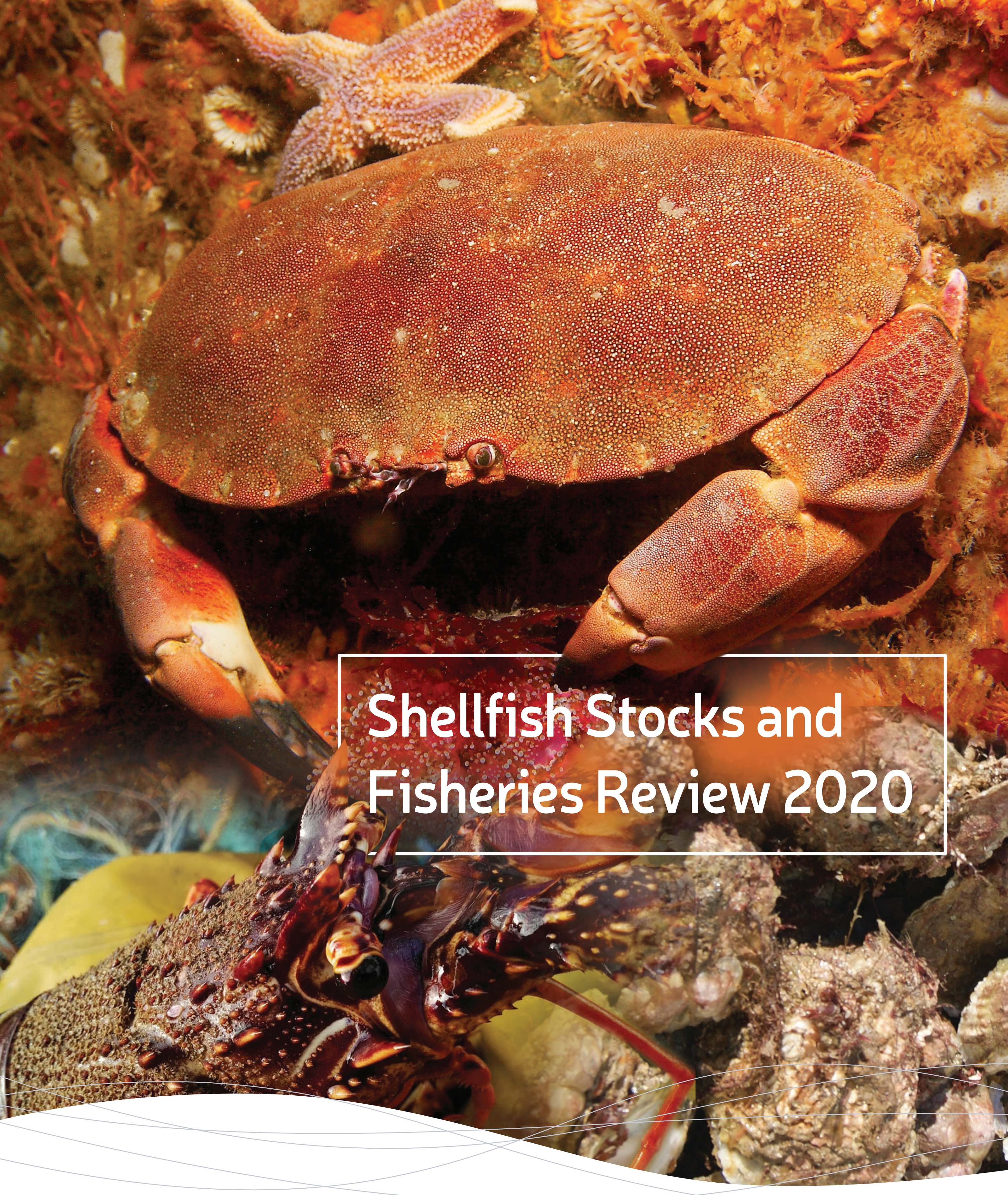

Shellfish Stocks and Fisheries Review 2020

BIM Ireland's Seafood Development Agency

Foras na Mara Marine Institute

Shellfish Stocks and Fisheries

Review 2020

An assessment of selected stocks

The Marine Institute and Bord Iascaigh Mhara

The data that underpins the advice provided in this book is collected under the Data Collection Framework, which is financed by the Irish government and the European Maritime & Fisheries Fund as part of the EMFF Operational Programme for 2014-2020

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Photographs on cover by Jonathan White (Brown Crab – Cancer pagurus), Cian Luck (Crayfish – Palinurus elephas) and Macdara O Cuaig (Oyster – Ostrea edulis)

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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 Communications, Climate Action and Environment (DCCAE) 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 and 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 2020, was 65,099 gross tonnes (GTs) and 1,996 vessels. The polyvalent general segment included 31,828 GTs and 1,390 vessels. The polyvalent potting segment had 329 registered vessels and 696 GTs while the bivalve (specific) segment had 1,261 GTs and 134 vessels. There were 10 beam trawl vessels, 11 scallop vessels over 10 m in the specific segment and 3 in the polyvalent 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 216 vessels more than in 2020.

In 2020 almost 74% 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 134 vessels were under 10 m.

Table 1. Number of vessels by length category in each segment of the Irish sea fishing fleet in 2020.

Segment	Length category					
	<10 m	10-12m	12-15m	15-18m	>18m	Total
Aquaculture	72	6	1	1	16	96
Polyvalent General	1,028	151	57	20	134	1,390
Polyvalent Potting	311	18				329
Specific	74	52	6		2	134
RSW Pelagic					23	23
Specific [Scallops >=10m LOA]		3	1		7	11
Polyvalent [Scallops >=10m LOA]		2	1			3
Beam Trawler					10	10
Total	**1,485**	**232**	**66**	**21**	**192**	**1,996**

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 14 vessels over 10 m in length were authorised to fish for scallops in 2020.

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 owners into the polyvalent general segment. There were 329 such vessels in 2020 compared to 490 in 2007. The number of vessels in the polyvalent general segment increased year on year between 2006 and 2012 but declined year on year from 2012-2020 (Table 2, Table 3, Figure 1).

Table 2. Length and capacity profile of the Irish shellfish fleet 2006-2020 (<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
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
Average GTs					
2006	3.26	4.68	2.96	7.24	4.78
2007	3.75	4.43	2.29	7.06	3.92
2008	3.29	4.20	2.22	6.88	3.80
2009	2.87	4.08	2.22	6.70	3.73
2010	2.72	3.96	2.16	6.73	3.64
2011	2.85	3.91	2.12	6.80	3.61
2012	2.84	3.85	2.10	6.90	3.58
2013	2.71	3.87	2.11	7.09	3.59
2014	2.72	3.92	2.11	7.14	3.62
2015	2.72	3.95	2.10	7.30	3.69
2016	2.87	3.93	2.09	7.50	3.72
2017	2.77	3.97	2.10	7.73	3.79
2018	2.85	3.89	2.12	7.64	3.79
2019	2.84	3.92	2.12	7.52	3.81
2020	2.85	3.89	2.12	7.19	3.75

Average KWs					
2006	45.45	35.49	44.50	65.64	38.72
2007	53.76	34.43	30.29	62.58	34.96
2008	37.68	32.66	29.79	60.44	33.84
2009	33.86	31.45	29.26	57.57	32.75
2010	31.55	30.43	28.93	59.38	31.97
2011	32.89	30.09	28.28	60.32	31.65
2012	33.65	29.60	28.03	61.55	31.42
2013	32.48	29.61	28.06	64.31	31.52
2014	32.11	30.20	28.23	65.84	31.96
2015	32.17	30.38	27.85	67.15	32.31
2016	30.32	30.19	27.35	68.86	32.22
2017	30.72	30.61	28.22	68.76	32.85
2018	31.53	30.27	28.76	67.77	32.98
2019	31.62	30.26	29.02	66.63	32.91
2020	31.78	29.99	28.94	64.13	32.37

Table 3. Annual change and percentage change in the numbers of vessels per fleet segment in the under 13 m Shellfish fleet 2006-2020.

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
2017-2108	1	29	-26	13	17
2018-2109	-4	4	-7	-2	-9
2019-2020	-1	0	-1	-9	-11
% 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
2017-2108	1	2	-7	10	1
2018-2109	-5	0	-2	-1	-1
2019-2020	-1	0	0	-7	-1

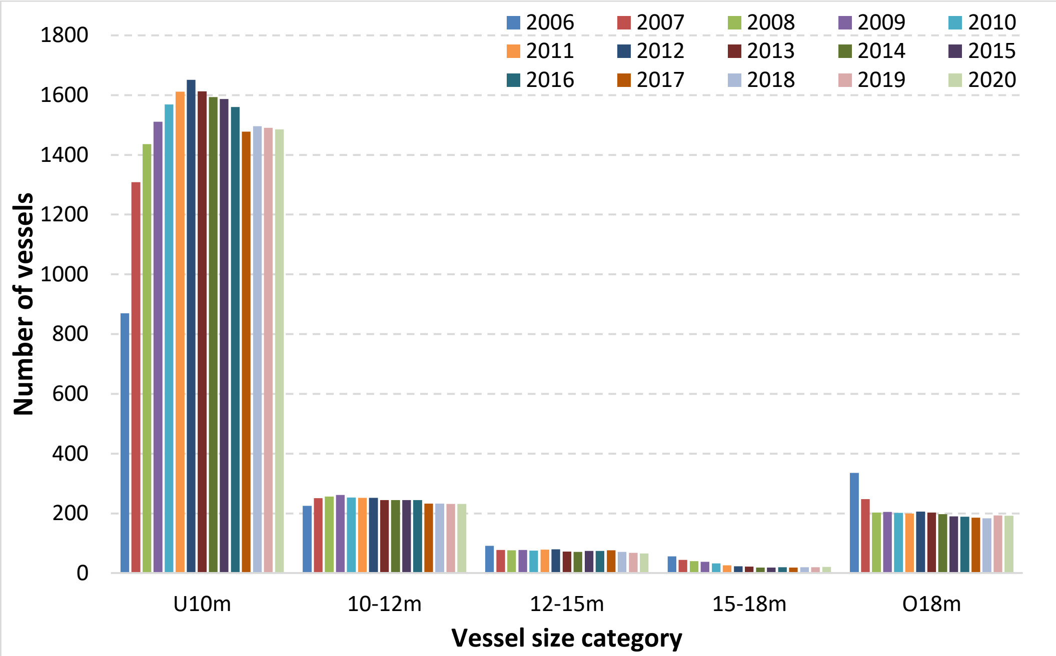


Figure 1. Annual trends in the number of registered sea fishing vessels by length category 2006-2020.

3 Shellfish Landings 2004-2020

Annual landings of crustaceans and bivalves, excluding *Nephrops* and wild blue mussel (*Mytilus*) seed, which is re-laid for on-growing, during the period 2004-2020, varied from a high of 29,000 tonnes in 2004 to a low of 13,790 in 2009. Landings were just under 16,000 tonnes in 2020 (Table 4).

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 (razor clams) provide additional data on landings separate to logbook data or sales notes.

The year 2020 was atypical. The Covid-19 pandemic led to very difficult and restricted markets for fish products across the world including Irelands exports to Europe and Asia. There were significant differences in landings of a number of species in 2020 compared to 2019. Although crab landings declined from 2016-2019 there was a further decline of 3,331 tonnes in 2020 compared to 2019. Scallop and whelk landings fell by 692 and 659 tonnes, respectively, in 2020 compared to 2019. There was an increase in cockle landings solely due to a higher TAC in Dundalk Bay in 2020 compared to 2019.

Total value of shellfish landings, excluding mussel and *Nephrops*, in 2020 was €53.4 million compared to €63.6 million in 2019.

Table 4. Estimates of annual landings (tonnes) and value (€) of crustacean and bivalve shellfish (excl. prawns and mussels) into Ireland 2004-2020 (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. No 2020 value data available for Native oyster at time of print.

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 (tonnes)
2004	14,217	2,471	856	1,674	7,589	405	543	110	291	28	180	80	400	268	207	29,533
2005	9,527	1,277	635	1,139	4,151	151	94	75	245		141	30	404	27	107	18,514
2006	10,827	742	625	1,210	3,144	319	233	172	281	26	153	34	547	46	7	18,522
2007	9,251	953	308	609	3,635	325	291	26	142	14	70	16	356	91	643	16,813
2008	7,640	1,322	498	1,141	1,947	180	88	4	268	55	153	18	451	72	9	13,890
2009	6,614	1,325	431	1,103	2,239	228	327		205	150	443	28	293	244	173	13,908
2010	8,622	1,950	477	1,280	2,976	135	349	748	342	162	415	30	410	129	5	18,121
2011	6,372	2,203	735	64	2,828	111	100	1,002	160	73	290	25	473	74	401	15,017
2012	6,691	2,701	249	103	3,440	152	100	1,479	168	15	818	33	428	253	400	17,030
2013	6,510	3,154	374	218	2,660	157	214	285	365	37	229	34	723	31	374	15,365
2014	7,105	2,834	456	1,135	2,172	301	265	100	283	67	210	23	1,040	49	3	16,043
2015	7,229	2,209	371		3,296	250	153	31	406	48	190	25	840	30	0	15,111
2016	11,181	2,464	398		6,292	361	190	205	289	51	108	8	927	165	321	22,966
2017	10,284	2,649	399		5,089	307	168	48	301	45	118	9	1,005	154	442	21,018
2018	8,963	2,367	343		5,449	238	150	36	233	47	105	9	487	149	446	18,711
2019	8,646	2,383	481	4	6,221	165	150	702	318	44	356	19	585	279	595	20,948
2020	5,335	1,691	423	0	5,562	233		738	312	12	357	13	641	154	1,128	16,622
Unit value 2020	€1.76	€10.54	€13.57	€2.49	€1.56	€15.30		€1.48	€1.93	€2.22	€0.51	€32.20	€5.00	€0.42	€2.30	
Total value 2020 (millions)	**€9.389**	**€17.818**	**€5.737**	**€0.000**	**€8.671**	**€3.565**	**€**	**€1.093**	**€0.602**	**€0.026**	**€0.182**	**€0.409**	**€3.205**	**€0.065**	**€2.660**	**€53.422**

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 individuals during 2002-2008, 10,000-15,000 during 2010-2013 and 25,000-32,000 annually during 2014-2018. The recent figures represent about 16 % of female lobsters landed. Approximately 300 fishermen participate in the programme.

In 2020, 61 % of the reproductive potential in the female portion of the stock consisted of legal lobsters between 87-127 mm, v-notched lobsters, between 87-127 mm, accounted for 12 %, 17 % was protected by the MLS and a further 9 % was accounted for by lobsters above the MaxLS. Approximately 33 % percent of the lobsters above the MaxLS were also v-notched. This double protection is a legacy of previous v-notching prior to introduction of the MaxLS. A combination of the MLS and MaxLS protects 26 % of current reproductive potential and v-notching protects a further 12 %.

Nominal stock status indicators, landings per unit effort, discards per unit of effort and v-notched lobsters per unit of effort showed stable or positive trends during the period 2013-2019 in most coastal areas. The index of undersized lobsters increased from 2015-2017 and was stable in 2017-2019.

Conservation measures should be maintained. The MaxLS is a size refuge for lobsters that have previously been v-notched. 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 is currently 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.

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; at least 600 vessels fish for lobster and it is a high value species. Landings data may be incomplete and compromises the use of different stock assessment methods.

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 and from the sentinel vessel programme (SVP). 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, and from the MI observer programme. This coverage is insufficient to provide precise estimates of catch rate given the variability in these data in time and space. A number of indicators can be estimated from the data including a recruitment index and an assessment of the % of v-notched lobsters in the catch.

4.3 Management units

Lobsters are probably distributed as regional stocks along the Irish coast. In 2006 six management units were proposed based on 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

Between 2002 and 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 (Figure 2).

Lobsters have been v-notched and released off 12 coastal counties reflecting the ubiquitous distribution of lobster fishing off the Irish coast. The increase in numbers released from 2014 onwards was mainly due to an increase in releases in Cork, Mayo and Dublin and in 2017 and 2018 in Donegal (Figure 3).

The percentage of the total landings that were v-notched increased from less than 1 % during 2004-2006 to 8 % in 2018. If the sex ratio in the population is 1:1 and 100 % of v-notched lobsters are female then up to 16 % of female lobster landings have been notched in recent years (Figure 4).

The number of vessel owners participating in the programme was approximately 200 in 2010-2012 and increased to just under 300 in the period 2014-2016. There are approximately 600 vessels registering sales of lobster in sales note and logbook data. The number of v-notching events, involving visits to ports by BIM staff, was generally between 100-200 during 2002-2013 to between 40-60 piers but increased significantly in 2015 to between 700-900 events (Figure 5).

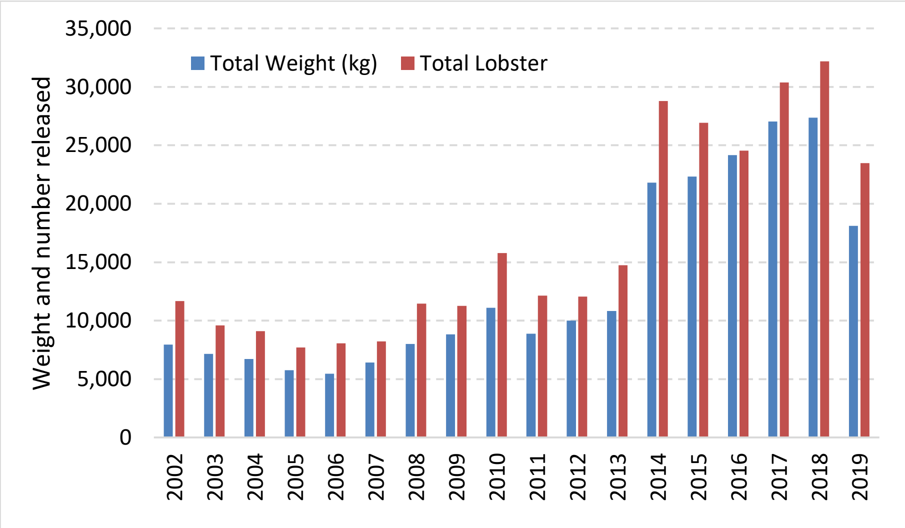


Figure 2. Total number and weight of V-Notched lobsters releases 2002-2019.

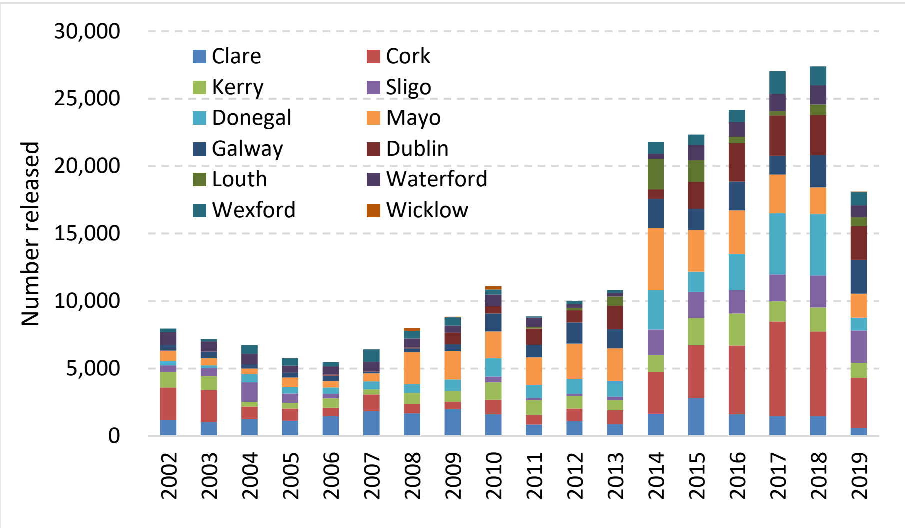


Figure 3. Total number of lobsters released across counties 2002-2019.

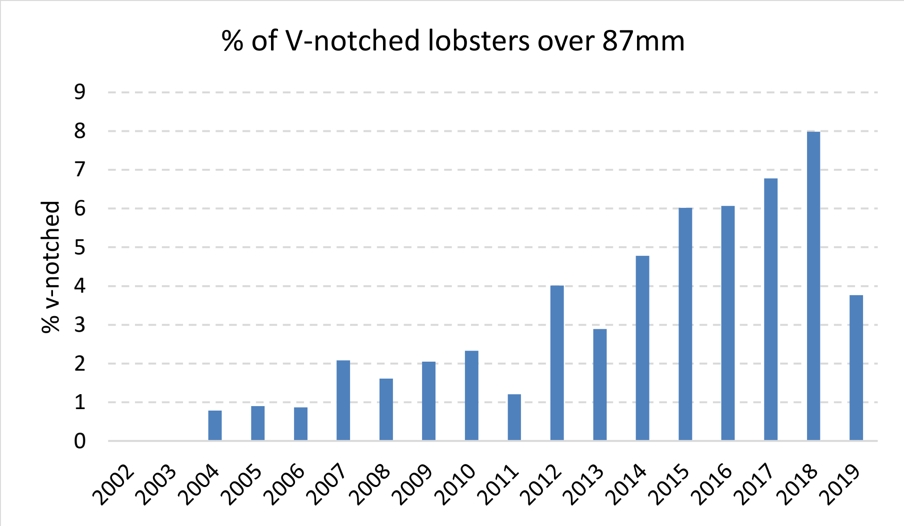


Figure 4. Percentage of lobsters over 87mm v-notched 2004-2019.

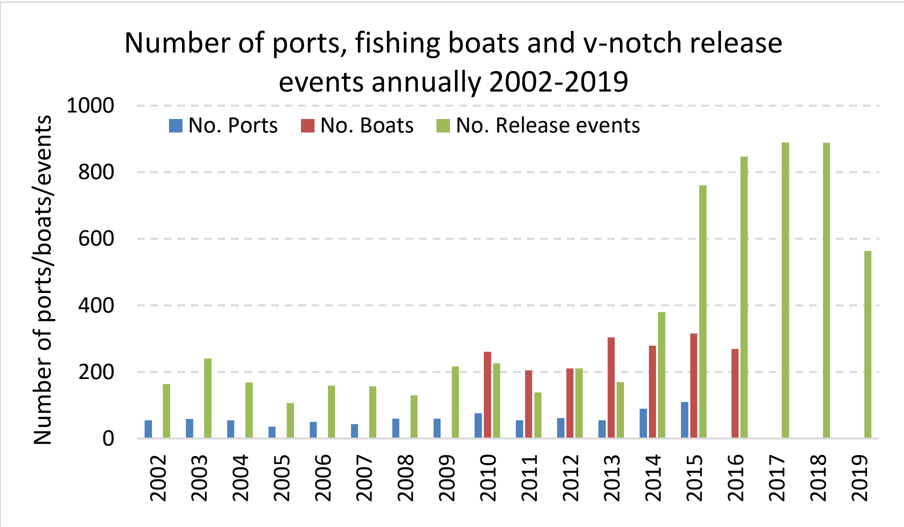


Figure 5. Annual number of ports, fishing boats and V-Notch release events 2002-2019.

4.5.2 Relationship between numbers released and numbers at sea

Evidence of the v-notching and release of lobsters annually should be visible in the catches of these lobsters in the commercial fishery; as the numbers notched and released accumulates the incidence of these lobsters in the commercial catch should increase. This depends on catchability, mortality rates of marked fish, the rate of moulting and repair of the v-notch and emigration from the fishing area.

The index (VPUE) of the size of the v-notched population of lobsters increased from 2016-2019, which corresponds to the increases in the number of lobsters released from 2015. This trend is more apparent in the MI observer data than in the SVP (Figure 6). The SVP data shows no significant increase during that time.

The average annual VPUE is correlated with the cumulative number of v-notch releases in the SVP data. This correlation is not evident in the MI observer data (Figure 6, Figure 7). Monitoring the v-notched component of the lobster population and correlating it with previous releases is difficult because catch rates are low and variable and the quantity of data available to investigate the correlations at local scale is low.

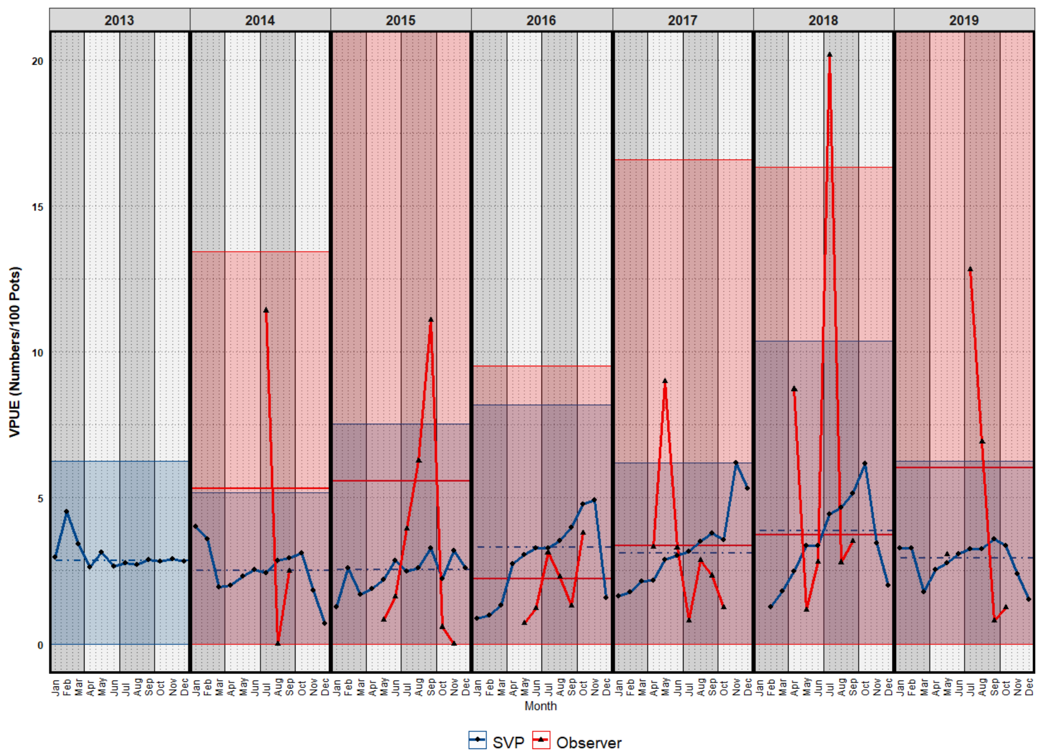


Figure 6. Monthly mean V-Notched lobsters per unit of effort (100 Pots) (VPUE) for the Sentinel Vessel and Observer data 2013-2019. Horizontal lines in each year show annual means with their standard deviation (Blue for SVP and Red for Observer Program). Year quarters are shaded grey and white.

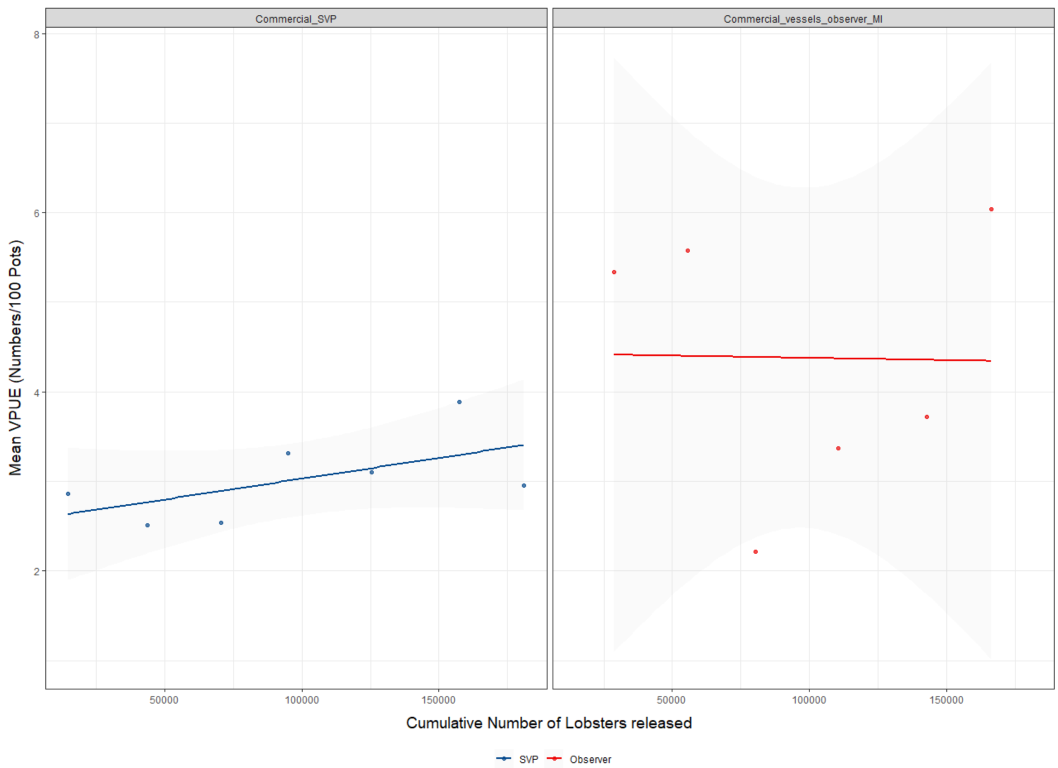


Figure 7. Annual V-notched lobsters per unit of effort (VPUE; 100 pots) during 2013-2019 in the SVP and MI observer data against the cumulative number of lobster releases.

4.6 Reproductive potential

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.

Between 60-70 % of the RP was accounted for by non-notched lobsters between 87-127 mm during 2009-2020 (Figure 8). This is the component of the stock that is subject to fishing mortality. In 2020, 61 % of the RP was accounted for by legal lobsters between 87-127 mm (legal lobsters), 12 % was accounted for by v-notched lobsters between 87-127 mm, 17 % of RP was protected by the MLS and a further 9 % was in lobsters above the MaxLS. Approximately 33 % percent of the lobsters above the MaxLS were also V-notched. A combination of the MLS and MaxLS conservation measures, protects 26 % of current population RP and v-notching protects a further 12 %. These relative contributions varied regionally (Figure 9).

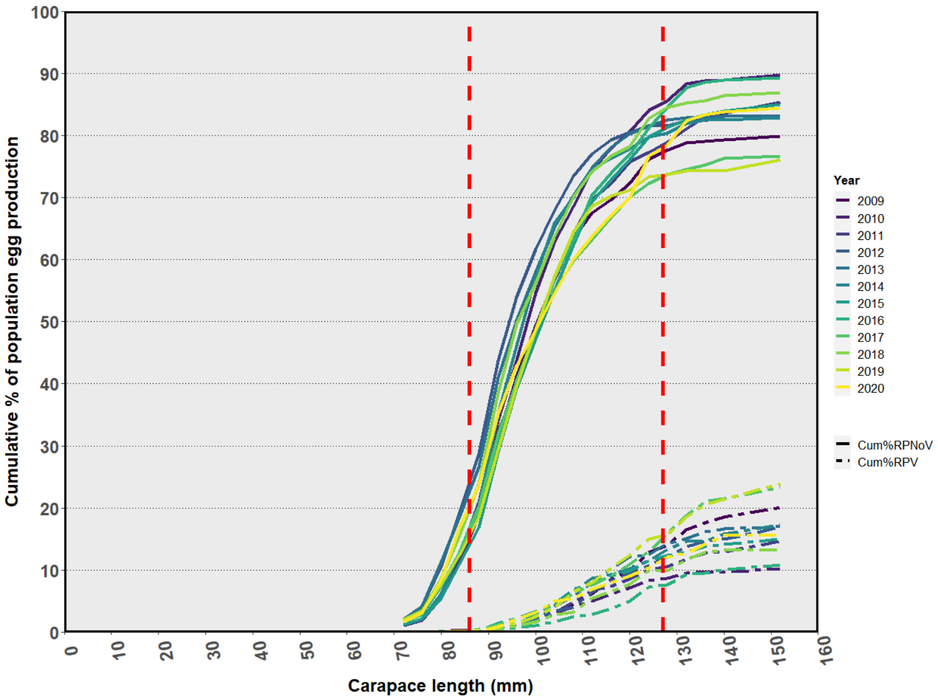


Figure 8. Cumulative distribution of reproductive potential (RP) across size classes of V-notched and non-V-notched lobsters all regions combined. Source: Marine Institute Observer data 2009-2020.

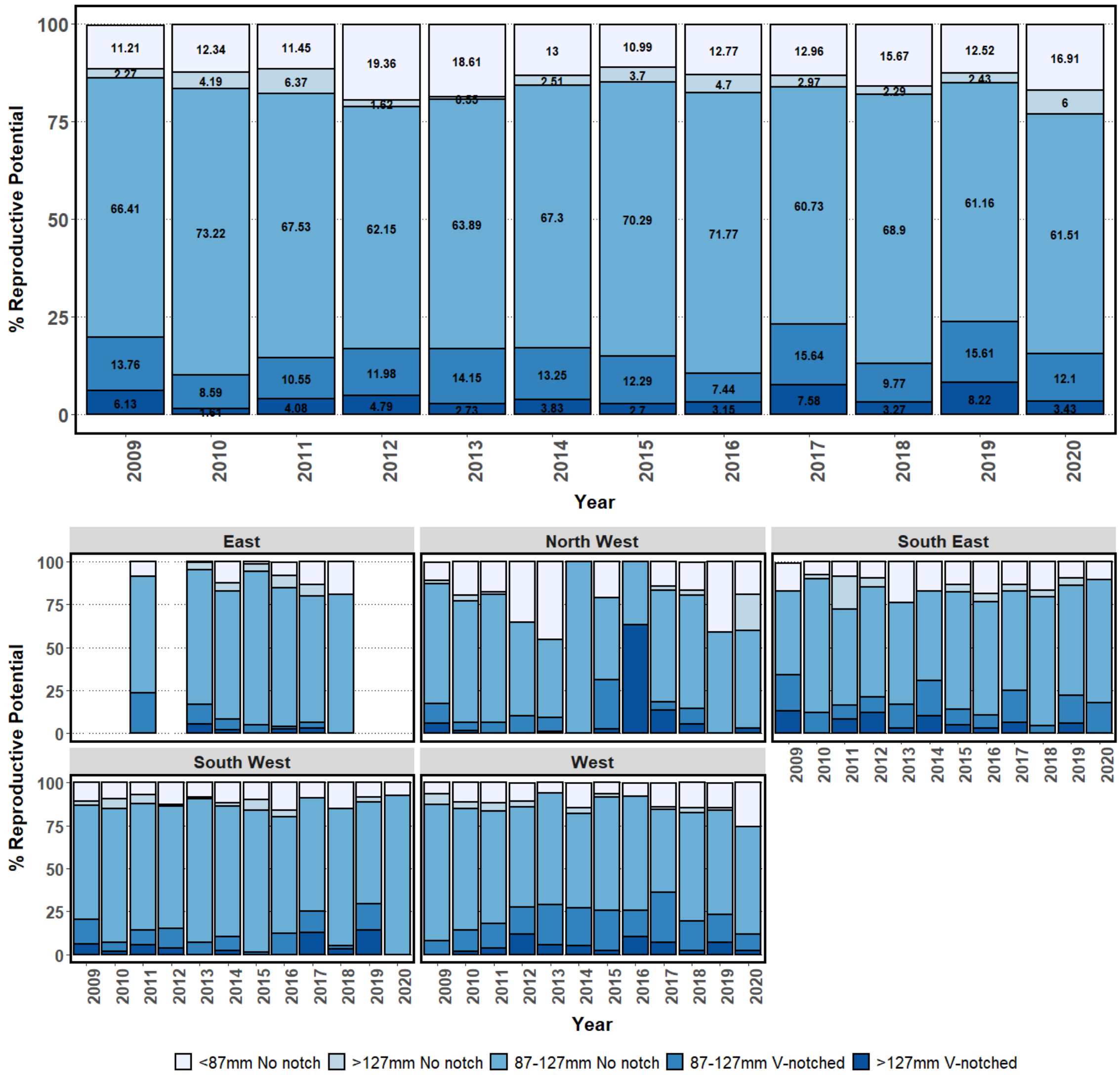


Figure 9. Summary of the distribution of the % reproductive potential in lobster stocks conserved by v- notching, minimum size and maximum size measures for a) all regions combined and b) across regions. Source: Marine Institute Observer data 2010-2020.

4.7 Catch rates

4.7.1 Seasonal and annual trends

This report includes the SVP data from 2013-2019 and the MI observer data from 2014-2019. Data for 2020 is not yet available. 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 ($\mathbf{W}=1.42*10^{-6}\mathbf{L}^{2.84}$) where W is weight and L is carapace length.

The catch rates of legal (LPUE) lobsters and underside (DPUE) lobsters from 2013-2019, all areas combined, were stable (Figure 10). Observer data generally reports higher catch rates, especially for the discarded component. Both data sets show that average annual DPUE increased from 2015-2017 and was stable from 2017-2019. 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.

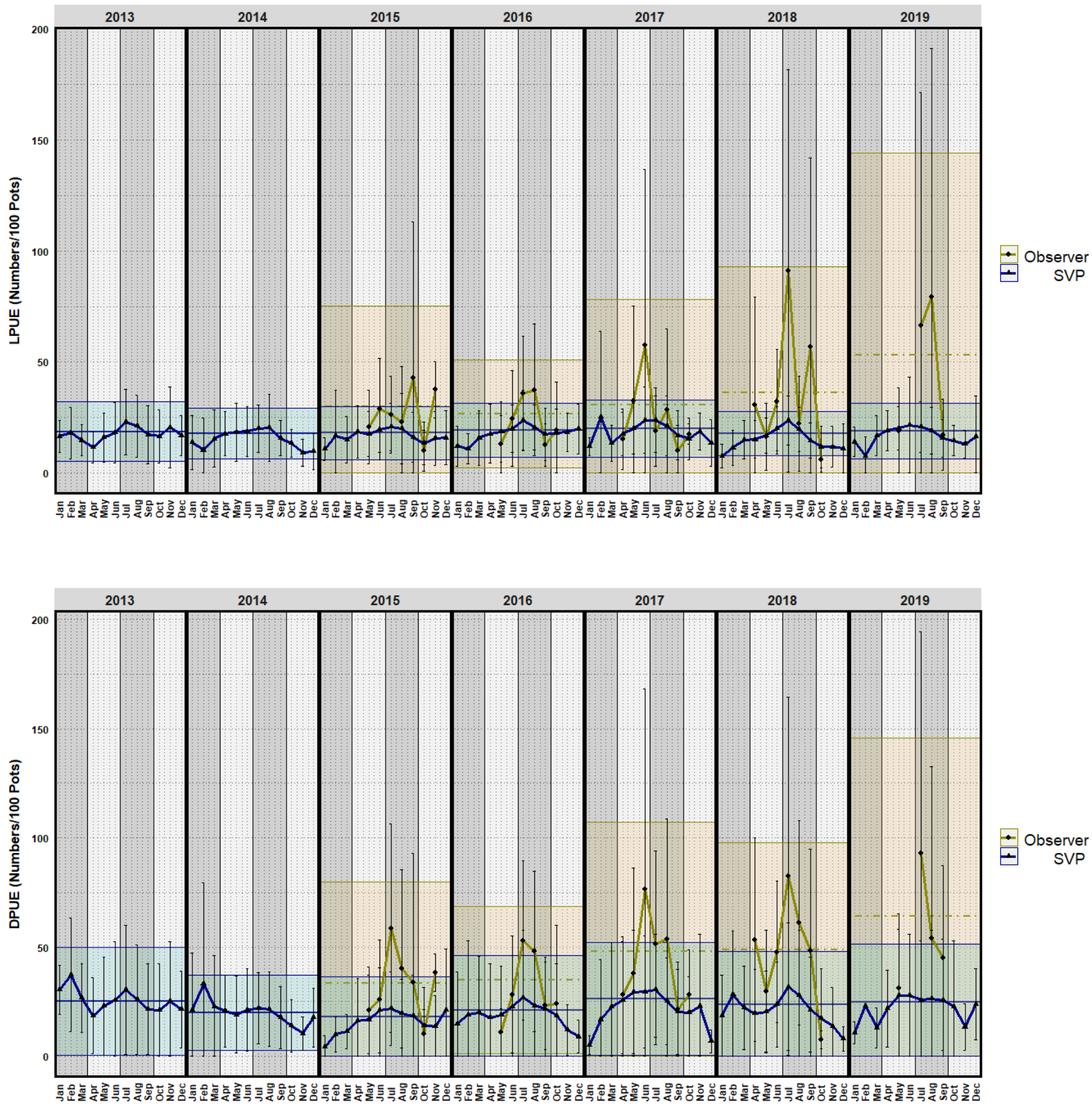


Figure 10. Annual mean landings (top; LPUE) and undersized discards (bottom; DPUE) of lobster per unit of effort (100 Pots) for the SVP (2013-2019) and MI Observer programme (2015-2019).

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 very limited conservation value as there is no v-notching scheme as such.

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. Spider crab, brown crab, crayfish and lobster are the most common species in the catch. Twelve species of elasmobranch fish (skates and rays) occur in the by-catch. White skate, angel shark, flapper skate and blue (common) skate are critically endangered.

Catches of crayfish vary from 5-25 individuals per nautical mile of net hauled. This varies seasonally and geographically. About 50 % of the catch is under the MLS but this is very variable across years.

Tagging data shows some connectivity, via migration, between crayfish stocks off northern France and the west of Ireland. However, tagged crayfish released off Kerry have been repeatedly re-captured close to release locations over a number of years indicating residency in Irish coastal waters.

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.

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 are sparse, of variable quality and have not been collected systematically prior to 2017. Size distribution data similarly has been collected sporadically. 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 (2017-2020) for the south west coast. This is ongoing and will be expanded to other areas in 2021. Tag recovery data from tagging in 2017 and 2018 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 dispersive larvae phase lasts for between 6-9 months and ocean scale dispersal is expected. Larval behaviour however and their possible association with small species of jellyfish may reduce the dispersal scale. The dynamics of larval supply 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 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 then 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 had been tagged under a research programme between 2017-2020 and enabled multiple mark recapture data to be collected.

5.5 Catch composition

Spider crab are, numerically, the most common species caught in tangle nets off north Kerry followed by brown crab and crayfish. 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. An additional 10 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).

Table 5. Species catch composition in tangle nets targeting crayfish off the south west coast of Ireland 2017-2020. Data are total numbers caught in each year by all boats in the sampling programme.

Species	2017	2018	2019	2020	Total
Spider Crab (*Maja brachydactyla*)	3,294	7,320	7,369	4,087	**22,070**
Brown Crab (*Cancer pagurus*)	3,548	7,034	3,783	3,530	**17,895**
Crayfish (*Palinurus elephas*)	3,992	4,147	3,328	4,069	**15,536**
Lobster (*Homarus gammarus*)	500	785	658	762	**2,705**
Pollack (*Pollachius pollachius*)	11	185	203	800	**1,199**
Turbot (*Scophthalmus maximus*)	37	58	87	233	**415**
Monkfish (*Lophius spp*)	38	89	79	139	**345**
Black Pollack (*Pollachius virens*)	0	0	0	50	**50**
Spurdog (*Squalus acanthias*)	49	155	1,115	584	**1,903**
Thornback (*Raja clavata*)	52	88	165	117	**422**
Grey Seal (*Halichoerus grypus*)	8	45	73	74	**200**
Unidentified Skate	70	26	1	18	**115**
Dog fish (*Scyliorhinus spp*)	37	6	1	59	**103**
Spotted Ray (*Raja montagui*)	0	11	22	59	**92**
Blonde Ray (*Raja brachyura*)	0	26	5	0	**31**
Flapper Skate (*Dipturus intermedius*)	0	5	8	0	**13**
Painted Ray (*Raja microocellata*)	0	6	0	4	**10**
Angel Shark (*Squatina squatina*)	0	0	2	1	**3**
Common Skate (*Dispturus batis*)	0	3	0	0	**3**
Sting Ray (*Dasyatis pastinaca*)	0	1	0	2	**3**
Cuckoo Ray (*Leucoraja naevus*)	0	0	2	0	**2**
White Skate	0	1	0	0	**1**
Undulate Ray (*Raja undulata*)	0	1	0	0	**1**
Total	**11,636**	**19,992**	**16,902**	**14,588**	**63,118**

5.6 Catch rates

Catch rates of crayfish generally varied from 5-25 fish per nautical mile of net during 2017-2020. This includes all sizes (Figure 11, Figure 12). The size distribution data shows variable proportions of the catch are above the minimum size in each year; 34 % in 2017 and 53-62 % in 2018-2020 (Figure 13).

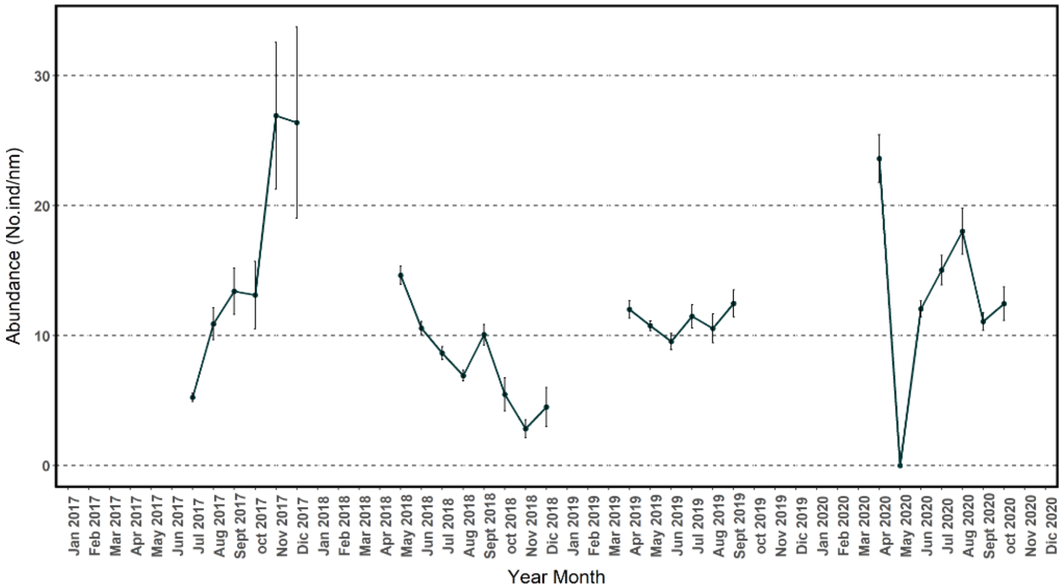


Figure 11. Catch rate (numbers.nmnet^{-1}) of crayfish off the south west coast of Ireland 2017-2020.

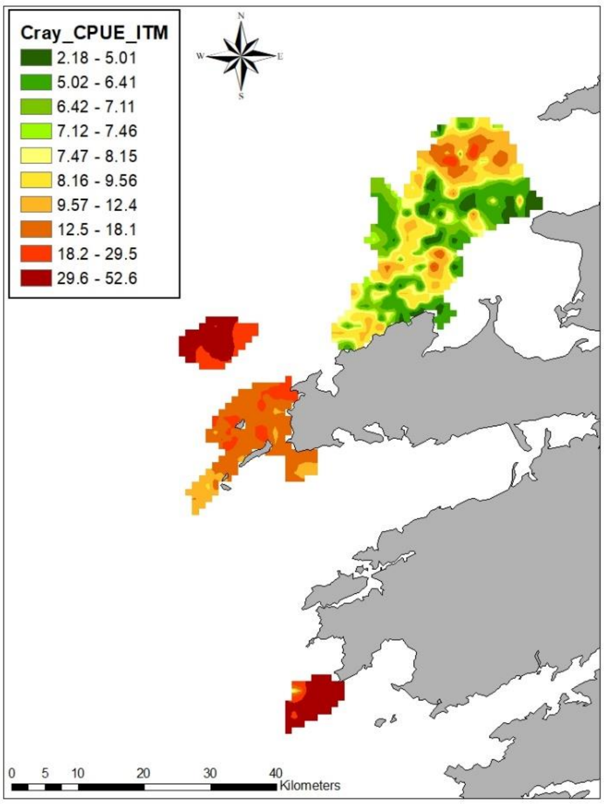


Figure 12. Distribution of catch rate (numbers.nmnet^{-1}) of crayfish 2017-2020 combined.

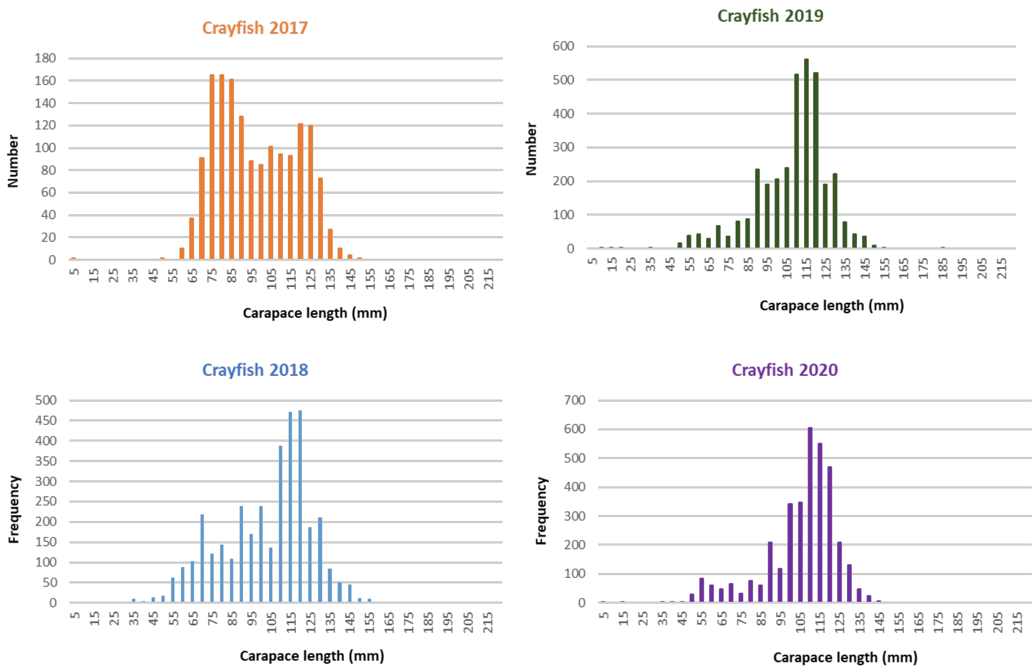


Figure 13. Size distribution of crayfish in the catch off the southwest coast or Ireland 2017-2020.

5.7 Tag recapture data

Crayfish were tagged and released in 2017 and 2018 off the Kerry coast and recaptured during the period 2017-2020. The rate of reporting of tag recaptures is unknown but is thought to be high in the area where the tagging was undertaken and probably lower outside of these areas.

Three crayfish tagged by IFREMER off Brittany in 2015 and 2016 were recaptured off the south west and west coast of Ireland in 2019. The northern most recapture was off Erris Head Co. Mayo.

The tagging data shows that most crayfish were recaptured locally close to release points even in the years following tagging (Figure 14). Some movements north from Blasket to Brandon and south from Blasket to Kenmare have been recorded.

It is still unclear if crayfish are resident or if they migrate in and out of the tagging area as the reporting rate of recaptures outside the tagging area is unknown. On the one hand the size distributions vary annually suggesting some migration but the tag recaptures are mainly local suggesting residency. There is extensive physically and biologically diverse reef habitat for crayfish in the area. The repeated local recaptures suggest that tagging data could be used to estimate stock size.

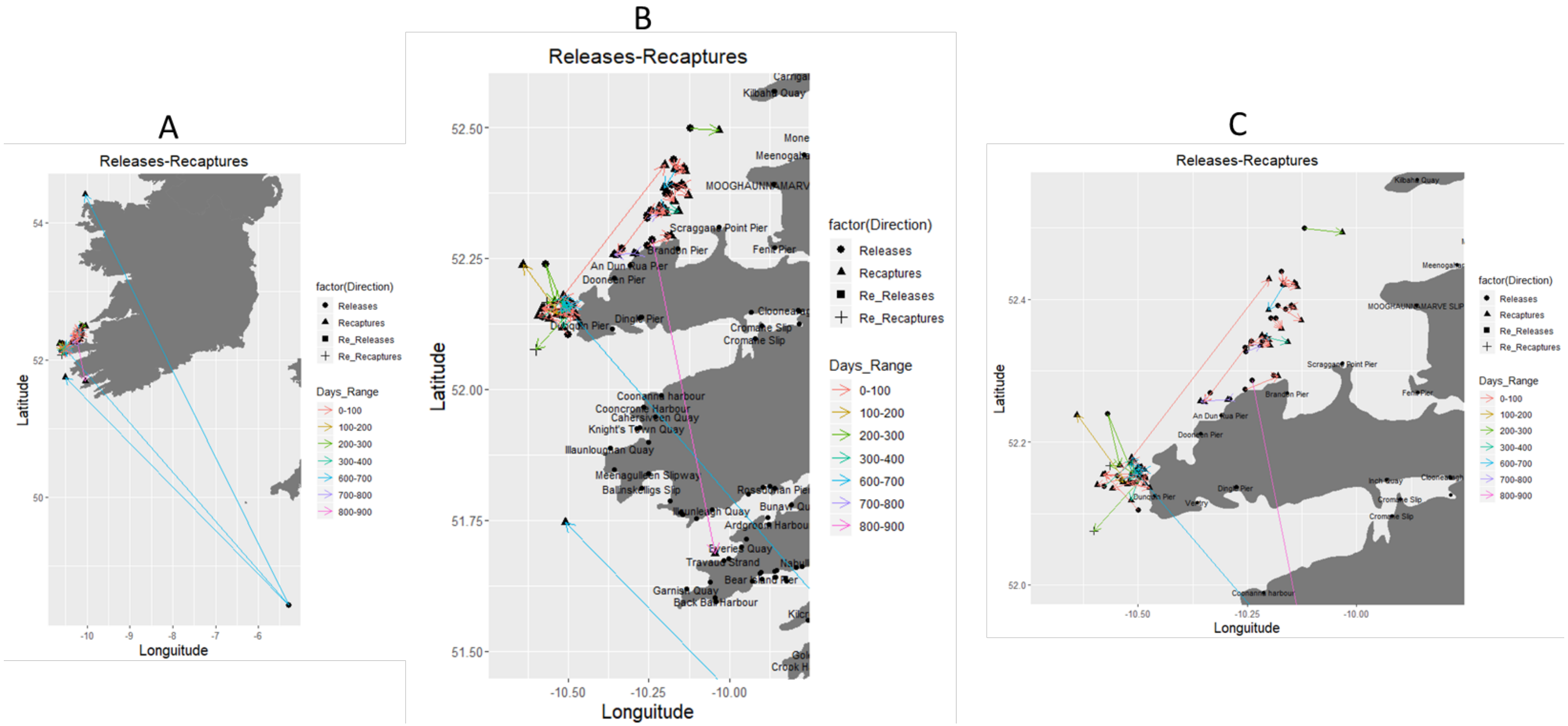


Figure 14. Release recapture data for crayfish 2017-2020. A. Migration of 3 crayfish tagged off Brittany in 2016 (source: Martial Laurens IFREMER) and recaptured off Kerry and Mayo in 2018. B. Movement of crayfish in relation to time since tagging off the Kerry coast. C. Zoom in on recapture data in relation to time since tagging in north Kerry. *Ignore straight lines overland*. The majority of recaptures are close to release sites even 2-3 years since tagging. Incomplete reporting of tag recapture will bias that conclusion.

6 Brown crab (*Cancer pagurus*)

6.1 Management advice

The crab fishery is managed by a minimum landing size of 140 mm. There are kwday 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.

The crab fishery is monitored using data from commercial vessels and a scientific observer programme. In addition, size distribution data of the landings is collected at processors. In 2020 questionnaire data on trends in catches and fishing effort, the viability of fishing and current perceptions of fishermen of the status of the stock were collected in Donegal. These data were combined with similar snapshots obtained in 1997 and 2005.

Monitoring data, and a standardised index of stock abundance derived from these data, show a steep year on year decline in both landings per unit effort and discards per unit effort since 2014/2015 in the fishery off Mayo and Donegal. These trends are also generally observed in other coastal areas. 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.

The trends observed in the Donegal fishery data are entirely consistent with questionnaire data which universally signals a significant decline in the performance of the fishery in recent years. Catch rates have declined, market prices have declined and fishing effort per vessel (and associated costs) has increased. The viability of fishing is reduced.

Additional management measures should be introduced to conserve spawning stock while recruitment remains low. There is unanimous agreement in questionnaire data for additional measures. Preferred options include a lengthy closed season, a stop on using crab as whelk bait, to land lower volumes and higher quality crab or introduce a total allowable catch. There is a significant risk of transfer of fishing effort into the more coastal lobster fishery if crab catches continue to decline.

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 do and to account for spatial and temporal effects in an annual standardised index depends on the resolution of the data.

As the data on catch rates reported here shows there are high levels of variation between vessels, areas, seasons and years and thus 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 15). On the Irish coast these units are identified from tagging data, distribution of fishing activity and larval distribution.

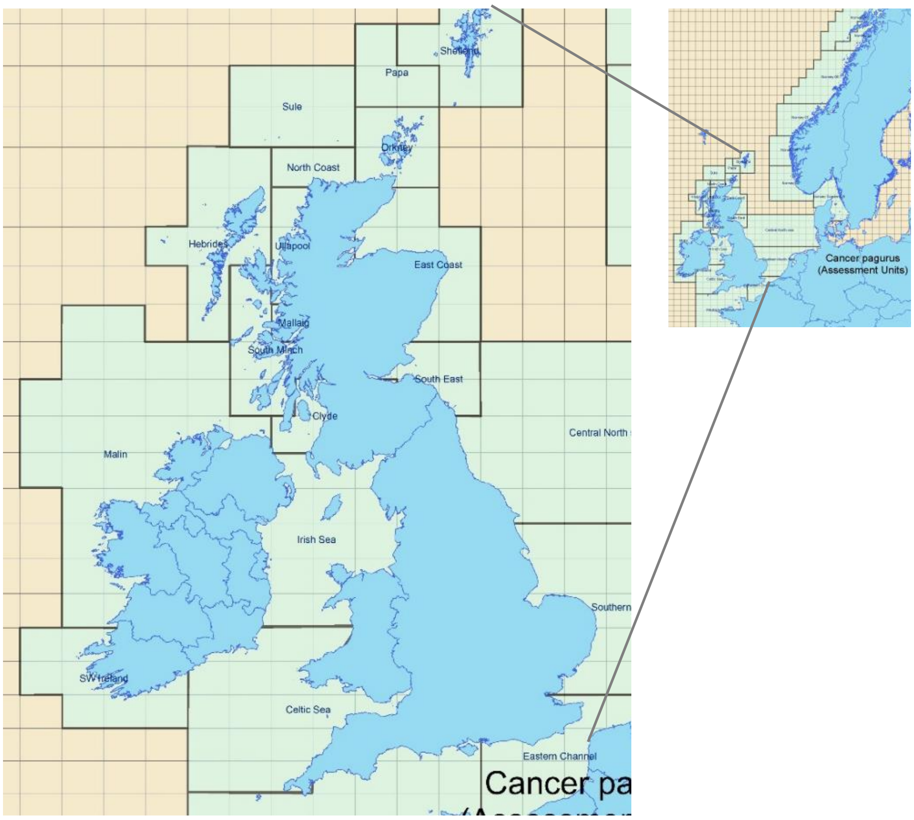


Figure 15. ICES stock assessment units for Brown crab.

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 north-west coast stock to the North Sea and on occasion some restrictions on 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 Size distribution indicators

Size distributions from the observer data were stable from 2015-2019 and similar modal sizes in both landings and discards are evident (Figure 16). The modal size of crab in the landings ranged between

150-160 mm across years indicating significant high grading above the minimum landing size of 130 mm (prior to 2019) and 140 mm in 2019.

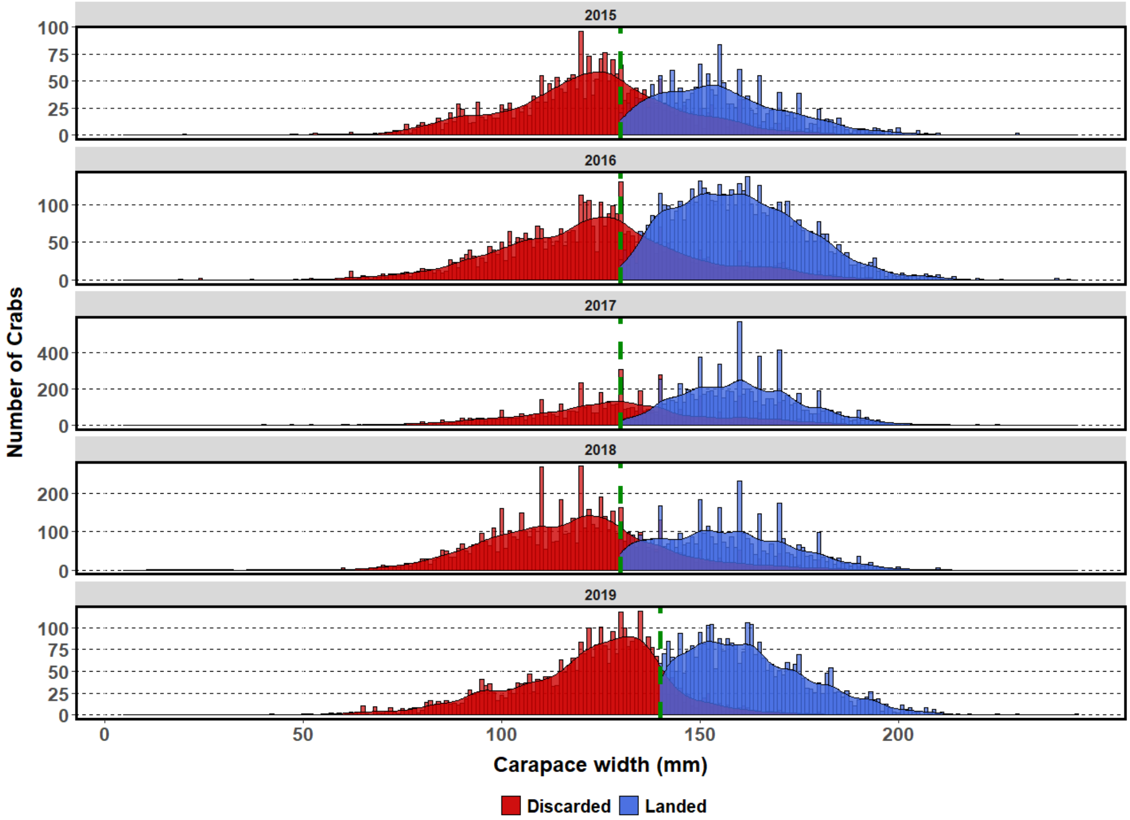


Figure 16. Size distribution (1 mm size bins) of crab from the MI observer programme between 2015-2019. Green dashed line shows the 130 mm (2015-2018) and 140 mm (2019) minimum landing size. Note the scale of the y-axis varies.

6.6 Catch rates

SVP data from 2013-2019 and the MI observer data from 2015-2019 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 report are recorded 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.

6.6.1 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 2019 to approximately 1.2 Kg/Pot and to approximately 0.5 Kg/Pot in the MI observer data in 2019 (Figure 17). This decreasing trend in LPUE was observed in all stocks (Figure 18). Discards per unit effort (DPUE) show similar trends in both SVP and MI observer data, with a marked decrease from 2015 onwards, and reaching values close to 0 Kg/pot in 2019. LPUE and DPUE of crab caught in gear targeting lobster were relatively stable but, as expected, significantly lower than in gear targeting crab.

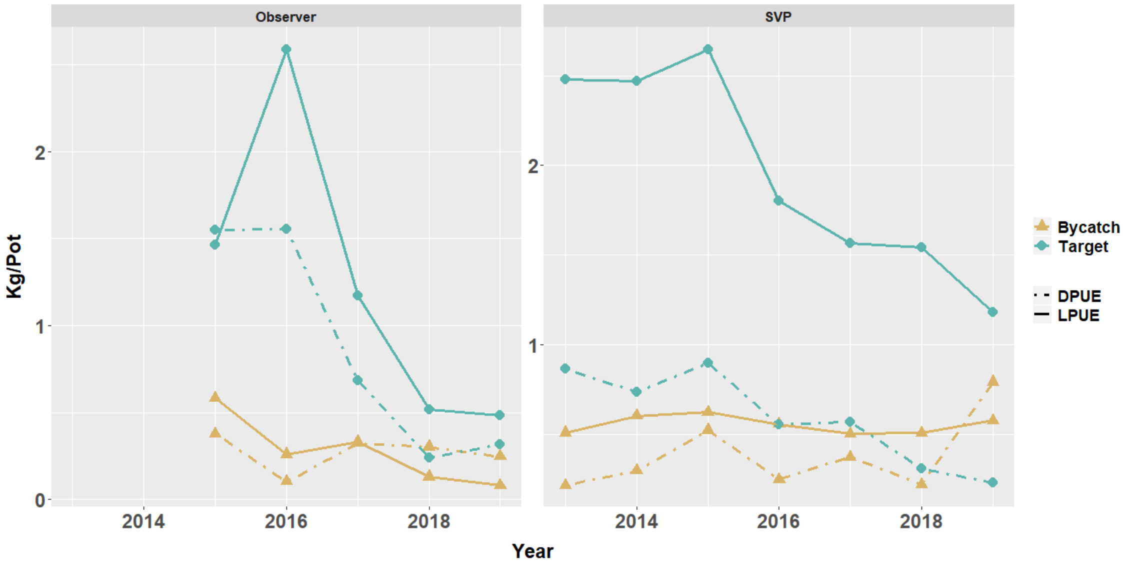


Figure 17. Annual mean LPUE and DPUE (Kg/pot) for Observer and SVP programme data from trips both targeting brown crab and where brown crab is caught as by-catch 2013-2019.

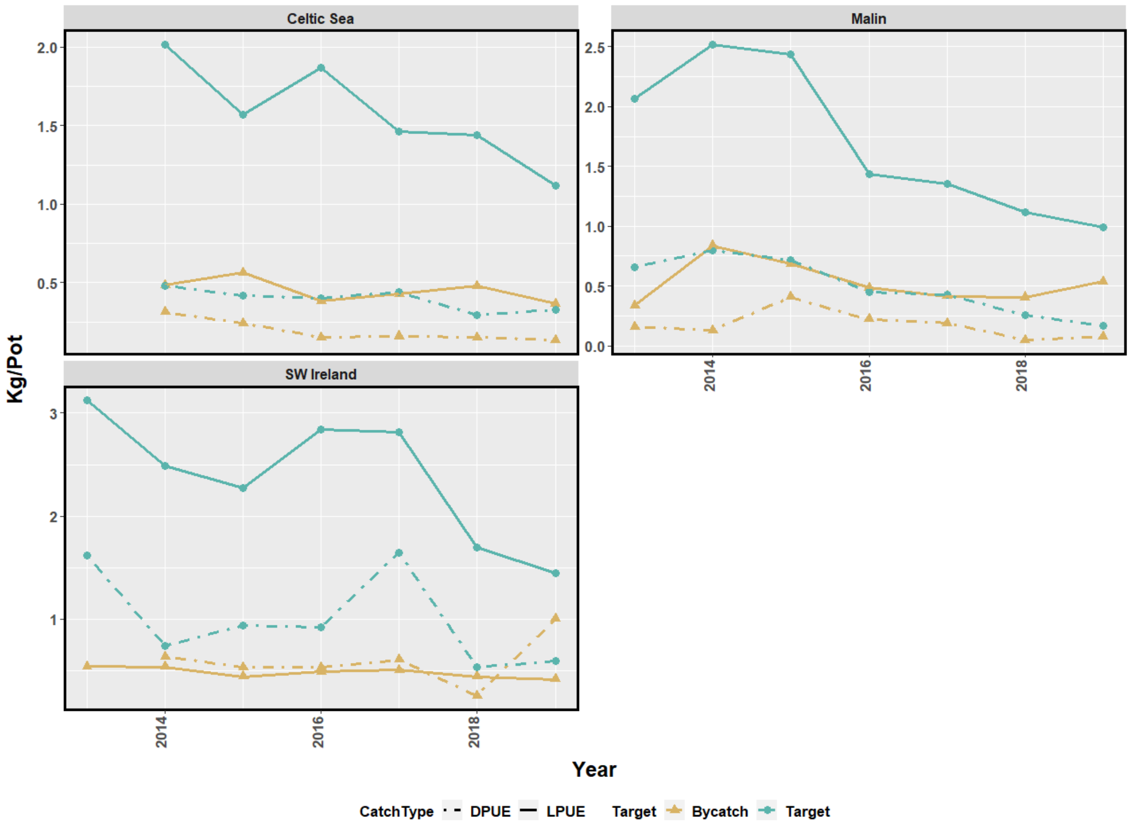


Figure 18. Annual mean LPUE and DPUE (Kg/pot) by stock area for SVP trips targeting crab and also where crab is caught as bycatch during 2013-2019.

6.6.2 Seasonal trends

Seasonal trends in LPUE in the SVP data are shown in Figure 19. Observer data is not shown as it is considerably less precise given the limited sampling. LPUE targeting crab generally show peaks in Quarter 3 and early Quarter 4 although in 2013-2016 peaks occurred in Quarter 1 and 2 (Figure 19). LPUE data of brown crab caught in pots targeting lobster peaked in Quarter 4 (Figure 19).

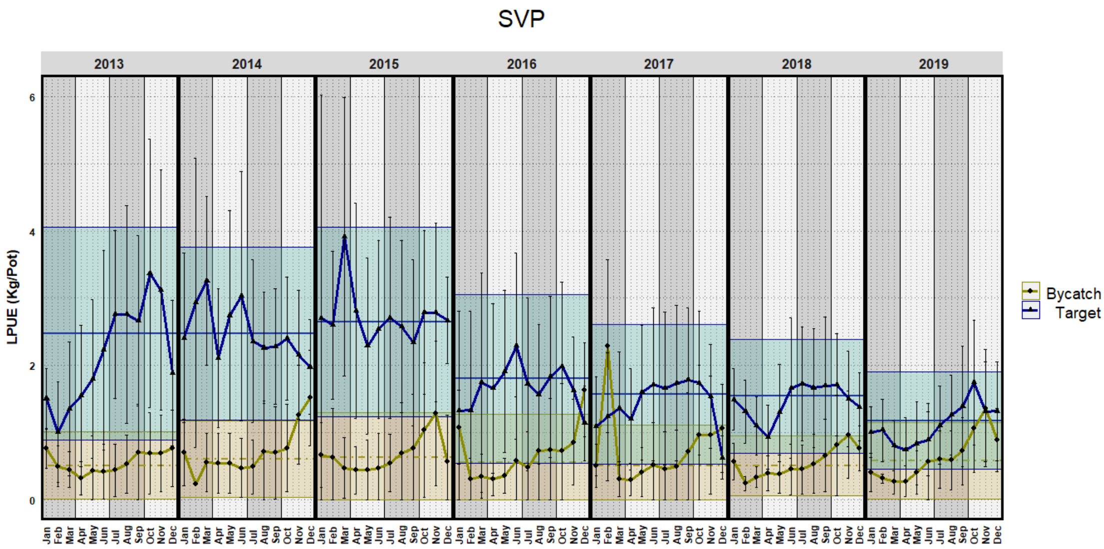


Figure 19. Monthly mean LPUE (Kg/pot) with standard deviation for SVP trips where crab was targeted (blue) and captured as bycatch (brown). Horizontal line in each year show annual means. Year quarters shaded in grey and white.

6.7 The Malin Stock

6.7.1 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. Landings increased peaking in 2004 at ~ 8,500 tonnes (Figure 20). Landings in recent years have ranged between 2,500-3,000 tonnes. These landings are by Irish vessels into Ireland. Additional landings from this stock are taken by vessels from Northern Ireland and Scotland.

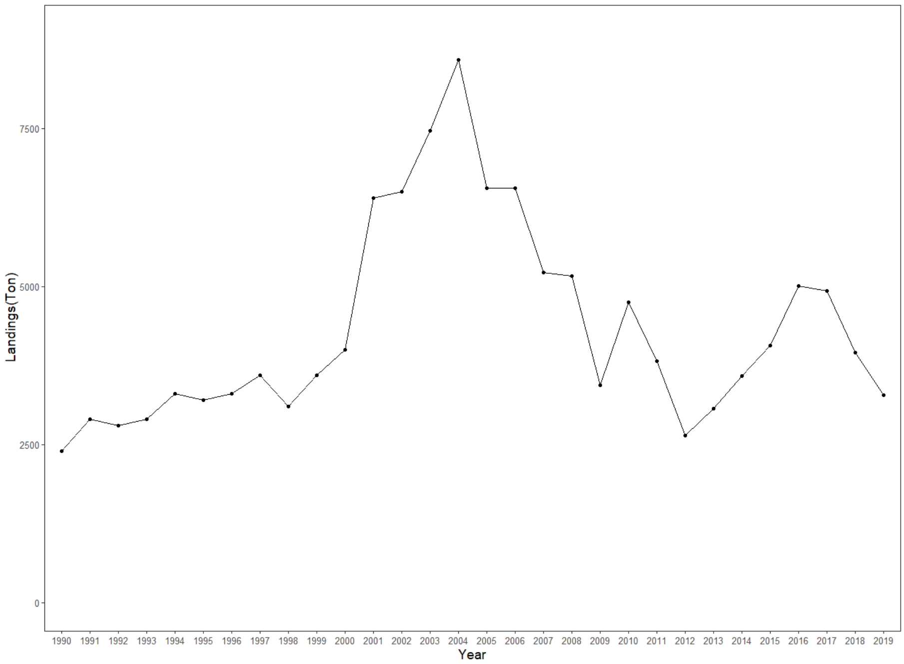


Figure 20. Landings (tonnes) of brown crab (*Cancer pagurus*) in ICES Divisions VIa and VIIb (Malin Shelf stock) 1990-2019 by Irish vessels. Source: Logbooks data for vessels above 10 m, and sales notes data for vessel under 10 m.

6.7.2 Assessment methods

The primary indicator of stock status for the Malin Stock consist of landings per unit effort collected in the Sentinel Vessel Programme (SVP) or earlier versions of it. Daily landings per unit of effort (LPUE) for the period 1996-2020 were collated. Data on discards are also available but are less often reported and are not included here. Only vessels over 8 meters in length were used in the analysis to reduce the variance in the LPUE estimates that would result if vessels targeting lobsters with a crab by-catch were included.

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. Among the methods commonly used to remove these effects are Generalised Linear Models (GLM's) and Generalized Additive Models (GAM's). A gamma GAM was applied to the raw SVP LPUE data with the following form:

$$\eta_i = log(\mu_i) = \beta_o + \text{offset (log (N° of pots))} + \beta_Y \text{Year} + \text{s(Soak Days}_i \sim \text{"cs")} + \text{s(Vessel}_i \sim \text{"iid")}$$

$$\text{Landings}_i \sim Gamma\ (\mu_i, \phi)$$

$$var[\text{Landings}_i] = \mu_i^2/\phi$$

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

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 β_Y 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. A second GAM model where the year effect was fitted as a cubic spline smoother was also fitted for model comparison.

The resulting index of abundance was based on the predictions of the fitted model for standard values of the covariates. Thus, standardized estimates were obtained for each year based on, the mean of the effort and the mode of soak days (2 days). The vessel effect was removed from the predictions.

Both GAM indices of abundances show a relative increase in LPUE in the first 10 years of the time series (Figure 21). A sharp decrease in the standardized LPUE occurred from 2014 onwards in both models. GAM_fixed (a fixed categorical year effect), shows substantially more inter-annual variability compared to GAM smooth; the splines in the second model smooths differences across years. In GAM_fixed, 2008 appears as a clear outlier in the standardized index. The limited sampling in this year for the Malin stock (4 vessels only compared to on average 13-15 vessels) are likely to be causing this outlying estimate.

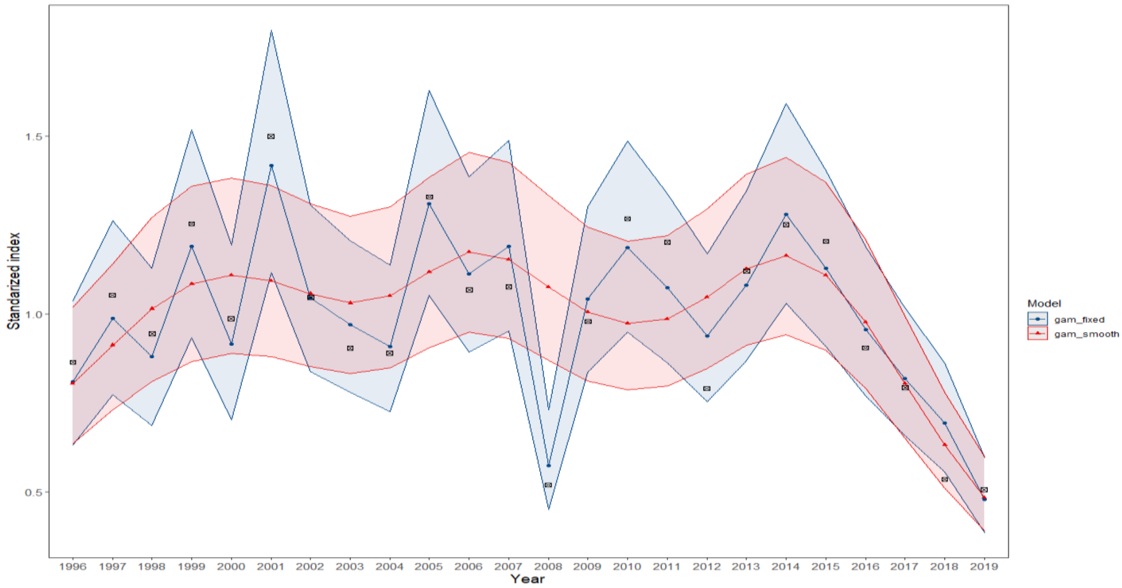


Figure 21. Standardized index of crab abundance from the SVP programme after applying two different GAM model formulations (Gam_fixed: Year as fixed effect, GAM_smooth: year as spline). Shaded regions indicate approximate 95% confidence intervals. Annual mean raw LPUE (black squares) added for comparison.

6.7.1 Interpretation of catch rate data

The year on year decline in the observed and standardised LPUE index between 2014 and 2019 has not been previously observed in the time series which extends back to 1996. Although this index 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 this instance. 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, if it is above 30% of what it would be in an unfished stock, and 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 should be reduced to avoid driving the stock to even lower levels.

6.7.2 Evolution of the fishery since the 1980s

In the early 1980s 15 vessels fished from the Inishowen peninsula. By 1985 this had increased to 33 vessels each fishing approximately 300 pots. From 1985 there was a gradual decline in the number of vessels and by 2005 just 17 remained. The relatively small area fished by the Malin Head fleet disguises it's importance as a major producer of crab at over 1,800 tonnes per annum in 2005. Employment on vessels in 1985 was 4-5 per boat and up to 105 fishermen. In 2005 vessel crew size was 2-3 representing a maximum of 51 fishermen. In 1997 an estimated 127 vessels fished crab in Donegal and a further 24 fished out of north Mayo giving a total of 151 vessels. The total number of vessels targeting the fishery out of north Mayo and Donegal combined in 2005 was 60 including those in the offshore vivier sector. The number of vessels targeting crab declined by more than 50 % between 1997 and 2005. In some areas the decline was higher than this.

Five vessels over 18 m in length began fishing during the early 1990s and this offshore fishing activity had fully expanded by 2005 to its current extent.

Although the number of vessels targeting the fishery declined very significantly between 1997 and 2005 potential effort (pots owned by the fleet) increased substantially. Inshore vessels had 26,000 pots in 1997 and 41,795 in 2005 (Figure 22, Figure 23). In the offshore fleet the potential total effort in 1997 was, approximately, 6,000 pots and in 2005 it was 15,200 pots. Total pots owned by crab vessels in Donegal and Mayo was 32,000 in 1997 and 56,995 in 2005. In 2020 the estimated number from questionnaire data in Donegal and from a separate assessment in Mayo was approximately 95,000 (Figure 22). These numbers are preliminary and subject to revision (Figure 24).

The factors responsible for the change in effort profile are probably complex and related to overall fishing opportunities and employment in the general economy. A decline in catch rates in the 1990s compared to the catches in the 1980s occurred. Prices for crab fell in real terms during the period 2000-2010 and a number of other fisheries declined or were closed (salmon) during this time. The profile of the surviving vessels may tell the true story and reflect the economic reality. To survive in the fishery at a time when LPUE was declining and prices were not keeping pace with this decline, or with inflation, the options were to increase fishing effort or to stop fishing. The increase in vessel effort occurred through vessel modernisation and increased vessel power all of which increased the capacity to haul more pots per day. This effort increase and fleet modernisation has continued into recent years.

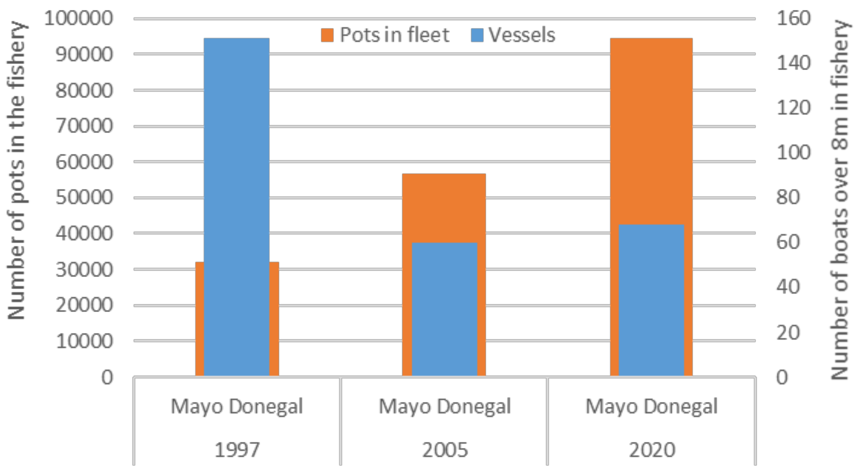


Figure 22. Number of vessels and pots in the crab fishery in 1997, 2005 and 2020 (preliminary).

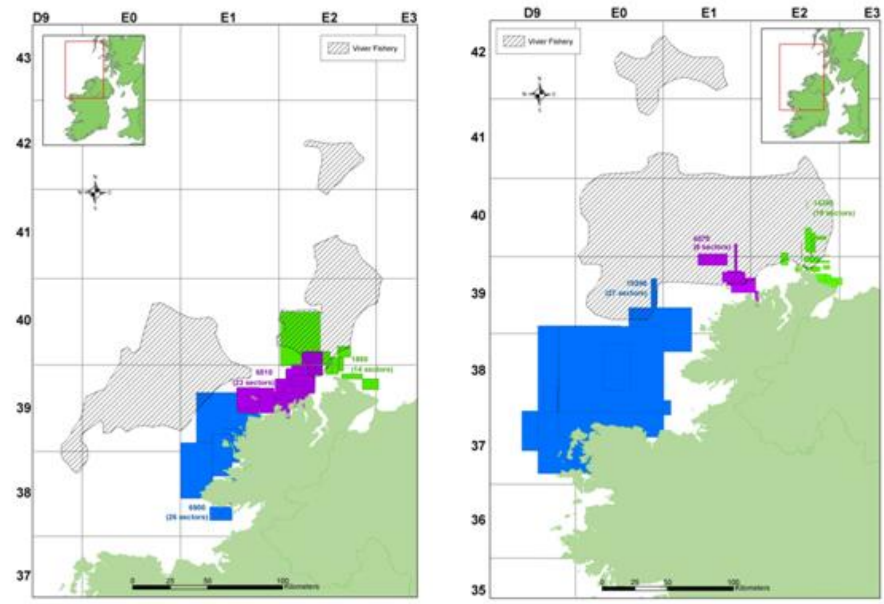


Figure 23. Distribution of fishing activity in Donegal in 1997 and in May and Donegal in 2005 (from Tully et al 2006; BIM fisheries resource series).

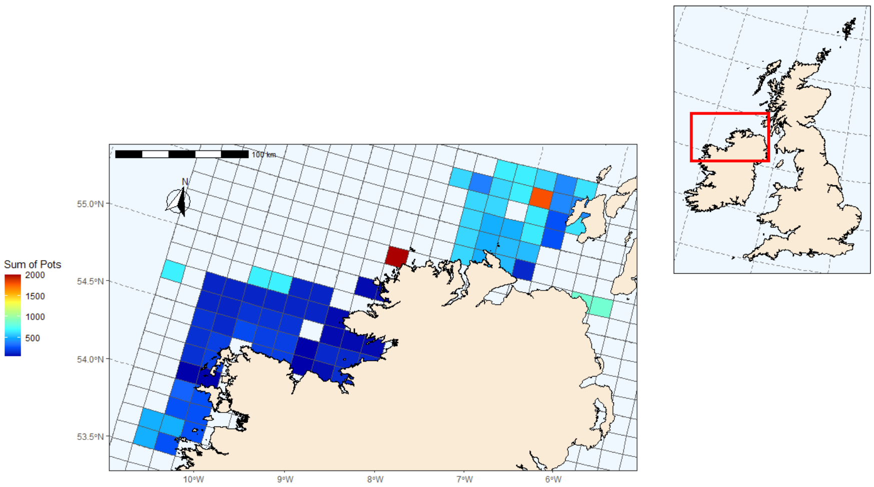


Figure 24. Distribution of fishing activity by the Mayo and Donegal under 15 m fleet targeting crab in 2017-2019. Data for a small number of vessels off north west Donegal are missing. Two Irish vessels under 15 m fish west of Scotland and north of the limit of the grid shown. Data for vessels over 18 m are not shown. Numbers subject to revision.

6.7.3 Questionnaire data on trends and attitudes

There have been various projects and discussion of management of the fishery and reviews of how the fishery has evolved over time. A Marine Stewardship Council (MSC) pre-assessment was completed in 2013 but no further actions were taken to certify the fishery. Some significant factors that have influenced participation and fishing effort in the fishery since the 1980s include market price fluctuation, decline in opportunity in other fisheries including a prohibition on salmon fishing since 2006, an open access licencing policy, fleet renewal and development and more recently the opening of a significant market in China which increased crab prices for fishermen.

In 2020 a questionnaire survey with vessel owners was completed in Donegal. Questions related to

- Fishing effort, landings, discards 2017-2019
- Operating costs and value of catch
- Distribution of fishing
- Issues affecting viability in the fishery and
- Management requirements to resolve the issues identified

6.7.3.1 Issues identified

Trends in catch rates and total catches were almost unanimously reported to be negative during years 2017-2019 and correspond to the trends seen in the data presented above. The following are some of the responses:

- Very poor
- Down 60 % since 2015
- Halving every year
- 2011 7,000 boxes landed using 800 pots, 2019 3,483 boxes using 2,000 pots
- Down; in trouble, gone, decline, down hard, future poor
- Description of fishery in recent successive years; great, good, slow, disaster

Most fishermen thought that fishing effort was too high (Figure 25). As described above both effort (pots per boat per day) and effort potential (pots in the fleet) have increased dramatically since the last census in 2005. High effort has resulted in higher landings in the past but in recent years catch rates have fallen and daily landings per vessel and overall landings have declined despite the increase in fishing effort. Crab clawing and use of crab for whelk bait were identified as key issues. In that respect although the volume of crab used in the whelk fishery is unknown fishing effort on whelk is also increasing. There are about 16,500 whelk pots in the fishery in north Donegal. Although most fishermen's primary fishery is crab there is an increasing switch to whelk when crab catches are poor. If the whelk pots are used for 50 days per year and say 0.5 kg crab is used in each as bait that equates to 412 tonnes of crab. There are also whelk fisheries in the Irish Sea and in the UK which are supplied with crab bait from various sources.

The questionnaire asked if individual businesses would survive if price reverted to 2015 before the market in China had developed. Of 13 respondents 9 answered 'No'. Only 1 respondent said 'Yes' because his business had been developed during the period when prices were low.

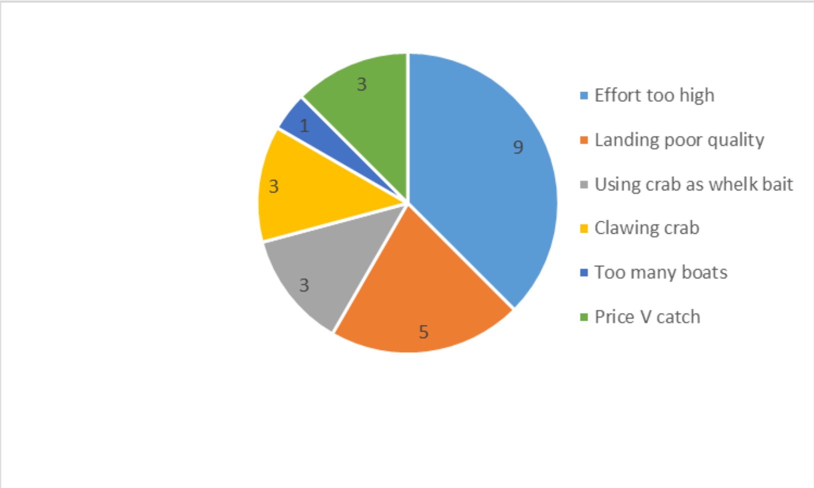


Figure 25. Issues causing economic difficulties in the Donegal crab fishery from questionnaire data collected in 2020 reflecting fishing conditions in 2017-2019.

6.7.3.2 Solutions identified

Most fishermen responding to the questionnaire proposed a closed season to resolve the issues identified in the fishery. Five proposed to close between Jan and June or for a number of months in the first half of the year. Two proposed to close from November to the following spring. Other solutions proposed included introduction of a total allowable catch, an increase in the minimum size or to enforce landing of high quality crab only (high grading and landing lower volume).

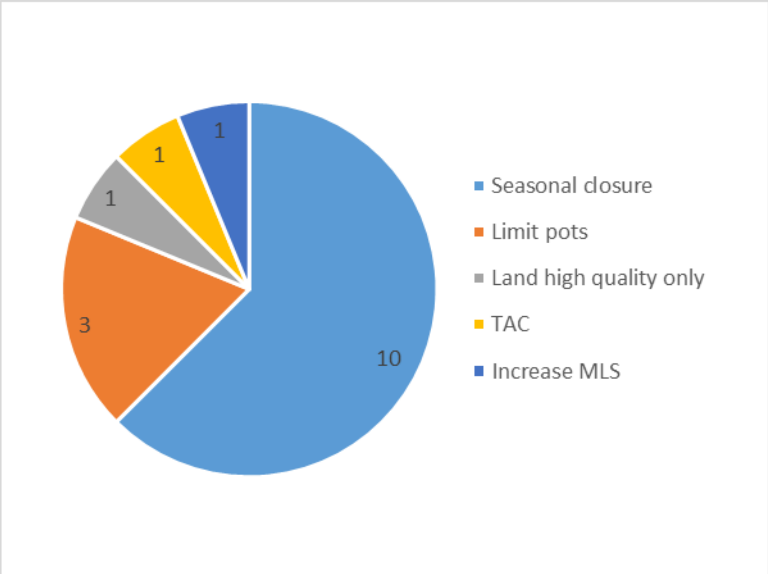


Figure 26. Solutions identified to economic difficulties in the Donegal crab fishery from questionnaire data collected in 2020 reflecting fishing conditions in 2017-2019.

7 Razor clam (*Ensis siliqua*)

7.1 Management advice

All commercially exploited razor clam stocks in Ireland are assessed by survey which provide estimates of biomass by size or grade. Weekly TACs apply to vessels in the north and south Irish Sea. 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 2015-2020. The number of vessels in the fishery increased from 49 in 2015 to 73 in 2016 and 2017 and declined to 56 in 2019. All indicators (daily landings per vessel, catch per hour) show significant and persistent declines up to 2017 but were stable from 2017-2019. Estimates of biomass, revised following a review of data standardisation protocols, varied from approximately 10,000 tonnes in 2017 to between 6,000-8,000 tonnes in 2018-2020. Exploitation rate was about 7 % per annum. Large size classes were depleted between 2017 and 2018 but were stable or increased between 2018-2020. Depletion corrected average catch (DCAC) assessment for the North Irish Sea indicates that high landings that occurred in the period 2014-2016 are not sustainable and that landings should be capped at 360 tonnes. Alternative options are 463 tonnes, which is the average landings for the period 2018-2020 during which survey biomass estimates were stable, or to apply the average exploitation rate, of close to 7 % when biomass was stable, to the 2020 biomass for a landing of 515 tonnes.

The south Irish Sea fishery opened in 2010 and expanded quickly to 2013. Annual landings declined from 2013-2018. A strong recruitment event in Rosslare Bay in 2014 (probably) was observed in the 2017 survey and biomass increased significantly between 2017 and 2020 surveys, from 2,000 to 6,500 tonnes. A further 1,000 tonnes occurs in the Curracloe bed. A TAC of 450 tonnes and 7 % exploitation rate is recommended on the basis that this exploitation rate led to stable biomass in the north Irish Sea between 2018-2020.

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 some bivalve fauna caught as by-catch is depleted in Dundalk Bay. Spatial management measures in Dundalk Bay should be introduced to enable recovery of these species and to monitor 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 mud and muddy sand 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 is currently known from the VMS data for the commercial fishery which operates in water depths of 4-14 m and from surveys where there are no fisheries. 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 occurs 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 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 in Clifden Bay, Iniskea Islands in Mayo, Ballinakill Bay and Waterford estuary.

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. 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 €4-9 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 (Figure 27). Vessel monitoring systems data (10 minute reporting frequency) shows fishing activity from Dundalk Bay to Malahide and at Lambay Island. Activity in 2020 was reduced compared to 2019 due to Covid-19 restrictions and fall in market demand.

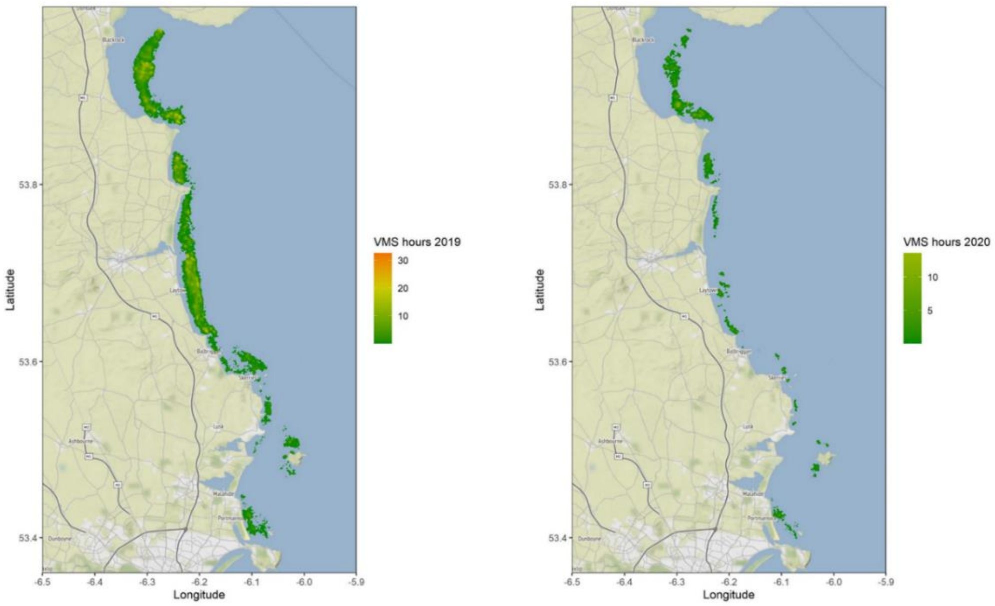


Figure 27. Distribution of fishing effort by vessels fishing for razor clams in the north Irish Sea during 2019 and 2020.

7.5.1 Landings

The NIS Razor Clam (*Ensis siliqua*) fishery began in 1998. The fishery developed quickly 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 involved in the fishery by 1999. Effort declined in 2002-2003 due to pipe laying in the sea area off Gormanstown. Post 2003 beds at Malahide, Skerries and south Dundalk Bay were being fished in addition to the Gormanstown bed. Market demand was limited at this time.

Landings increased from 274 tonnes in 2012 to 1,064 tonnes in 2015. This was paralleled by an increase in the number of vessels from 21 to 49. The number of vessels peaked in 2016 and 2017 at 73 but landings declined from 2015 to 2019. The number of vessels declined to 56 in 2019. Total landings for 2019 was 533 tonnes. Logbook and sales note data suggest a landing of just 300 tonnes in 2020. The Dundalk Bay and Gormanstown production areas account for most of the landings (Figure 28).

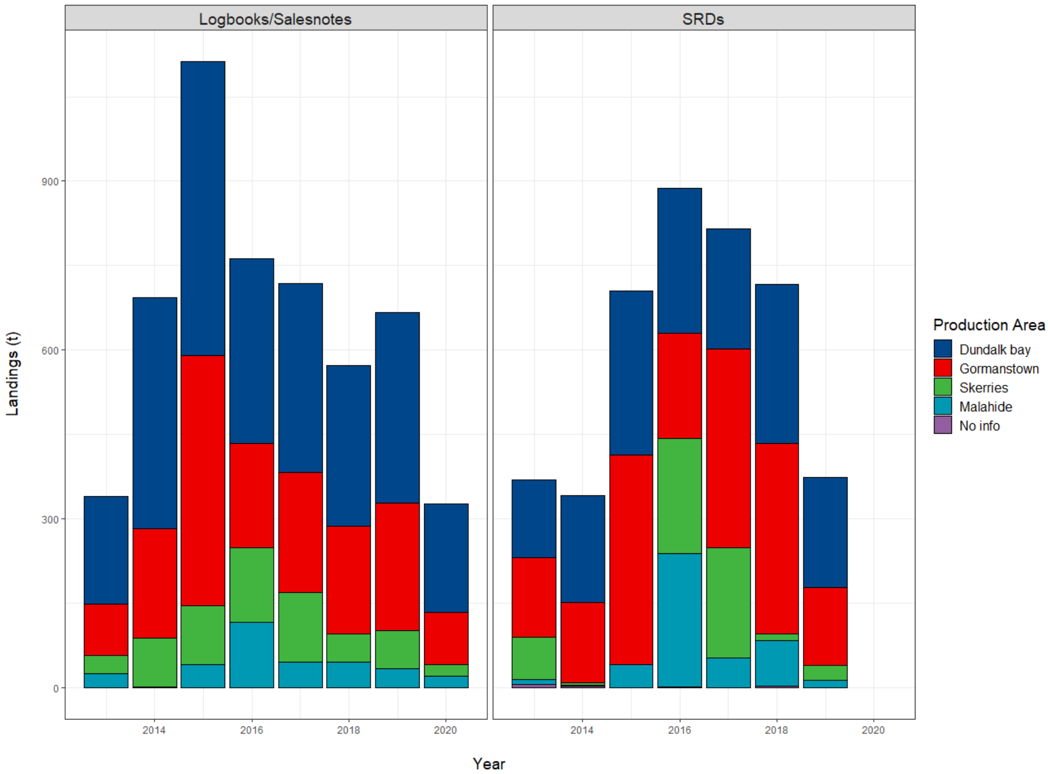


Figure 28. Annual landings of *Ensis siliqua* in the north Irish Sea (NIS) 2013-2020 sourced from SFPA logbook, shellfish gatherers data and sales notes.

There was a consistent relationship between iVMS activity and landings during 2016-2020. Effort and landings accumulate through the year other than June when the fishery is closed. VMS effort declined generally during the period 2016 to 2020 and landings declined from 2017 (Figure 29).

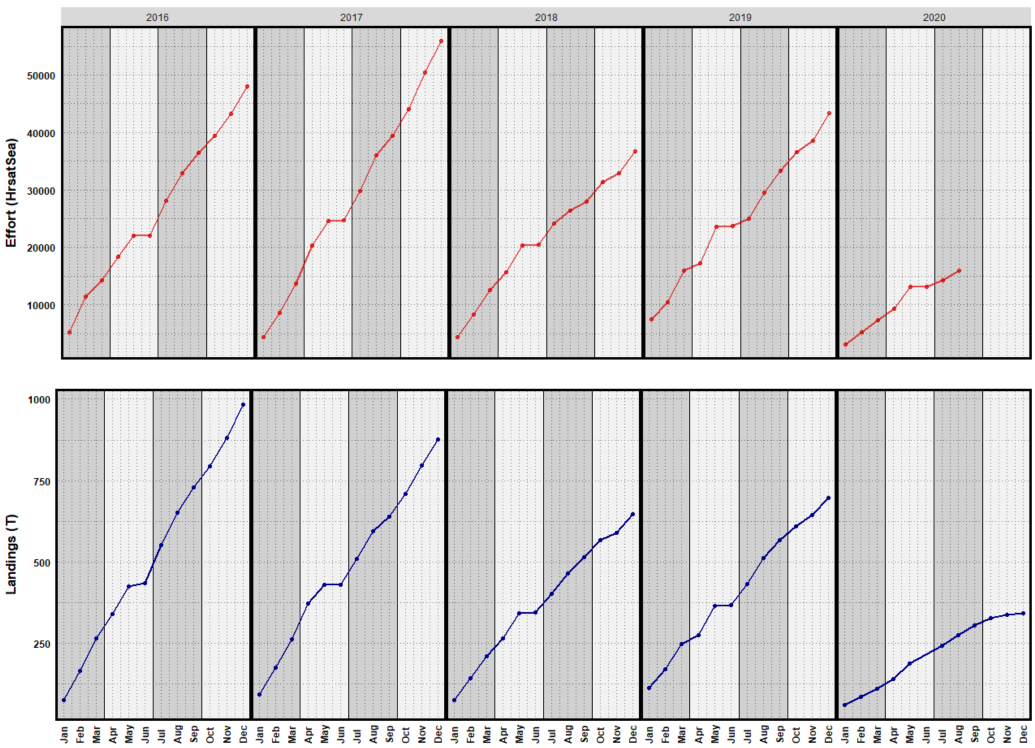


Figure 29. Relationship between monthly fishing effort (VMS hrs) and landings in the North Irish Sea razor clam fishery 2016-2020.

7.5.2 Survey 2020

A survey encompassing all of the areas which are commercially fished for Razor clams was completed in the NIS in June 2020. The survey follows the design in 2017-2019 which used an iVMS grid to allocate survey effort; 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 where defined, and 50 stations were randomly assigned within each strata, 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. Biomass was then interpolated over a 100 m x 100 m grid using ordinary kriging on log(biomass). 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 2017-2020 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 2017-2020

Biomass varied from approximately 10,000 tonnes in 2017 to between 6,000-8,000 tonnes in 2018-2020 (Figure 30, Figure 31). Over 90 % of the biomass is above the minimum landing size of 130 mm.

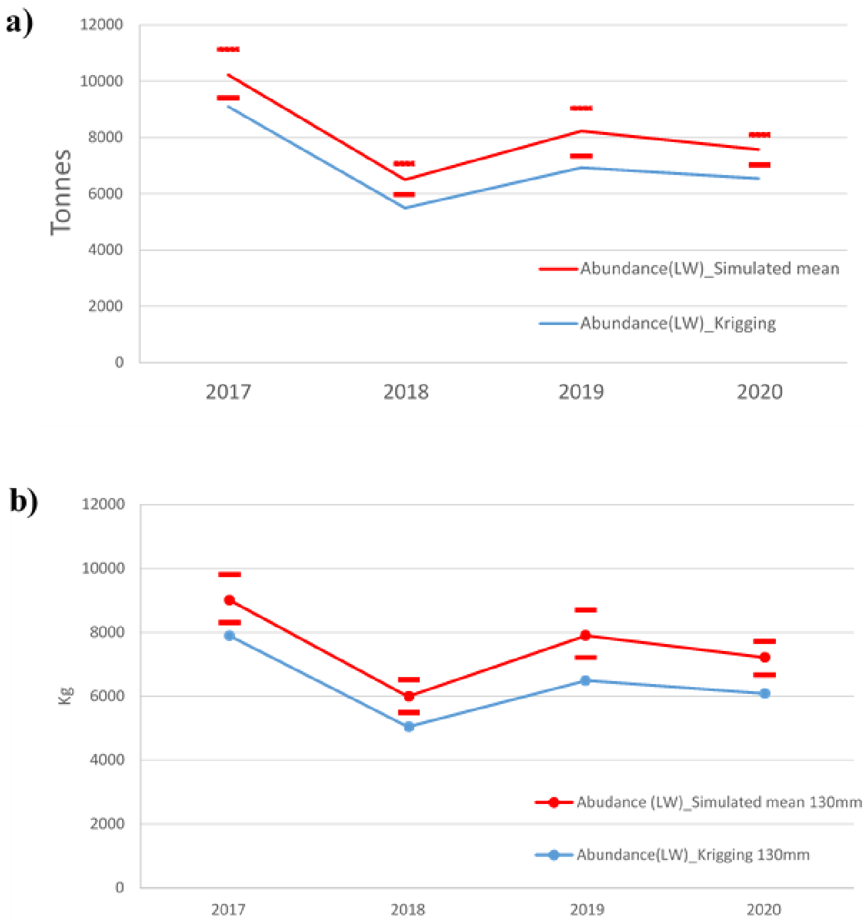


Figure 30. Trends in stock biomass of razor clams 2017-2020 in the north Irish Sea. Top: total biomass. Bottom: biomass greater than shell length 130 mm.

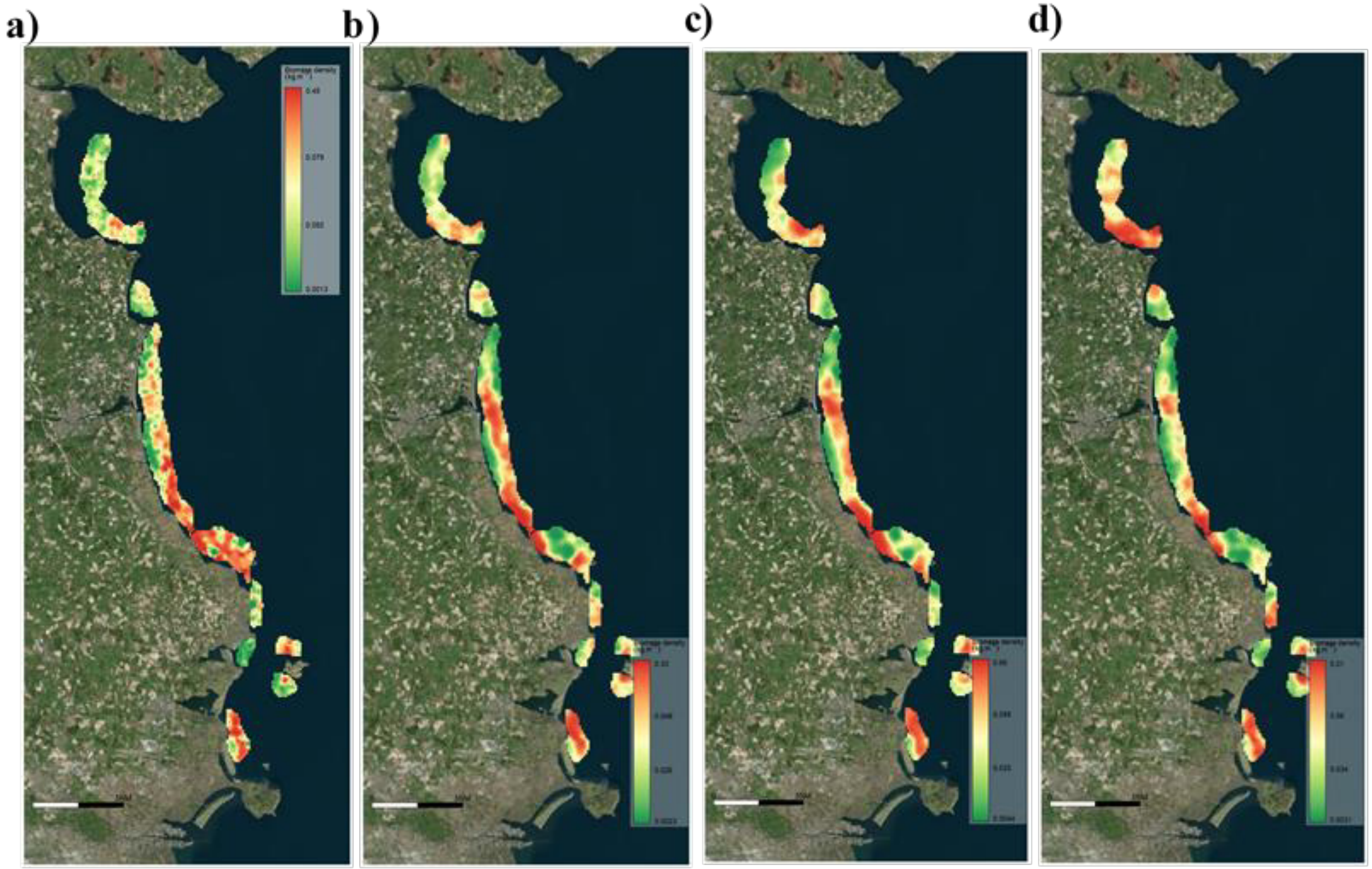


Figure 31. Distribution of biomass of razor clams in the north Irish Sea in June surveys 2017-2020 (a-d). Note scale differences across years.

7.5.2.2 Size distribution

The dominant modal shell size in 2017 was 130 mm with a second mode at 180 mm. In 2018 the modal size was approximately 145-150 mm as a result of annual growth of the main cohort present in 2017 (Figure 32). The mode at 180 mm present in 2017 was absent in 2018 indicating that clams over approximately 170 mm were depleted between 2017 and 2018. There was no evidence of significant recruitment into the stock in 2018 or 2019 and changes in size and biomass in those years are due to growth and mortality. Recruitment was observed in 2020 and there was an increase in the modal size of commercial clams from 150 mm in 2019 to 160 mm in 2020.

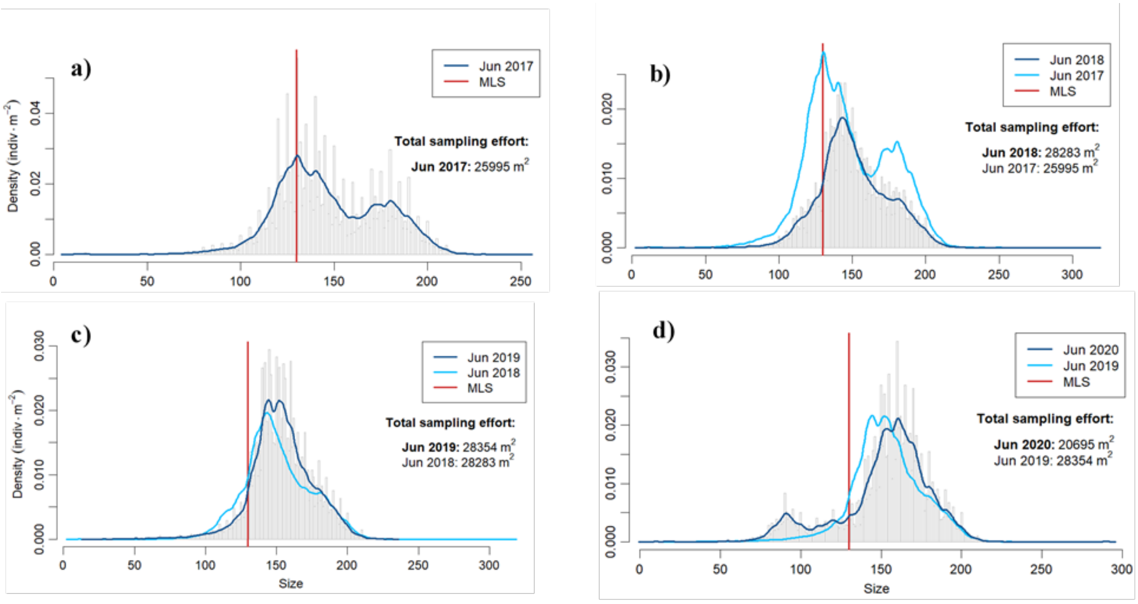


Figure 32. Size distribution of razor clams in the North Irish Sea from 2017-2020 survey data.

7.5.3 Depletion corrected average catch assessment (DCAC)

DCAC assessment estimates the sustainable catch by penalizing the average yearly landings based on the observed depletion in abundances indices. If there is no depletion the sustainable catch is simply the average of the historic catch. The base formula only gives a single estimate, with no confidence interval. A Bayesian implementation of the DCAC model, using life history based methods to estimate the B_{msy}/B_o and F_{msy}/M ratios, was developed to take into account most of the known sources of uncertainty and to provide a confidence interval for the sustainable catch. The model was fitted to landing per unit effort (LPUEs) estimated from logbooks and diaries from 2001-2005 and 2009-2016, as well as LPUEs for the Gormanstown bed extracted from Fahy and Gaffney (2001) (for reference as they estimated 60 % depletion in July 1999). Any changes in high grading at sea will affect the estimate.

The DCAC assessment suggests that the sustainable yield for Razor clams in the North Irish Sea is 360 tonnes, with a 95 % confidence interval of 301 to 409 tonnes (Figure 33).

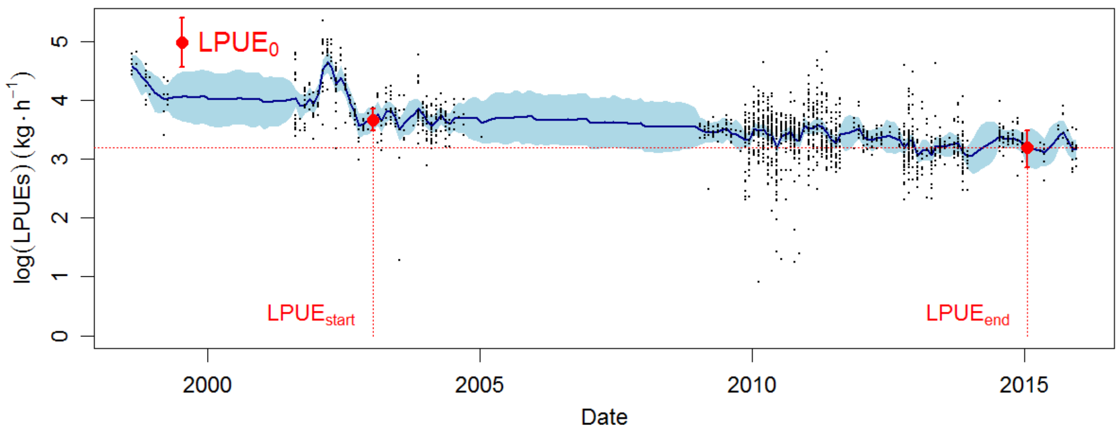


Figure 33. LPUEs fitted by the Bayesian DCAC model with a yearly trend and autocorrelation AR(1) between month (blue: mean and 95%CI). The values retained to estimate the delta of the DCAC models are shown in red.

7.5.4 Stock biomass indicators

Stock biomass indicators (LPUE kgs.day^{-1}, LPUE kgs.hr^{-1}) were estimated from data from shellfish registration dockets (SRD) in 2013-2019 and from SVP data in 2011-2019. The indicators may be increasingly biased in recent years due to high grading at sea given that the market price increases significantly with size grade and Skippers will try and maximise the value of the weekly quota of 600 kgs. These data are available for a longer time series than the actual survey biomass estimates.

Catch per vessel per day (Figure 34) in the SRD data declined from approximately 300 kgs in 2013, to just under 200 kgs in the period of 2017-2019. The SVP data shows a similar decreasing trend, with a slight increase in 2019 to approximately 250 kgs. Catches per hour in the SVP data declined from 20 kg/hr at the beginning of the time series to 12.5 kg/hr by 2017-2019 (Figure 35).

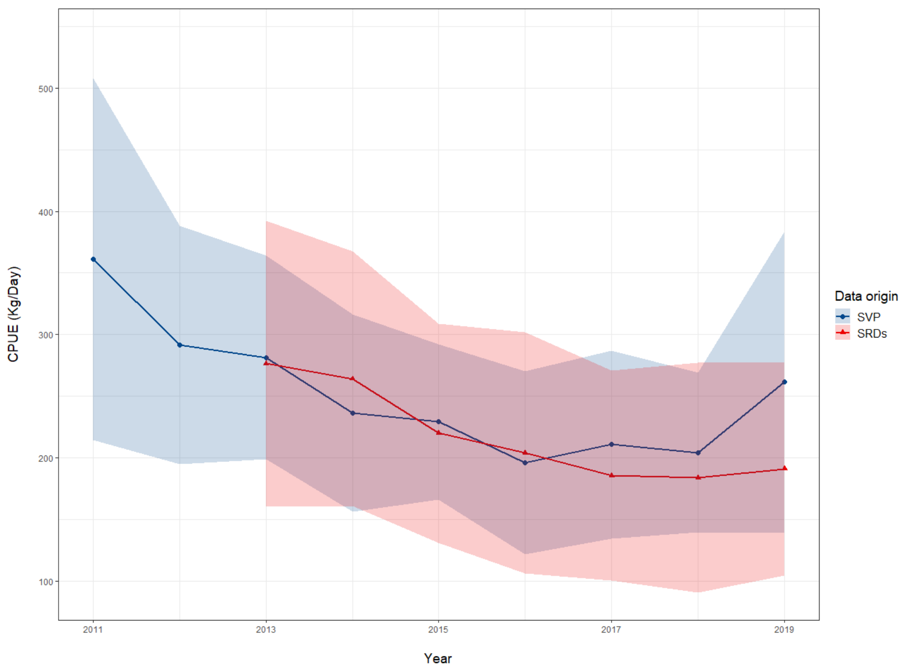


Figure 34. Average (and standard deviation) of catches per vessel per day of *Ensis siliqua* in the North Irish Sea from the Sentinel Vessel fleet (SVP) and Shellfish Registration Dockets (SRDs) from SFPA.

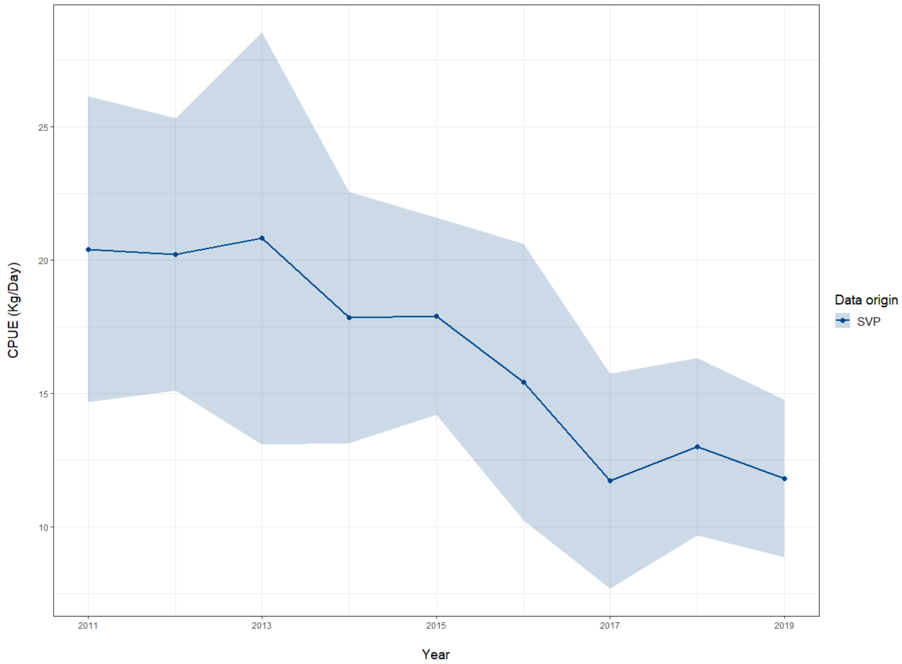


Figure 35. Annual catch (kgs) per hour at sea from the SVP data.

7.5.5 Catch advice

Average catch and % of biomass landed in the period 2018-2020 was 463 tonnes and 6.9 %, respectively. Surveys indicated that biomass was stable during that period and there was some evidence of increase in modal shell size and grade structure between 2018-2020. LPUE varied from 184-203 kgs per day (SRD data) (Table 6). These average landings, during a period of stable biomass and LPUE, is consistent with the DCAC estimate of sustainable yield of 360 tonnes. Landings in the period 2015-2017 averaged 933 tonnes and biomass declined in 2018 and LPUE declined from 203 to 187 kgs per day.

Landing options for 2021 are therefore:

- Apply the DCAC estimate of 360 tonnes
- Apply the 2018-2020 average landings of 463 tonnes
- Apply the 2018-2020 average exploitation rate of 6.87 % to 2020 biomass estimate for a landing of 515 tonnes

Table 6. Trends in landings, biomass, % of the biomass fished and landings per day in recent years relative to DCAC sustainable outtake estimates.

Year	Landings	Biomass	% Exploitation	CPUE (ks/day)
2013	369			290
2014	341			268
2015	1,100			220
2016	887			204
2017	814	10,000	8.14	186
2018	716	6,000	11.93	184
2019	374	8,000	4.68	191
2020	300	7,500	4.00	203
2018-2020 average	**463**	**7,167**	**6.87**	**187**
DCAC estimate of sustainable landings	**360**			

7.5.6 Economic indicators

Indicators of economic viability of fishing are derived from SVP data that includes partial costs; namely fuel. Net value per hour at sea increased from 2011-2015 due to significant price increases for razor clams and also reductions in fuel price even when catch rates were declining. Value per hour at sea peaked in 2015 and 2016 and then declined due to continued fall in catch rates, increase in hours at sea and increases in fuel price (Figure 36, Table 7). Price increases in 2019 increased profitability relative to 2017 and 2018.

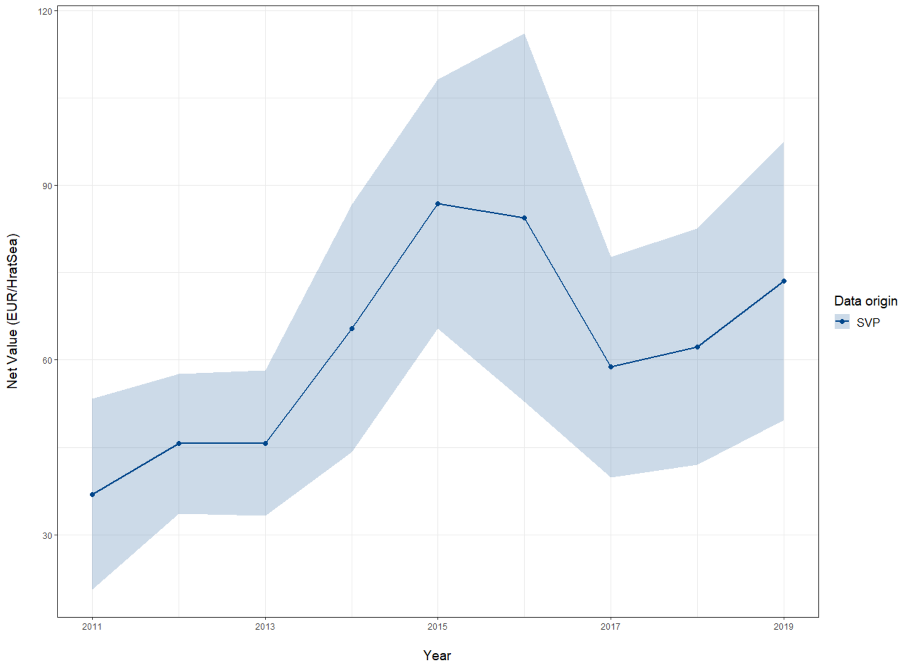


Figure 36. Net value (Landed value minus fuel costs) per hour at sea in the Razor Clam North Irish sea fishery from the SVP data.

Table 7. Annual trends in fuel costs, hrs at sea, price of clams, LPUE and net (of fuel) value of the catch between 2010 and 2019.

Year	Daily fuel cost	Diesel per Litre	Hrs at sea per day	Price of clams per kg	Kgs per hr at sea	Net value of daily landings	Net value per hr at sea
2010	€208	€0.65	13.2	€2.21		€599.00	
2011	€243	€0.80	17.1	€2.54	20.40	€638.00	€36.90
2012	€272	€0.92	14.2	€3.45	20.20	€669.00	€45.60
2013	€226	€0.88	14.7	€3.79	19.03	€702.00	€45.70
2014	€180	€0.79	12.9	€4.60	17.81	€908.00	€65.00
2015	€148	€0.73	12.6	€5.60	17.90	€1,185.00	€88.00
2016	€136	€0.60	13.4	€6.20	15.40	€1,077.00	€85.00
2017	€214	€0.62	19.2	€5.90	11.70	€1,087.00	€59.00
2018	€197	€0.63	16	€5.78	13.00	€1,063.00	€62.00
2019	€302	€0.76	19.9	€7.49	12.20	€1,553.00	€74.00

7.5.7 Ecosystem effects of the fishery

The fishery may impact a number of ecosystem components in the NIS including seafloor faunal communities and sediments and also some seabirds that rely on bivalves for food and which are sensitive to disturbance by marine traffic.

7.5.8 Recent monitoring of infaunal deep burrowing bivalves

The dominant deep burrowing bivalve species caught as by catch in razor clam surveys 2017-2020 were Otter shell (*Lutraria lutraria*), the locally called 'blood razor' (*Pharus legumen*) and the saltwater clam (*Mactra stultorum*). These are locally very abundant in some areas. There is significant year to year variation suggesting episodic recruitment of some species (Figure 37). Total abundance of bivalves in areas south of Dundalk Bay was higher in 2020 although this was driven mainly by high abundance of *Pharus legumen*.

Dundalk Bay has a different community characterised by lower diversity and abundance of deep burrowing infaunal bivalves compared to areas to the south. Abundance of infaunal bivalve species in Dundalk Bay also declined from 2017-2020 (Figure 38).

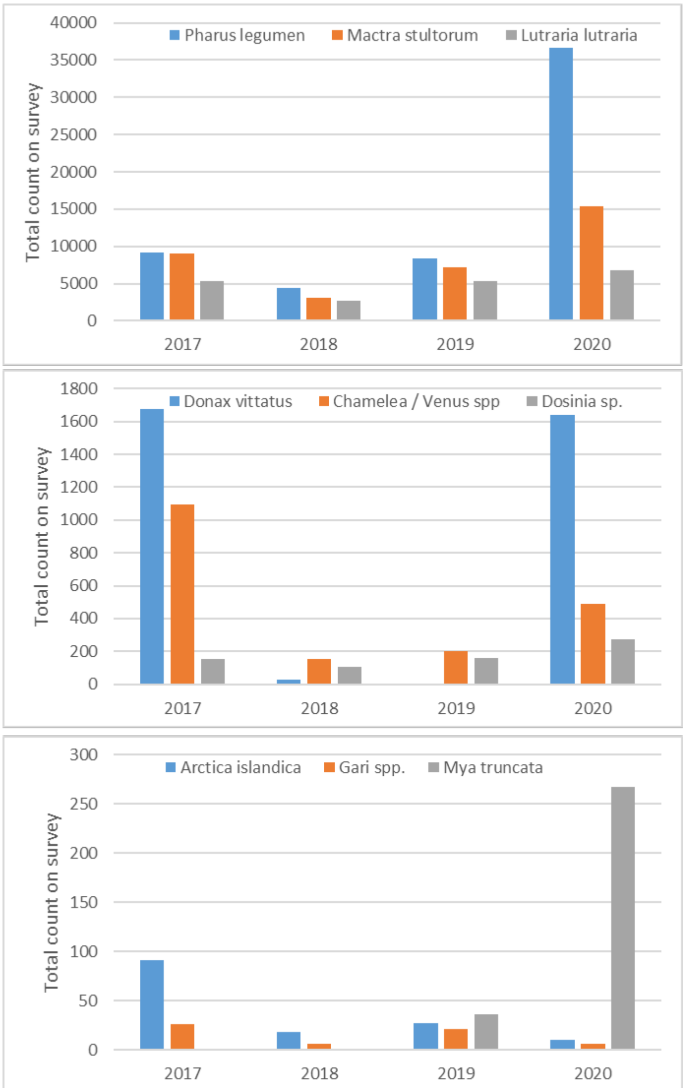


Figure 37. Abundance of dominant species of bivalves recorded during Razor clam (*Ensis*) surveys in the NIS 2017-2020. Total numbers recorded on each annual survey standardised to the 2017 survey effort is shown. Note different scales on y axes.

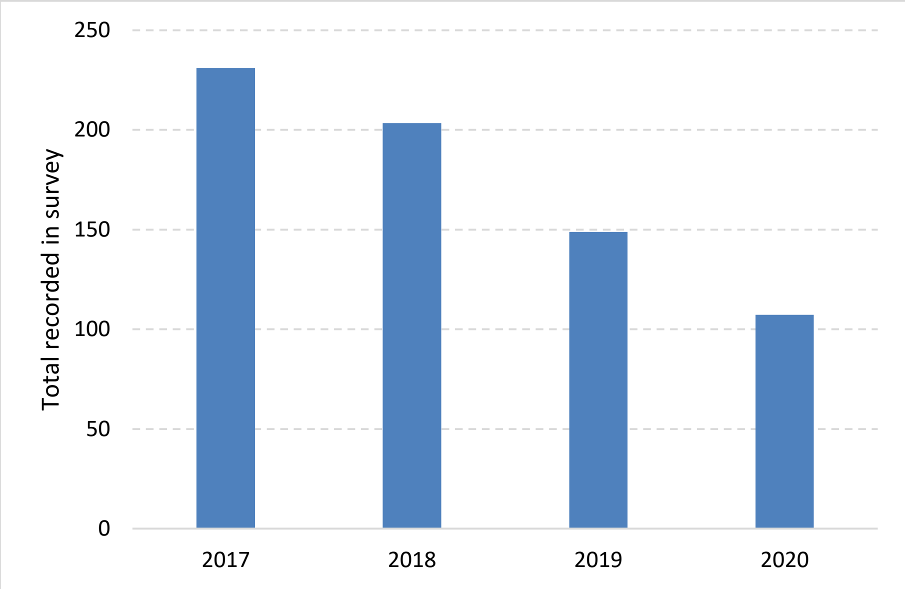


Figure 38. Abundance of dominant species of bivalves recorded during Razor clam (*Ensis*) surveys in Dundalk Bay 2017-2020. Total numbers recorded on each annual survey standardised to the 2017 survey effort is shown.

There is a potential for disturbance and displacement of Common Scoter from their feeding grounds in shallow coastal waters of the north Irish sea due to the presence of fishing vessels. However, there is no evidence that this disturbance is actually displacing Common Scoter.

Common Scoter forage on surficial bivalves as opposed to deep burrowing bivalves in the area. Therefore, any changes in structure and function of the habitat resulting from the razor clam fishery will impact on the foraging of Common Scoter. Aerial digital seabird data shows high numbers of Common Scoter occur along the Gormanstown coast and in outer Dundalk Bay in areas where the razor fishery occurs.

7.6 South Irish Sea

7.6.1 Landings

The fishery in the south Irish Sea opened in 2010. Landings increased from 50 tonnes in 2010 to 150-170 tonnes between 2013-2015 and over 200 tonnes in 2016 (Figure 39). Landings declined to between 100-125 tonnes in 2017-2020 (logbook and sales data). These 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 a strong 2014 year class. Markets were limited in 2020. The Waterford estuary fishery was closed by court order in 2019.

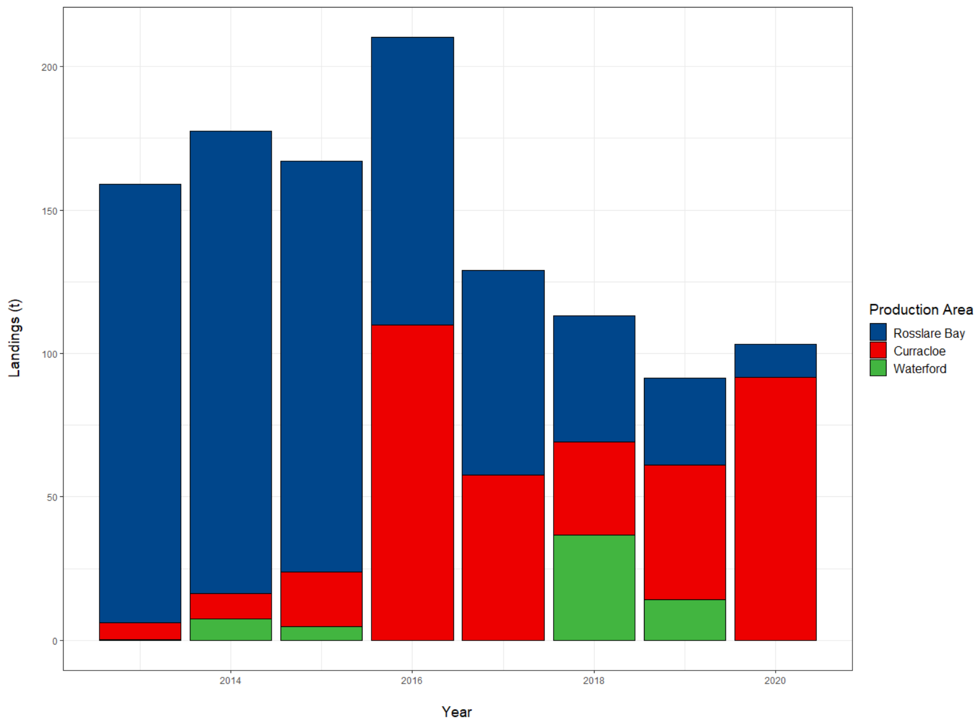


Figure 39. Landings (tonnes) of razor clams in the South Irish Sea by classified production area (CPA). Source: Logbooks/ Sales notes. CPA is assigned by port of landing.

7.6.2 iVMS fishing effort

The majority of iVMS effort occurred in Rosslare Bay in 2015 and 2016 (Figure 40) although the landings data in 2016 are higher for Curracloe. There are no VMS data for 2017 or 2018 in either area. Annual landings in these years was about 70 tonnes and there was a voluntary ‘closure’ in place by agreement in Rosslare Bay. Some of the effort switched to Waterford estuary in 2018 and early 2019.

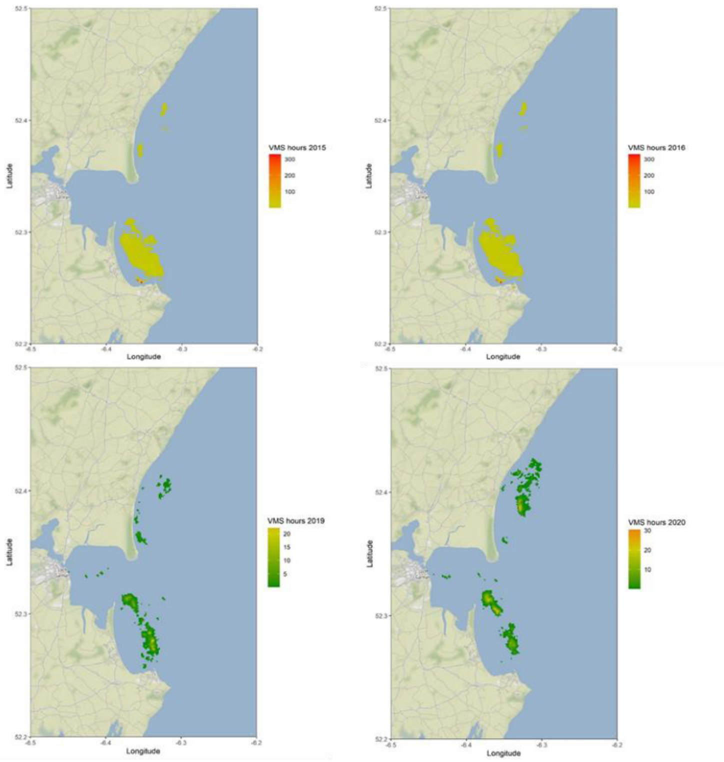


Figure 40. Distribution of fishing effort (VMS hrs) in Curracloe and Rosslare Bay for 2015-2016 and 2019-2020.

7.6.3 Survey data

Stocks of Razor clams in the South Irish Sea are distributed in two main beds; Rosslare and 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.

7.6.3.1 Rosslare Bay

In Rosslare, higher densities of razor clams occur in the core of the survey area (Figure 41), and similar spatial patterns are found among all size classes. A strong recruitment event was reported by the Skippers in 2014. Figure 42 shows the growth pattern of this cohort for the period 2017-2020. This growth accounts for the linear increase in biomass from 2,000 tonnes to 6,500 tonnes during 2017-2020 (Figure 43). About 85 % of the biomass is above the 130 mm MLS.

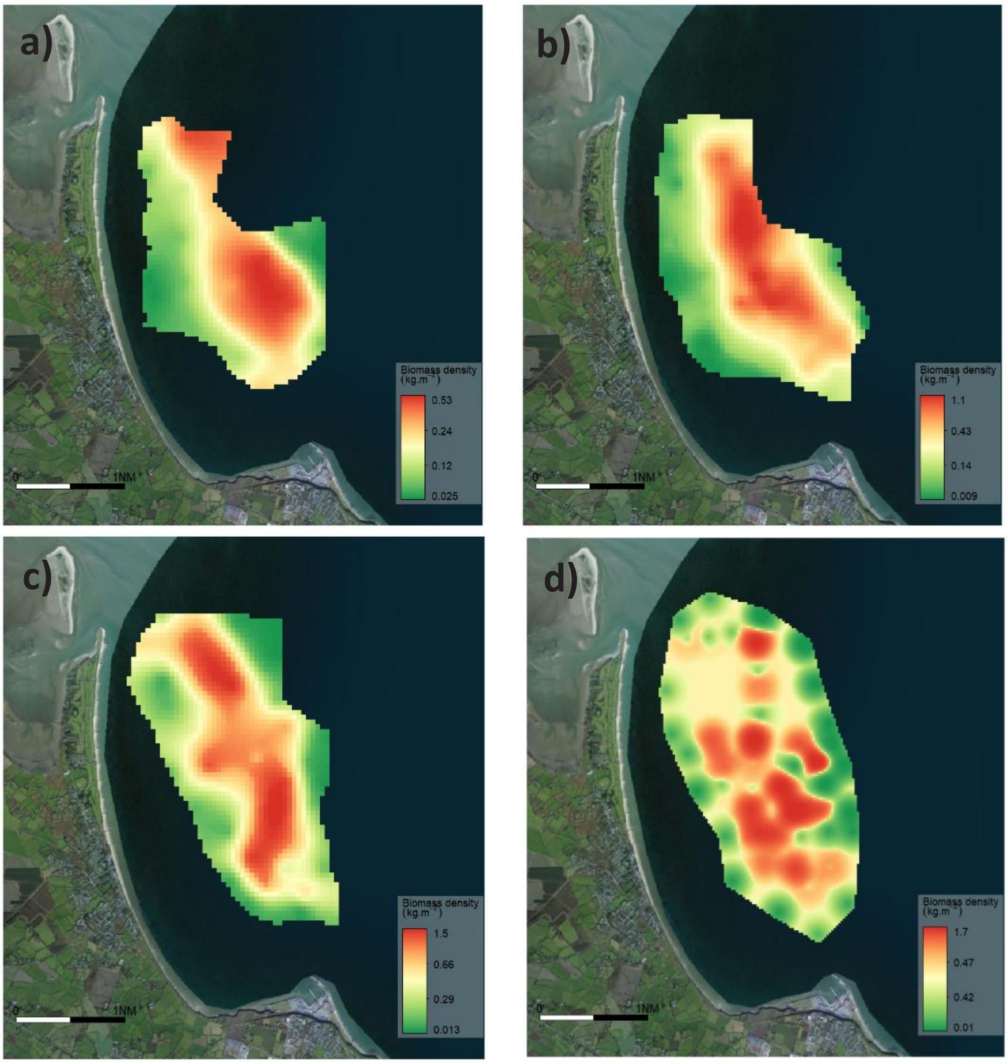


Figure 41. Distribution of *Ensis siliqua* for all size classes in Rosslare Bay in: a) **2017,** b) **2018,** c) **2019 and** d) **2020. Note different scaling across years.**

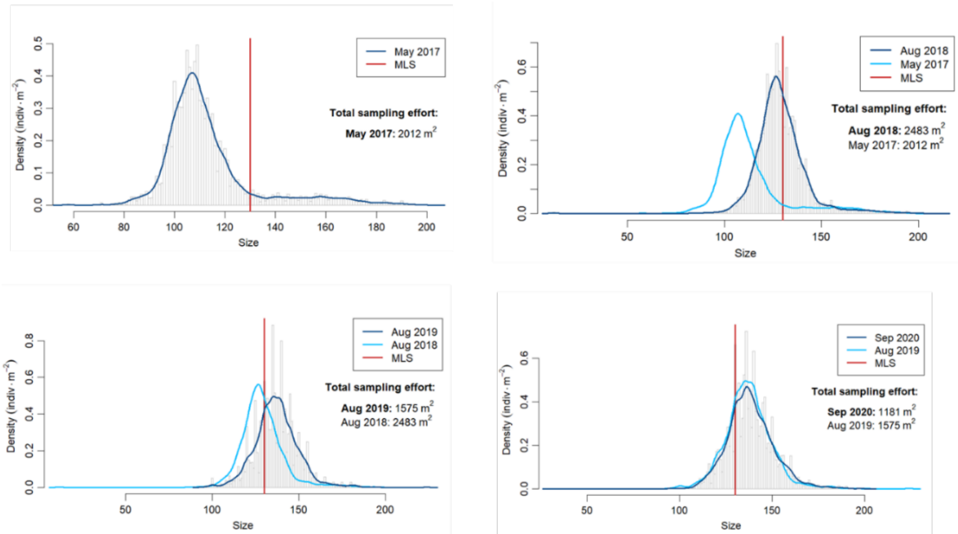


Figure 42. Size distribution of razor clams (*Ensis siliqua*) in the Rosslare Bay survey in a) **2017,** b) **2018/2017,** c) **2019/2018 and** d) **2020/2019. Data are standardised to sampling effort regardless of its spatial distribution.**

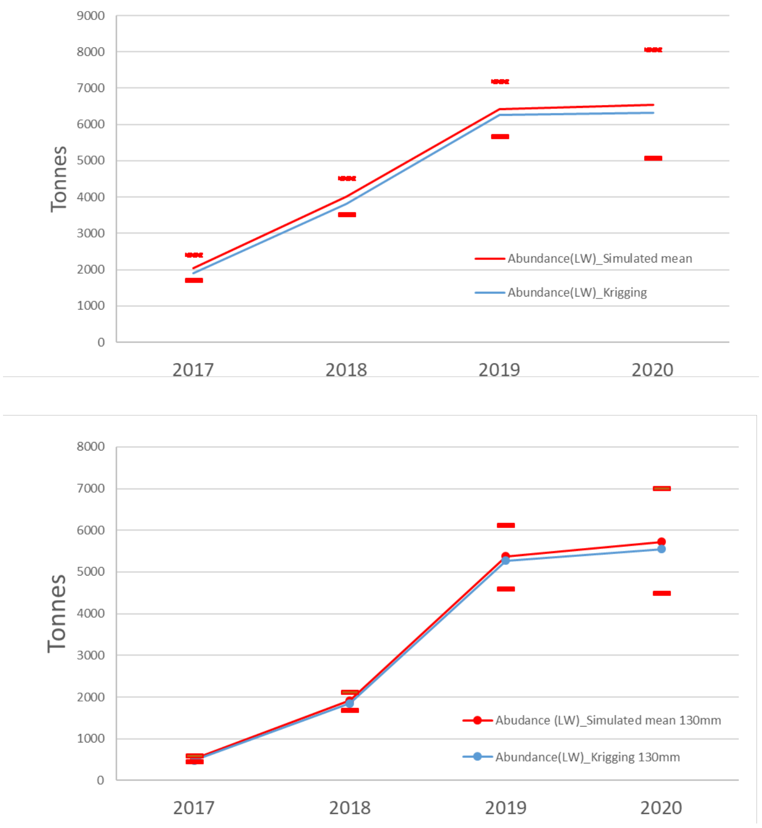


Figure 43. Estimates of biomass of razor clams (*Ensis siliqua*) in Rosslare Bay in 2017-2020 for all size classes (top) and size >130 mm (bottom).

7.6.3.2 Curracloe

At Curraloe, the highest biomass of razors is found in the southern limit of the survey area (Figure 44). Figure 45 shows a clear shift in the size distribution from 2019 to 2020 due to annual growth, and a mode at approximately 160 mm. This inter-annual growth explains the increase in biomass shown in Figure 46. Biomass was approximately 1,000 tonnes in this area in 2020.

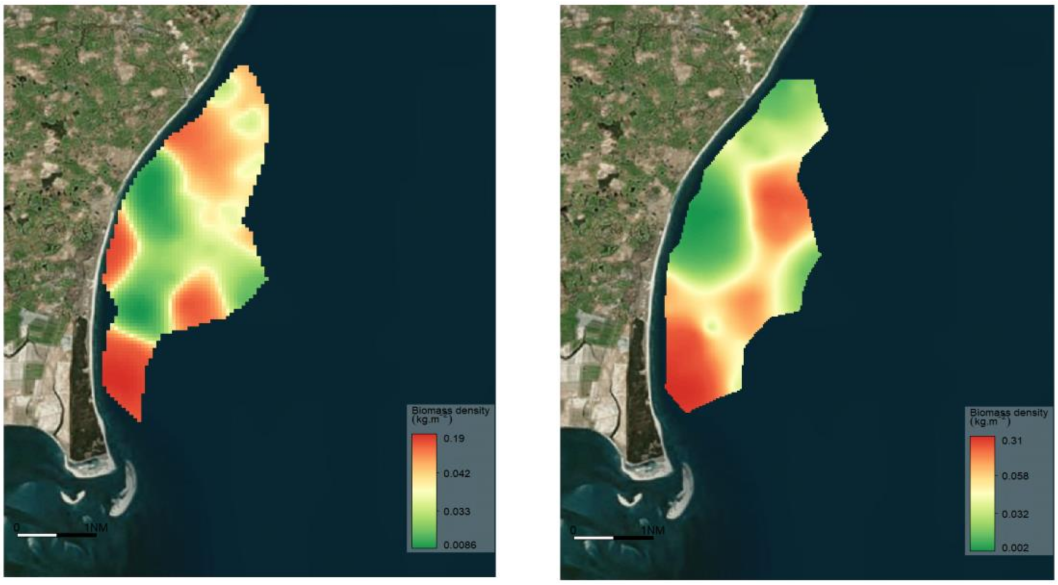


Figure 44. Distribution of *Ensis siliqua* for all size classes in Curracloe in: 2019 left) and 2020 right). Note different scaling across years.

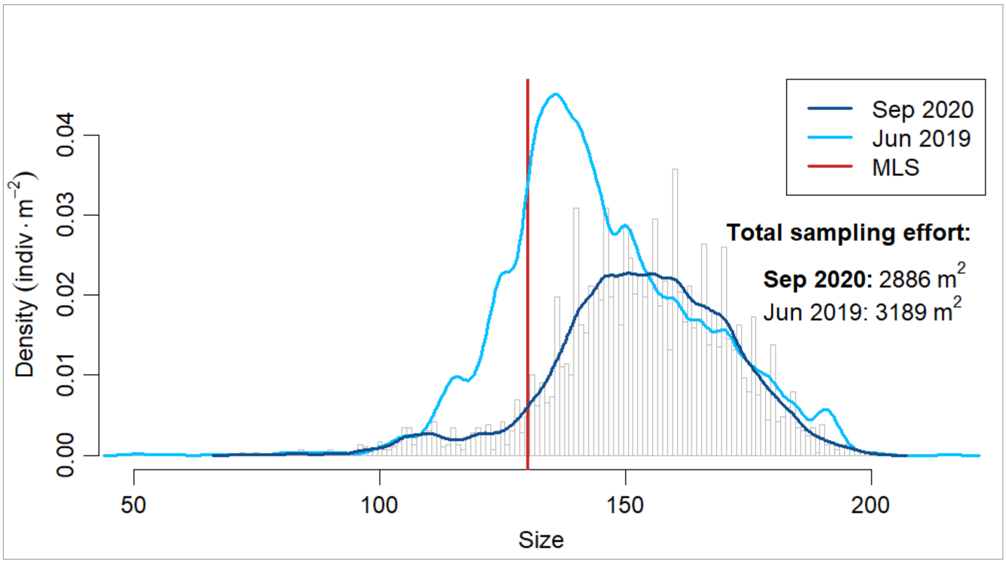
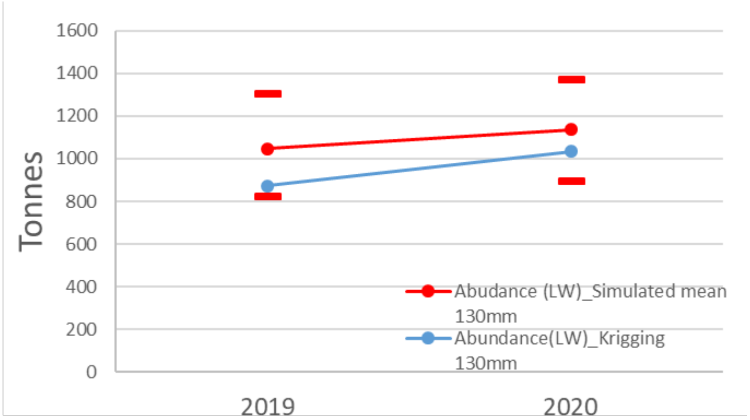


Figure 45. Size distribution of razor clams (*Ensis siliqua*) in the Wexford survey for 2019 and 2020. Data are standardised to sampling effort regardless of its spatial distribution.



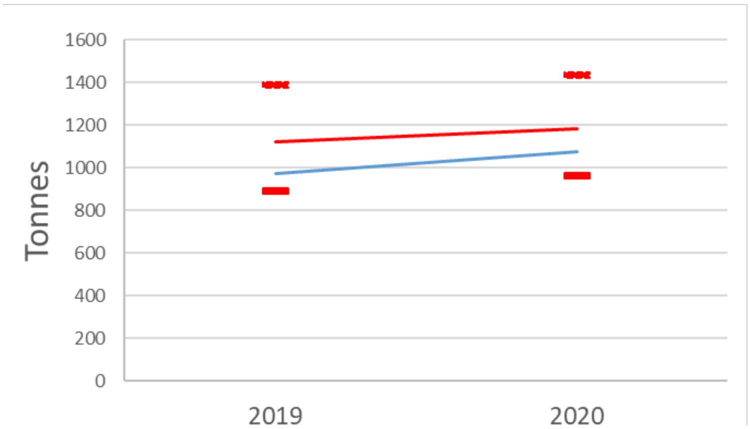


Figure 46. Estimates of biomass of razor clams (*Ensis siliqua*) in Curracloe combined in 2019-2020 for all size classes top) **and >130mm** bottom)**.**

7.6.3.3 Catch advice

Survey estimates of razor clam biomass between 2017 to 2020 continue to show significant increase in biomass mainly due to growth of a year class that recruited to Rosslare Bay probably in 2014.

Biomass in 2020 was approximately 6,500 tonnes. Over 80 % of this was in Rosslare Bay. Landings overall should not exceed 450 tonnes in 2021 (applying 6.8 % exploitation rate as in option 3 above for the North Irish Sea). Not more than 20 % of this (68 tonnes) should come from the Curracloe razor bed.

8 Cockle (*Cerastoderma edule*)

8.1 Management advice

The Dundalk Bay cockle fishery is managed under a Natura 2000 site fisheries Natura (management) plan. No fishing occurs at biomass less than 750 tonnes. The fishery closes when the TAC (33 % of biomass over 750 tonnes) is taken, on November 1st or if the average catch per boat per day declines below 250 kg. The MLS 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. A review of the 2016-2020 fishery plan shows that intertidal habitats and marine communities were stable. The long term (1994-2019) average number of birds at the site ranged from 30,000 to 61,000. Declines during the period 2011-2015 were reversed in 2015-2019. There is a correlation between the post fishery biomass of cockles and the number of oystercatchers at the site in the following winter.

Pre-fishery survey estimate of cockle biomass in 2020 was 3,420 tonnes. This was the second highest biomass since surveys began in 2007 and follows from a strong recruitment in 2018. The TAC and landings for 2020 was 1,128 tonnes.

The harvest control rules which have been in place since 2007 should be continued but the limit reference biomass at which a fishery opens should be increased to at least 1,000 tonnes because of the observed correlation between post fishery cockle biomass and oystercatcher numbers. 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 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 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). Commercial 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 and 2016-2020) and specified in 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). A new five year plan will be proposed by industry for the period 2021-2025. The performance of the previous plans in terms of protecting cockle stocks, benthic habitats and bird populations were reviewed in 2020.

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 at 33 % of biomass estimated from a mid-summer survey. 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 annually as part of the management plans and the prospect of an annual fishery depends on annual 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- 2020

Biomass estimates from annual surveys in 2007-2020 are not strictly comparable because of differences in the time of year in which surveys were undertaken (Table 8). 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. 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 % (2017-2020). 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.

Table 8. Annual biomass, TAC and landings of cockles in Dundalk Bay 2007-2020.

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

8.5.2 Survey in 2020

8.5.2.1 Biomass

A pre-fishery survey was completed in June 2020. The survey area was 27.2 km^2. Total biomass was 3,420 tonnes (Table 9) based on a geostatistical model. Biomass of cockles over 22 mm was 1,162 tonnes (Figure 47).

Table 9. Biomass of cockles in Dundalk Bay in June 2020.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Biomass All sizes	3,420	3,780	3,360	4,230
Biomass (tonnes) > 22mm	2,350	2,560	2,310	2,880
Biomass (tonnes) > 18mm	3,250	3,620	3,220	4,060
Biomass (tonnes) < 18mm	117	185	140	245

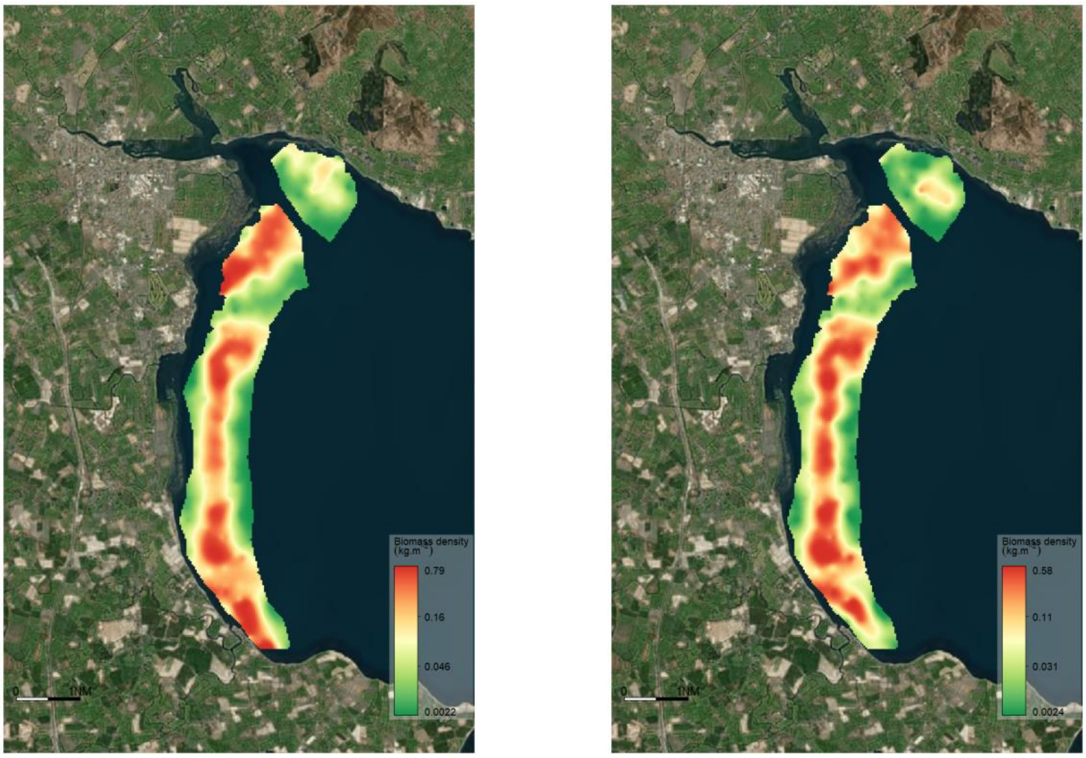
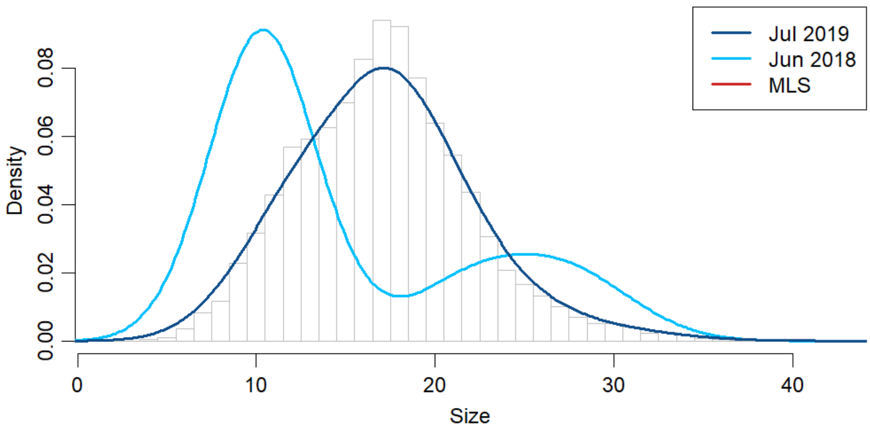


Figure 47. Distribution and density (kgs.m^{-2}) of all cockles (left) and commercial cockles (>22 mm shell width) (right) in Dundalk Bay in June 2020.

8.5.2.2 Size distribution and recruitment

Comparison of the 2018-2020 data shows growth of the 2018 0+ cohort to a modal size of approximately 18 mm in 2019 and to 24 mm in 2020 (Figure 48). No significant recruitment (spat settlement) occurred in 2019 or 2020 although survival of the 2018 cohort has been strong as indicated by the increase in biomass and high landings in 2018-2020.



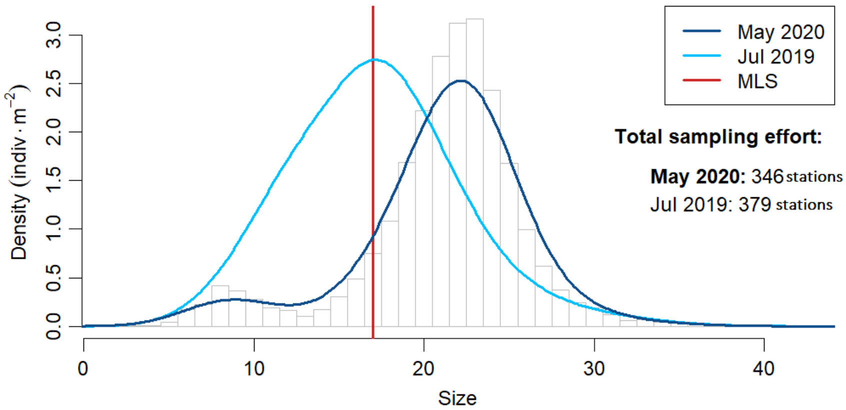


Figure 48. Size distribution of cockles in Dundalk Bay in July 2019 and June 2018 and July 2019 and May 2020.

8.5.3 Fisheries monitoring and exploitation rate

In the years 2016-2020 in season depletion in catch rates were observed in 2016 (28 %), 2017 (21 %) and 2018 (31 %) (Figure 49). No depletion was observed in 2019 or 2020 where catches remained close to the 1,000 kg per day limit throughout the season. The level of observed depletion is negatively correlated with pre-fishery biomass. When biomass is high fishing time is reduced and the fleet can move to different areas to maintain catches. When biomass is lower (1,800-2,300 tonnes in 2016-2018) the fleet is less able to maintain catches. The observed depletions or absence of depletion indicates that in no case was the 33 % harvest rule broken (depletions were 21-31 %). The depletion rates also suggest that the pre-fishery survey correctly estimates the biomass which is used to estimate the TAC. The survey estimate in fact is likely to underestimate the fishable biomass at the start of the fishing season as there is a significant increase in cockle size between the survey and opening of the fishery even if this is usually only 3-6 weeks. This could explain the less than expected depletion rates.

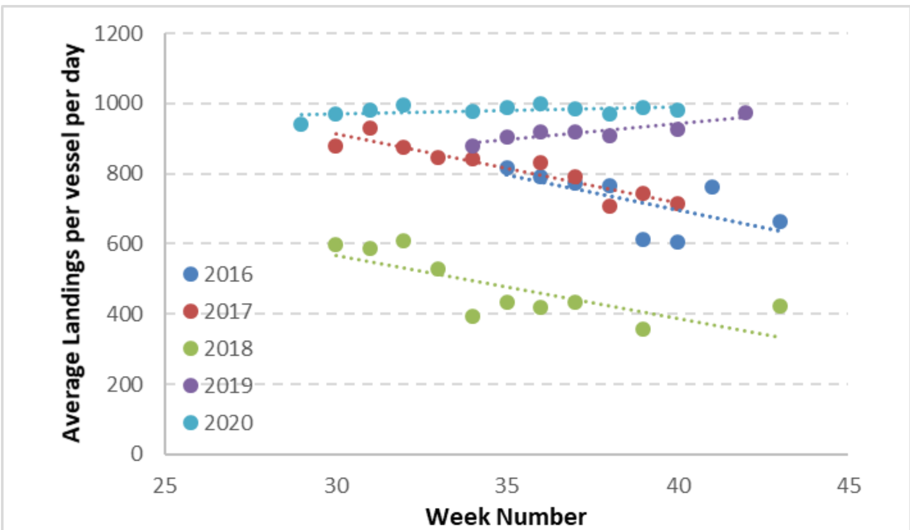


Figure 49. In season changes in average landings per vessel per day grouped by week for each week of the cockle fishery in 2016-2020

8.5.4 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. The Fishery Plans included restrictions and limits on outtakes and in particular 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 from intertidal habitat and bird population monitoring since 2007 is summarised below.

8.5.4.1 Intertidal habitats

The 3 numerically dominant species of bivalve in the intertidal habitat of Dundalk Bay are cockle (*Cerastoderma edule*), *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 *Angulus 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 lighter 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 annual summer surveys 2007-2020. Both *A. tenuis* and *M. balthica* can occur in high densities (Table 10, Figure 50). The average abundance of both bivalves was stable between 2013-2020. Distribution maps show similar distributions across the time series (Figure 51).

Table 10. 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 2011-2020.

Year	*Angulus tenuis*		*Macoma balthica*		*Arenicola marina*		Redox Potential Discontinuity (RPD) layer	
	Average	S.d.	Average	S.d.	Average	S.d.	Average	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	9.981	7.29

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 2020 (Table 10). It has been consistent at an average depth of about 10 cm since 2015.

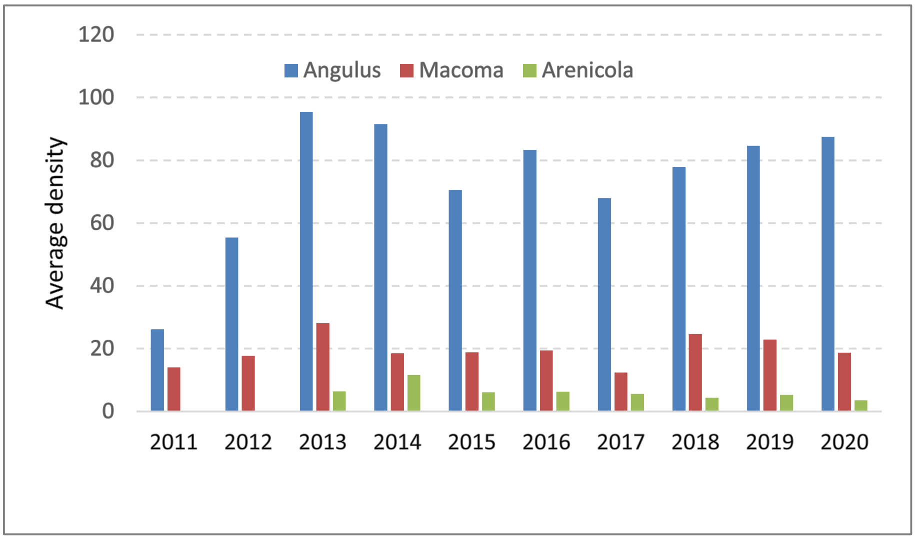


Figure 50. Average densities of *Angulus tenuis*, *Macoma balthica* and *Arenicola marina* in intertidal sediments in Dundalk Bay 2011-2020.

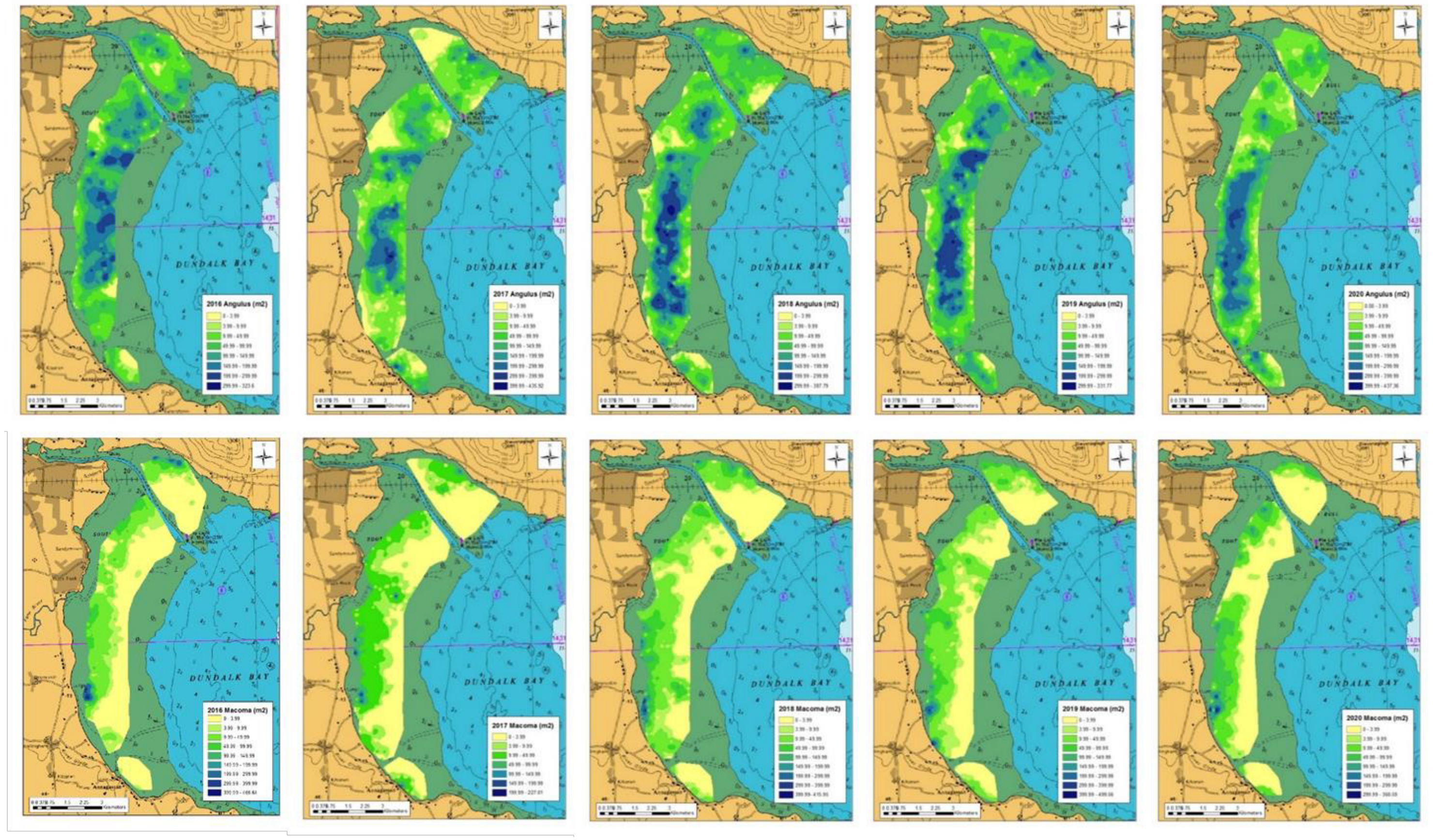


Figure 51. Annual distribution of *Angulus tenuis* (top) and *Macoma balthica* (bottom) during mid summer surveys in Dundalk Bay 2016-2020.

8.5.4.2 Birds

Overwintering birds in Dundalk Bay have been monitored since the mid-1990s by iWeBs (Irish Wetlands Bird Survey). Counts are taken at key roost locations at high tide. Additional low tide counts have been undertaken periodically by the National parks and Wildlife Service and the Marine Institute.

The highest numbers of birds (all species, 61,255) in Dundalk Bay were recorded in winter 2003/2004 (Figure 52). The long term (1994-2019) average is stable with a range between 30,000 and 61,000 birds. Year on year declines during the period 2011-2015 were reversed in the period 2015-2019.

Data for different feeding groups namely Bivalve feeders, Fish feeders, Generalist feeders, Invertebrate feeders and Vegetation feeders show variable patterns (Figure 53). Bivalve feeders declined in 2012/13 and remained on average at lower levels up to 2018/19 compared to earlier years. This decline also occurred in the generalist group with the exception of 2017/18.

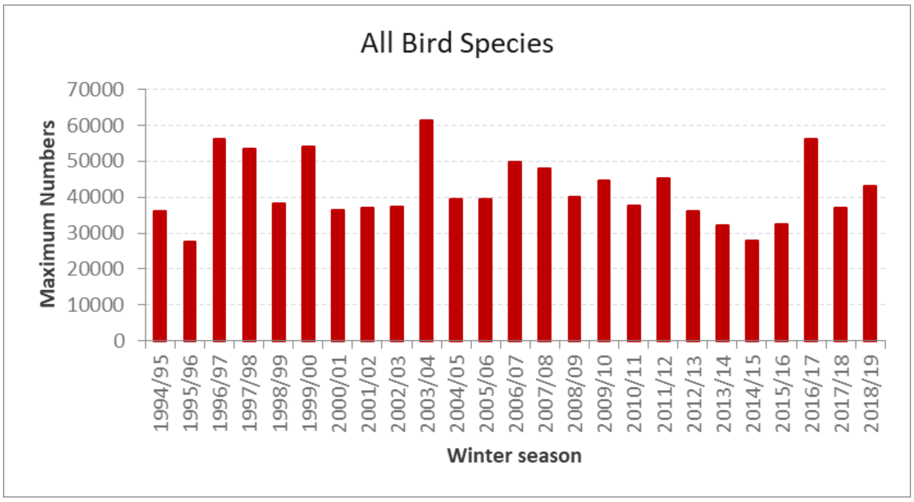


Figure 52. Trends in the number of all bird species from September to February during the winter seasons from 1994/1995 to 2018/2019 in Dundalk Bay.

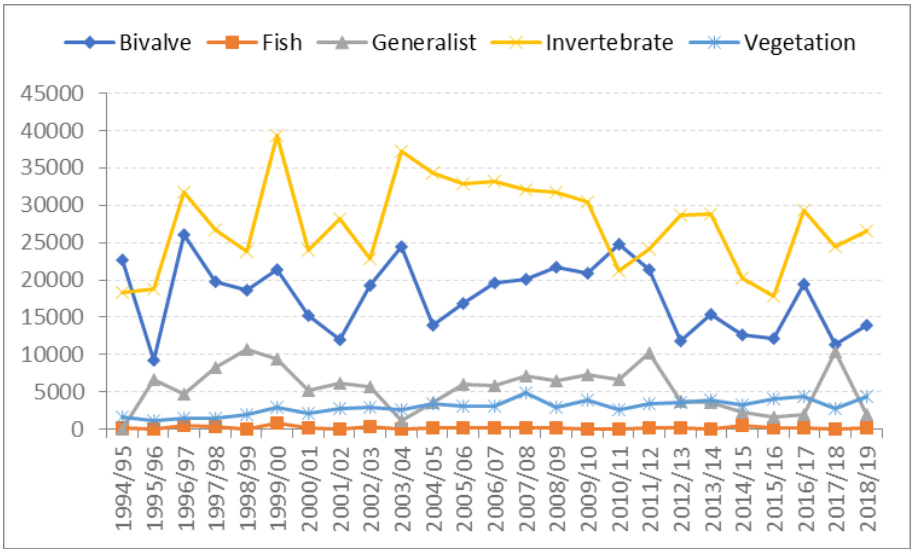


Figure 53. Trends in the number of bird feeding groups from September to February in Dundalk Bay. from 1994/1995 to 2018/2019.

There has been no change in the structure, function or distribution of intertidal habitats which support these bird populations in Dundalk Bay since 2007 and no significant effects of cockle fishing on habitats has been found. Bird populations not relying on cockle as a food source are unlikely to be impacted by the fishery

8.5.4.3 Oystercatcher

Oystercatcher feeds on cockles. However, work contracted in recent years by the Marine Institute in Dundalk Bay also shows that it feeds on other prey and in particular it feeds extensively in grasslands bordering Dundalk Bay. NPWS report average maximum counts of 8,746 birds in their reference period 1995/96 to 1999/00. iWeBs counts of over 14,000 oystercatchers in 1999/00 and 2006/2007 were the highest counts in the 24 years time series (Figure 53). Recent 5 year averages and longer term 10 year averages were 5,945 and 7,117 birds, respectively. A year on year decline occurred from 2008/09 to 2014/15. Numbers increased from 2014/15 to 2018/19.

The number of oystercatcher at other east coast sites south of Dundalk Bay hold lower numbers of birds than Dundalk Bay (Figure 55). Ten year trends in oystercatcher are stable or negative at most of these sites. There is a small upward trend in Dublin Bay. The year on year variation in counts is much higher in Dundalk than in other sites. The 5-year population trend for oystercatcher in Dundalk Bay is in line with or better than the 5-year population trend in other east coast sites without a cockle fishery suggesting that the fishery in Dundalk Bay is not adversely affecting oystercatcher populations.

The number of oystercatchers overwintering in Dundalk Bay is positively correlated with the post fishery cockle biomass (Figure 56). This is the biomass that is available in autumn when the fishery is closed. The relationship is leveraged by the cockle biomass and high oystercatcher count in 2008/09. At a cockle biomass between 1,000-2,000 tonnes oystercatcher numbers are variable. Nevertheless, the minimum cockle biomass to open the cockle fishery is 750 tonnes and the relationship between cockle biomass and oystercatcher numbers suggest this may be too low and could reduce the capacity of the site to support oystercatchers. A change in this harvest rule to a higher cockle biomass before a fishery could open would be more precautionary.

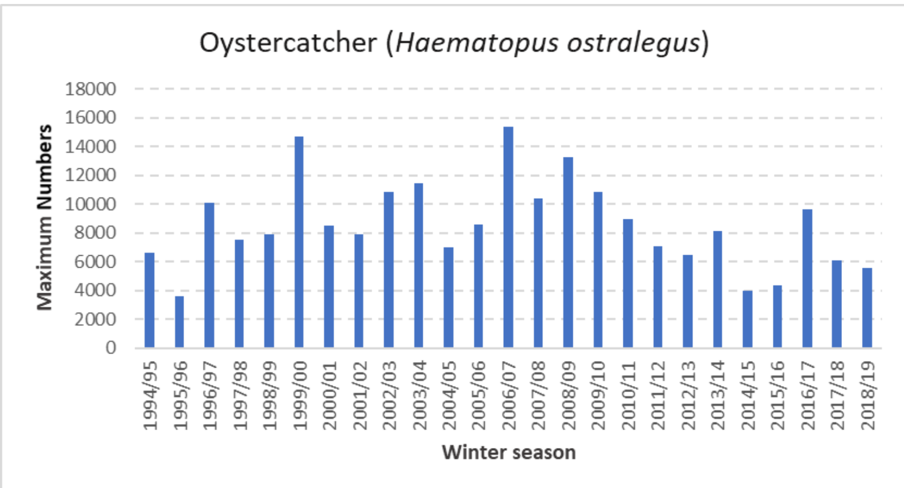


Figure 54. Trends in the number of oystercatcher (*Haematopus ostralegus*) from September-February during the winter seasons from 1994/1995 to 2018/2019 in Dundalk Bay.

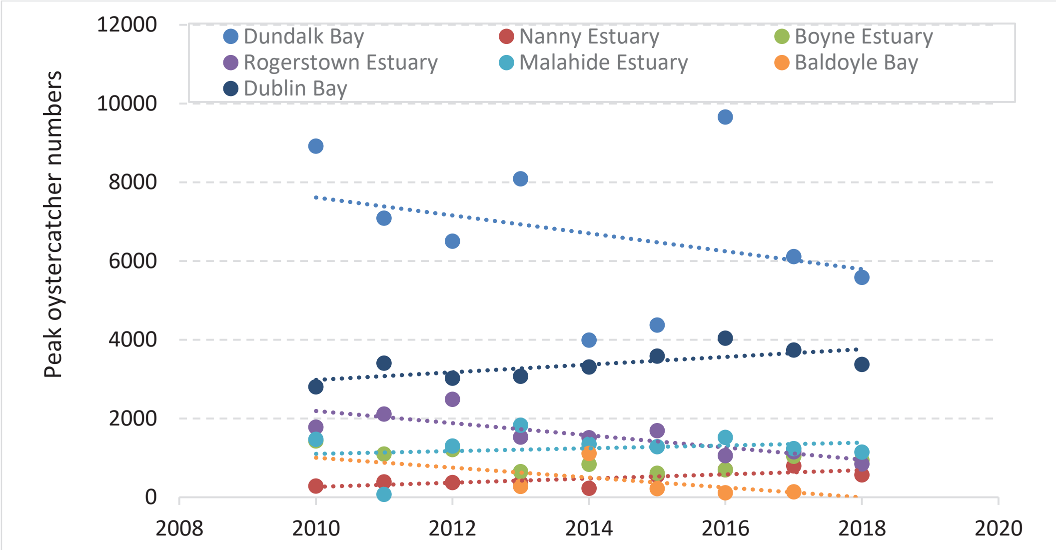


Figure 55. Trends in the number of oystercatcher (*Haematopus ostralegus*) from September-February during the years 2010/2011 to 2018/2019 from several wintering sites along the east coast including Dundalk Bay.

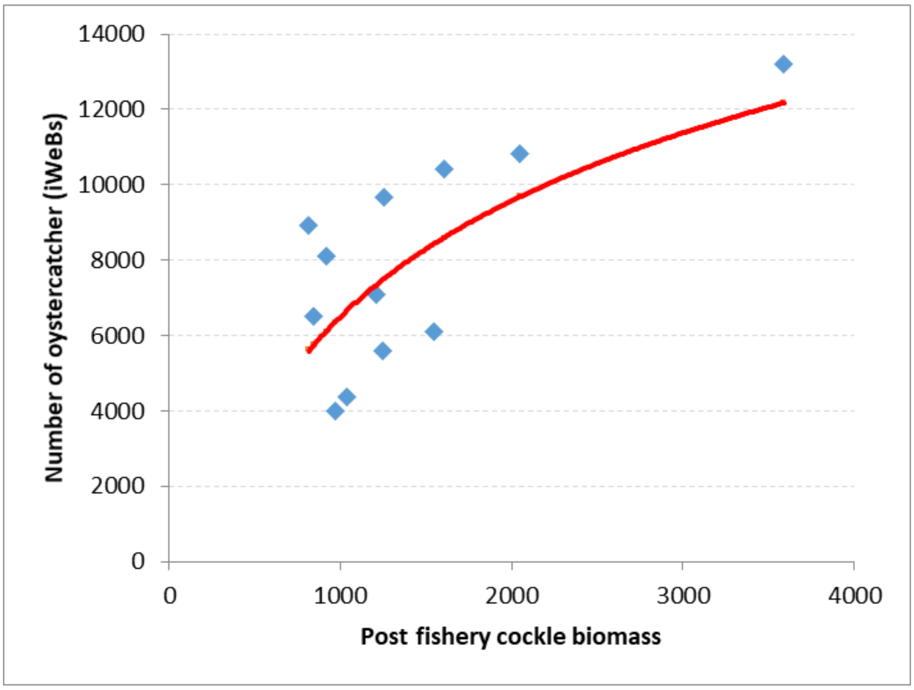


Figure 56. Relationship between oystercatcher (*Haematopus ostralegus*) numbers (iWeBs data) and post fishery cockle biomass in Dundalk Bay 2007-2018. The fitted curve is a Beverton and Holt stock (cockle) and recruitment (oystercatcher) function R=aS/(b+S), a = 18587 (the asymptote of the curve) and b = 1870 (steepness) or the cockle biomass required to recruit 0.5 of the asymptotic value.

9 Oyster (*Ostrea edulis*)

9.1 Management advice

Oyster 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 has in some years supported 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 to stocks. This should include a range of actions including removal of Pacific oysters, maintenance or recovery of habitat including cultching, closure of fisheries where only a small proportion of oysters are over the minimum size to allow for growth and use of various stock recovery measures.

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. Restoration is consistent with the conservation objectives.

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 and Clew 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 this species 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.

These issues were discussed at the Native Oyster Workshop in October 2017 hosted by Cuan Beo in Clarinbridge (www.cuanbeo.com). A new forum, the Irish Native Oyster Fisheries Forum (INOFF) was established in 2018 representing all oyster co-ops to discuss site specific issues and future management and restoration of oyster stocks. A project supported by the European Monetary Fisheries Fund (EMFF) Biodiversity Scheme on restoration of native oyster has been co-ordinated by the MI since 2017 and is working with Cuan Beo and a number of oyster co-ops. These projects are linked to the Ireland UK native oyster restoration network (https://nativeoysternetwork.org/).

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. 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 2014 survey estimate is an outlier in the time series. The area surveyed usually contains the entire stock which is distributed over approximately 4 km^2 (Table 11).

Table 11. Stocks biomass trends for native oyster in Inner Tralee Bay 2010-2019.

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	1265
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	1161
2019	October	3.7	237.57	879
2020	September	5.32	304.14	1618

9.5.2 Survey September 2020

9.5.2.1 Biomass and landings in 2020

A pre fishery survey was carried out from the 8-10th September in Inner Tralee Bay. A total of 106 tows were undertaken, 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 5.32 km^2 east and west of Fenit pier (Figure 57).

Biomass of oysters uncorrected for dredge efficiency varied from 0-0.8 $kgs.m^{-2}$ (Figure 57). Biomass of oysters over 76 mm ranged from 0-0.2 $kgs.m^{-2}$.

Total biomass of oysters, assuming a dredge efficiency of 35 %, was 1,618 tonnes (Table 12). The equivalent biomass of oysters 78 mm or over was 463 tonnes (Table 12) or approximately 29 % of the total biomass.

Table 12. Distribution of oyster biomass, corrected for a dredge efficiency of 35%, in Inner Tralee Bay in September 2020.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for efficiency				
Biomass_*Ostrea_edulis*	566.6	697	551.2	863.7
Biomass_>78mm_*Ostrea_edulis*	162.1	204.6	160	255.4
Corrected_35% dredge efficiency				
Biomass_*Ostrea_edulis*	1,618.9	2,001.1	1,567.2	2,483.4
Biomass_78_Inf_*Ostrea_edulis*	463.2	579.2	461.8	721.66

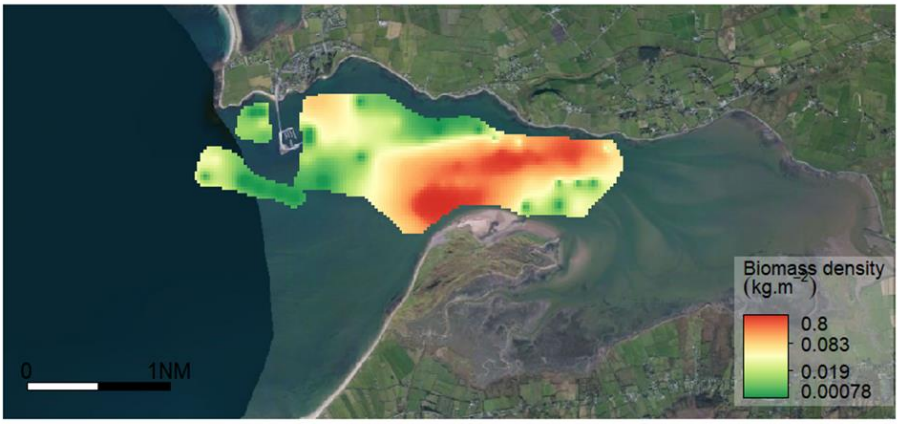


Figure 57. Distribution of biomass of native oyster in Inner Tralee Bay, September 2020.

9.5.2.2 Size distribution 2020

The size distribution of oysters caught during the survey shows a strong mode at about 70 mm and a smaller mode at 30 mm (Figure 58). The location of both modes is similar to that in 2019. The substantially higher density at the 70 mm mode, compared to 2019, cannot be explained solely by growth. The higher survey effort in 2020 and the differences in the spatial distribution of the GPS tracks compared to 2019 suggest the 2020 survey is more reliable.

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.

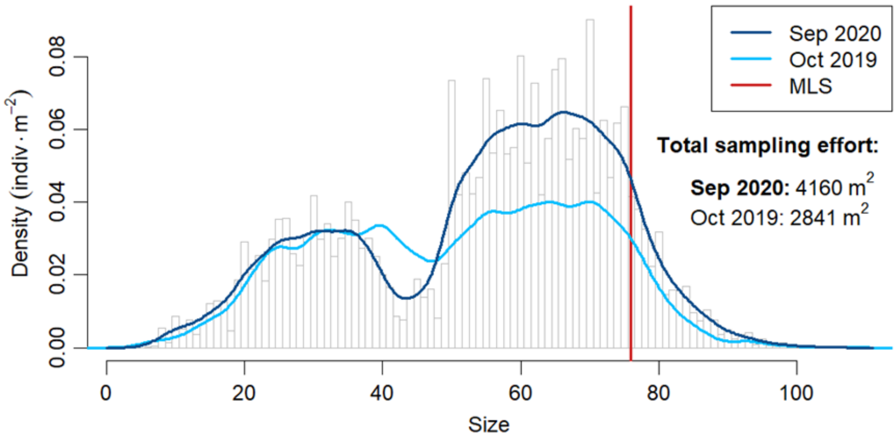


Figure 58. Size distribution of native oysters in the Inner Tralee oyster bed in September 2020. The MLS (76 mm) is also shown. Data are standardised to sampling effort regardless of its spatial distribution.

9.6 Cill Chiaráin

9.6.1 Stock trends

Only four surveys had been carried out by the Marine Institute on the Cill Chiaráin oyster beds prior to October 2020 and the surveyed area has varied each time (Table 13). Prior to 2010 Taighde Mara Teo and BIM carried out surveys in 2002, 2003 and 2006. Historically the oyster beds in Cill Chiaráin provided a steady return of 50+ tonnes of native oyster per annum for much of the 1990s and in 1998 120 tonnes were landed. Some habitat management (clutching) occurred at that time but ceased in 1998.

Table 13. Stocks biomass trends for native oyster in Cill Chiaráin 2010-2020.

Year	Month	Survey Area (km^2)	Biomass km^{-2}	Biomass
2010-2011	October/January	2.51	30.6	76.81
2012	October	1.06	12.9	13.68
2018	October	2.36	51.3	121.09
2019	October	1.78	38.9	69.2
2020	October	2.86	48.3	138.07

9.6.2 Survey October 2020

A survey was carried out on October 14-15st on the oyster beds of Cill Chiaráin. A total of 99 tows were undertaken (97 valid), with a single toothless dredge of width 1.20 m. GPS data for each tow line was recorded on a Trimble GPS survey unit and swept area for each tow estimated. The survey encompassed a combined area of 2.86 km^2 and a total sampling effort of 4,886 m^2.

9.6.2.1 Biomass

Biomass of oysters uncorrected for dredge efficiency varied from 0-0.075 $kgs.m^{-2}$, with the highest biomasses in the centre and south-east beds of the study region (Figure 59). Biomass of oysters over 76 mm ranged from 0-0.011 $kgs.m^{-2}$ following a similar distribution pattern.

The biomass of oysters, assuming a dredge efficiency of 35 % gives a total of 138 tonnes (Table 14). The equivalent biomass of oysters 76 mm or over the national minimum landing size was 28 tonnes (Table 14) indicating that the biomass of commercial size is 20 % of the total stock in the bay. The dredge efficiency co-efficient used was that recorded during the Cill Chiaráin Oyster survey of 2010. This dredge efficiency was estimated along 17 separate tracks using divers to be 32±32 %.

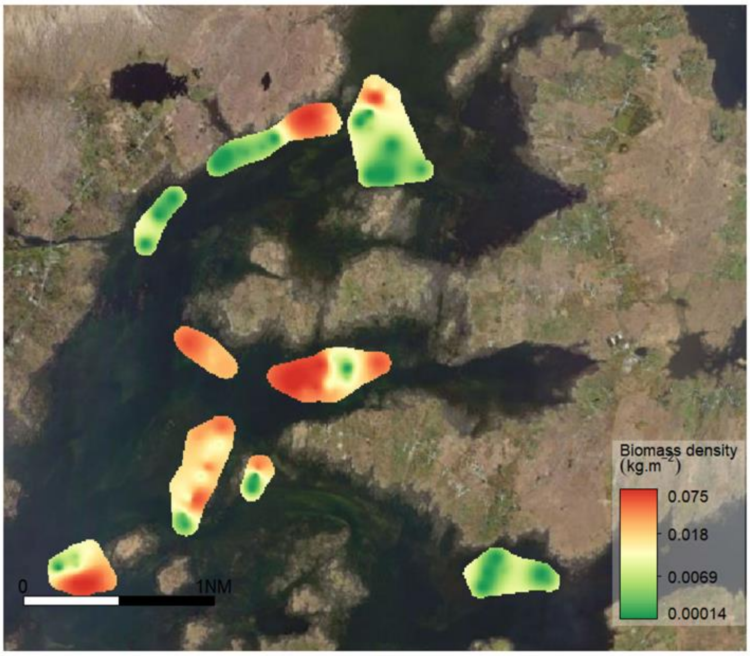


Figure 59. Distribution and biomass of native oyster in Cill Chiaráin in October 2020 (uncorrected for dredge efficiency).

Table 14. Biomass of native oyster in Cill Chiaráin in October 2020 based on a dredge efficiency of 32.5%.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for Dredge Efficiency				
Biomass_Ostrea_edulis	44.87	54.40	43.78	67.76
Biomass_>76mm_*Ostrea_edulis*	9.25	10.88	7.80	14.08
Corrected for 32.5% Dredge Efficiency				
Biomass_Ostrea_edulis	138.07	166.53	133.42	207.93
Biomass_>76mm_*Ostrea_edulis*	28.47	32.96	25.07	44.17

9.6.2.2 Size distribution

The size distribution of oysters caught during the 2020 survey shows a very similar pattern to 2019 (Figure 60). The modal size was 60 mm in both years. There was no evidence of in year recruitment.

The size distribution data continues to show apparent high rates of mortality above 60 mm as shown by the reduced numbers of oysters in the stock above that size. Fishing mortality should only contribute to reduced numbers above 76 mm. The strong mode at about 60 mm is evident in 2018, 2019 and 2020. There is no signal, however, that these size classes are progressing towards the minimum landing size which would significantly increase the commercial stock size. The cause of this is currently unknown.

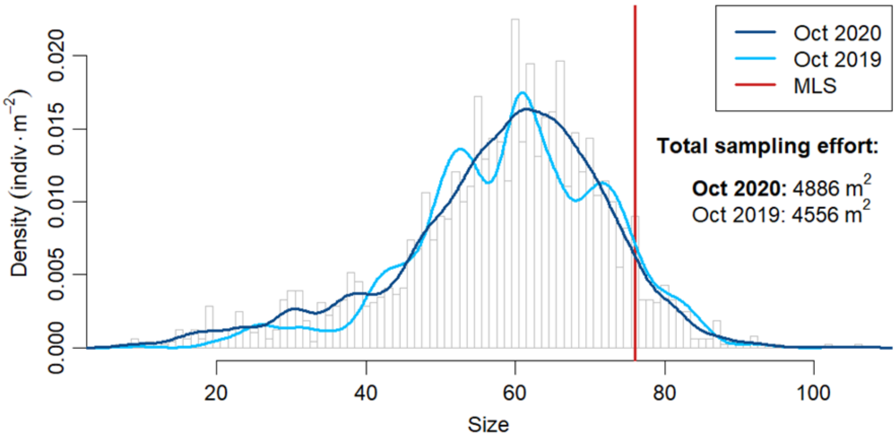


Figure 60. Size distribution of native oysters (*Ostrea edulis*) in Cill Chiaráin in October 2019 and October 2020. The minimum landing size (76 mm) is shown. Data are standardised to sampling effort regardless of its spatial distribution.

9.7 Lough Swilly

A survey of native (*Ostrea edulis*) and Pacific oysters (*Magallana gigas*), involving 153 stations, was completed in Lough Swilly in July 2020 using a single toothless dredge of width 1.52 m.

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 15). In general, biomass, corrected for dredge efficiency of 35 %, is between 15-44 tonnes.km^{-2}. Biomass.km^{-2} was higher in 2017, 2018 and 2020 than previous years. There was an average of 31.8 tonnes.km^{-2} in 2020.

Table 15. Stocks biomass trends for native oyster at Lough Swilly 2011-2020.

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

9.7.1.2 Distribution and Biomass in 2020

Biomass of native oysters (*Ostrea edulis*), uncorrected for dredge efficiency and including all sizes, varied from 0-0.057 kgs.m^{-2}. Abundance and biomass was higher in the southern part of the survey area (Figure 61). Biomass of oysters over 76 mm ranged from 0 - 0.018 kgs.m^{-2}.

The biomass of native oysters, assuming a dredge efficiency of 32.5 % was 318 tonnes (Table 16). The equivalent biomass of oysters 76 mm or over the national minimum landing size was 18 tonnes or 5.6 % of the total stock. The size distribution data indicates that mortality rates between 60-76 mm are high.

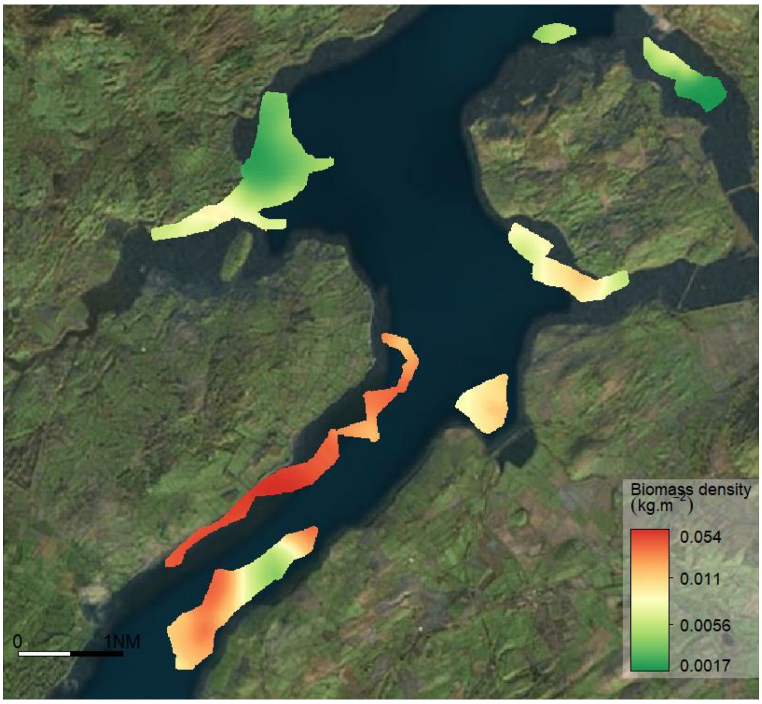


Figure 61. Biomass of native oysters in Lough Swilly, July 2020 (uncorrected for dredge efficiency).

Table 16. Distribution of native oyster biomass, uncorrected and corrected for a dredge efficiency of 32.5 %, Lough Swilly, July 2020. Data from all oyster beds were combined.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for Dredge Efficiency				
Biomass_Ostrea_edulis	102.5	134.6	87.5	186.2
Biomass_>76mm_*Ostrea_edulis*	5.79	7.2	3.1	13.5
Corrected for 32.5% Dredge Efficiency				
Biomass_Ostrea_edulis	317.8	412.8	272.9	554.8
Biomass_>76mm_*Ostrea_edulis*	17.8	22.6	9.0	43.7

9.7.1.3 Size distributions

The size distribution of native oysters in the survey showed a strong mode at ~50 mm with few individuals above the 76 mm minimum landing size. There was no indication of recent recruitment.

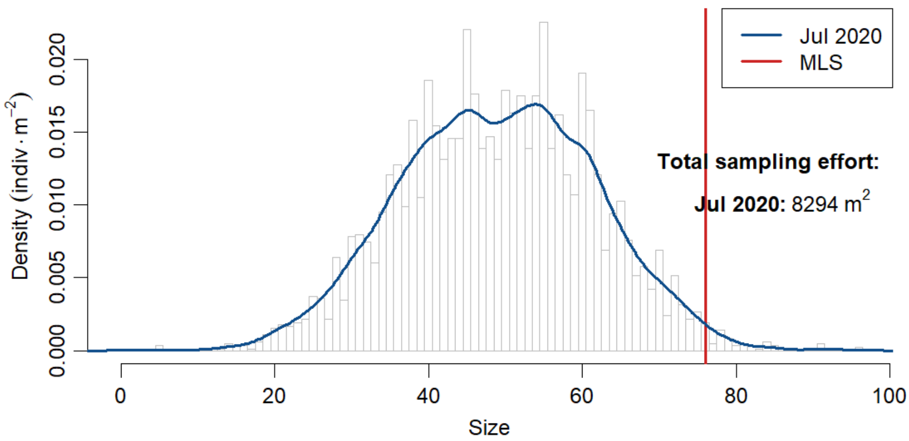


Figure 62. Size distribution of native oysters in Lough Swilly, July 2020 (uncorrected for dredge efficiency).

9.7.2 Pacific oyster (*Magallana gigas*)

9.7.2.1 Distribution and Biomass in 2020

Biomass of pacific oysters (*Magallana gigas*) uncorrected for dredge efficiency varied from 0- 0.55 kgs.m^{-2}, with the highest biomasses in the south and north west of the survey area (Figure 63).

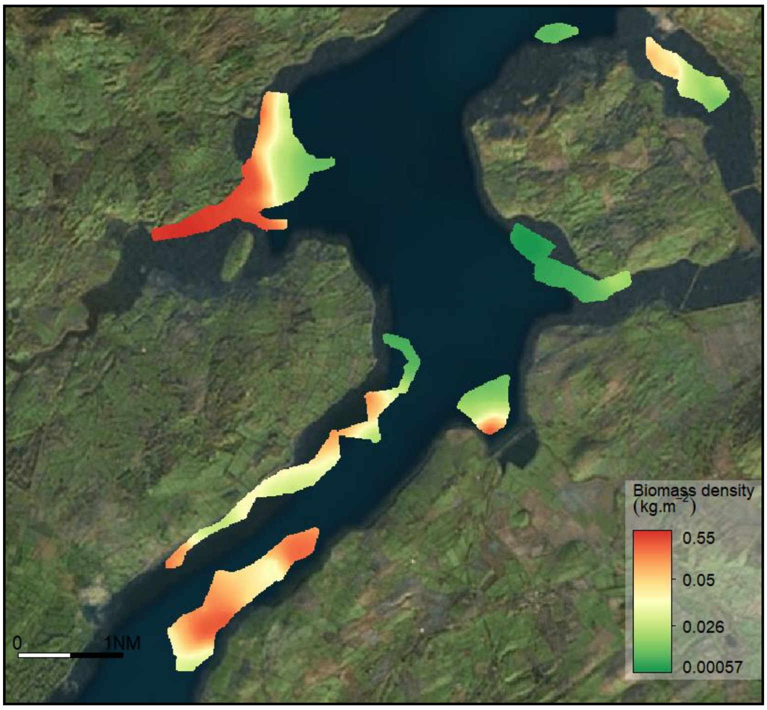


Figure 63. Biomass of pacific oysters in Lough Swilly, July 2020 (uncorrected for dredge efficiency).

The biomass of pacific oysters, assuming a dredge efficiency of 32.5 % gives a total of 1,718 tonnes (Table 17). The previous estimate in 2018 was 1,128 tonnes.

Table 17. Distribution of pacific oyster biomass, uncorrected and corrected for a dredge efficiency of 32.5 %, Lough Swilly, July 2020. Data from all oyster beds were combined.

	Biomass (tonnes)		95% HDI inf	95% HDI sup
	Mean	Median		
Uncorrected for Dredge Efficiency				
Biomass_*Magallana gigas*	561.3	556.3	401.1	754.2
Corrected for 32.5% Dredge Efficiency				
Biomass_*Magallana gigas*	1,718.3	1,702.6	1,237.5	2,288.2

9.7.2.2 Size distributions

The size distribution of Pacific oysters in the survey indicate a strong mode at ~60 mm. These are probably 2 year old oysters spawned in 2019.

There has been a decline in the prevalence of larger size classes of Pacific oysters since 2018. In 2017 and 2018 two main cohorts were present; model sizes of about 45 mm and 90 mm (Figure 64). The larger cohort was not as evident in the 2020 survey (Figure 65). This reduction is probably due to fishing. The size distributions, however, also show active annual recruitment of Pacific oysters in the area.

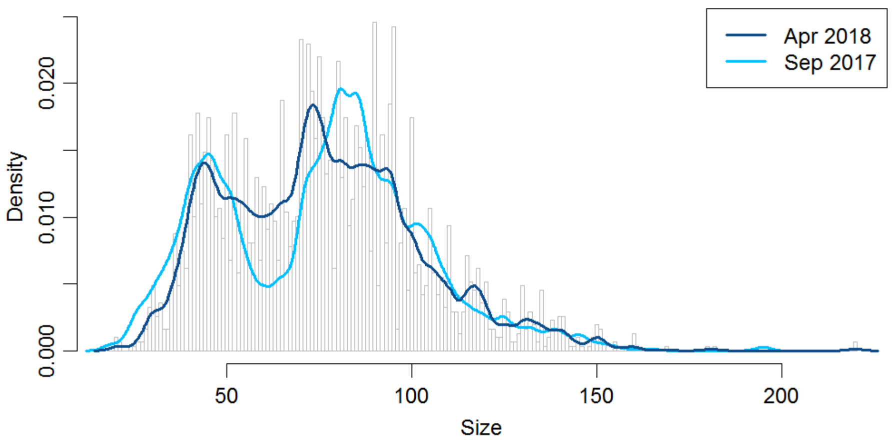


Figure 64. Size distribution of Pacific oyster in September 2017 and April 2018, Lough Swilly.

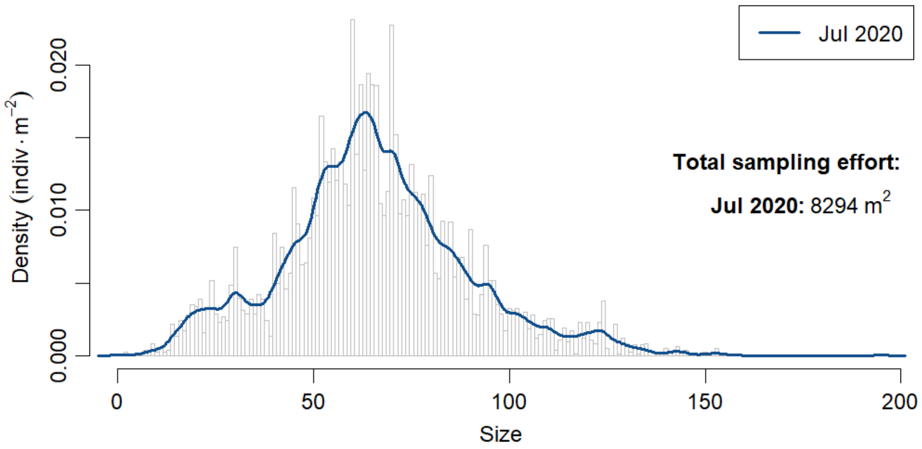


Figure 65. Size distribution of Pacific oyster in July 2020, Lough Swilly.

10 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, eg metric tonne, of a stock at a given time.

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

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

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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