EMFF Operational Programme 2014-2020

Marine Biodiversity Scheme

Catch and bycatch in the tangle net fishery for crayfish (*Palinurus elephas*) off the south west coast of Ireland

Catch composition

Economics of fishing

Bycatch

Protected species

Lead Partner: Marine Institute

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Marine Institute
Foras na Mara

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Executive Summary

Crayfish or spiny lobster is fished off the south west coast of Ireland. There are also smaller fisheries on the west and north west coasts. Although historically, prior to the 1970s, the main fishing gear used in the fishery was top entrance traps crayfish are now targeted with large mesh tangle nets. The selectivity of these nets is poor and there is known to be a by-catch of finfish, skates and rays and protected species such as grey seal. The fishery usually occurs from mid-March to December.

The species composition and size distribution of the catch and by-catch was surveyed over a 4 year period from 2017-2020 from Dingle Bay north to the Shannon Estuary. Additional data south of this area was obtained in 2020. A crayfish tagging programme was undertaken in 2017 and 2018. Between 2 and 6 vessels participated in the programme depending on year Most of the data was reported directly by Skippers and crew who were contracted to supply data. Scientific observers covered a proportion of trips in 2017 and 2019.

A total of 1500 nmiles of tangle net hauls were surveyed across 6 vessels. A total of 11792 crayfish and 899 lobsters were measured, 1234 crayfish were tagged and released and 45 recaptures were reported.

Spider crab, brown crab and crayfish were the numerically dominant species in the catch. Lobster, pollack, thornback ray, spurdog, monkfish and turbot were caught regularly in low numbers. There was no cetacean by-catch. A total of 200 grey seals were caught over the 4 year period by the vessels participating in the survey. Endangered and critically endangered species, including flapper skate, common skate, angel shark and white skate, were caught in very low numbers. The finfish catch is mainly lost to scavengers or seal depredation before nets are retrieved and because of long soak times which averaged 8 days. This reduces the value of the catch. The average value of the live crustacean (crayfish, lobster, brown crab) catch was approximately €300 per mile of net hauled.

Crayfish were tagged and released in 2017 and 2018 and recaptured during the period 2017-2020. 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. 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.

The by-catch of critically endangered species poses a high risk to the continued presence of these species in Irish waters and indeed in European waters given that the area is known to hold the last European remnant populations of species such as angel shark and white skate.

Grey seal by-catch was related to the distance between the fishing event and the nearest seal colony haul out at the Blasket Islands. Sixty % of seals were caught within 10km of the haul out. The probability of capture in a single net haul declined from 30-35% within 10km to 9-14% at distances of 10-30km to 4% at distances of 40-60km and zero at distances greater than 60km (data for 39 hauls >60km). The high by-catch of grey seal is a significant risk to the Blasket Island seal colony. It is unlikely that the Blasket population can sustain this level of by-catch mortality without inward migration from other colonies.

Introduction

The spiny lobster or crayfish (*Palinurus elephas*) is fished mainly off the south west coast of Ireland with smaller fisheries on the west and north west coasts. The fishery in Ireland evolved gradually from the 1930s initially as a by-catch in the lobster fishery. From the 1930s to the 1970s there was a gradual increase in the use of French barrel pots which increasingly targeted fishing for crayfish (Figure 1). With the exception of the early 1940s there was a corresponding increase in landings during this period peaking during the early 1950s-1970s at an approximate average of 150 tonne per annum. Tangle nets were introduced into the fishery, quickly replacing top entrance pots, in the early 1970s. Landings declined between 1974 and 1988. Over 200 tonnes were landed in 1989 but landings declined thereafter and up to the present day. Landings are currently about 20-30 tonnes per annum.

The main gear used in the fishery are large mesh (>150mm) tangle nets which are soaked for periods of 1-10 days depending on catch rates and weather conditions. The nets have poor selectivity and there is significant by-catch (BIM 2007, unpublished) of skates and rays some of which are endangered or critically endangered. Grey Seal are also captured as they attempt to depredate whitefish that are entangled in the nets. The fishery occurs close to some significant grey seal colonies.

No detailed information on catch and by-catch in the crayfish tangle net fishery, other than landings data by species reported through logbooks by vessels over 10m, has been collected since 2007. Those data reported the following catch composition and features of the fishery

- The catch composition comprised of 9 species of teleost (bony fish), 7 species of elasmobranchs, some of which are critically endangered, and Grey seal
- Four species of crustacean including Crayfish, Lobster, Spider crab and Brown crab
- The dominant by-catch species in shallow water was spider crab
- There was high mortality of by-catch
    - The vast majority of vertebrate by-catch were dead on retrieval of nets
    - A high % of by-catch mortality of fish was caused by scavenging by peracarid crustaceans (skinners). Seal depredation also reduced the value of the fish catch
    - Undersized brown crab and spider crab suffered loss of limbs during extraction from the nets and a high % mortality could be expected
    - Crayfish mortality or physical damage was between 18-26% and was highest in crayfish under the MLS of 110mm
    - Lobster by catch was low

Catches of critically endangered species, such as angel shark and flapper skate, is of concern as the local and European population size of these species is very low and may not be able to support incidental by-catch mortality (Clarke *et al*. 2016). The Tralee Bay area supports a high diversity of elasmobranch species including these endangered species (Varian *et al*. 2009, 2020). Grey Seal are not endangered but are protected by the Habitats Directive. The by-catch mortality may affect the status of local populations using haul outs in the area. There are also economic losses to the fishery caused by seal depredation and additional losses caused by the entangling of crustaceans in the nets that would otherwise be discarded live.

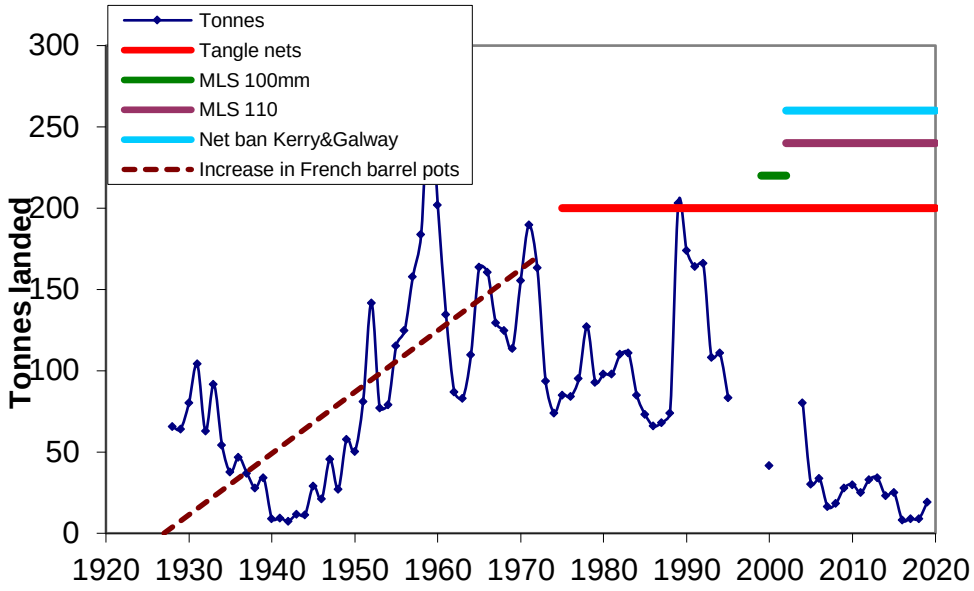

Figure 1. Evolution of the landings and regulation of crayfish in Ireland.

Project Objectives

The project set out to collect new and more extensive information on the species catch and by-catch in the tangle net fishery targeting crayfish. New data on the size distribution of lobster and crab in tangle nets were obtained and a tagging programme to investigate movement, migration and connectivity with crayfish stocks in and outside the study area was completed. The study was undertaken between 2017 and 2020. Data collection continued under a new project in 2021. Data reported here are from 2017-2020 only.

Methods

Study Area

The study was undertaken mainly in north Kerry seaward of Tralee and Brandon Bays and south to the Blaskets and seaward of Dingle Bay (). Between 2 and 6 vessels provided data depending on year. In the period 2015-2019 these vessels were responsible for landings of about 8 tonnes of crayfish and 23% of landings for all vessels in area from Loop Head to Mizen Head. Twenty vessels in this area were responsible for 87% of the landings during the period 2015-2019. In the area north of Dingle,

where most of the data reported here originates, about 10 vessels target crayfish. Five of them provide data to this report.

Recording of data

Catch and by-catch were mainly reported by Skippers and crew using data sheets and sampling kits provided by the Marine Institute. Observers covered a proportion of trips in 2017 and 2019 (Table 1). Observers in 2018 were employed on a separate dedicated survey of elasmobranchs in the same study area (Tully *et al*. 2021). From 2018 participating vessels had iVMS on board and reported position at 10-15min frequency.

Table 1. Number of observer and self-sampling trips and % of trips observed by year 2017-2020

Year	Observer Trips	Self sampling Trips	% observed	Total trips
2017	151	65	70	216
2018		332	0	332
2019	36	244	13	280
2020		280	0	280
Total trips	**187**	**921**		**1108**

The latitude and longitude position of the start and end of each net haul (Figure 2, Figure 3), the net soak time, the length of the net and the number of individuals of each species, including all by-catch, was recorded. Lobster, crayfish and elasmobranchs were measured. The number of individuals caught of each species were converted to catch per nautical mile of net.

Crayfish were tagged with an individually numbered T-Bar floy tag (from Hallprint Australia). Where no observers were on board tagging and release were verified using video collected and reported using a mobile phone (Fulcrum) application. This recorded the position of the vessel during tag releases and showed video of the releases.

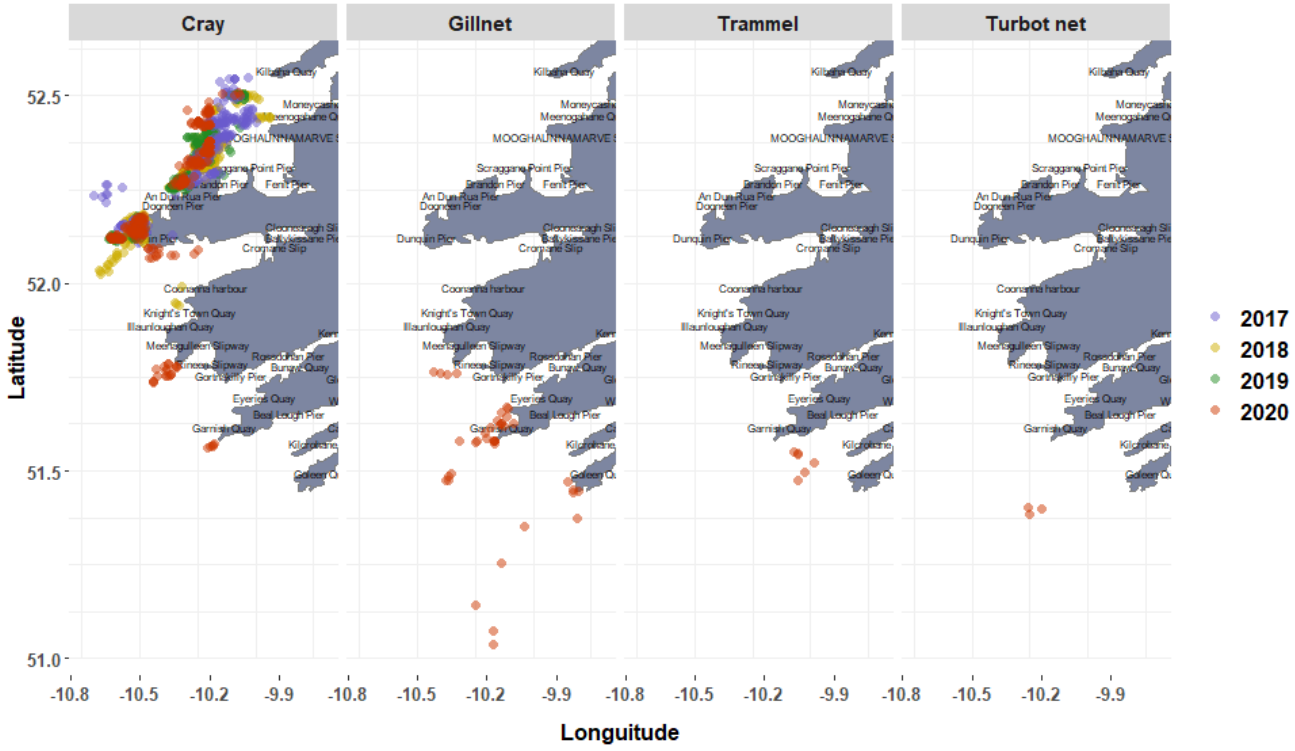

Figure 2. Location of net hauls reported including tangle net (cray), gill net, turbot net and trammel net during 2017-2020.

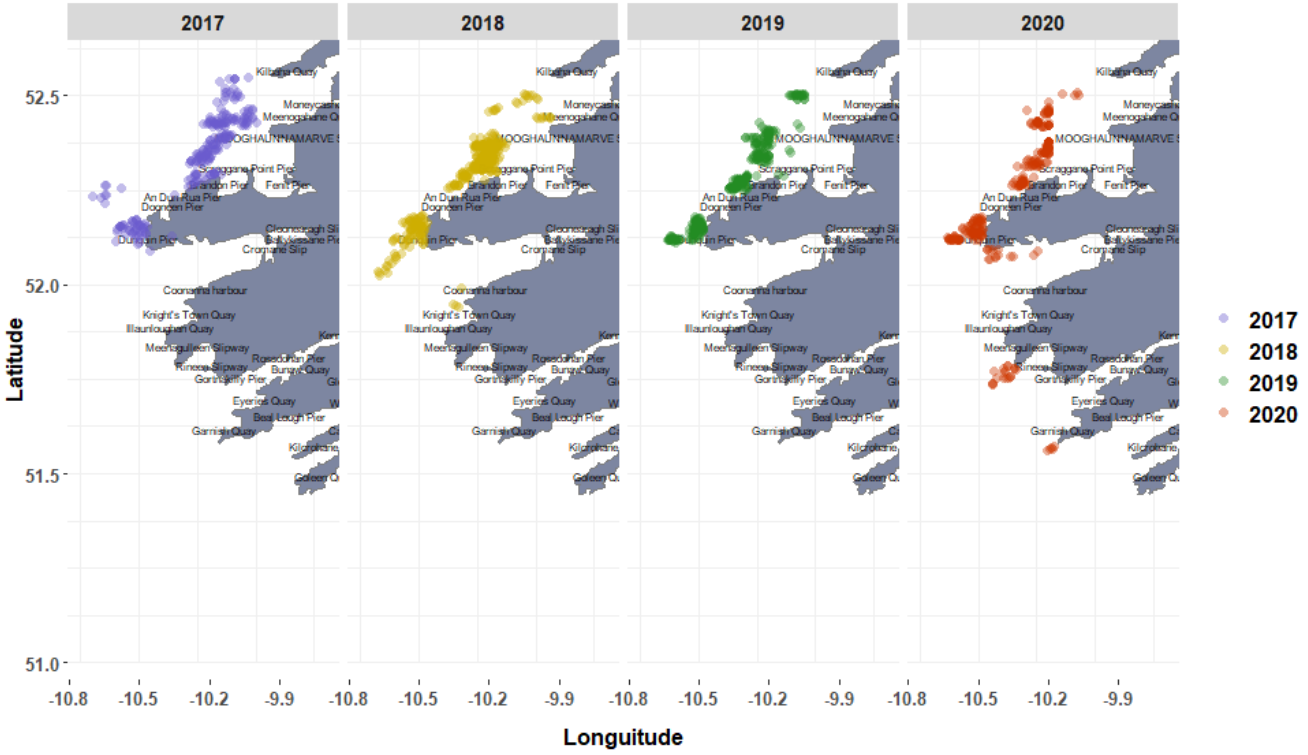

Figure 3. Location of hauls of tangle nets targeting crayfish by year.

Results

Total fishing effort surveyed

A total of 1500 nmiles of tangle net hauls were surveyed across 6 vessels. The average soak time of the nets was 8 days. Not all vessels participated in each year (Table 2). A total of 11792 crayfish and 899 lobsters were measured (Table 3). A total of 1234 crayfish were tagged and released and 45 recaptures were reported (Table 4).

Table 2. Nautical miles of net hauls sampled annually across vessels

Vessel	2017	2018	2019	2020	Total
Vessel 1	30				30
Vessel 2	145	41			185
Vessel 3				29	29
Vessel 4	126	273	218	207	825
Vessel 5	30				30
Vessel 6	99	111	96	94	400
Grand Total	430	425	314	331	1500

Table 3. Number of crayfish and lobster measured annually

Year	Crayfish	Lobster	Total
2017	1575	183	1758
2018	3605	205	3810
2019	3461	250	3711
2020	3151	261	3412
Grand Total	**11792**	**899**	**12691**

Table 4. Number of crayfish released and recaptured annually

Year	Recapture	Release	Total
2017	1	785	786
2018	18		18
2019	16	449	465
2020	10		10
Grand Total	**45**	**1234**	**1279**

Species recorded in the catch

Spider crab, brown crab and crayfish were the numerically dominant species in the catch. Lobster, pollack, thornback ray, spurdog, monkfish and turbot were caught regularly in low numbers. There was no cetacean by-catch. A total of 200 grey seals were caught over the 4 year period by the 6 vessels participating in the survey. Endangered and critically endangered species, including flapper skate, common skate, angel shark and white skate, were caught in very low numbers (Table 5).

Catch and bycatch in the tangle net fishery for crayfish

Table 5. Relative abundance, in descending order, of commercial and non-commercial species in tangle nets catches by year during 2017-2020. The international conservation status of species of elasmobranch fish found in this study are is described in Tully et al. 2021.

SPECIES	2017	2018	2019	2020	Total
Spider Crab (*Maja brachydactyla*)	3294	7320	7369	4087	**22070**
Brown Crab (*Cancer pagurus*)	3548	7034	3783	3530	**17895**
Crayfish (*Palinurus elephas*)	3992	4147	3328	4069	**15536**
Lobster (*Homarus gammarus*)	500	785	658	762	**2705**
Pollack (*Pollachius pollachius*)	11	185	203	800	**1199**
Turbot (*Scophthalmus maximus*)	37	58	87	233	**415**
Monkfish (*Lophius spp*)	38	89	79	139	**345**
Saithe (*Pollachius virens*)	0	0	0	50	**50**
Spurdog (*Squalus acanthias*)	49	155	1115	584	1903
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 (*Dipturus 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 (*Rostroraja alba*)	0	1	0	0	1
Undulate Ray (*Raja undulata*)	0	1	0	0	1
Total	**11636**	**19992**	**16902**	**14588**	**63118**

Annual and seasonal variability in CPUE by species

Crayfish

Net soak time and crayfish mortality

The average soak time (time of deployment to time of hauling) for tangle nets was 8 days. Longer average monthly soaks of up to 14 days occurred periodically due to poor weather (Figure 4). There was no clear relationship between net soak times and crayfish mortality. Mortality increased up to soak day 7 at close to 40% but was lower between days 8-12 (Figure 5). Mortality rates were only reported for a sub-set of data. Crayfish mortalities are not sold and have no economic value.

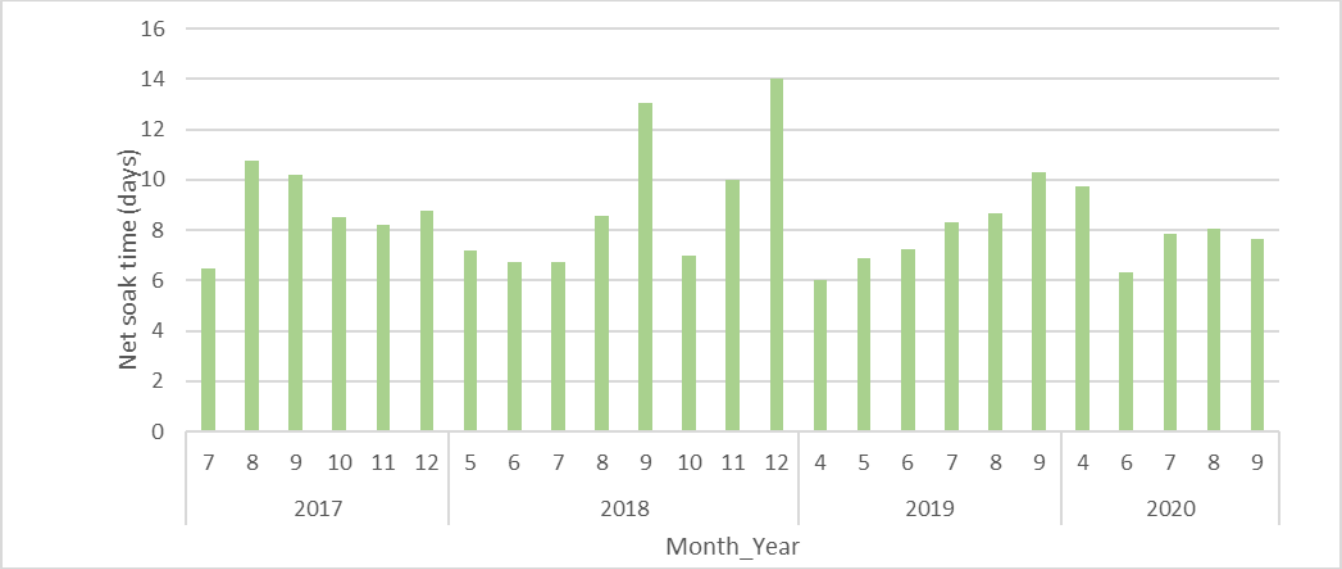

Figure 4. Average monthly net soak times 2017-2020.

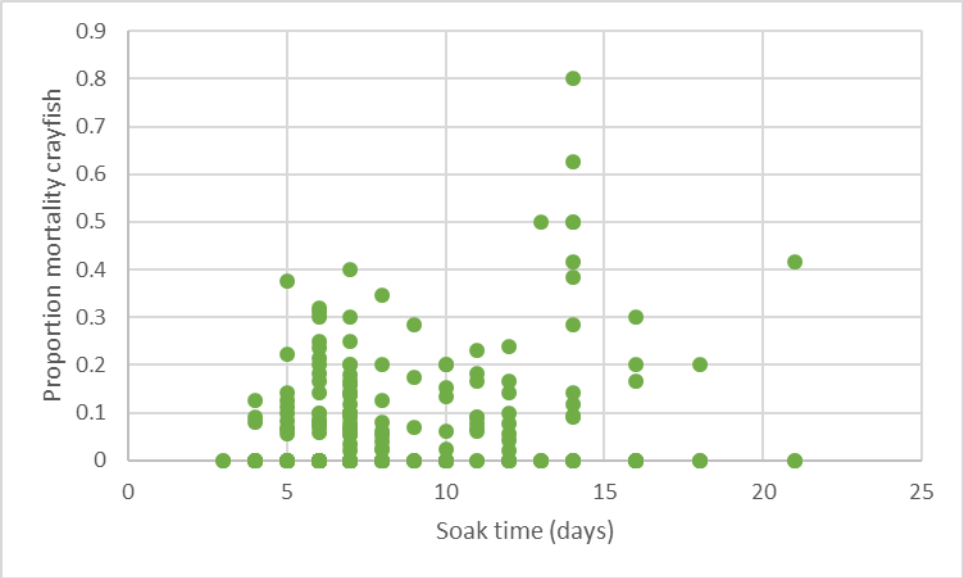

Figure 5. Relationship between the proportion of crayfish that are dead on retrieval of nets and the soak time of nets. Each point is from a single net haul

Catch rates

Crayfish catch varied from 5-25 fish per nautical mile of net. Highest numbers were reported in the autumn of 2017. Catches declined month on month during 2018 but were stable during 2019. Some decline also occurred as the 2020 season progressed from about 22 individuals per mile of net in April to 12 individuals in the autumn (Figure 6). Highest catches were reported around the Blaskets and west of Blasket (Figure 7).

Catch and bycatch in the tangle net fishery for crayfish

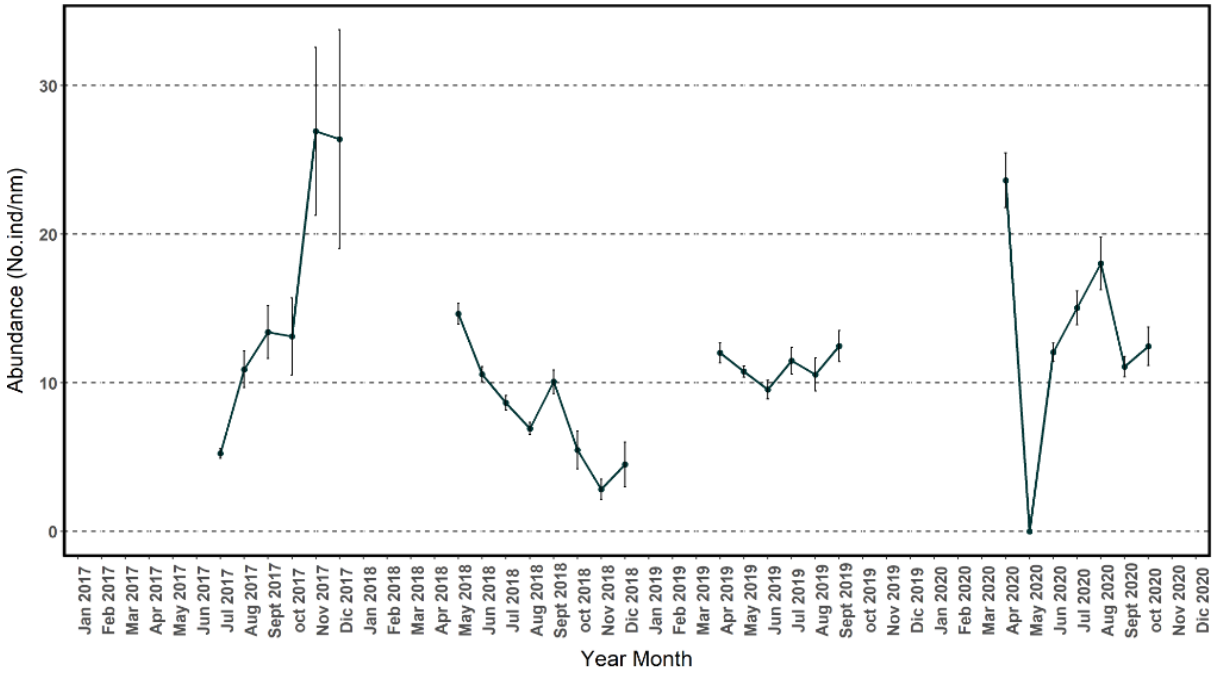

Figure 6. Monthly average (±95% confidence limits) catch per unit effort (CPUE) expressed as abundance per nautical mile of net hauled of Crayfish in tangle nets 2017-2020.

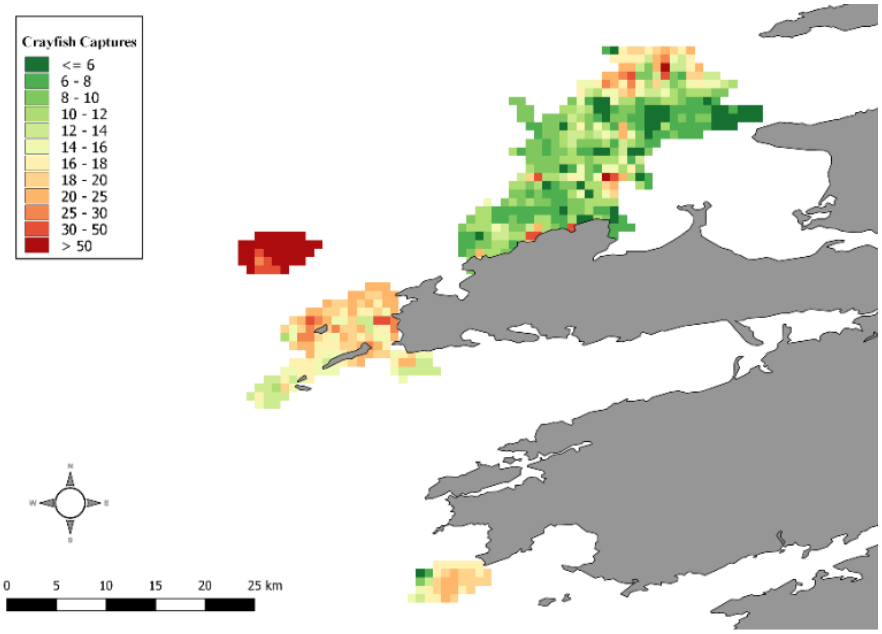

Figure 7. Spatial interpolation (IDW) of Crayfish cpue (N per nmile of net haul).

Size distribution

The size distribution data showed variable proportions of the catch above the minimum size (110mm) in each year; 30 % in 2017 and 48-57 % in 2018-2020 (Figure 8). A high proportion of undersized crayfish were observed in 2017 but this was significantly lower in subsequent years.

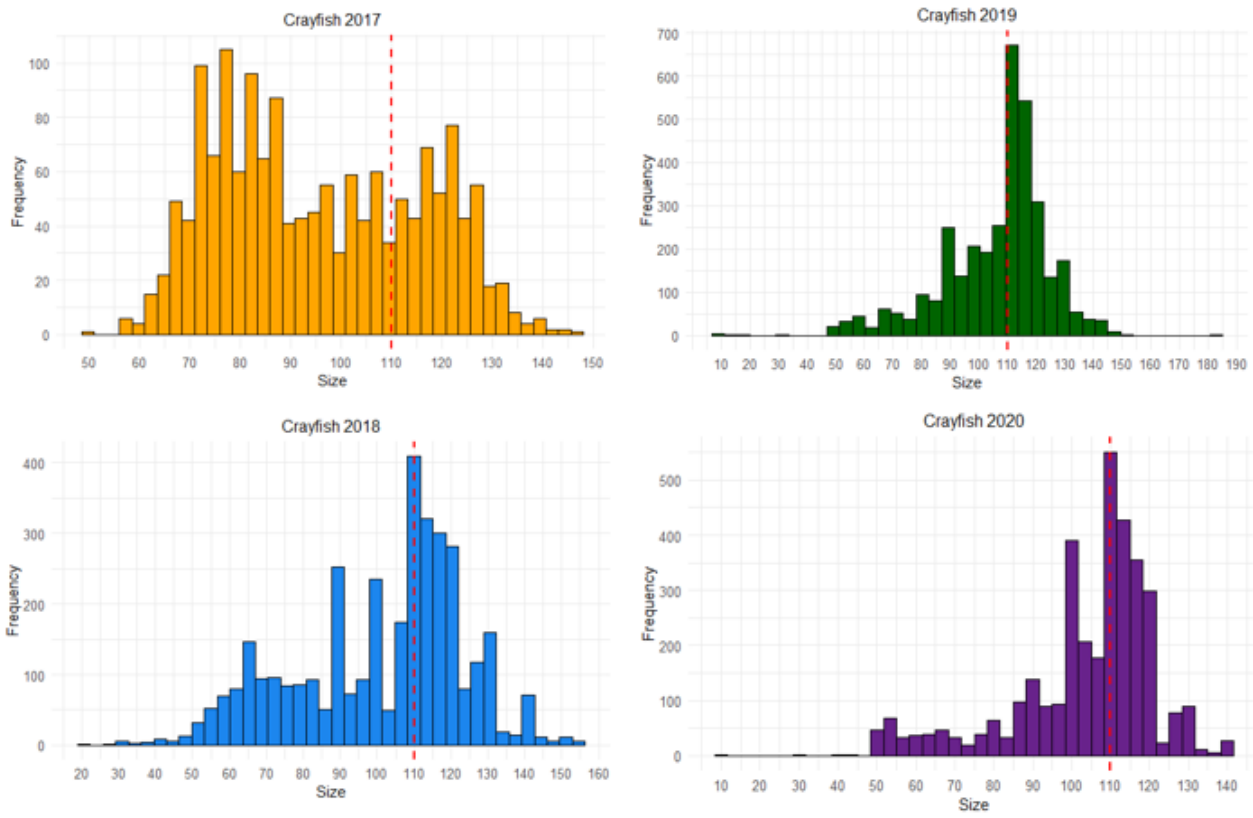

Figure 8. Annual size distribution of crayfish in 2017-2020. The minimum landing size of 110mm is shown.

Sex ratio

The sex ratio of crayfish was typically 60:40 in favour of males. This was fairly consistent across years (Figure 9).

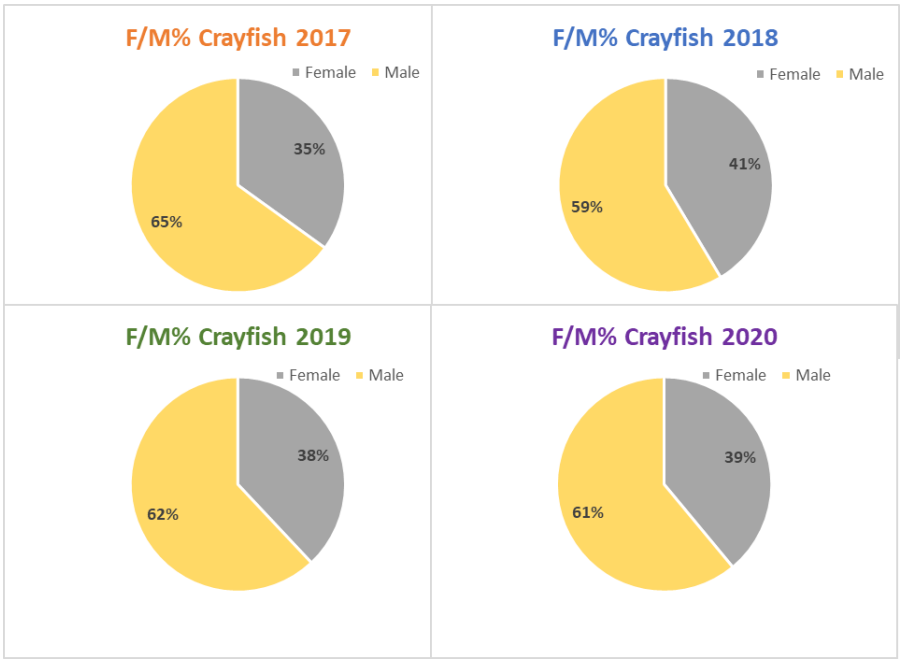

Figure 9. Annual sex ratio of crayfish in 2017-2020.

Catch and bycatch in the tangle net fishery for crayfish

Tag release and recapture data

Crayfish were tagged and released in 2017 and 2018 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 10). Some movements north from Blasket to Brandon and south from Blasket to Kenmare were 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. The repeated local recaptures suggest that tagging data could be used to estimate stock size.

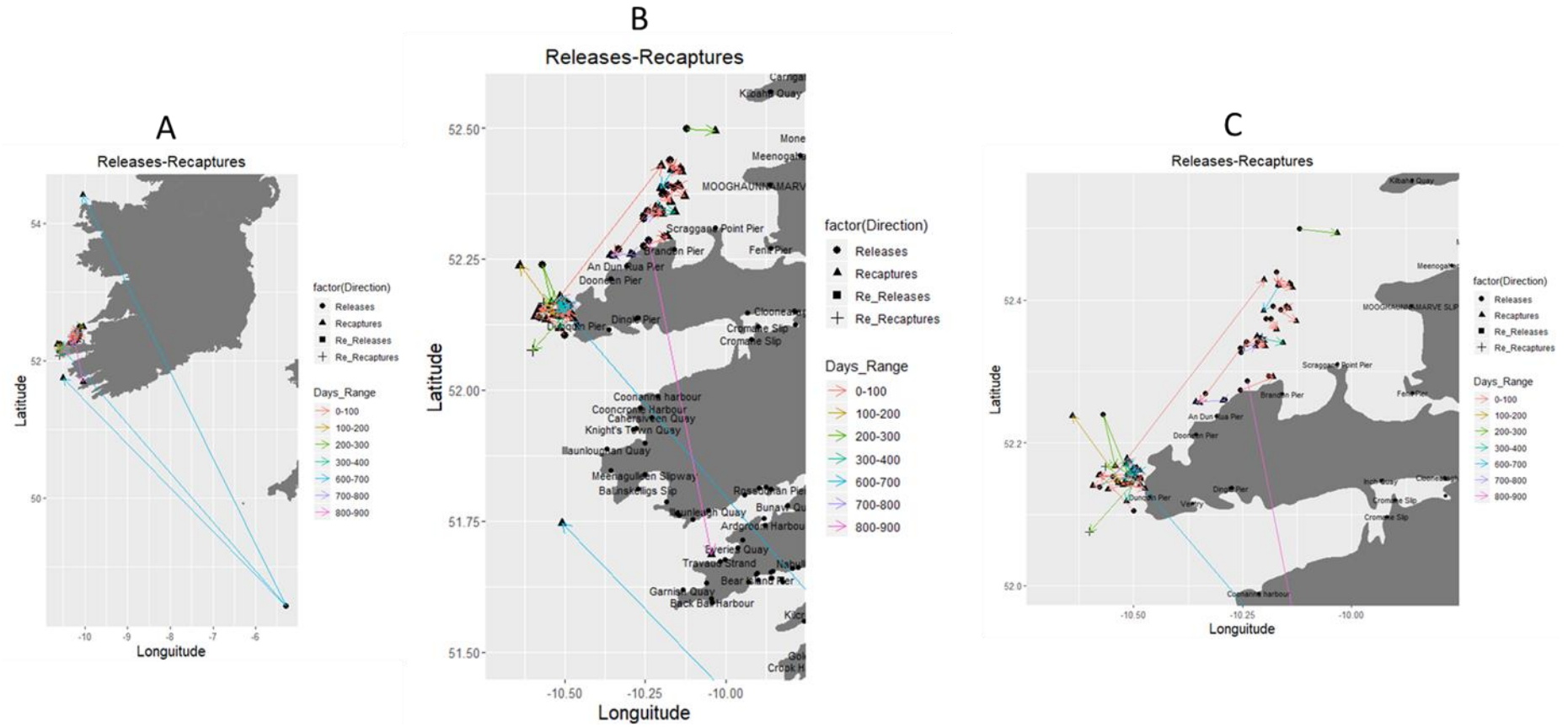

Figure 10. Release recapture data for crayfish 2017-2020. A. Migration of 3 crayfish tagged off Brittany in 2016 (source: Martial Laurens IFREMER) and recaptured off Kerry and Mayo in 2018. B. Movement of crayfish in relation to time since tagging off the Kerry coast. C. Zoom in on recapture data in 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 may bias that conclusion.

Lobster

Catch rates

Lobster catch rates were low at around 2 per nautical mile of net. They remained below two and declined during the season in 2017 (Figure 11).

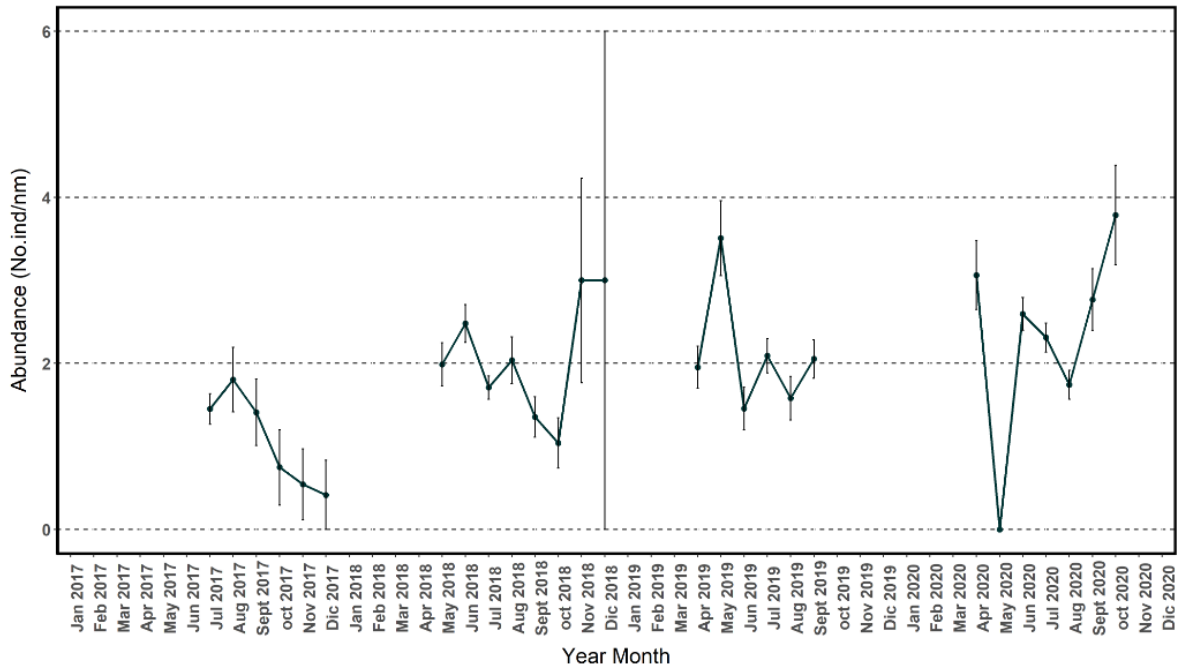

Figure 11. Monthly catch per unit effort (CPUE) of Lobster in tangle nets 2017-2020.

Size distribution

The size of lobster in the catch ranged from 45mm to over 200mm carapace length. The proportion of lobsters over the maximum landing size of 127mm varied from 23% in 2017 to 2% in 2018, 15% in 2019 and 4% in 2020 (Figure 12).

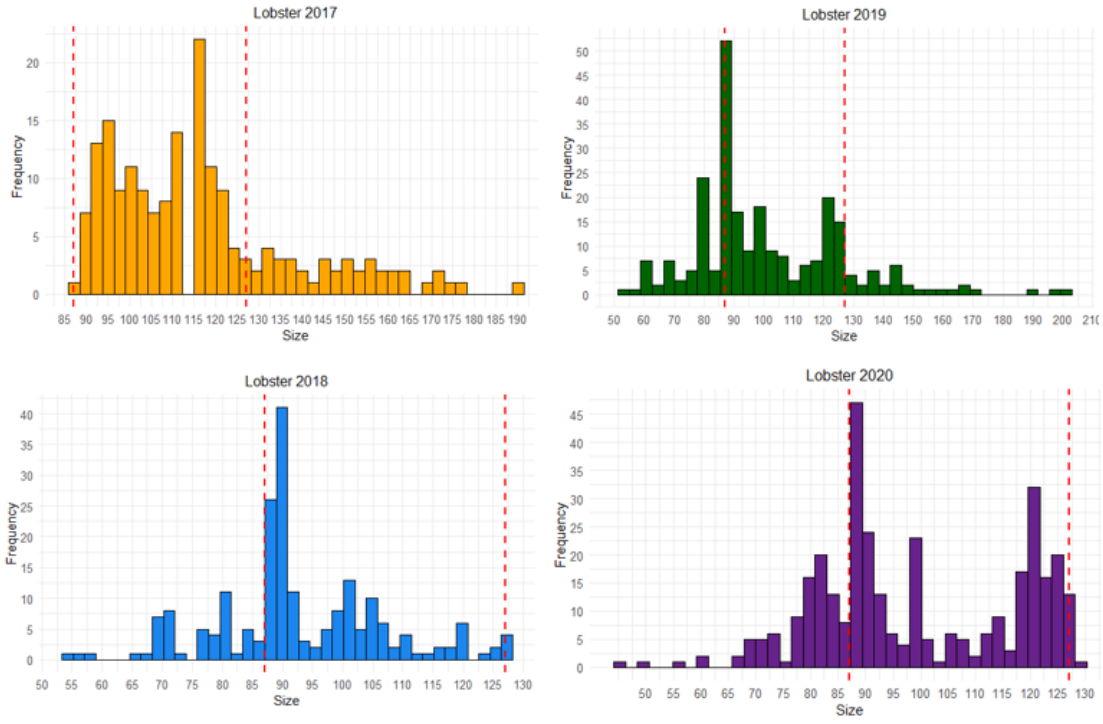

Figure 12. Annual size distribution of lobster in 2017-2020. The MLS of 87mm and MaxLS of 127mm are shown.

Sex ratio

The annual sex ratio of lobsters was close to 50:50 other than in 2019 where 67% of lobsters were male (Figure 13).

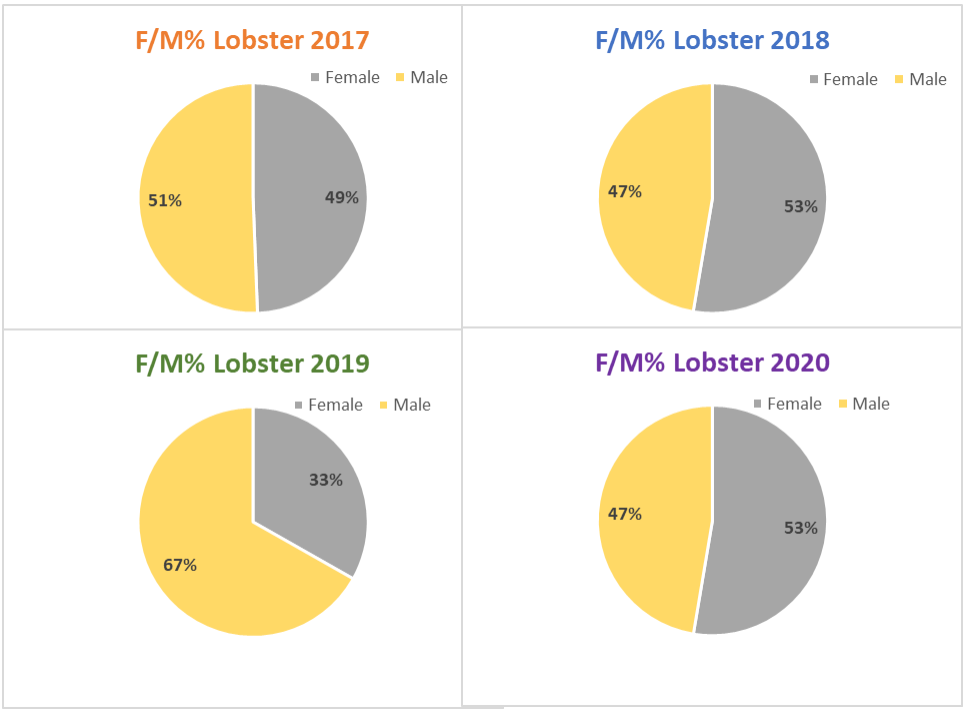

Figure 13. Annual sex ratio of crayfish in 2017-2020.

Brown crab

Brown crab catches varied from 10-20 crabs per mile of net. Average annual catch of 17 crabs per mile was highest in 2018 (Figure 14).

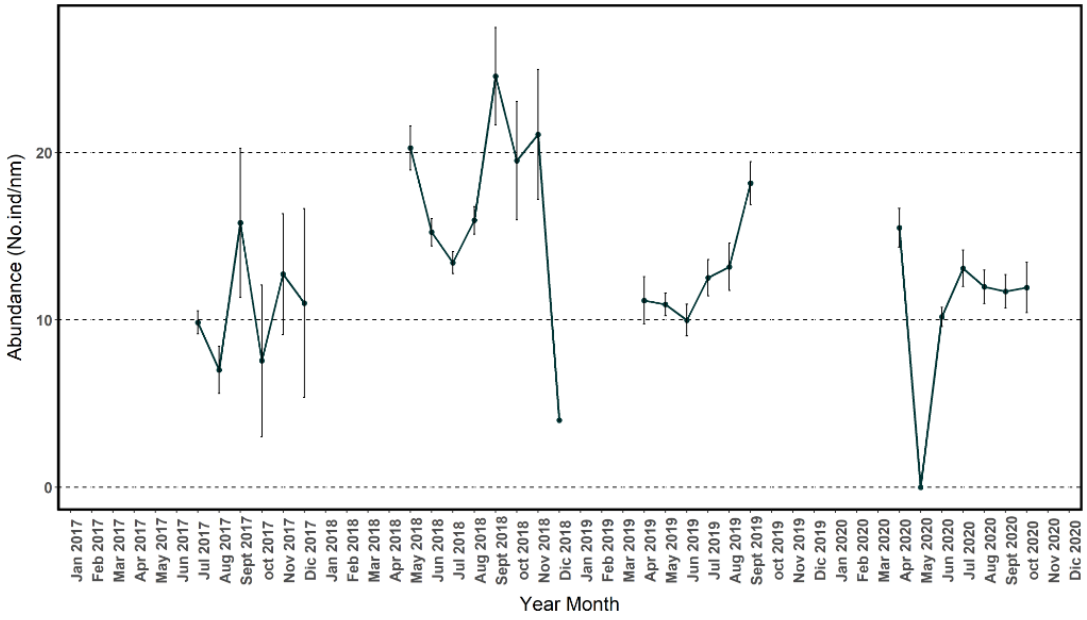

Figure 14. Monthly catch per unit effort (CPUE) of Brown Crab in tangle nets 2017-2020.

Spider crab

Spider crab catches tended to increase during the fishing season and also from 2017-2019. Catches were lower in 2020 (Figure 15).

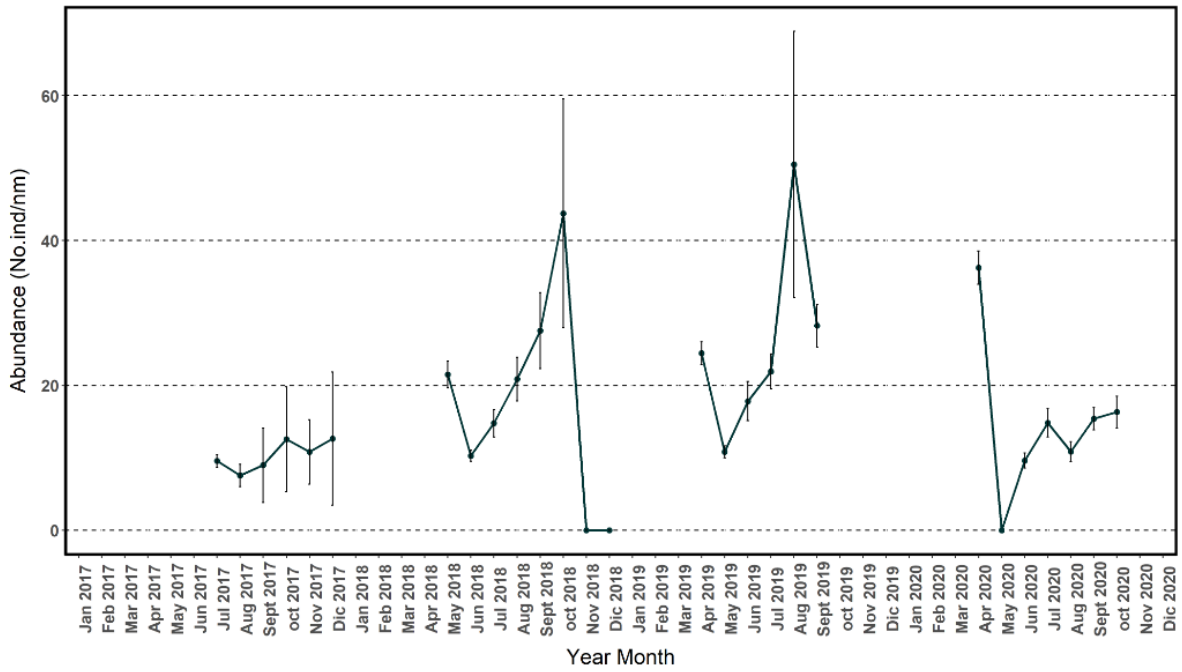

Figure 15. Monthly catch per unit effort (CPUE) of Spider Crab in tangle nets 2017-2020.

Pollack

Pollack are targeted with smaller mesh gill nets in the area and are a by-catch in tangle nets. Catches in tangle nets were insignificant (Figure 16). Data from autumn 2020 shows catches of 50-80 fish per mile of gill net (Figure 17).

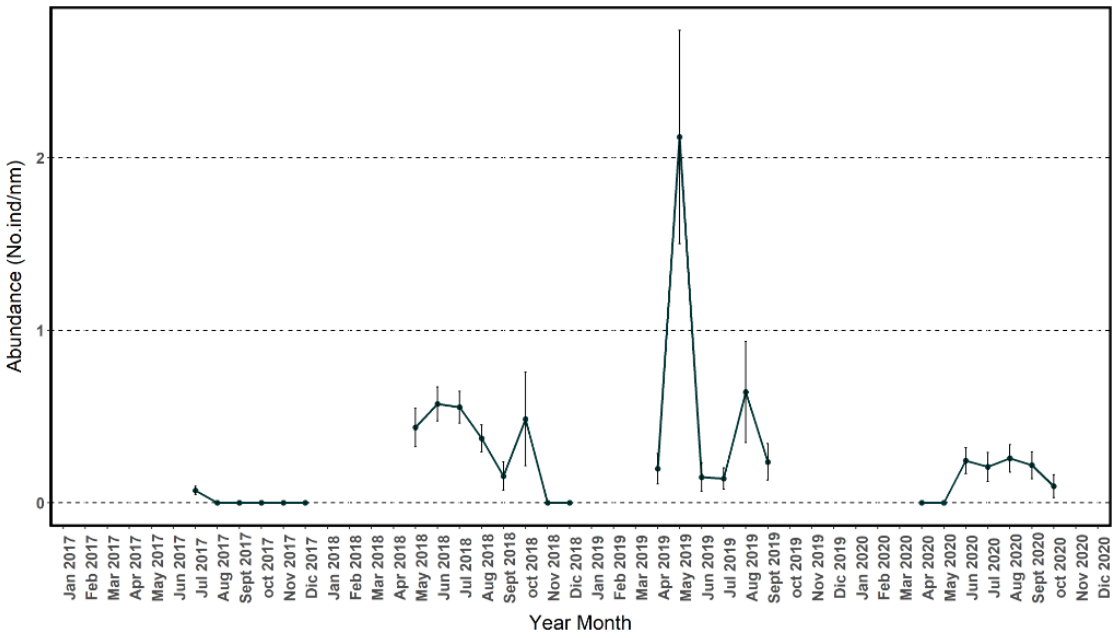

Figure 16. Monthly catch per unit effort (CPUE) of Pollack in tangle nets 2017-2020.

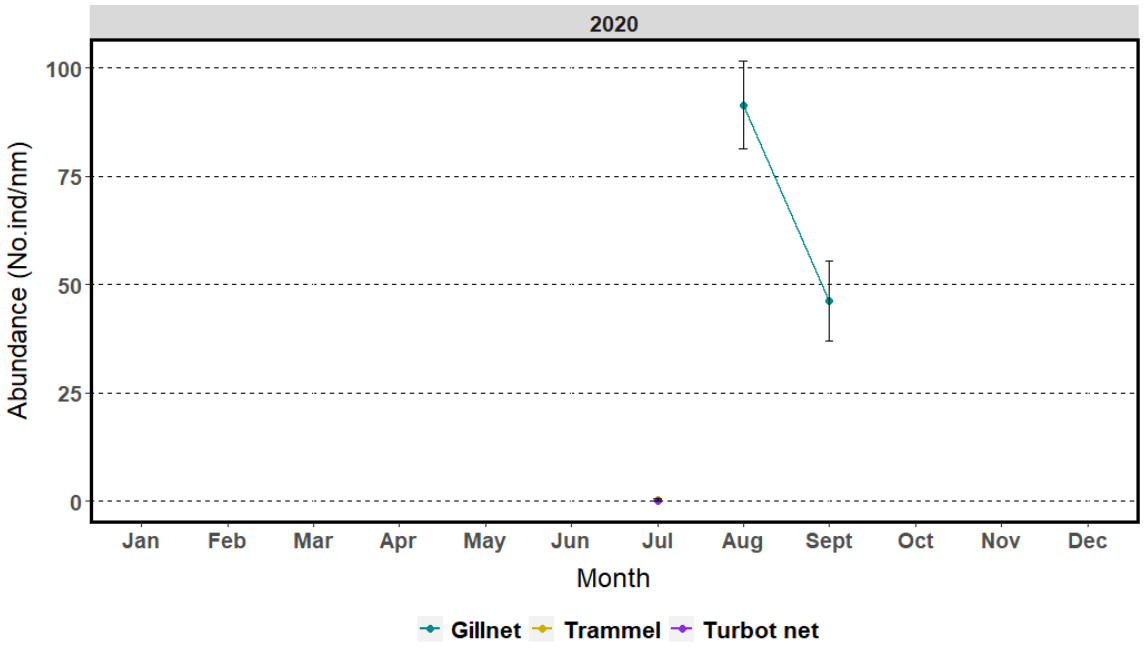

Figure 17. Monthly catch per unit effort (CPUE) of Pollack in Gillnet, Trammel and Turbot net 2020.

Turbot

Turbot occurred in low numbers in tangle nets. Catches increased from close to 0 in 2017 to 0.7 fish per mile of net in summer 2020 (Figure 18). Up to 10 fish per mile were captured in turbot gear in summer of 2020 (Figure 19).

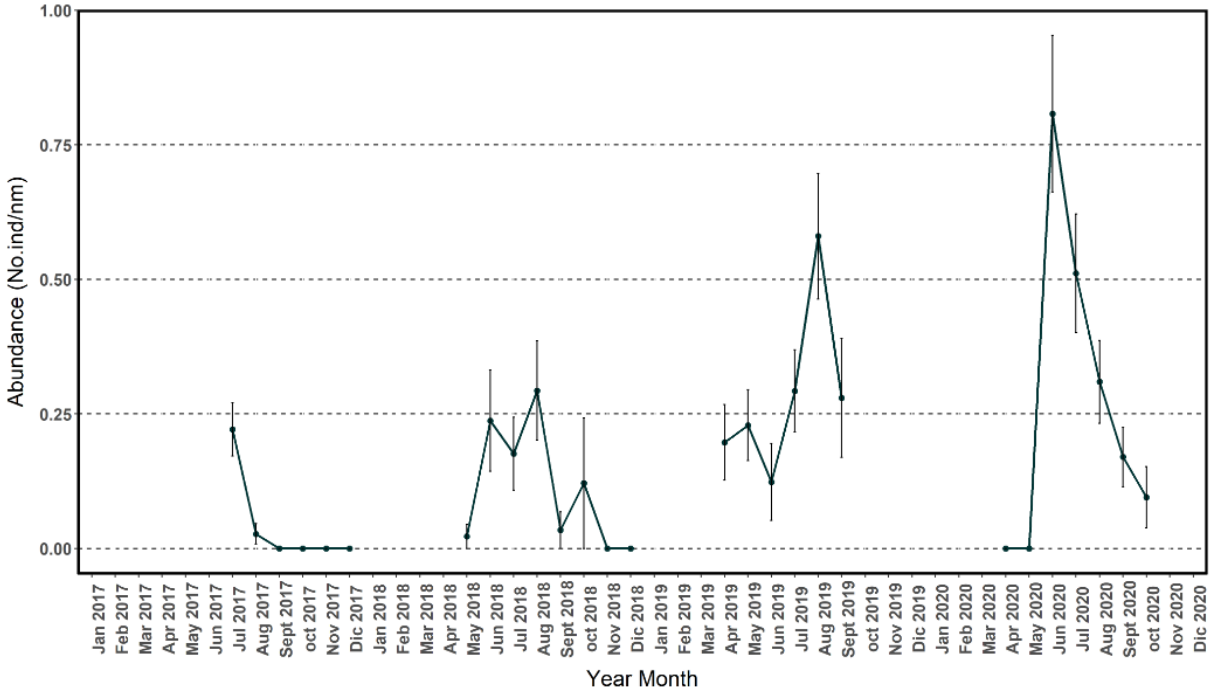

Figure 18. Monthly catch per unit effort (CPUE) of Turbot in tangle nets 2017-2020.

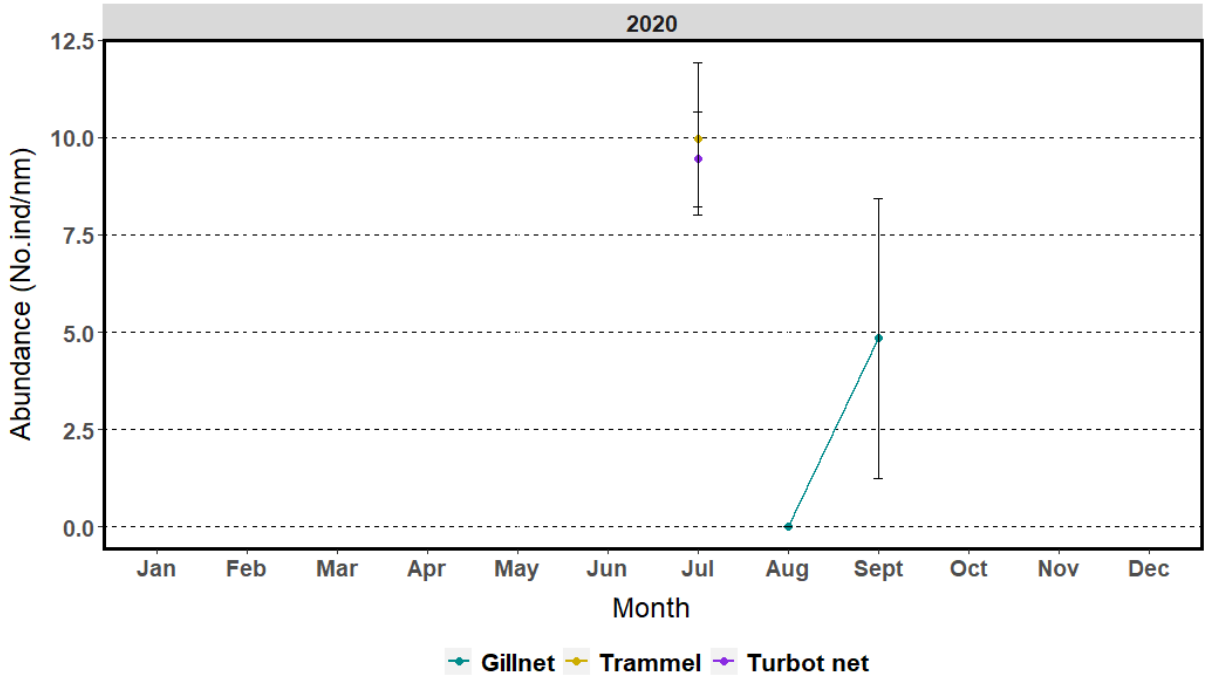

Figure 19. Monthly catch per unit effort (CPUE) of Turbot in Gillnet, Trammel and Turbot net 2020.

Monkfish

Monkfish occurred in low numbers in tangle nets (Figure 20). These fish were usually damaged by seals. Data from July 2020 in Turbot nets shows about 15 fish per mile of net (Figure 21).

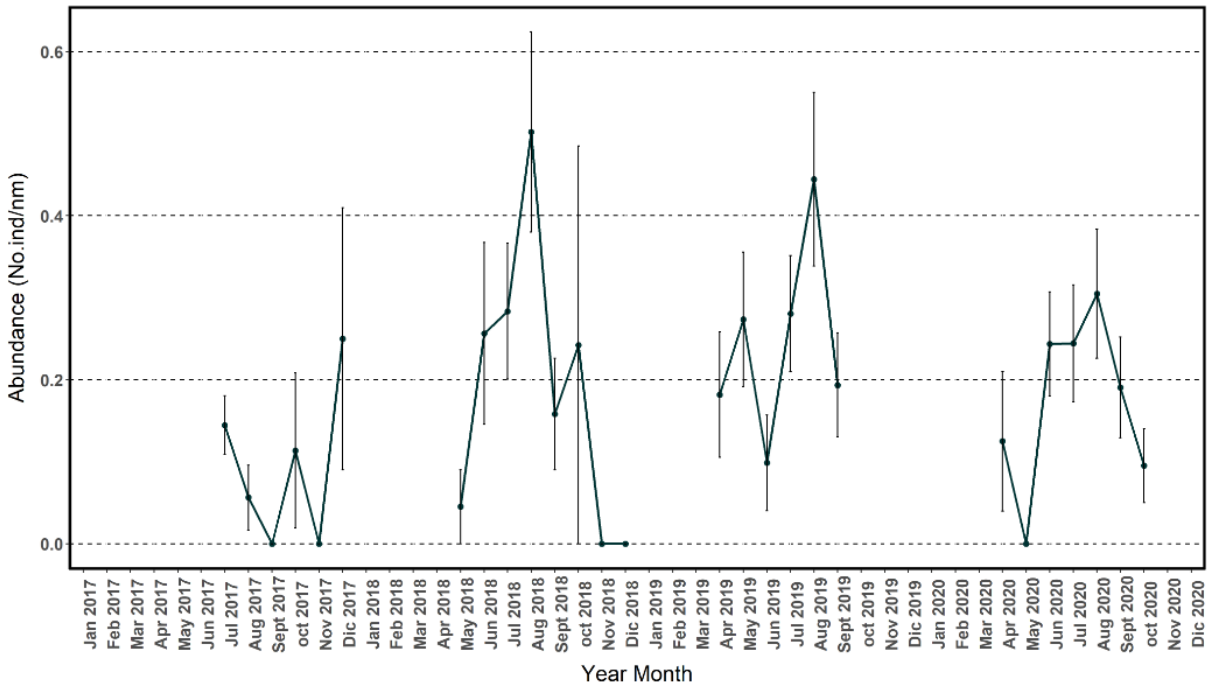

Figure 20.Monthly catch per unit effort (CPUE) of Monk in tangle nets 2017-2020.

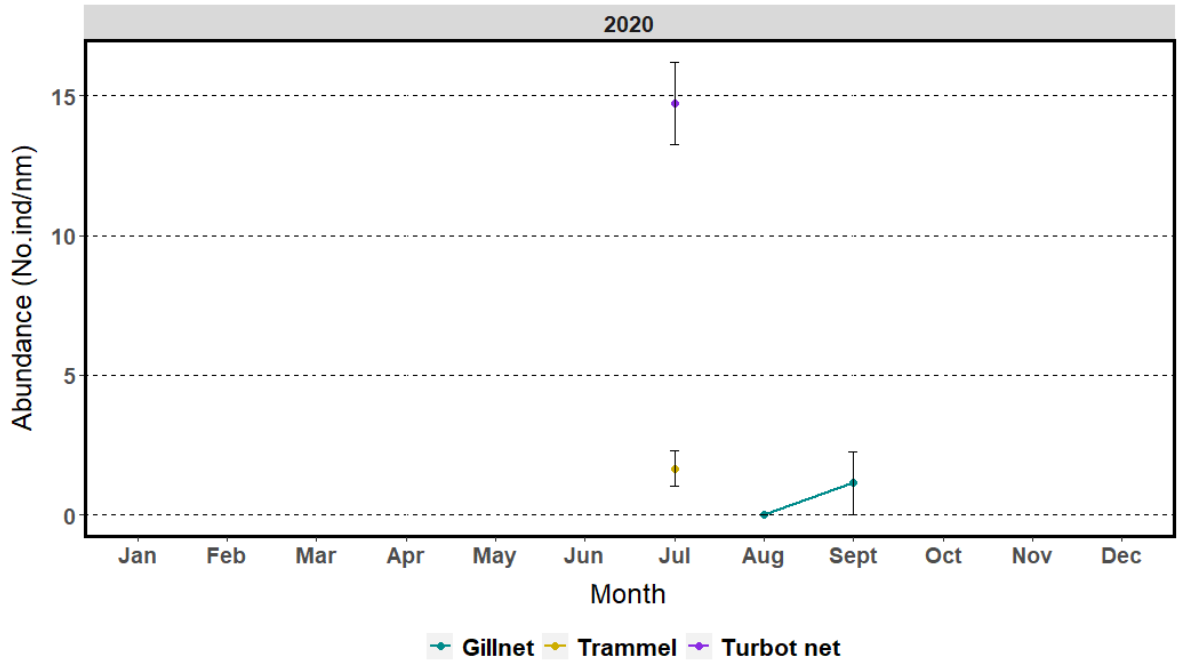

Figure 21. Monthly catch per unit effort (CPUE) of Monk in Gillnet, Trammel and Turbot net 2020.

Black Pollack

Saithe or black Pollack were only reported from gill nets (Figure 22).

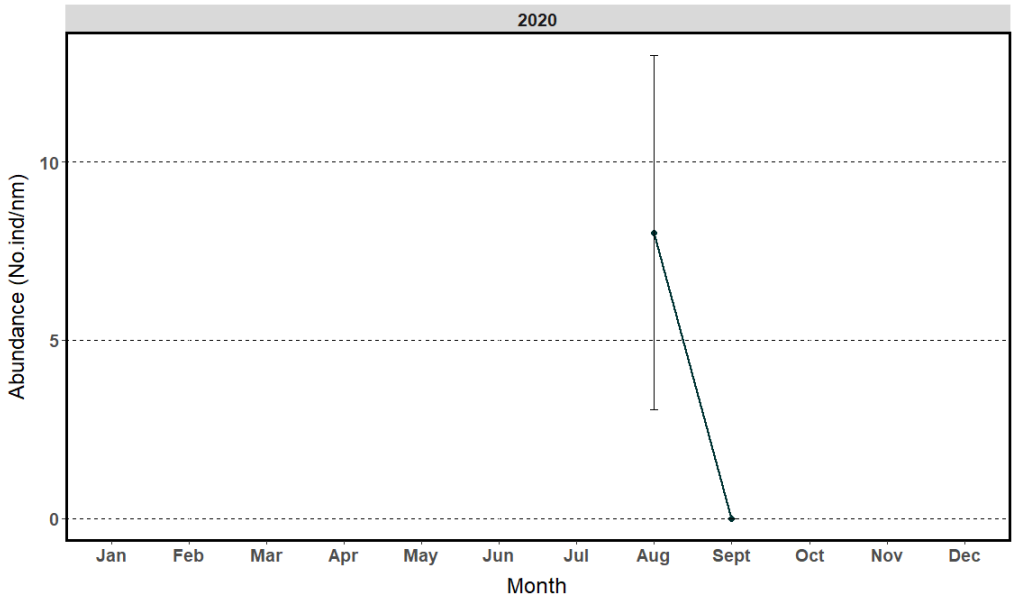

Figure 22. Monthly catch per unit effort (CPUE) of Black Pollack in Gillnets 2020.

Spurdog

Spurdog catch rates increased significantly between 2017 and 2019 but were lower in 2020. In 2019 peak catches occurred in months Aug and Sept (Figure 23). Catches were higher along the north coast of and seaward of the Dingle peninsula (Figure 24).

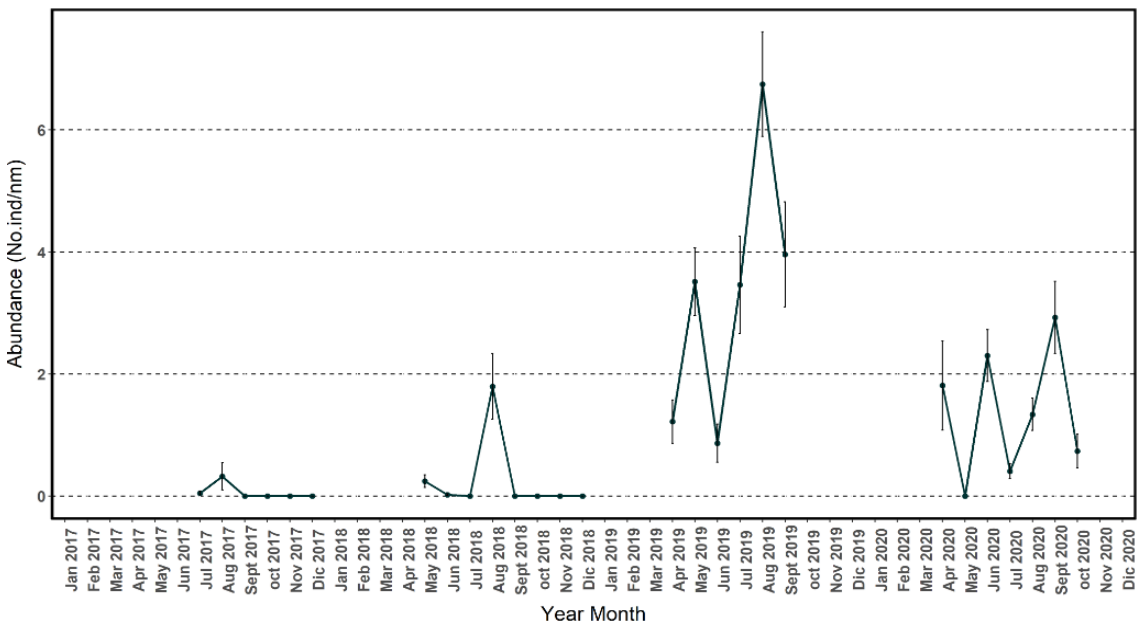

Figure 23. Monthly catch per unit effort (CPUE) of Spurdog in tangle nets 2017-2020.

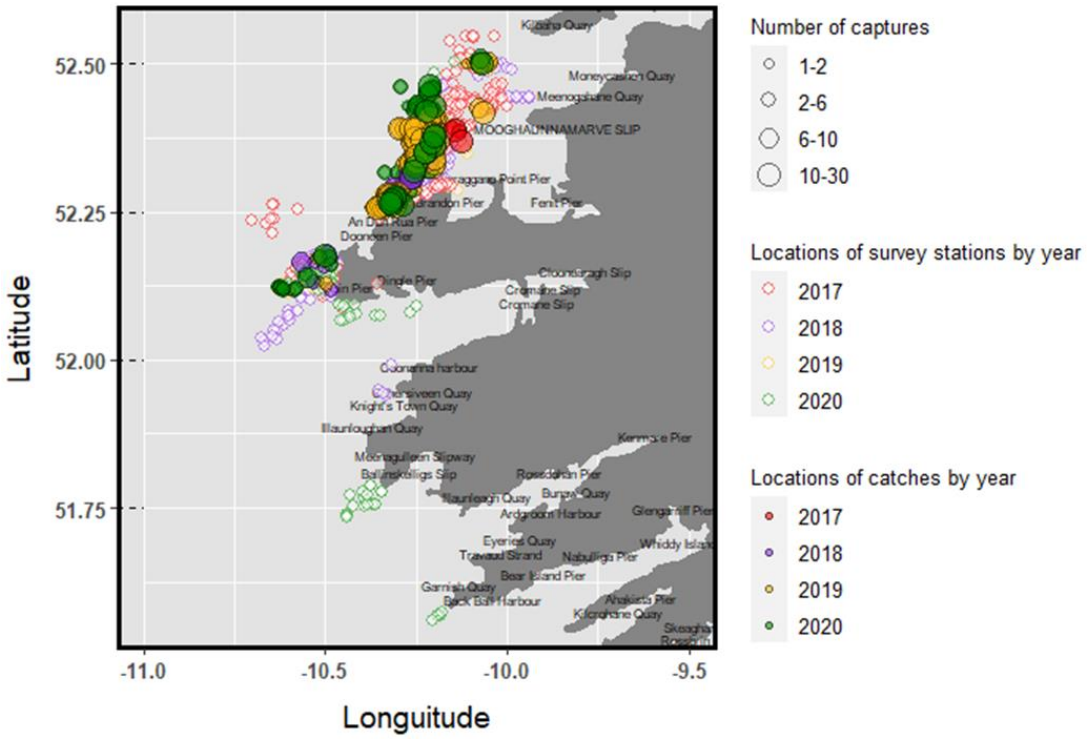

Figure 24 Spatial distribution of Spurdog catches in 2017-2020.

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Thornback Ray

Mean numbers per mile of net varied from 0-0.5 fish (Figure 25). Thornback Ray were common in low numbers north of Dingle Bay (Figure 26).

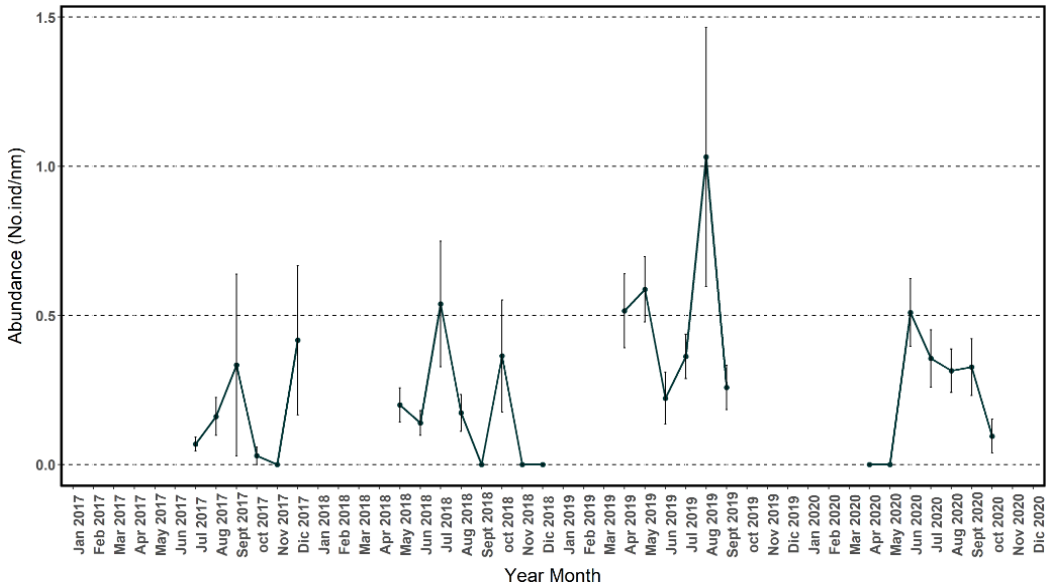

Figure 25. Monthly catch per unit effort (CPUE) of Thornback in tangle nets 2017-2020.

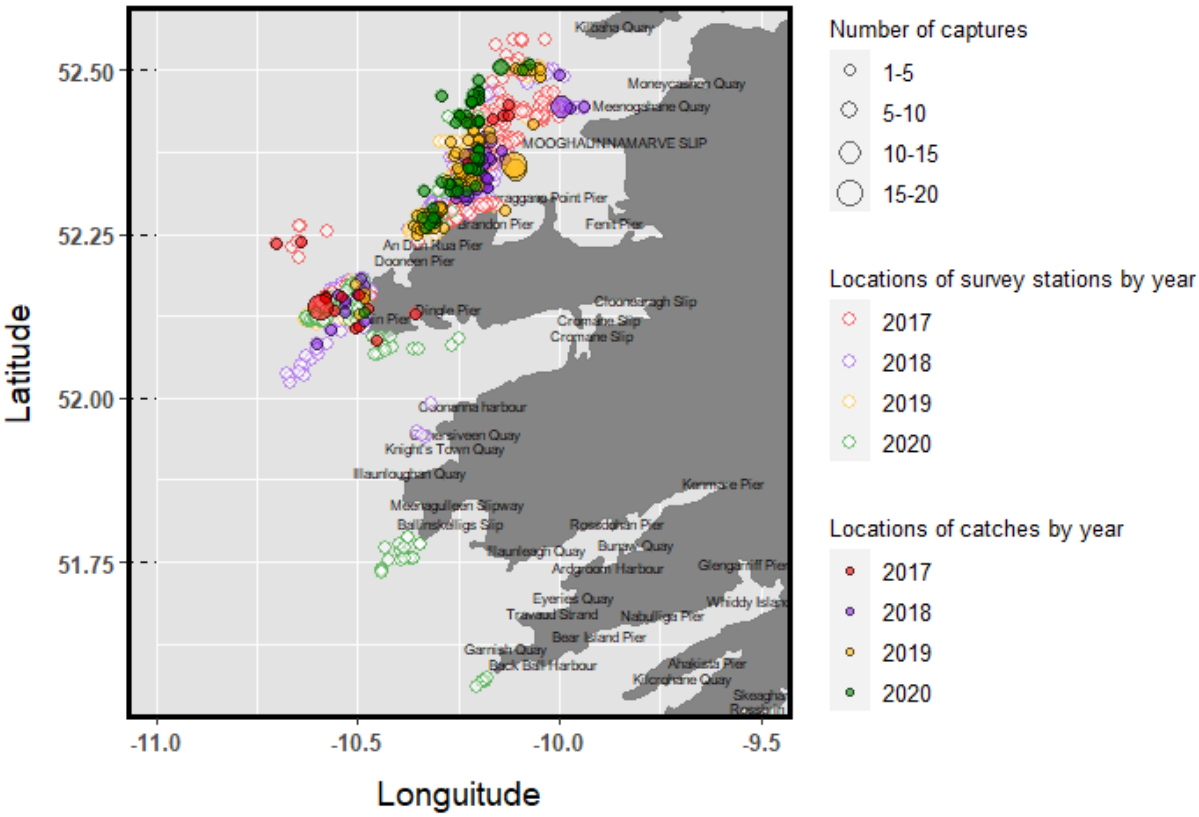

Figure 26. Spatial distribution of Thornback 2017-2020.

Unidentified Skate

Skate that were unidentified in the catch reports occurred in low numbers (Figure 27) west of the Shannon estuary (Figure 28).

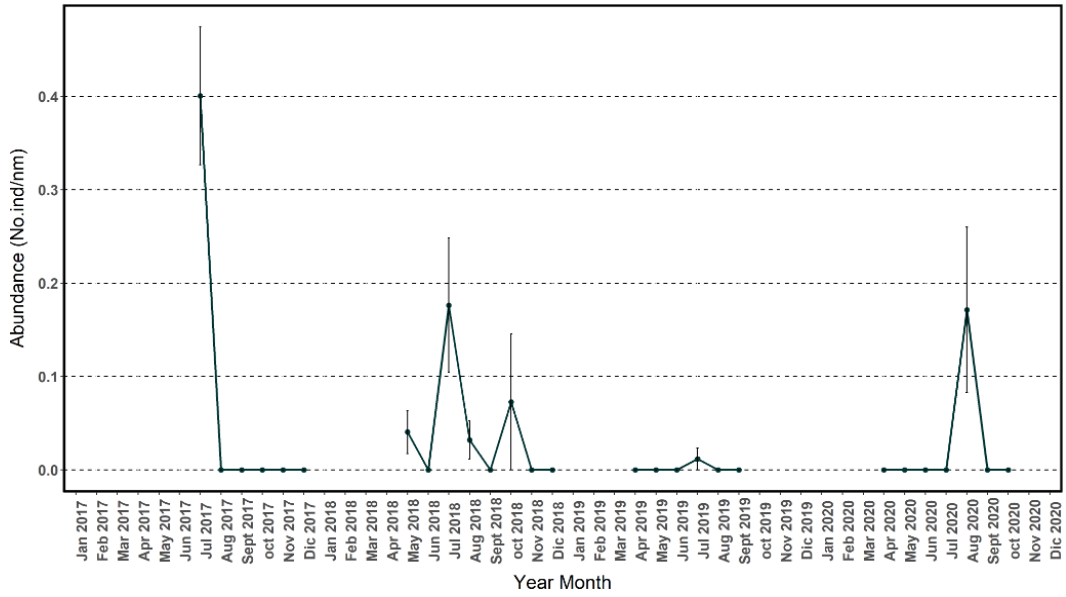

Figure 27. Monthly catch per unit effort (CPUE) of unidentified Skate in tangle nets 2017-2020.

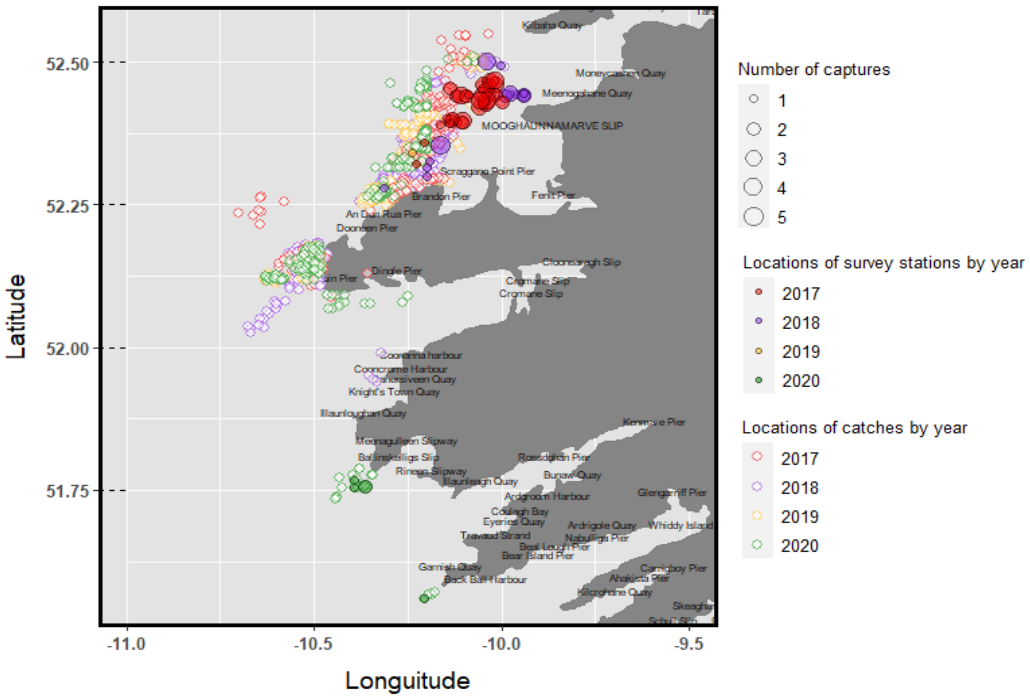

Figure 28. Spatial distribution of Unidentified Skate 2017-2020.

Greater spotted Dogfish

Dogfish were rare in the catches prior 2020 (Figure 29). Catches mainly occurred west of Kerry Hd (Figure 30).

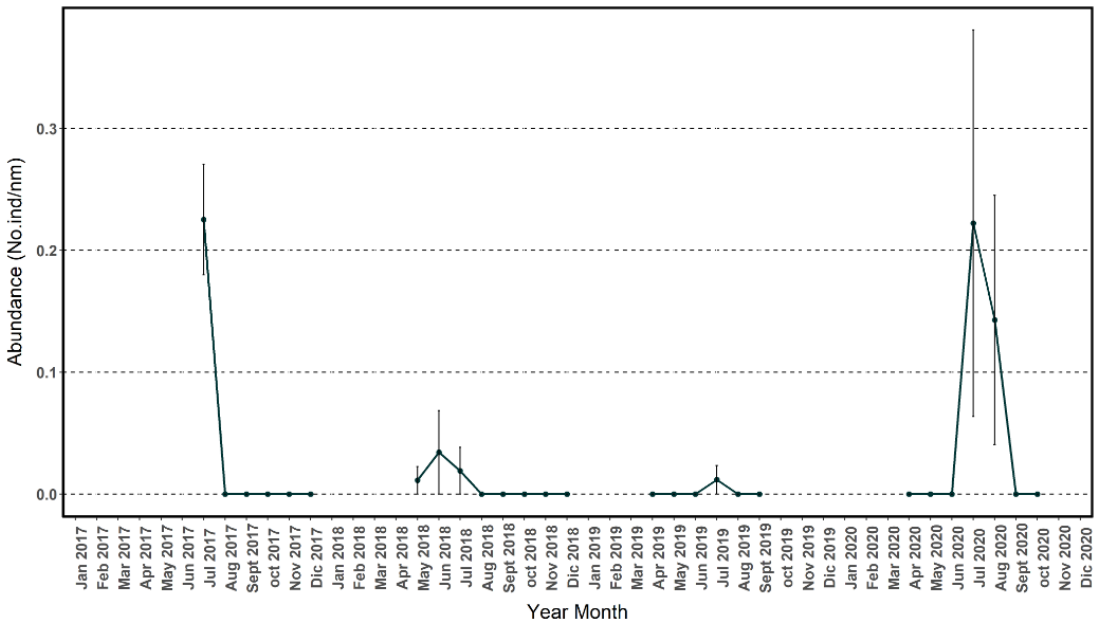

Figure 29. Monthly catch per unit effort (CPUE) of Greater spotted dogfish in tangle nets 2017-2020.

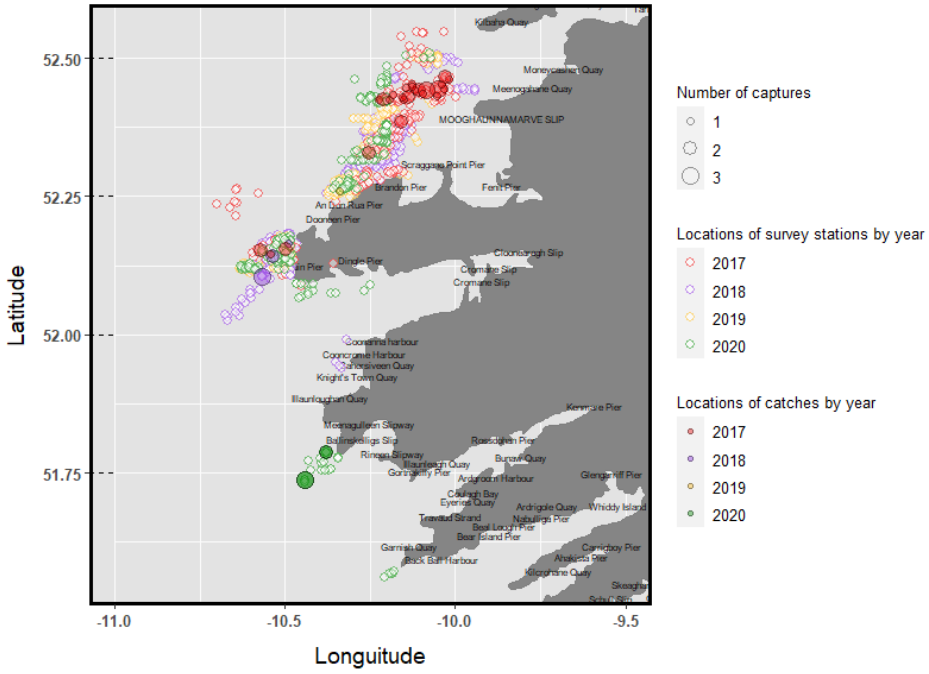

Figure 30. Spatial distribution of Greater spotted dogfish 2017-2020.

Spotted Ray

Spotted ray were more common in 2019 and 2020 than in 2017 (no records) and 2018 (Figure 31). All catches occurred north of the Dingle peninsula (Figure 32).

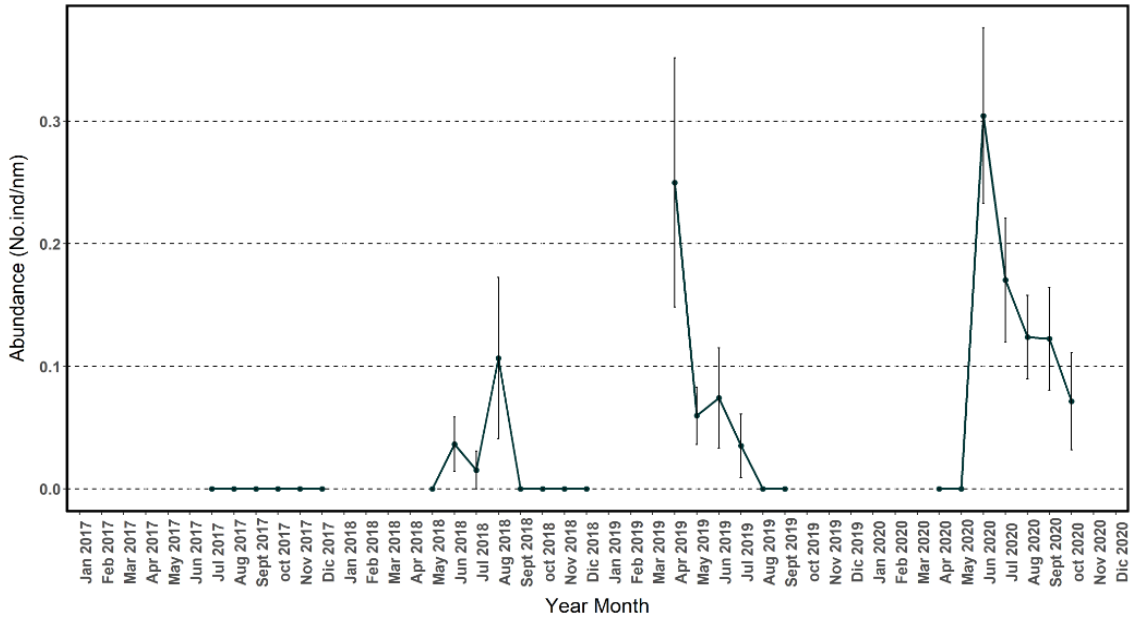

Figure 31. Monthly catch per unit effort (CPUE) of Spotted Ray in tangle nets 2017-2020.

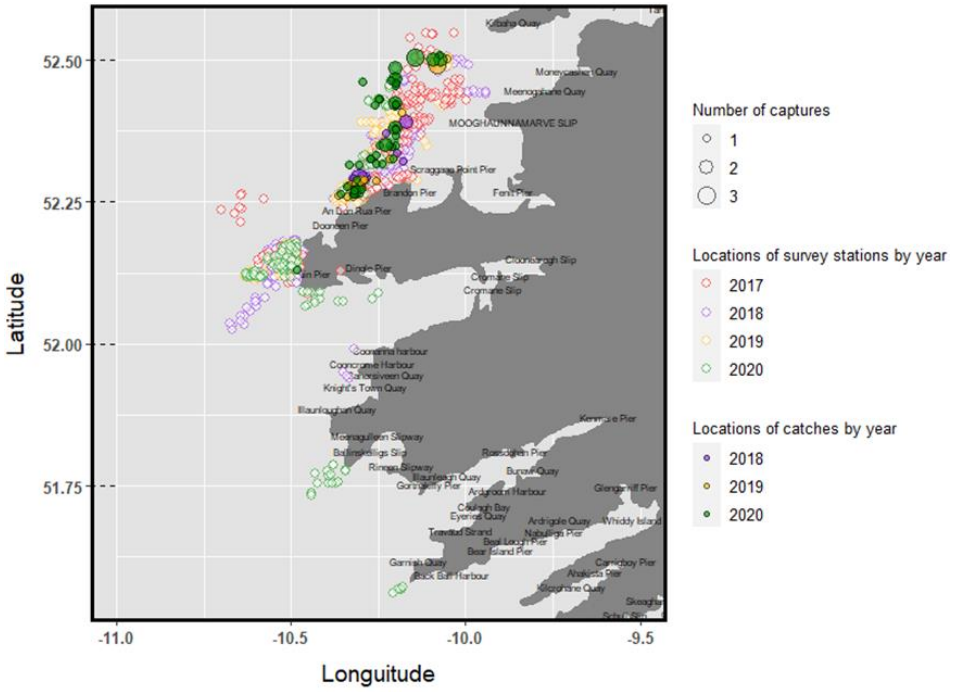

Figure 32. Spatial distribution of Spotted Ray 2017-2020.

Blonde Ray

Blonde Ray were only recorded in 2018 and 2019 (Figure 33). Catches occurred around the Blasket Islands and sporadically north of this area (Figure 34).

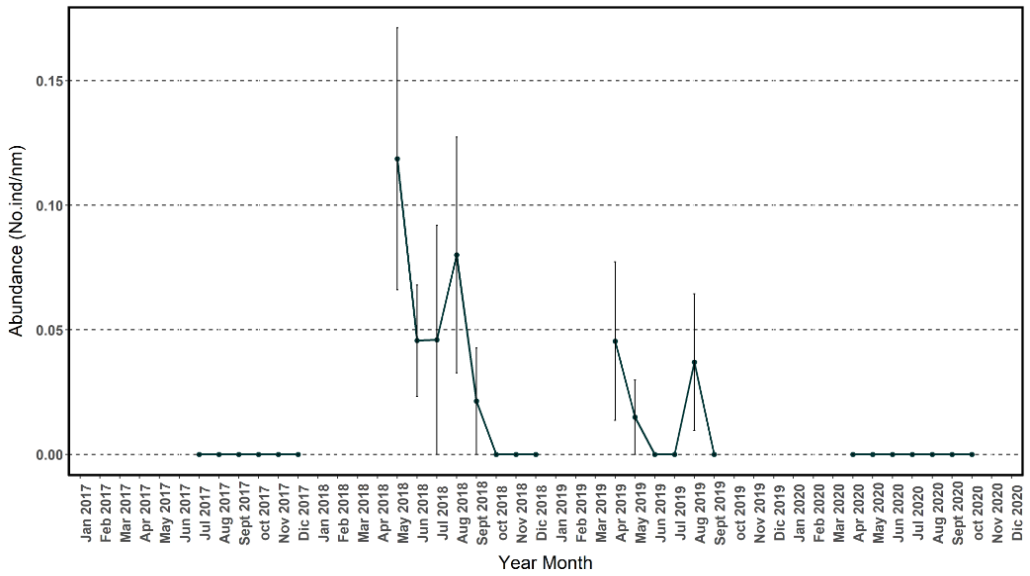

Figure 33. Monthly catch per unit effort (CPUE) of Blonde Ray in tangle nets 2017-2020.

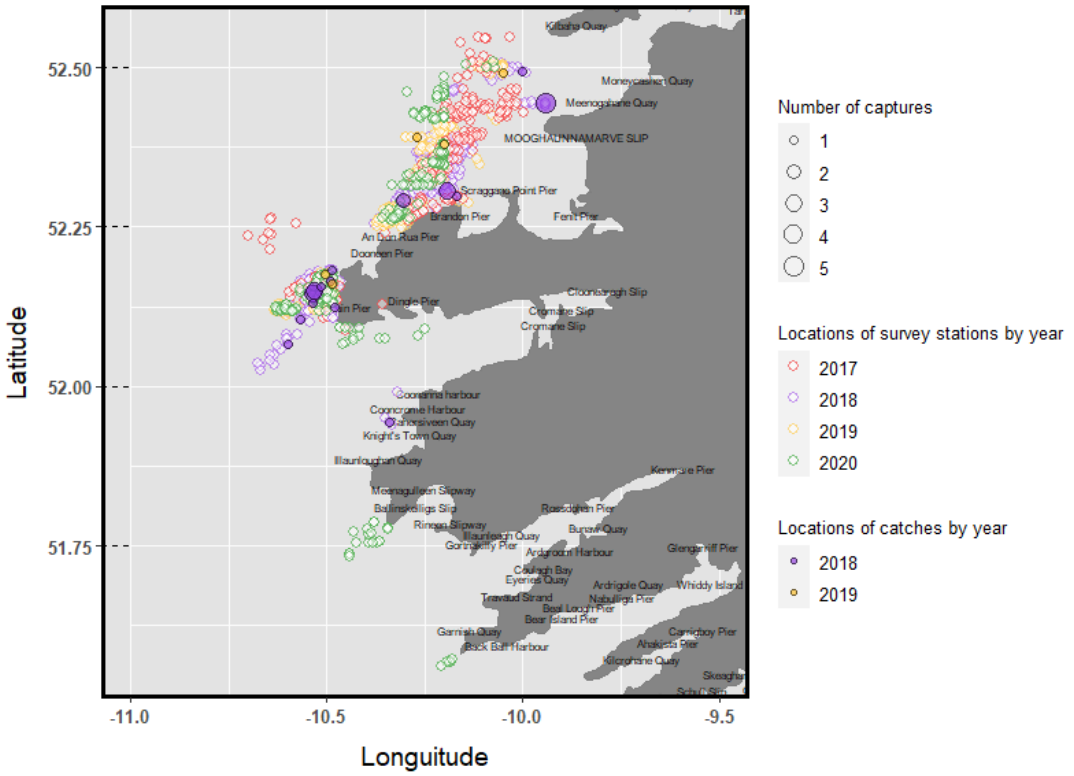

Figure 34. Spatial distribution of Blonde Ray 2017-2020.

Flapper skate

Flapper skate were only recorded in 2018 and 2019 sporadically and usually as single individuals north of the Dingle peninsula to west of the Shannon estuary (Figure 35,Figure 36).

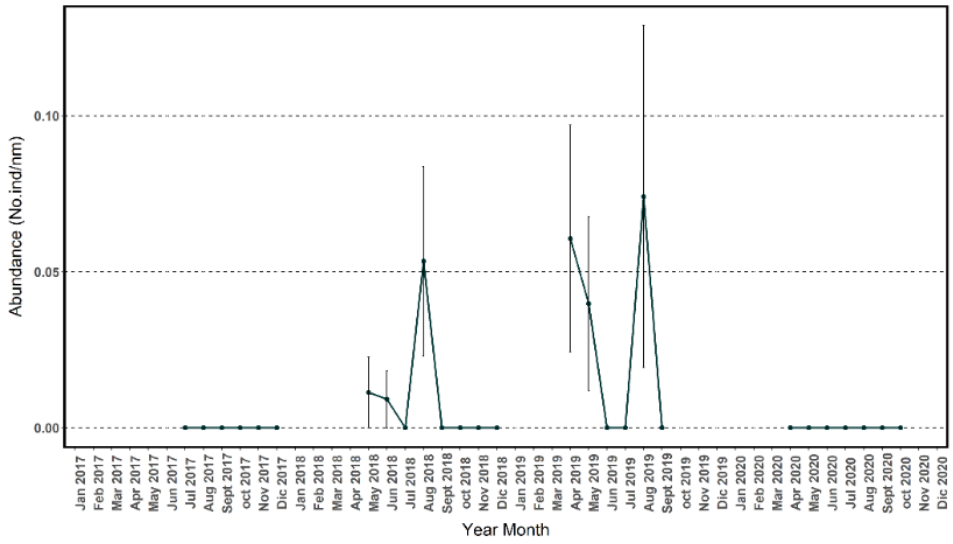

Figure 35. Monthly catch per unit effort (CPUE) of Flapper Skate in tangle nets 2017-2020.

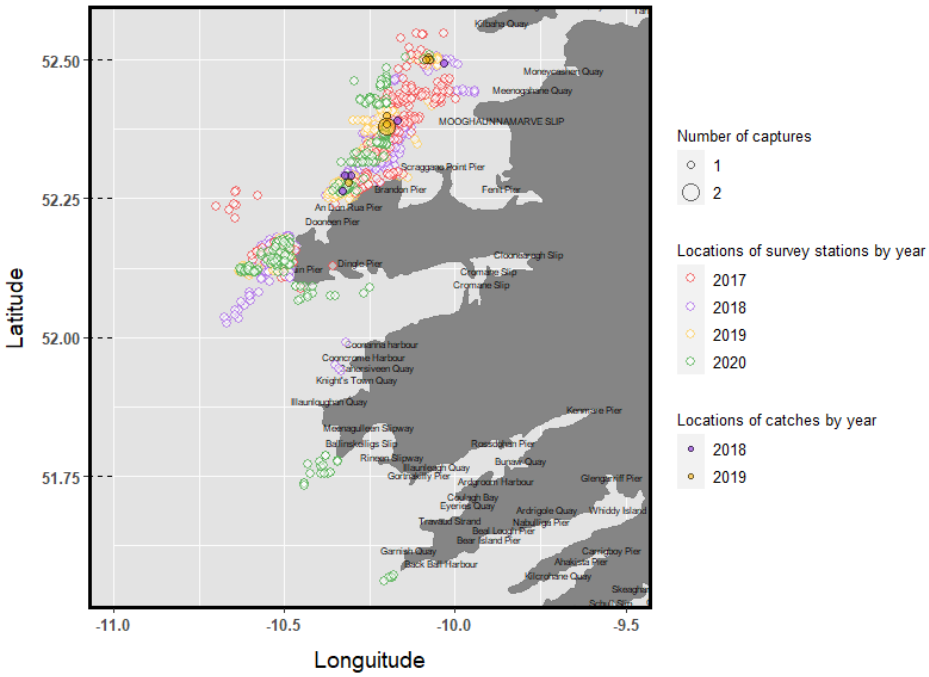

Figure 36. Spatial distribution of Flapper Skate 2017-2020.

Painted Ray

Painted ray were recorded in 2018 and 2020 (Figure 37) sporadically at the Blasket Islands and west of Shannon (Figure 38).

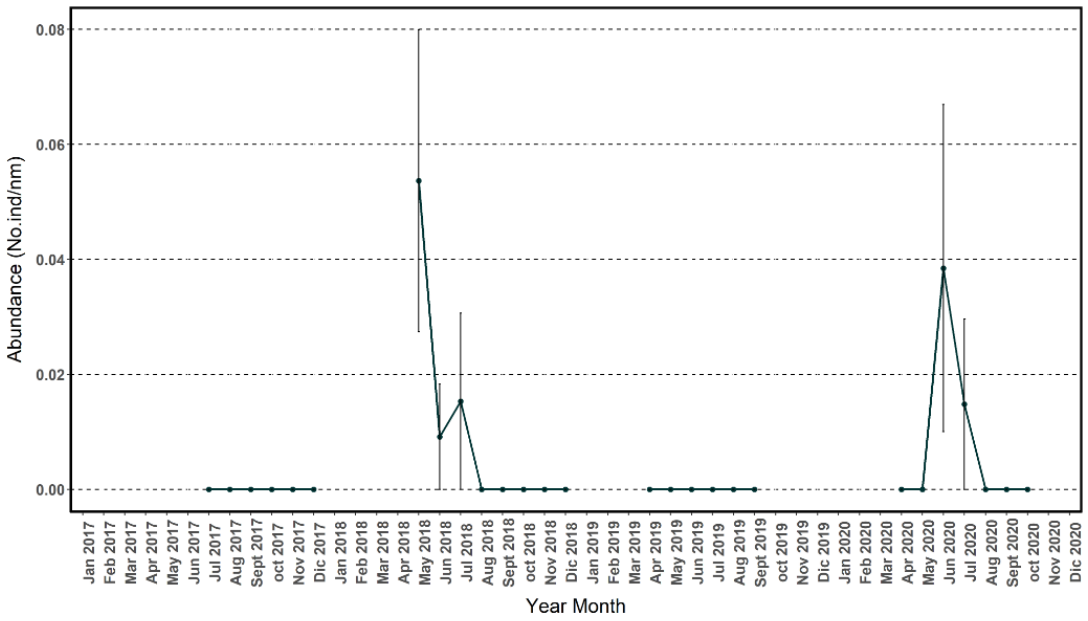

Figure 37. Monthly catch per unit effort (CPUE) of Painted Ray in tangle nets 2017-2020.

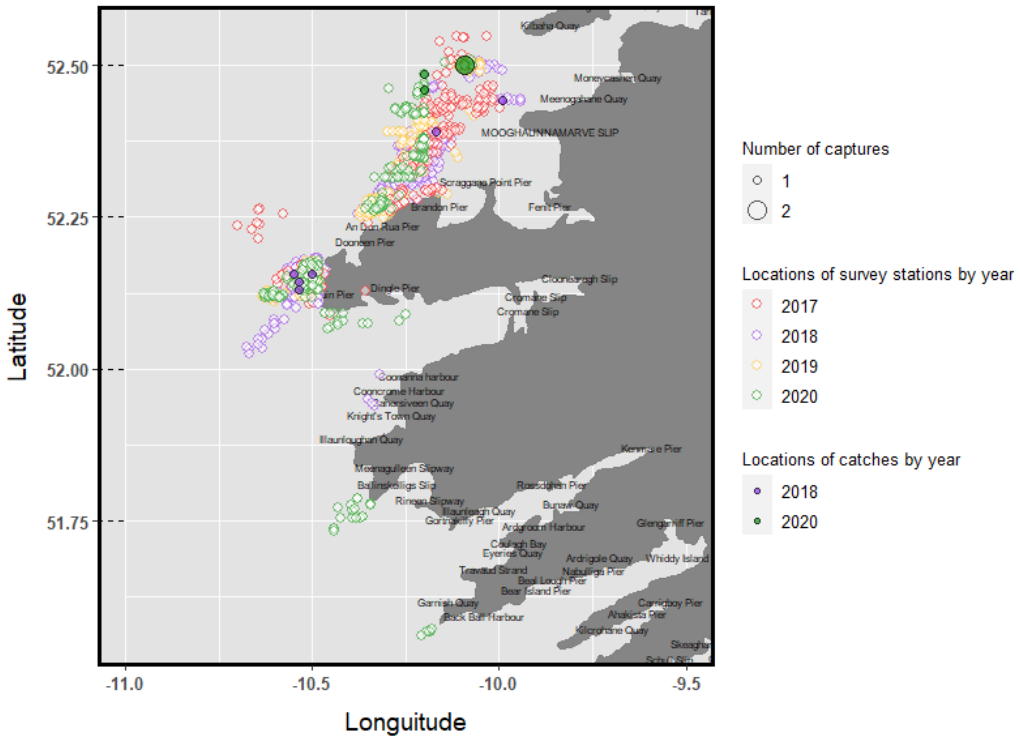

Figure 38. Spatial distribution of Painted Ray 2017-2020.

Angel shark

Three angel shark were captured during 2017-2020. Two were recorded in April 2019 and one in May 2020 (Figure 39, Figure 40).

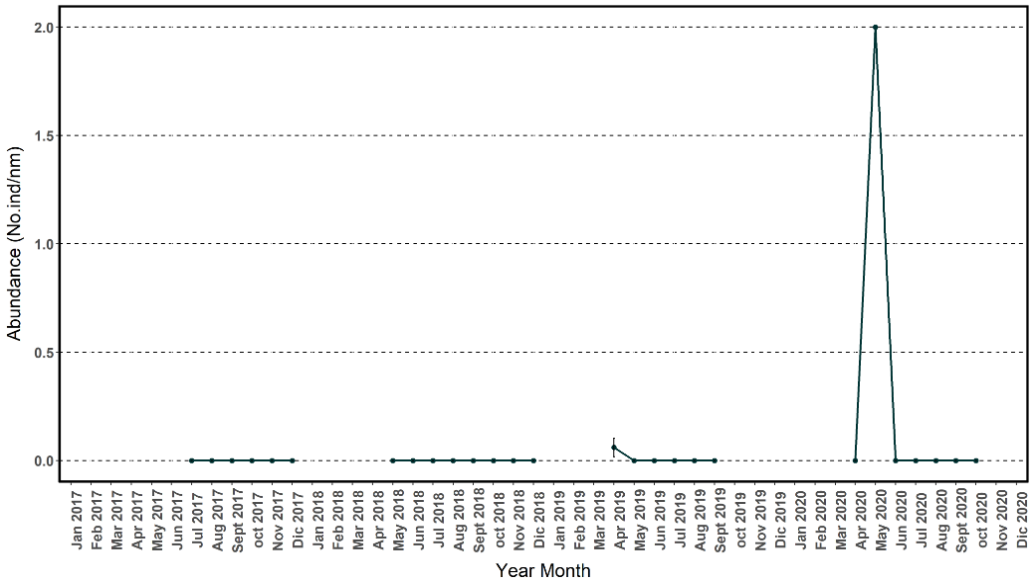

Figure 39. Monthly catch per unit effort (CPUE) of Angel Shark in tangle nets 2017-2020.

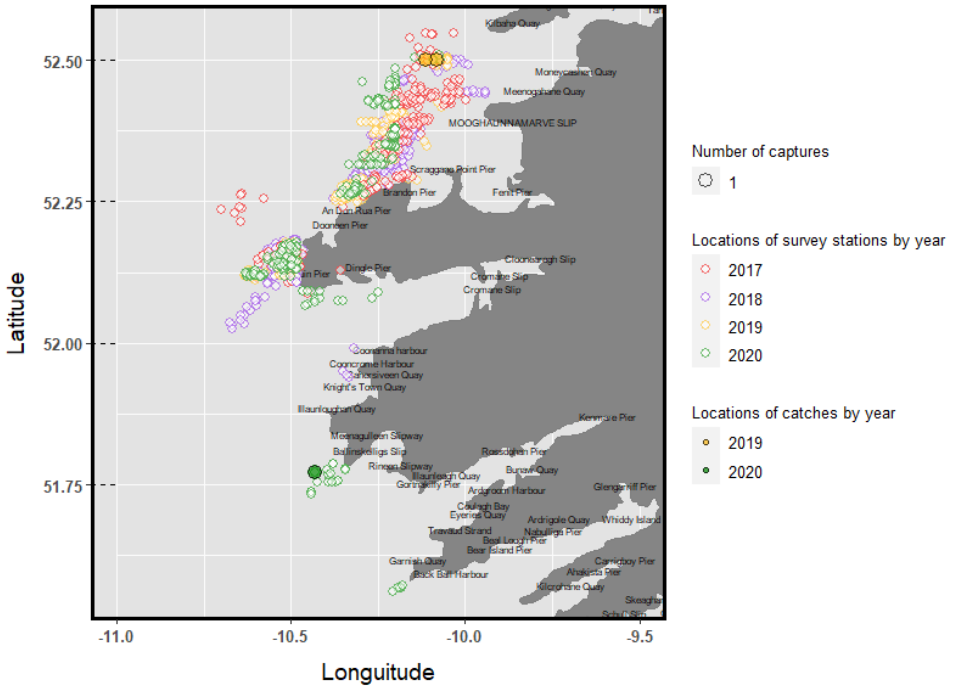

Figure 40. Spatial distribution of Angel Shark 2017-2020.

Common Skate

Three common skate were recorded west of the Shannon estuary in 2018 (Figure 41, Figure 42).

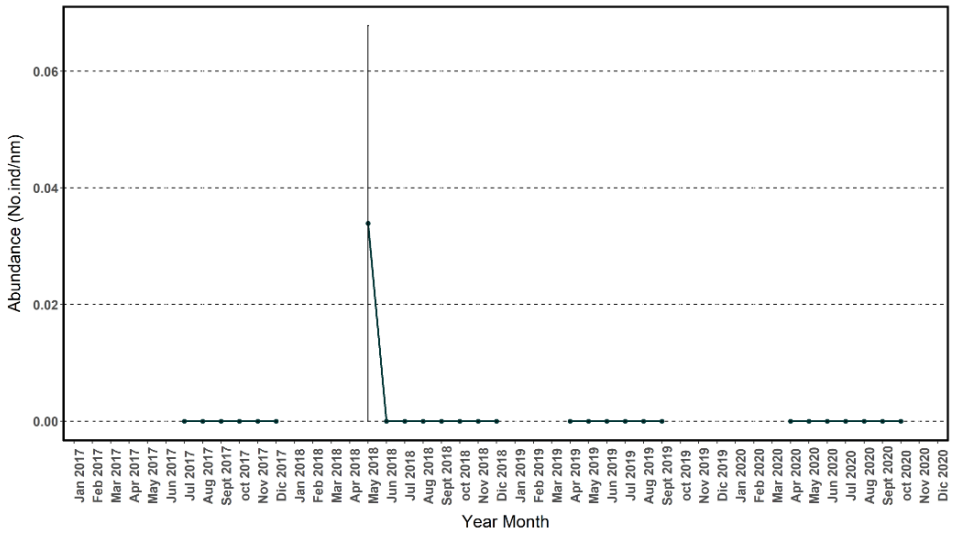

Figure 41. Monthly catch per unit effort (CPUE) of Common Skate in tangle nets 2017-2020.

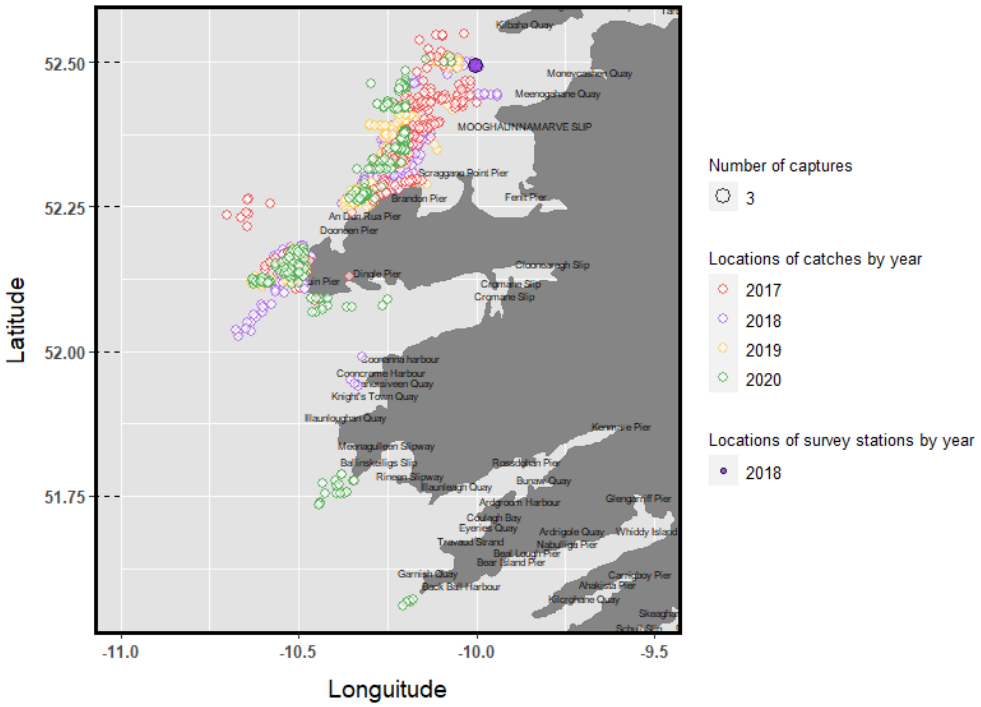

Figure 42. Spatial distribution of Common Skate 2017-2020.

Sting Ray

Sting ray were caught in 2018 and 2020 as single individuals offshore west of Tralee Bay and at the Blasket Islands (Figure 43, Figure 44).

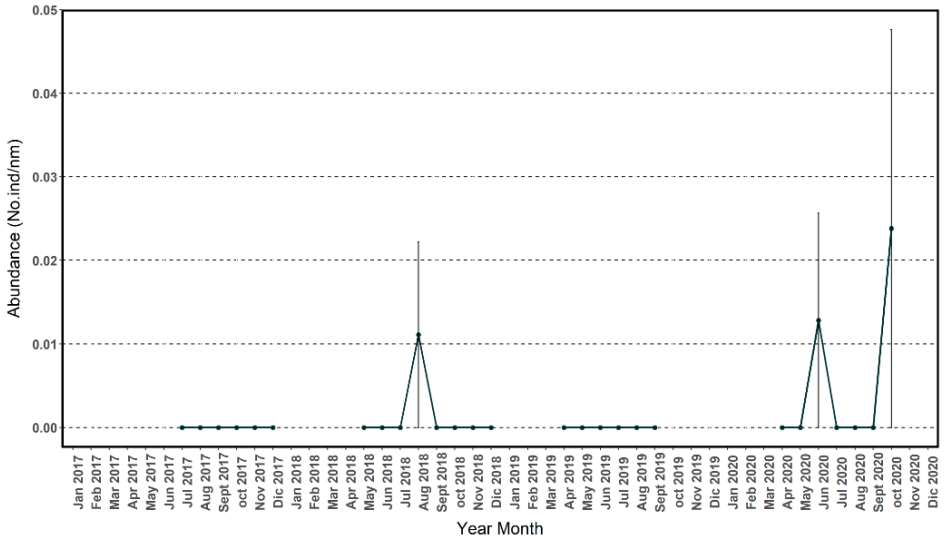

Figure 43. Monthly catch per unit effort (CPUE) of Sting Ray in tangle nets 2017-2020.

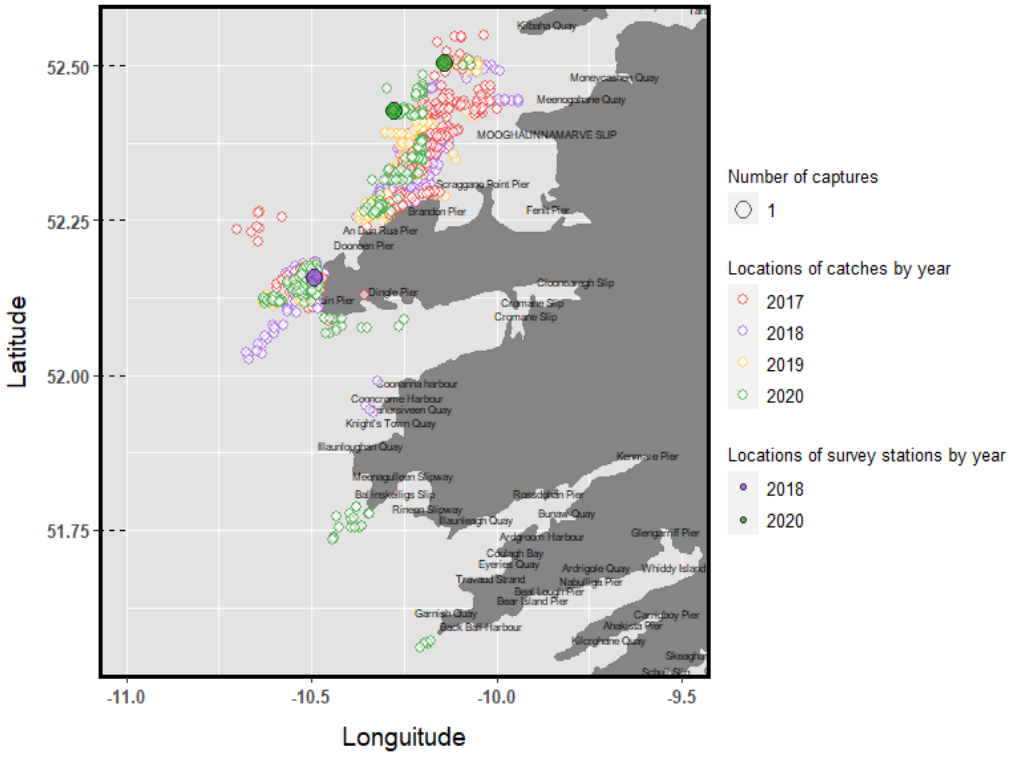

Figure 44. Spatial distribution of Sting Ray 2017-2020.

Cuckoo Ray

Two cuckoo ray were captured in 2019 (Figure 45, Figure 46).

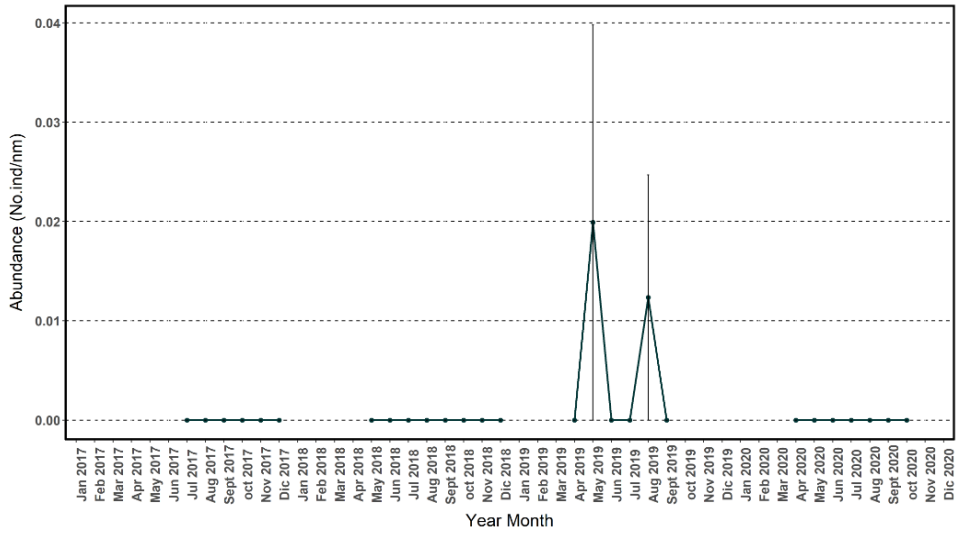

Figure 45. Monthly catch per unit effort (CPUE) of Cuckoo Ray in tangle nets 2017-2020.

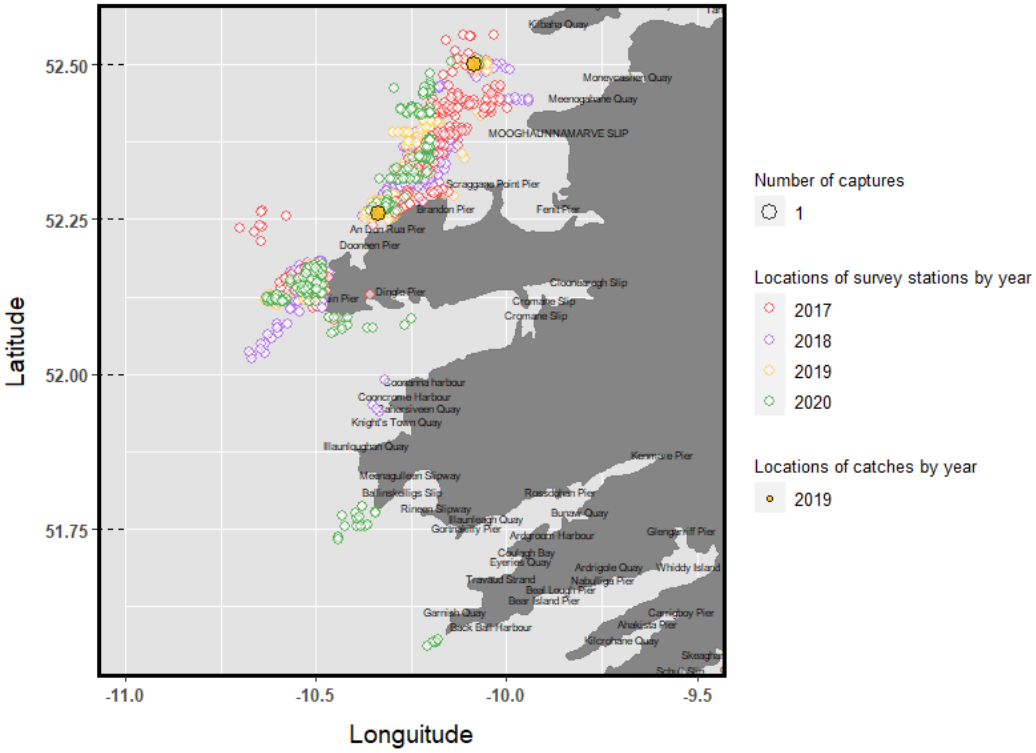

Figure 46. Spatial distribution of Cuckoo Ray 2017-2020.

Undulate Ray

One undulate ray was recorded only in May 2018 (Figure 47, Figure 48).

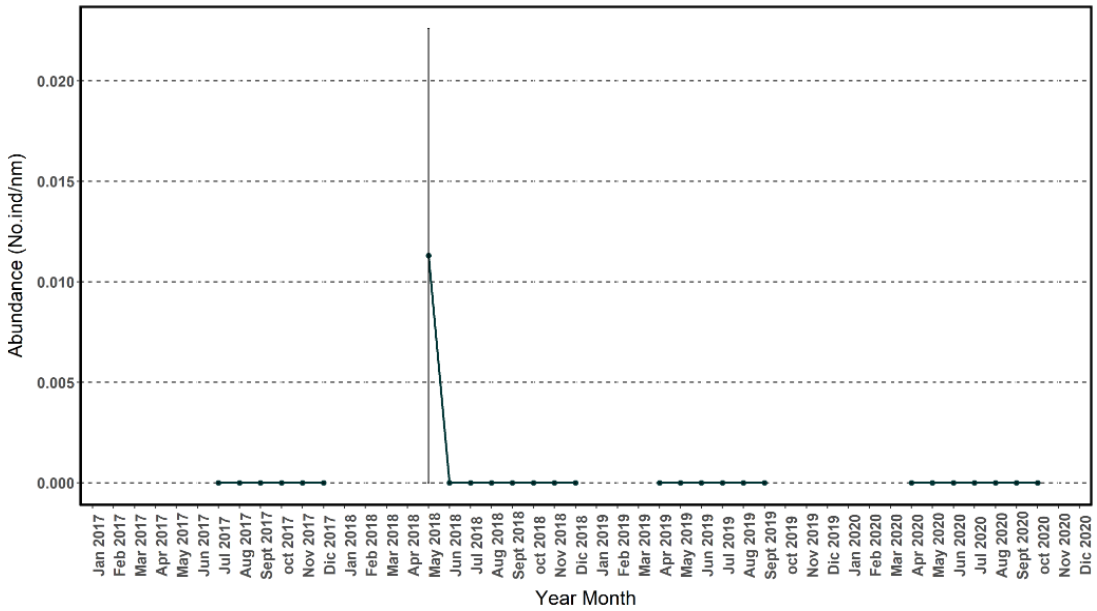

Figure 47. Monthly catch per unit effort (CPUE) of Undulate Ray in tangle nets 2017-2020.

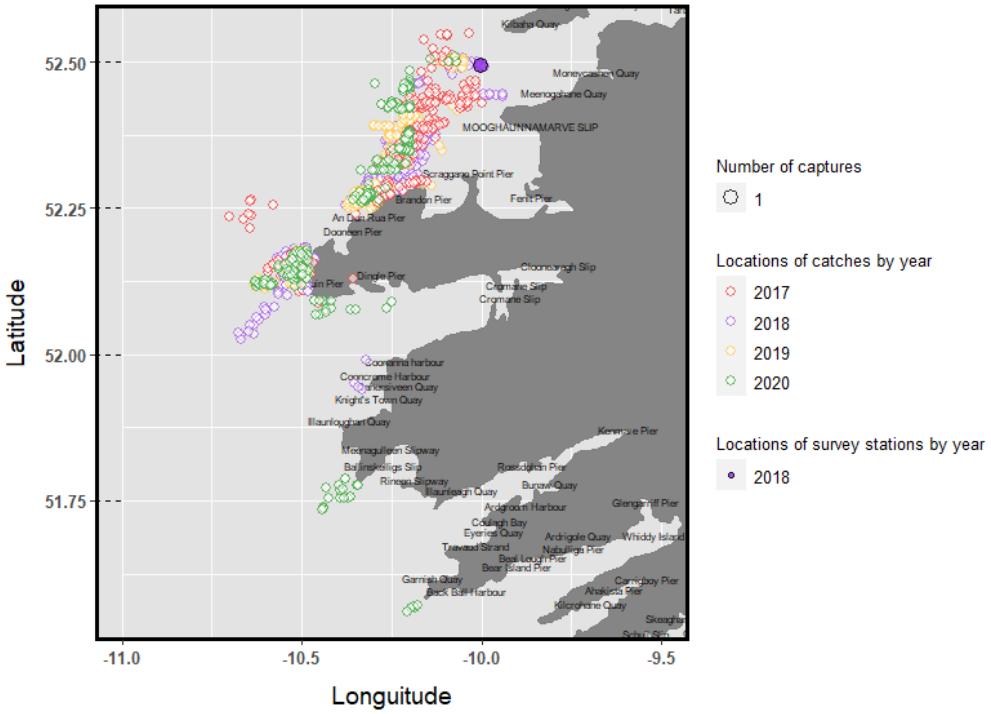

Figure 48. Spatial distribution of Undulate Ray 2017-2020.

Value of the catch

The economic value of the landings of crayfish, lobster and brown crab per mile of net haul was estimated using the size distribution data to estimate the proportion of the catch that was legal size, applying an average unit weight for the legal portion of the catch using established size weight relationships and using average market price data for each species (Table 6). Fishing occurred from April to November generally and with much lower fishing activity in December.

The average value of the catch per mile of net peaked in Nov and Dec 2017 due to higher than average catch rates and high market price. In contrast the value in autumn of 2018 was much lower. In 2019 and 2020 values were stable at about €300 per mile of net hauled (Figure 49). Almost all the value is due to crayfish. Lobster by-catch is low so even though its unit value is high it does not contribute significantly to the economic value of the catch.

The value of the fin fish catch is excluded from these estimates because almost all of it is damaged when retrieved due to scavengers or seal depredation. Monkfish is a potentially valuable component of the catch but its catch rate is low and the losses due to seal depredation is high.

Table 6. Data used to estimate the total value of the catch in tangle nets. Average weights and proportion legal is from the size distribution data collected during the survey.

Species	Average weight (kg)	Price	Proportion legal
Crayfish	1.32	€35 (€40 in Nov and Dec)	0.47
Lobster	0.78	€16 (€20 in Nov and Dec)	0.72
Brown crab	0.49	€3	0.65

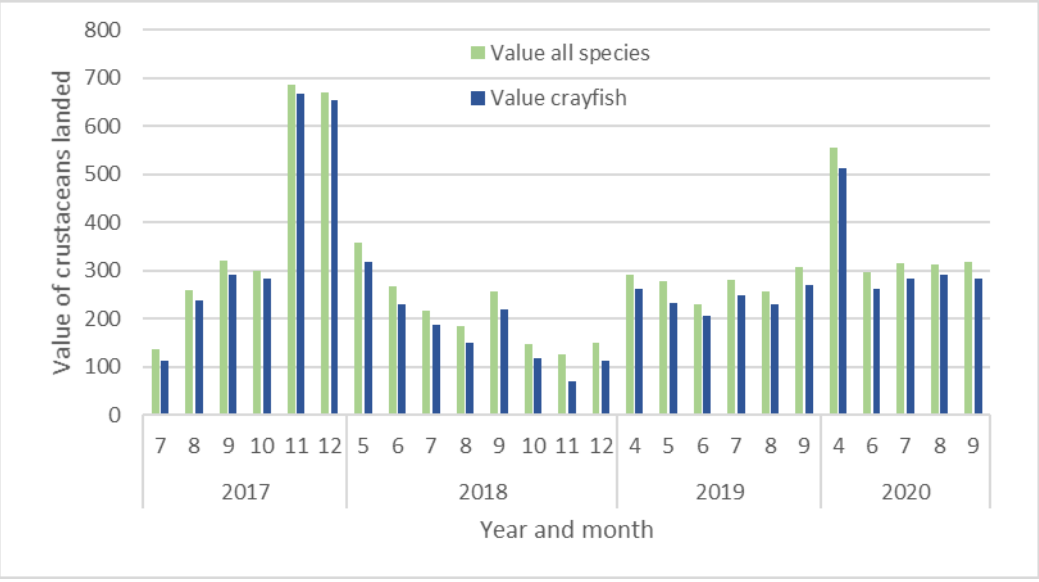

Figure 49. Average value of the crustacean catch (crayfish, lobster, brown crab) per mile of net hauled by month for 2017-2020. The value of the crayfish catch is shown separately.

By-catch of Grey Seal

The total number of grey seals reported captured in tangle nets was 8 in 2017, 45 in 2018, 73 in 2019 and 67 in 2020. Given that the geographic and seasonal distribution of fishing with tangle nets in each year was similar this trend may reflect changes in the abundance of seals in the area during the period. These trends are reflected in the by-catch per mile of net which varied from less than 0.1 seal in 2017 to a peak of 0.7 seals in May 2019. In 2018 and 2019 seal by-catch was higher in early summer and declined month on month during the year. In 2020 by-catch increased from June to Sept (Figure 50).

The rate of by-catch of seals was higher around the Blasket Island where there is a haul out site (at white strand) and by-catch was lower in the north of the fishing area towards Kerry Hd and the Shannon (Figure 51). There was a relationship between the probability of by-catch (defined as the number of hauls with by-catch divided by the total number of hauls taken within a given distance to the haul out), the proportion of the total by-catch and the distance between the fishing activity and the haul out site (Figure 52, Figure 53). Sixty percent of seals were caught within 10km of the haul out site although only 29% of hauls were taken in that zone. The probability of capture in a single net haul declined from 30-35% within 10km to 9-14% at distances of 10-30km to 4% at distances of 40-60km and zero at distances greater than 60km (data for 39 hauls >60km). Of the 172 hauls with seal by-catch 86% involved a single seal, 11% had 2 seals and 4 events had 3 seals (Table 7).

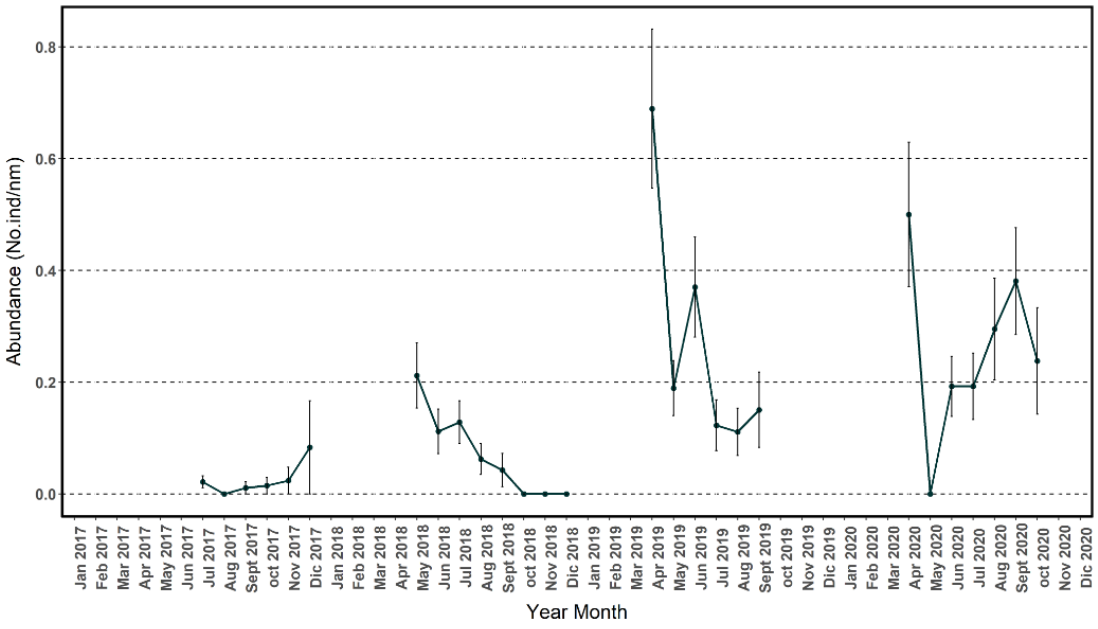

Figure 50. Monthly catch per unit effort (seals per nm of net) of Grey Seal in tangle nets 2017-2020.

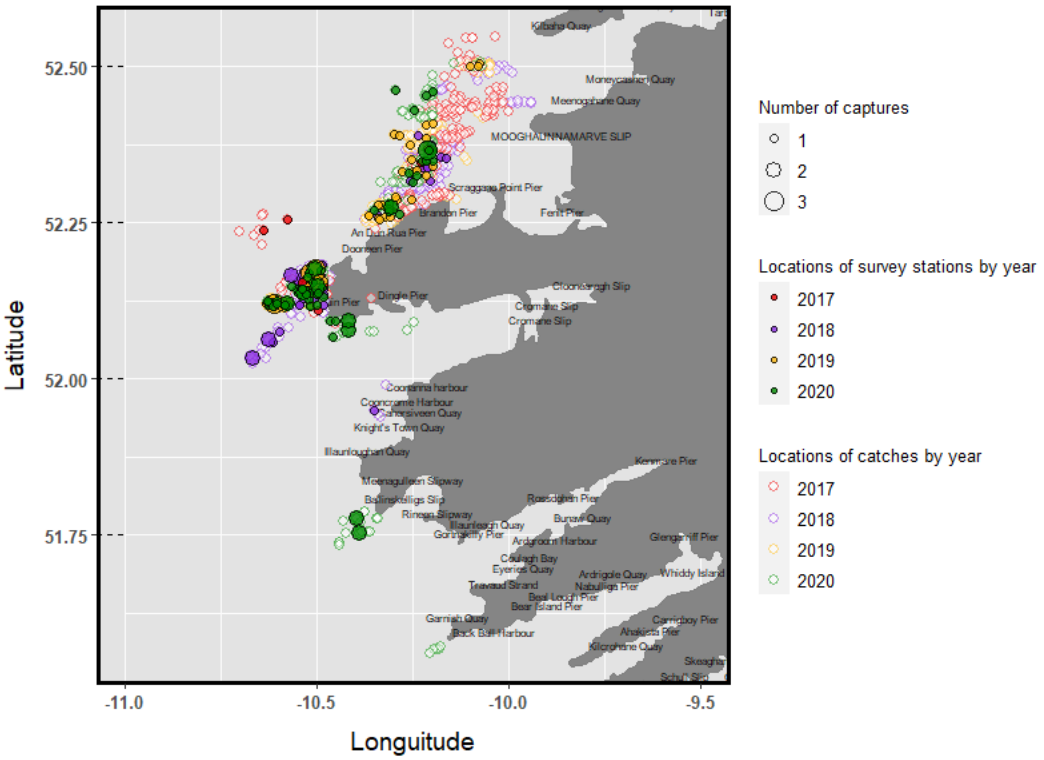

Figure 51. Spatial distribution of Grey Seal captures in tangle nets in 2017-2020.

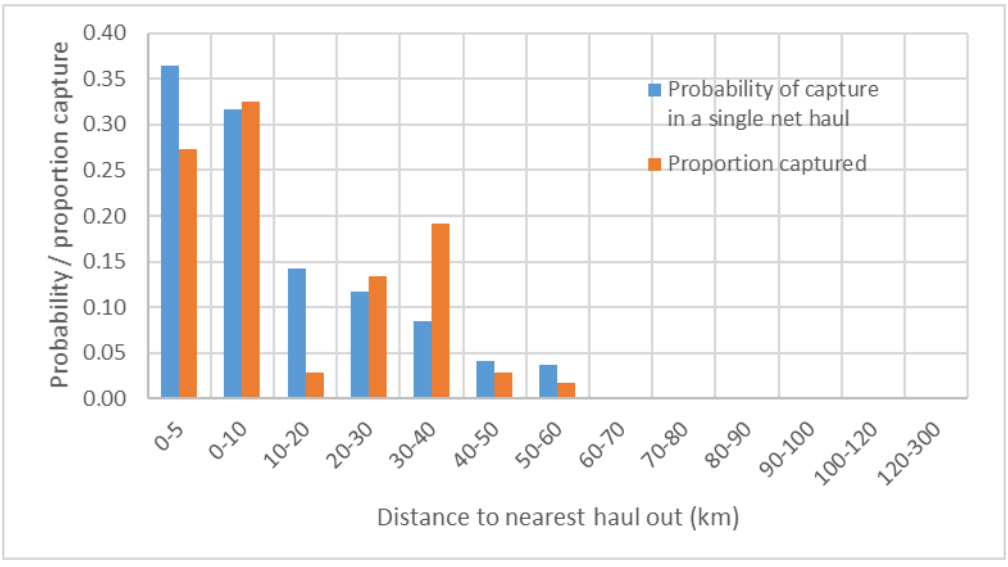

Figure 52. Relationship between probability of capture and the proportion of all seals captured and the distance to the haul out site at White Strand on the Blasket Is 2017-2020.

Table 7. Data on by-catch of grey seal in relation to the distance between hauls of tangle nets and the grey colony seal haul out site at the Blasket Island. All data 2017-2020

			Number of hauls with seal by-catch					
Distance from haul out site (km)	Net hauls	% of hauls	With seals	1 seal	2 seals	3 seals	Probability of capture	Proportion captured
0-5	129	11.03	47	42	5	0	0.36	0.27
0-10	177	15.13	56	42	11	3	0.32	0.33
10-20	35	2.99	5	4	1	0	0.14	0.03
20-30	197	16.84	23	22	1	0	0.12	0.13
30-40	388	33.16	33	31	1	1	0.09	0.19
40-50	123	10.51	5	4	1	0	0.04	0.03
50-60	82	7.01	3	3	0	0	0.04	0.02
60-70	19	1.62	0	0	0	0	0.00	0
70-80	7	0.60	0	0	0	0	0.00	0
80-90	7	0.60	0	0	0	0	0.00	0
90-100	3	0.26	0	0	0	0	0.00	0
100-120	2	0.17	0	0	0	0	0.00	0
120-300	1	0.09	0	0	0	0	0.00	0
Total	1170		172	148	20	4	Average= 0.15	

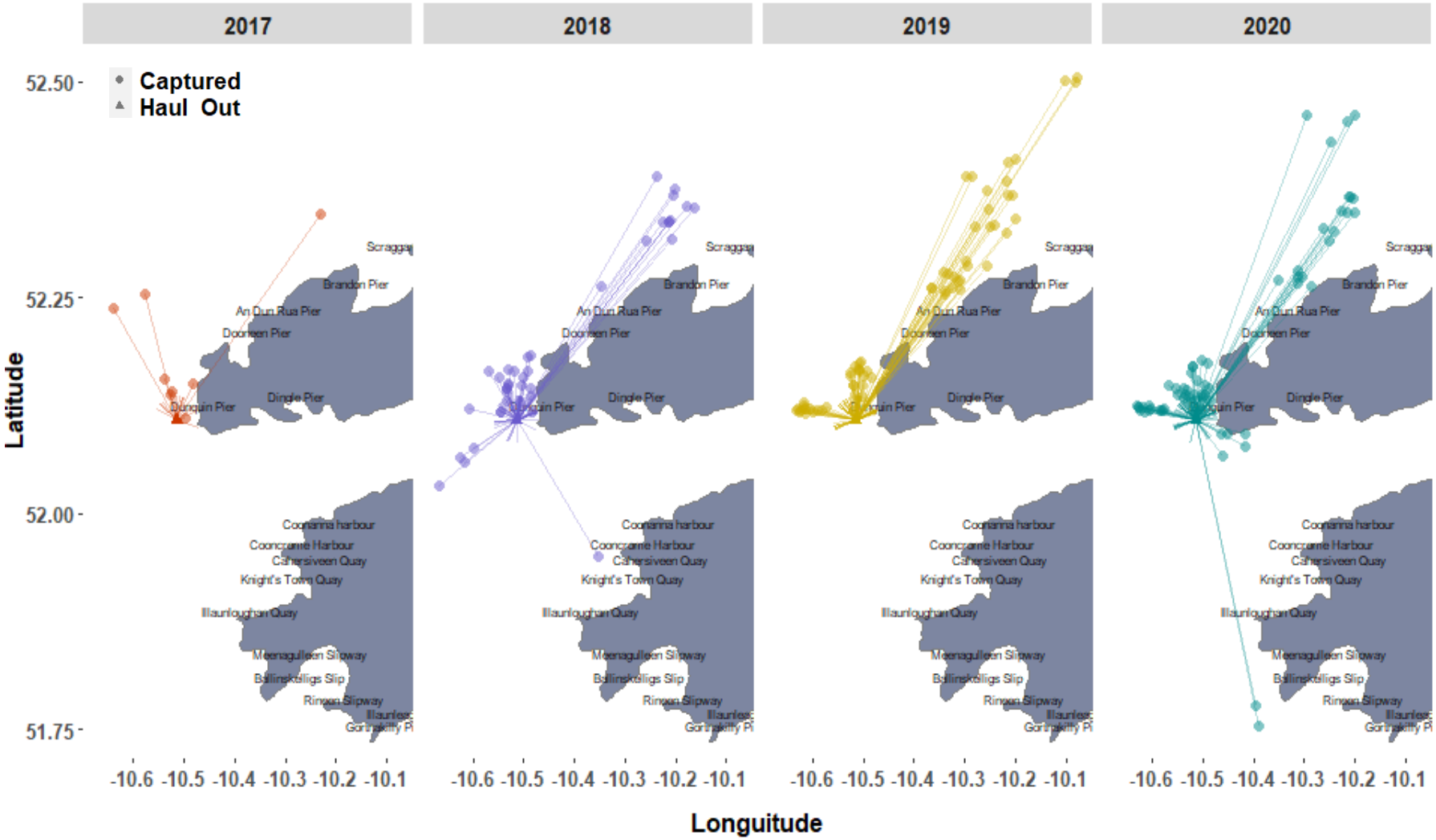

Figure 53. Grey seal by-catches vs distance to haul out 2017-2020.

Discussion

The tangle net fishery off the south west coast of Ireland targets spiny lobster or crayfish. The fishery is profitable mainly due to the high unit value of crayfish even though the volume of the catch is low. Although high value lobster and crab are also captured this by-catch contributes a relatively small proportion of the overall catch value. Other high value species such as monkfish and turbot are caught but they are usually damaged by scavenging crustaceans and depredation by seals. Some loss of crayfish also occurs due to physical damage caused by nets and scavenging by peracarid crustaceans.

A number of species of elasmobranch are captured in the fishery especially in the outer Tralee Bay and Brandon Bay areas. The area is known to be an important hotspot for elasmobranch biodiversity. A number of these species including angel shark, flapper skate and white skate are classified as endangered or critically endangered on the Irish red list (Clarke et al, 2016). They have been extirpated throughout much of their former range mainly through over fishing including unintentional by-catch mortality. Angel Shark is critically endangered globally, the last remaining stronghold for the species is in the Canary Islands and there is a significant extinction risk due to continued pressures on small local populations (Lawson *et al*. 2019). In Ireland the remnants of formerly larger populations (Shepherd *et al*. 2019) have been shown from recent surveys and fishery observations to occur off the south west coast. White Skate may already be extirpated from the NE Atlantic other than for two known (from egg case identification) refuge locations in Ireland. Common Skate and Flapper Skate were historically one of the most abundant and widely distributed skates in the NE Atlantic. These species are now extirpated from the Irish Sea and North Sea and their status is regarded as endangered or critically endangered in Ireland given that fishing pressures, which have resulted in their decline, have not ceased (Clarke *et al.* 2016).

Under the Common Fisheries Policy (CFP) it is prohibited for EU vessels to fish for, retain on board, tranship, land, store, sell, display or offer for sale species listed in Annex I of Regulation (EU) 2019/1241 (EU, 2019b). Four of the elasmobranch species listed in this report are on this prohibited species list (Tully *et al*. 2021); Angel shark, common skate, white skate, spurdog. This measure effectively allows discarding of dead or alive specimens, and does not in itself regulate mortality on these species. Several other species are included in a generic ray TAC for ICES Sub-areas 6 and 7, and some species are not dealt with under the CFP at all, and are hence un-managed. Finally, undulate ray is excluded from the generic ray TAC in ICES Divisions 7b and 7j, which is effectively the same degree of management as being listed on the CFP PSL, in those areas only.

ICES has recently provided advice on the current status of various elasmobranch species (ICES, 2020). The advice is provided in the context of fishing opportunities. Species/stocks are reported as being variously depleted, declining or recovering. The ICES advice for endangered species and the inclusion of designation of species as prohibited under Regulation (EU) 2019/1241 may, however, be insufficient to protect their status or to improve their future prospects. For instance, although the ICES advice may be for zero TAC, for no targeted fishing and for discarding of individuals that are caught as by-catch some species are at such a low

level that any extra mortality that may be caused by incidental by-catch in fisheries may increase the risk of extinction locally and regionally. Populations that are in a severely depleted state, which are exposed to any fishing mortality and where inward migration is effectively zero are at risk of extinction.

There are a number of mitigation measures that could be developed to eliminate or reduce elasmobranch by-catch. These include transition of fisheries from nets to pots, illumination of nets to reduce by-catch, excluding large mesh tangle nets from critical elasmobranch habitats and limiting net soak times to increase survival of by-catch. None of these are simple to implement without significant economic effects on local fisheries. For instance potting for crayfish is currently uneconomic (unpublished data Marine Institute 2021) given that the stock is significantly lower than it was when it supported a pot fishery prior to the 1980s. However, removal of nets, which intercept crayfish during foraging or migration and short term reduction in landings would increase stock levels and subsequent catches in pots. Also, pots commonly used in the industry have not been optimally designed for crayfish. In the top entrance pot fishery prior to the 1980s pots were hauled a number of times a day to counter the high escapement of crayfish. This is not economically viable in today's fishery but various measures can be designed to reduce escapement to enable longer pot soak times. Netting in inner Tralee Bay has been prohibited since 2006 (Crawfish Fisheries Management and Conservation Regulations S.I. 233/2006). However, as shown in this report there is significant by-catch seaward of this exclusion area in outer Tralee and Brandon Bays. Additional data on the distribution, behavior and habitat use of elasmobranch species in the area would enable a more appropriate protected area to be designed. Finally, net illumination has been shown to reduce by-catch of turtles, elasmobranchs, squid and non-commercial fish in other fisheries (Bielli, et al 2019, Senko et al 2022).

By-catch of grey seal in the tangle net fishery was significant. The nearby Blasket Islands is a Special Area of Conservation (SAC) for Grey Seal and supported a population of 1099-1413 seals in 2012 (O'Cadhla *et al*. 2013)There is a small colony of 10-50 seals at the Maharees Is in Tralee Bay (Morris and Duck 2019). The distance between fishing operations and this smaller colony is not considered here. If all seals in the by-catch originate from the Blasket Island seal colony and if it is a separate breeding population then given its limited population size it is biologically implausible that it could persist unless supplemented by inward migration. Genetic studies of seals at breeding sites shows there are separate breeding stocks in the UK and Baltic. Grey seal population models do show an absence of large scale redistribution of breeding females between regions implying a high degree of philopatry or fidelity to natal sites (SCOS, 2009). Pomeroy *et al* (2006) also demonstrated philopatry at site level and at finer spatial scale within sites which suggested kin clustering and recognition. However, grey seal colonies are not spatially isolated year-round (SCOS 2017) and there is regular movement of seals between haul-out sites. The mean distance travelled from haul-out sites by tagged seals is 51km, and the mean foraging trip duration is 40 hours but up to 15 days (Cronin *et al* 2013). Habitat use maps show that activity is concentrated at and in the vicinity of (<80km) haul out sites. The main interactions with fisheries, therefore, are expected to occur within this area. If seals in by-catch belong to an isolated breeding population at the

Blasket Is, then, given the by-catch reported here, the population should be declining. This is not the case. Seals in the by-catch may therefore originate from other colonies during foraging trips or the Blasket Is population is not reproductively isolated. SCOS (2017), in reporting on the impact of fisheries on grey seals in the Celtic Sea, also conclude that the by-catch exceeded the potential of the population to maintain itself and that some bycaught seals were immigrants from Scottish populations.

The seal by-catch data reported here can be used to model the fine scale distribution of seal by-catch around the haul out site and to predict the proportional reduction in by-catch. Although there is no favourable population reference size in the conservation objectives and targets for grey seal at the Blasket Island (NPWS 2014) a targeted reduction, that would result from spatial protection measures such as netting exclusion zones, could be predicted using the data reported here. Net illumination may also offer potential to reduce by-catch given that water turbidity is a significant factor in by-catch (Luck *et al* 2019) and illumination has been effective in by-catch reduction for other species as discussed above. Gotz and Janik (2016) also show that sound (startling devices) can be effective at reducing activity of seals close to salmon farms.

Conclusions and recommendations

1. The by-catch of critically endangered species of elasmobranch in an area that is recognised as supporting the last remnants of these species in Irish, European and Global waters represents a high risk for the continued survival of local populations
2. The by-catch of grey seal around the Blasket Is SAC is such that it is likely that inward migration is needed to support the continued viability of the population. However, other factors such as the origin of the seals in the by-catch and the genetic structure of grey seal populations in Ireland and UK need to be considered in evaluation of the effects of by-catch on seal colonies in proximity to tangle net fisheries.
3. Crayfish are a high value commercial species and support important local inshore fisheries in the study area. Netting causes some economic losses of this species and others because of the long net soak times and the interaction with invertebrate scavengers and seal depredation
4. A number of mitigations to reduce by-catch and in parallel to protect the future viability of the crayfish fishery are possible. Effecting the transition from a net fishery to a pot fishery, netting exclusions zones in critical habitat for endangered species and use of light and sound on nets to reduce by-catch are options. Work is ongoing and planned, through projects in 2021-2024, to evaluate and implement these or other measures. This work will involve the direct collaboration and assistance of the inshore fishing industry in the area.

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