afbi

AGRI-FOOD
& BIOSCIENCES
INSTITUTE

QUEEN'S
UNIVERSITY
BELFAST

Northern Ireland Lobster Science

September 2021
Version 1.2

Contents

Prepared by:

Dr Carrie McMinn (Agri-Food and Biosciences Institute)

Professor Paulo Prodöhl (Queen's University of Belfast)

1. Background

The European lobster, *Homarus gammarus*, is common around coastal waters of Britain and Ireland where it occurs to depths of about 50m (although they can be found in deeper waters). Lobsters are solitary and sedentary animals and aggressive competitors for shelter on rocky substrates. Lobster growth is by moult, which decreases in frequency during the juvenile stages until becoming an annual part of the mating, spawning and egg hatching cycle. This life history pattern is also affected by seasonal variation in sea temperature. Sexual maturity is reached around 4 – 7 years of age, at a size of around 75 – 80mm carapace length (CL). While large lobsters are thought to have a bi-annual spawning pattern, smaller individuals may spawn annually. Reproduction takes place during the summertime and is linked with the moulting cycle. After extrusion, the eggs are held on the pleopods for nearly another year (10 – 11 months) until hatching in the following summer. The number of eggs produced is linked to size ranging from 5,000 to 40,000 for small and larger lobsters respectively. The first few weeks post hatching is characterised by a pelagic phase of some 14 - 35 days before young lobsters settle on the sediment. Lobsters are long-lived with males and females living, on average, for some 30 and 54 years respectively. Age at size is highly variable with at least seven year-classes potentially entering the fishery at 85mm CL.

Lobsters along with crabs are traditionally fished using pots or creels. These can be single or double chambered style. Lobsters climb in to the pot to feed on the bait through the entrance. However, with single chamber pots the animal can get back out with relative ease, and therefore these pots have to be checked regularly to prevent loss of catch. Pots which have two chambers (parlour pots) are much more difficult for the animal to get back out of. These pots are traditionally used in areas where weather can prevent fishermen getting out to check the pots regularly. Escape panels may be added to either style of pots. These panels allow undersized animals and some bycatch species to leave the pot easily. Fishermen who use escape gaps report a reduction in sorting time and therefore overall fishing time and fuel consumption, along with a reduction in the bait used (Pers. Comm.).

Pot fishing is seen as a relatively benign form of fishing having little impact on the environment (Kinnear et al. 1996; Holt et al. 1998; Eno et al. 2001; Adey et al. 2006; OSPAR Commission, 2009). Indeed, in areas where other forms of fishing have been prohibited, the use of static gear has been allowed to continue. Mortality of bycatch by pot fishing is also low in comparison to other fishing gear (Welby, 2014).

Anyone fishing for shellfish on a commercial scale must have a fishing licence for their vessel (which permits commercial fishing under the Fisheries Act 2020), with a shellfish entitlement. This entitlement has been granted by the 2003 UK Restrictive Shellfish Licensing Scheme, which was set up to cap levels of crab and lobster fishing. Through this scheme, fishermen were granted a shellfish entitlement based on track record (if they had landed or sold more than 200kg lobsters or 750kg crabs during any 12 month consecutive period between 1 January 1998 and 31 December 2002). Anyone who now wants a shellfish entitlement can only do so by transferring the licence from a fisherman who is leaving the sector or by buying a vessel with a licence attached to it which has a shellfish entitlement.

Fishing for lobster, similar to crab, is not subject to European total allowable catch regulations and there are no national quotas. The primary means of managing stocks is through a minimum landing size (MLS), which is the minimum size at which it is legal to keep or land an animal. This is thought to be an effective way of managing the reproductive population as it protects a proportion of the females carrying eggs from the fishery. Whilst a MLS may not be as effective for fish species, which are usually dead when returned, for shellfish a MLS is an effective tool as most shellfish survive when returned and can re-enter the population where they can reproduce until they have reached the MLS and can be landed. The current MLS for lobsters in Northern Ireland waters is 87mm carapace length.

In Northern Ireland, the Unlicensed Fishing for Crabs and Lobster Regulations (Northern Ireland) 2008 was introduced by the Department of Agriculture, Environment and Rural Affairs (DAERA) to improve the management and conservation of crab and lobster and to prevent the increase in fishing by hobby fishermen who did not hold a licence. Under the regulations it prevents anyone without a licence from:

- Landing more than five crab and one lobster per day
- using more than 5 pots
- using a stock cage

V-notching involves the notching of the tail of any berried female (usually of legal landing size i.e. 87mm CL) before returning it to the sea. Any female that has been v-notched is legally protected and should not be landed. This reduces the harvest rate on reproductive females, and, as the v-notch can last several moults, it means the female is protected for a number of years (two to four years depending on the lobster size). The aim of v-notching is to increase the total number of reproductive females and hence to increase total egg production of the fishing stock.

In Northern Ireland there are two lobster associations running v-notching schemes in parallel. One run by the North Coast Lobster Fishermen's Association (NCLFA) and the other by the North-East Lobster Co-operative (NELCO). The NELCO scheme, which has remained unchanged for over 12 years, sees berried lobsters v-notched at the site of capture. In each case, a subsample of fertilized eggs are removed and placed in preservative (storage buffer) along with the female v-notch. V-notched lobsters are returned to the site of capture and the eggs and v-notch are sent to Queen's University Belfast where they undergo DNA profiling analysis. While the NCLFA have now adopted this scheme, until 2013 they ran a different scheme whereby any berried female was brought back to port where it was verified by a port officer before being v-notched. The lobster was then returned to sea by the fisherman.

A comparison of the maternal genetic profile (DNA extracted from v-notches) with that of the offspring (DNA extracted from eggs) enables confirmation that the v-notch is indeed from a berried lobster. This greatly simplifies the logistics of the monitoring procedure as it eliminates the need to hold/transport berried lobsters (this was initially as a form of evidence to permit a small compensation to be paid). DNA profiling also enables a number of relevant management and conservation questions to be addressed. The profiling analysis produces genetic identity 'bar codes' for the v-notched female and her eggs. From these, the genetic profile of the "father" DNA can also be extrapolated. This scheme has led to the establishment of a genetic database for lobster "families" from Northern Ireland. Thus, lobsters caught in future years can have their genetic profile checked against the database to identify if they have come from families belonging to the v-notching scheme. By identifying the percentage of lobsters that are derived from the v-notching scheme, this unique scheme can be used to assess the effectiveness of v-notching as a management strategy. Previous results from the genetic analysis showed that between 2007 and 2013, between 9 and 33% of all lobster landings by NELCO originated from the v-notching scheme. It was estimated through the genetics work that in 2013 almost 26,000 lobsters recruited into the fishery were resulting from the v-notching scheme (McMinn *et al*, 2015).

The most recent v-notching scheme ran between 2017 and 2020. For the first time, based on recommendations from previous v-notching analysis, the scheme introduced "premium" lobsters. These are animals that are 127mm carapace length or greater, male or female, which gain a larger incentive for v-notching.

This report will focus on the data collected during this time frame, in terms of the fishery, biology and genetics of the Northern Ireland lobster stocks.

2. Methods

2.1 Landings Data

In Northern Ireland a Monthly Shellfish Return (MSR) must be submitted by all fishermen who have a shellfish entitlement, declaring their landings and effort (number of pots fished) for the month. Those without a shellfish entitlement are not obliged to complete an MSR but many do, so as to maintain a track record of fishing. Port officers then input the landings information onto the Department of Agriculture, Environment and Rural Affairs (DAERA) database.

Landings data from 2006 to 2020 was obtained for Northern Ireland from DAERA. The raw data was analysed to examine the temporal and spatial patterns in fishing activity by NI registered vessels, providing a summary of the Northern Ireland pot fishery, and in particular, those targeting lobsters. Landings were examined by landing port and for the entirety of NI pot boats.

2.2 Data Collection Onboard Commercial Vessels

AFBI (Agri-Food and Biosciences Institute) carry out observer coverage of commercial pot fishing vessels within NI inshore waters. This programme not only collects biological information on the species caught, but, with the majority of vessels being under 12m in length and thus not requiring a vessel monitoring system, the observer programme helps provide some information on the spatial extent of the fishery. Between 2010 and 2019 the annual average number of trips sampled was 18. Due to the Covid-19 pandemic in 2020, observer trips were not possible from March 2020 and therefore 2020 has been excluded from the analysis. There was increased effort in 2014-2015 through a dedicated lobster tagging project (funded through the European Fisheries Fund), with an assigned AFBI scientist from June 2014 – July 2015.

When onboard the fishing vessel the observer will record:

Fishing operations
- date of trip
- boat name and skipper
- the soak time of the pots
- the start and end position of each string
- the number of pots on each string

Catch & Biological variables
- Number of crabs and lobsters caught (landed and discarded)

- Length and sex of crabs and lobsters
- Incidence of berried females
- Incidence of v-notched lobster
- Release position and length of any tagged lobsters

For the purposes of this report, observer trips have been split by the ICES rectangle which the string sampled was in. Figure 1 shows the location of observer sampling.

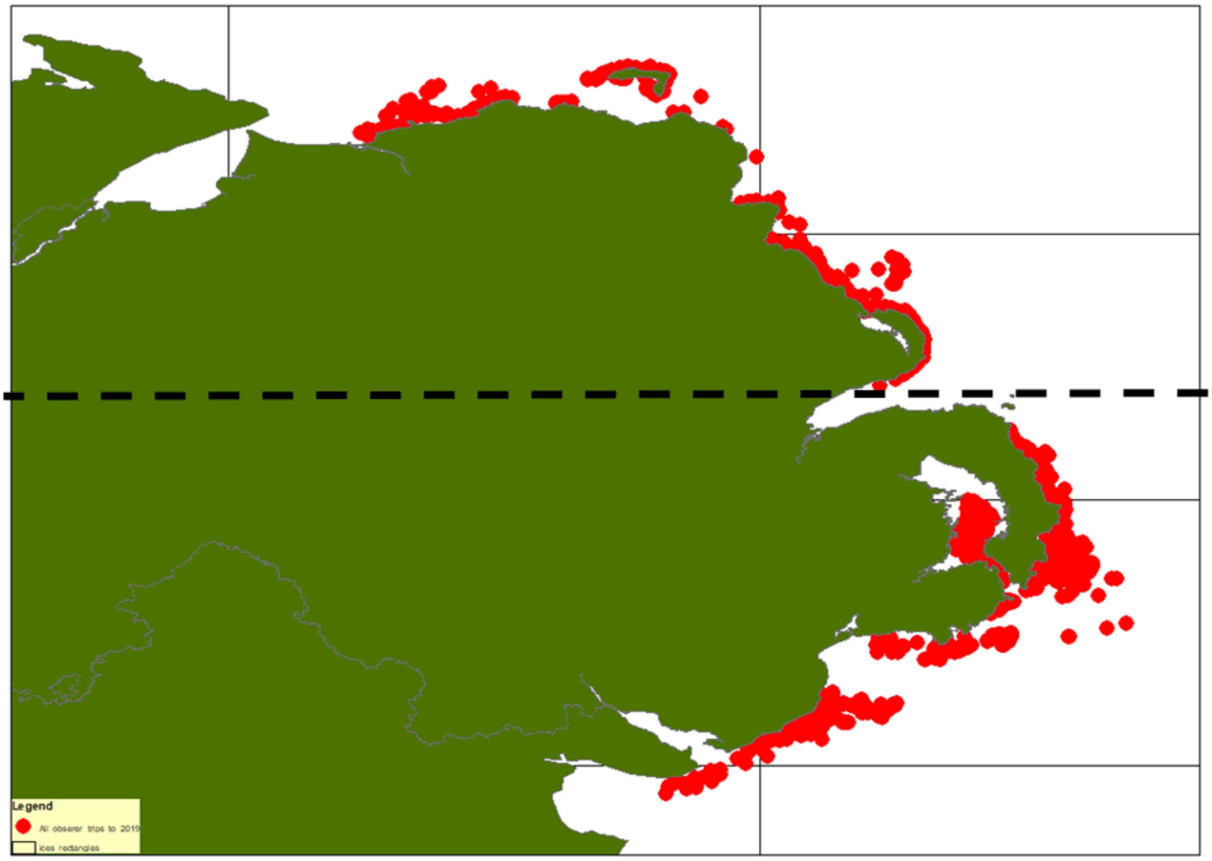

Figure 1: Location of observer sampling between 2010 and 2019. The North Coast Lobster Fishermen's Association operate north of the dashed line whilst the North East Lobster Co-Operative operate south of the dashed line.

2.3 V-notching

When fishermen provide a v-notch sample it is labelled with information including the size of the lobster, the date v-notched, and position the lobster was caught. This information has been analysed for the purposes of this report.

2.4 Genetic Analysis

Lobster sampling: European lobster v-notches and eggs for genetic analyses were collected from 2003 to 2014, and from 2017 to 2020, along the County Down coastline of Northern Ireland by NELCO (Figure 1). NCLFA adopted the genetic tagging approach for lobster v-notching in 2013, and have been providing QUB with v-notches and eggs from along the County Antrim coastline of Northern Ireland (Figure 1) between 2013 and 2014, and from 2017 to 2020, which corresponds to the period covered by the current scheme. Since the beginning of the genetic tagging monitoring scheme in 2003, 34,435 (average 2,152/year) lobsters have been processed for genetic analyses. See Table 1 for details of the number of lobsters v-notched per month/year since the start of the genetic tagging programme.

The sampling procedure for genetic analyses has been described in detail in a previous report (McMinn *et al*. 2015). Briefly, from each berried lobster, both v-notch and egg samples (~20-100 fertilised eggs) were non-destructively removed, and stored in a labelled vial containing preserving solution (molecular grade ethanol). The removal of a small number of eggs has a negligible impact on individuals. Furthermore, since berried lobsters are rapidly returned to sea following the sampling procedure, egg losses and individual stress are much reduced in comparison to the previous monitoring approach involving confinement in cages and transportation of berried lobsters ashore for inspection before releasing them back. A standard v-notching tool is used by all members participating in the scheme to ensure consistency (adequate amount + quality) of v-notch biopsy for subsequent DNA work. All samples were processed following robust data curation protocols, specifically developed for the project, which involved the implementation of a rigorous coding system that allowed for authentication (i.e. origin) of all biological material to be analysed. In addition to information on the sampler (i.e. lobster fishermen), location, date of sampling and approximate carapace length (mm) was also recorded for all v-notched lobsters.

Table 1: Number of v-notched lobsters by NELCO (2003-2013), and both by NELCO and NCLFA (equal numbers from both associations) between 2013-2014 and 2017-2020. Numbers are displayed by year and month.

Month	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2017	2018	2019	2020	Total
January				88	7	14	11			100	394	205		980	120	205	2,124
February			21	9		6	304		98	136	23	32			16	56	701
March		43	87	206		117	252		229	38		284			332	63	1,651
April		202	181	168			194		64	350		132		127	308	61	1,787
May	150	222	562	411		130	928		76		10	112		264	150	344	3,359
June	408	317	125	195	10	149	322	646	293	235	85	130		171	256		3,342
July	178	238	280	111	269	40	298	162	600	112	234			52	361	1	2,936
August	198	322	58	29	410	137	319	306	357	774	374	15	18	503	227		4,047
September	275	434	375	47	291	962	412	202	167	582	155	346	9	237	256		4,750
October	289	129	319	26	414	283	264	41	287	611	636	183		117	59	2	3,660
November	127	139	449		412	178	481	208	141	331	1104	415		90	88	2	4,165
December	49	309	179	21	8	99		305	185	329	51	262		8	102	6	1,913
Total	**1,674**	**2,355**	**2,636**	**1,311**	**1,821**	**2,115**	**3,785**	**1,870**	**2,497**	**3,598**	**3,066**	**2,116**	**27**	**2,549**	**2,275**	**740**	**34,435**

DNA extraction and DNA profiling: DNA extraction was carried out using both the Promega Wizard DNA Purification system (http://www.promega.com) and, more recently using the faster, and substantially less expensive, HotSHOT protocol (Truett *et al.* 2000). Both DNA extraction approaches have been modified and optimised to allow for the effective processing of a large number of samples. Resulting lobster DNA were screened for a panel consisting of 11 highly informative microsatellite marker loci developed at QUB for lobster genetic research (see **https://cordis.europa.eu/project/id/FAIR984266** for summary). Technical details for the microsatellite DNA profiling screening methodology, including genotype quality control (QC) assessment to ensure good quality genetic data has been provided in a previous report (McMinn *et al*. 2015). Further details can be obtained from Prof. P. Prodöhl at QUB.

Analyses: Descriptive genetic diversity statistics (e.g. expected and observed heterozygosity, mean number of alleles per locus, mean proportion of loci typed and the mean polymorphic information content) for the lobster parental pool (i.e. lobsters v-notched between 2003 and 2004) have been previously estimated and presented in a previous report (McMinn *et al*. 2015). The power of the marker panel for parentage analyses, including estimation of the exclusion probabilities for parentage inference has also been previously reported. Briefly, (and including an update on account of the new data), 9 to 25 alleles were found per marker locus (average 15.2). The combined exclusion probability for parentage assignment for the 11 marker loci is higher than 99%. Simulation analyses showed that 1) the marker panel can unambiguously identify related from unrelated individuals and, 2) offspring of the 2003-2004 lobster parental pool can be assigned to correct family with over 99% confidence. Temporal stability of the genetic makeup of the lobster stock was examined by comparing allele frequency distribution at the 11 microsatellite loci screened for the period of 16 years covered by the genetic tagging scheme (McMinn *et al*. 2015).

The analytical approaches for 1) reconstructing paternal genetic profiles from the genetic information generated from each berried lobster and associated offspring (v-notches and fertilized eggs N~10,000 samples in total), and 2) parentage assignment of lobsters subsequently caught in the fishery to these families have also been detailed in a previous report McMinn *et al.* (2015). In total 1,546 lobster families, representing 38% of the v-notched parental pool of 2003 and 2004 were reconstructed, and used to identify parentage for candidate offspring sampled from 2007-2020 through the v-notching scheme. The number of positive assignments to family per year was used to quantify the impact of v-notching on local lobster stocks. Assignments to family were also used as an indicator of larval dispersal by recording the area of capture of lobsters assigned to particular “families” in comparison to the area where these “families” were originally caught.

3. Results

3.1 Landings Data

3.1.1 All Species

The main species targeted by NI licensed vessels fishing static fishing gear are brown crab, lobster, velvet crab, whelk, *Nephrops* and green crab. Additional species (predominantly fish including mackerel, ling and flounder) are captured by pots but these are rarely targeted and are an incidental bycatch.

The peak in landings by NI registered vessels was recorded in 2017 when 4,149 tonnes of mixed species were landed (Figure 2). In 2020 2,209 tonnes of mixed species were landed, this is the second lowest value over the time period analysed (this may be an effect of the Covid-19 pandemic which limited market opportunities due to countries being placed into lockdown and restaurants etc. being closed). Whilst these landings are all made by NI registered vessels, they are not all made into NI (Figure 2). Between 2006 and 2020, an average of 50% of total landings biomass is made into a NI port. On average, landings into non-NI ports are: Irish port, 47%, Scottish port, 1.8%, Welsh port, 1%, English port, 0.1% and Isle of Man port, 0.04% (all figures rounded up).

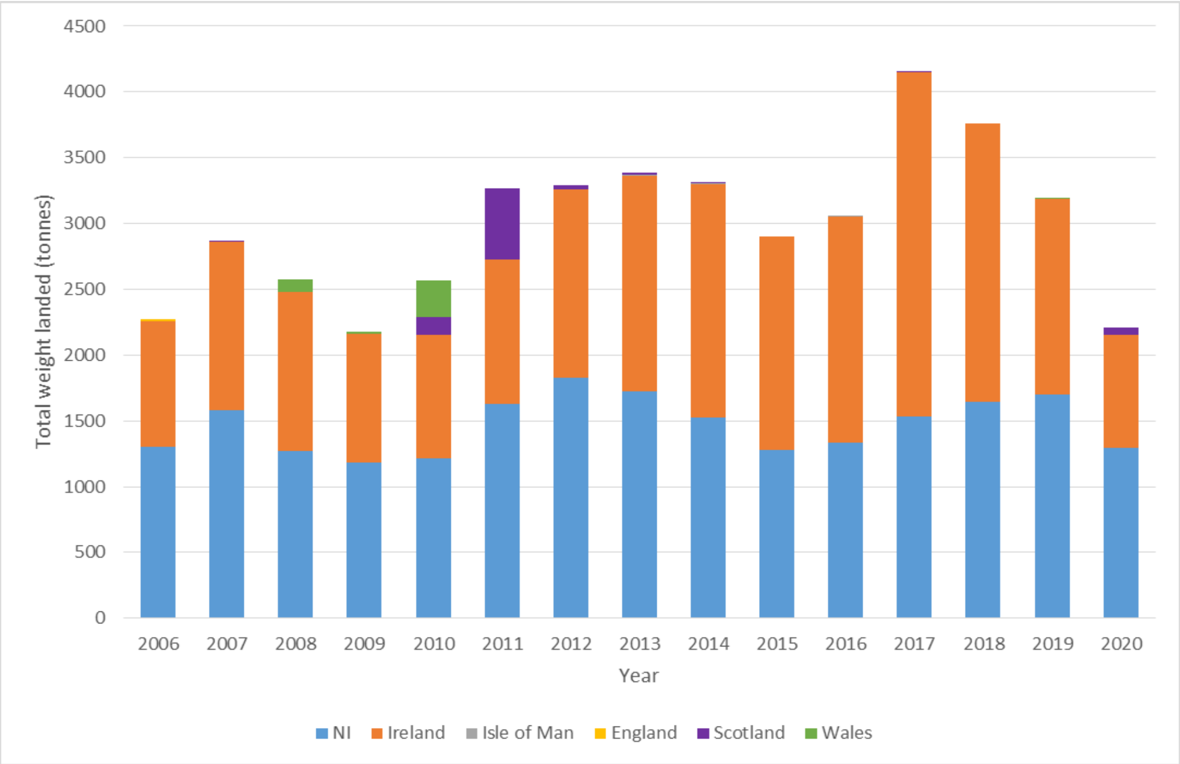

Figure 2: Total tonnage of all species landed by pots between 2006 and 2020 for all NI registered vessels (Source: DAERA landings figures).

Between 2006 and 2020, brown crab (*Cancer pagurus*) has consistently made up the highest tonnage of any individual species landed by pots (Figure 3). In 2020, 1,547 tonnes of brown crab were landed which accounted for 70% of total pot landings. Velvet crabs were the second highest species landed in terms of live weight (10.8% of total landings). Accounting for 3.4% of total weight of landings, lobsters had the fifth highest biomass landed.

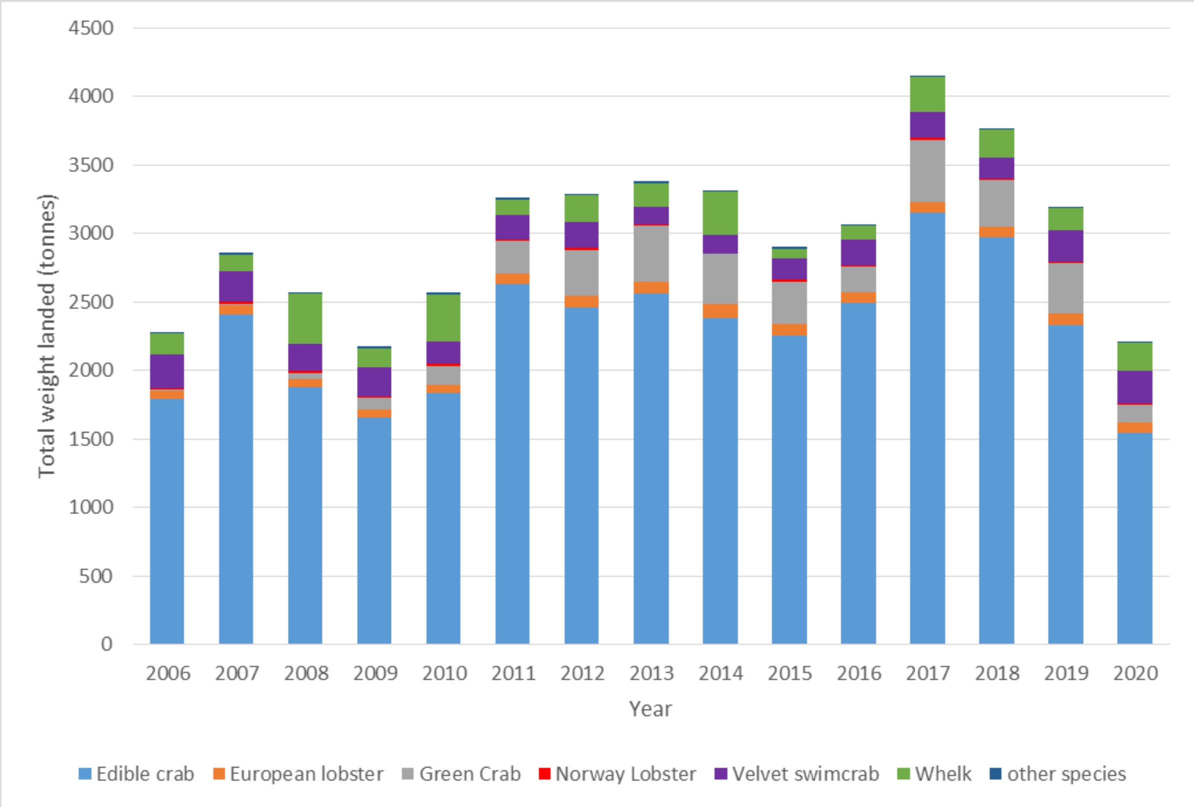

Figure 3: Live weight (tonnes) of each species landed by pots between 2006 and 2020 (Source: DAERA landings figures).

Between 2006 and 2020, 372 unique NI registered vessels landed species caught by pots. The majority of these vessels (84%) were less than 10m in length. The annual number of boats fishing pots averaged at 132, ranging from 109 in 2006 to 153 in 2019. However, not all these vessels land into NI. For example, in 2020 129 NI registered vessels landed pots. Of these vessels, 115 landed into NI (Figure 4). In 2020, more than 50% of all vessels landed into Kilkeel, Portavogie, Ardglass or Annalong. Figure 5 shows the average number of vessels landing into each port between 2006 and 2020.

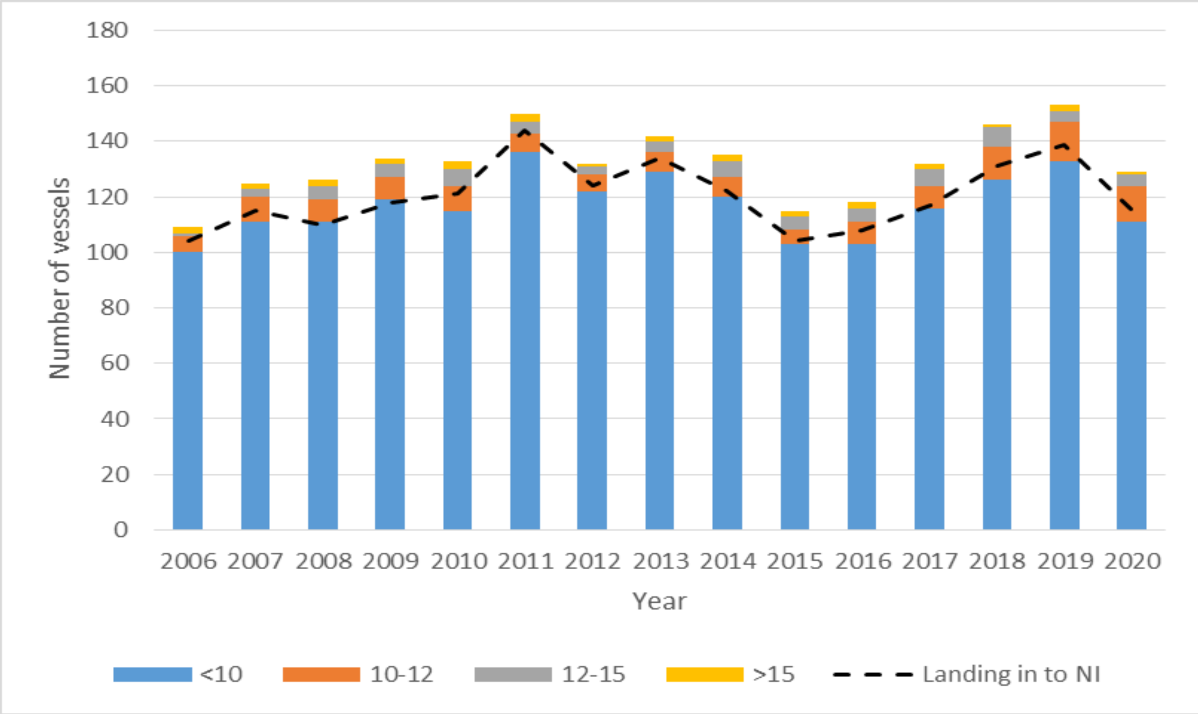

Figure 4: Number of NI registered vessels landing pot caught species between 2006 and 2020. The black dashed line represents the number of vessels landing into NI.

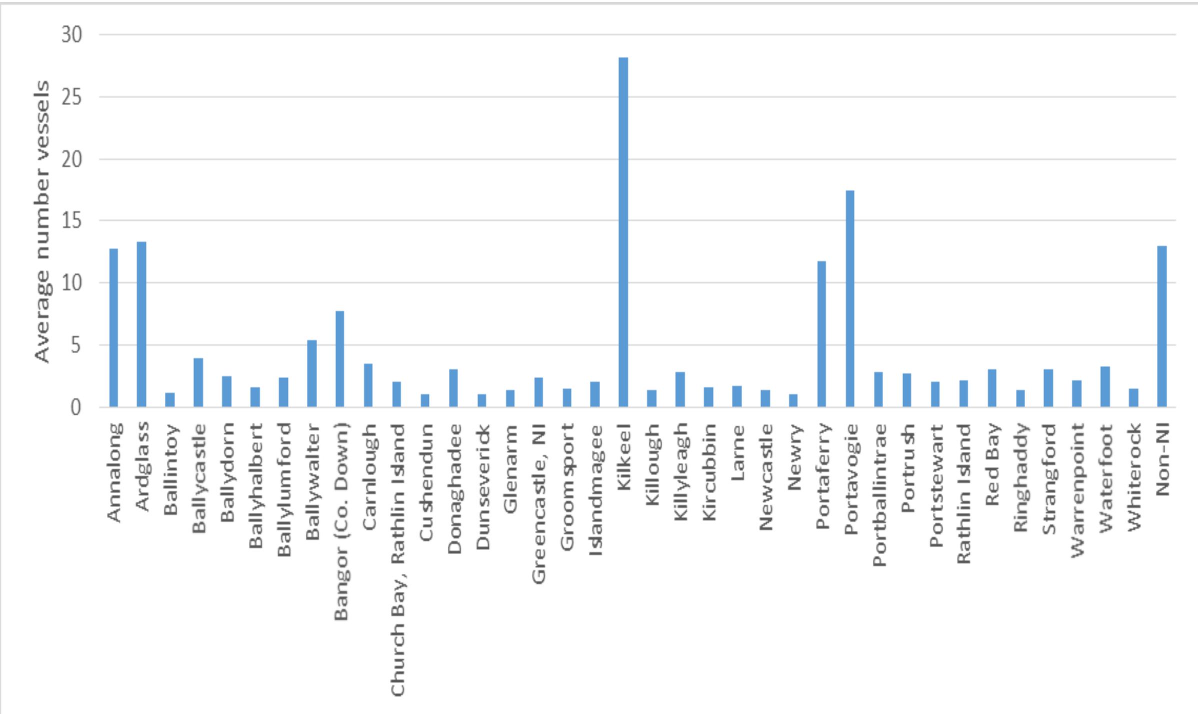

Figure 5: Average number of vessels landings into each port between 2006 and 2020.

3.1.2 Lobster landings

In 2020, 76 tonnes of lobsters were landed by NI registered vessels. This is down from a peak of 96 tonnes in 2014, and is the lowest landings total recorded from 2010 (Figure 6). Between

2006 and 2020, an average of 87.1% of lobster landings have been made into a NI port. The remaining landings have been made into Ireland (11.3%), Scotland (1.1%), England (0.4%), Wales (less than 0.1%) and Isle of Man (less than 0.1%). In 2020, lobsters were landed into 23 NI ports and four Irish ports (Figure 7).

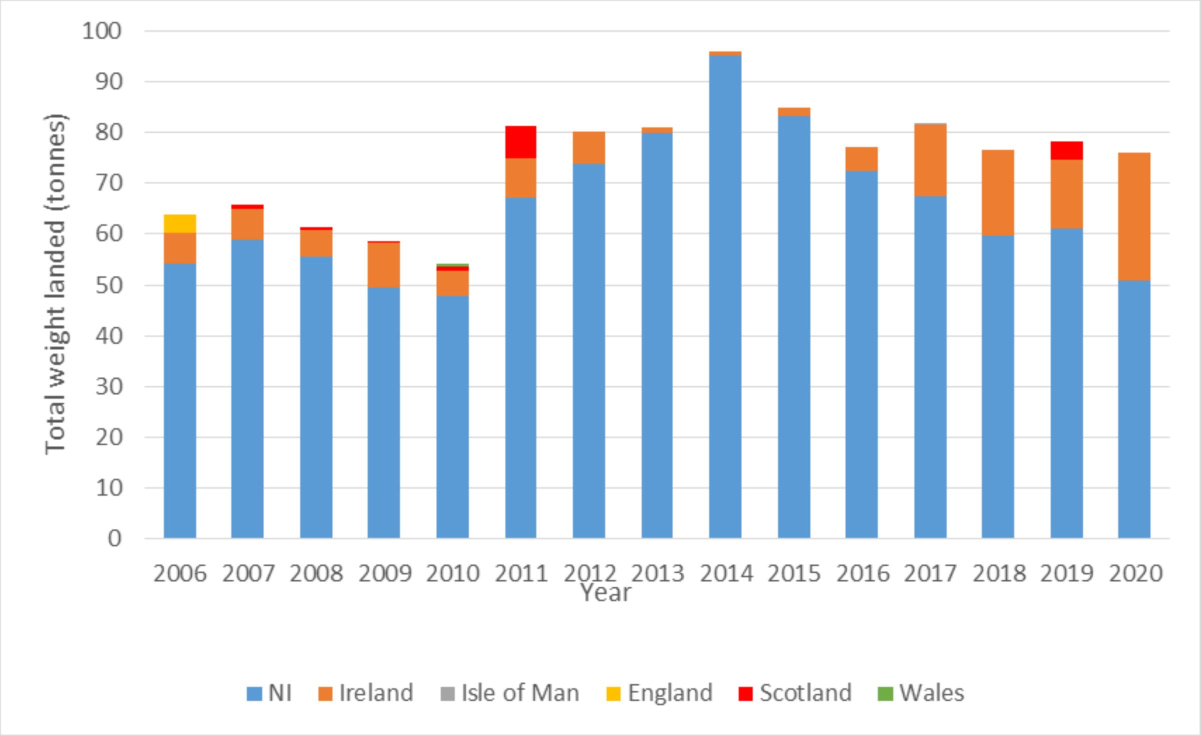

Figure 6: Landings of lobsters by Northern Ireland registered vessels between 2006 and 2020, by the country in which the landings were made (Source: DAERA landings figures).

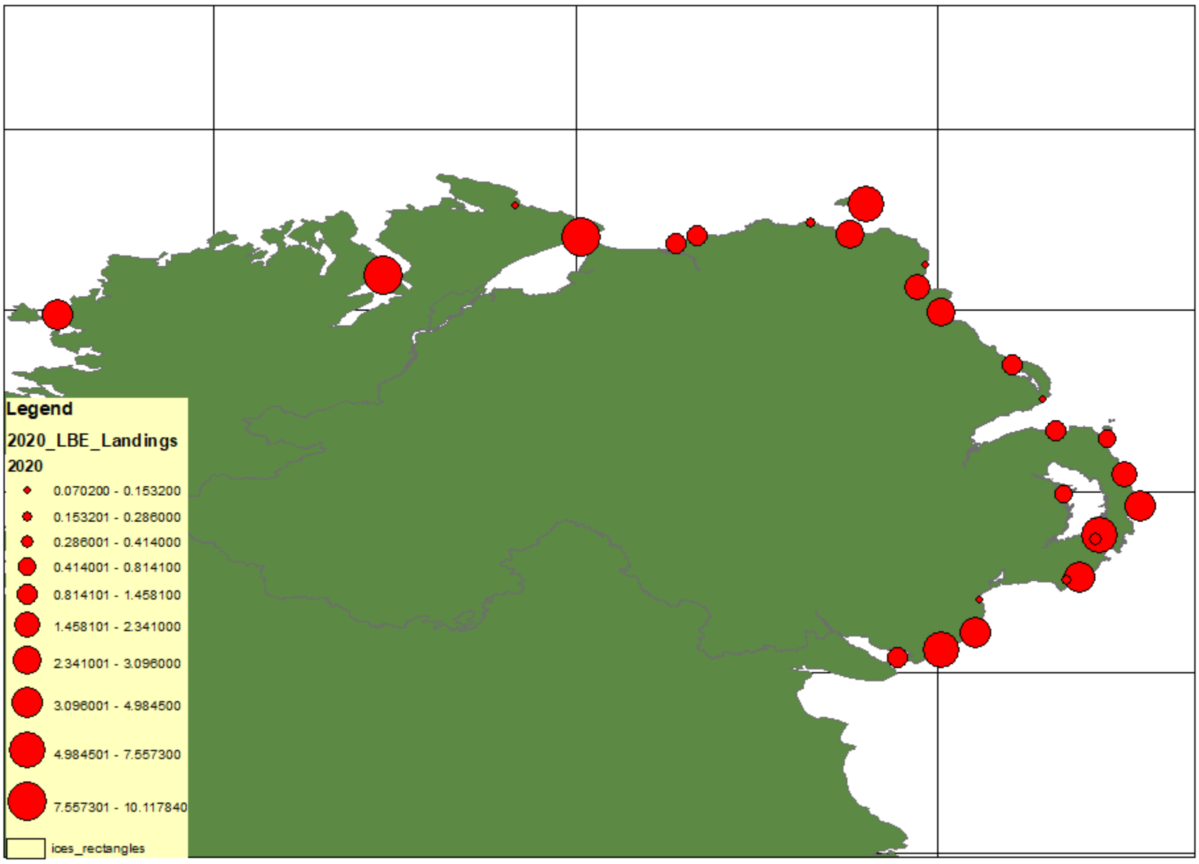

Figure 7: Location of landings of lobsters in 2020. Size of circle is indicative of the size (tonnes) of landings made.

The proportion of total catch made up from lobsters varies with port. Lobsters make up the highest proportion of total landings for the North Coast. In 2020 lobsters contributed more than 75% of total pot fishing landings for the harbours of Ballintoy (100%), Portrush (100%), Killough (92%) and Portstewart (89%). Figure 8 shows the percentage contribution of lobsters to the total landings by pots (all species) into each port in 2018, 2019 and 2020. When the data for all ports is pooled, it shows that the contribution of lobsters towards total landings peaks during the summer months. In 2020, the peak in overall contribution of lobsters is in July when 5.8% of all pot landings by NI registered vessels are lobsters.

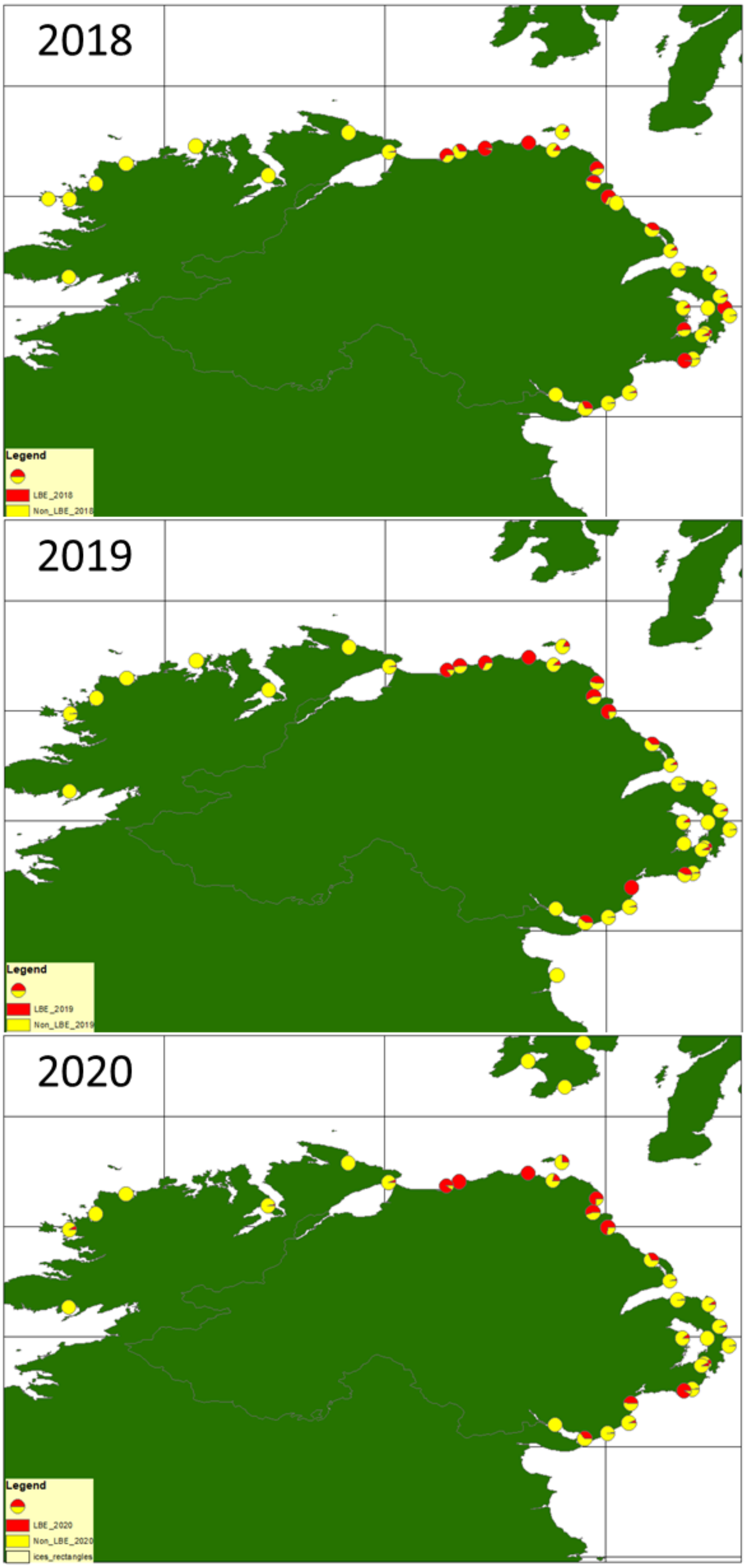

Figure 8: Proportion of total pot landings into each port which is attributed to lobsters in 2018, 2019 and 2020 (red indicates proportion of lobsters, yellow indicates proportion of all other species landed by pots).

Between 2006 and 2020 the average number of NI registered vessels annually landing lobsters was 118, ranging from 99 in 2006 to 141 in 2019 (Figure 9). Again, not all these vessels landed into NI. For example, in 2020, 113 NI registered vessels landed lobsters. Of these, 104 landed into NI. The average overall length of vessels landing into a NI port is slightly lower than the length of NI registered vessels landing lobsters into any port, being 7.5m as opposed to 7.8m. This is primarily due to the occurrence of vessels greater than 15m in overall length which do not land their catch into NI.

In 2020, more than 50% of all vessels landed lobsters into Kilkeel, Portavogie, Ardglass or Annalong. Figure 10 shows the average number of vessels landing lobsters into each port between 2006 and 2020.

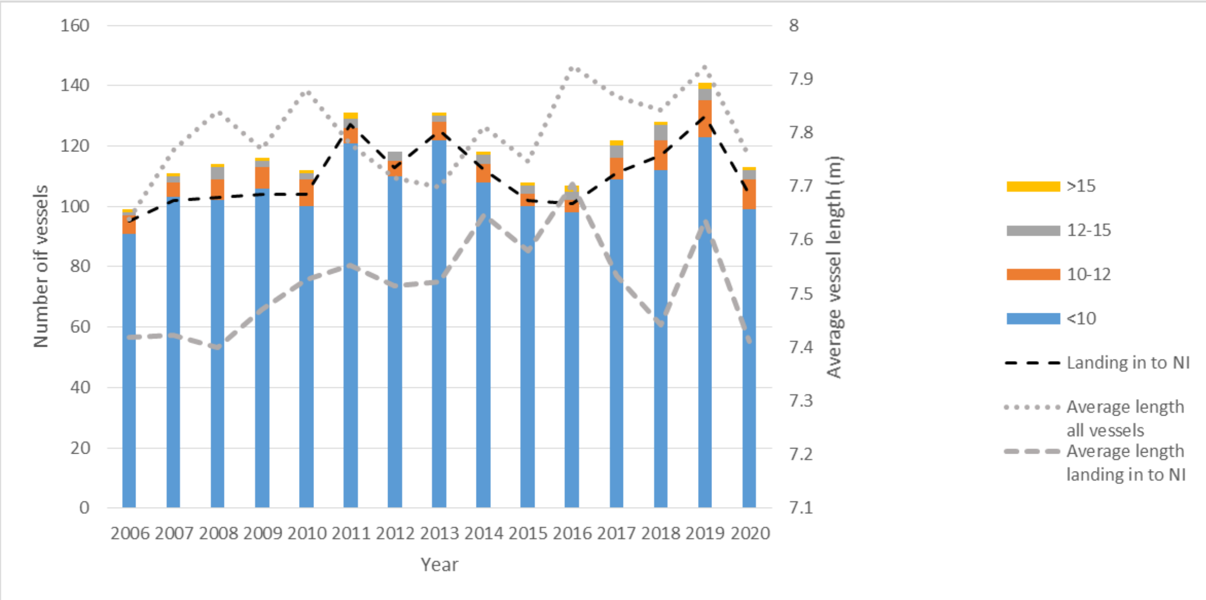

Figure 9: Number of NI registered vessels landing lobsters between 2006 and 2020. The black dashed line represents the number of vessels landing into NI. The grey dashed lines represent the average length of vessels landing lobsters by all NI registered vessels and by those landing into an NI port.

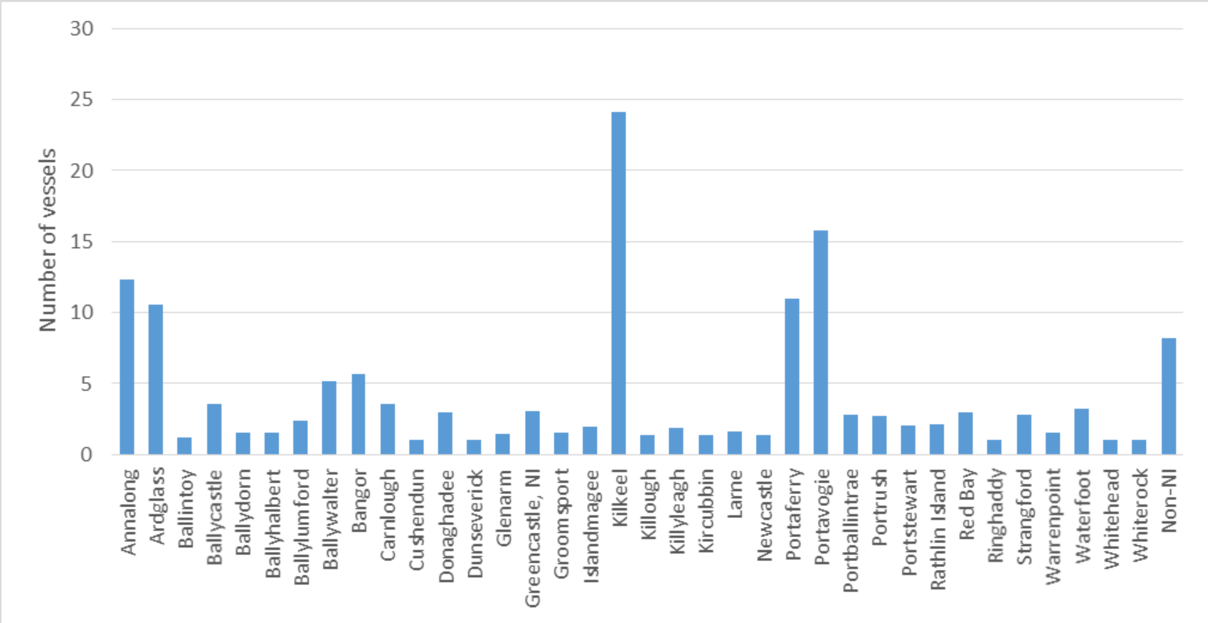

Figure 10: Average number of vessels landing lobsters into each port between 2006 and 2020.

Effort on the fishery can be examined as the number of pots used[1]. For this report, annual effort is calculated by summing the monthly effort of each vessel. Overall effort by NI registered vessels has shown an increase over the analysed period. The number of pots fished peaked in 2019 at over 42,500. In 2020 effort decreased by over 30%. It is presumed that this is an effect of the Covid-19 pandemic, which limited the export markets to European countries impacted by the pandemic, plus closure of local restaurants who would usually buy lobster.

The largest number of pots landing lobsters was in the areas of Kilkeel, Ardglass, and Portavogie (Figure 11). The pots landed into these four ports accounted for almost 50% of the total effort used by NI registered vessels.

[1] Landings figures include the number of pots used during the reporting period. With data not always available on the number of trips, effort data in this report is based on the number of physical pots used and not the number of actual hauls. In addition, effort data is missing for a number of boats, particularly those landing to a port outside of NI, therefore the information presented here is a best estimate of effort based on available landings figures

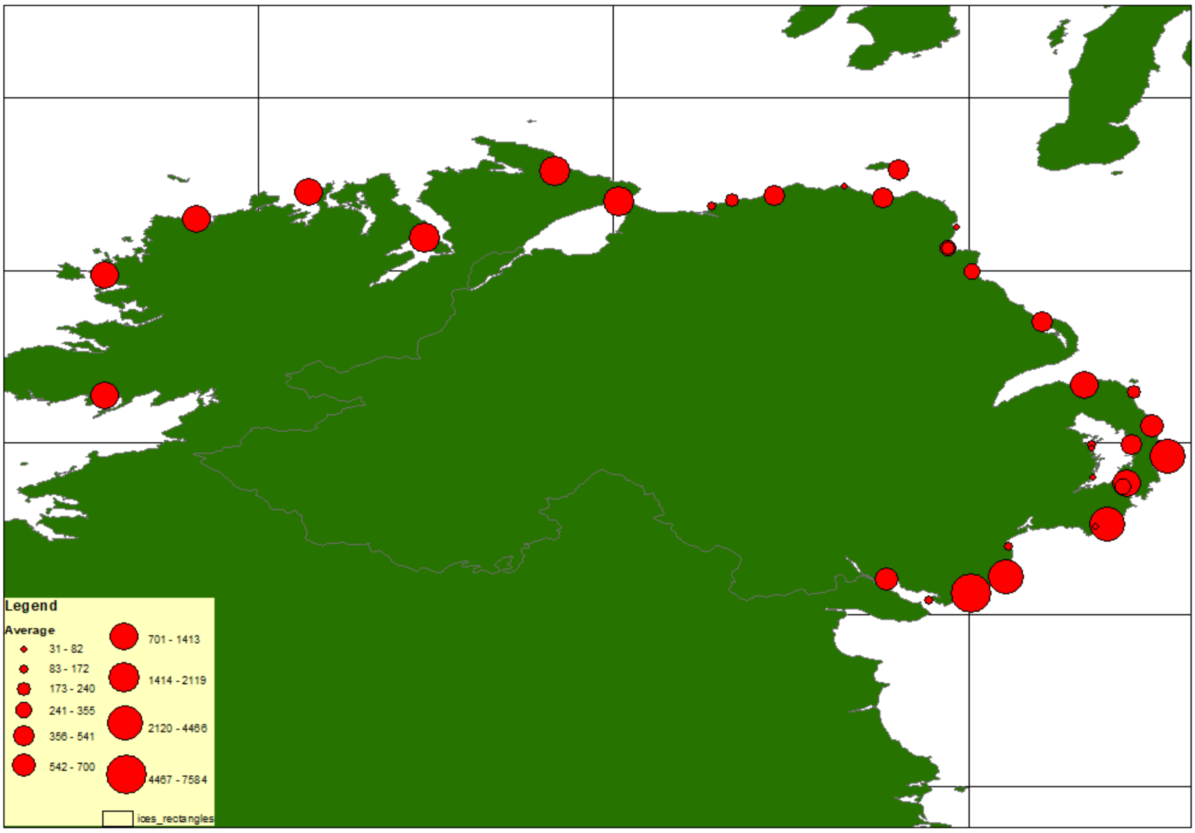

Figure 11: Average annual number of pots (not individual hauls) fished by NI registered vessels, between 2018 and 2020. Effort is attributed to the port where the landings were made.

Calculating the average landings of lobsters per pot, Landings Per Unit Effort (LPUE) shows a downward trend over the analysed time period (Figure 12). The areas which have a lower effort tend to have a have a higher LPUE (Figure 13). For example, along the NI North Coast which has the lowest effort, the average LPUE for lobsters is highest at 0.65kg per pot (average for 2018-2020). In County Down where the effort is more than 15 times higher, the LPUE is lower at 0.36kg per pot. This shows that a negative trend is evident, with LPUE decreasing as the number of pots used increases (Figure 14). LPUE for lobsters peaks during the summer months (Figure 15).

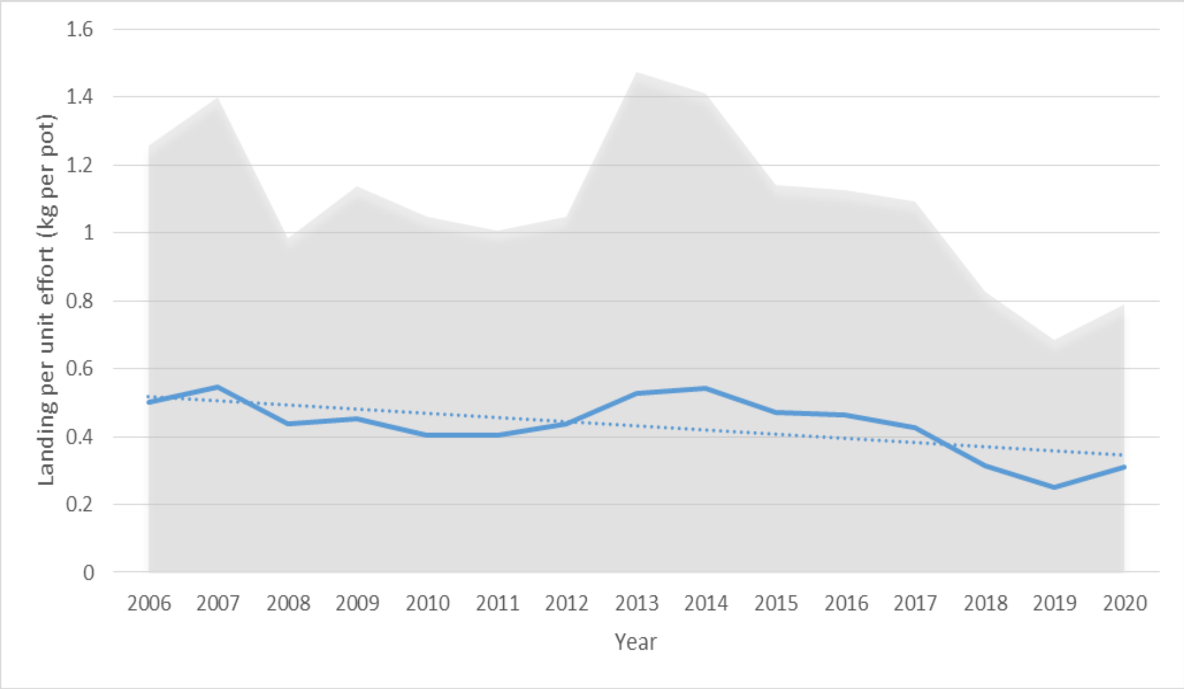

Figure 12: LPUE for lobsters, averaged for all NI registered pot fishing vessels. The grey area represents the deviation from the mean.

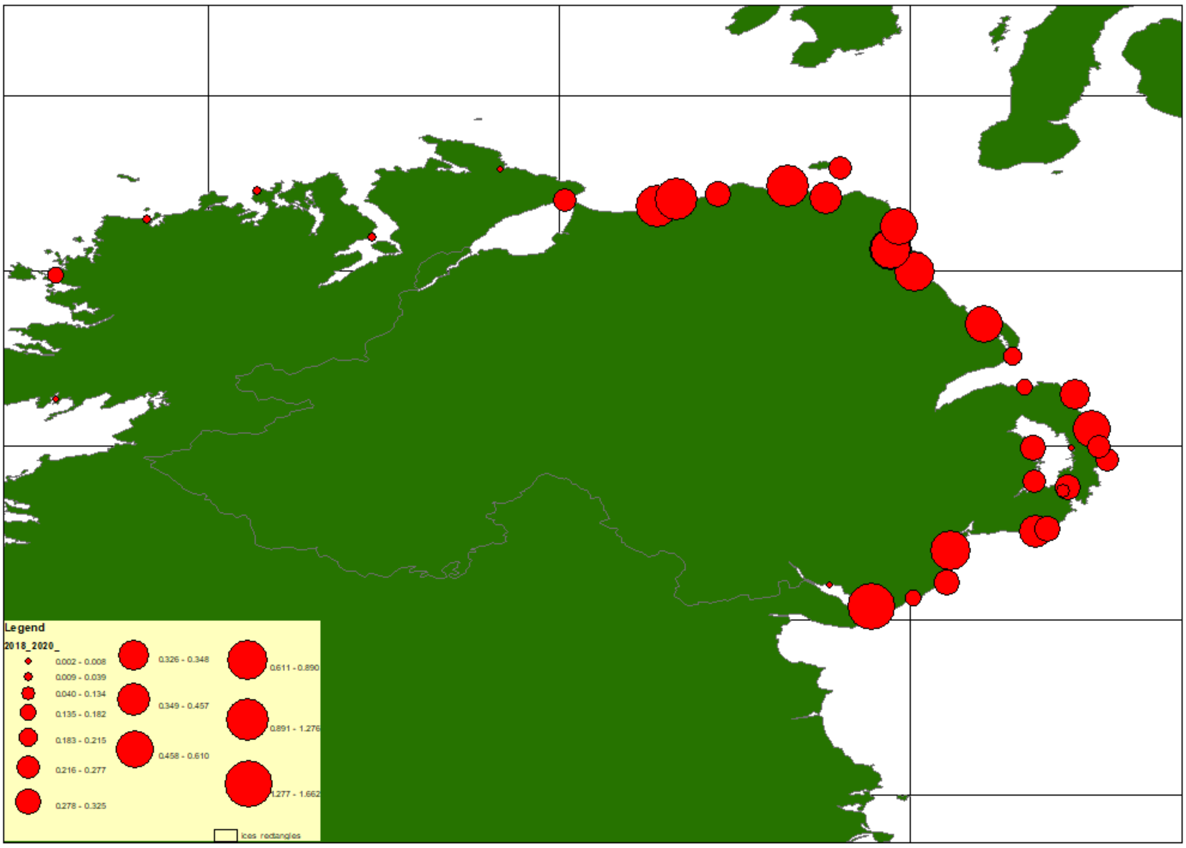

Figure 13: LPUE of lobsters landed by NI registered vessels, averaged from 2018-2020.

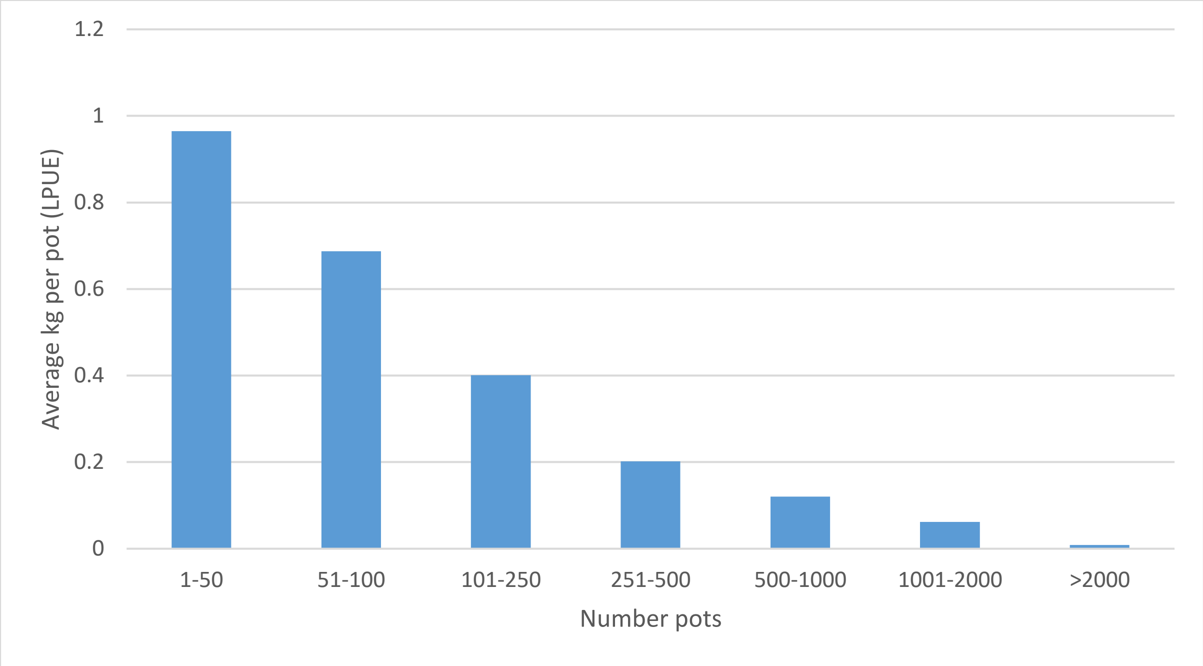

Figure 14: Relationship between the number of pots fished and the LPUE.

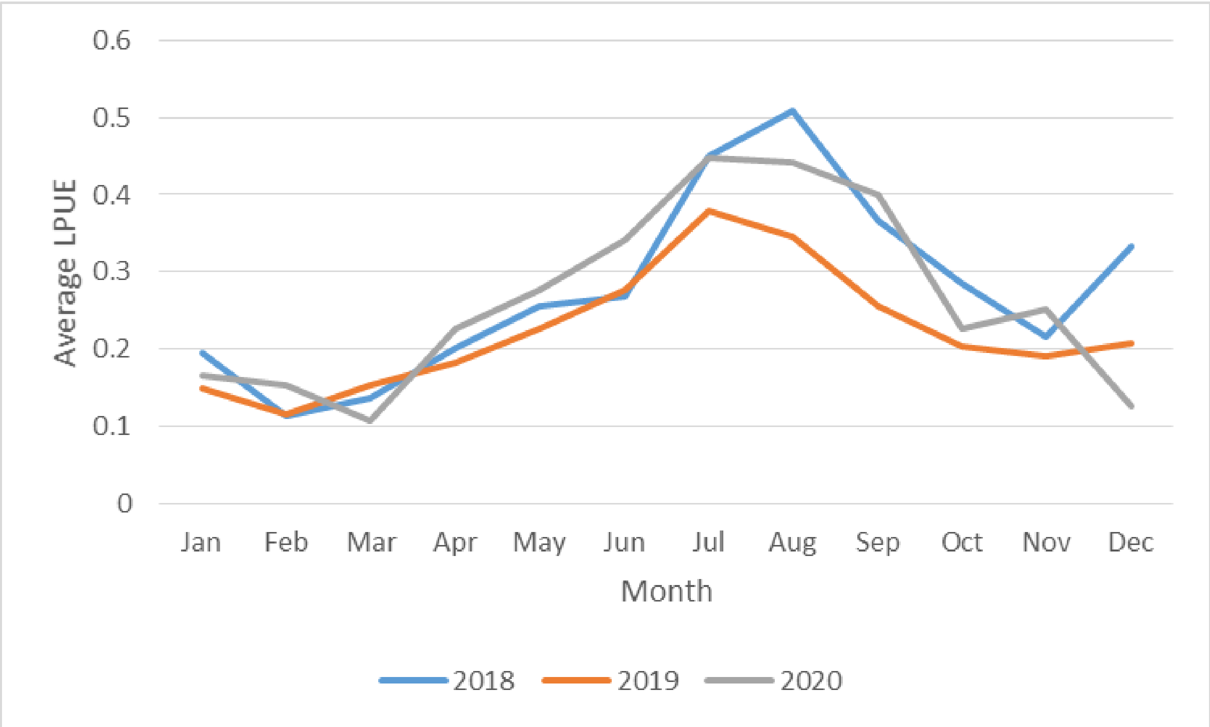

Figure 15: Average lobster LPUE by month.

3.2 Data Collection Onboard Commercial Vessels

The carapace length (CL) of lobsters caught during the observer trips was measured using callipers. The smallest lobster recorded was 29mm CL and the largest recorded was 192mm CL. Length frequency data of lobsters caught from the different geographic areas is illustrated in Figure 16.

Of all the lobsters measured, 68% were under the MLS. Strangford Lough had the highest percentage of lobsters which were above the MLS, with an average of 52% of males and 55% of females having a CL of 87mm or greater.

Whilst an average of 32% of animals were greater than the MLS, an average of only 25% of catch are actually landed. The primary reasons for discarding lobsters which are of a landable size are if they are v-notched or berried. Details from the observer programme (Table 2) show that around 17% of landable sized female lobsters have a visible v-notch on the tail and therefore cannot be landed, and 25% of landable sized female lobsters are berried. Whilst there is no law to prevent the landing of berried lobsters (unless they are v-notched), many fishermen will return these berried hens.

Figure 17 provides the length frequency of berried lobsters. The smallest berried female recorded was 54mm, recorded from the 37E4 ICES Statistical Rectangle. The largest was 192mm, recorded in 38E4. Around 25% of berried lobsters caught during this study were less than the current MLS of 87mm.

The incidence of v-notched female lobsters increased with carapace length (Figure 18). Whilst a small proportion of lobsters under the MLS are v-notched, for animals of 87mm CL, 9% are v-notched. At 111mm CL, over 50% of female lobsters at this size are protected by a v-notch.

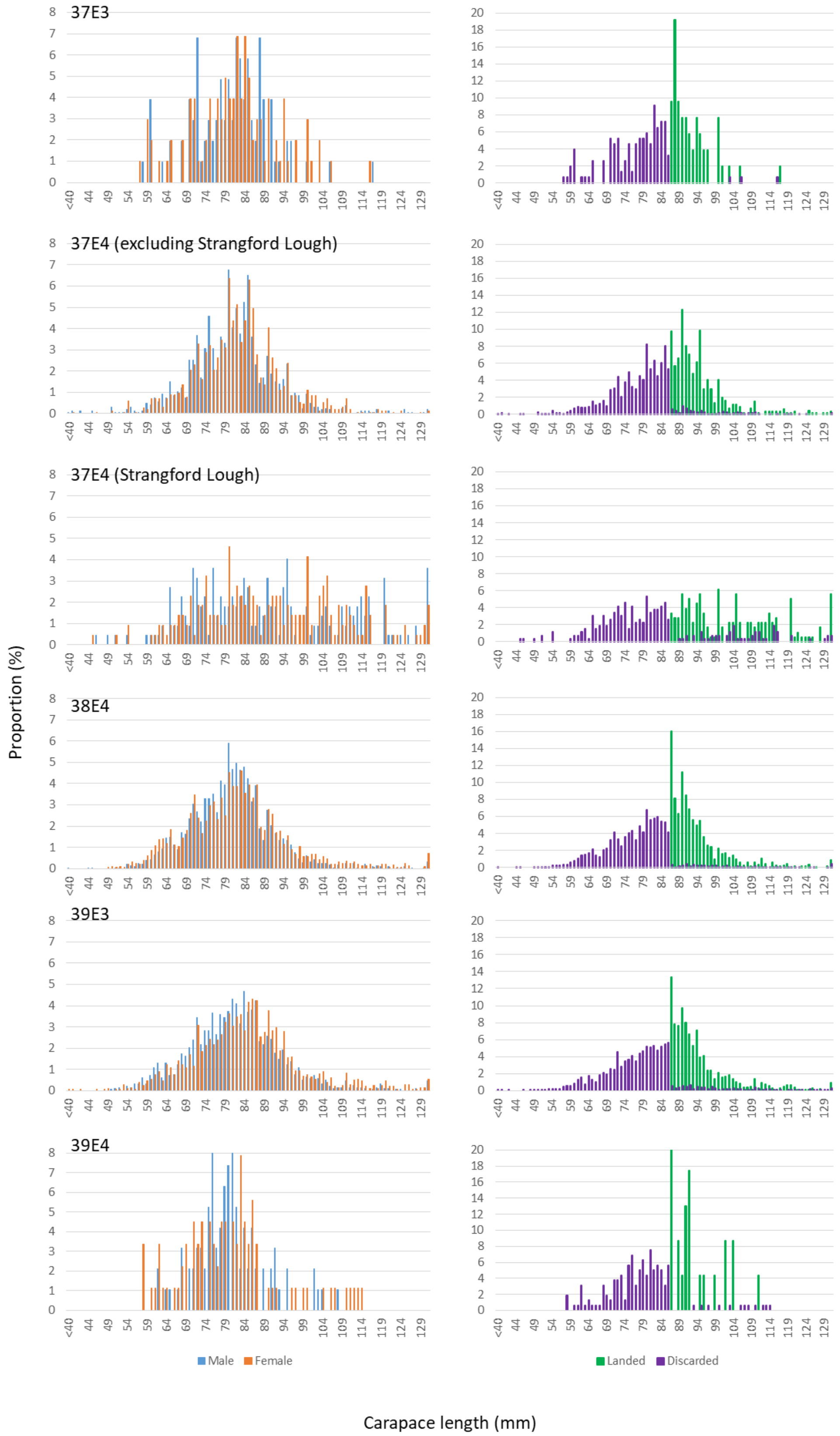

Figure 16: Carapace length (mm) of lobsters as recorded by the observer programme. The left column shows the length frequency of male and female lobsters whilst the right column shows the length frequency of those lobsters discarded and landed.

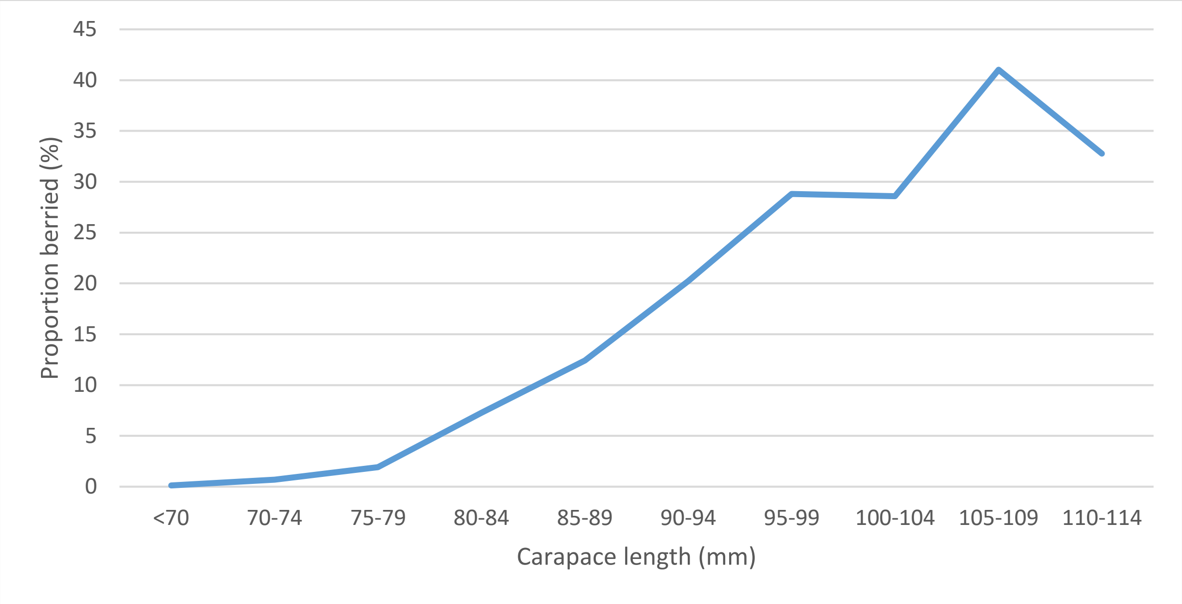

Figure 17: Length frequency of berried lobster. Size categories with less than 100 animals in total (i.e. sizes greater than 114mm CL) have not been included as due to the lower numbers percentage frequency is unreliable for these large lobsters.

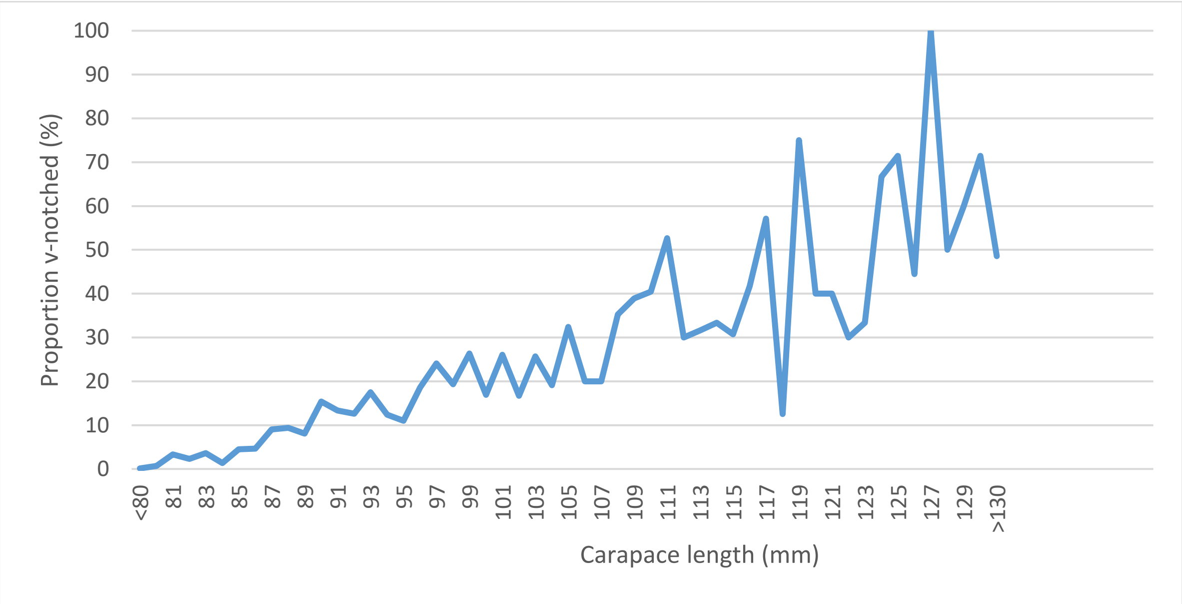

Figure 18: Proportion of female lobsters v-notched, by carapace length (mm).

Table 2: Summary details on lobster recorded during the observer programme

	36E3		37E3		37E4 (excl. Strangford Lough)		Strangford Lough		38E4		39E3		39E4	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Number measured	70	75	103	102	1660	1557	223	217	2547	2342	1976	2013	95	89
Average (mm)	82	86	81	82	81	83	91	91	81	82	82	85	80	80
Median (mm)	84	83	82	82	81	82	88	90	81	81	81	84	80	79
Mode (mm)	85	81	72	84	80	80	95	80	80	83	84	86	81	83
Minimum recorded (mm)	57	69	58	57	30	40	46	45	29	49	50	33	62	58
Maximum recorded (mm)	107	160	117	116	140	151	168	153	161	192	155	150	108	114
% less than MLS (mm)	70	64	75	72	76	71	48	45	76	70	70	59	82	80
% MLS or greater (mm)	30	36	25	28	24	29	52	55	24	30	30	41	18	20
% landed	30	20	25	25	24	17	51	30	24	22	30	27	14	11
Average size landed (mm)	94	99	92	93	95	94	106	102	94	94	95	94	93	95
% berried	NA	29	NA	3	NA	14	NA	24	NA	7	NA	11	NA	2
% berried (of landable sized animals)	NA	44	NA	7	NA	30	NA	44	NA	20	NA	22	NA	6
% v-notched (all sizes)	0	4	0	2	0	9	0	9	0.2	5	0.4	9	2	8
% v-notched (of landable sized animals)	0	0	0	7	0	25	0	17	0.5	14	1	20	12	39

3.3 V-notching

In the most recent v-notching scheme, run by the two Associations between 2017 and 2020, 5,986 lobsters were notched (this includes only those which were reported through the scheme) (Figure 19). The scheme was taken up by 45 vessels; 28 in 2018, 29 in 2019 and 21 in 2020. The reduction in vessels in 2020 may be due to the fact that the scheme finished in May before some of the seasonal fishing vessels had started. In addition, Covid-19 may have stopped some boats from fishing both for safety reasons and due to the lack of market during this time. In some regions, 100% of vessels fishing lobsters have contributed to the v-notching scheme (Figure 20).

The peak in v-notching occurred in the months of August and September. However, May 2020 saw the greatest number of lobsters v-notched (Figure 21). Again this may be attributed to the Covid-19 pandemic and the limited market available for selling lobsters.

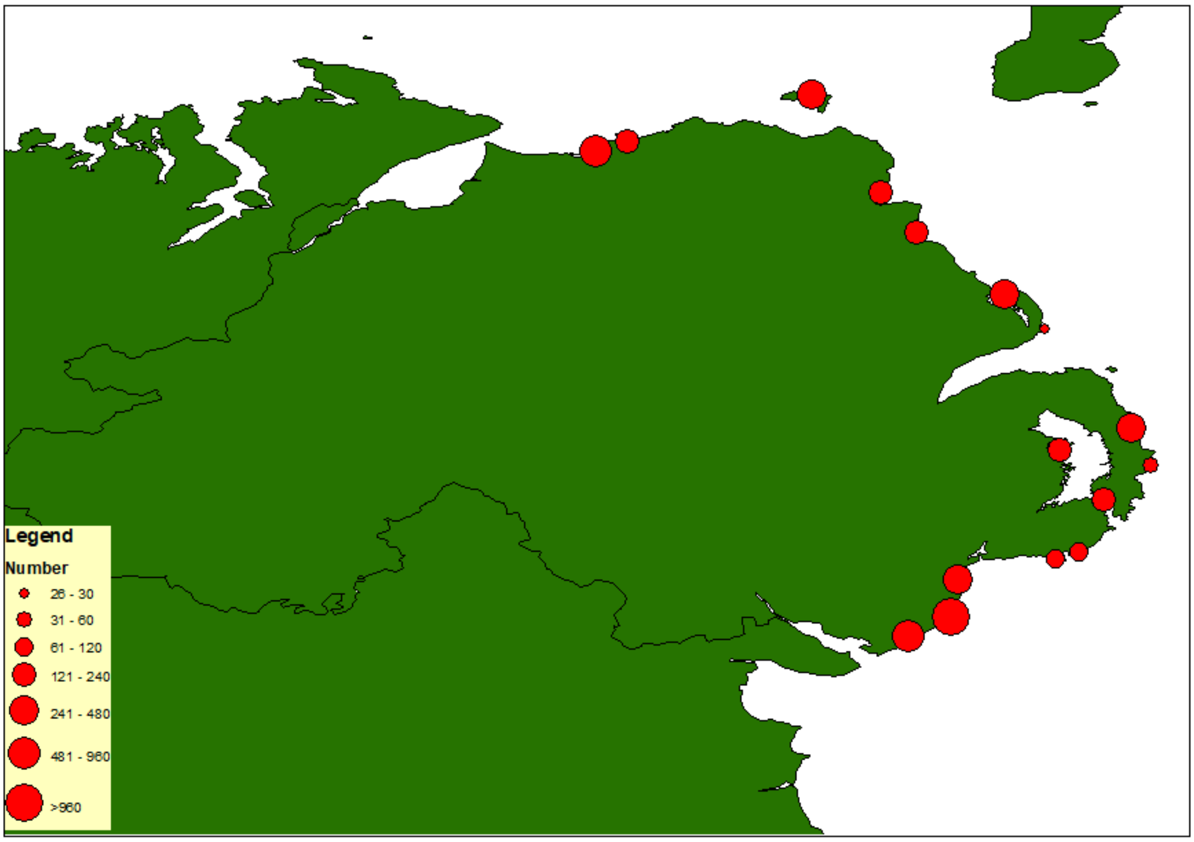

Figure 19: Number of lobsters v-notched as reported by the 2017-2020 v-notching scheme, by the port from which the vessel fishes.

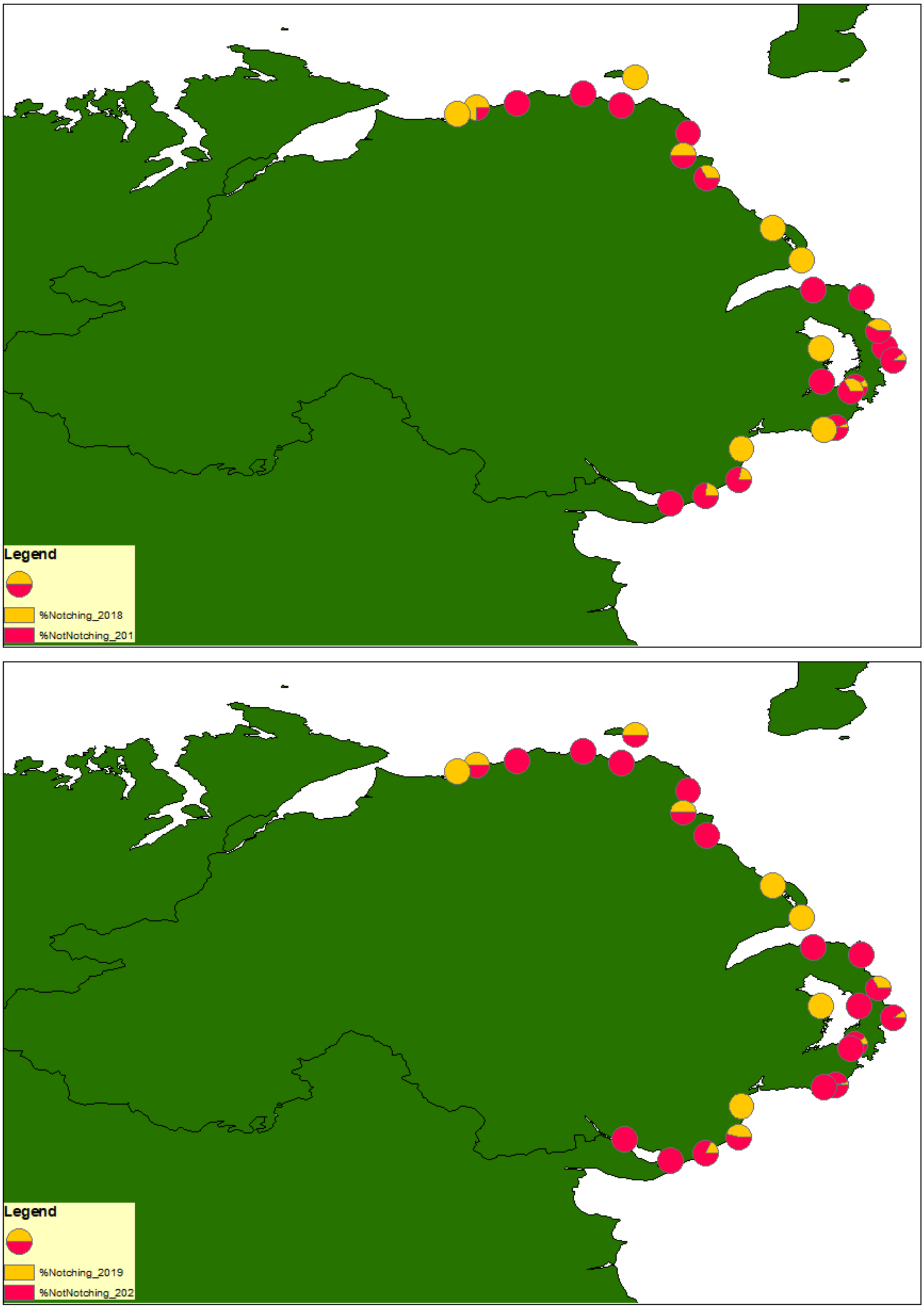

Figure 20: Percentage of vessels taking part in the v-notching scheme (yellow) against the total number of vessels landing lobsters into each port in 2018 and 2019.

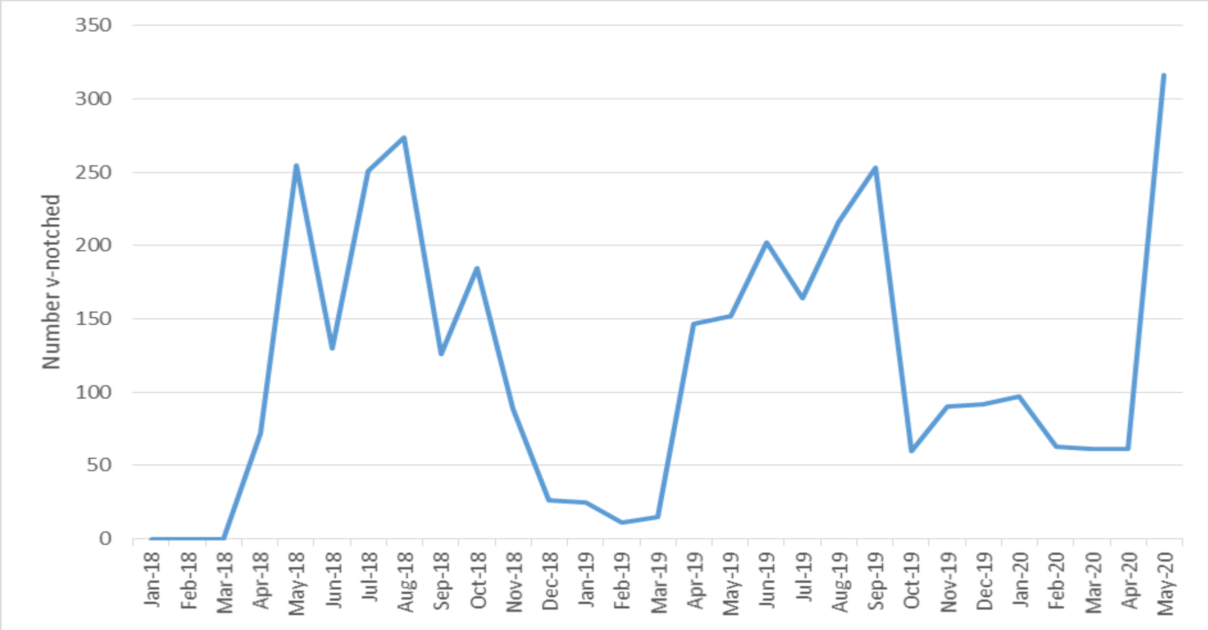

Figure 21: Number of lobsters v-notched during the 2018-20 scheme.

The average length of lobsters v-notched during the most recent scheme was 99mm. This includes notching of "premium" sized lobsters, those of 127mm CL or greater which was encouraged during the most recent funding scheme. Males, which could also be v-notched during the scheme if they were of premium size, accounted for 1% of all animals v-notched. Figure 22 shows the length frequency of v-notched lobsters, as reported through the scheme, for the different ICES rectangles.

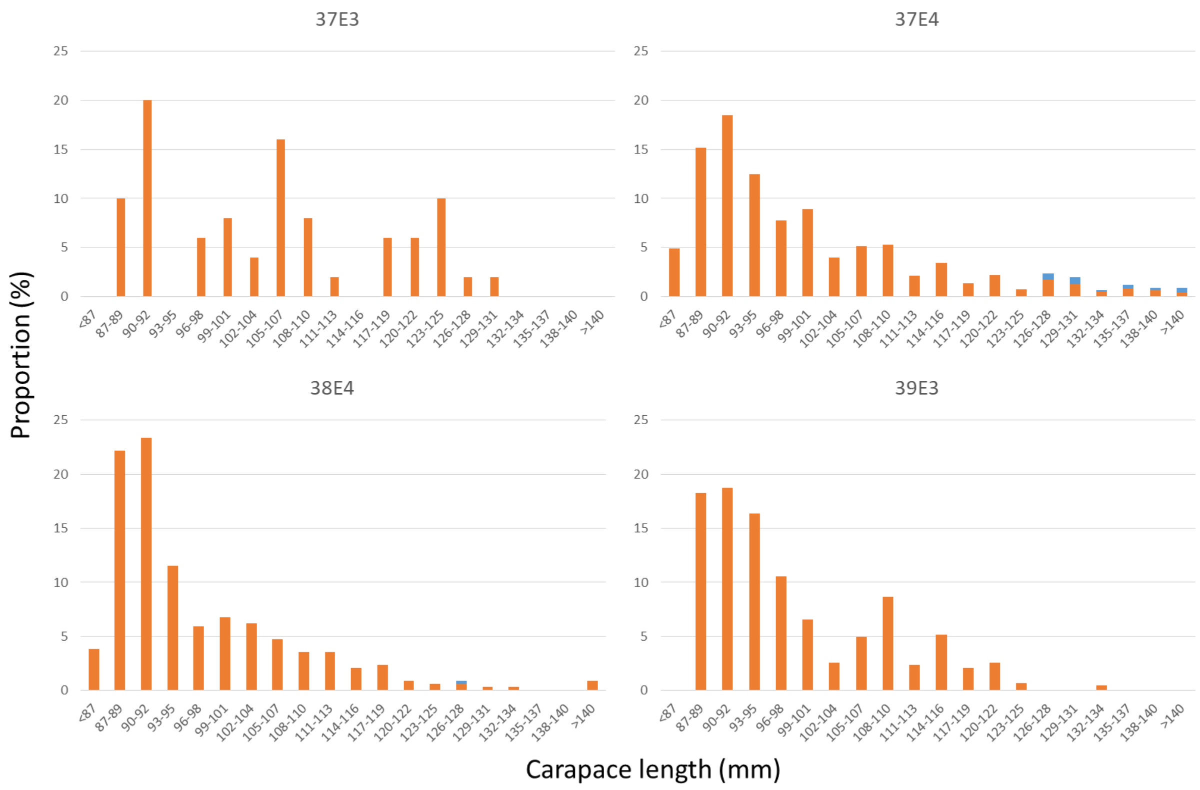

Figure 22: Length frequency of lobsters v-notched through the 2018-2020 scheme (includes both females (orange bars) and males (blue bars)).

3.4 *Lobster assessment*

After trialling different stock assessment methods, a length-based model was used to examine the health of the lobster stock. The assessment, using data collected from the observer programme, separated male and female lobsters and also excluded those from Strangford Lough as they have a different growth rate. For a stock to be healthy, the mean length should be at Lopt (Length at which growth is optimum). Using this model, female lobsters appear to be in a healthy state (Figure 23). However, male lobsters are shown to be overexploited (mean length is below Lopt).

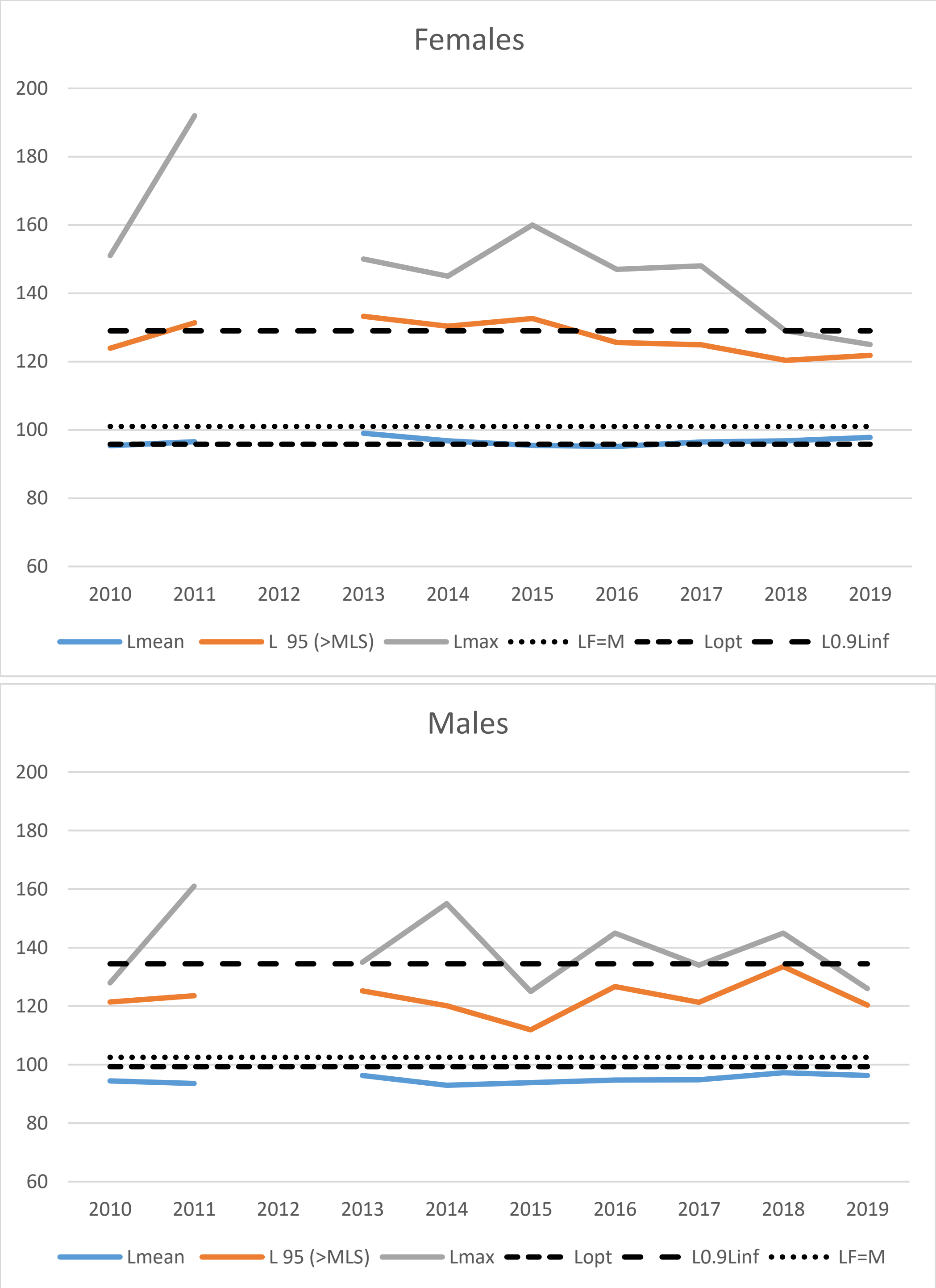

Figure 23: Length based assessment of Northern Ireland lobsters.

3.5 Genetic Analysis

Data quality control: Resulting genetic data, for lobsters caught between 2017 and 2020, was of very good quality with over 80% and 92% of all individuals successfully genotyped for 10+ and 7+ marker loci respectively. To ensure reliable parentage inference, only those samples with full genetic data for seven or more marker loci (i.e. at least 70%) were retained for subsequent analyses.

Lobster stock genetic stability: Temporal examination of the genetic make-up of lobster stock (Figure 24), representing the areas covered by both NELCO and NCLFA, confirms the pattern of genetic stability reported in the previous report McMinn *et al.* (2015). Thus, no significant variation was observed in allele frequency distributions at any of the 11 loci examined. Furthermore, there was no evidence for population substructuring within the area covered by the scheme. These observations validate both the sample size used for examining temporal variation and that, at present, there is no evidence for changes in the effective population size (number of breeding lobsters) in the stock.

Parentage assignment of fishery caught lobster: The results of the parentage assignment of lobsters caught in the fishery are summarised in Table 3. Results have been corrected from the previous version presented in McMinn *et al.* (2015) to also take into account unsampled males. In the previous version of this analysis, only female lobsters were accounted for in parentage assignments. However, assuming a 1:1 female:male ratio in the lobster stock, for every female assigning to a particular family, it is reasonable to assume that an unsampled male will also assign to this family. To account for this bias, female assignments were corrected by a factor of two. Thus, for every female assigning to one of the 2003-2004 families, it was assumed that at least one male also assigned to the same family. While this approach is not ideal, it does account for the fact that the genetic data set predominantly comprises female lobsters. Hence, the figures reported in McMinn *et al.* (2015) were underrepresented (only accounted for female lobsters). To reduce possible biases caused by this ad-hoc correction factor, assignment stringency was increased by reducing accepted error levels to 0.001.

Notwithstanding this correction, the trends of recruitment have not changed from the previous report. Thus, the offspring of lobsters v-notched in 2003-2004 began to appear in the fishery (as berried females) in relatively small numbers in 2007 (1% of berried lobsters), four years after hatching. Numbers increased to peak in 2009, when 28% of the v-notched lobsters assigned to the 2003-2004 families, six years after hatching. Assignment numbers started to decrease between 2010 (20%) to 2014 (8%). Somewhat unexpected, however, numbers of caught lobsters assigning to the 2003-2004 lobster families increased again to 14% between 2017 and 2020. In summary, genetic data indicates that the offspring of lobsters v-notched in 2003-2004 can be detected in the fishery at least 16 years after hatching.

While the length data is not always reliable, given inconsistencies between records from different fishermen, it is interesting to note that there is a detectable increase in size range (CL) of offspring assigning to the 2003-2004 families over the years. Thus, on average, the offspring of lobster v-notched in 2003-2004, caught between 2017 and 2020, are larger than those caught in previous years. Nevertheless, there is still considerable variation in size range indicating that size at age varies considerably among families.

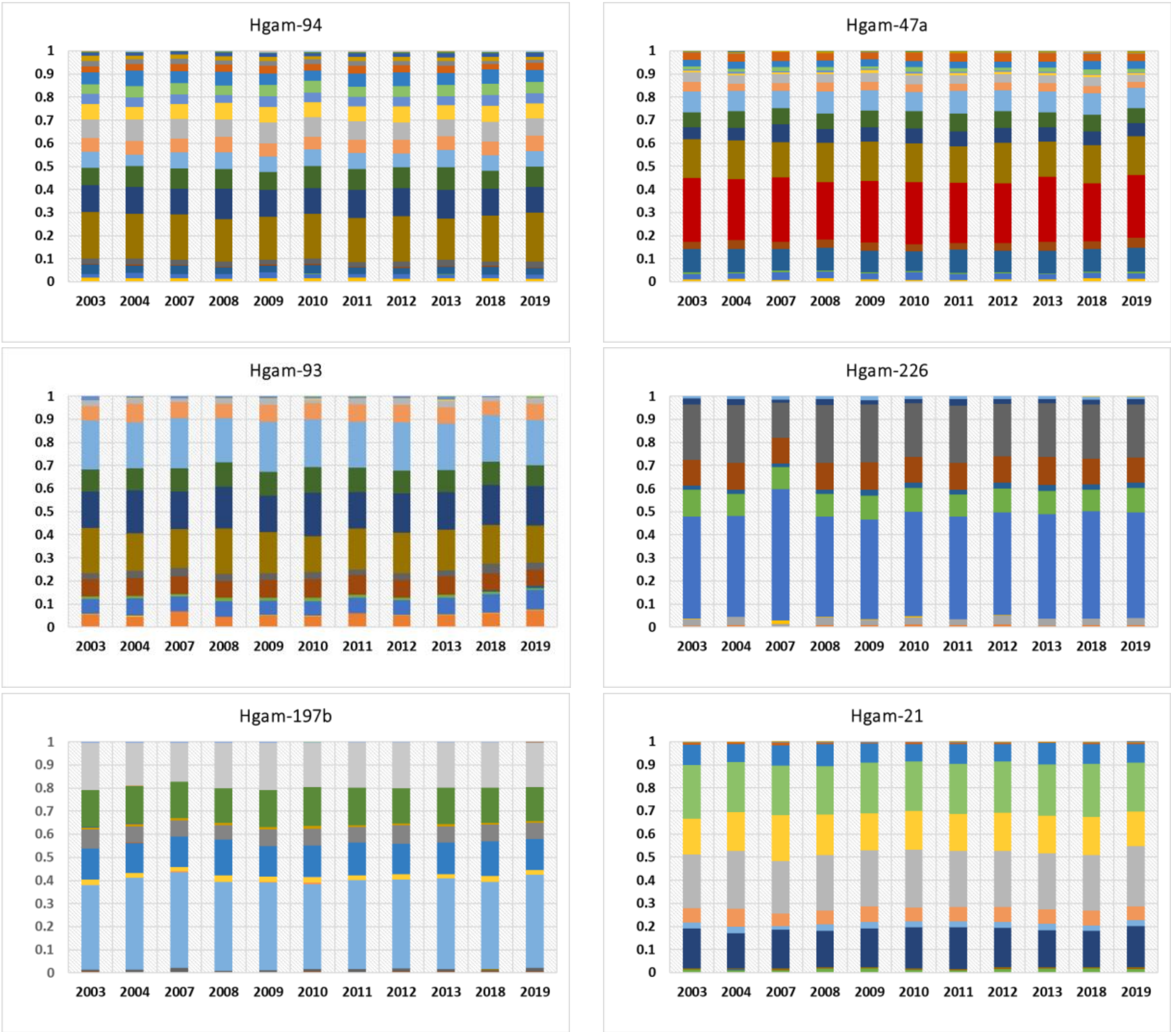

Figure 24: Allele frequencies distribution for six randomly selected marker loci used to analyse samples from both NELCO and NCLFA lobster v-notching scheme. In each case, allele frequencies are represented per year as a multi-colour bar. Different colours represent distinct alleles and the size proportion of the colour in each bar represents the frequency of particular alleles within a given year.

Table 3: Summary results or parentage assignments (assuming an error rate of allele calls of 0.001) to 2003-2004 reconstructed families. Results are displayed by year and include: 1) number of v-notched lobsters (NELCO scheme only from 2007 to 2012 and both NELCO and NCLFA between 2013 and 2014 between 2017 and 2020); 2) number of v-notched lobsters assigning to 2003-2004 families; pool; 3) DAERA recorded landings (metric tons) for NELCO area ports; 4) estimated number of lobsters based on DAERA recorded landings (converted from weight landings); 5) Estimated number of lobsters derived from the NELCO/NCLFA schemes (i.e. offspring of families comprising the 2003-2004 families); 6) Estimated contribution (weight in metric tons) derived from the NELCO/NCLFA scheme; and 7) Contribution (%) of NELCO/NCLFA V-notching scheme to the lobster stock. In each case, totals (2007-2020) are also provided.

Calendar Year	No. V-notched lobsters	No. of lobster assigned to families	DAERA recorded Landings (tons) - NELCO area port	Estimated No. of lobsters based on DAERA landings	Estimated No. of lobsters derived from V-notching scheme	Estimated weight (tons) - V-notch contribution	Contribution of v-notching scheme to fishery (corrected for males)
2007	1,821	13	31	48,129	668	0.4	1%
2008	2,115	197	29	46,494	8,679	5.4	19%
2009	3,785	537	27	45,257	12,832	7.8	28%
2010	1,870	189	40	72,874	14,712	8.0	20%
2011	2,497	225	33	55,970	10,089	6.0	18%
2012	3,598	314	44	76,859	13,396	7.7	17%
2013	3,785	190	45	77,195	7,762	4.5	10%
2014	2,116	81	71	121,420	9,275	5.4	8%
2017/18	2,576	184	36	60,871	8,716	5.1	14%
2019/20	3,015	216	40	67,605	9,683	5.7	14%
2007-2020	27,178	2,145	249	422,778	68,138	39.9	13%

Correlation between female size and contribution to stock recruitment: Further examination of results from the parentage assignment analyses indicate that ~35% of the families have contributed more than one offspring to the stock (i.e. more than one offspring recruiting to the stock as a berried lobster) (Figure 25). Given inconsistencies of length data, a robust correlation analyses between female size and contribution to stock recruitment is not possible. It is worth noting, however, that 9 of the 15 families, which were assigned with more than 10 offspring, involved larger females ranging from 100 to 120 mm CL.

Identity analysis (mark-recapture): Since the beginning of the genetic tagging scheme, several v-notched lobsters were caught twice or more either within the same year or over multiple years (Figure 26). Over 90% of the cases linked to recaptures within the same year, involved the same boat and sampling areas (broad geographical location), but were spaced by a number of months (one to three months between captures). The number of lobster recaptured decreases over time with most recaptures noted in the first few years. Interestingly, lobsters tend be recaptured within the same geographical areas but over time, recaptures increasingly involved additional boats that are, however, fishing in the same broad geographical areas. While over 99% of all recaptures involved observing the same lobster twice over one or more years, five lobsters were recaptured three times over the time of the genetic tagging scheme. Not unexpectedly, lobsters recaptured over longer gap periods (5 years or more) were found to be noticeably larger (>105 mm CL). In summary, several v-notched lobsters continue to contribute to the local stock. There is strong evidence, based on these recaptures that lobsters in general tend to remain within a narrow geographical range.

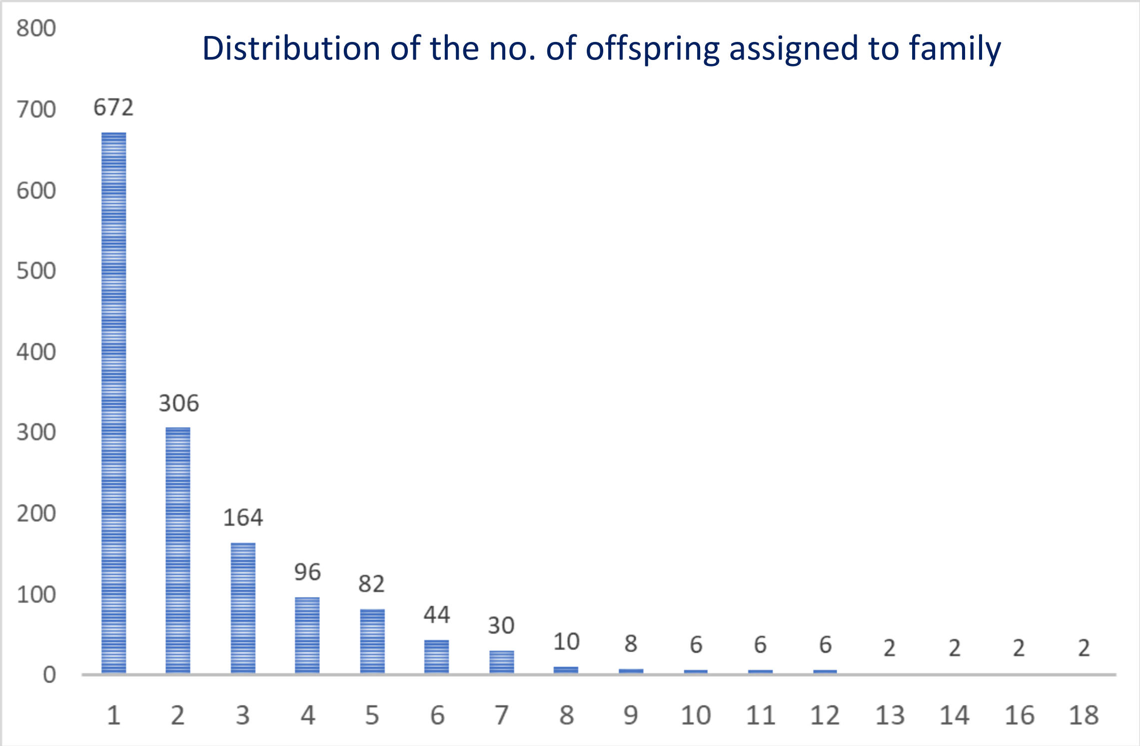

Figure 25: Distribution of the number of offspring assigning to individual 2003-2004 families (i.e. contribution of families measured by the number of offspring detected in the fishery). Numbers have been corrected for males by a factor of 2.

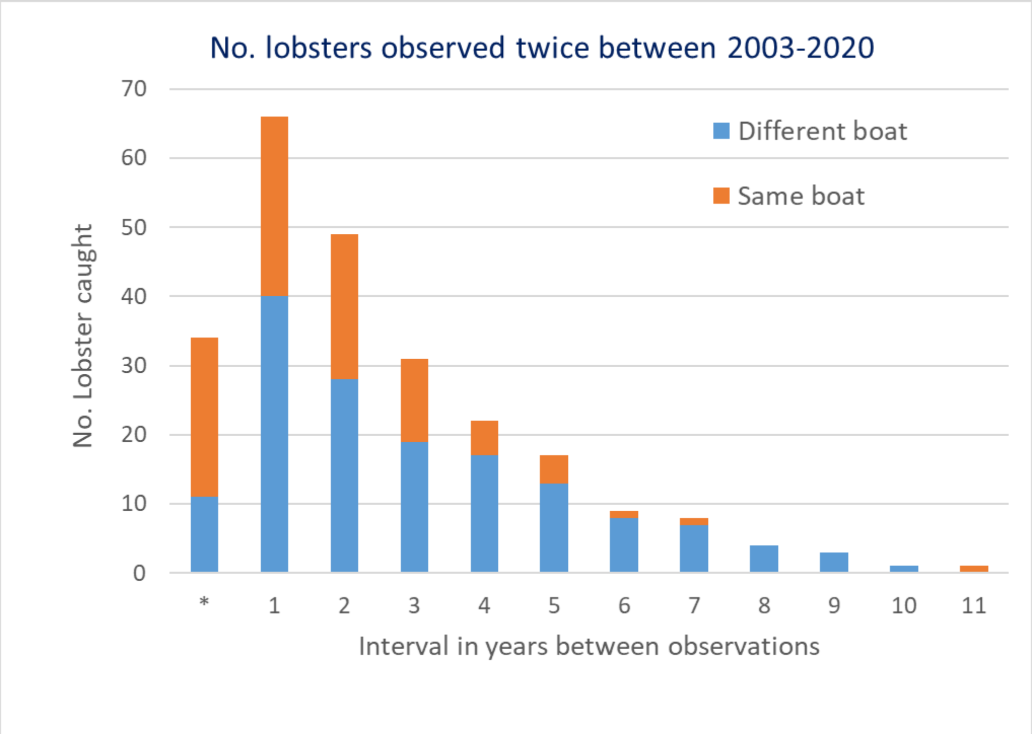

Figure 26: Distribution of the number of times that lobsters are recaptured within a time period ranging from * - same year, 1 – one year between capture-recapture, 2- two years between sight and recapture…11- years between capture and recapture.

Lobster movement/dispersal: As outlined in the previous report (McMinn *et al*. 2015), comparisons involving the broad geographical location of lobsters comprising the 2003-2004 reconstructed families against the location of lobsters caught in the fishery from 2007 onwards that assign back to these families, allows for an indirect assessment of larval dispersal. The rationale is that genetic tagging (through family assignment) offers a powerful and viable approach to track offspring from "fertilised egg" to adulthood. This analyses shows that 76% of lobsters caught between 2017 and 2020 within the NELCO area, assign to females also caught in this area during 2003 and 2004. The remaining 24% of lobsters also assigning to the 2003-2004 families were caught in the Outer-Ards area, covered by NCLFA. These results suggest an active movement northwards. These figures are highly in agreement with those reported in McMinn *et al* (2015) showing assignments levels of 81% and 20%, of lobsters caught in both the NELCO and NCLFA areas, to the 2003-2004 lobster families. Over 80% of the lobster caught in NCLFA did not assign to any of the 2003-2004 lobster families, indicating that they are most likely offspring of lobster that have previously hatched in the area. This hypothesis has yet to be tested.

4. Discussion

Notwithstanding that it represents only a small proportion of the total UK landings, the Northern Ireland lobster fishery is important to the Northern Ireland fishing sector. Whilst the County Down coastline has the highest total landings of lobsters, it is the North Coast and Antrim which show the highest LPUE. Between 1965 and 1973 the CPUE for Northern Ireland (assumed to be LPUE), decreased from 13.1kg per 100 lobster pots, to 7.0, recovering to 10.1 in 1972 (Watson, 1974). In 1974 Watson reported a higher CPUE on the North coast in comparison to that on the East coast (all fishing south of 55ºN), at 8.9kg per 100 pots and 5.9kg per 100 pots respectively.

During this investigation, the average LPUE calculated from observer trips targeting lobsters averaged at 11kg per 100 pots. Whilst this is on par with the historic records, the total landings have increased massively from mean landings between 1954 and 1973 of 17 tonnes. As the LPUE is similar, even with an increase in landings and effort, the lobster fishery today can be viewed as being in a better condition.

The length frequency of lobsters was found to be skewed by the presence of large female lobsters, which cause a significant difference in the lengths of males versus females. In a study of the American lobster by Pugh *et al.* 2013, it explained that if the length frequency of a stock is skewed, particularly in the larger size classes, this could prevent the larger females from finding a suitable male to mate with. Not only may it not be possible for the smaller male to physically mate with the lobster but these smaller males contribute smaller spermatophores. As the fecundity of female lobster increases with size, this could mean that the limited sperm produced by the smaller males may not be sufficient to fertilise the entire clutch of a large female. This was reported in McMinn *et al*, 2015, which recommended that "*future v-notching schemes should contemplate the protection of a percentage of males to ensure large females will still be able to contribute to the fishing stock*". The current scheme now allows large males to be v-notched. While there was a slow uptake of this part of the scheme due to the evidence required to claim the payment for these "premium" animals, numbers of males being v-notched had increased towards the end of the scheme. The most recently funded v-notching project (2020-2022) has continued to fund male v-notching and there has been a higher number of male samples being provided.

Berried lobsters started appearing in the catch at 70mm. This is slightly smaller than the figure of 75mm, which is commonly used as the figure for when lobsters start carrying eggs. In the Firth of Forth and the Hebrides, the onset of sexual maturity was 82mm and 87mm respectively (Lizarraga-Cubedo, *et al.* 2003). In the Irish lobster, Tully (2004) reported that size at maturity (the size at which 50% of female lobsters are mature and capable of spawning) varied from 92-96mm meaning the 87mm MLS only allows approximately 15% of the lobsters to spawn prior to being fished.

The results of the genetics analysis have confirmed the observation of McMinn *et al.* (2015), further validating genetic tagging as a useful and robust methodology for monitoring lobster stocks. Thus, in addition to providing a logistically simpler (less stressful to lobsters) monitoring approach, in comparison to traditional methods, it also provides valuable additional information (e.g. quantification of v-notching approach, dispersal/movement patterns of lobsters, natural "mark-recapture" approach, assessing temporal fluctuations in effective population size, etc.) that can be translated into management.

Results from the genetic tagging programme (incorporating data from 2007-2020) further confirms the value of V-notching to safeguard the reproduction potential of local lobster stocks. Indeed, the impact of the approach (corrected for unsampled males) is higher than previously reported (even taking into consideration reduced tolerance to typing errors in the analyses). Thus, between 2007 and 2020, on average, 13% of lobsters, currently in the fishery, are thought to be linked to the original 2003-2004 reconstructed families (16 years' time gap). This level of contribution is based on very stringent analytical criteria (conservative) in order to accept parentage assignments as correct. Thus, it is possible that the real contribution level is even higher.

The continuing contribution of one given "year cohort" for 16 years, to the standing lobster fishing stock merits further consideration. In a classical recruitment model, for an exploited stock, the expectation is that the offspring of a given breeding cohort will increase in numbers, as they mature, with subsequent decreasing being a function of both natural and fishing mortality, thus giving space for new generations. The results presented here, however, clearly indicate this type of model is not appropriate for lobsters. This is most likely because of the unusual longevity and low natural mortality rates observed in lobsters.

In a comprehensive study, based on the natural rate of lipofuscin accumulation in eyestalk ganglion from microtagged European lobsters, Sheehy *et al*. (1999) showed that lobsters can naturally reach exceptionally old ages with males and females reaching on average 31 years (maximum 42 ± 5 years) and 54 years (maximum 72 ± 9 years) respectively. The authors concluded that age-at-size is highly variable with at least seven year-classes entering the fishery at 85mm CL. This greatly limits the estimation of annual cohorts in size composition and complicates the development of recruitment indices.

The findings of this report confirms this. Thus, most likely the 2003-2004 parental pool comprises families representing very distinct age classes (i.e. breeding cohorts). Results have shown that the offspring of v-notched lobsters can recruit for a very long period of time to the fishery (16 years or potentially more). Thus, the overall "high" contribution (13% average with maximum of 28% in 2009) is actually the sum of the contribution of several year-classes comprising the 2003-2004 lobster samples. Thus, it is certainly feasible to assume an even larger contribution of any specific age class. That is, the contribution levels reported here are likely to be an underestimation only.

Another important result of this report is the confirmation that lobster movement/dispersal is predominantly limited to "local areas". This is in agreement with what has been recorded from parallel physical tagging work (McMinn *et al*. 2015, and this report). An additional related and relevant observation, from a management perspective, also confirmed in this report, is that recruitment patterns are largely local. Thus, the larger proportion of lobster caught in the NELCO fishing area assigns to parents from the same area. Therefore, local lobster fishermen can directly capitalise, in terms of future fishing gains, by participating in the v-notching scheme. There is good evidence, however, suggesting directional dispersal to the north. In addition, ~80% of lobsters caught in the NCLFA area remain unassigned. Most likely, given the localised assignment patterns recorded for the NELCO fishing area, the "parents" for lobsters derived from the NCLFA area are also linked to this area. QUB and AFBI are examining the possibility of using some of the NCLFA samples caught between 2013 and 2014 to build a regional parental pool to test this hypothesis.

In summary, genetic tagging has been providing a direct measurable approach for monitoring the v-nothing scheme. Genetic tagging offers several advantages over other more traditional tagging methods. Thus, it provides a sound mechanism for monitoring both the v-notching scheme (bypassing field logistics) and the “health” status of lobster stocks (temporal stability in the number of breeders). It also provides continuing information on dispersal and connectivity. The main value of the approach, however, is in the long-term data series. This allows managers and other relevant stakeholders to quickly identify changes in stock composition and structure that are relevant to stock management. Of particular relevance is the Close-Kin Mark-Recapture method that is based on the multi-generation genetic data series. Bravington *et al.* (2016) have successfully developed a genetic based method based on the “recapture of closely-related kin” that can be used to estimate stock abundance and other demographic parameters. ICES are promoting this method for the management of marine fish stocks. Ultimately, the argument is that genetic tagging should be readily included alongside other more traditional approaches to collect the relevant fishery and biological data required for stock management. Recent (and continuing) advances in genetic based technology means that screening costs have been greatly reduced (and this trend is likely to continue). Given the value of the genetics data, the cost/benefit ratio is justified.

5. References

Addison, J. T. and Lovewell, S. R. J. (1985). "Pot selectivity and the size composition of catches of lobster (*Homarus gammarus* L.) and crab (*Cancer pagurus* L.) on the East coast of England." International Council for the Exploration of the Sea; Shellfish Committee **CM 1985/K: 35**.

Adey, J.M., Atkinson, R.J.A., Smith, I.P., Tuck, I.D. Taylor, A.C. (2006) "The environmental impact of the Nephrops creel fishery". Final report to Scottish Natural Heritage 168pp.

Bannister, R. C. A. and Lovewell, S. R. J. (1985). "Sampling the size composition of catches of the Lobster (*Homarus gammarus* L.) on the East Coast of England." International Council for the Exploration of the Sea; Shellfish Committee **CM 1985/K:36**.

Bravington, M.V., Skaug, H.J. and Anderson, E.C. (2016). "Close-Kin Mark-Recapture." Statist. Sci. 31 (2) 259 - 274, May 2016,

Eno, N.C., MacDonald, D.S., Kinnear, J.A.M, Amos, C.S., Chapman, C.J., Clark, R.A., Bunker, F.St P.D., and Munro, C. (2001) "Effects of crustacean traps on benthic fauna". ICES Journal of Marine Science 58: 11-20.

Holt, T.J., Rees, E.I., Hawkins, S.J., and Seed, R. (1998) "Biogenic Reefs (volume IX). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs". Scottish Association for Marine Science (UK Marine SACs Project) 170pp.

Kinnear, J.A.M., Barkel, P.J., Mojsiewicz, W.R., Chapman, C.J., Holbrow, A.J., Barnes, C., and Greathead, C.F.F. (1996) "Effects of Nephrops creels on the Environment". SOAEFD Marine Laboratory, Aberdeen.

Lizarraga-Cubedo, H. A., I. Tuck, N. Bailey, G. J. Pierce, and J. A. M. Kinnear. (2003). Comparisons of size at maturity and fecundity of two Scottish populations of the European lobster, Homarus gammarus. Fisheries Research **65**:137-152.

Lovewell, S. R. J. and Addison, J. T. (1986). "Further pot selectivity experiments in the fisheries for lobster and crab on the east coast of England." International Council for the Exploration of the Sea; Shellfish Committee **C.M. 1986/K:7**.
Committee.

McMinn, C., Prodöhl, P., Clements, A., Bailie, D., Service, M., Beattie, J. (2015) Report on Northern Ireland lobster science. Unpublished.

OSPAR Commission (2009) "Background Document for *Modiolus modiolus* beds". Biodiversity series. 28pp.

Sheehy, M.R.J & Bannister, RCA & Wickins, J & Shelton, PMJ. (2011). New perspectives on the growth and longevity of the European lobster (Homarus gammarus). Canadian Journal of Fisheries and Aquatic Sciences. 56. 1904-1915. 10.1139/cjfas-56-10-1904.

Truett G.E., Heeger P., Mynatt R.L., Truett A.A., Walker J.A., Warman M.L. (2000) Preparation of PCR-quality mouse genomic DNA with hot sodium hydroxide and tris (HotSHOT). Biotechniques. 2000 Jul;29(1):52, 54. doi: 10.2144/00291bm09. PMID: 10907076.

Tully, O. (2004). Integration of biology and management in lobster fisheries. The biology and management of clawed lobster (Homarus gammarus L.) in Europe. O. Tully, Bord Iascaigh Mhara. Fisheries Resource Series **No 2**.

Watson, P. S. (1974). "The Northern Ireland lobster fishery 1954-1973." International Council for the Exploration of the Sea; Shellfish and Benthos Committee **C.M.1974/K:19**.

Welby, P. R. (2014). Crab and lobster stock assessment research report 2014. Eastern Inshore Fisheries and Conservation Authority. 49.