFFs). These bodies are consultative forums, the members of which are representative of the inshore fisheries sector and other stakeholder groups. The National forum (NIFF) provides a structure with which each of the regional forums can interact with each other and with the Marine Agencies, DAFM and the Minister.

Management of oyster fisheries is the responsibility of The Department of Environment, Climate and Communications, implemented through Inland Fisheries Ireland (IFI). In many cases, however, management responsibility for oysters is devolved through Fishery Orders or Aquaculture licences to local co-operatives.

The main customers for this review are DAFM, RIFFs, NIFF and other Departments and Authorities listed above.

2 Registered Fishing Fleet

2.1 *Fleet structure*

The Irish fleet is, currently divided into 5 segments. Of these five segments (Aquaculture, Specific, Polyvalent, Beam Trawl and RSW Pelagic) two are broken into sub-segments, namely the Polyvalent and Specific Segments. Aquaculture vessels do not have fishing entitlements. Beam trawl vessels fish mixed demersal fish using beam trawls and RSW Pelagic are large pelagic vessels with refrigerated seawater tanks which target pelagic species. The Polyvalent Segment is divided into the following four Sub-segments;

(1) Polyvalent [Potting] Sub-segment; vessels of <12 m length overall (LOA) fishing exclusively by means of pots. Such vessels are also <20 Gross Tonnes (GT). Target species are crustaceans and whelk.
(2) Polyvalent [Scallop] Sub-segment; vessels ≥10 m LOA with the required scallop (*Pecten maximus*) fishing history. These vessels also retain fishing entitlements for other species excluding those listed in Determination No. 28/2018 (http://agriculture.gov.ie/fisheries/).
(3) Polyvalent [<18 m LOA] Sub-segment; Vessels with fishing entitlements for a broad range of species other than those fisheries which are authorised or subject to secondary licencing as listed in Determination No. 28/2018
(4) Polyvalent [≥18 m LOA] Sub-segment; Vessels with fishing entitlements for a broad range of species other than those fisheries which are authorised or subject to secondary licencing as listed in Determination No. 28/2018.

The Specific Segment, which entitles vessels to fish for bivalves only, is divided into the following two Sub-segments;

(1) Specific [Scallop] Sub-segment for vessels ≥10 m LOA with the required scallop (*Pecten maximus*) fishing history
(2) Specific [General] Sub-segment for all other Specific vessels irrespective of LOA.

2.2 *Fleet capacity*

The total registered capacity of the Irish fishing fleet, as of December 2022, was 66,454 gross tonnes (GTs) and 1,991 vessels. The polyvalent general segment included 32,353 GTs and 1,392 vessels. The polyvalent potting segment had 326 registered vessels and 673 GTs while the bivalve (specific) segment, including scallop vessels, had 2,174 GTs and 142 vessels. There were 10 beam trawl vessels, 9 scallop vessels over 10 m in the specific segment and 23 RSW pelagic vessels (Table 1).

The total number of registered vessels in the fleet peaked in 2012 at 2,212 vessels which was 221 vessels more than in 2022.

In 2022 74.7 % of vessels in the fleet were under 10 m in length. These are typically open or half-decked traditional fishing vessels that fish seasonally in coastal waters. Ninety-four percent of polyvalent potting vessels were less than 10 m in length and all were under 12 m. Approximately 55 % of the specific fleet of 133 vessels were under 10 m.

Table 1. Number of vessels by length category in each segment of the Irish sea fishing fleet in December 2022.

Segment	U10m	10-12m	12-15m	15-18m	O18m	Total
Aquaculture	72	8	1	1	16	98
RSW Pelagic					23	23
Specific [Scallops >=10m LOA]		1	1		7	9
Beam Trawler					10	10
Polyvalent [Scallops >=10m LOA]		2	1			3
Polyvalent [>=18m LOA]					135	135
Polyvalent [Potting]	310	16				326
Polyvalent [<18m LOA]	1,032	143	59	20		1,254
Specific [General]	74	52	5		2	133
Grand Total	**1,488**	**222**	**67**	**21**	**193**	**1,991**

2.3 *Fleet capacity transfer rules*

The following rules apply to the transfer of capacity within segments;

(1) Polyvalent capacity is privately transferable within its segment. Where an applicant for a polyvalent fishing licence has evidence of holding such capacity (a capacity assignment note) and has an approved fishing vessel then a fishing licence will be issued to such an applicant. Capacity attached to vessels under 18 m cannot be transferred to vessels over 18 m and vice versa.
(2) Excluding the fisheries licenced by secondary authorisation the polyvalent capacity is not coupled to any given quota or entitlement. The capacity assignment note simply enables the vessel owner to complete the registration of a vessel.
(3) In the case of fisheries fished with a permit or secondary licence the authorisation to fish such stocks is effectively coupled with the capacity if the capacity is transferred i.e. this transfer is essentially a transfer of track record in the particular fishery. Such entitlement is, however, also governed by TAC & Quota and any other policies or harvest control rules that might apply to those stocks.
(4) Polyvalent potting capacity is not transferable within its segment other than to first degree relatives of the person to which the capacity was originally assigned. When it is no longer attached to a registered vessel it is negated.
(5) Polyvalent general capacity that is not attached to a registered vessel for a period of more than 2 years expires.

2.4 *Vessels targeting Shellfish*

The shellfish fleet is here defined as vessels under 13 m in length, as the vast majority of such vessels depend largely on shellfish. This cut off, however, is not reflective of any licencing or policy condition and many of these vessels also fish for other species. In addition, a number of vessels over 18 m target crab mainly in offshore waters (vivier vessels) and 12 vessels over 10 m in length were registered in scallop specific and polyvalent segments in 2022.

The number of vessels in the Shellfish fleet increased significantly in 2006-2007 as a result of the ‘Potting Licence Scheme’ which regularised many vessels that were operating outside of the registered fleet prior to 2006. The polyvalent potting segment was established at this time. The number of vessels in this segment is declining year on year due to de-registration and movement of vessel into the polyvalent general segment. There were 326 such vessels in 2022 compared to 490 in 2007. The number of vessels in the polyvalent general segment increased year on year between 2006 and 2012 but numbers declined overall from 2012-2022 (Figure 1, Table 2 and Table 3).

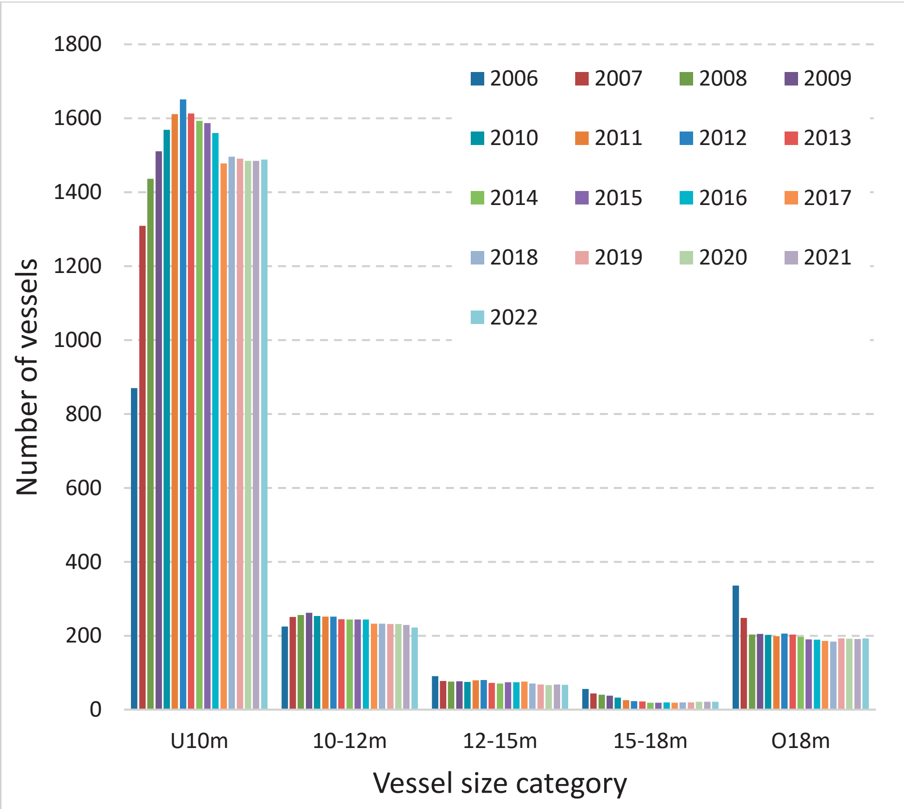

Figure 1. Annual trends in the number of registered sea fishing vessels by length category 2006-2022.

Table 2. Number of vessels and length of vessels in the Irish shellfish fleet 2006-2022 (<13 m polyvalent, all polyvalent potting, all vessels in specific segment, all aquaculture vessels). Vessels over 18 m fishing for crab and scallop are not included.

Year	Aquaculture	Polyvalent General	Polyvalent Potting	Specific	Total
Number of vessels					
2006	3	953	80	97	1,133
2007	13	999	490	93	1,595
2008	46	1,081	482	115	1,724
2009	60	1,146	474	124	1,804
2010	68	1,198	467	120	1,853
2011	78	1,239	461	118	1,896
2012	85	1,269	460	122	1,936
2013	86	1,233	454	117	1,890
2014	89	1,218	448	112	1,867
2015	89	1,226	426	123	1,864
2016	87	1,218	404	126	1,835
2017	83	1,171	363	125	1,742
2018	84	1,200	337	138	1,759
2019	80	1,204	330	136	1,750
2020	79	1,204	329	127	1,739
2021	80	1,201	330	132	1,743
2022	81	1,203	326	127	1,737
Average Length (m)					
2006	7.96	7.95	7.32	9.40	8.03
2007	8.20	7.84	6.76	9.38	7.60
2008	7.41	7.73	6.71	9.32	7.55
2009	7.15	7.65	6.71	9.33	7.50
2010	7.11	7.57	6.67	9.36	7.44
2011	7.23	7.54	6.64	9.39	7.42
2012	7.24	7.51	6.62	9.36	7.41
2013	7.14	7.50	6.62	9.41	7.39
2014	7.15	7.53	6.62	9.52	7.41
2015	7.10	7.53	6.62	9.56	7.44
2016	7.15	7.52	6.59	9.66	7.44
2017	7.09	7.56	6.59	9.70	7.49
2018	7.07	7.52	6.59	9.64	7.49
2019	7.05	7.54	6.61	9.59	7.50
2020	7.07	7.53	6.62	9.55	7.48
2021	7.06	7.54	6.60	9.63	7.49
2022	7.16	7.51	6.58	9.5	7.47

Table 3. Annual change and percentage change in the numbers of vessels per fleet segment in the under 13 m Shellfish fleet 2006-2022.

Years	Aquaculture	Polyvalent General	Polyvalent Potting	Specific	Total
Change in number of vessels					
2006-2007	10	46	410	-4	462
2007-2008	33	82	-8	22	129
2008-2009	14	65	-8	9	80
2009-2010	8	52	-7	-4	49
2010-2011	10	41	-6	-2	43
2011-2012	7	30	-1	4	40
2012-2013	1	-36	-6	-5	-46
2013-2014	3	-15	-6	-5	-23
2014-2015	0	8	-22	11	-3
2015-2016	-2	-8	-22	3	-29
2016-2017	-4	-47	-41	-1	-93
2017-2018	1	29	-26	13	17
2018-2019	-4	4	-7	-2	-9
2019-2020	-1	0	-1	-9	-11
2020-2021	1	-3	1	5	4
2021-2022	1	2	-4	-5	-6
% change in number of vessels					
2006-2007	333	5	513	-4	41
2007-2008	254	8	-2	24	8
2008-2009	30	6	-2	8	5
2009-2010	13	5	-1	-3	3
2010-2011	15	3	-1	-2	2
2011-2012	9	2	0	3	2
2012-2013	1	-3	-1	-4	-2
2013-2014	3	-1	-1	-4	-1
2014-2015	0	1	-5	10	0
2015-2016	-2	-1	-5	2	-2
2016-2017	-5	-4	-10	-1	-5
2017-2018	1	2	-7	10	1
2018-2019	-5	0	-2	-1	-1
2019-2020	-1	0	0	-7	-1
2020-2021	1	0	0	4	0
2021-2022	1.3	0.2	-1.2	-3.8	-0.3

3 Shellfish Landings 2004-2022

Annual landings of crustaceans and bivalves, excluding *Nephrops* and wild blue mussel (*Mytilus*) seed, which is re-laid for on-growing, landed into Ireland by Irish vessels during the period 2004-2022, varied from a high of 29,000 tonnes in 2004 to a low of 13,790 in 2009. Landings were just over 19,000 tonnes in 2022 (Table 4). Data in Table 4 has been reviewed, relative to previous annual reports, based on updated logbook and sales note data and also by excluding landings by Irish vessels if they are not landed into Ireland.

A number of species such as lobster, native oyster and shrimp are targeted by vessels under 10 m in length. As these vessels do not report landings capturing these data is difficult due to the large number of vessels and the small daily consignments involved. Prior to 2015 these data were captured by the SFPA through information gathering from buyers and post 2015 using data collected under the buyers and sellers of first sale fish regulation which obliges buyers to log the purchase of fish at the first point of sale from a fishing vessel.

Landings data for certain species that are subject to management plans (cockle), that are managed locally (oysters) or where SFPA have digitised shellfish registration dockets and consignment data to buyers (cockles, razor clams) provide additional data on landings separate to logbook data or sales notes.

Total value of shellfish (molluscs and crustaceans) landings, excluding mussel and *Nephrops*, in 2022 was €64.1 million.

Table 4. Estimates of annual landings (tonnes) and value (€) of crustacean and bivalve shellfish (excl. prawns and mussels) by Irish vessels into Ireland 2004-2022 (source: Logbook declarations and sales notes for vessels under 10 m, shellfish registration dockets, co-op data). Unit value (per kilo) is from sales note data or other sources.

Year	Edible crab	King Scallop	Lobster	Periwinkle	Whelk	Shrimp	Native oyster	Queen scallop	Velvet crab	Surf clam	Spider crab	Crayfish	Razor clams	Shore crab	Cockle	Total tonnage
2004	13,119	2,421	855	1,674	2,600	416	543	110	291	28	182	80	401	266	207	23,193
2005	9,413	1,229	644	1,139	4,154	153	94	75	253	0	146	31	404	27	107	17,867
2006	9,248	644	611	1,210	2,917	312	233	172	270	5	151	34	507	46	7	16,368
2007	7,158	917	297	609	2,644	324	291	28	138	14	66	16	339	91	643	13,575
2008	7,029	1,217	498	1,141	2,097	180	88	4	260	34	148	20	456	72	9	13,254
2009	5,525	2,610	423	1,103	2,163	224	327	3	204	26	443	28	229	233	173	13,712
2010	8,093	1,959	470	1,280	2,975	134	349	0	342	25	414	30	443	129	5	16,649
2011	6,825	2,612	250	64	3,174	111	100	0	184	36	303	25	523	74	401	14,682
2012	6,115	2,621	244	103	3,446	148	100	12	169	16	402	35	465	253	400	14,528
2013	6,227	2,797	367	218	2,628	172	214	134	366	37	228	34	852	30	374	14,679
2014	6,953	2,597	445	1,135	2,180	289	265	80	231	67	137	23	903	50	3	15,358
2015	6,900	2,077	363		5,014	295	153	31	202	49	193	14	1,265	23	0	16,579
2016	9,332	2,237	402		5,822	363	190	201	277	51	161	10	1,127	165	321	20,658
2017	9,086	2,580	415		4,977	281	168	7	313	45	143	10	961	127	442	19,553
2018	8,167	2,301	345		4,638	272	150	4	213	47	119	9	1,041	118	446	17,870
2019	8,095	2,345	488		5,090	430	150	3	253	44	425	30	783	288	595	19,020
2020	6,406	1,940	437		5,302	343		1	240	12	451	15	672	154	1,152	17,126
2021	6,644	2,739	482		4,938	338	250	0	263	0	477	49	595	391	642	17,807
2022	7,006	2,223	552		5,964	276	150	823	274	25	470	58	637	635	0	19,093
Unit price 2022	€3.00	€3.82	€19.60	€3	€1.57	€19.05	€5.64	€1.29	€2.55	€5.04	€0.58	€33.58	€6.11	€0.49	€0.00	
Value 2022 (million)	€21.02	€8.49	€10.82	€0.00	€9.36	€5.26	€0.85	€1.06	€0.70	€0.13	€0.27	€1.95	€3.89	€0.31	€0.00	**€64.11**

4 Lobster (*Homarus gammarus*)

4.1 *Management advice*

Lobster stocks are managed using a minimum landing size (MLS) of 87 mm, a maximum landing size (MaxLS) of 127 mm and a prohibition on the landing of v-notched lobsters.

The number of v-notched lobsters released annually was 5,000-11,000 during 2002-2008, 10,000-15,000 during 2010-2013, 25,000-33,000 annually during 2014-2021 and 40,000 in 2022. The minimum size, maximum size and v-notch conservation measure collectively conserve about 25-39 % of the reproductive potential (RP) in the lobster population. This varies regionally and by year; in 2022 over 39 % of the RP was in size categories protected by the conservation measures according to data from pots. Data from tangle nets off the south west coast from 2017-2022 indicate that larger size classes and lobsters above the maximum size are more prevalent in the stock than indicated by data from pots and provide evidence that there is a significant 'size refuge' and conservation effect in larger size classes in the stock. V-notched lobsters were present in very low numbers in net catches.

Nominal stock status indicators, landings per unit effort, discards per unit of effort and v-notched lobsters per unit of effort were stable during the period 2013-2021 in most coastal areas. The index of undersized lobsters increased from 2015-2019 and was stable in 2019-2021.

Conservation measures should be maintained. The MaxLS is a size refuge for lobsters that have previously been v-notched in the case of net fisheries especially where they may be more vulnerable to capture. V-notching should target lobsters over 95 mm to maximise egg production prior to repair of the v-notch and should be directed to coastal areas where the prevalence of v-notched lobsters or lobsters above 127 mm is low. Specific targets should be set for the proportion of the mature female lobster stock to v-notch and achievement of this figure should be monitored through logbook and observer programmes.

Reliance on the v-notch programme, which is based on voluntary participation, to protect RP should be reduced and replaced with other measures if there is any decline in uptake of the programme. Uptake should be reviewed annually. Uptake in 2022 was the highest on record.

4.2 *Issues relevant to the assessment of the lobster fishery*

Lobster is the most important species exploited by inshore fishing vessels in Irish inshore waters.

Lobsters cannot be aged. Size distribution data varies spatially and raising to the size distribution of the landings is difficult due to spatial variability. These data come from observers working on board lobster vessels, mainly between May and October, from the sentinel vessel programme (SVP) and since 2021 from a Skipper self-sampling programme. There is also some port sampling of landings.

Growth rate data are available for Irish stocks from tag returns. Size at maturity has been estimated a number of times. Growth parameter estimates need to be reviewed.

Egg per recruit assessments have been used to compare the relative merits of different technical conservation measures; namely size limits and v-notching. Estimating the exploitation status (fishing mortality rate) on the egg per recruit curves is difficult given that this relies on size distribution data and estimates for growth and natural mortality. Reproductive potential of different size components of the stock can be estimated from size distribution, size at maturity and fecundity data. This indicates the relative contribution of different conservation measures to spawning potential and is reported below.

Catch rate indicators are available from the SVP, which covers approximately eight percent of the fleet, from the Skipper self-sampling programme and from the MI observer programme. This coverage is still insufficient to provide precise estimates of catch rates at local level given the variability in these data in time and space.

4.3 *Management units*

Lobsters are probably distributed as regional stocks along the Irish coast. This has been shown by larval dispersal modelling. Juvenile and adult lobsters do not move over large areas and the stock structure is determined mainly by larval dispersal. Genetic and larval dispersal modelling studies are ongoing through a project that will indicate the range of dispersal of progeny from v-notched lobsters released in different areas between Loop Head and Slyne Head.

4.4 *Management measures*

The lobster fishery is managed using technical measures. The minimum size is 87 mm carapace length. A maximum size limit of 127 mm was introduced in 2015 following an egg per recruit assessment which showed low egg production and to protect v-notched lobsters growing into larger size classes. It is prohibited to land v-notched lobsters. The v-notching of lobsters is voluntary. There is no limit on fishing effort or catch.

4.5 *Contribution of conservation measures to reproductive potential*

4.5.1 Implementation of the v-notched programme

From 2002 to 2008 between 5,000 and 11,000 lobsters were released annually. This increased to between 10,000 and 15,000 during the period 2010 to 2013. From 2014-2018 releases increased to between 25,000 and 32,000 annually but were lower in 2019 and 2020. Numbers increased from 2020 to record highs of 27.74 tonnes and 40,000 lobsters in 2022 (Figure 2). The average size at release was approximately 0.7 kg in the period 2020-2022.

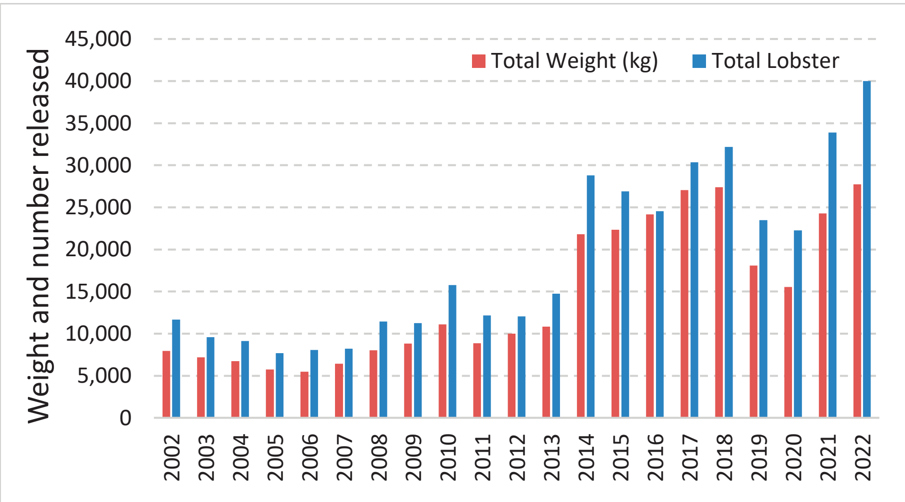

Figure 2. Total number and weight of V-Notched lobsters releases 2002-2022.

4.6 *Reproductive potential (pot data)*

The reproductive potential (RP) of a given size class of lobsters is the product of the number of lobsters in the size class, the probability of maturity, spawning frequency and size related fecundity. It is a measure of the relative contribution of different size classes and v-notched or non-v-notched components of the stock to overall reproduction. An indicator of the implementation and effect of the v-notch programme should be evidenced through changes in RP of the v-notch component of the stock relative to non-v-notched components. Similarly changes in RP of lobsters over the MaxLS may increase over time as lobsters' escape fishing mortality and grow above 127 mm.

On average across years 15-20 % of RP is in lobsters below the minimum landing size of 87 mm (Figure 3, Figure 4 and Figure 5). A further 50-60 % is in lobsters between 87-127 mm, which is the size range that is fished. V-notched lobsters generally account for 10-20 % of the RP. In 2022 observer data showed that lobsters below 87 mm accounted for 26.5 % of RP, lobsters in the fishable size range accounted for 59 % of RP, v-notched lobsters in that size range accounted for 9.6 % of RP and the remainder of RP was in lobsters over 127 mm (1.8 % in v-notched lobsters over 127 mm and 2.7 % in lobsters over 127 mm that are not v-notched). In 2022, the contribution of v-notched lobsters both in the 87-127 mm size range and above the 127 mm maximum size limit are substantially smaller than in 2021. Observer data in 2021 was less comprehensive than the rest of the time series, but 2022 data is an exception to the increasing trends in numbers of V-notched lobsters observed from 2017 onwards. Data in 2022, also shows the highest RP contribution in lobsters below the 87mm MLS of the time series. The variability shown in these figures might reflect changes in both the amount and spatial variability of sampling. The data from the new Skipper self-sampling programme established in 2021 have yet to be incorporated into these figures.

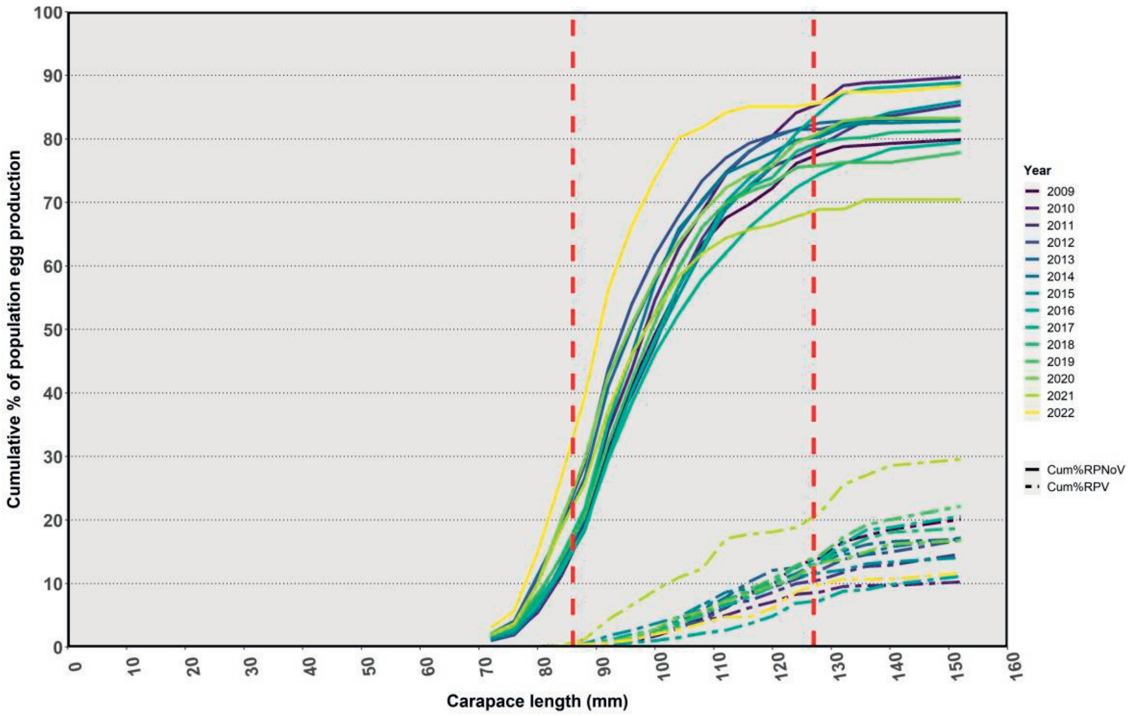

Figure 3. Cumulative distribution of reproductive potential (RP) across size classes of V-notched and non-V-notched lobsters for all regions combined. Source: Marine Institute Observer data 2009-2022.

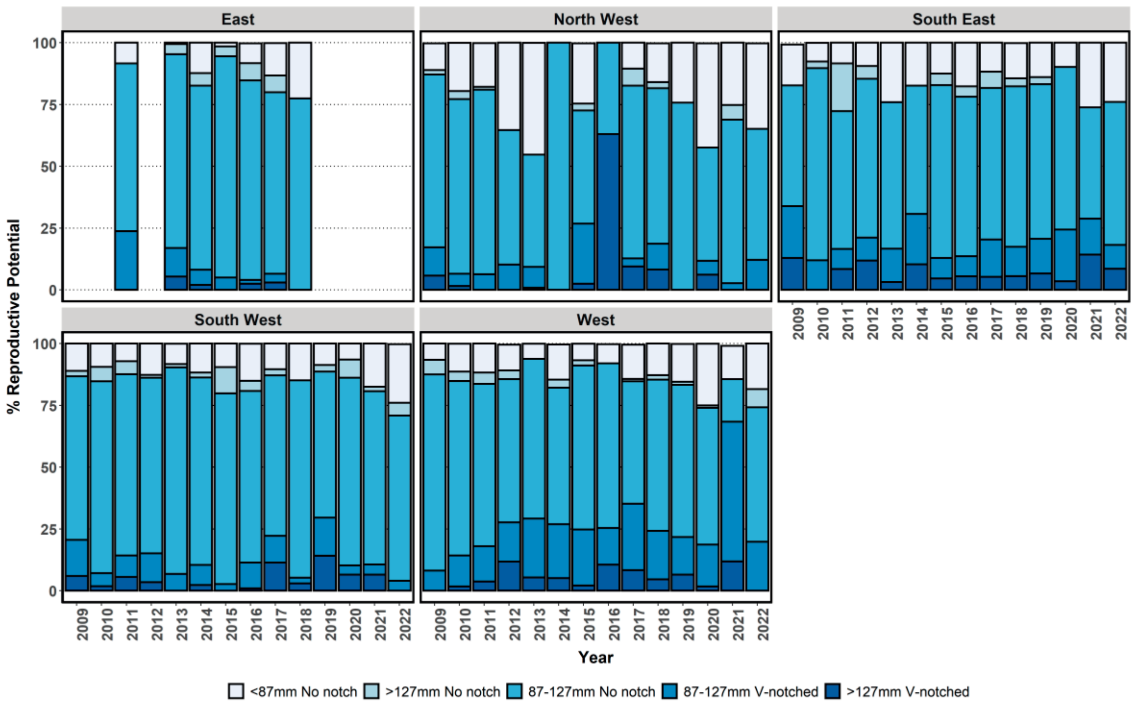

Figure 4. Summary of the distribution of the % reproductive potential in lobster stocks conserved by v- notching, minimum size and maximum size measures by region. Marine Institute Observer data 2010-2022.

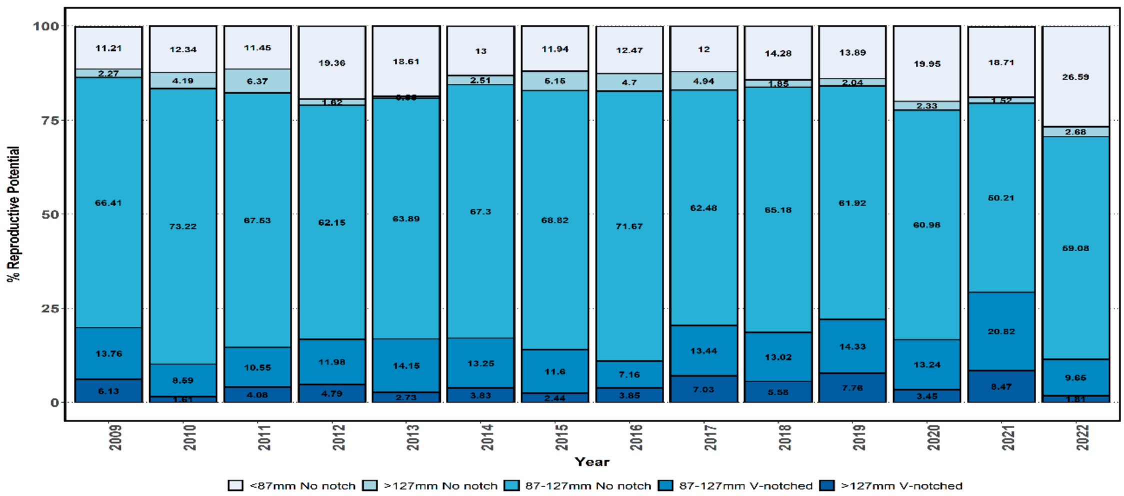

Figure 5. Summary of the distribution of the % reproductive potential in lobster stocks conserved by v- notching, minimum size and maximum size measures for all regions combined. Source: Marine Institute Observer data 2010-2022.

4.7 *Reproductive potential (tangle net data)*

The cumulative % RP curves for net data (Figure 6) were significantly different than pot data (Figure 3). Large size classes contributed more RP when estimated from net data compared to pot data. On average, across years 2017-2022, the distribution of % RP of lobsters below 87 mm, between 87-127 mm, over 127 mm and whether v-notched was different in tangle nets compared to pots (Figure 7). The main features were that 20 % of the RP was in lobsters above the maximum size limit compared to just 2.5 % in pot data, v-notched lobsters contributed <1 % RP in tangle net data compared to 5.6 % in pot data and lobsters below 87 mm contributed 1.2 % in net data compared to 14 % in pot data.

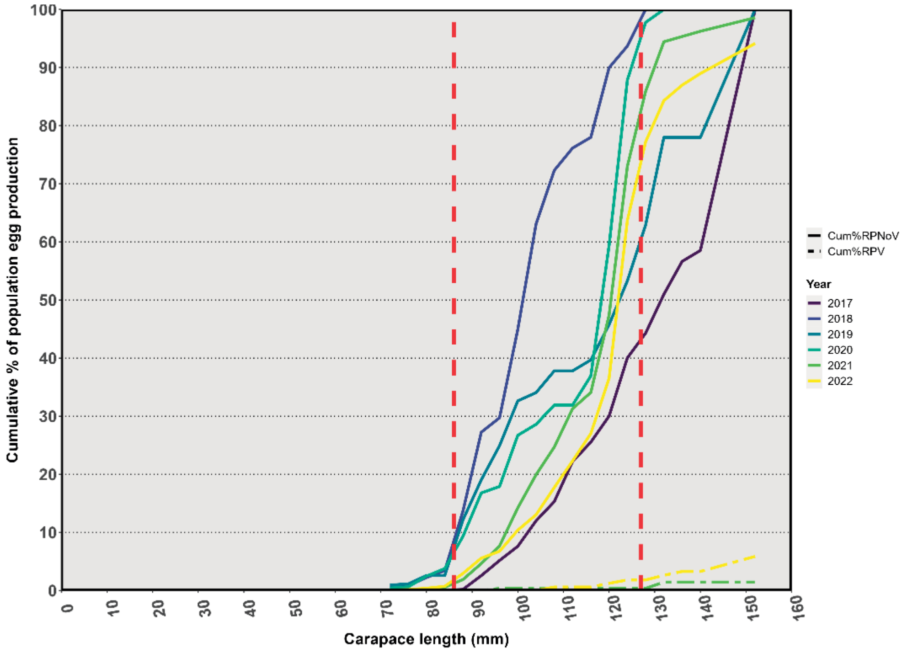

Figure 6. Cumulative distribution of reproductive potential (RP) across size classes of V-notched and non-V-notched lobsters from tangle net catch data off the south west coast. Source: Marine Institute Observer and Skipper data 2017-2022.

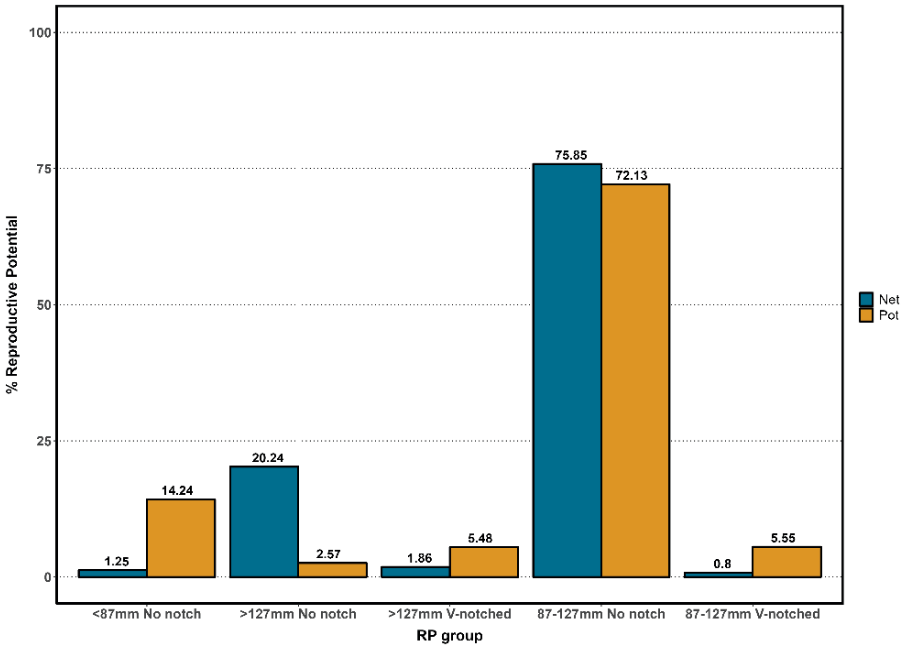

Figure 7. Comparison of % reproductive potential of lobsters in different size categories estimated from pot and net catch data off the south west coast 2017-2022 combined.

4.8 *Catch rates*

This report includes the SVP data from 2013-2021 and the MI observer data from 2014-2021. Before 2014, observer trips were very limited and thus, catch rate data is not shown. SVP data and data from various earlier voluntary logbook programmes prior to 2013 are being compiled.

In the SVP, lobsters are generally reported in either numbers or kilograms. Numbers are reported in this analysis. Weights were transformed to numbers based on the modal size for V-notched lobsters

(106 mm) from observer data. A length-weight relationship from port-processor data was applied (**W**=1.42*10-^{6}**L**$^{2.84}$) where W is weight and L is carapace length.

The catch rates of legal sized (LPUE) lobsters and undersized discarded (DPUE) lobsters from 2013-2021, all areas combined, were stable without any clear trends (Figure 8, Figure 9). Observer data generally reports higher catch rates, especially for the discarded component. Seasonally, LPUE generally peaks in quarter 3 and declines in quarter 4. This is probably a combined effect of in season landings and reduced catchability, related to declining temperatures, later in the year.

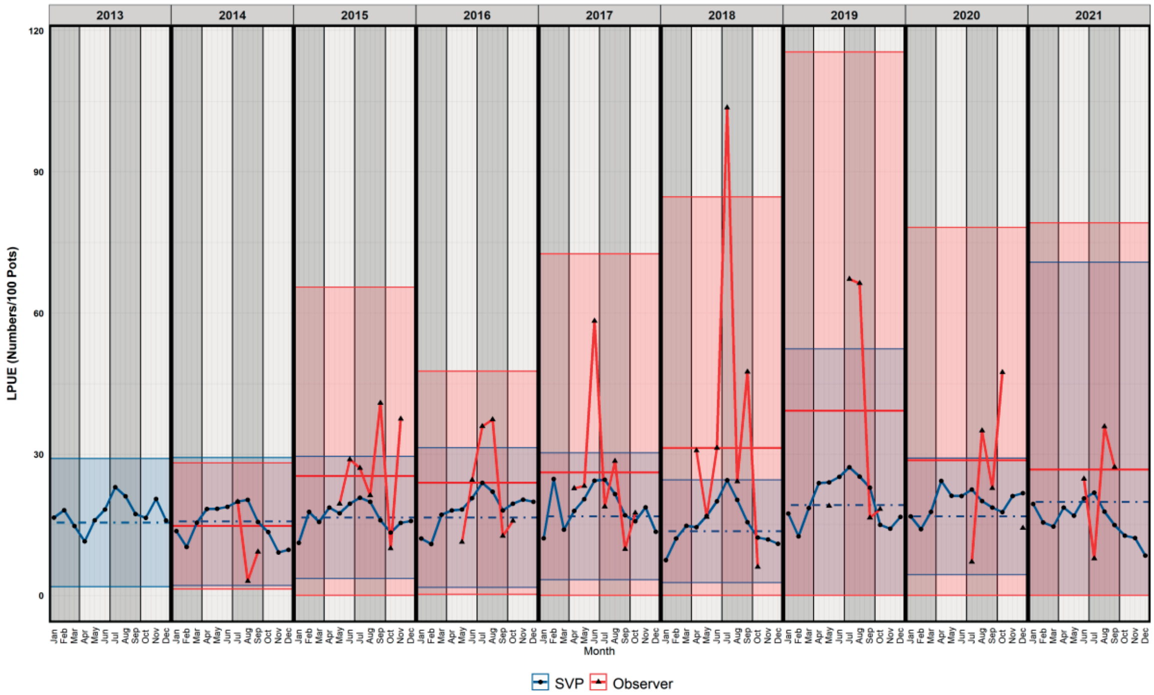

Figure 8. Annual mean landings of lobster per effort (LPUE per 100 Pots) for the SVP (2013-2021) and MI Observer programme (2014-2021).

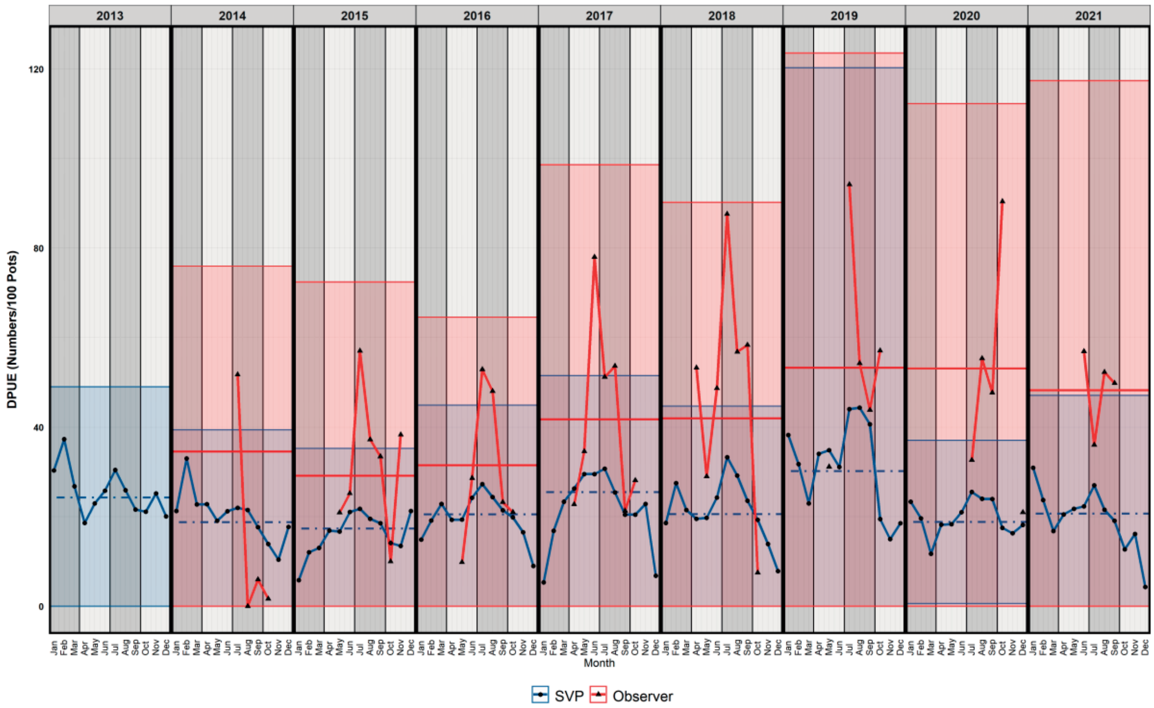

Figure 9. Annual mean discards of lobster per effort (DPUE per 100 Pots) for the SVP (2013-2021) and MI Observer programme (2014-2021).

4.9 *Size composition*

4.9.1 Pots

The annual size composition data of discarded and landed lobsters in pots used to target lobster is stable (Figure 10). The number of lobsters measured in the observer programme however has declined in recent years but this has been augmented by a Skipper sampling programme since 2021.

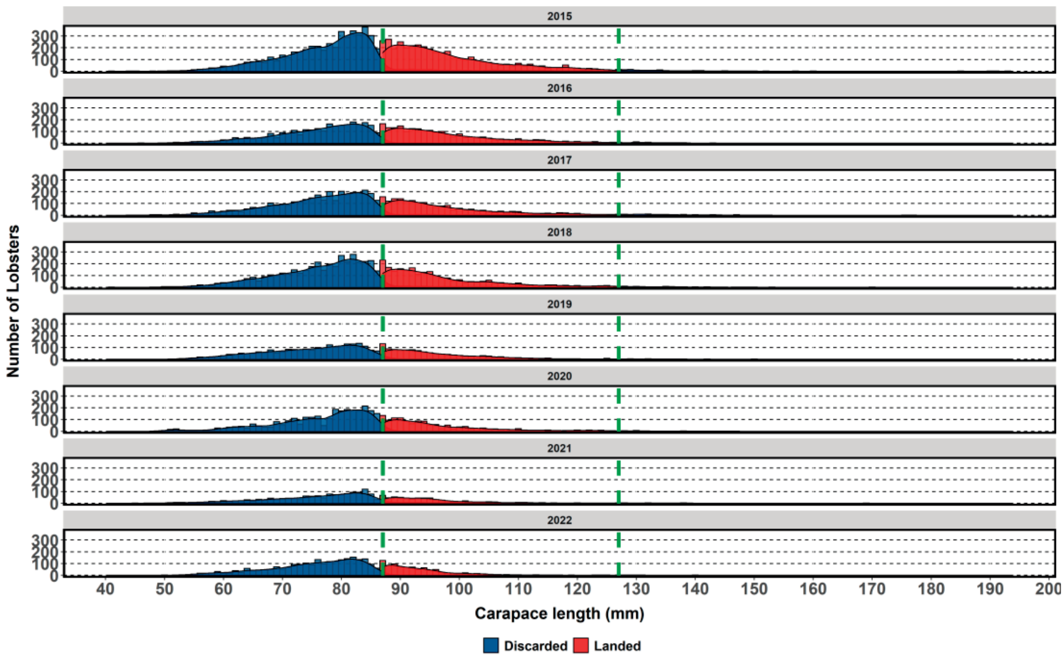

Figure 10. Annual size distributions of discarded (<87 mm, >127 mm) and landed lobsters across all regions. Marine Institute observer data 2015-2022.

4.9.2 Tangle nets

Data on lobster size distribution, caught as a by-catch in the crayfish tangle net fishery, has been collected off the Kerry coast since 2017 (Figure 11). Compared with the size distribution data from soft eye pots in the south west region and over the same time period data from nets generally show a higher proportion of lobsters in larger size classes including the proportion of lobsters above the maximum landing size of 127 mm. Nets may also be selecting fewer lobsters below the minimum size of 87 mm compared to pots. These data suggest that the catchability of larger size classes of lobster in pots is low and that the reproductive or spawning potential of larger size classes of lobsters, estimated using pot data alone is underestimated.

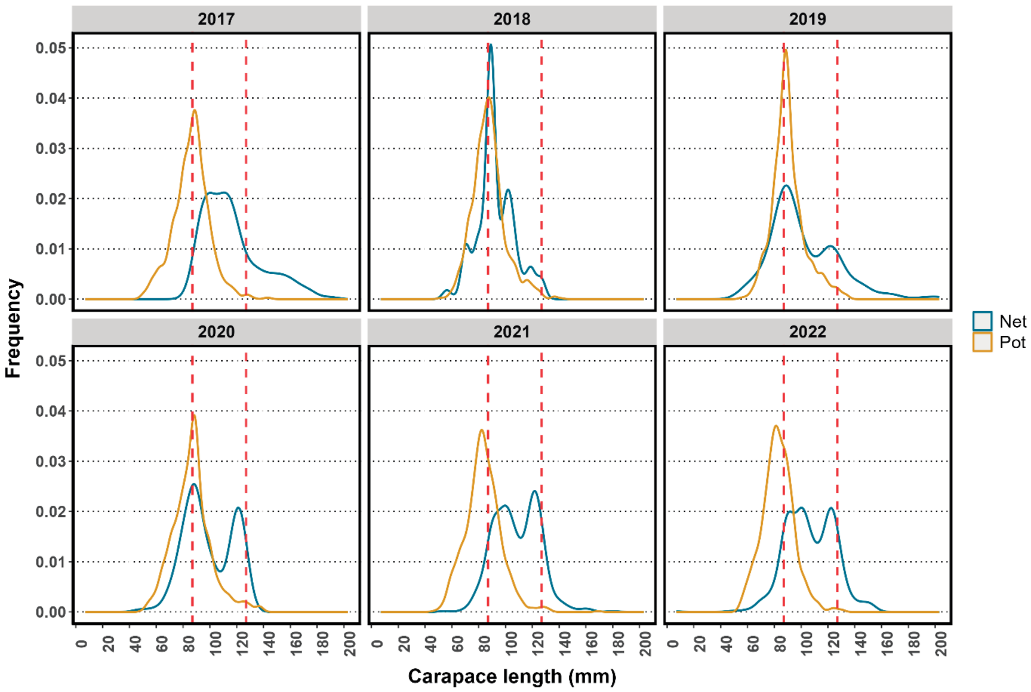

Figure 11. Annual size distributions of lobsters in the catch in pots and large mesh tangle nets off the south west coast 2017-2022. The minimum and maximum landing sizes are shown. Source: Marine Institute observer and Skipper data.

5 Crayfish (*Palinurus elephas*)

5.1 *Management advice*

Crayfish are managed using a minimum landing size (MLS) of 110 mm. There are two areas, one off west Galway and a second in Tralee Bay, closed to netting. V-notched crayfish cannot be landed. This measure was introduced to protect tagged crayfish and currently has limited conservation value as there is no v-notching scheme as such.

Spider crab, brown crab, crayfish and lobster are the most common commercial species in the catch. Catches of crayfish vary from 5-25 fish per nautical mile of net hauled. This varies seasonally and geographically. Unit value is between €35-50 per kg. About 50 % of the catch is under the MLS but this varies by year. Mortality of crayfish caught in nets can reach 50 % at certain times of year. Tagging data suggests a high level of residency on reef habitat in coastal waters.

A number of endangered and protected species are caught as by-catch in large mesh tangle nets used to target crayfish. The fishery off the south west coast in particular overlaps with an area of high diversity of elasmobranch fish and is close to grey seal haul outs and areas designated for harbour porpoise. Twelve species of elasmobranch fish (skates and rays) occur in the by-catch. Of these white skate, angel shark, flapper skate and blue (common) skate are critically endangered. There is a high by-catch of grey seal relative to the size of the seal population at the Blasket Islands.

Critically endangered species cannot sustain by-catch mortality caused by the tangle net fishery. Measures should be introduced to eliminate the by-catch of critically endangered species and to significantly reduce the by-catch of protected species. Alternative fishing practices to reduce by-catch and mortality of crayfish in the catch need to be considered.

5.2 *Issues relevant to the assessment of the crayfish fishery*

Crayfish have, since the mid-1970s, been fished primarily with large mesh (25 cm) entangling nets. Prior to this top entrance pots were the main gear used in the fishery. Fisheries data, other than landings, have not been routinely collected. Data on catch per unit effort could provide indices of biomass but these data and size distribution data are sparse, of variable quality and were not collected systematically prior to 2017. Sampling effects and crayfish movement in and out of sampling areas probably confound these data and their use in estimating fishing mortality rates.

New data on species catch composition in the tangle net fishery, catch rates and size distributions have been obtained recently (2017-2022) off the south west coast and is ongoing. Tag recovery data suggests that mark-recapture methods may be used to estimate the stock size.

5.3 *Management units*

The life cycle of crayfish suggests that there is a single stock in north west Europe where high levels of connectivity may be maintained by larval dispersal. The larvae phase lasts for between 6-9 months and larvae produced off the Irish coast may disperse into oceanic waters to the west of Ireland. Larval behaviour however and their possible association with small species of jellyfish may reduce the dispersal scale. The dynamics of larval supply back to coastal reef habitats have not been established and it is also possible that there is a link between larval production and recruitment at smaller spatial scales.

Although crayfish tagged off Brittany have recently been recorded off the west of Ireland crayfish tagged off the south west coast of Ireland have also been recaptured locally and repeatedly in different years and there are no reported captures over wider areas. Acoustic tagging data for crayfish in the Mediterranean indicates homing to release location. There are no significant stocks of crayfish north of Ireland. The fishery closest to Ireland is at the Scilly Isles and Brittany. Until connectivity, relevant to management, across these areas is shown Irish stocks should be managed separately.

5.4 *Management measures*

The minimum landings size in Ireland is 110 mm (compared to 95 mm in EU regulations). Many areas in Britain and elsewhere also use an MLS higher than 95 mm. Netting is prohibited in Tralee Bay and in an area off west Galway. It is prohibited to land v-notched crayfish. This measure currently has little conservation effect given that there is no v-notching scheme for crayfish. The measure was introduced to protect crayfish that are tagged and enabled multiple mark recapture data to be collected.

5.5 *Catch composition tangle nets*

Species catch composition and catch rates have been estimated from observer and Skipper sampling data between 2017-2022. Between 300 and 600 nm of net hauls are observed annually. In 2022 crayfish were, numerically, the most common species caught in tangle nets off the Kerry coast followed by spider crab and brown crab. Significant numbers of lobsters are caught. Commercial fish caught in tangle nets include turbot, monkfish, pollack and spurdog and thornback rays along with low numbers of spotted and blonde rays. Other non-commercial species are caught including protected species such as grey seal and critically endangered species such as angel shark, flapper skate, blue or common skate and white skate (Table 5 and Table 6).

Table 5. Species catch composition in tangle nets targeting crayfish off the south west coast of Ireland 2017-2022. Data are total numbers caught in each year by all boats in the sampling programme. The geographic areas sampled in 2021 and 2022 were broader and involved more vessels.

Species	2017	2018	2019	2020	2021	2022	Total
Spider Crab (*Maja brachydactyla*)	3,294	7,320	7,369	3,931	6,538	8,411	**36,863**
Crayfish (*Palinurus elephas*)	3,992	4,147	3,328	3,893	7,836	10,663	**33,859**
Brown Crab (*Cancer pagurus*)	3,548	7,034	3,783	3,360	5,353	6,304	**29,382**
Lobster (*Homarus gammarus*)	500	785	658	757	561	777	**4,038**
Pollack (*Pollachius pollachius*)	11	185	203	65	386	876	**1,726**
Monkfish (*Lophius spp*)	38	89	79	72	246	359	**883**
Turbot (*Scophthalmus maximus*)	37	58	87	133	100	207	**622**
Black Pollack (*Pollachius virens*)	0	0	0	0	2	25	**27**
Spurdog (*Squalus acanthias*)	49	155	1,115	583	1,861	2,162	**5,925**
Thornback (*Raja clavata*)	52	87	165	117	277	532	**1,230**
Dog fish (*Scyliorhinus spp*)	37	6	1	10	563	606	**1,223**
Spotted Ray (*Raja montagui*)	0	11	22	59	196	298	**586**
Grey Seal (*Halichoerus grypus*)	8	45	73	74	55	141	**396**
Blonde Ray (*Raja brachyura*)	0	22	5	0	74	208	**309**
Common/Flapper Skate (*Dipturus spp*)	0	8	12	0	117	172	**309**
Unidentified Skate	70	26	1	5	0	0	**102**
Painted Ray (*Raja microocellata*)	0	5	0	4	54	16	**79**
Sting Ray (*Dasyatis pastinaca*)	0	1	0	2	24	27	**54**
Angel Shark (*Squatina squatina*)	0	0	2	1	0	16	**19**
Undulate Ray (*Raja undulata*)	0	1	0	0	3	12	**16**
Cuckoo Ray (*Leucoraja naevus*)	0	0	2	0	0	0	**2**
White Skate	0	1	0	0	0	0	**1**
Total	**11,636**	**19,986**	**16,905**	**13,066**	**24,246**	**31,812**	**117,651**

Table 6. Species catch composition in tangle nets targeting crayfish off the south west coast of Ireland 2017-2022 standardised to 100 nm of net hauls observed.

Species	2017	2018	2019	2020	2021	2022	Total
Spider Crab (*Maja brachydactyla*)	766	1,723	2,346	1,265	1,344	1,260	**8,704**
Crayfish (*Palinurus elephas*)	928	976	1,060	1,253	1,611	1,597	**7,424**
Brown Crab (*Cancer pagurus*)	825	1,656	1,205	1,081	1,101	944	**6,811**
Lobster (*Homarus gammarus*)	116	185	210	244	115	116	**986**
Pollack (*Pollachius pollachius*)	3	44	65	21	79	131	**342**
Monkfish (*Lophius spp*)	9	21	25	23	51	54	**182**
Turbot (*Scophthalmus maximus*)	9	14	28	43	21	31	**144**
Black Pollack (*Pollachius virens*)	0	0	0	0	0	4	**4**
Spurdog (*Squalus acanthias*)	11	36	355	188	383	324	**1,297**
Thornback (*Raja clavata*)	12	20	53	38	57	80	**259**
Dog fish (*Scyliorhinus spp*)	9	1	0	3	116	91	**220**
Spotted Ray (*Raja montagui*)	0	3	7	19	40	45	**114**
Grey Seal (*Halichoerus grypus*)	2	11	23	24	11	21	**92**
Blonde Ray (*Raja brachyura*)	0	5	2	0	15	31	**53**
Common and Flapper Skate (*Dipturus spp*)	0	2	4	0	24	26	**56**
Unidentified Skate	16	6	0	2	0	0	**24**
Painted Ray (*Raja microocellata*)	0	1	0	1	11	2	**16**
Sting Ray (*Dasyatis pastinaca*)	0	0	0	1	5	4	**10**
Angel Shark (*Squatina squatina*)	0	0	1	0	0	2	**3**
Undulate Ray (*Raja undulata*)	0	0	0	0	1	2	**3**
Cuckoo Ray (*Leucoraja naevus*)	0	0	1	0	0	0	**1**
White Skate	0	0	0	0	0	0	**0**
Total	**2,704**	**4,704**	**5,383**	**4,204**	**4,985**	**4,765**	**26,745**

5.6 *Catch rates*

Landings increased in 2022 to 58 tonnes which is the highest since 2004. Catch rates of crayfish generally varied from 5-25 fish per nautical mile of net during 2017-2022. This includes all sizes (Figure 12). The size distribution data shows variable proportions of the catch are above the minimum size in each year; 34 % in 2017 and 48-57 % in 2018-2022 (Figure 13). This variability in the size composition suggests that there is significant movement of crayfish into or out of the area although this is not borne out by the tagging data which suggests a high level of residency and repeated re-captures of individual crayfish close to release sites.

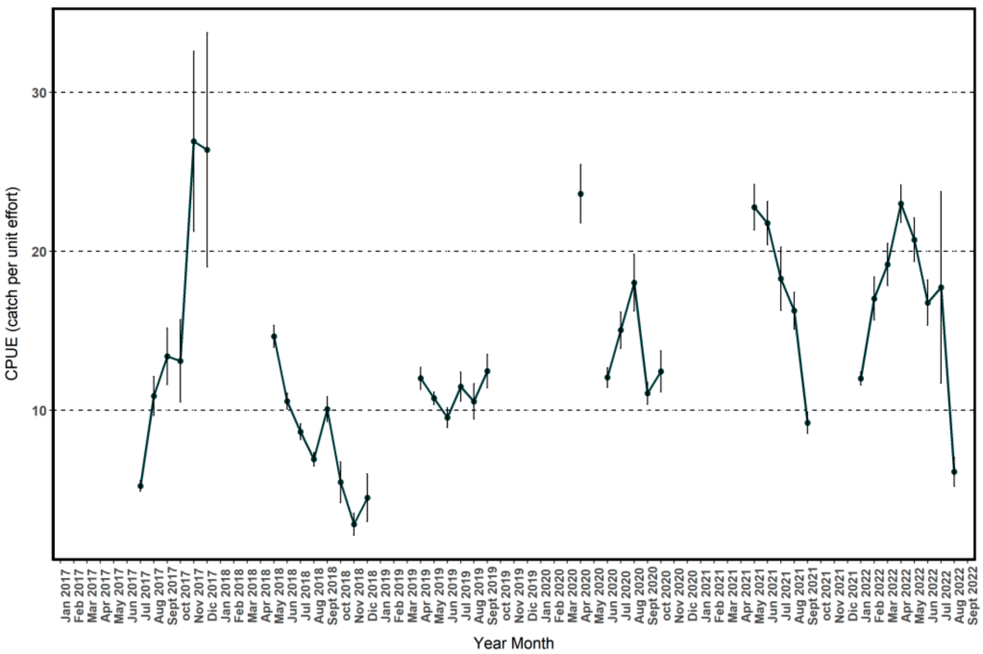

Figure 12. Catch rate (numbers.nmnet^{-1}) of crayfish off the south west coast of Ireland 2017-2022.

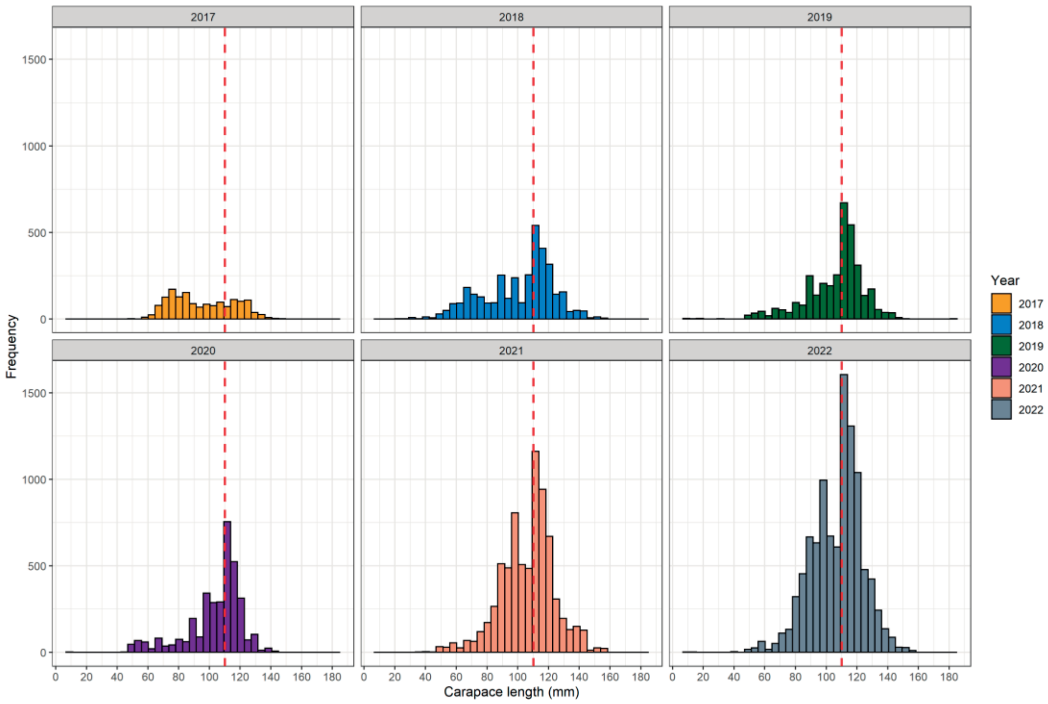

Figure 13. Size distribution of crayfish in the catch off the southwest coast or Ireland 2017-2022.

5.7 *Tag release and recaptures*

5.7.1 Releases

A total of 3,814 crayfish were tagged and released between 2017-2022; 778 in 2017, 449 in 2019, 1,614 in 2021 and 973 in 2022 (Figure 14). Releases were in two main areas; generally south or west of the Blasket Islands and west and north west of Brandon point. A small number were released in the Celtic Sea in 2022.

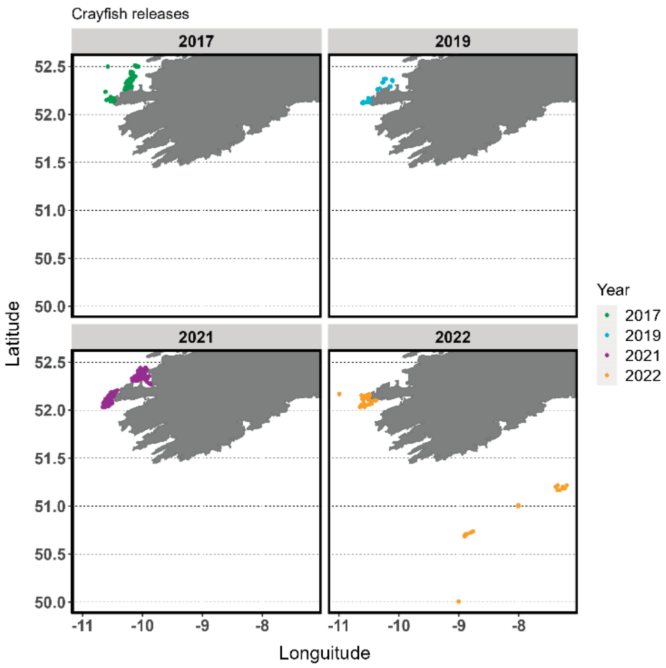

Figure 14. Release locations of tagged crayfish in 2017-2022. Releases in the Celtic Sea in 2022 were by a gillnetting boat targeting hake.

5.7.2 Recaptures

Although 3 crayfish tagged off Brittany (France) in 2016 have been recaptured on the Irish south west and north west coast almost all recaptures have been within the release area and very few recaptures have been reported by netters, potters or trawlers outside the area.

Multiple recaptures of the same individuals have occurred and crayfish have been recaptured in the release zone for a period of up to 5 years. Movement of crayfish between the two main release areas is generally low (Figure 15, Figure 16, Figure 17). This all suggests a high level of residency of crayfish on reef habitat in the area.

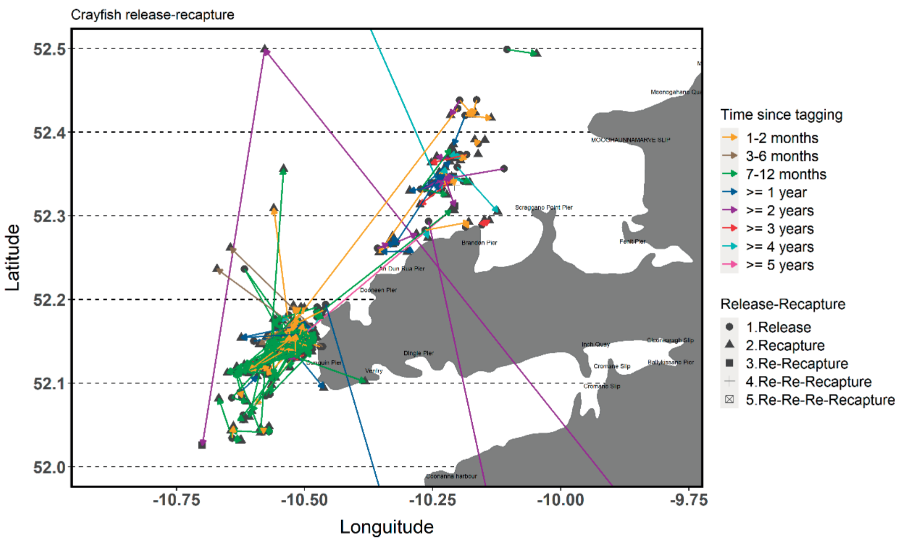

Figure 15. Recaptures of tagged crayfish released in the Blasket Island area and further north at Brandon showing low connectivity between the two areas.

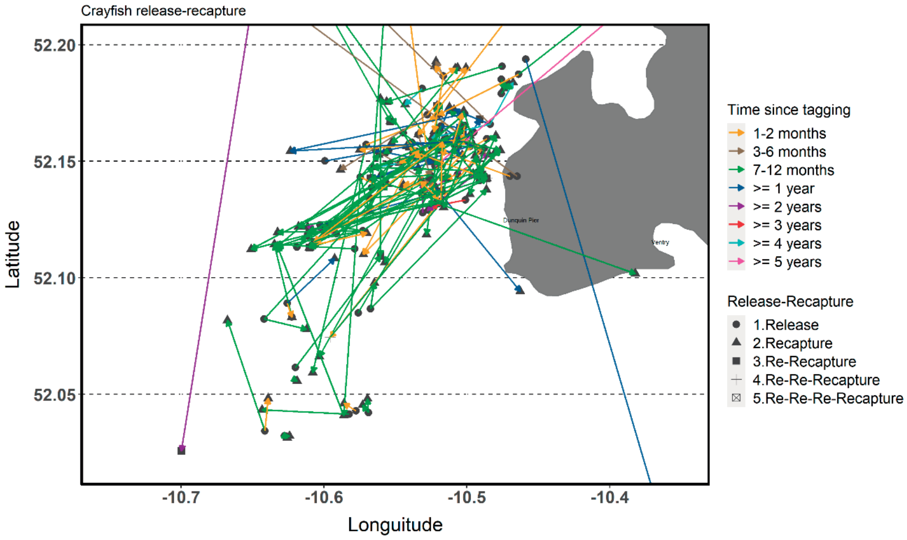

Figure 16. Recaptures of tagged crayfish released in the Blasket Island area showing local movement generally within 1 year of release.

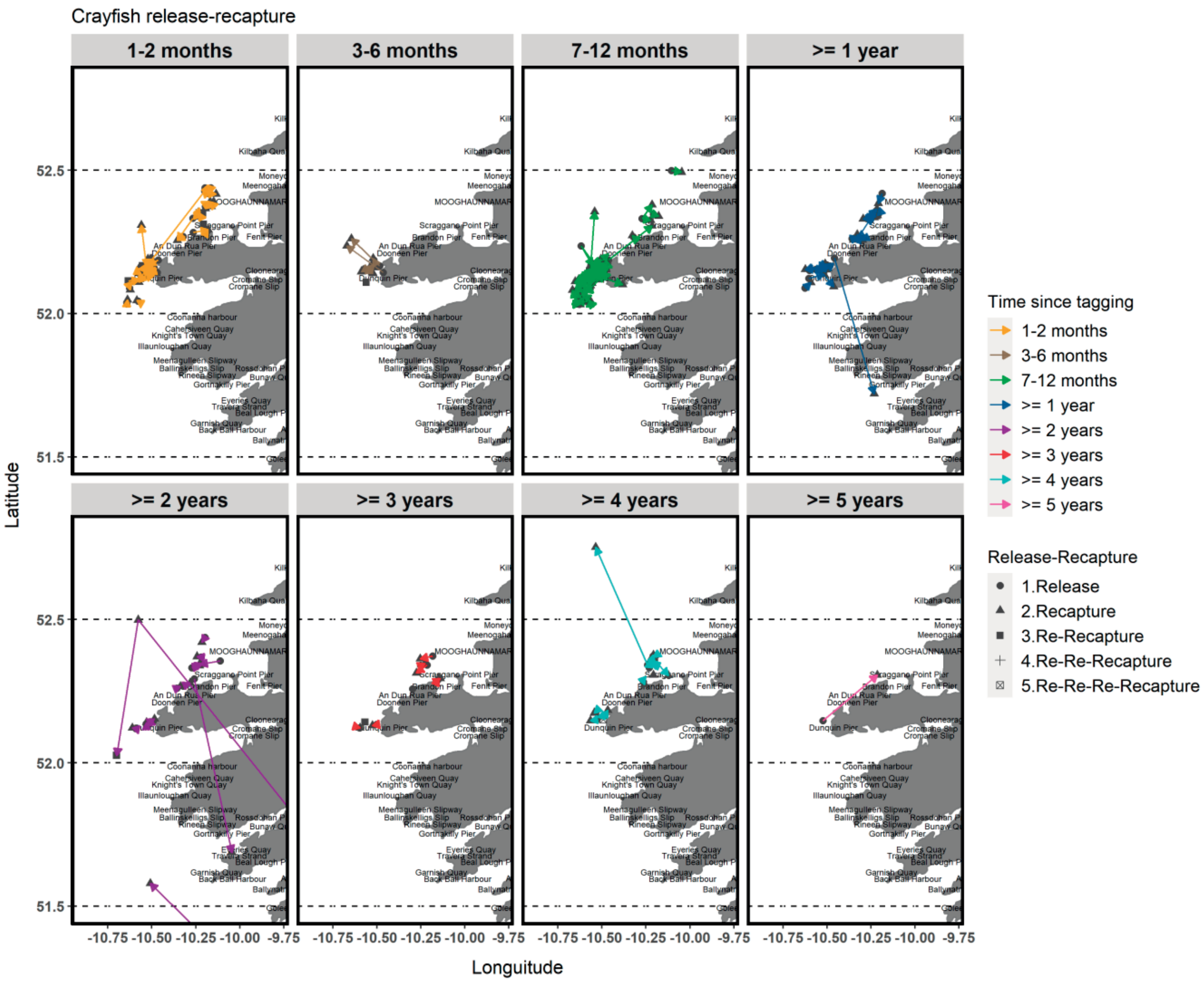

Figure 17. Tag recapture data for crayfish off the Irish coast 2017-2022. Three crayfish tagged off Brittany in 2016 were captured on the south west and north west coast. Otherwise no recaptures of crayfish have been reported outside the tagging area from Blasket north to Loop Head.

6 Brown crab (*Cancer pagurus*)

6.1 *Management advice*

The crab fishery is managed by a minimum landing size of 140 mm carapace width. There are kilowatt day effort limits on vessels over 10 m in the biologically sensitive area which includes coasts from north Mayo south and east to Waterford and on vessels over 15 m in ICES area VI.

Standardised index of stock abundance and a stock assessment, based on a production model, show a steep year on year decline in both landings per unit effort, discards per unit effort, increasing fishing mortality and declining biomass since 2014/2015 in the Malin Shelf fishery. The production model assessment incorporates landings by Scottish and Northern Irish vessels. These trends are also generally observed in other crab stocks off the Irish coast.

Advice based on the negative trends in stock indices or on the fishing mortality (F/F_{msy}) ratio, in the case of the Malin stock, all indicate the need to reduce fishing mortality. Corresponding landings at F/F_{msy} =1 for the Malin Shelf would be 3,900 tonnes (all fleets combined) or 4,500 tonnes using other harvest control rules for stocks where only relative estimates of fishing mortality and trends are available. Using the latter harvest rule landings for the south west coast would reduce to 960 tonnes and landings for the Celtic Sea would reduce to 632 tonnes.

Although the MLS of 140 mm significantly protects the stock from recruitment overfishing the data clearly signals a decline in stock abundance and a likely decline in recruitment in recent years given that trends in discard rates (of smaller crab) are also negative.

A significant proportion of crab landed is used directly for bait in the whelk fishery. Estimates vary from 1,300-2,000 tonnes. Reduction in landings by that amount would reduce fishing mortality close to the F_{msy} target.

6.2 *Issues relevant to the assessment of the crab fishery*

Assessments based on length data and biological parameters can provide estimates of fishing mortality (exploitation status). However, there are a number of assumptions underlying these methods and estimates are highly sensitive to growth rate parameters which are poorly estimated.

Landings per unit effort indicators are compromised by unknown grading practice on vessels and it is important that discard data is also available to construct the total catch if these data are to reflect changes in stock abundance. Given recent increases in fishing effort gear saturation effects may also be reducing catch per unit effort (CPUE). Standardising the nominal catch rate data for these and other effects is, therefore, important. Capacity to account for spatial and temporal effects in an annual standardised index depends on the spatial resolution of the data in particular.

As the data on catch rates reported here shows there are high levels of variation between vessels, areas, seasons and years it is difficult to identify patterns. An increase in the quantity of catch and effort data reported for the fishery is needed to ensure absence of bias and increase precision and to take into account geographic, seasonal and other effects on catch performance.

6.3 *Management units*

Targeted fisheries for brown crab in Ireland developed during the 1960s. The fishery developed off Malin Head in Donegal and along the Donegal coast and, to a lesser extent, on the south coast during the 1970s. The Malin Head fishery accounted for 25 % of national landings during the 1980s. The offshore fishery developed in 1990 and by the mid-1990s had fully explored the distribution of brown crab on the Malin Shelf. This stock, which extends from Donegal to the edge of the continental shelf and south to Galway, is the largest stock fished by Irish vessels. Crab stocks off the southwest and southeast coasts are exploited mainly by Irish vessels <13 m in length inside 12 nm.

ICES (WG Crab) has identified stock units for the purpose of assessment (Figure 18). On the Irish coast these units are identified from tagging data, distribution of fishing activity and larval distribution.

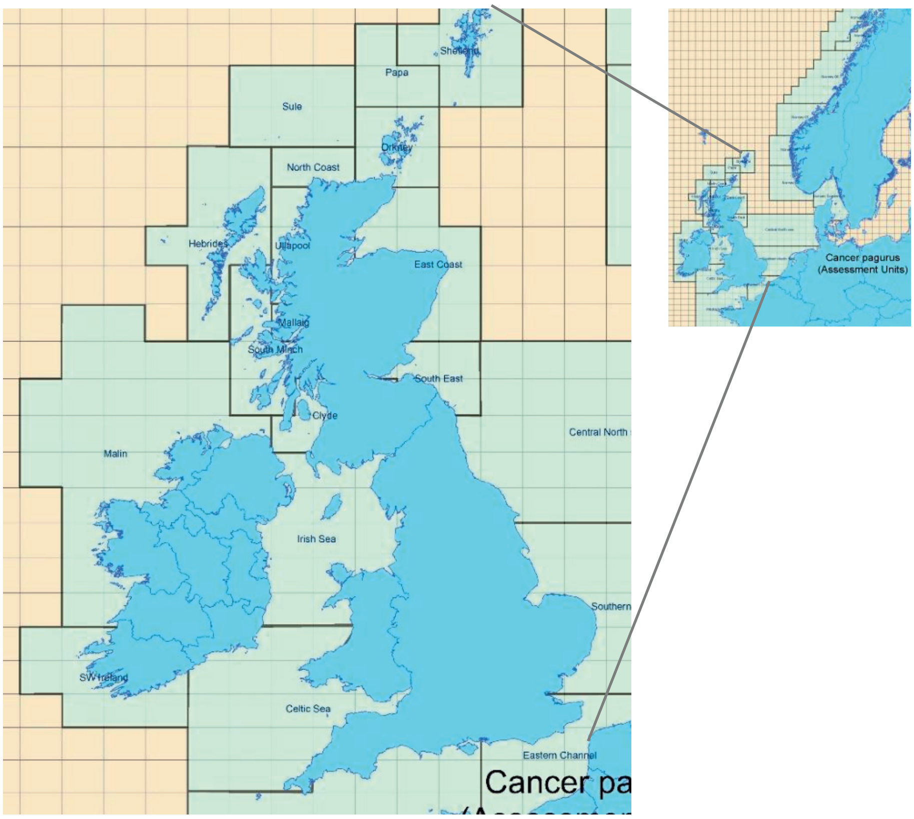

Figure 18. ICES stock assessment units for Brown crab.

6.4 *Management measures*

Crab are managed using a minimum landing size of 140 mm. Annual effort by vessels over 15 m in length is restricted (1415/2004 EC) to 465,000 kw.days in ICES Area VI (north west stock), to 40,960 kw.days in ICES Area VII outside of the Biologically Sensitive Area (BSA) and to 63,198 kw.days in the BSA for all vessels over 10 m in length. These restrictions have resulted in some displacement of effort of offshore vessels (>18 m in length) from the Malin Shelf to the North Sea and on occasion the restrictions may limit fishing activity towards the end of the year by vessels over 10 m. Effort by vessels under 10 m in length is unrestricted in all areas.

6.5 *Catch rates*

Sentinel vessel (SVP) data from 2013-2021 and the MI observer data from 2015-2021 for all coasts are presented here. Data prior to 2014 is presented for the Malin Shelf stock only as data for other areas is still being compiled.

Landings and discards of brown crab in the SVP are reported in different units, i.e. kilograms, boxes, trays and numbers. The data for this review is reported in kilograms. A box of landings/discards was assumed to be approximately 30 Kg based on previous reports from observer trips. One tray was assumed to represent half a box.

6.5.1 Annual trends

Landings per unit effort (LPUE) was stable during 2013-2015 in SVP vessels targeting crab with an annual mean of approximately 2.5 Kg/Pot. This declined between 2015 and 2021 from approximately 2.3 Kg/Pot in 2015 to approximately 1 Kg/Pot in 2021. The MI observer data declined from 2 Kg/Pot in 2016 to 0.18 Kg/Pot in 2021 (Figure 19). This decreasing trend in LPUE was observed in all stocks (Figure 20). Targeted LPUE was higher in the Celtic Sea in 2020 than in the previous 3 years for both legal and undersized crabs. Estimates in 2021, however, show the lowest LPUE's of the time series for this stock. Discards per unit effort (DPUE) showed decreasing trends in both SVP and MI observer data up to 2019, but SVP data is showing a recovery in the past two years at ~0.5 Kg/pot. LPUE and DPUE of crab caught in gear targeting lobster were relatively stable from 2018 but generally less than 0.5 Kg/Pot. The MI observer data is probably more reflective of mixed targeting of lobster and crab compared to the SVP where the data shows distinctly higher crab catches in pots intended for crab.

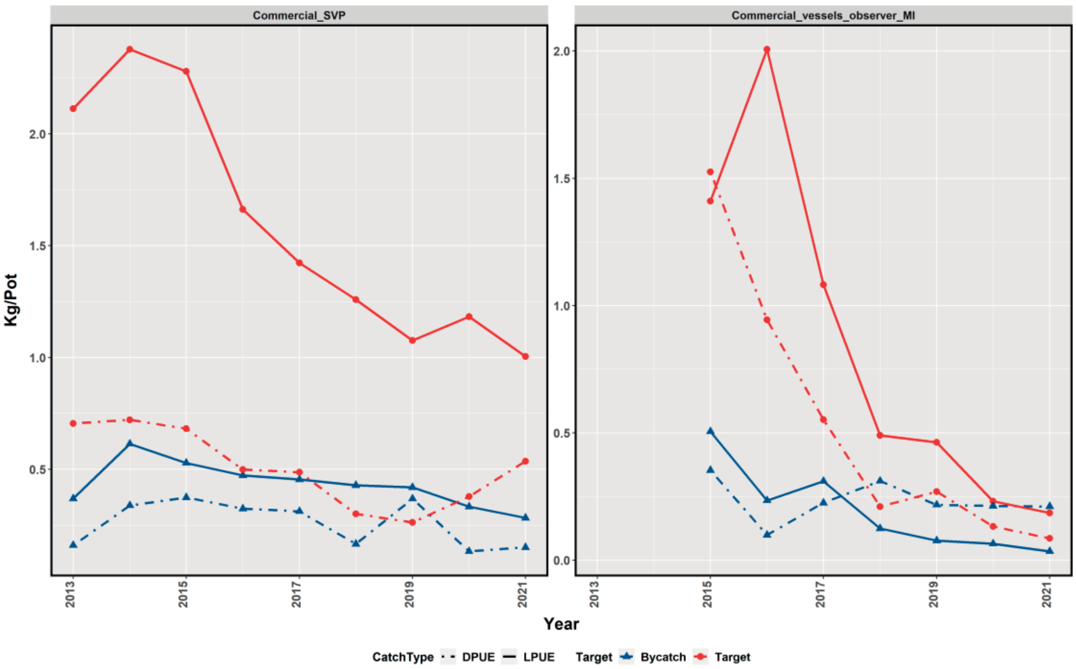

Figure 19. Annual mean LPUE and DPUE (Kg/pot) for Observer and SVP programme data from trips both targeting brown crab and where brown crab is caught as by-catch during 2013-2021. All stocks are combined.

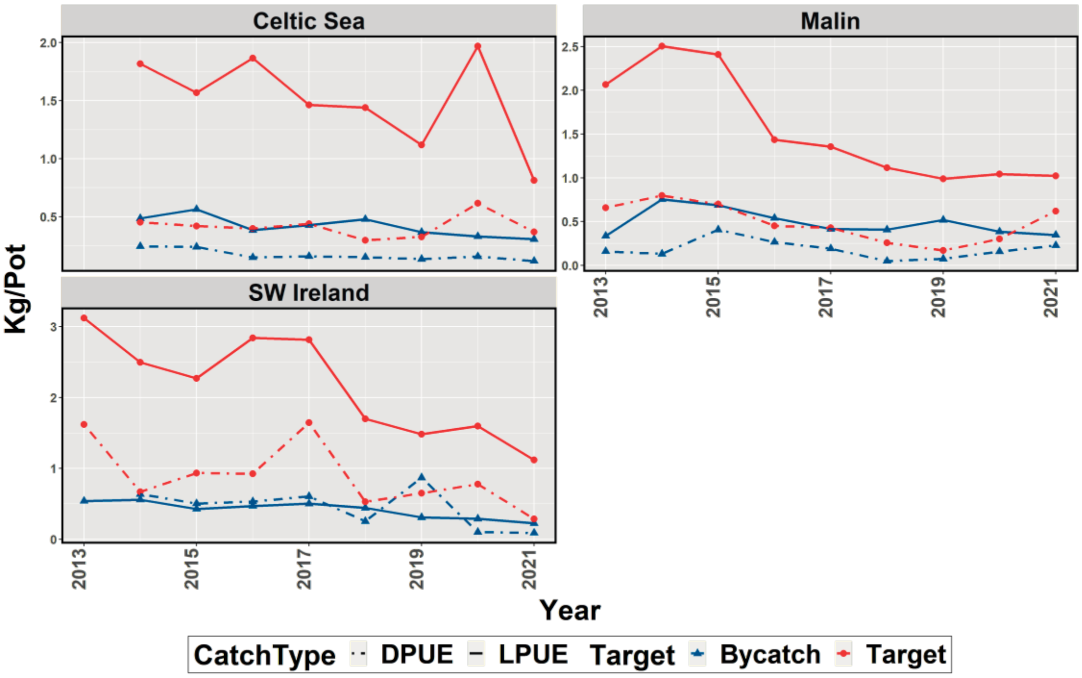

Figure 20. Annual mean LPUE and DPUE (Kg/Pot) by stock area for SVP trips targeting crab and also where crab is caught as bycatch during 2013-2021.

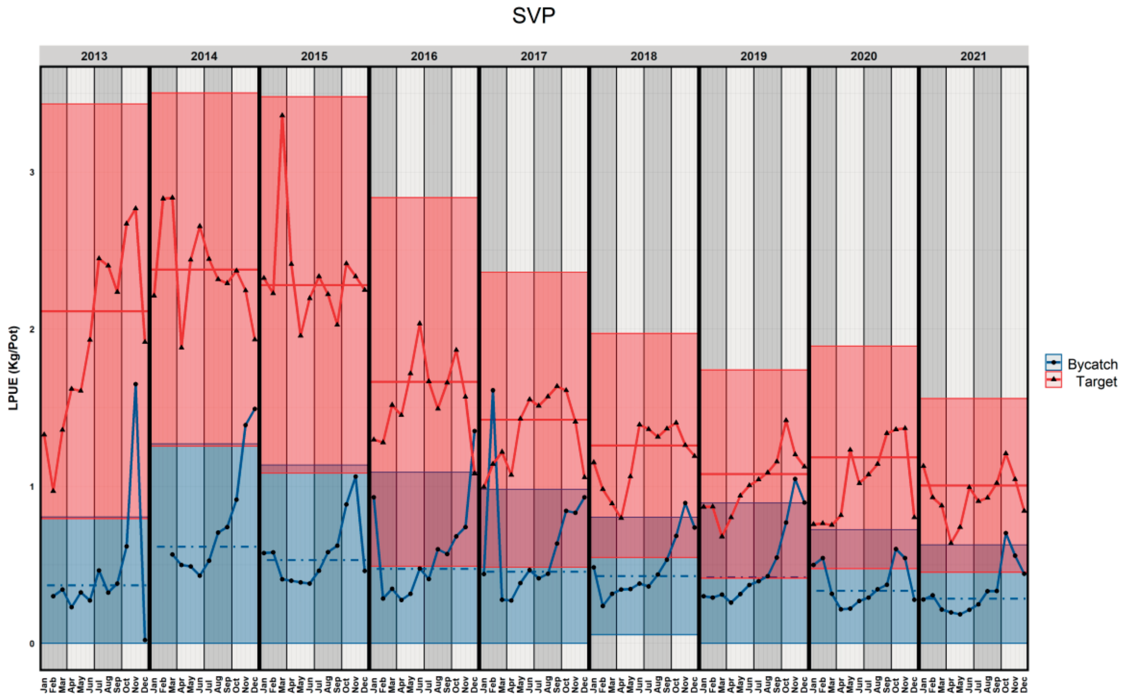

Figure 21. Monthly mean LPUE (Kg/pot) with standard deviation for SVP trips where crab was targeted (red) and captured as bycatch (blue). Horizontal lines in each year show annual means. Year quarters shaded in grey and white.

6.5.2 Seasonal trends

Seasonal trends in LPUE in the SVP data are shown in Figure 21. Observer data is not shown as it is considerably less precise given the limited sampling. LPUE in gears targeting crab generally show peaks in Quarter 3 and early Quarter 4 although in 2013-2016 peaks occurred in Quarter 1 and 2. LPUE of brown crab caught in pots targeting lobster generally peaks in Quarter 4.

6.6 *The Malin Stock*

6.6.1 Landings

The northwest crab fishery developed during the 1970s on a small scale and further development occurred during the 1980s in inshore waters especially off Malin Head. In 1990 the offshore vivier fleet was introduced and there was incremental modernisation of the inshore fleet. Throughout the time series, from 1980 to 2021, Irish vessels landed the largest proportion of Brown crab from the Malin stock. Landings peaked in 2004 at almost 8,000 tonnes. The peak in Irish landings observed in this year did not occur in the Scottish or Northern Irish data. Scottish landings remained relatively stable from the early 90's, whereas Northern Irish landings show a continuous increase with the exception of 2019 when landings started falling (Figure 22).

Figure 22. a) **Landings (tonnes) of brown crab (*Cancer pagurus*) in ICES Divisions VIa and VIIb (Malin Shelf stock) 1990-2021 by Irish (IRL), Northern Irish (NI) and Scottish (SCO) vessels. Source: Logbooks data for vessels above 10 m and sales notes data for vessel under 10 m.** b) **Data for Northern Ireland are reconstructed from 1990-2011 based on a general linear modelling framework using data from 2002-2019 (red line = R, reconstructed landings).**

6.6.2 Biomass indices

Two potential indices of abundance are available for the stock

1- Daily landings per unit effort (LPUE) collected in the SVP or earlier versions of it from 1996-2020 and
2- Georeferenced haul by haul LPUE (Figure 23), from the Irish Offshore crab fleet from 1991-2006.

Additional information available in both datasets include soak times and unique vessel identifiers. Data on discards was available in the SVP programme but are not always reported and are not included here.

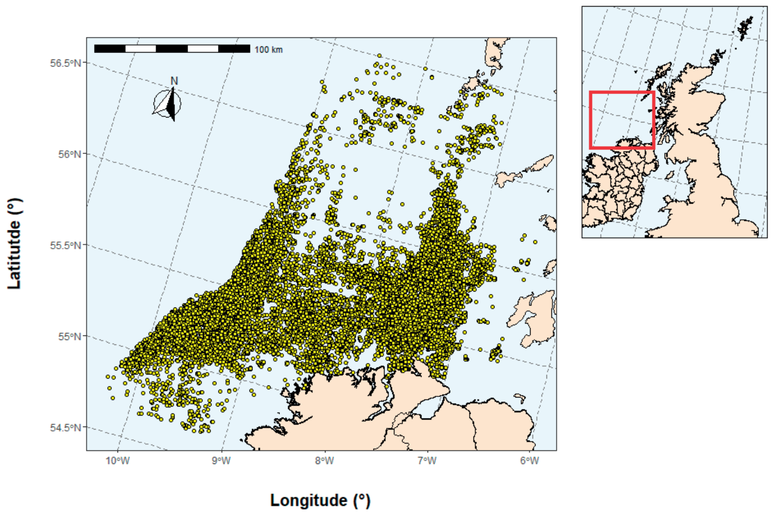

Figure 23. Haul locations for the offshore vivier crab fleet 1990-2006.

Commercial catch rate data can be used as a true index of abundance if the effects on catch rates of factors (co-variates) other than changes in crab abundance can be accounted for. This process is usually referred as catch rate standardization. In the case of the SVP programme, only trips targeting crab were used in the standardization analysis to reduce the variance in the LPUE estimates that would result if vessels targeting lobsters with a crab by-catch were included. When the target species intention was not recorded for a particular vessel or trip, it was assumed that vessels above 8 m total length tend to target brown crab. An extensive data exploration was carried out before any model implementation to identify potential issues, such as outliers (in both landings or effort) or missing data.

For both datasets, two independent gamma distributed Generalised Additive Model's (GAM) were developed with the following base form:

$$\eta_i = log(\mu_i) = \beta_o + offset\big(log(Noofpots)\big) + \beta_Y Year + s(SoakDays_i \sim "cs") + s(Vessel_i \sim "iid")$$

$$Landings_i \sim Gamma(\mu_i, \phi)$$

$$var[Landings_i] = \mu_i^2/\phi$$

$$\phi = exp(\theta)$$

where mean μ_i is the expected landings (kg of crab) on trip i and is linked (log link) to the linear predictor η_i, φ is the precision parameter from the gamma distribution and βY is the coefficient for the explanatory variables (Y= year), fitted as fixed effects. The term s() defines smoothing effects, as cubic spline ("cs") for SoakDays, to account for potential non-linear relationships between catch and soak time, and a single random effect ("iid") for Vessel ID, to account for potential correlation of observations from the same vessels. The "offset()" is used to incorporate the fishing effort (Number of pots) into the model based on a 1:1 relationship between catch and effort. This accounts for changes in catch rates that might be related to overall effort rather than changes in crab abundance. The offshore vivier index standardization, besides the terms described above, also accounted for potential gear saturation, defined as the effect on LPUE of the number of pots set 3 days before a specific fishing event and within a 5 km buffer zone, as well as an additional random effect to account for spatial and temporal correlation among observations at haul level.

In both models, the resulting index of abundance was based on the predictions of the fitted model for standard values of the covariates, and for every location in the case of the spatiotemporal model. The vessel effect was removed from the predictions.

The SVP index show a relative increase in LPUE in the first 10 years of the time series, although inter-annual variability suggest data quality issues in this period (Figure 24). A sharp decrease in the standardized LPUE occurred from 2014 onwards, although there is signs of recovery in 2020-2021. The limited sampling in 2008 for the Malin stock (4 vessels only compared to on average 13-15 vessels) are likely to be causing this outlying estimate.

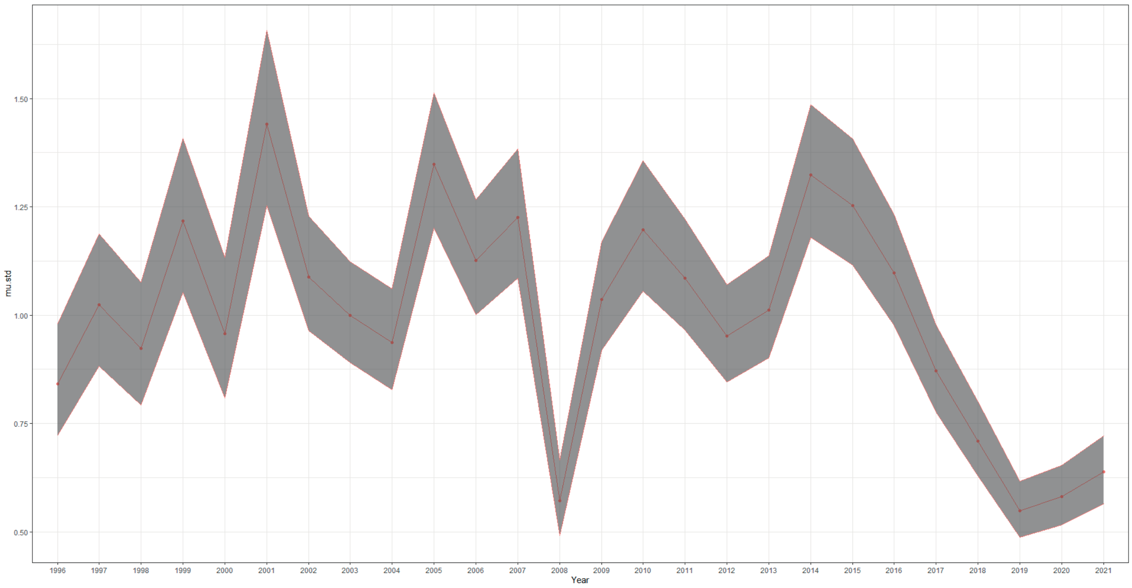

Figure 24. Standardized index of crab abundance from the SVP programme after applying GAM model (1996-2021). Shaded regions indicate approximate 95 % confidence intervals.

The offshore vivier standardized index shows a declining trend at the beginning of the time series and stable LPUE between 1994 and 2000 followed by small declines from 2000-2006. This trend was similar across different spatial-temporal model formulations (Figure 25).

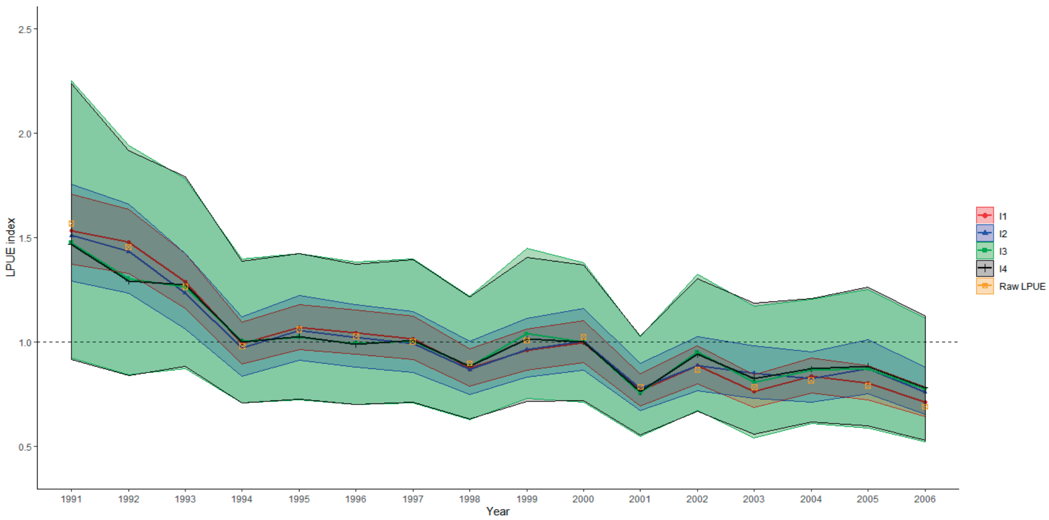

Figure 25. Standardized offshore LPUE time series using four different spatial-temporal model formulations in INLA (1991-2006). Nominal LPUE as squares included for comparison.

6.6.2.1 SPiCT assessment

SPiCT (surplus production in continuous time) is a version of a surplus production model which are commonly used in fisheries assessments. The model enables error in the catch process to be reflected in the uncertainty of estimated model parameters and management quantities. Estimates of exploitable biomass and fishing mortality can be obtained at any point in time from data sampled at arbitrary intervals. A number of model scenarios were tested which included varying the time series of landings and catch rate indices included in the assessment and the initial settings for key model parameters (symmetry of the production curve, depletion at the beginning of the time series and intrinsic growth rate for crab).

SPiCT outputs indicate that the stock entered an overfished state around 2016 (Figure 26). Fishing mortality (F) reached its highest point ~2019, and has shown a slight decrease in recent years. Nevertheless, F is still higher than optimum fishing mortality rates (F_{msy}) and stock biomass (B) is well below the biomass that, on average, would optimize stock productivity (B_{msy}).

6.6.3 Catch advice

The assessment shows that fishing mortality should be reduced in all stocks. The level to which fishing mortality is reduced depends on the harvest control rule that is adopted. Two rules are considered below;

1. Fish at F_{msy}
2. Apply the so called 2/3 rule as applied to ICES category 3 stocks for which only trends, rather than a full stock assessment, are available.

The F_{msy} advice is taken directly from the assessment model presented in Section 6.6.2.1. The F_{msy} rule reduces the F/F_{msy} ratio (and corresponding landings) back to 1 or the fishing mortality rate that may lead to recovery of the stock to B_{msy} levels. The 2/3 rule takes the average index value (LPUE) in the 2 most recent years in the assessment and for which full data are available (2020, 2021), divides it by the average index value in the 3 years prior to that (2017-2019) and applies it to the most recent year for which landings are available (2021). As the index is declining this rule advises a reduction in landings (Table 7).

Table 7. Current landings and advised landings based on F_{msy} and implementation of the 2/3 rule.

Stock	Current landings	Landings at Fmsy	Landings 2/3 rule
Malin Shelf	5,463	3,900	4,500
South west	1,413	-	960
Celtic Sea	951	-	632

Implementation of the harvest rules to reduce fishing mortality provides scope for stock recovery but does not guarantee recovery. Other sources of mortality may also have increased in recent years. These are unknown.

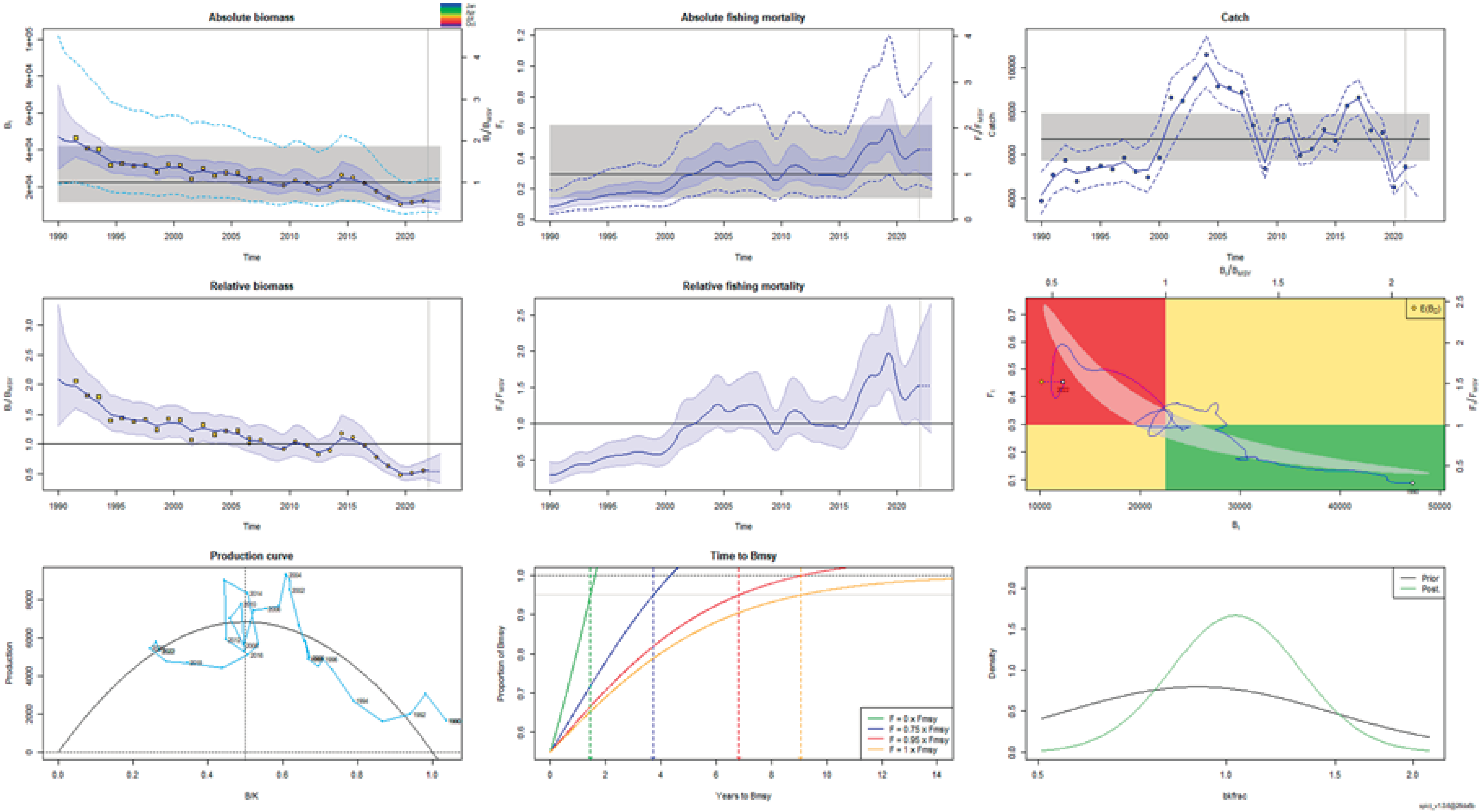

Figure 26. SPiCT outputs showing the evolution of fishing mortality (F) and biomass (B) relative to reference points F_{msy} and B_{msy}.

6.6.4 Interpretation

The year on year decline in the observed and standardised LPUE index between 2014 and 2020 has not been previously observed in the time series which extends back to 1990. Although the LPUE indices can be confounded by changes in grading practice, unrelated to the minimum landing size, it is unlikely to be the cause of the decline in recent years. Observed discard rates (DPUE) also declined from 2016-2019 in parallel with the LPUE index. Decline in LPUE could be linked to growth overfishing whereby the removal of crabs above the MLS occurs at a higher rate than they can be replaced by growth but corresponding declines in DPUE and LPUE signal an overall year on year reduction in the abundance of crab in the fished area. Crabs in the discards are not all recent recruits to the stock and include a number of age classes. The decline in discards, therefore, may signal a reduction in recruitment in the past number of years.

The minimum size of 130 mm and more recently 140 mm has been regarded as sufficient to protect the stock from recruitment overfishing given that the size at maturity is approximately 120 mm. Spawning escapement is, therefore, significant and above 30 % of what it would be in an unfished stock. A number of spawning events occur before crabs are exposed to fishing mortality. High grading at observed modal size of about 150 mm provides further protection. Fishing is unlikely to be the sole cause of the recent declines in stock abundance. However, recruitment decline combined with high fishing effort will further reduce spawning stock biomass. In such a case, fishing mortality (landings) should be reduced to avoid further depletion in stock biomass.

6.7 *Estimate of tonnage of brown crab used in the whelk fishery*

6.7.1 Context

As shown in the previous section, crab stocks status indicators have declined in recent years and stock assessments indicate the need to reduce fishing mortality across Irish stocks. Crabs are landed in Ireland for both live export and for processing. Crab quality (meat content) varies seasonally and a component of the stock is of poor quality during many months of the year due mainly to the moult and reproductive cycles or due to low temperatures and reduced feeding activity. The quality of crab that are landed also varies according to grading practice on board and the ability of crew to distinguish good quality and poor quality crab. Landing of poor quality crab, however, and given that total landings of individual vessels are not limited, is still profitable if there is a market outlet for it. One such outlet is the sale of poor quality crab for whelk bait. Male crab or female crab that are not suitable for processing may also be de-clawed and the bodies used as whelk bait. The demand for crab as whelk bait may, therefore, be increasing fishing mortality rates on crab as those crab not suitable for processing would otherwise be discarded live if the market did not exist. In this scenario Skippers would be forced into high grading or risk consignments being rejected by buyers.

Estimates of the volume of brown crab being used in the Irish whelk fishery, using data on whelk landings, crab landings, whelk catch rates, bait volumes per unit of whelk effort and crab sales for whelk bait are provided below.

6.7.2 Methods

Three independent methods were used to estimate the amount of crab being used as bait in the whelk fishery. They use difference data sources and analyses:

- Method 1: total number of pots used in the whelk fishery can be estimated based on the annual Landings per Unit of Effort (LPUE) from vessels participating in the Sentinel Vessel Programme (SVP). Knowing an average amount of crab bait used per pot (based on direct interviews from a

small sample of whelk fishermen), the total volume of crab bait needed to make the whelk landings can be calculated per year.
- Method 2: Processors buying whelk and crab usually provide crab bait to fishermen who supply them with whelk. Sample data on the volume of crab being used for whelk bait in proportion to the volume of whelk purchased by processors also provides an estimate of crab bait used for a given volume of whelk landed which can then be raised to the total whelk landings.
- Method 3: Crab bait purchased and whelk landed on a daily basis is also reported in the SVP logbooks. The ratio can also be used to estimate the crab bait required to land a kg of whelk and therefore the total volume of crab required to make the whelk landings. This is similar to method 2 but data is from individual vessels daily reported catches and bait usage rather than bulk sales from processors.

6.7.3 Estimates

Taking whelk landings from 2021 as a reference year (~5000 tonnes, Table 4), methods 2 and 3 described above, largely agreed in the ratio of crab required to land whelk (Figure 27), resulting in an estimate of 1,300-1,400 tonnes of crab used as whelk bait for the given landings. Method 1, however, resulted in considerably higher figures at ~2,000 tonnes. Nevertheless, estimates are arguably comparable given the uncertainty in the estimation process. The differences may also be accounted for by direct transfer of crab bait to whelk pots i.e. a vessel fishes for crab and uses a proportion for whelk bait where vessels target both crab and whelk. This crab would not be included in processor crab bait sales or in SVP vessels crab bait purchase details but would be incorporated in Method 1 which estimates the annual number of whelk pot hauls. The estimates provided here are for crab used in the Irish whelk fishery and excludes any crab exported for use as whelk bait in the UK whelk fishery. This export figure is unknown.

The dependency of the whelk fishery on brown crab has declined in recent years (not shown), both due to the declining catches of brown crab but also due to increased processing of spider crab by some buyers. The status of spider crab stocks is unknown but the stock is probably underexploited currently other than in Tralee Bay where a targeted fishery occurs in spring and summer.

The advice presented above on the reduction in fishing mortality and landings needed to bring the fishery into line with MSY targets is similar in scale to the reduction that would occur if crab were not used for whelk bait and would otherwise be discarded live at sea.

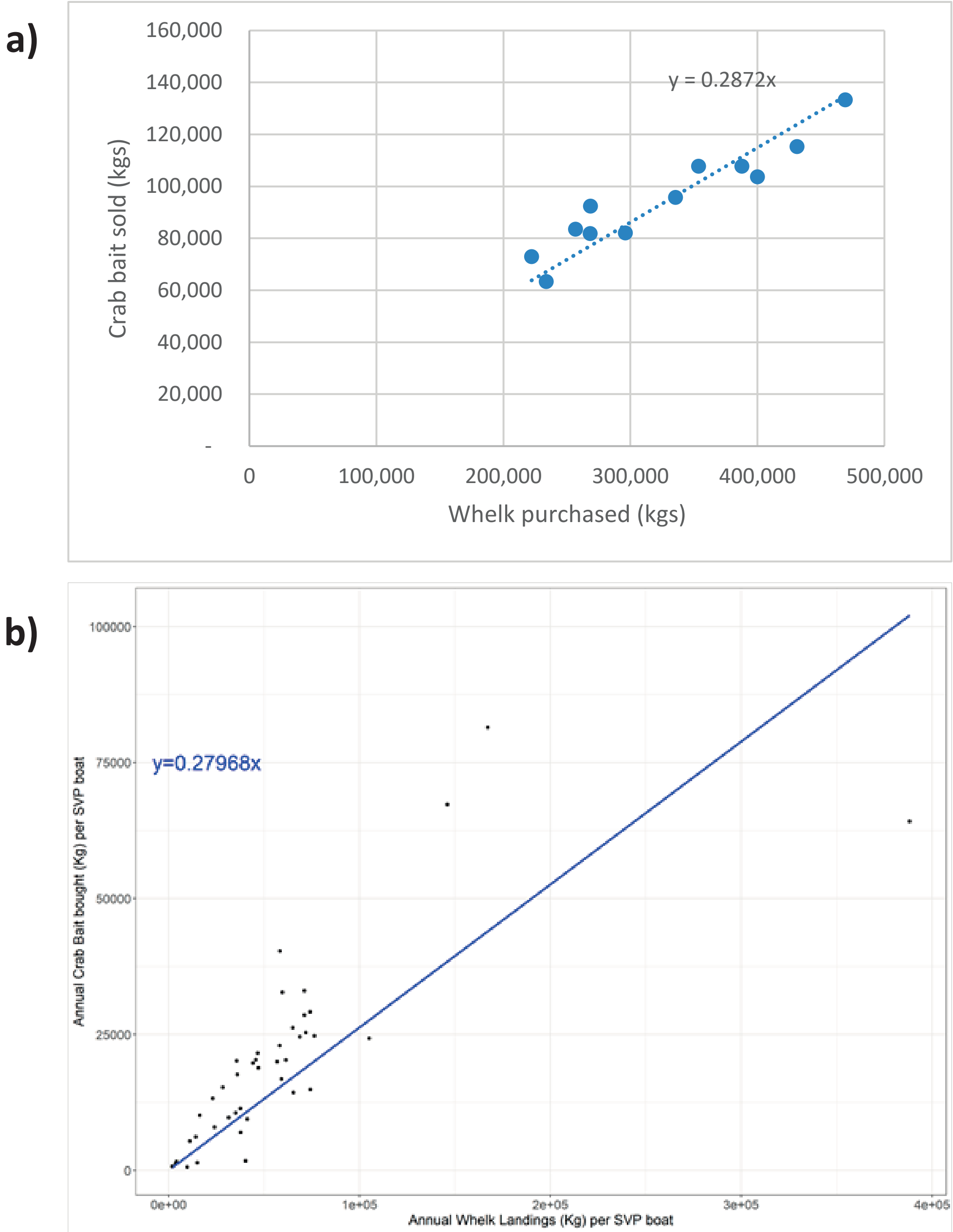

Figure 27. Relationship between a) **monthly whelk purchased and crab bait used by the crab and whelk processing sector (Method 1) and** b) **annual whelk landings and brown crab bait purchased from SVP participating boats (2014-2022) (Method 2). Both regression lines are forced through zero.**

7 Razor clam (*Ensis siliqua*)

7.1 *Management advice*

Razor clams in the Irish Sea are managed by minimum landing sizes and weekly quotas. The fishery is closed in June. All vessels report iVMS data. Smaller scale fisheries on the west coast have operated successfully under voluntary management plans in recent years.

Landings in the North Irish Sea declined between 2015-2021. There is no evidence of high grading in the fishery. All indicators (daily landings per vessel, catch per hour) show significant and persistent declines up to 2017 but were stable from 2017-2020. Estimates of biomass, revised following a review of data standardisation protocols in 2020, varied from approximately 9,000 tonnes in 2017 to between 6,000-7,000 tonnes in 2018-2020 and ~9200 tonnes in 2021-2022. Large size classes were depleted between 2017 and 2018 but were stable or increased between 2018-2021. Using the ICES 2/3 harvest control rule, with penalty clause limiting annual change in landings to 25 % or less, landings should not exceed 636 tonnes (6.9 % exploitation) in the period July 1st 2022 to May 31st 2023.

The south Irish Sea fishery opened in 2010 and expanded up to 2013. A strong recruitment event in Rosslare Bay in 2014 (probably) was observed in the 2017 survey and biomass increased significantly between the 2017 and 2020 from 2,000 to 6,300 tonnes. The estimate for 2022 was 5,889 tonnes. A further 574 tonnes was estimated in the Curracloe bed in 2022. On the basis that a 6.9 % exploitation rate has, in recent years, led to stable biomass, size distribution and commercial catch rates in the North Irish Sea landings for 2022 in the south Irish Sea should not exceed 486 tonnes.

Many razor clam fisheries or potential fisheries occur within or close to Natura 2000 sites. The conservation objectives for species and habitats in these areas are integrated into razor clam fishery management advice. In the north Irish Sea bivalve fauna caught as by-catch in the fishery occurs at very low densities in Dundalk Bay SPA relative to other areas. A closed area in Dundalk Bay is recommended to allow monitoring of changes in marine communities following removal of fishing pressure.

7.2 *Issues relevant to the assessment of the razor clam fishery*

Razor clams (*Ensis siliqua*) occur along the east coast of Ireland in mixed sediments from Dundalk to Dublin and from Cahore to Rosslare and in numerous areas along the west coast. A second species, *Ensis magnus*, is abundant in well sorted sands on the west coast. Both species may occur in the same area. The distribution of commercial stocks and fisheries is currently known from high frequency VMS data for the commercial fishery which operates in water depths of 4-14 m. Surveys of small areas along the west coast in 2016 provide further information on distribution of these species. Many of these areas are not currently fished. Fishing depth is limited because of the fishing method which uses hydraulically pressurised water to fluidise sediments in front of the dredge. The distribution of razor clams may extend to deeper water outside of the range of the fishery as the species occur at depths of up to 50 m. However, there is no evidence that significant biomass occurs outside of those areas already fished.

The efficiency of the hydraulic dredge used in razor clam fisheries has been measured at 90 %. The dredge, therefore, is very efficient at removing organisms in the dredge track. This is in contrast to non-hydraulic dredges used in other bivalve fisheries such as scallop and oyster where dredge efficiency may be in the region of 10-35 %. Discard mortality rates are unknown but may be significant given that damage can be observed on the shell of discarded fish and unobserved shell damage may occur at the dredge head.

Ensis siliqua is slow growing, reaches a maximum shell length of approximately 220 mm and has relatively low productivity. The apparent resilience to date of the species in areas subject to persistent fishing by highly efficient gears may possibly be explained by immigration of juvenile and adult razor clams from areas outside of the fishery. Some evidence of size stratification by depth has been shown in Wales and given the known mobility of the species suggests that post settlement movement and recruitment into fished areas may occur. *Ensis magnus* is faster growing, occurs in higher densities and reaches a smaller maximum size than *E. siliqua*.

Ecosystem effects of the fishery on the seafloor and on seabirds which feed on benthic bivalves is considered in the assessment advice.

7.3 *Management units*

Stock structure is unknown. Larval dispersal and movement of juveniles and possibly adults suggest that the stock structure is relatively open along the east coast of the north Irish Sea and that individual beds are unlikely to be self-recruiting. Fishing is continuous from north Dundalk Bay south to Malahide. Stocks in the south Irish Sea are likely to be separate to that north of Dublin given the different hydrodynamic and tidal regimes in the two areas.

Other isolated stocks occur in many locations on the south, west and north west coasts. Fisheries occur or have previously occurred in Clifden Bay, Ballinakill Bay, Killary Harbour, Rutland sound Co. Donegal, Waterford estuary and off Iniskea Islands and Inisbofin.

7.4 *Management measures*

New management measures were introduced for the Rosslare – Curracloe fishery in December 2014. These include an increase in MLS from 100 mm to 130 mm, fishing hours from 07:00 to 19:00, 2.5 tonne quota per vessel per week (currently 2,000 kg), 1 dredge per vessel not to exceed 122 cm width with bar spacing not less than 10 mm, prior notice of intention to fish and advance notice of landing, mandatory submission of gatherers docket information on landings, date and location of fishing and a defined fishing area to minimise overlap with Natura 2000 sites. The Rosslare Bay fishery was closed by voluntary agreement in 2017 and 2018 due to growth overfishing.

In the north Irish Sea the weekly vessel TAC is 600 kgs (from January 1st 2016) with a prohibition on landing on Sundays (SI 588/2015). The fishery is closed by voluntary agreement in June during the spawning season. The minimum landing size increased to 125 mm in 2018.

Fisheries on the west coast have voluntary TAC arrangements in place based on survey biomass estimates and an agreed harvest rate.

All vessels fishing for Razor clams must have a functioning iVMS system on board and report GPS position at defined frequencies. Only 1 class of production area (A, B, C) can be fished during a fishing trip (SI 206/2015).

7.5 *North Irish Sea*

The North Irish Sea (NIS) fishery began in the early 1980s and quickly developed due to high quality (size) of clams in the Gormanstown bed which attracted premium prices compared to other *Ensis* species fished in Europe. There may have been 50 vessels in the fishery by 1999. Post 2003 beds at Malahide, Skerries and south Dundalk Bay were being fished in addition to the Gormanstown bed. The number of vessels in the fishery, total fishing effort and annual landings expanded significantly between 2014 and 2018. The fishery has supported over 70 vessels in recent years and landings peaked at over 1,100 tonnes and a value of approx. €6.5m in 2015. The catch is exported mainly to the Far East. Unit prices vary by grade or shell size from €4-10 per kg. The fishery, relative to other shellfish, could be classed as 'medium price and medium volume'.

The fishery occurs close to the coast in shallow sub-tidal waters along the east coast from Dundalk south to Malahide.

7.5.1 Landings

Landings increased from 274 tonnes in 2012 to over 1,100 tonnes in 2015. This was paralleled by an increase in the number of vessels from 14 in 2012 to 54 in 2015. The number of vessels peaked in 2016-2018 to between 71 and 78 but landings declined to 600-700 tonnes in 2016-2019. The number of vessels declined to 56 in 2019. Landings were about 500 tonnes in 2020 but fishing effort was low (42 active vessels) due to Covid 19 restrictions and poor market conditions. Landings have remained stable in 2020-2022 at ~500 tonnes. The Dundalk Bay and Gormanstown production areas account for most of the landings (Figure 28).

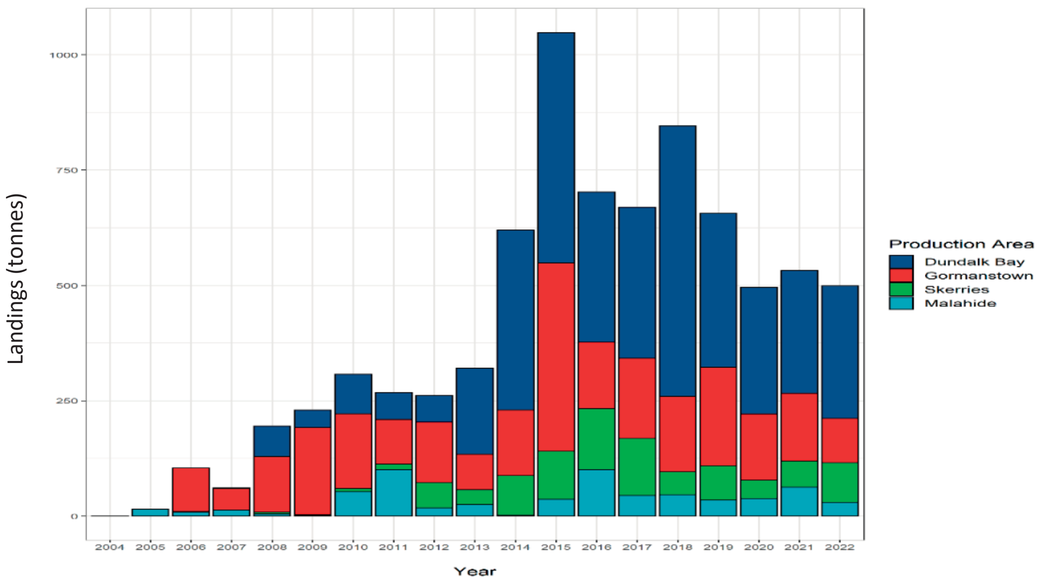

Figure 28. Annual landings of *Ensis siliqua* in the north Irish Sea (NIS) 2013-2022 sourced from SFPA logbook, and sales notes data. Figures reported have been updated according to latest sales note data.

7.5.2 Survey 2022

A survey encompassing all of the areas which are commercially fished for Razor clams was completed in the north Irish Sea in June 2022. The survey follows the same design to that used in 2017-2021 where survey effort was allocated from an iVMS grid; iVMS activity is seen as a proxy for the abundance of razor clams. The survey domain, which extended from north Dundalk Bay south to Malahide and Lambay, was divided into 5 areas with approximately 160 stations in each area allocated to each of 5 survey vessels. Within each area, 4 iVMS effort strata of the same surface area were defined, and 50 stations were randomly assigned within each stratum, to ensure an even distribution of randomly assigned grid cells across the range of iVMS effort. The survey was mostly completed over a 4-5 day period, depending on area and vessel.

Biomass at each station was estimated as the product of density (number of individuals caught per meter squared towed area) and mean individual weight calculated from the size distribution at the station and a weight-length relationship. Total biomass was then estimated as the sum of mean estimated biomass, using a geostatistical (kriging) model, raised to the surface area of the cells. Ninety-five percent confidence intervals were estimated based upon 250 random realisations of the modelled biomass using conditional Gaussian simulations. This method preserves the spatial structure in the biomass, as described by variograms, which modelled the spatial autocorrelation and spatial structure in the survey data.

A standardised protocol was established and applied to the NIS survey data from 2017-2022 in order to avoid potential differences in biomass estimates from year to year due to the change in the total surveyed area, the geostatistical assessments modelling routines and to control for various issues surrounding the acquisition of accurate GPS data during surveys. In this report these protocols have been applied retrospectively and biomass estimates may, therefore, be different to those reported in previous years

7.5.2.1 Biomass 2017-2022

Survey estimates of biomass, since surveys began in 2017, vary from 5,500 to over 9,000 tonnes.

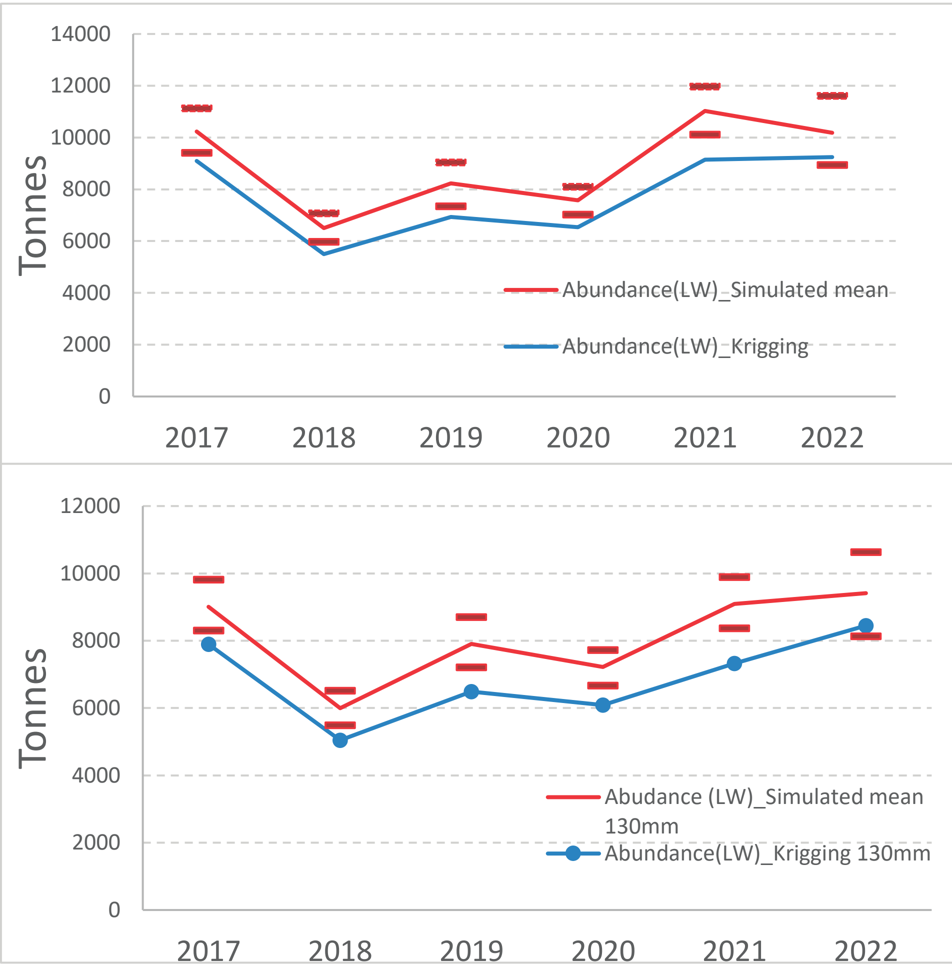

Figure 29: Trends in stock biomass of razor clams 2017-2022 in the north Irish Sea. Kriging estimates are regarded as more reliable and precautionary. Top: total biomass. Bottom: biomass greater than shell length 130 mm.

Biomass increased in 2021 due to recruitment and was similar in 2021 and 2022 at just over 9000 tonnes (Figure 29).

Higher biomass (kgs.m^{-2}) occurred in south Dundalk Bay, south Gormanstown and at Malahide in the south of the survey area. Nevertheless, densities were low in Dundalk and catches were predominantly of large clams compared to Malahide where densities were high and catches were dominated by small size clams (Figure 30).

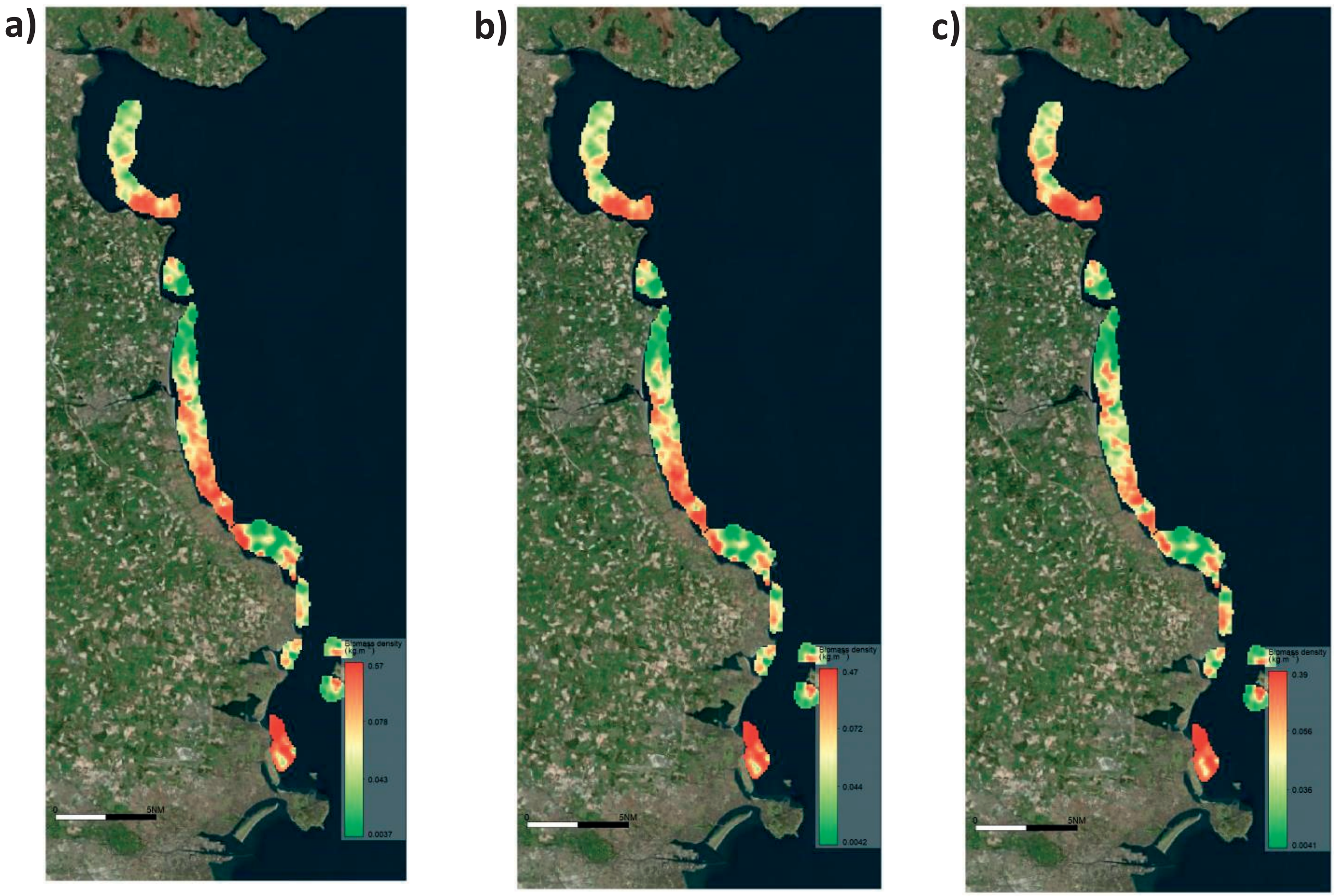

Figure 30. Distribution of biomass of razor clams in the north Irish Sea in June 2022. a) all sizes, b)>130mm, c)>150mm.

7.5.2.2 Size distribution

The size distribution of razor clams in the North Irish Sea in 2022 showed a shift of the ~120mm modal size class observed in the 2021 survey to a mode of ~150mm. Densities of razors above 130 mm were similar to the 2021 survey. No sign of recruitment was observed and there were fewer clams below the MLS in 2022 compared to 2021 (Figure 31).

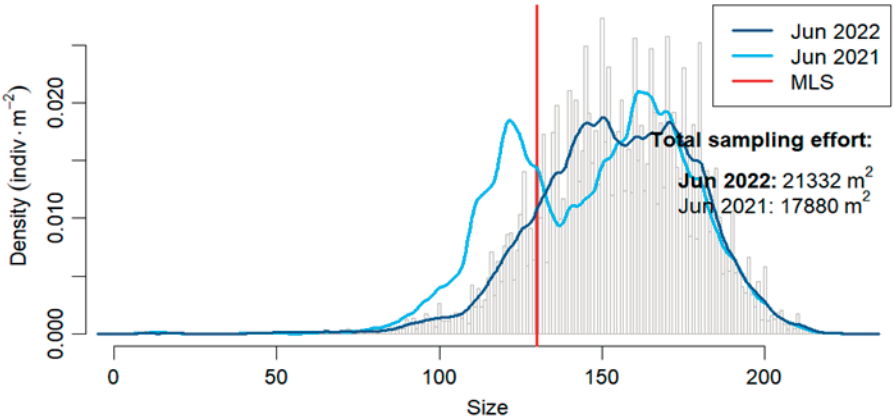

Figure 31. Size distribution of razor clams in the North Irish Sea from 2021-2022 survey data.

7.5.3 Grades in the landings and in the survey

Data on grade composition of the landings from 2017-2021 from 1 buyer (source: SFPA) show that the XL (>200 mm) grade and the L (180-200 mm) grades declined during the period but were stable in the survey time series from 2018-2022 (Figure 32). This is explained by the recent decline in market preference for large and extra large clams in favour of medium grades (source: SFPA). There is no evidence of high grading in the fishery.

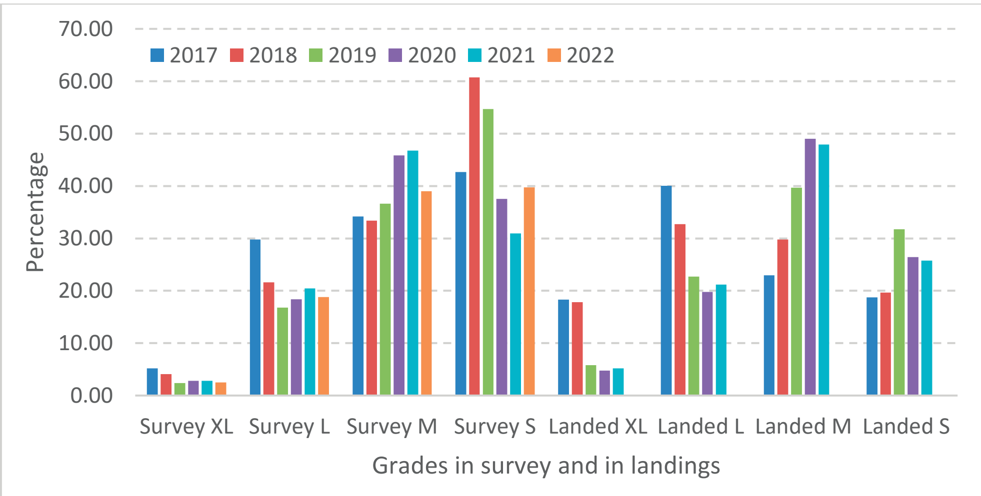

Figure 32. Grade structure of clams in the landings (source:SFPA) and in the survey 2017-2022.

7.5.4 Catch advice

Catch advice in 2021 was based on average exploitation rate in 3 previous years when biomass was stable. For 2022 the ICES WKLIFE 2/3 catch advice rule is used. The 2/3 rule is the mean biomass in the two most recent years/mean biomass in 3 years previous to that. Where this rule allows for greater than 20 % increase in landings in the advice year a 20 % precautionary penalty clause is applied which caps annual change to 20 % of the previous year.

The 2/3 rule allows for a TAC of 770 tonnes (Table 8). As this allows for a 45 % increase in landings (530 in 2021 to 770 in 2022) the WKLIFE 20 % precautionary penalty clause is applied. The advised TAC is therefore 636 tonnes for July 2022 to May 2023.

The 2/3 advice rule is looking at changes in biomass only and not in size and age structure. As the value of clams is significantly correlated to size (grade) managing outtake so that the biomass of larger size grades is optimised by balancing fishing mortality and growth would be a better basis for advice. Development of this advice will involve obtaining new data on the biological parameters of razor clams.

Table 8. Landings, biomass, exploitation and catch rate indicators for razor clams in the north Irish Sea. The catch advice rules are based on ICES WKLIFE as described above.

Year	Landings (tonnes)	June Biomass (tonnes)	2/3 rule	% Exploitation	SRD data (kg.day^{-1})
2015	1,100				220
2016	700				204
2017	620	9,097		6.82	186
2018	850	5,497		15.46	184
2019	630	6,936		9.08	191
2020	500	6,542		7.64	203
2021	530	9,145		5.80	-
2022	500	9,244		5.70	-
Landing advice for July 2022 to May 2023					
2/3 rule			**770**	***8.33***	
2/3 rule with 20% penalty clause			**636**	***6.88***	

7.6 *Bycatch and habitat effects*

Fishing for razor clams may cause the structure and function of seafloor habitats to change as a result of the disruption of sediments and direct and indirect mortality to fauna due to contact with the dredge. Large bodied deep burrowing bivalves are captured as by-catch. These include other species of *Ensis* namely *E. magnus* and *E. ensis,* the false (blood) razor clam *Pharus legumen* is also found in high numbers in some areas as are species such as the spiny cockle (*Acanthocardia spp) clams (Venus spp). Chamelia spp.* and the endangered and long lived Icelandic clam *(Arctica islandica).* Within the Dundalk Bay SAC and SPA by-catch and abundance of these species is extremely low (Figure 33) and species richness in Dundalk Bay has declined since 2017. *Arctica islandica* has not been recorded in Dundalk Bay since 2018.

Based on the low and declining densities of bivalves in the Dundalk Bay SPA relative to other areas a closed area has been proposed to enable a monitoring programme to be established to monitor any habitat recovery or change that might occur relative to fished areas (Figure 34).

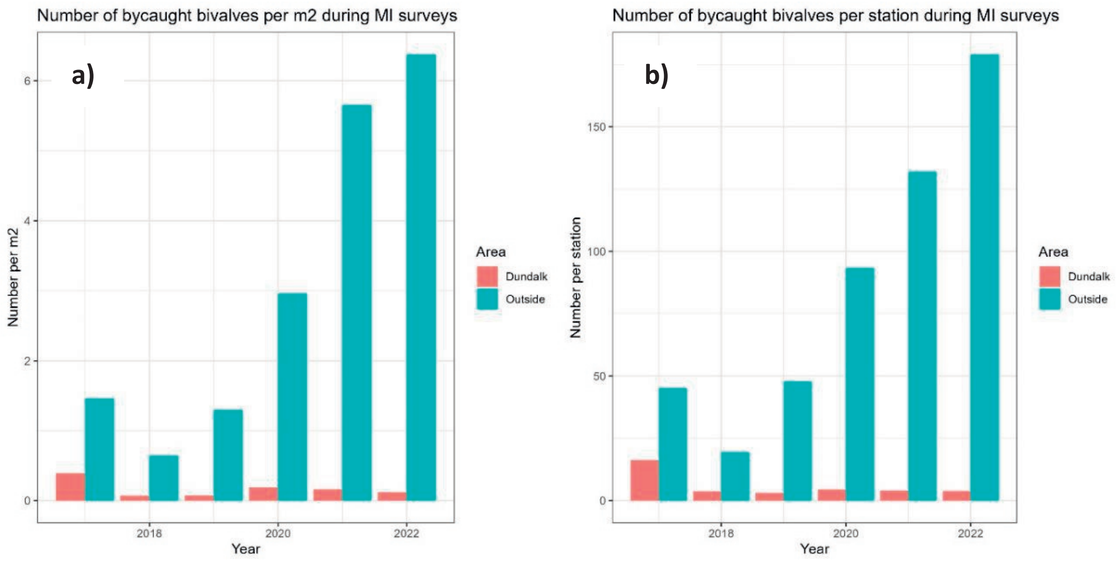

Figure 33. Number of bivalves caught per metre squared a) **and number of bycaught bivalves per survey station** b) **between 2017- 2022 within Dundalk Bay (red) and outside Dundalk Bay (blue).**

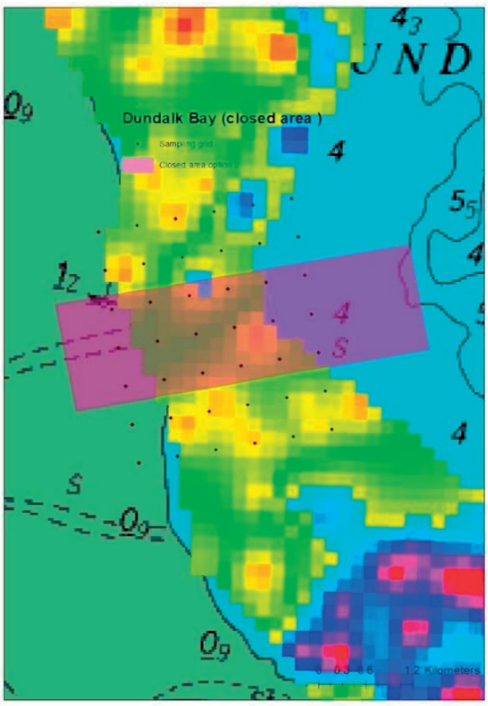

Figure 34. Proposed closed area to mobile fishing gears in the south of Dundalk Bay SAC and SPA. Underlying gridded data is fishing activity as measured by iVMS. The grid of dots are benthic monitoring stations surveyed in 2022.

7.7 *South Irish Sea*

7.7.1 Landings

The fishery in the south Irish Sea opened in 2010 (Figure 35). Landings increased from 50 tonnes to 100 tonnes in 2011 and 2012 and peaked at over 200 tonnes in 2016. Landings declined from 2016 to 2019, but increased in 2020 to 150 tonnes, mostly from Curracloe. Landings in 2021 were about 30 tonnes and increased in 2022 to ~125 tonnes. The recent declines corresponded with a reduction in fishing effort in the Rosslare Bed in particular as biomass of large grade clams had declined in the period up to 2017 and there was voluntary closure (or part closure) in the period 2018-2019 to enable growth of the strong 2014 year class. The Waterford estuary fishery was closed by court order in 2019.

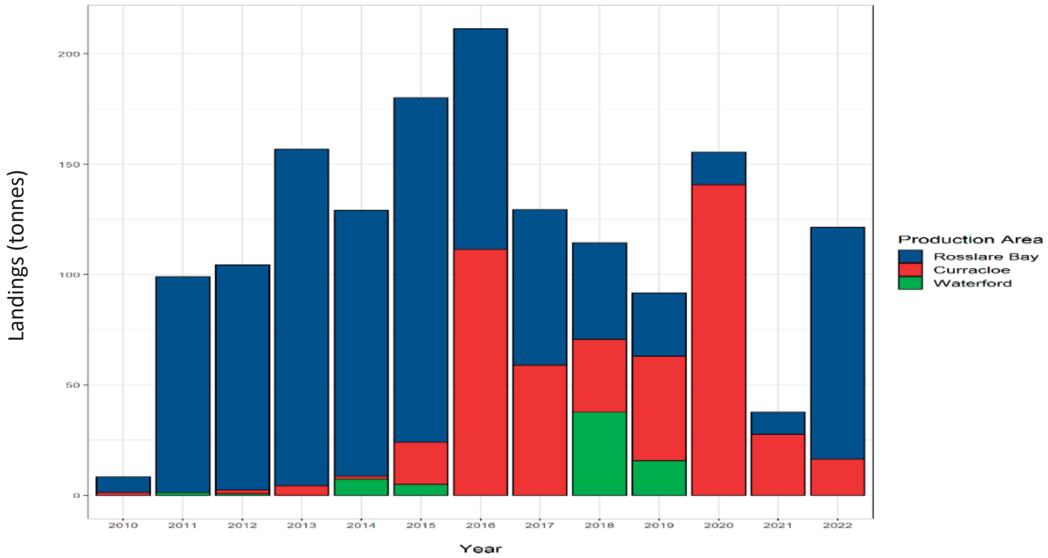

Figure 35. Landings (tonnes) of razor clams in the South Irish Sea by classified production area (CPA). Source: Logbooks/ Sales notes. CPA is assigned by port of landing.

7.7.2 Survey data

Stocks of Razor clams in the South Irish Sea are distributed in two main beds; Rosslare Bay and north along the east coast of Wexford at Curracloe. With the exception of the southern limit of the Curracloe Bed, the distribution of razor clams is well known, and the extent of the beds is included in both surveys.

7.7.2.1 Rosslare Bay

The razor bed of Rosslare was surveyed on September 19th 2022. A total of 39 tows were undertaken, with a single hydraulic dredge of width 1.25 m. The survey encompassed a total area of 10.3 km^2 and a total sampling effort of 926 m^2. Biomass of all size classes of razors, assuming a dredge efficiency of 100 %, varied from 0-2.6 $kgs.m^{-2}$. The estimated biomass was 5,899 tonnes 88 % of which was above 130 mm (Table 9, Figure 36).

Table 9. Estimates of biomass of razor clams in Rosslare Bay in September 2022.

Ensis siliqua	Biomass		95% HDI inf	95% HDI sup
	Mean	Median		
Biomass_*Ensis siliqua*	5,889.8	5,914.9	4,945.2	7,026.3
Biomass_>130mm_*Ensis siliqua*	5,223.2	5,263.5	4,434.1	6,284.4
Biomass_>150mm_*Ensis siliqua*	1,686.2	1,710.1	1,401.3	2,066.0

Higher densities of razor clams <130 mm MLS were found at the centre of the bed (Figure 36b), whereas razors >150 mm were more abundant towards the northern part of the surveyed area (Figure 36c). Modal size was similar in 2022 and 2021 at approximately 140 mm (Figure 37). There was no evidence of recruitment in either year.

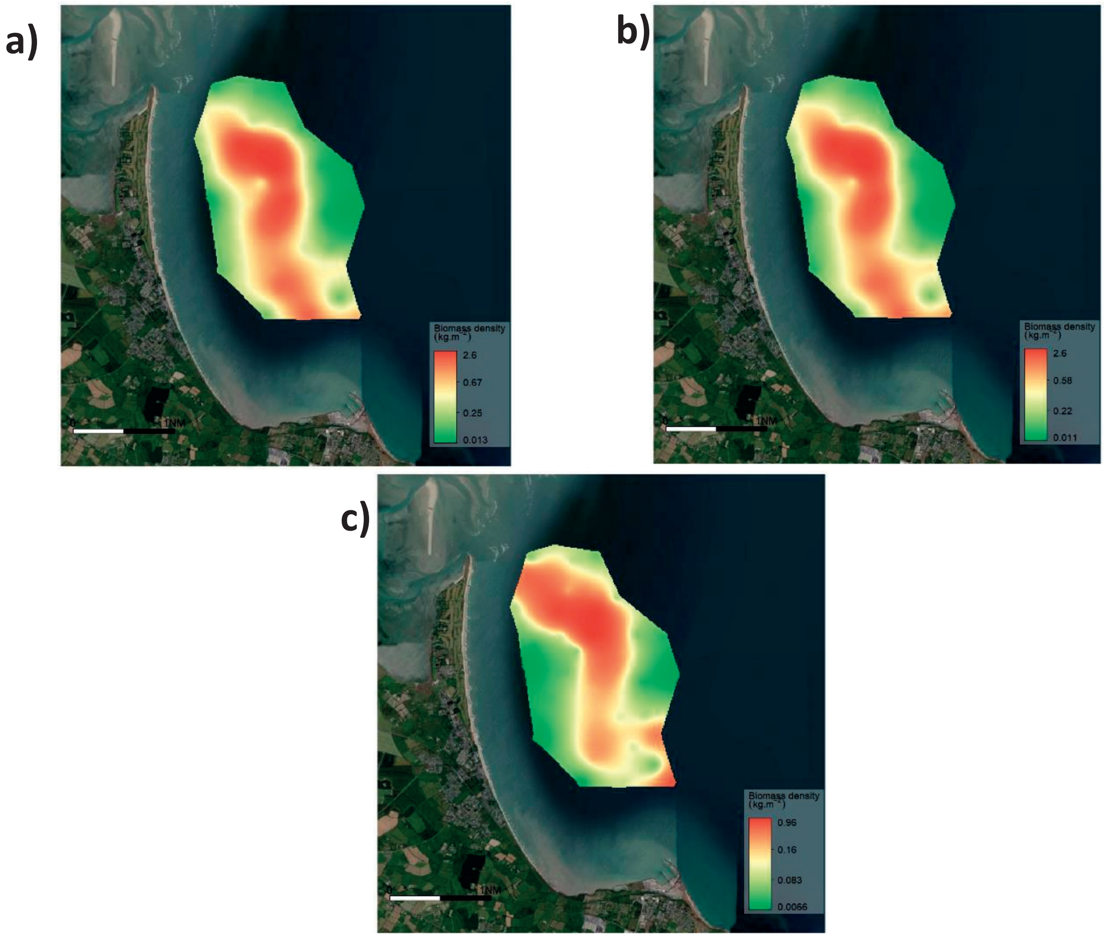

Figure 36. Distribution of *Ensis siliqua* in Rosslare Bay in in 2022, a) all size class, b) >130 mm and c) >150 mm.

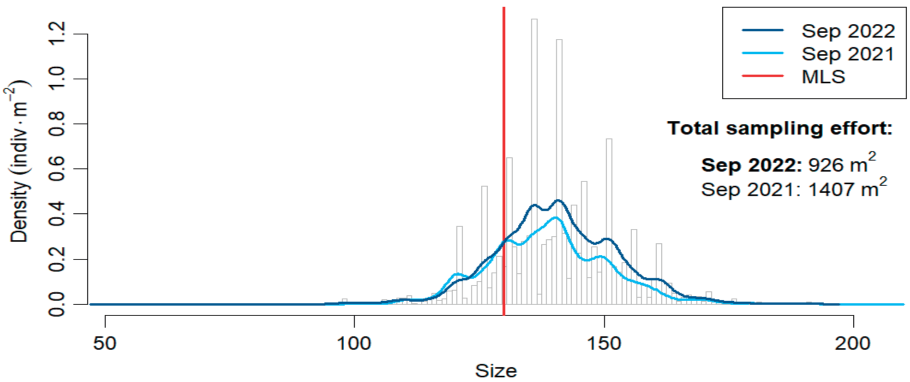

Figure 37. Size distribution of razor clams (*Ensis siliqua*) in the Rosslare Bay 2021 and 2022. Data are standardised to sampling effort regardless of its spatial distribution.

Trends in biomass shows an increase from ~2000 tonnes in 2017 to approximately 6,000 tonnes in 2019. Biomass have remained stable from 2019 to 2022 (Figure 38).

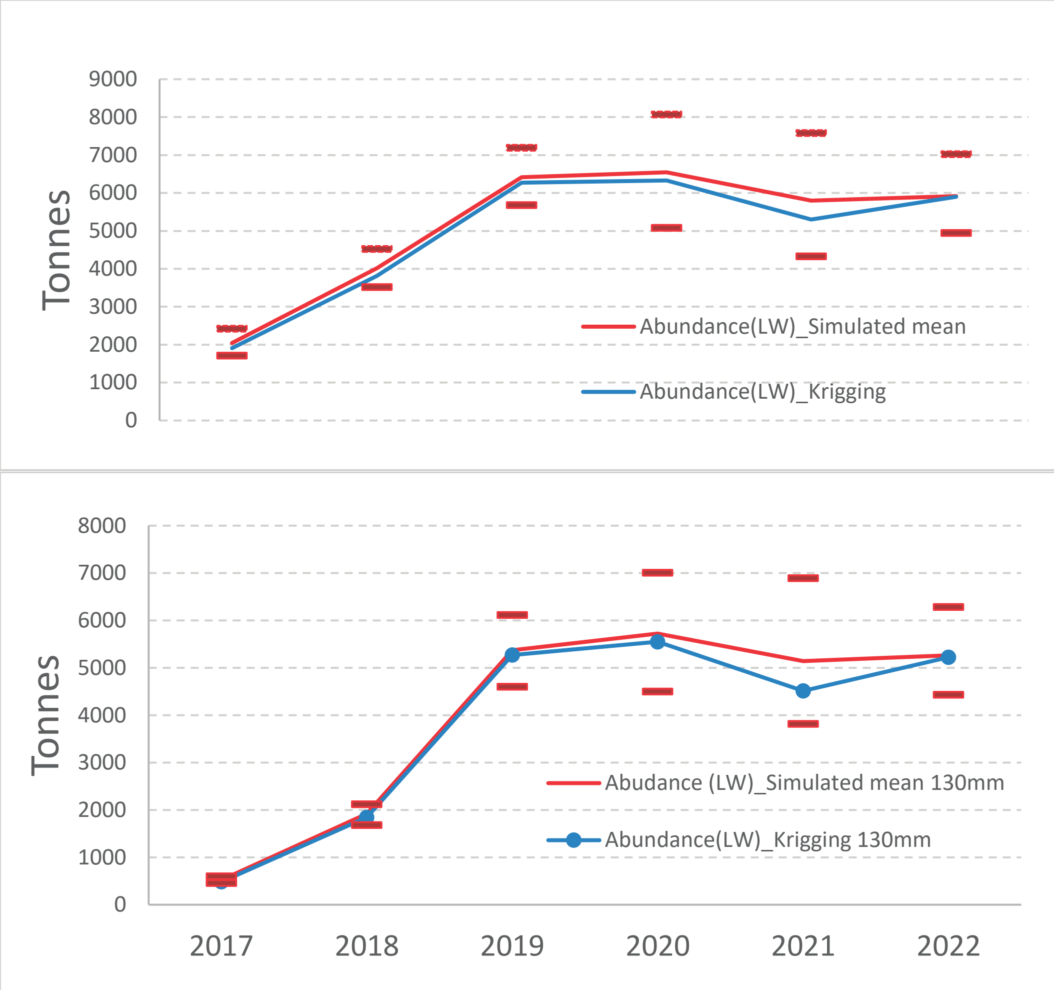

Figure 38. Estimates of biomass of razor clams (*Ensis siliqua*) in Rosslare Bay in 2017-2022 for all size classes (top) and size >130 mm (bottom).

7.7.2.2 Curracloe

The razor bed of Curracloe was surveyed on September 20th 2022. A total of 42 tows were undertaken, with a single hydraulic dredge of width 1.25 m. The survey encompassed a combined area of 11.8 km^2 and a total sampling effort of 1817 m^2. The southern edge of the bed was not surveyed due to high numbers of whelk pots in the area.

Biomass of all size classes of razors varied from 0-0.4 kgs.m^{-2} (Figure 39). Distribution of high density patches is similar across size ranges and occurred in the centre of the survey area (Figure 39).

The estimated biomass was 574 tonnes, almost all of which (91.8 %) was above the 130 mm MLS (Table 10).

Table 10. Estimates of biomass of razor clams at Curracloe in September 2022.

	Biomass		95% HDI inf	95% HDI sup
	Mean	Median		
Biomass_*Ensis siliqua*	574.3	565.5	441.7	711.9
Biomass_>130mm_*Ensis siliqua*	527.8	527.4	396.9	669.7
Biomass_>150mm_*Ensis siliqua*	440.1	444.6	334.5	569.0

The modal size of razor clams in Curracloe in 2022 was approximately 160 mm, similar to the main mode in 2021 (Figure 40). The lower densities of razors above 130 mm may reflect the different spatial coverage of the survey during 2021, which extended further south to high-density areas of large razors not covered in 2022. This is also reflected in the sharp decline in survey biomass trends in 2022 (Figure 41). No recruitment signal is indicated as densities of small razor clams were low.

Figure 39. Distribution of *Ensis siliqua* in Curracloe in 2022, a) all size class, b) >130 mm and c) > 150 mm.

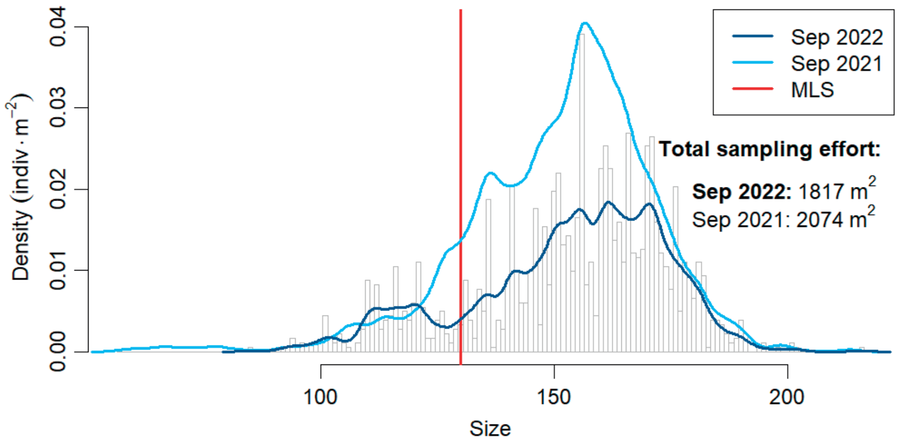

Figure 40. Size distribution of razor clams (*Ensis siliqua*) in Curracloe for 2021 and 2022. Data are standardised to sampling effort regardless of its spatial distribution.

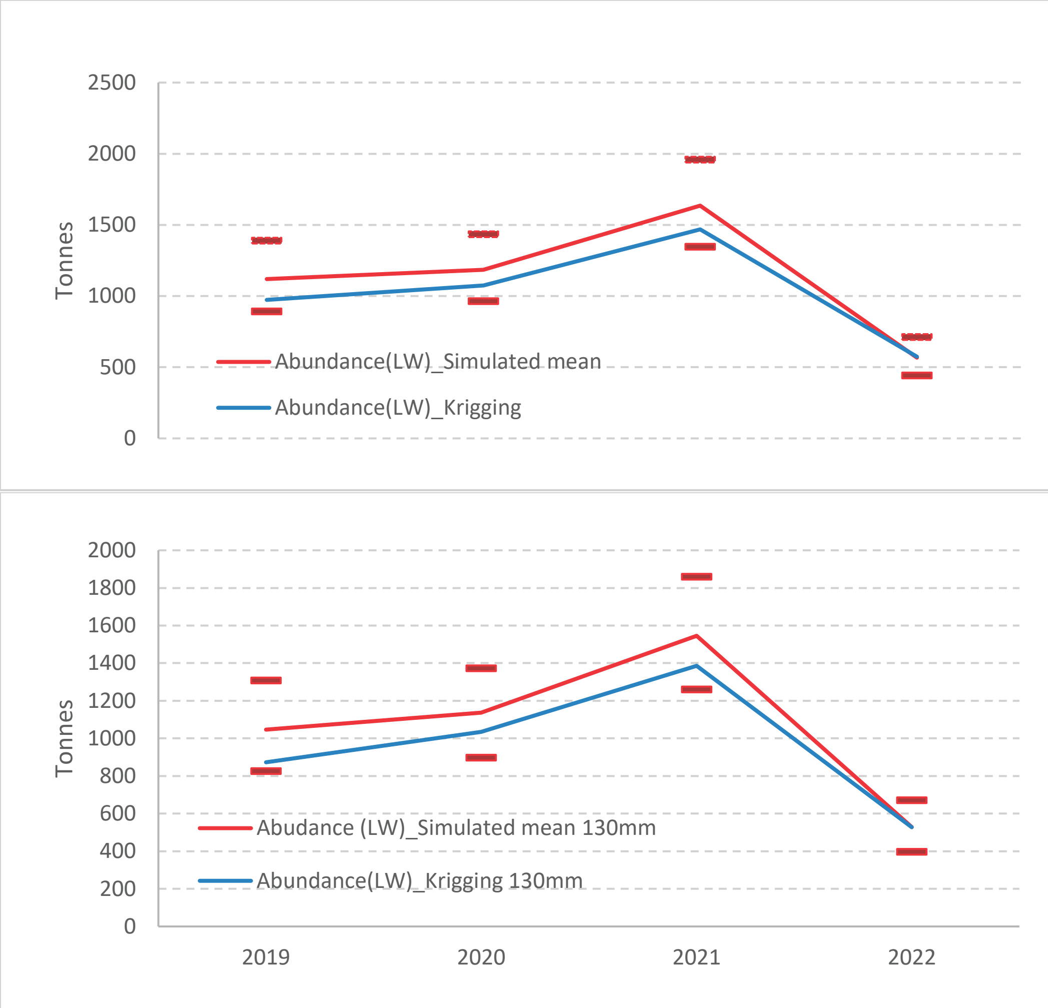

Figure 41. Estimates of biomass of razor clams (*Ensis siliqua*) in Curracloe combined in 2019-2022 for all size classes (top**) and >130mm (**bottom**). The southern edge of the beds was not surveyed in 2022.**

7.7.2.3 Catch advice

Average catch and % of biomass landed in the period 2019-2022 was 85 tonnes and 1.36 %, respectively. Surveys indicated that biomass was stable during that period, with the exception of Curracloe in 2022, but this was probably due to limited coverage of the surveyed area compared to 2021 (Table 11). Size structure was stable following a progression in modal size from 2020 to 2021 due to growth of a strong recruitment event that may have occurred in 2014 (Figure 40).

Based on recent stable or increasing biomass estimates, stable size structure the landing options for 2022 are:

- Based on average landings from 2019-2022 the landings in 2023 should not exceed 95 tonnes.
- Based on applying the average exploitation rate of 6.98 % for the North Irish Sea to the average survey biomass estimates for the same period, the landings in 2022 should not exceed 486 tonnes. The average exploitation rate for the south Irish Sea 2019-2022 was 1.36 %. However, the substantial increase in biomass from 2017-2020 suggests that higher harvest rates can be supported to exploit the 2014 recruitment event which has now matured to commercial size classes.
- Given recent trends in fishing effort and current market conditions it is unlikely that a 7.5 % exploitation rate will be achieved.

Table 11. Landings, biomass and exploitation rate of razor clams in the south Irish Sea 2017-2022.

Year	Landings	Biomass			% Exploitation
		Rosslare	Curracloe	Total	
2017	130	1,907		1,907	6.82
2018	100	3,818		3,818	2.62
2019	70	6,268	972	7,240	0.97
2020	160	6,330	1,074	7,404	2.16
2021	30	5,299	1,468	6,767	0.44
2022	121	5,889	574	6,463	1.87
2019-2022 average	**95**	**5,946**	**1,022**	**6,968**	**1.36**

8 Cockle (*Cerastoderma edule*)

8.1 *Management advice*

The Dundalk Bay cockle fishery is managed under a Fisheries Natura (management) Plan (FNP) which is a legal mechanism to incorporate environmental protection measures into fisheries management plans when such fisheries occur in Natura 2000 sites. No fishing occurs at a biomass less than 1,200 tonnes. The fishery closes when the TAC (17-33 % of biomass over 1,200 tonnes) is taken or on November 1st or if the average catch per boat per day declines below 250 kg. The minimum landing size is 22 mm shell width. A quota of 1 tonne per vessel per day for 28 permit holders is in force.

The stock is assessed by annual survey and in season LPUE data. Trends in other ecosystem indicators (benthic habitats, bird populations) are integrated into management advice and the FNP.

Pre-fishery survey estimate of cockle biomass in 2022 was 1,826 tonnes a decrease of 100 tonnes on the 2021 biomass (1,927 tonnes). The TAC in 2022 was 608 tonnes. Fishermen agreed not to take the TAC or to open the fishery in 2022 due to low market price and worked to find better market conditions for a fishery in 2023.

The harvest control rules in the 2021-2025 FNP should be implemented annually. The FNP will be reviewed in 2025. The estimation of post fishery cockle biomass should be improved.

Maintenance of favourable conservation status of intertidal habitats in which cockle fisheries occur is a primary management objective in order to reduce the risk of future recruitment failure and to ensure that conservation objectives for designated habitats and species are protected. Any cockle fisheries in other SACs or SPAs should be subject to management plans considering their potential effects on designated habitats and birds.

8.2 *Issues relevant to the assessment of the cockle fishery*

There are a number of cockle beds around the Irish coast, however, in recent years the main fishery has occurred in Dundalk Bay.

Recruitment of cockles in Dundalk Bay occurs regularly but overwinter survival, in particular, is highly variable. As a consequence, biomass in some years, is insufficient to support a fishery. In most areas growth rates are lower than in Dundalk and cockles need to survive over 2 winters to reach commercial size compared to 1 winter in Dundalk.

Annual surveys, provided they are completed close to the prospective opening date for the fishery, provide good estimates of biomass available to the fishery and the prospective catch rates. Growth and mortality result in significant changes in biomass over short periods of time. Reference points for sustainable outtakes are unknown. In the case of Dundalk the harvest rules applied since 2007 seem to have stabilised stock biomass and maintained productivity.

Dundalk Bay is under a Natura 2000 site management regime and a fishery Natura plan for cockles. Cockle is both a characterising species of designated habitats within these sites and also an important food source for overwintering birds. Management of cockle fisheries takes into account the conservation objectives for these habitats and species.

Continuing commercial fisheries for cockles in Natura 2000 sites will depend on favourable conservation status of designated environmental features that may be affected by this fishing activity or a clear demonstration that changes to designated features are not due to cockle fishing.

8.3 *Management units*

Cockle stocks occur in intertidal sand and mud habitats. These habitats occur as isolated and discrete areas around the coast and as a consequence cockle stocks are probably local self-recruiting populations.

Although there are many cockle populations around the coast only Dundalk Bay has supported commercial dredge fisheries in recent years. There is a small scale commercial hand gathering fishery in Castlemaine Harbour (Kerry) and in Drumcliffe Bay (Sligo). Stocks also occur in Tramore Bay and Woodstown Co. Waterford and in Clew Bay Co. Mayo but these stocks have not been commercially fished in recent years. In addition, cockle stocks occur in Mayo (other than Clew Bay), Kerry, Sligo and Donegal in particular but these have not been surveyed and are not commercially fished.

8.4 *Management measures*

The management measures for the Dundalk fishery are described in 5 year Fishery Natura plans (FNPs; 2011-2016, 2016-2020, 2021-2025) and harvest rules are implemented through annual legislation in the form of Natura Declarations (www.fishingnet.ie). These plans were subject to screening and appropriate assessment as required by the EU Habitats Directive Article 6 and the EU Birds and Habitats Regulations (S.I. 290 of 2013).

In Dundalk Bay a cockle permit is required to fish for cockles either by vessel or by hand gathering. The number of vessel permits is limited to 28 (formerly 33).

Annual TAC is set according to harvest control rules set out in the FNP and based on the biomass estimated from a mid-summer survey. There is no fishing at a biomass below 1,200 tonnes. Landings are capped at 1,200 tonnes when biomass reaches 2,400 tonnes. At higher biomass levels therefore the harvest rate declines as biomass increases. The cap of 1,200 tonnes is to avoid bumper years which could de-stabilise the market. Depending on overwintering mortality this also helps to support and stabilise fisheries in successive years when recruitment is weak. The fishery closes if the average catch per boat per day declines to 250 kg even if the TAC is not taken. This provides additional precaution given uncertainty in the survey estimates. Opening and closing dates are specified annually. The latest closing date of November 1st is implemented even if the TAC has not been taken or if the catch rate remains above the limit for closure. Vessels can fish between the hours of 06:00 and 22:00. Maximum landing per vessel per day is 1 tonne. Dredge width should not exceed 0.75 m in the case of suction dredges and 1.0 m for non-suction dredges. The national minimum legal landing size is 17 mm but operationally and by agreement of the licence holders the minimum size landed in Dundalk Bay is 22 mm. This is implemented by using 22 mm bar spacing on drum graders on board the vessels.

Environmental performance indicators are reviewed periodically as part of the management plans and the prospect of an annual fishery depends on evidence that there is no causal link between cockle fishing and in particular the abundance of oystercatcher and other species of bird that feed on bivalves and the status of characterising bivalve species in intertidal habitats.

8.5 *Dundalk Bay*

8.5.1 Biomass and landings 2007- 2022

Biomass estimates from annual surveys in 2007-2022 are not strictly comparable because of differences in the time of year in which surveys were undertaken (Table 12). The annual biomass estimates are sensitive to the timing of in year settlement and seasonal mortality of established cohorts relative to the time in which the surveys are undertaken. Nevertheless, since 2009 surveys have been undertaken either in May, June or July.

Biomass has varied from a low of 814 tonnes in 2010 to 3,790 tonnes in 2019. Biomass increased annually between 2014 and 2017 from 972 tonnes to 2,316 tonnes and was between 3,420-3,790 tonnes in 2019-2020. The biomass in 2022 decreased by 100 tonnes from that reported in 2021. No fishery has occurred when the biomass was less than 1,032 tonnes (2015). In years when the fishery is opened the TAC uptake has varied from 15 % (2009) to 100 % (2017-2021). This depends on distribution of biomass and the commercial viability of fishing and market prices. The TAC was lower than allowed for in the fishery plan in 2020 by agreement with industry. Despite the biomass being estimated as 1,826 tonnes in 2022 no fishery occurred due to market price.

Table 12. Annual biomass, TAC and landings of cockles in Dundalk Bay 2007-2022.

Year	Survey Month	Biomass (tonnes)		TAC (tonnes)	Landings (tonnes)	
		Mean	95% CL		Vessels	Hand gatherers
2007	March	2,277	172	950	668	Unknown
2008	August	3,588	1,905	0	0	0
2009	June	2,158	721	719	108	0.28
2010	May	814	314	0	0	0
2011	May	1,531	94	510	325	0.25
2012	May	1,234	87	400	394	9.4
2013	June	1,260	99	416	343	0
2014	June	972	188	0	0	0
2015	June	1,032	100	0	0	0
2016	July	1,878	87	626	410	0
2017	June	2,316	95	772	775	0
2018	June	1,785	175	542	446	0
2019	July	3,790	110	600	594	0
2020	June	3,420	870	1,128	1,128	0
2021	June	1,927	406	642	638	0
2022	May	1,826	375	608	0	0

8.5.2 Survey in 2022

8.5.2.1 Biomass

A pre-fishery survey was completed in late May 2022. The survey area was 27.8 km^2. Total biomass was 1,826 tonnes (Table 13) based on a geostatistical model. Biomass of cockles over 22 mm was 912 tonnes (Figure 42).

Table 13. Biomass of cockles in Dundalk Bay in May 2022.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Biomass All sizes	1,826	2,022	1,841	2,201
Biomass (tonnes) > 22mm	912	1,184	1,039	1,346
Biomass (tonnes) > 18mm	1,376	1,626	1,469	1,812
Biomass (tonnes) < 18mm	391	405	371	443

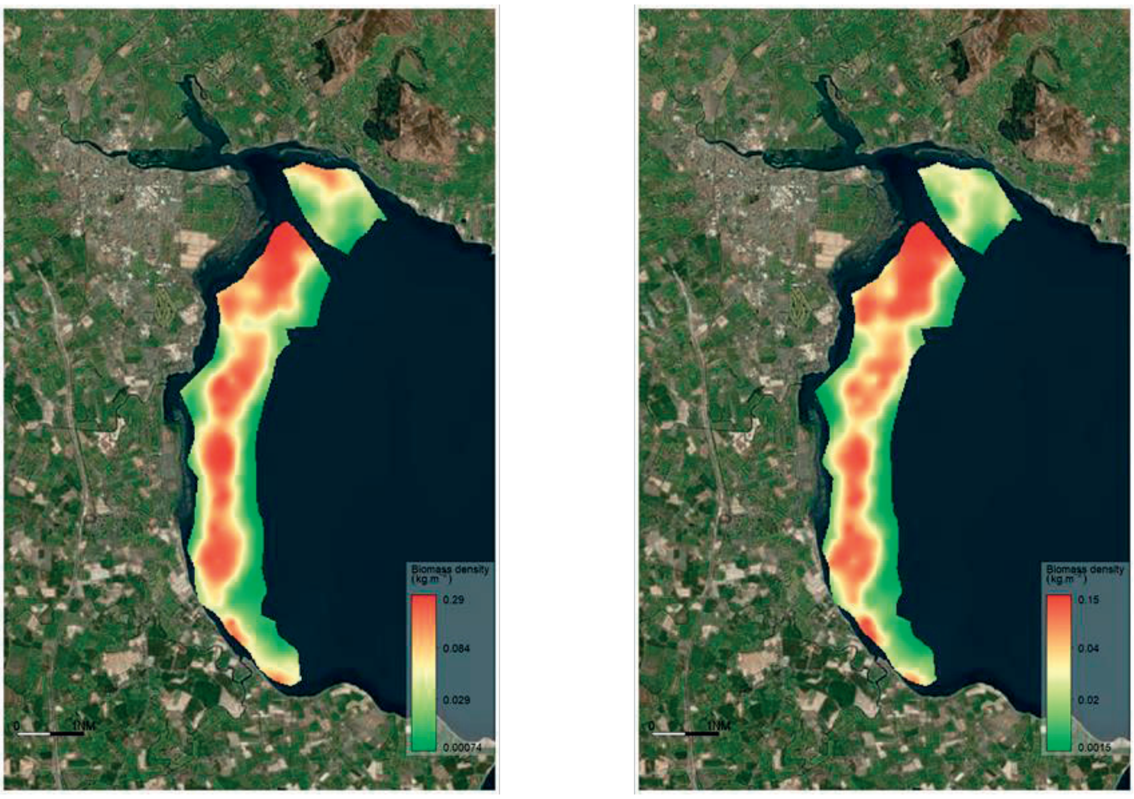

Figure 42. Distribution and density (kgs.m^{-2}) of all cockles (left**) and commercial cockles (>22 mm shell width) (**right**) in Dundalk Bay in May 2022.**

8.5.2.2 Size distribution and recruitment

The 0+ cohort seen in 2018 at a modal size of approximately 10.3 mm increased to approximately 18 mm in 2019, 22 mm in 2020 and to 25 mm in 2021 (Figure 43). No significant recruitment (spat settlement) was detected in 2019-2021. The growth of the 2018 cohort lead to an increase in biomass and landings in 2019 and 2020. Biomass was significantly lower in 2021. In 2022 a strong 0+ cohort at approximately 8 mm was recorded. A larger cohort can be seen at 18 mm following the growth progression of the smallest cohort detected from the 2021 survey. The main 2021 mode of large cockles ~27 mm was lower in 2022.

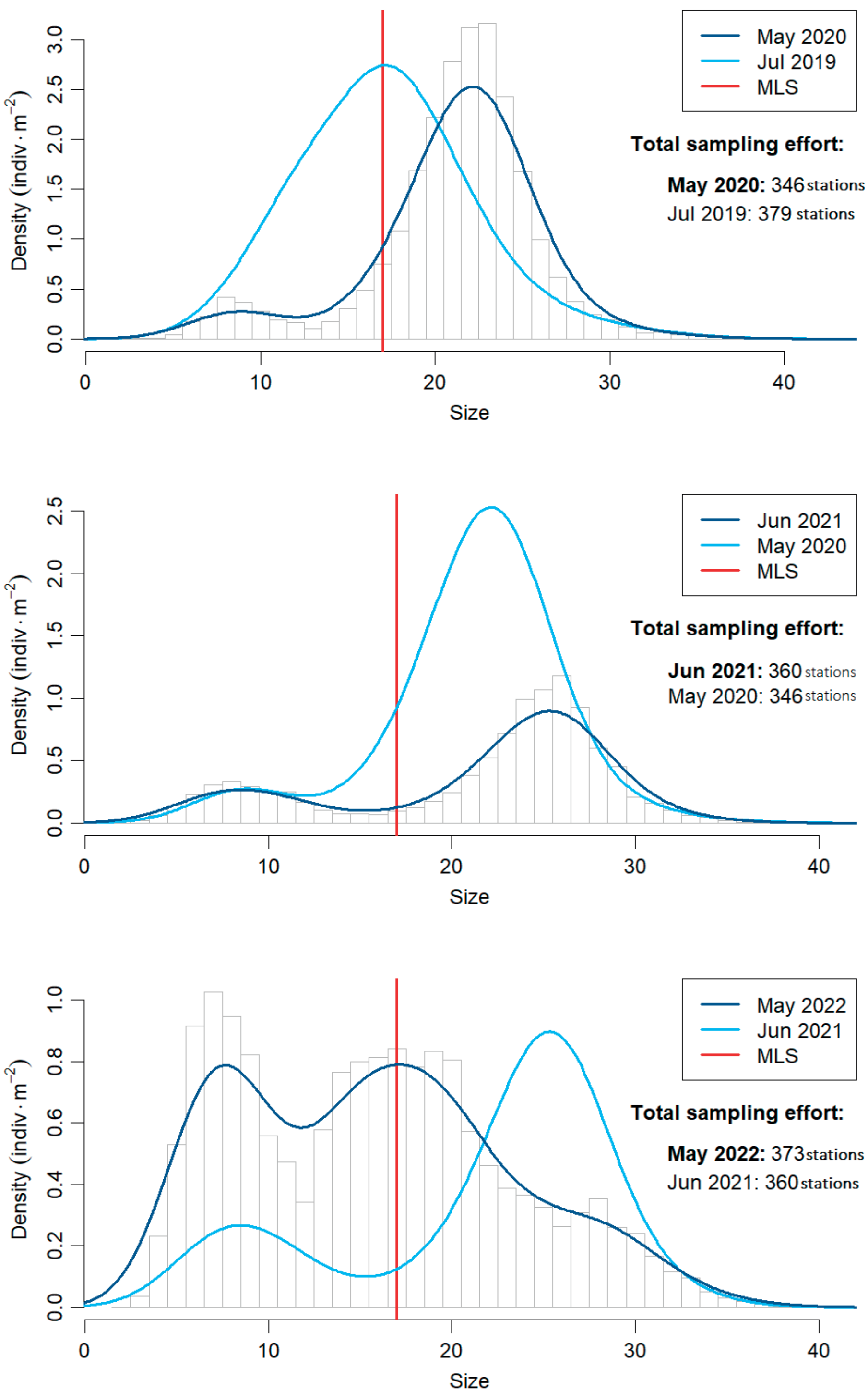

Figure 43. Size distribution of cockles in Dundalk Bay in July 2019 and May 2020, May 2020 and June 2021 and June 2021 and May 2022.

8.5.3 Review of ecosystem effects

Two five-year Fishery Natura Plans (FNP) (2011-2015 and 2016-2020) for cockles (*Cerastoderma edule*) in Dundalk Bay SAC and SPA have been implemented and a new FNP for the period 2021-2025 was established prior to the fishery in 2021. The FNPs include a requirement to monitor effects on the environment and the ecological features for which the

Bay was designated under the Habitats and Birds Directives. Data on characterising species in intertidal habitats which are disturbed by cockle fishing is reported here. Data on overwintering water birds were reviewed in 2020.

8.5.3.1 Intertidal habitats

The three numerically dominant species of bivalve in the intertidal habitat of Dundalk Bay are *Cerastoderma edule* (cockles), *Angulus tenuis* and *Macoma balthica*. The Baltic clam, *Macoma balthica,* is more abundant on the upper shore, cockles mainly occur along the mid shore and *A. tenuis* is dominant from the mid to lower shore. The distribution of all 3 species overlap. Previous studies in Dundalk Bay shows that cockle dredging causes mortality of *Angulus* in particular as its shell is more fragile compared to the other two species. However, its overall sensitivity to abrasion pressure is low given its short life cycle and high recoverability. *Macoma* is much less exposed to the cockle fishery as it is distributed on the upper shore. Counts of the casts of the polychaete worm, *Arenciola marina* have been recorded since 2013.

The distribution of these species is estimated during the annual summer surveys carried out from 2007-2022. Both *A. tenuis* and *M. balthica* can occur in high densities (Table 14, Figure 44). The average densities of *Angulus tenuis* have increased from 2018 to 2022 while those of *Macoma balthica* have declined year on year since 2018. The distribution of *Angulus* and *Macoma* from the 2020, 2021 and 2022 cockle surveys is shown in Figure 45.

Average densities of the lugworm, *Arenicola marina* have shown an overall decrease since 2014 when the highest densities of 11.62 m^{-2} were recorded. In 2021, average densities of *A. marina* increased slightly, however a further decrease was recorded during the 2022 survey (Table 14).

Table 14. Mean density (m^{-2}) of the bivalves *Angulus tenuis*, *Macoma balthica* and the polychaete worm *Arenicola marina*, along with the average Redox potential discontinuity layer in intertidal habitats during the mid-summer cockle surveys 2011-2022.

Year	*Angulus tenuis*		*Macoma balthica*		*Arenicola marina*		Redox Potential Discontinuity (RPD) layer	
	Mean	S.d.	Mean	S.d.	Mean	S.d.	Mean	S.d.
2011	26.14	38.74	13.98	36.25			9.43	4.63
2012	55.35	62.18	17.74	41.21				
2013	95.43	89.82	28.10	57.49	6.43	8.10	12.74	7.08
2014	91.61	83.19	18.53	42.23	11.62	9.18	18.66	10.8
2015	70.56	76.90	18.80	40.06	6.08	5.33	9.34	6.00
2016	83.33	75.07	19.41	51.29	6.26	4.82	11.21	6.28
2017	67.89	90.11	12.39	30.15	5.58	4.45	10.11	4.43
2018	77.89	88.09	24.64	51.15	4.35	3.10	10.27	6.81
2019	84.66	86.40	22.91	48.60	5.26	3.27	10.43	6.13
2020	87.51	99.59	18.72	42.77	3.49	3.15	9.98	7.29
2021	88.27	85.2	14.56	28.73	4.27	3.65	10.44	4.96
2022	101.22	96.55	13.41	30.24	3.43	3.01	10.50	4.07

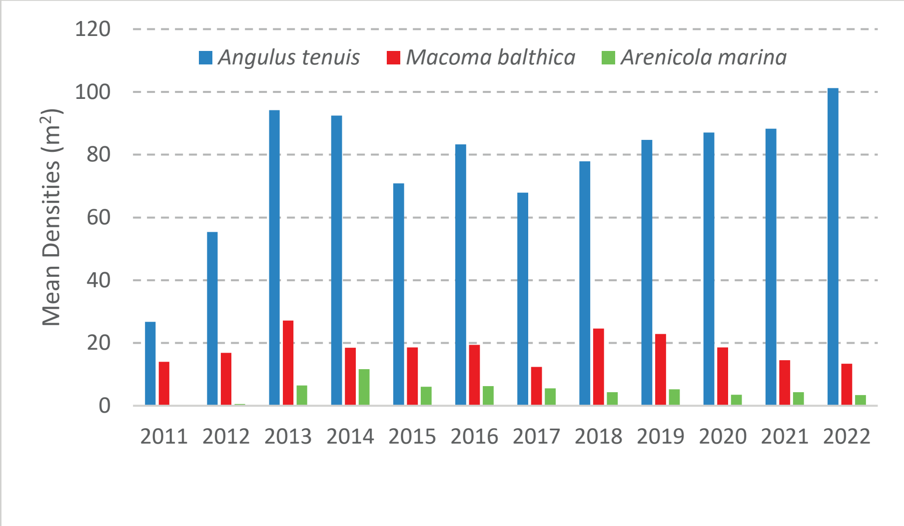

Figure 44. Mean densities of *Angulus tenuis*, *Macoma balthica* and *Arenicola marina* in intertidal sediments in Dundalk Bay 2011-2022.

The divide between the surface oxygenated and sub-surface anaerobic sediment is known as the redox potential discontinuity (RPD) layer. This divide appears as a grey layer of sediment above the black deoxygenated sediment below. Sediment mobility and biological bioturbation caused by feeding of infaunal deposit feeders increases oxygen supply to sediments and thus makes the oxygenated surface layer of sediment deeper. Eutrophication and increased biological oxygen demand in the sediment reduces oxygen availability and the RPD layer can then occur very close to the sediment surface. Filter feeding bivalves such as cockles occur above the RPD or at least must reach the aerobic layer when feeding. The depth of the RPD was measured at each station during the summer surveys from 2011 to 2022 (Table 14). It has been consistent at an average depth of about 10 cm since 2015.

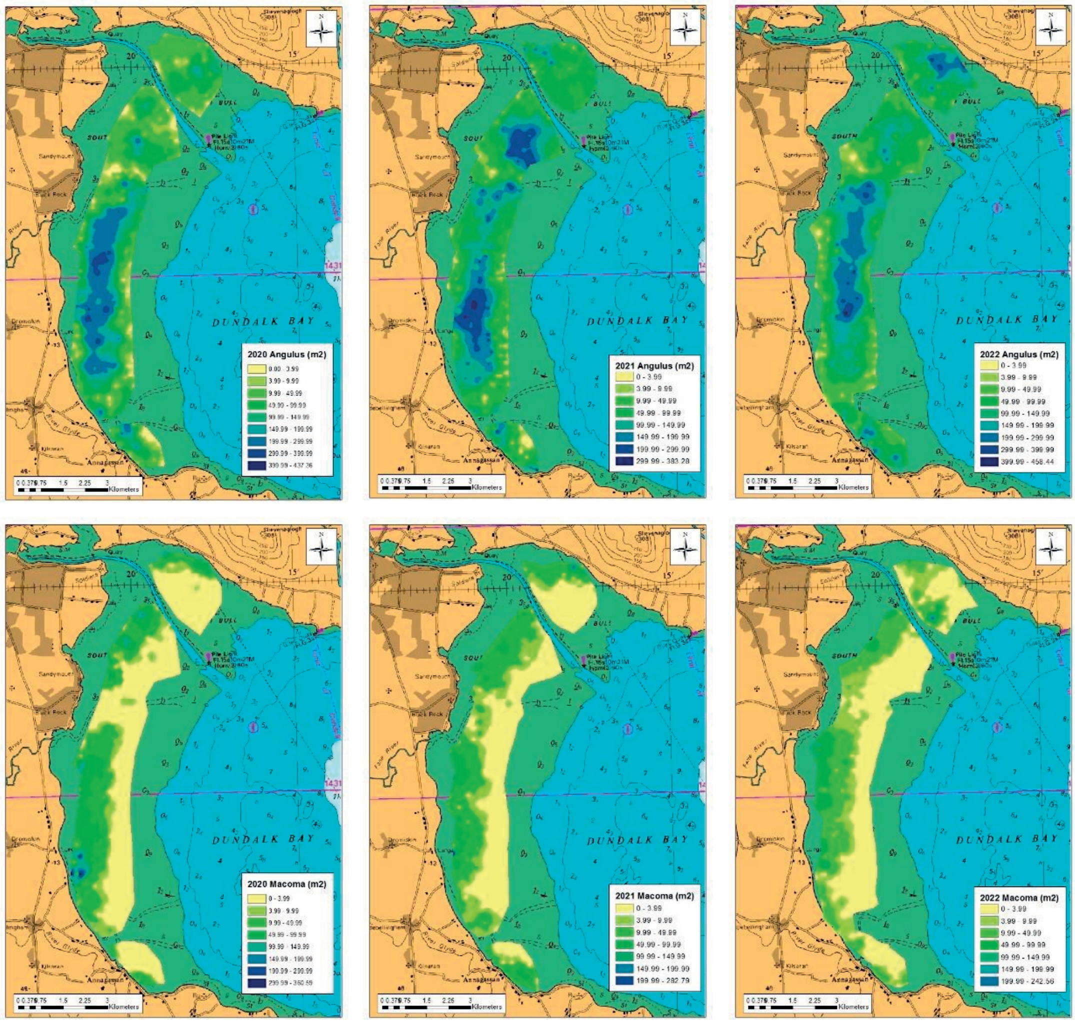

Figure 45. Annual distribution of *Angulus tenuis* (top row of maps**) and *Macoma balthica* (**bottom row of maps**) during summer surveys undertaken in Dundalk Bay 2020-2022.**

9 Oyster (*Ostrea edulis*)

9.1 *Management advice*

Oyster stocks are managed locally by Oyster Co-operatives who have delegated authority to manage oysters in specific areas. Minimum sizes of 76-78 mm apply. Local quotas or TACs may be in force. The number of dredge permits issued annually is limited.

Stocks are assessed by annual surveys which provide biomass estimates, although dredge efficiency (catchability) is uncertain. Stock biomass is generally low in all areas, except inner Tralee Bay, and management measures to restore recruitment and re-build spawning stocks are necessary. Various threats to native oyster stocks exist including naturalisation of Pacific oyster (*Magallana gigas*), *Bonamia* infection, poor water quality, unfavourable habitat conditions for settlement and low spawning stocks. Pacific oyster has naturalised in Lough Swilly in recent years and supports a commercial fishery.

Generally, although seasonal quotas and minimum size regulations are in place for some fisheries, management plans or recovery plans should be developed in order to restore productivity of stocks. A range of actions should be considered including areas closed to fishing where spawning stock could be re-built, removal of Pacific oysters, maintenance or recovery of habitat for settlement, development of harvest control rules and improving operational management locally.

Oyster beds are also constituents of habitats designated under the Habitats Directive in many areas. Specific conservation objectives have been defined for these habitats in some sites. Oyster management plans also need to consider the conservation objectives for oyster habitat or for habitat in which oyster is a characterising species.

9.2 *Issues relevant to the assessment of the oyster fishery*

A number of native oyster beds occur as separate stocks in Bays around the coast. Biomass is currently low, compared to historic levels, in most areas. Inner Tralee Bay holds the majority of the national biomass of native oyster.

Recruitment is variable in most areas although settlement occurred in all areas recently surveyed. Larval production and settlement is conditional on density of spawning stock, high summer temperatures and the availability of suitable settlement substrate.

The fishery is managed primarily by a minimum landing size (MLS) of 76-78 mm. The minimum size is generally reached at age 4-5. Oysters generally mature well below the MLS.

Oyster stocks face a number of threats including *Bonamia* infection, which decimated stocks in the 1970s, and is prevalent in a number of beds today and in 2017 was detected in the previously *Bonamia* free Cill Chiaráin Bay. Native oyster is also competing for habitat with naturalised Pacific oyster in some areas such as Lough Swilly. Poor substrate conditions for settling oysters may be limiting recruitment and low stock density may also be reducing reproductive output. Increases in freshwater inflows to estuaries in inner Galway Bay reduces the area of suitable oyster habitat.

Management authority has been devolved to local co-operatives through fishery orders issued in the late 1950s and early 1960s or through 10-year Aquaculture licences. Although conditions, such as maintaining oyster beds in good condition or having management plans in place, attach to these devolved arrangements in most cases management objectives and management measures are not sufficiently developed. In Lough Swilly and the public bed in inner Galway Bay all management authority rests with the overseeing government department rather than with local co-operatives.

Although management may be devolved through the fishery orders or aquaculture licences vessels fishing for oysters must be registered on the sea fishing vessel register (DAFM) and operators must also hold a dredge licence which is issued by Inland Fisheries Ireland (IFI).

The oyster co-operatives operate seasonal fisheries and may also limit the total catch. The TACs may be arbitrary or based on the annual surveys.

All the main oyster beds in Ireland occur within Natura 2000 sites. Oyster is a characterising species of sedimentary habitats of large shallow inlets and bays. It can also be a key habitat forming species in conditions where recruitment rates are high and where physical disturbance is low. Seagrass and maerl or other sensitive reef communities are commonly found on oyster beds in Galway Bay, Cill Chiaráin Bay, Tralee Bay and Clew Bay. Dredging may damage these communities. Management of oyster fisheries needs to consider the conservation objectives for oyster and its associated habitats and communities.

Annual surveys provide biomass indices or absolute biomass estimates and size structure of oyster stocks annually. Poor information on growth rate, which varies across stocks, limits the assessment of mortality rates and yield predictions.

9.3 *Management units*

Oyster stocks occur as discrete stock units in a number of Bays around the coast. Although native oysters were historically widespread in many areas, including offshore sand banks in the Irish Sea and along the south east coast their distribution is now reduced. The main stocks occur in inner Tralee Bay, Galway Bay, Cill Chiaráin Bay in Connemara, Clew Bay, Blacksod Bay and Lough Swilly.

9.4 *Survey methods*

Oyster beds are surveyed annually by dredge. Dredge designs vary locally and these locally preferred dredges are used in the surveys. Dredge efficiencies were estimated in 2010 by comparison of the numbers of oysters caught in the dredge and the numbers subsequently counted on the same dredge track by divers immediately after the dredge tow had been completed. Separate estimates were obtained in 2021 in Lough Swilly by quantitative quadrat sampling at low tide followed by dredge sampling in the same area at high water. Biomass is estimated using a geostatistical model accounting for spatial autocorrelation in the survey data.

9.5 *Inner Tralee Bay*

9.5.1 Stock trends

Biomass estimates, standardised to a dredge efficiency of 35 %, varied from a low of 409 tonnes in 2015 to a high of over 1,000 tonnes in 2014, 2018 and 2020. The area surveyed usually contains the entire stock which is distributed over approximately 4 km^2 (Table 15). The biomass reported in 2020 was the highest in the time series. The larger area sampled along with the considerably shorter haul lengths recorded and the distribution of the tracks over the survey area in 2020 compared to other years suggest that the 2020 estimate may not be comparable to other years. A different pattern in haul lengths was also observed between 2017 and 2018, which may also have affected density and biomass estimates. Other than 2020 annual biomass estimates for all size classes of oysters corrected for dredge efficiency has varied from just over 600 tonnes to over 1,000 tonnes.

Table 15. Stock biomass trends for native oyster in Inner Tralee Bay 2010-2022.

Year	Month of survey	Survey Area (km^2)	Biomass km^{-2}	Biomass
2010	September	4.26	230.54	982
2011	September	3.57	87.03	631
2012	February	3.8	85.02	655
2013	September	3.76	66.33	506
2014	September	3.8	164.16	1,265
2015	September	4.51	44.78	409
2016	September	3.66	121.44	901
2017	September	4.28	197.08	843
2018	September	3.92	296.17	1,161
2019	October	3.7	237.57	879
2020	September	5.32	304.14	1,618
2021	September	4.05	152.35	617
2022	September	4.55	176.04	801

9.5.2 Survey September 2022

A pre fishery survey was carried out on the 8-9th September in Inner Tralee Bay. A total of 79 tows were completed, with a single toothless dredge of width 1.22 m. GPS data for each tow track was recorded on a Trimble GPS survey unit and the swept area for each tow was estimated. The survey encompassed an area of 4.55 km^2 east of Fenit pier (Figure 46).

9.5.2.1 Distribution and Biomass in 2022

Biomass of oysters uncorrected for dredge efficiency varied from 0-0.42 $kgs.m^{-2}$ (Figure 46). Biomass of oysters over 76 mm ranged from 0-0.09 $kgs.m^{-2}$.

Total biomass of oysters, assuming a dredge efficiency of 35 %, was 801 tonnes (Table 16). The equivalent biomass of oysters 76 mm or over was 234 tonnes or approximately 29 % of the total biomass.

Table 16. Distribution of oyster biomass in Inner Tralee Bay in September 2022.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for Dredge Efficiency				
Biomass_Ostrea_edulis	280.3	287.6	245.9	338.0
Biomass_>76mm_Ostrea_edulis	82.1	96.9	80.2	115.6
Corrected_35% Dredge Efficiency				
Biomass_Ostrea_edulis	800.9	824.5	706.9	961.1
Biomass_76_Inf_Ostrea_edulis	234.6	280.4	232.9	337.5

Figure 46. Distribution and biomass of native oyster in Inner Tralee Bay from the September 2022 survey (uncorrected for dredge efficiency).

9.5.2.2 Size distribution 2022

The size distribution of oysters caught during the survey showed a strong mode at 60-70 mm and a smaller less defined mode at 30 mm (Figure 47). There was no evidence of modal progression (growth) between 2021 and 2022. The biggest difference in density is seen in the 30-50 mm size category, where the 2022 densities are significantly higher than in 2021.

Future prospects for the stock remain strong given that all size classes from 50-78 mm are well represented in the stock. Mortality rates on oysters below 78 mm appear to be low.

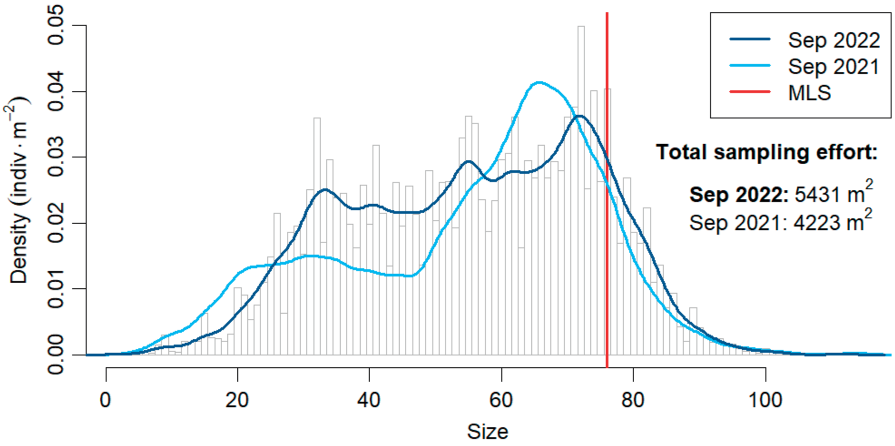

Figure 47. Size distribution of native oysters on the Inner Tralee oyster bed in September 2022. The MLS (76 mm) is also shown. Data are standardised to sampling effort regardless of its spatial distribution.

9.6 *Outer Tralee Bay*

9.6.1 Stock trends

The oyster beds in outer Tralee Bay are not surveyed annually and the survey area has varied over time (Table 17). An initial survey of the outer Tralee oyster beds was undertaken in September 2010. Two beds were surveyed, Corkerys Bed, close to the landward edge of the middle of Tralee Bay and the Maharees bed just off the coast from the Maharees tombolo. Both areas were assessed separately in February 2012. However subsequent surveys have amalgamated both beds and assessed them as the outer Tralee Bay oyster bed. Stocks in outer Tralee Bay have varied year on year with the highest biomass being reported in February 2016. The latest survey was undertaken in January 2023 rather than the usual Autumn survey in an effort to avoid living seagrass. This had died back in January and impacts of the survey were therefore minimised. This is validated by research on impacts of winter dredging on summer seagrass undertaken previously by the Marine Institute in Kilkieran Bay.

Table 17. Stock biomass trends for native oyster in Outer Tralee Bay 2010-2023.

Year	Month	Survey Area (km^2)	Biomass km^{-2}	Biomass (tonnes)
2010	September	3.63	27.40	99.47
2012	February (Corkerys Bed)	1.38	50.43	69.6
2012	February (Maharees Bed)	2.3	86.86	199.78
2014	September	7.68	26.61	204.08
2016	February	8.34	34.24	285.56
2020	September	9.0	48.3	150.9
2021	September	8.0	10.75	86.0
2023	January	9.1	9.2	83.7

9.6.2 Survey January 2023

A survey was carried out on the 25th January 2023 on the outer Tralee Bay oyster bed. A total of 55 tows were completed with a single toothless dredge of width 1.22 m. GPS data for each tow track was recorded on a Trimble GPS survey unit and swept area for each tow estimated. The survey encompassed an area of 9.1 km^2 (Figure 48).

9.6.2.1 Distribution and Biomass in 2023

Biomass of oysters, uncorrected for dredge efficiency, varied from 0-0.0079 kgs.m^{-2} (Figure 48), while the biomass of oysters over 76 mm ranged from 0-0.0062 kgs.m^{-2}.

Total biomass of oysters, assuming a dredge efficiency of 35 %, was 83.7 tonnes (Table 18). The equivalent biomass of oysters 76 mm or over was 61.3 tonnes (Table 18) or approximately 70 % of the total biomass.

Table 18. Distribution of oyster biomass, corrected for a dredge efficiency of 35 %, in outer Tralee Bay in January 2023.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for Dredge Efficiency				
Biomass_Ostrea_edulis	29.29	31	25.3	37.3
Biomass_>76mm_Ostrea_edulis	21.44	22.64	18	27.4
Corrected_35% Dredge Efficiency				
Biomass_Ostrea_edulis	83.7	89.2	72.2	105.7
Biomass_76_Inf_Ostrea_edulis	61.3	64.1	52.8	77.5

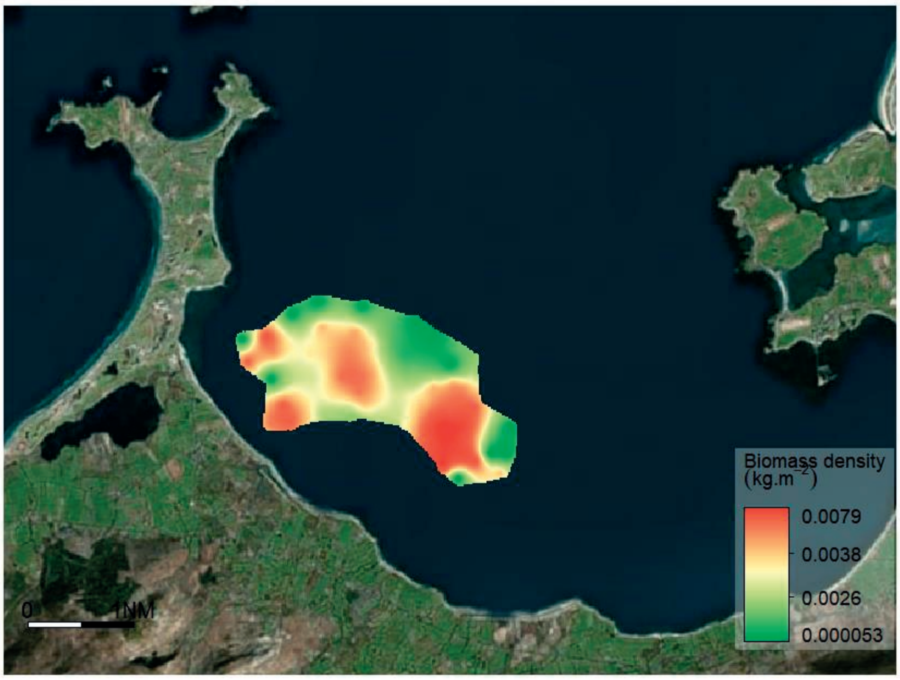

Figure 48. Distribution and biomass of native oyster in Outer Tralee Bay in January 2023 uncorrected for dredge efficiency).

9.6.2.2 Size distribution

The size distribution of oysters caught during the survey show slightly higher densities between 70-80 mm and between 25-35 mm (Figure 49). Approximately 32 % of the oysters were above the minimum landing size of 76 mm. There is no evidence of significant mortality of oysters in size classes between 60-76 mm as is evident in other stocks and the high densities above the minimum size is also unusual in both fished and unfished stocks in areas infected with *Bonamia*.

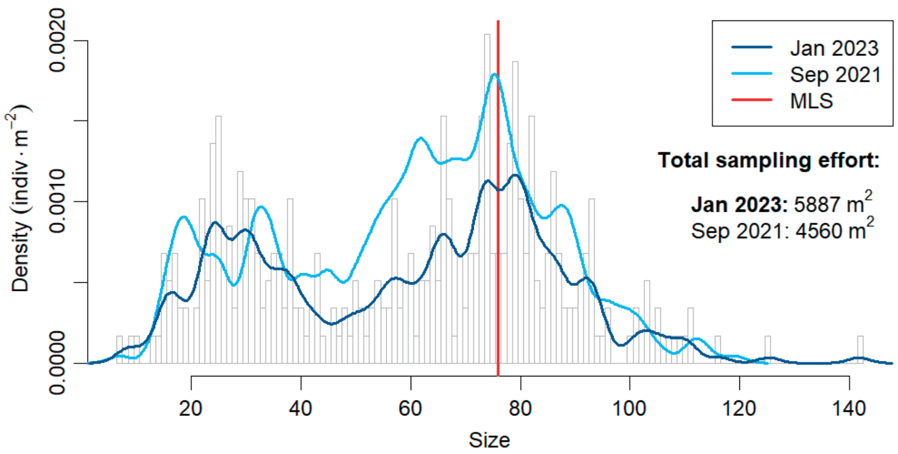

Figure 49. Size distribution of native oysters on the Outer Tralee Bay oyster bed in January 2023. The MLS (76 mm) is also shown. Data are standardised to sampling effort regardless of its spatial distribution.

9.7 *Lough Swilly*

A survey of native (*Ostrea edulis*) and Pacific oysters (*Magallana gigas*), consisting of 153 dredge hauls, was undertaken in Lough Swilly on 30th November and 1st-2nd December 2022 using a single toothless dredges of width 1.5 m. GPS data for each tow track was recorded on a Trimble GPS survey unit and the swept area for each tow estimated.

9.7.1 Native Oyster (*Ostrea edulis*)

9.7.1.1 Stock trends

The area covered by the surveys has varied significantly during the time series which compromises inter year comparisons (Table 19). Surveys from 2011-2022 standardised for survey area show that native oyster biomass per square kilometre of survey area varied from 6-44 tonnes. The biomass.km^{-2} (26 - 43 tonnes) was higher in 2017, 2018, 2020 and 2022 than previous years, however a lower estimate of 13.6 tonnes.km^{-2} was recorded in 2021.

9.7.1.2 Distribution and Biomass in 2022

Biomass of native oysters (*Ostrea edulis*), uncorrected for dredge efficiency and including all sizes, varied from 0-.0012-0.04 kgs.m^{-2}. Abundance and biomass was higher in the upper Lough, similar to 2021 (Figure 50). Biomass of oysters over 76 mm ranged from 0.00031 - 0.013 kgs.m^{-2}.

The biomass of native oysters, assuming a dredge efficiency of 35 % was 259 tonnes (Table 20). The equivalent biomass of oysters 76 mm or over was 46 tonnes, which is equivalent to 17 % of the total stock.

Table 19. Stocks biomass trends for native oyster at Lough Swilly 2011-2022.

Year	Month	Survey Area (km^2)	Biomass km^{-2}	Biomass
2011	March	1.56	25.64	40
2011	November	13.07	9.52	124
2012	October	11.48	15.46	177
2013	October	5.96	14.14	84
2014	October	13.19	15.85	209
2015	August	5.19	6.50	33
2016	August	5.58	17.40	97
2017	September	7.19	43.99	316
2018	April	7.81	26.48	207
2020	July	10	31.78	318
2021	Nov-Dec	8.1	13.64	110.5
2022	Nov-Dec	8.2	31.6	259.1

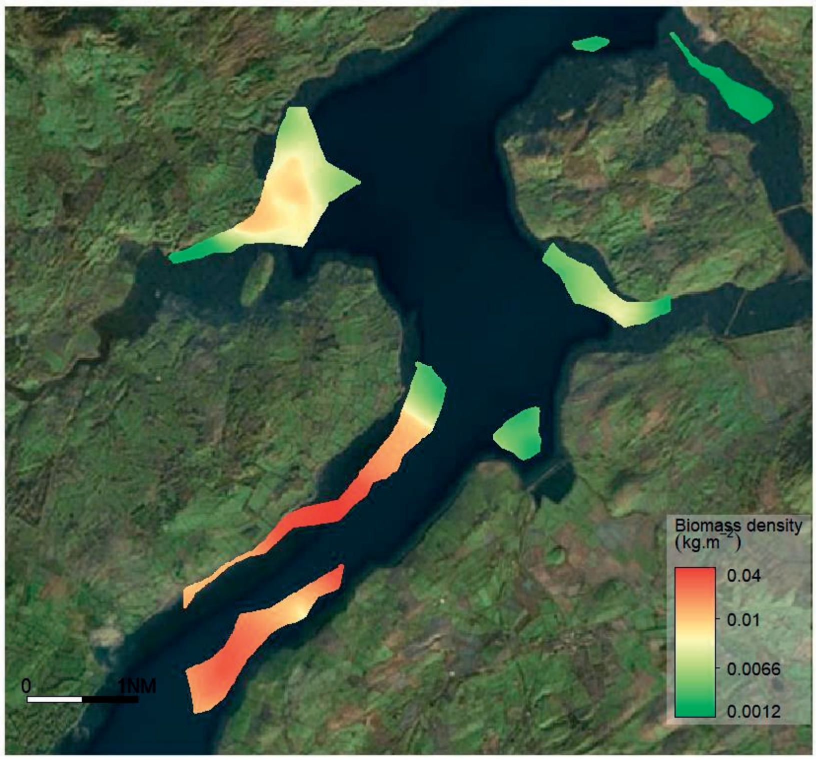

Figure 50. Biomass of native oysters in Lough Swilly, November-December 2022 (uncorrected for dredge efficiency).

Table 20. Distribution of native oyster biomass, uncorrected and corrected for a dredge efficiency of 35 %, Lough Swilly, November-December 2022. Data from all oyster beds were combined.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for Dredge Efficiency				
Biomass_Ostrea_edulis	90.7	118.1	89.4	140.4
Biomass_>76mm_Ostrea_edulis	16.2	18.4	10.9	28.2
Corrected_35% Dredge Efficiency				
Biomass_Ostrea_edulis	259.1	338.1	249.9	408.5
Biomass_>76mm_Ostrea_edulis	46.4	53.1	32.1	86.7

9.7.1.3 Size distributions

The size distribution of native oysters in the survey showed a mode at approximately 45 - 55 mm with a low proportion of oysters above the 76 mm minimum landing size. This is approximately 10 mm smaller than the mode from 2021 but the density is significantly higher (Figure 51). The significantly higher densities recorded in 2022 and the differences in the size distribution suggests changes in survey catchability across years.

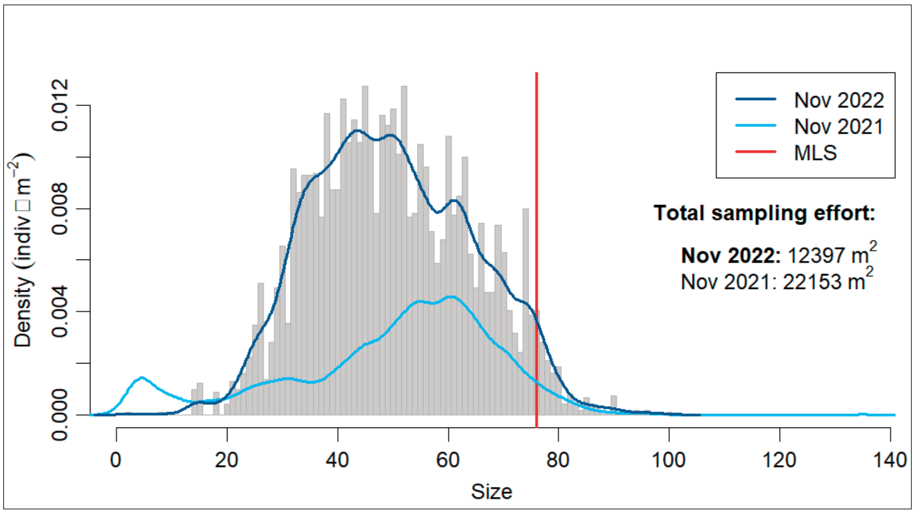

Figure 51. Size distribution of native oysters in Lough Swilly, November –December 2022 (uncorrected for dredge efficiency).

9.7.2 Pacific oyster (*Magallana gigas*)

9.7.2.1 Distribution and Biomass in 2022

Biomass of pacific oysters (*Magallana gigas*), uncorrected for dredge efficiency, varied from 0.0007- 0.5 kgs.m^{-2}, with the highest biomass occurring in the south and north west (Delap Bay) of the survey area (Figure 52).

The biomass of pacific oysters, assuming a dredge efficiency of 35 % was 3,275.5 tonnes(Table 21). The previous estimate in 2021 was 745.5 tonnes.

Table 21. Distribution of pacific oyster biomass, uncorrected and corrected for a dredge efficiency of 35 %, Lough Swilly, November-December 2022. Data from all oyster beds were combined.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for Dredge Efficiency				
Biomass_Magallana gigas	1131.5	1318.0	1101.7	1531.4
Corrected for 35% Dredge Efficiency				
Biomass_Magallana gigas	3275.5	3745.9	3613.6	4400.9

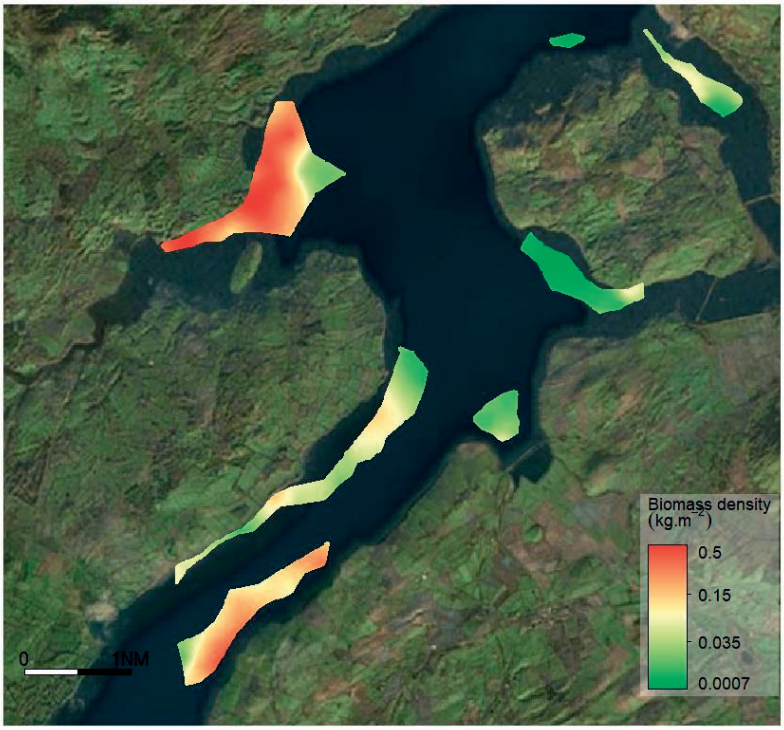

Figure 52. Biomass of pacific oysters in Lough Swilly, November-December 2022 (uncorrected for dredge efficiency).

9.7.2.2 Size distributions

The size distribution of Pacific oysters from the survey indicate two strong modes at approximately 50 mm and 80 mm. A third mode of very small oysters (~3mm) is also clear, indicating recent settlement. The significantly higher densities in the 2022 survey and the differences in the size distribution suggests changes in survey catchability across years (Figure 53).

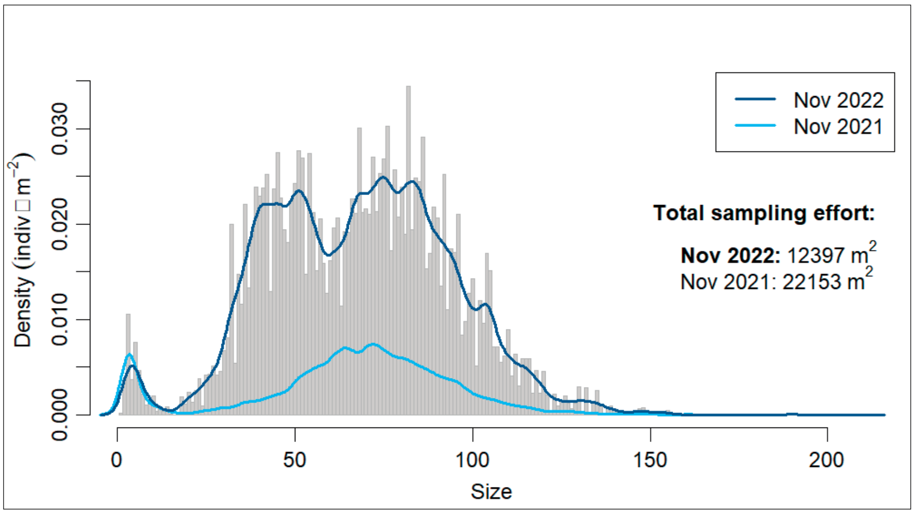

Figure 53. Size distribution of Pacific oyster in November-December 2021 and November-December 2022, Lough Swilly.

9.8 *Trends in Mortality Estimates of oyster*

Data collected from the annual surveys provide size structure of the oyster stocks sampled. The size distribution data are used in the estimation of biomass, recruitment and mortality rates. Oysters cannot be aged but size is a proxy for age and if time required to grow from one size class to the next is known (i.e. growth rate) then size can be converted to pseudo-age and the total instantaneous mortality rate (Z) can be estimated by the decline in the numbers between successive pseudo ages. Mortality rate (Z) is made up of mortality caused by fishing (F) and mortality caused by all other sources (natural mortality = M).

Three length based methods of mortality estimation are reported here; the Beverton-Holt method, a variation on the Beverton-Holt method and the Length Converted Catch Curve (LCCC) method. The Beverton-Holt length based mortality estimator uses observed mean lengths, along with growth parameters (L_{inf} and K) to calculate an estimate of total instantaneous mortality rate (Z) (King, 1995). This method carries certain assumptions which may not be met by native oysters. A variation of the Beverton-Holt method was also looked at, which removes the need to meet one of the assumptions of the original method. This variation follows significant changes in the mean length of a population over time and provides estimates of Z before and after the change in mean length (Gedamke and Hoeing, 2006). The length converted catch curve method uses data on the decline in numbers of oysters, fully selected by the fishing gear, with size (but converting size to age to account for changes in growth with size) (Pauly, 1983). L_{inf} and K growth parameters estimated for native oysters were taken from work carried out by Tully and Clarke (2012).

Indices of mortality of native oysters were estimated for inner Galway Bay and inner Tralee Bay. The fishery in inner Galway Bay has been closed since 2018 due to stock decline. Inner Tralee Bay, on the other hand, holds the majority of the national native oyster biomass (Figure 54) and is fished annually. The Galway stock is infected with *Bonamia*, which is known to cause high mortality of oysters, while the Tralee Bay stock is not.

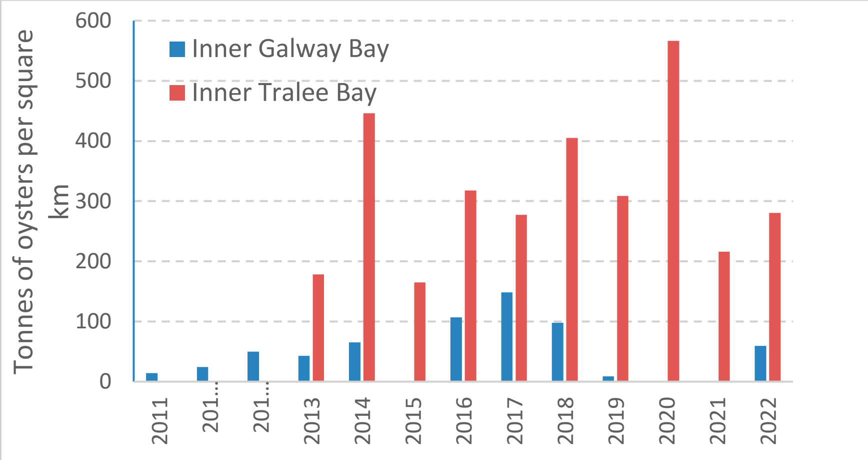

Figure 54. Comparison of annual biomass estimates for Inner Galway Bay and Inner Tralee Bay. In Inner Galway Bay, two surveys were conducted in 2012; February and November. No surveys were undertaken in 2015 and 2020. The 2022 biomass estimates are from samples taken in November 2021 and January 2022.

The mean size of oysters in Inner Galway Bay decreased over the survey time period but stabilised between 40-45 mm in recent years. The Inner Tralee Bay mean size showed fluctuations across years, possibly caused by changes in catchability during the surveys or good recruitment years but currently the average oyster size is between 50-55 mm, 10 mm larger than Galway Bay oysters (Figure 55).

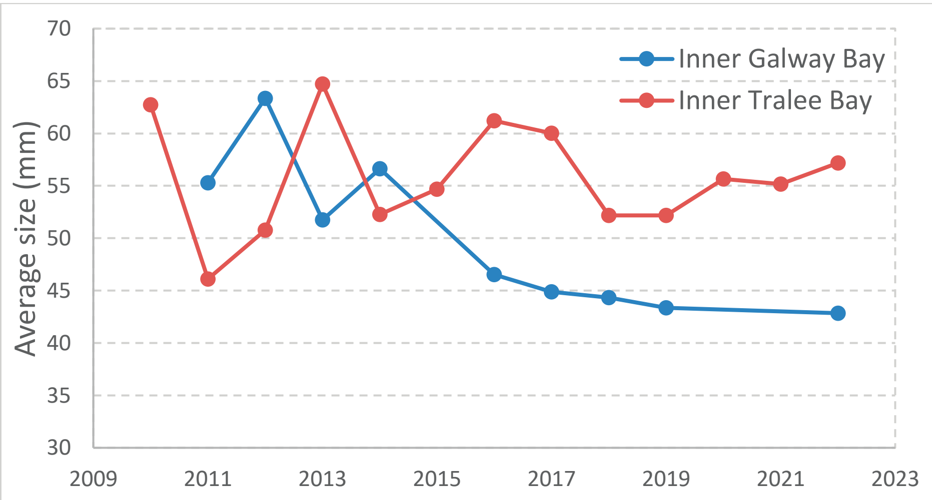

Figure 55. Average size of native oysters in Inner Galway Bay and Inner Tralee Bay across the survey period.

Mortality rates increased over the time series in inner Galway Bay (Table 22). In Tralee Bay, the Beverton-Holt method and the variation on the method indicated low and very stable mortality rates between 2010-2022. The LCCC estimates were much more variable and a lot higher than expected (Table 23). The LCCC method provided implausibly high estimates in both Bays. The methods are known to provide variable estimates of mortality (Huynh *et al.*, 2018).

Mortality estimates for Tralee are much lower and more stable compared to Galway even though significant harvests of 100-150 tonnes are taken from Tralee annually while none were taken from Galway Bay in recent years. Natural mortality caused by Bonamia or environmental stress or a combination of both in Galway Bay is the likely cause of these differences.

Table 22. Results from the mortality estimates calculated for Inner Galway Bay based on the Beverton-Holt method, variation on Beverton-Holt and LCCC method.

Year	Beverton-Holt	Beverton-Holt variation	LCCC
2011	0.69	0.55	1.208
2012	0.45	0.55	1.025
2013	0.62	0.55	1.043
2014	0.56	0.55	0.982
2016	0.62	1.126	1.444
2017	0.94	1.126	1.053
2018	1.03	1.126	1.773
2019	0.98	1.126	1.288
2022	1.14	1.126	1.553

Table 23. Results from the mortality estimates calculated for Inner Tralee Bay based on the Beverton-Holt method, variation on Beverton-Holt and LCCC method.

Year	Beverton-Holt	Beverton-Holt variation	LCCC
2010	0.490	0.533	1.17
2011	0.524	0.533	1.52
2012	0.564	0.513	2.2
2013	0.442	0.513	1.68
2014	0.443	0.513	1.72
2015	0.476	0.513	1.36
2016	0.496	0.513	1.32
2017	0.429	0.513	1.07
2018	0.495	0.513	1.54
2019	0.557	0.513	1.32
2020	0.492	0.513	1.28
2021	0.493	0.513	1.23

9.9 *Native Oyster Restoration – a case study using cultch*

Oyster spat require 'clean' hard substrate on which to settle. Any bivalve shell and many artificial substrates are suitable for oyster settlement. Productive oyster beds produce new shell through recruitment and growth. In cases where fishing is absent or well managed, limited amounts of shell (live oysters) are removed and the shell budget is positive i.e. more shell is produced than is lost through removal or fragmentation caused by dredging or natural disturbance from wave action. This may not be the case where fishing is uncontrolled and where recruitment declines. Wave action and fishing can both bury shell and upturn new shell that may be suitable for settlement. In estuarine conditions in particular where the siltation rate may be high new shell may be covered by silt, rendering it unsuitable for oyster spat settlement.

Spreading of clean bivalve shell (cultch) is one method of providing new clean substrate to increase the shell budget and to enhance spat fall, especially where there is evidence of low shell cover on the seabed which may be causing a bottleneck to recruitment. In Galway Bay, surveys since 2010, indicate poor shell availability in many areas.

In June 2021, 200 tonnes of whole flat scallop shell were deployed in the south St Georges fishery order area in Galway Bay. The scallop shells were left to settle until sampling commenced in October 2021 using a grab sampler and dredge. Sampling commenced again in June 2022 by snorkelling on the site. Regular monthly sampling was undertaken from June 2022-January 2023 (Figure 56).

A total of 113 samples were collected. The length distribution from each month showed a gradual increase in size until September 2022, when new spat settlement was detected (Figure 56). The average size of spat from October 2021 to September 2022 shows good growth during the summer months but growth slowed in the winter months (Figure 57).

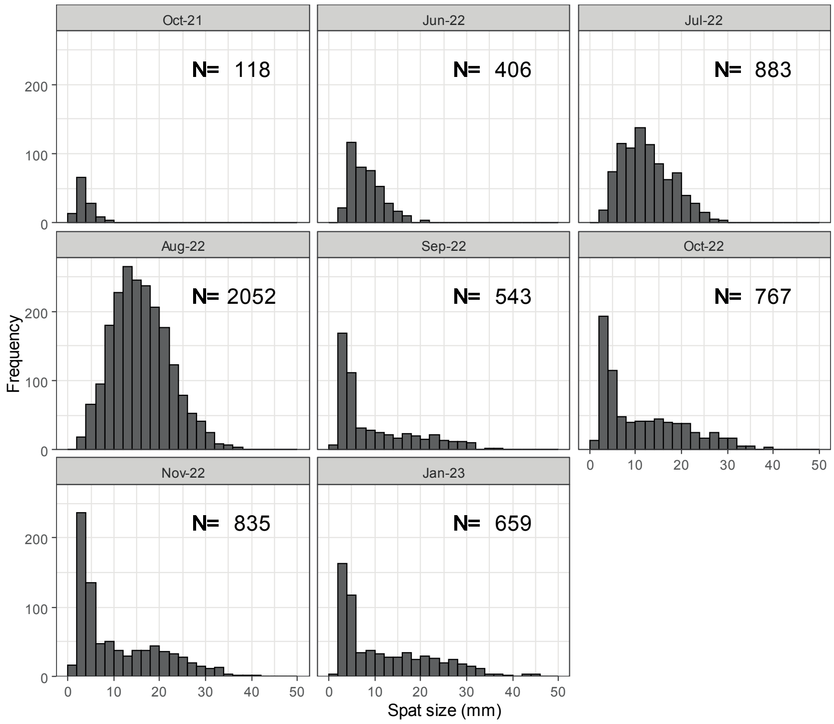

Figure 56. Monthly length frequency plots of native oyster spat settled on deployed scallop shell cultch. N = sample size for each month.

The total spat recruitment onto scallop shell in 2021 was estimated. The average weight of a clean scallop shell was 46 g, which equates to approximately 4.3 million shells in 200 tonnes of scallop cultch deployed. The frequency distribution of oyster spat on individual scallop shells was recorded for a sample of 308 scallop shells taken in Oct 2021 and June and July 2022, 5, 13 and 14 months post cultch deployment respectively. This distribution was raised to the total number of scallop shells deployed (Figure 58) to provide an estimate of 20.7 million spat recruited in 2021.

This study shows that provision of shell substrate is a feasible method of increasing settlement and recruitment of oysters and that it can be used at a scale that would have significant population level benefits.

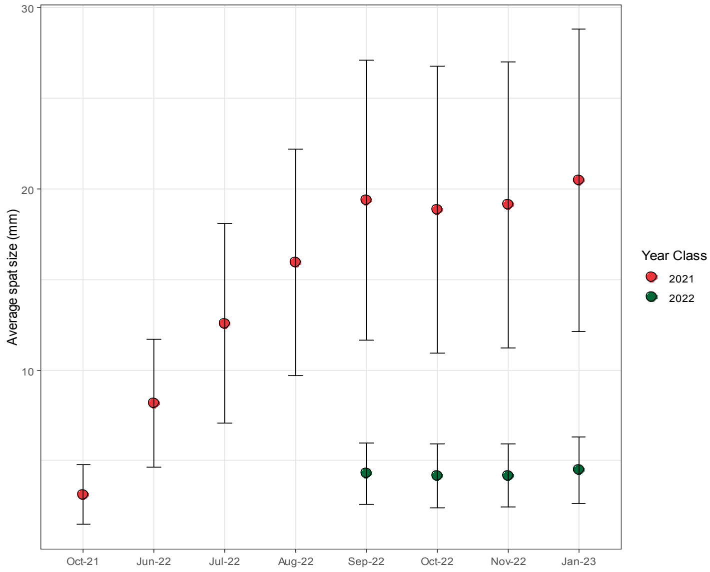

Figure 57. Average size of oyster spat measured on scallop shell cultch between October 2021 and January 2023 for the 2021 and 2022 year classes.

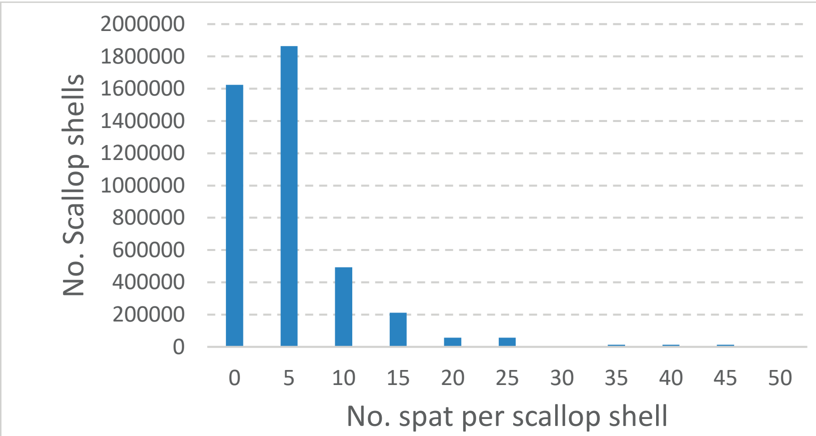

Figure 58. Number of native oyster spat per scallop shell divided in 5 spat count bins. The counts have been raised to the total number of scallop shells deployed.

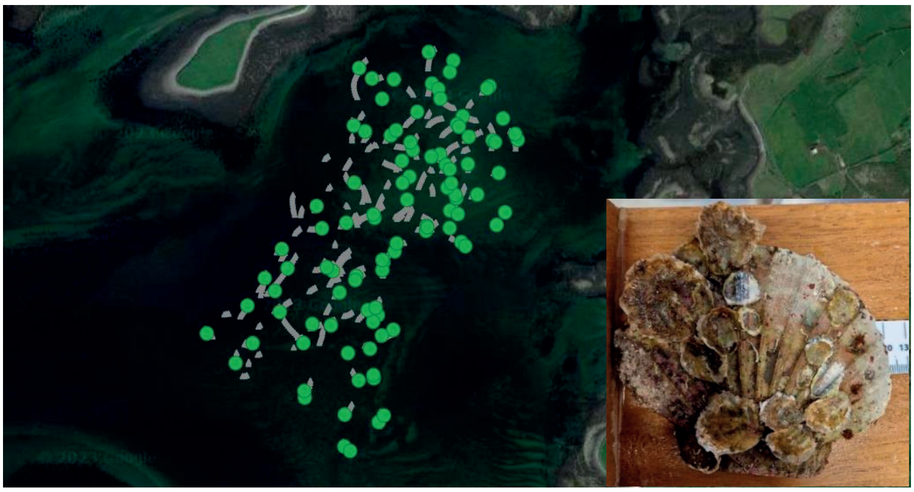

Figure 59. Scallop cultch deployment tracks (grey polygons) and the sites sampled for spat settlement to January 2023 (green circles) in the south St Georges fishery order area. Insert: scallop shell with native oyster spat settlement.

10 Scallop (*Pecten maximus*)

10.1 *Management advice*

The scallop fishery is managed by a minimum landing size of 100-110 mm shell height. There are kilowatt day effort limits in ICES area VII. Seasonal closures apply in the eastern Irish Sea and English Channel. Additional measures may apply locally for inshore stocks.

Offshore scallop stocks in the Irish Sea, Celtic Sea and English Channel are fished by Irish, UK and French fleets. There is currently no integrated international stock assessment or advice. In Ireland spatially referenced catch rate indicators have been developed for the Irish fleet in the Celtic Sea, Irish Sea and English Channel. Some inshore stocks are assessed by survey, and more recently the Celtic Sea and South Irish Sea stocks have been surveyed which provides relative biomass estimates.

Effort distribution across stocks varies annually. The Celtic Sea stock is the most important to the Irish fleet. From 2006–2012, catch rates increased for most stocks but declined in the period 2013–2016 in the Celtic Sea and Irish Sea. An increase in catch rate was seen in some areas in 2017 followed by a subsequent decrease in 2018. Irish fleet effort and landings has increased in the Eastern English Channel in recent years, but this fishery is recruitment driven and future catch rates may, therefore, be more variable than in other stocks.

Fishing effort/landings should be managed at the stock level in proportion to changes in spatially referenced standardised catch rate indicators, using data for all fleets, until more comprehensive assessments are developed.

Inshore scallop fisheries can have significant negative effects on marine habitats including sedimentary habitats and biogenic reef. Spatial management of scallop fishing should be used to protect such habitat

10.2 *Issues relevant to the assessment of scallop*

No analytical assessments are currently undertaken. Size and age data are available from opportunistic sampling of landings from Irish vessels and a series of annual surveys undertaken in the period 2000−2005 in the Celtic Sea. More recent surveys in the Celtic Sea and the Tuskar/Barrels area of the South Irish Sea have resulted in relative biomass estimates for the areas surveyed. Spatial variability in growth rates in particular indicates the need for a spatially explicit approach to assessment and, therefore, the need for spatially explicit and systematic sampling programmes.

The main uncertainty in survey estimates is catchability which varies according to ground type. Surveys carried out in the Celtic Sea have indicated that scallops are present in densities up to five times higher on coarse sediments, comprised mainly of gravel, compared to sand sediments. Geostatistical analysis of survey data can allow these differences across ground types to be taken into account, but only when a complete seabed/substrate map is available for the surveyed area.

A number of other approaches to assessment have been explored including depletion assessment of commercial catch and effort data with variable success. Age-based stock assessment methods commonly applied to exploited aquatic species are used in some countries for the assessment of scallop. However, these methods rely on the collection of accurate age data which is difficult to obtain for some stocks such as the Celtic Sea.

10.3 *Management units*

Offshore scallop stocks in the Irish Sea, Celtic Sea and Western and Eastern English Channel are spatially discrete (Figure 60), but some can be variously interconnected during larval dispersal. Larval dispersal simulations show connectivity between the south Irish Sea and north east Celtic Sea, but limited east-to-west connectivity across the south Irish Sea between stocks in Cardigan Bay and off the Irish coast. There is also a general separation of stocks in the Northern Irish Sea and around the Isle of Man from stocks further south.

Inshore stocks are small and limited in distribution within bays on the south west and west coasts and are regarded as separate populations to the offshore stocks.

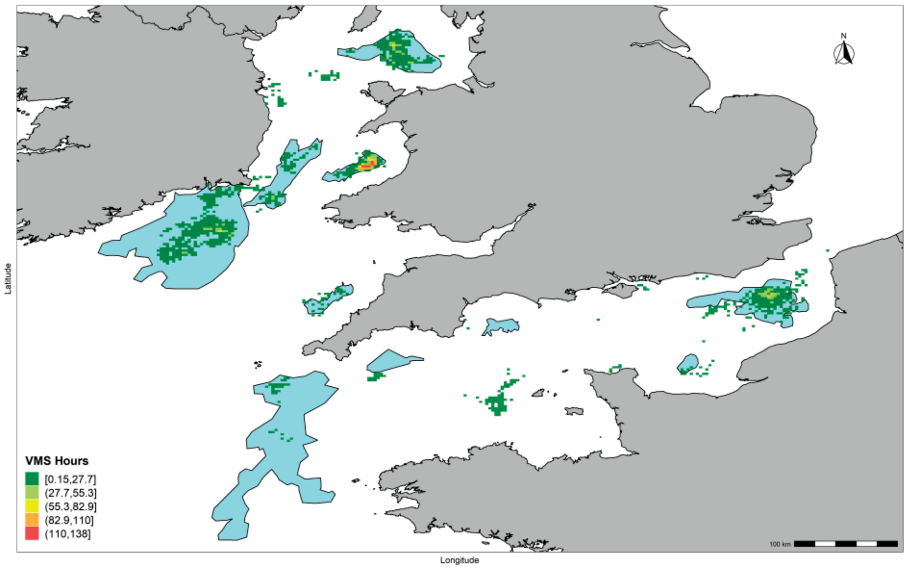

Figure 60. **Scallop grounds fished by the Irish fleet in the Irish Sea, Celtic Sea and English Channel. Boundaries are defined from the distribution of fishing activity by the Irish fleet 2000–2015 as shown by VMS data and some UK VMS data. The stock boundary limits are likely to be larger particularly in inshore areas of the Irish Sea and English Channel considering that the UK and French fleets fish mainly in these areas. VMS data from the offshore Irish fleet for 2021 (raster 3 km^2 grid) are shown relative to the spatial extent of the stocks that are fished.**

10.4 *Management measures*

In Ireland the capacity of the scallop fleet over 10 m in length has been limited (ring fenced) since 2006 and an authorisation is required to fish for scallop. The total annual effort (kwdays) of the fleet is also capped by the Western Waters agreement (EC 1415/2004). Given the relationship between vessel length and dredge number the number of dredges in the fleet can be predicted annually from the length of the vessels authorised. Since 2012 the number of dredges in the fleet varied from 198-230 compared to the estimated 522 dredges prior to the decommissioning of part of the fleet in 2006.

The minimum landing size (MLS) is 100 mm shell width for most of the offshore stocks other than those in the Irish Sea north of 52.5°N where the MLS is 110 mm. For some inshore stocks, MLS of up to 120 mm are used locally by agreement or as conditions established by shellfish co-operatives that may have aquaculture licences to manage scallop stocks locally e.g. Cill Chiaráin Bay, Co. Galway.

Scallop fishing is excluded from areas supporting sensitive habitats. These include seagrass, maerl and reef communities in Roaringwater Bay, Co. Cork and Blacksod Bay, Co. Mayo, as well as the SACs established south of the Saltee Islands and Hook Head, Co. Wexford.

10.5 *Offshore scallop fisheries*

10.5.1 Landings

Landings increased from 1995–2004 due to fleet expansion of the geographic areas fished, particularly in the Celtic Sea (Figure 61). The Irish fleet also began to target scallop in the north east Irish Sea around the Isle of Man and in the Western Approaches to the English Channel. The fleet was partly decommissioned in 2006 and restricted in capacity thereafter and landings consequently declined. New vessels entered the fleet after 2006 and landings increased to an all-time high by 2013. Other than in 2020 total landings have remained above 2,000 tonnes per annum since 2013 (Figure 61).

The majority of landings by Irish vessels are usually from the Celtic Sea, although the Eastern English Channel has become an increasingly important area for the fleet in recent years (Figure 61). The increase in landings from the Eastern English Channel since 2016 is correlated with a decline in landings from the Irish Sea (Figure 61).

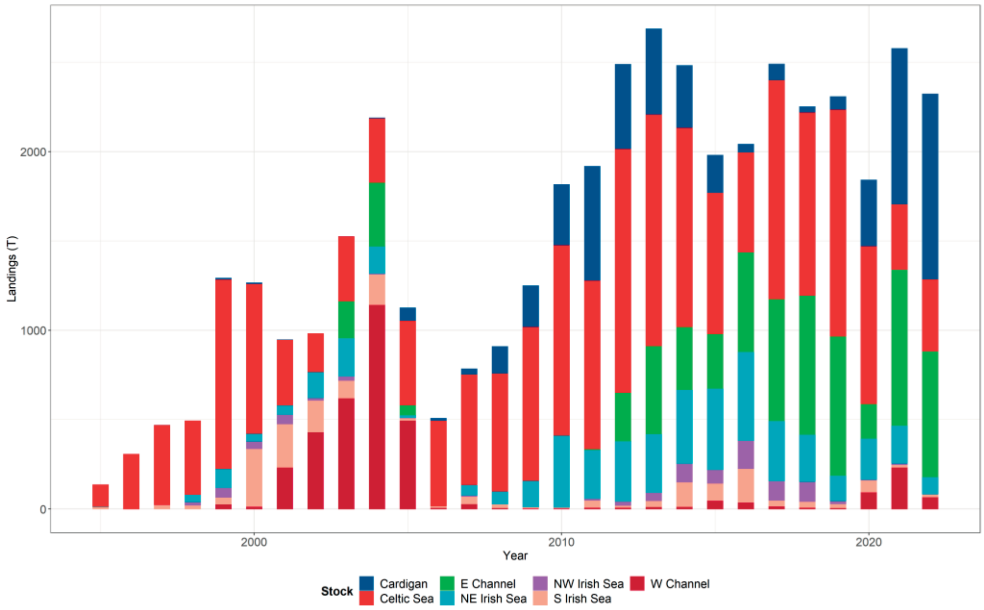

Figure 61. Annual landings of scallop by the Irish fleet from stocks in the Celtic Sea, Irish Sea and English Channel areas 1995–2022.

10.5.2 Catch rate indicators

In the Celtic Sea, catch rates ranged from 20–60 kgs.dredge^{-1}.day^{-1} up to 2006 and increased to 80 kgs.dredge^{-1}.day^{-1} from 2010–2012 (Figure 62). Generally, catch rates follow similar trends across the areas fished. Catch rates declined between 2010 and 2016 in most areas and fluctuated in 2017 and 2018. Catch rates declined substantially in the Western English Channel in 2018, although landings and effort in this area has been negligible since 2006. The most notable trend in recent years is from the Eastern English Channel where catch rates peaked at 160 kgs.dredge^{-1}.day^{-1} in 2016 (Figure 62) which is more than double that of any other area prior to 2019. The Cardigan Bay area and western Channel have also yielded high catch rates in recent years. The Irish fleet fish in the eastern Channel during winter months (November–

February), which was previously the time when the fleet targeted the north east Irish Sea area south of the Isle of Man. In addition, there has been a decreasing trend in recent years in the NW Irish Sea with no landings reported from this area in 2022.

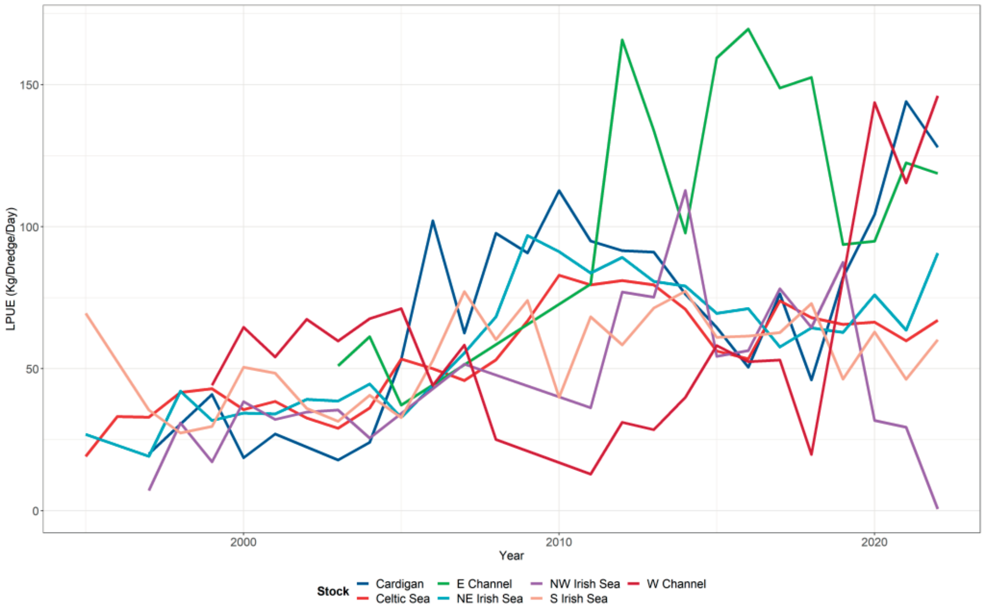

Figure 62. Annual average catch rate (kgs.dredge^{-1}.day^{-1}) from the main scallop stocks fished by the Irish fleet 1995–2022.

10.6 *Scallop surveys and Biomass Assessment*

10.6.1 Comharchumann Sliogéisc Chonamara (Galway) Survey 2022

Scallop surveys were carried out on the 30th November and 1st December 2022 on the scallop (*Pecten maximus*) beds of Cill Chiaráin and Caisín Bays. A total of 43 tows were completed in Cill Chiaráin and Caisín Bays using 3 x 0.75 m wide spring-loaded scallop dredges. Scallop catch and bycatch were recorded, weighed and measured on board from each tow. These surveys are a follow-on from surveys previously undertaken by the Marine Institute in these areas in November 2019 and October 2021. The local shellfish co-operatives, Comharchumann Sliogéisc Chonamara (CSC), minimum landing size for scallop is 120 mm shell width which is equivalent to 104 mm shell height. The survey dredges use commercial ring sizes and are, therefore, unlikely to select 1 or 2-year-old scallops or to provide evidence of recent recruitment.

10.6.2 Biomass in 2022

Density of all scallops and scallops over 120 mm shell width (104 mm equivalent in shell height) in Cill Chiaráin Bay, uncorrected for catchability, varied from 0.0029-0032 kgs.m^{-2} and 0.0022-0.029 kgs.m^{-2} respectively (Figure 63).

The total biomass of scallops and scallops over 120 mm shell width in the survey area of 2.8 Km^2, uncorrected for catchability, was estimated to be 45.5 tonnes and 40.7 tonnes respectively (Table 24). A decrease on the biomass estimates from the 2021 survey of 58 tonnes.

Table 24.Estimates of scallop biomass (uncorrected for dredge efficiency) in Cill Chiaráin Bay survey area, November/December 2022.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for Dredge Efficiency				
Biomass_*Pecten maximus*	45.5	46.2	39.5	52.5
Biomass_>120mm_ *Pecten maximus*	40.7	41.4	35.8	47.4

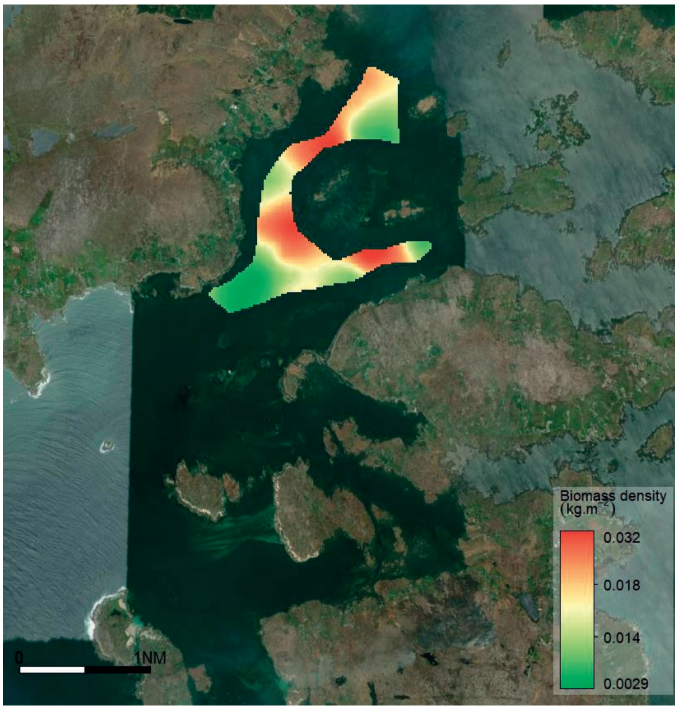

Figure 63. Distribution and biomass of all sizes of scallop (uncorrected for dredge efficiency) in Cill Chiaráin Bay, November/December 2022.

Density of all scallops and scallops over 120 mm shell width in Caisín Bay, uncorrected for catchability, varied from 0.00003-0.019 $kgs.m^{-2}$ and 0.00003-0.011 $kgs.m^{-2}$, respectively (Figure 64).

The total biomass of scallops and scallops over 120 mm shell width in the survey area of 1.28 Km^2, uncorrected for catchability, was 9.6 tonnes and 6.8 tonnes, respectively (Table 25). The biomass of commercial size scallop therefore comprises 70 % of the total stock biomass estimated to be present in Caisín Bay. The slight increase on the 8.8 tonnes estimated from the 2021 survey is most likely explained by the slightly larger area surveyed in 2022.

Table 25. Estimates of scallop biomass (uncorrected for dredge efficiency) in Caisín Bay survey area, October 2021.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for Dredge Efficiency				
Biomass_ *Pecten maximus*	9.6	9.7	7.2	12.9
Biomass_>120mm_ *Pecten maximus*	6.8	7.0	5.3	9.2

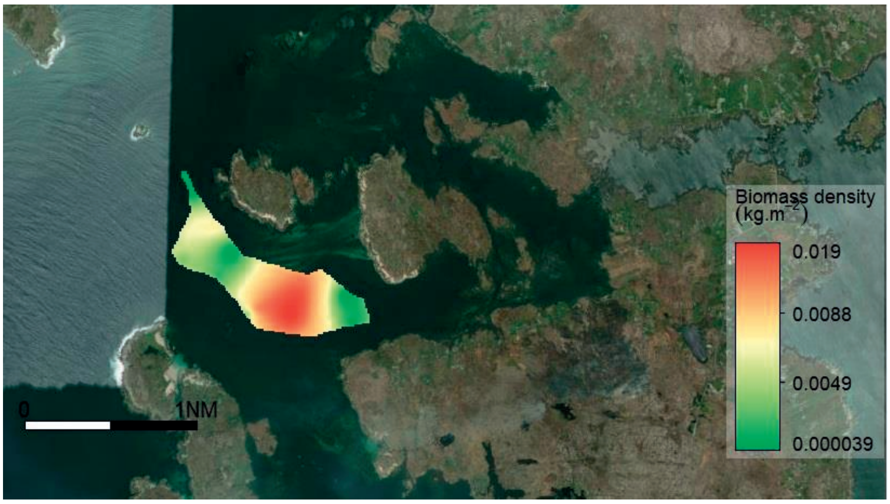

Figure 64. Distribution and biomass of all sizes of scallop (uncorrected for dredge efficiency) in Caisín Bay, December 2022.

10.6.3 Size distribution

The size distribution of scallop in Cill Chiaráin Bay showed a strong mode at ~117 mm shell height (Figure 65), and a smaller mode at 90 mm. Size distributions are similar to those recorded during the 2021 survey. The size distribution of scallop in Caisín Bay showed a mode at ~110 mm (Figure 66).

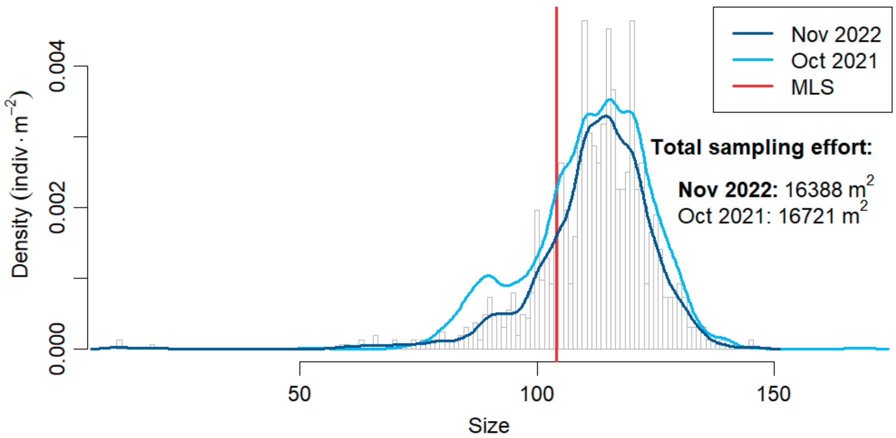

Figure 65. Size distribution and densities of scallop in Cill Chiaráin Bay December 2022. The size data presented here are measurements of scallop shell height (mm). Vertical red line corresponds to the CSC MLS of 120 mm shell width. The size distribution of scallop from the October 2021 survey is included for comparison.

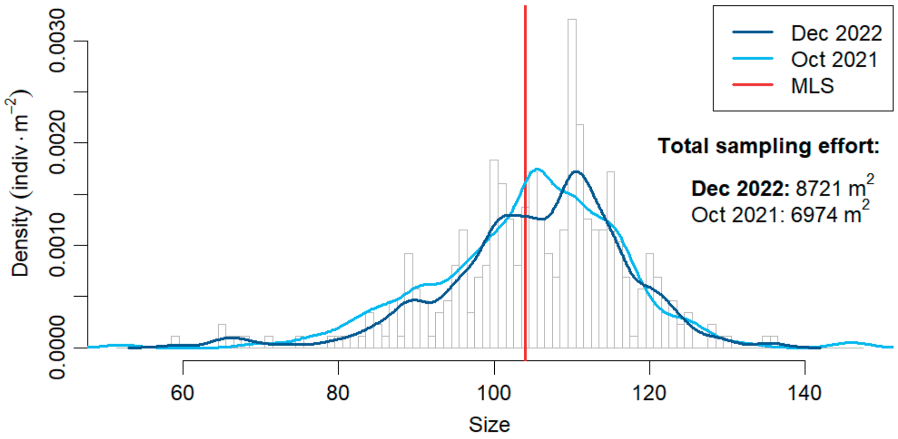

Figure 66. Size distribution and densities of scallop in Caisín Bay December 2022. The size data presented here are measurements of scallop shell height (mm). Vertical red line corresponds to the CSC MLS of 120 mm shell width. The size distribution of scallop from the October 2021 survey is included for comparison.

11 Whelk (*Buccinum undatum*)

11.1 *Management Advice*

Whelk stocks are managed through a minimum landing size (MLS) regulation of 45mm shell height. The main whelk fishery occurs in the south Irish sea, from Howth to Rosslare, with a smaller fishery north of Malin Head, Co. Donegal.

A preliminary assessment on trends in mortality for Counties Dublin, Wexford and Wicklow has been estimated from monthly port sampling data. Mortality rates increased off Wexford and Wicklow in recent years, whereas mortality rates off Dublin were stable. These mortality estimates are substantially higher than older estimates in the area. The high spatial variability in size distribution, growth and difficulty in estimating growth increases the uncertainty around growth parameters and therefore the subsequent estimation of mortality. More resolved analysis at a finer spatial scale which could account for this variability is required.

The size at maturity is significantly higher than the MLS and the reproductive potential of the stock may not be sufficiently protected. Whelk have no larval dispersal phase and are vulnerable to local depletion.

Improved estimates of biological parameters are needed to provided better estimates of mortality rates. Catch rate indicators should be developed as a feasible method to monitor changes in stock status and to provide advice on the fishery.

11.2 *Issues relevant to the assessment of the whelk fishery*

Common whelk have been fished commercially in the south Irish Sea, from Howth to Rosslare, since the 1960s.The fishery expanded in the early 1990s due to a new markets in South Korea and Japan. The fishery is managed by a minimum landing size of 25 mm shell width equivalent to 45 mm shell height. Biological characteristics such as growth rate and size at maturity are known to vary geographically.

Area based assessment and management within the Irish Sea may be necessary given the probably complex population structure and spatial variability in growth and reproduction. Sampling requirements for length or age based assessments are onerous given the spatial and seasonal variability in size composition and growth rates. The size at maturity is well above the minimum landing size (MLS) and it is, therefore, not feasible to manage solely using MLS. Increasing the MLS to the average size at maturity would severely limit landings.

Data provision is currently limited to sampling at processing plants and provision of catch and effort data by a small number of vessels through the Sentinel Vessel Programme (SVP).

11.3 *Management units*

Although whelk are common in many areas around the Irish coast commercial sized populations occur only in the Irish Sea south of Howth and to a much lesser extent in a small area north of Malin Head, Co. Donegal. Whelks do not have a dispersive larval phase so dispersal capacity is limited. Individual stocks almost certainly exist in different coastal areas. In the southern Irish Sea size composition, growth rates and size at maturity all vary spatially suggesting some degree of isolation of stocks in different areas although all of these biological characteristics could also be environmentally determined. The physical environment in the south Irish Sea is also dynamic and dispersive which may also play a role in the dispersal of whelk in the region. Nevertheless, if the objective is to control local fishing mortality and to adjust the minimum size to optimise yields and egg production then separate management units could be identified in the south Irish Sea.

11.4 *Whelk Landings Port Sampling Data*

A monthly (where possible) sampling programme to gather size data of whelk (*Buccinum undatum*) in the landings has been undertaken since 2007. Data reported here is from 2015 to 2021. Numbers of whelk measured annually varied from 11,000-22,000 (Table 26, Figure 67). Sample size varied monthly and the landings from many vessels were sampled on each occasion.

Table 26. The quantity of sampling events and whelk measured from 2015-2021.

Year	Number of Sampling Events	Number of Whelk Measured
2015	9	11,838
2016	11	23,385
2017	12	22,860
2018	11	21,744
2019	12	18,181
2020	11	15,737
2021	11	15,561

11.5 *Mortality estimates*

11.5.1 Methods

A preliminary assessment of the trends in total morality (Z = natural and fishing mortality), was undertaken for Counties Dublin, Wicklow and Wexford using the port sampling data. Whelk exhibit a highly resolved spatial variability in size distribution, maturity and growth parameters, and it is likely that by aggregating to county level local trends will be hidden. Nevertheless, this was deemed necessary for the current analysis, as raising of the size distribution to the total landings at harbour level is not currently possible due to data constraints. By aggregating to county level, potential biases in the sampling programme regarding sampling of grades in the landings is minimised. The results shown in this report, are a preliminary analysis.

The Beverton-Holt length based mortality estimator, and a generalization of the Mean-Length estimator (MLZ) (which removes some of the model assumptions required by the Beverton-Holt method that may not be met in the case of whelk), were used. The rationale in both methods is to track the changes in the length distribution of the portion of the stock that is vulnerable to fishing. They both require growth parameters from the von-Bertalanffy growth function (asymptotic length (L_{∞}) and growth coefficient (K)) and a known length at first capture (smallest size at which individuals are fully vulnerable to the fishing gear (L_c)). Growth parameters and associated uncertainty were estimated using the port sampling data for all counties combined.

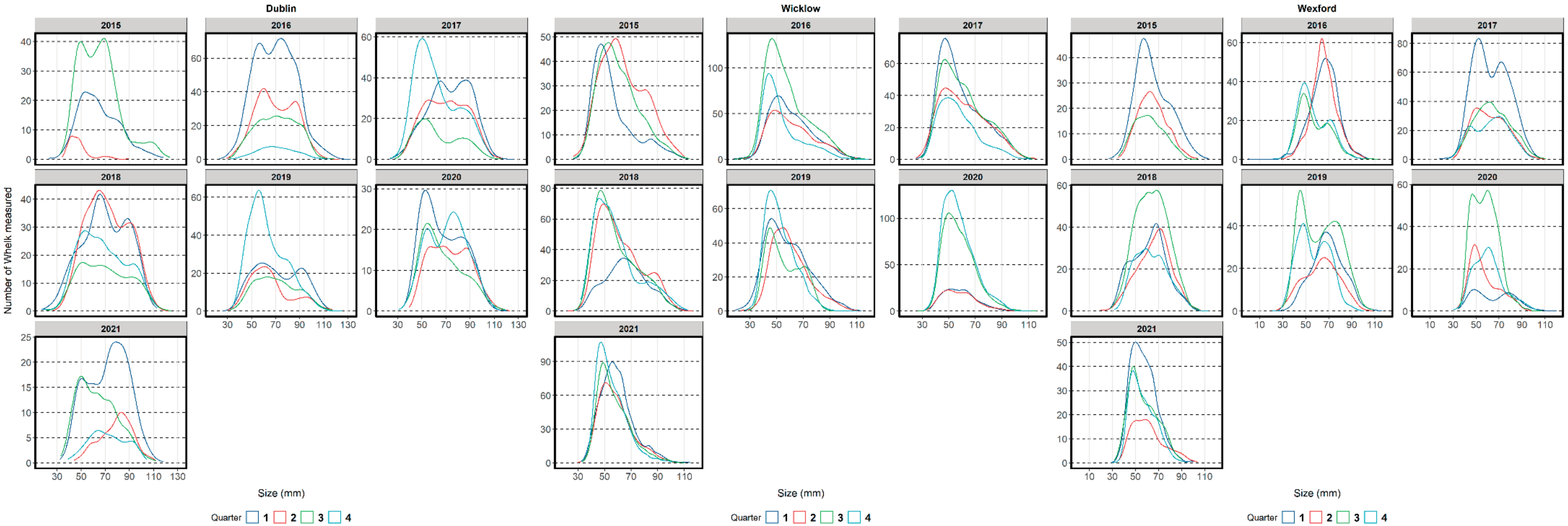

Figure 67. Size distribution by Quarter by Year from Dublin, Wexford and Wicklow (Source: MI Port Sampling data 2015-2021).

11.5.2 Results

Growth rate estimates (L_{oo}= 94.08 ± 0.21; K=0.74 ± 0.12) are within the range of the previous coefficients reported in the literature for this species. The growth coefficient (K), however, is substantially larger than those reported by Fahy *et al*., 1995 in the area, but similar to those reported in other regions. Fahy *et al*., 1995 determined whelk age by counting the number of rings on the surface of the operculum (Table 27). This methodology was later found to have limited success in contrast with the novel statolith age determination technique (Hollyman *et al*., 2018) (Table 27). The chosen value of L_c scales up or down the final estimate of Z, as it provides the threshold to assess changes in the size distribution of the stock vulnerable to fishing. A range of values of L_c (30-55 mm) were assessed, and Z estimates were stable when L_c > 45 mm.

Table 27. Von Bertalanffy life history parameters for whelk previously reported in the literature

Reference	Region	L_{oo}(mm)	K
Fahy *et al.*, 1995	Ireland – Courtown	115.5	0.08
Fahy *et al.*, 1995	Ireland – Howth/Kish	121.7	0.13
Fahy *et al.*, 1995	Ireland – South Irish Sea	121.6	0.11
Hollyman *et al.*, 2018	Scotland - Shetland	122.2	0.55 ± 0.02
Hollyman *et al.*, 2018	Wales – Menai Strait	80.04	0.88 ± 0.02
Hollyman *et al.*, 2018	Jersey	68.57	0.97 ± 0.06

Estimates of Z for both methods are shown in Figure 68. The Beverton-Holt method estimates annual Z rates while MLZ estimates the point in time in which total mortality changed. Only three estimates are provided for Wexford and Wicklow, whereas the MLZ estimate for County Dublin has been replicated, as it remained constant. There was good agreement across methods, both in terms of scale and trends in total mortality. Total mortality has remained stable in county Dublin at ~ 0.6, whereas it increased significantly in Counties Wexford and Wicklow from ~ 1-1.2 to ~ 1.8 in the last two to three years of the time series.

Previous estimates from Fahy *et al*., 1995 in the region ranged from 0.5-0.9 depending on the method and area of study. Estimates provided in this report are considerably higher, particularly for Wexford and Wicklow in the last years of the time series. Landings in Wicklow have increased considerably in recent years, but this trend is not observed in Wexford (Figure 69). Even if the observed increase in Z was driven by increased fishing mortality, it is unlikely these stocks could support such high levels of exploitation. The scale of Z is highly dependent on the growth parameter estimates, and, as mentioned before, whelk exhibits high spatial variability in growth coefficients. Estimation of growth coefficients and subsequent estimation of Z at a more spatially resolved scale is deemed necessary. Work is ongoing in this regard by raising the sample size distribution to the local landings.

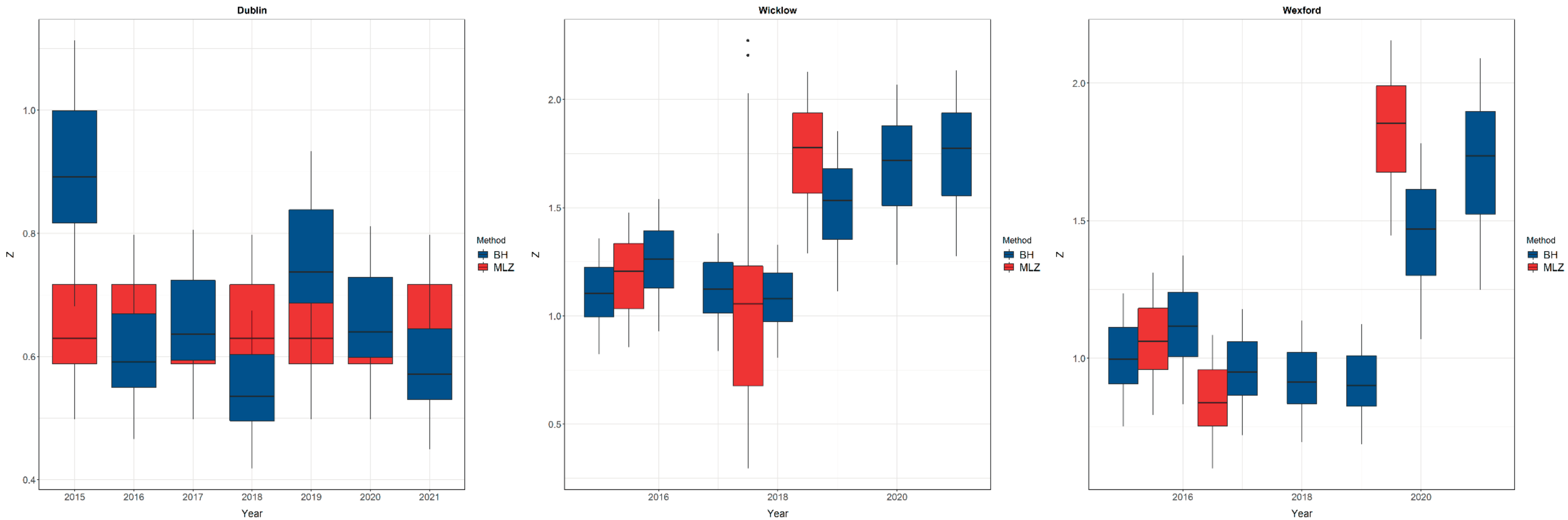

Figure 68. Total mortality (Z) estimates for Counties Dublin, Wexford and Wicklow using the Beverton-Holt and Mean Length estimators.

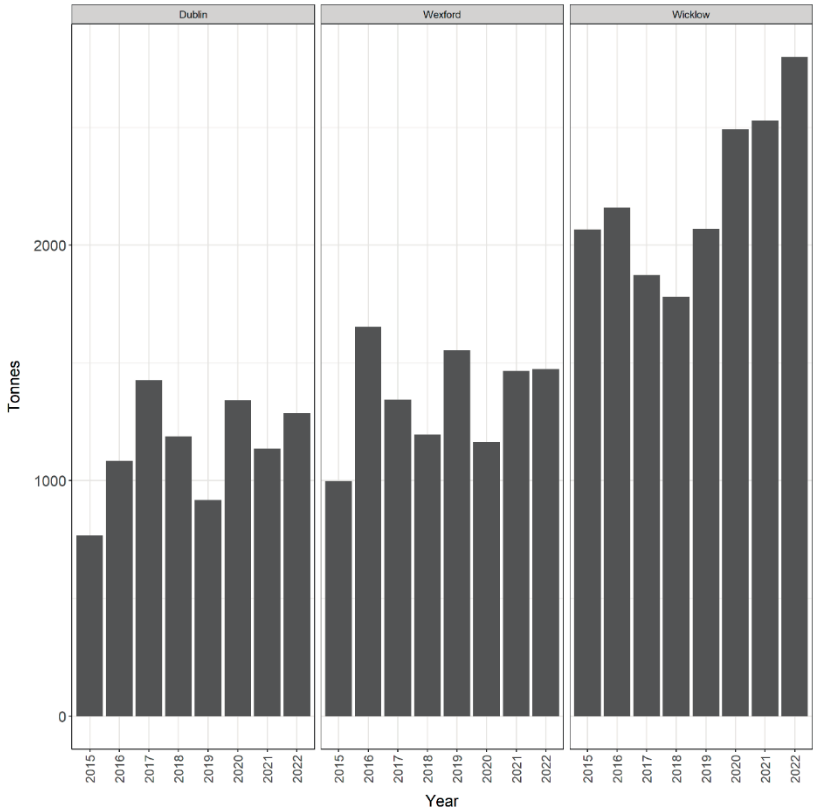

Figure 69. Whelk landings by County (Source: Logbook declarations and sales notes for vessels under 10 m 2015-2022).

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13 Glossary

Accuracy A measure of how close an estimate is to the true value. Accurate estimates are unbiased.

Benthic An animal living on, or in, the sea floor.

Bonamia (ostrea) A parasite of native oyster which infects the blood cells and causes mortality of oysters.

Biomass Measure of the quantity, e.g. metric tonne, of a stock at a given time.

Bi-valve A filter feeding mollusc with two shells e.g. scallops, cockles.

Cohort (of fish) Fish which were born in the same year.

Cultch Shell material deposited on the seabed to provide settlement surface for oyster larvae.

Ecosystems are composed of living animals, plants and non-living structures that exist together and 'interact' with each other. Ecosystems can be very small (the area around a boulder), they can be medium sized (the area around a coral reef) or they can be very large (the Irish Sea or even the eastern Atlantic).

Exploitation rate The proportion of a population at the beginning of a given time period that is caught during that time period (usually expressed on a yearly basis). For example, if 720,000 fish were caught during the year from a population of 1 million fish alive at the beginning of the year, the annual exploitation rate would be 0.72.

Fishing Effort The total fishing gear in use for a specified period of time.

Fishing Mortality Deaths in a fish stock caused by fishing usually reported as an annual rate (F).

Fishery Group of vessel voyages targeting the same (assemblage of) species and/or stocks, using similar gear, during the same period of the year and within the same area (e.g. the Irish flatfish-directed beam trawl fishery in the Irish Sea). Also referred to as a metier.

Fishing Licences A temporary entitlement issued to the owner of a registered fishing vessel to take part in commercial fishing.

Fleet Capacity A measure of the physical size and engine power of the fishing fleet expressed as gross tonnage (GTs) and kilowatts (KWs).

Fleet Segment The fishing fleet register, for the purpose of licencing, is organised in to a number of groups (segments).

Growth overfishing Reduced yields of fish due to reduction in average size/weight/age caused by fishing mortality and indicating that the rate of fishing is higher than the rate at which fish grow to given sizes to replace those being removed

Management Plan is an agreed plan to manage a stock. With defined objectives, implementation measures or harvest control rules, review processes and usually stakeholder agreement and involvement.

Management Units A geographic area encompassing a 'population' of fish de-lineated for the purpose of management. May be a proxy for or a realistic reflection of the distribution of the stock.

Minimum Landing Size (MLS) The minimum body size at which a fish may legally be landed.

Natura A geographic area with particular ecological features or species designated under the Habitats or Birds Directives. Such features or species must not be significantly impacted by fisheries.

Natural Mortality Deaths in a fish stock caused by predation, illness, pollution, old age, etc., but not fishing.

Polyvalent A type of fishing licence. Entitlements associated with these licences are generally broad and non-specific. Vessels with such licences are in the polyvalent segment of the fishing fleet.

Precision A measure of how variable repeated measures of an underlying parameter are.

Quota A portion of a total allowable catch (TAC) allocated to an operating unit, such as a Vessel class or size, or a country.

Recruitment The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year. This term is also used in referring to the number of fish from a year class reaching a certain age. For example, all fish reaching their second year would be age 2 recruits.

Recruitment overfishing The rate of fishing, above which, the recruitment to the exploitable stock becomes significantly reduced. This is characterised by a greatly reduced spawning stock, a decreasing proportion of older fish in the catch, and generally very low recruitment year after year.

Reference points Various reference points can be defined for fished stocks. These can be used as a management target or a management trigger (i.e. point where more stringent management action is required). Examples include fishing mortality rate reference points, biomass reference points, indicator eg catch rate reference points or those based on biological observations.

Sales Notes Information on the volume and price of fish recorded for all first point of sale transactions.

Shellfish Molluscan, crustacean or cephalopod species that are subject to fishing.

Size composition The distribution, in size, of a sample of fish usually presented as a histogram.

TAC Total Allowable Catch

Vivier A fishing vessel, usually fishing for crab, with a seawater tank(s) below decks, in which the catch is stored live.

VMS Vessel Monitoring System. Vessels report GPS position periodically when fishing

V-notch A conservation measure used in lobster fisheries in Ireland and elsewhere whereby lobsters marked with a v-notch are protected from fishing

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