EMFAF Operational Programme 2021-2027

Marine Biodiversity

Crayfish (*Palinurus elephas*): Catch and bycatch in the tangle net fishery off the southwest coast of Ireland in 2021-2024

EMFAF 2021-2027

Marine Institute Report Series

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Summary

1. National landings of crayfish (*Palinurus elephas*) increased from ~10 to ~83 tonnes during the period 2017 to 2024. The number of vessels targeting crayfish also increased very significantly during this period, particularly in Kerry and Cork but also Galway and Mayo. New targeted fisheries developed in Waterford in 2021 and Wexford in 2023. Over 100 vessels landed more than 100kgs of crayfish in 2024, compared to less than 30 vessels during the period 2017-2020. The increases were driven by improved catch rates, the continued high unit value of crayfish, a decline in the crab fishery, and possibly due to the closure of the pollack fishery in 2024. Similar increases in landings have been observed in France and southwest England in recent years.
2. Targeted catch and bycatch data were collected from vessels targeting crayfish with tangle nets for two fleets fishing from Kerry Head south to Brandon point (Tralee fleet) and in outer Dingle Bay north to the Blasket Islands (Dingle fleet) during 2021-2024. Data for 2017-2020 were collected on a previous project on a more limited scale.
3. Data were collected using a combination of scientific observer and skipper self-reporting. Skippers were contracted by the Marine Institute to provide operational (haul) level data on catch and bycatch of all species, and the size of crayfish and lobster in the catch for a given number of days during the fishing season. Fishing activity of the vessels was monitored using inshore vessel monitoring systems (iVMS) which reported geographic position, speed and bearing of the vessel every 10 minutes. Most of the vessels targeting crayfish in the project area with tangle nets were included in the contracted sampling programme.
4. The combination of observer coverage and contracted skipper reporting enabled high levels of monitoring, necessary for the estimation of bycatch of endangered and protected species where capture rates are low. The iVMS data provide information on days at sea and raising factors for the reported data to obtain estimates of catch and bycatch at fleet level.
5. Fishing days at sea and landings were estimated from logbook declarations (vessels over 10m in length), sales notes (vessels under 10m) and iVMS. Days at sea per vessel and year obtained from logbook declarations ranged from 21-68% of the iVMS days. Sales notes captured from 11-87% of the estimated landings per vessel depending on vessel. Annual days at sea per vessel, estimated from iVMS data, ranged from 58-150 days. Logbook declarations and sales note data significantly underestimated days at sea and landings.
6. Tralee vessels hauled an estimated 5,239 nm of net over four years, compared to 2,307 nm by Dingle vessels. Annually, the estimated miles of net hauled by the Tralee fleet ranged from 1,241-1,393 nm, while in Dingle, it ranged from 498-689 nm. Almost all fishing occurred from March to November.
7. Approximately 67% of the crayfish catch in Tralee were above the minimum landing size (MLS) of 110mm carapace length, compared to 38% in Dingle.
8. Crayfish mortality in tangle nets averaged 7.2% of the catch over the four years and reached 20% in some months. Mortality was positively correlated with net soak time. However, although soak time was higher in the Dingle fleet, crayfish mortality was lower. Higher mortality in the Tralee fleet, for any given soak time, was caused by nocturnal scavenging by benthic isopods and amphipods.
9. Annual fleet level landings ranged from 7.6-11.3 tonnes in Tralee and 4.4-6.5 tonnes in Dingle. The annual estimated value per fleet ranged from €270K to €422k in Tralee and €165k to €233k in Dingle. Prices per kg, according to sales notes, ranged from €35-55, peaking in December. Total value to the local Dingle and Tralee fleets was €0.8million and €1.5million respectively.

10. Catch rates of crayfish, standardised to fishing effort, doubled from 2017-2021 and were stable from 2021-2023. They increased further in 2024 although not consistently across all months or vessels.
11. Lobster (*Homarus gammarus*) was the main commercial bycatch species in tangle nets although the numbers of lobster caught was only 9% of the number of crayfish caught. Brown crab (*Cancer pagurus*) was caught in low numbers. Spider crab was abundant but economically their value was marginal due to low market demand and price. Monkfish (*Lophius* spp), turbot (*Scophthalmus maximus*), pollack (*Pollachius pollachius*), thornback ray (*Raja clavata*) and spurdog (*Squalus acanthias*) were caught. Spurdog was much more abundant in the Tralee fleet than in the Dingle fleet. The commercial value of these species relative to crayfish was insignificant.
12. Estimates of bycatch of endangered and protected species, raised to Tralee and Dingle fleets, were significant relative to the population status of these species.
    a. An estimated 1,161 grey seals (*Halichoerus grypus*) were caught over the period 2021-2024. Bycatch was generally higher from April to August and was equally distributed across the Dingle and Tralee fleets. The likelihood of seal bycatch was higher closer to the seal haul out site at the Blasket Islands. The seal population in the Blasket Island, Species Area of Conservation (SAC), could not sustain this level of mortality unless it was sub-vented by inward migration.
    b. An estimated 81 angel shark (*Squatina squatina*) were caught. This species is critically endangered globally. At least a proportion of these fish were released alive. Almost all reported captures were from the Tralee fleet, demonstrating the continued importance of Tralee Bay for this species. Continued bycatch represents a significant threat to the survival of the species in this area. As Tralee Bay is one of the last refuges for this species globally, this level of bycatch increases the risk of extinction of the species.
    c. An estimated 1,712 critically endangered flapper skate (*Dipturus* spp.) were caught, 78% of which were reported by the Tralee fleet.
    d. Two critically endangered white skate (*Rostroraja alba*) were reported outside of the sampling programme.
    e. Endangered undulate ray (*Raja undulata*) were caught in low numbers.
    f. Tope (*Galeorhinus galeus*), which are critically endangered in areas other than the northeast Atlantic, were caught mainly in Tralee (estimated 409 occurrences) with lower numbers (123) in Dingle.
    g. Cetacean bycatch was rare with 3 common dolphin and 4 Risso's dolphin over 4 years.
    h. No seabird bycatch was observed

Recommendations

1. Fishing effort and landings of crayfish nationally increased significantly from 2017-2024. This was driven by increases in catch rate which doubled during the period and other factors. Given the high unit value of crayfish (€33-55 per kg) any signal of increase in catch performance attracts fishing effort. This, in turn, reduces stock biomass and reduces the viability of transitioning to low impact fishing gears. There is also a risk of further population level impacts on species that are caught as bycatch. Management of fishing effort or landings of crayfish would enable stocks in local reef habitats to re-build and increase the viability of fishing generally but especially with pots. Fishing with pots would also eliminate bycatch of protected and endangered species.
2. Bycatch of endangered, threatened and protected (ETP) species such as grey seal, angel shark, flapper skate, undulate ray and white skate should be reduced to safe biological limits. In the

case of angel shark and white skate there are probably no safe limits given that these species are at risk of extinction locally, in European waters, and globally.

3. Spatial distribution of seal bycatch indicates that a netting exclusion zone around the Blasket Islands could significantly reduce seal bycatch albeit the displaced fishing activity would continue to catch seals in other locations but in lower numbers.
4. Switching of fishing gears from tangle nets to pots for crayfish is the optimum solution to eliminate bycatch. Trials (reported elsewhere under this project) show that the value of the catch in standard top entry pots with short soak times can be equivalent to the value in an equivalent amount of netting effort. Trials are continuing.
5. Existing spatial closures for tangle nets are inadequate to mitigate bycatch effects on critically endangered species. Compliance with the closures is not monitored, as almost all vessels targeting crayfish are under 12m and do not report position. These vessels should report position at high frequency (1-10minutes) so that compliance with areas closed to tangle nets can be monitored. However, distinguishing between fishing events that use nets and pots is difficult even with high frequency iVMS data. Methods to distinguish these two fishing methods in high resolution spatial data, or in combination with gear sensors, is continuing.
6. Seasonal closures would partly mitigate against escalation of tangle net fishing effort as the season has tended to expand in recent years.

Introduction

In Irish waters, the spiny lobster or crayfish (*Palinurus elephas*) is fished mainly in coastal reef habitat off the southwest coast, with smaller fisheries in other areas. The fishery in Ireland evolved gradually from the 1930s, initially as a bycatch 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 crayfish. With the exception of the early 1940s, there was a corresponding increase in landings during this period, peaking during the early 1950s-1970s at ~ 150 tonne per annum. Tangle nets were introduced into the fishery, quickly replacing top entry pots, in the early 1970s. Over 200 tonnes were landed in 1989, but landings declined thereafter. Official national landings of crayfish ranged from 49-83 tonnes with an annual value of €1.7 to €2.8million during the period 2021-2024.

The main gear used in the fishery today 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 bycatch (Tully and Palma-Pedraza 2022) of skates and rays, some of which are endangered or critically endangered. Grey seals are also captured as they attempt to depredate fish that are entangled in the nets. The fishery occurs close to some significant grey seal colonies.

This report expands on estimates of catch and bycatch reported by Tully and Palma-Pedraza (2022). A further four years of data are reported. Increased levels of monitoring have been achieved through expanded observer coverage and contracted skipper reporting involving more vessels. In addition, deployment of an 'always on' fleet tracking system (inshore vessel monitoring systems, iVMS), that reports vessel position at 10min intervals, has enabled observed and reported data on catch and bycatch to be raised to fleet level for the first time.

Study area

The fishery for crayfish occurs on coastal reef habitat (Figure 1). Most of the data on catch and bycatch reported here were obtained in the area from Kerry Head south to the Blasket Islands. Lesser amounts of data were collected further south close to Castletown Bearhaven.

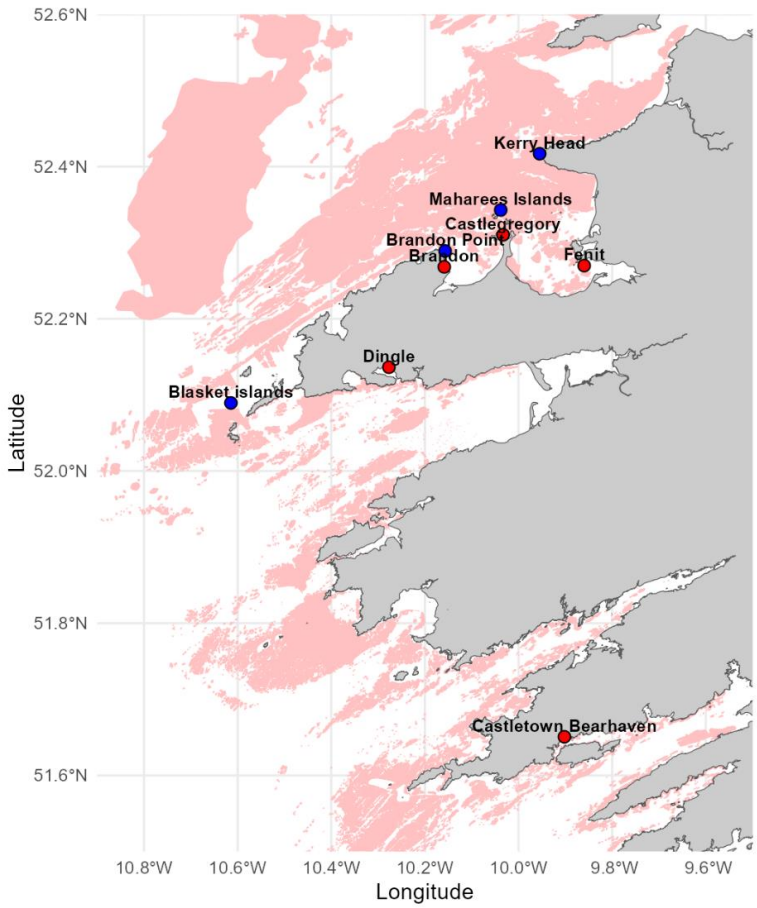


Figure 1. Southwest coast of Ireland including place names mentioned in the text. The distribution of coastal reef habitat which supports populations of spiny lobster (crayfish) is shown.

Methods

Data on landings and the number of fishing vessels targeting crayfish were compiled for all coasts from EU logbook declarations and sales note data.

Catch and bycatch sampling

Data on catch and bycatch in tangle nets were collected monthly from commercial inshore fishing vessels targeting crayfish from Castletown Bearhaven north to Kerry Head. Data were reported by both skippers and observers on board. Fourteen participating vessels (Figure 2) were contracted by the Marine Institute through a Framework Agreement in 2021 (ITT21-019) to collect and report data on catch and bycatch in tangle nets during normal commercial fishing operations. Data was collected from April to November 2021-2024. This constituted almost all vessels targeting crayfish in the Dingle to Tralee Bay area. Scientific observers from the Marine Institute also undertook observer work on these vessels during this time. A total of 746 fishing trips were reported by skippers and a further 75 trips were reported by observers during the period 2021-2024 (Table 1). Data on the date, net length, GPS position for the start and end of the net, soak time, total number of commercial and non-commercial species caught, and the size and sex of crayfish and lobster (*Homarus gammarus*) were reported in all cases for each net haul.

Between 9 and 11 vessels operating from Tralee Bay, Brandon, Dingle and Castletownbere, provided data in any given year. The vast majority of the data came from outer Tralee Bay from Kerry Head to Brandon Point and south in an area around the Blasket Islands. Some data were reported from Castletownbere vessels. This latter data was excluded from analysis as it is geographically outlying relative to the other vessels and the amount of data provided was much less. Given that the iVMS data

showed that the Tralee and Dingle vessels fished distinctly different and generally non-overlapping areas, these vessel groups are reported separately. This also allows for catch and bycatch estimates to be raised to each vessel group separately.

Detailed data on catch and bycatch in tangle nets were also collected from 2017 to 2020. However, as iVMS devices were not installed on vessels during that time, these data cannot be used to estimate total days at sea, total effort, or to raise catches and bycatches to fleet level. The 2017–2020 dataset was only incorporated in this report, therefore, to examine temporal trends in crayfish catches. The total annual sampled fishing effort in Tralee and Dingle, between 2017-2020, ranged from 207.3 to 313.8 nm of net and 94 to 129 nm respectively. These data are reported in Tully and Palma-Pedraza (2022).

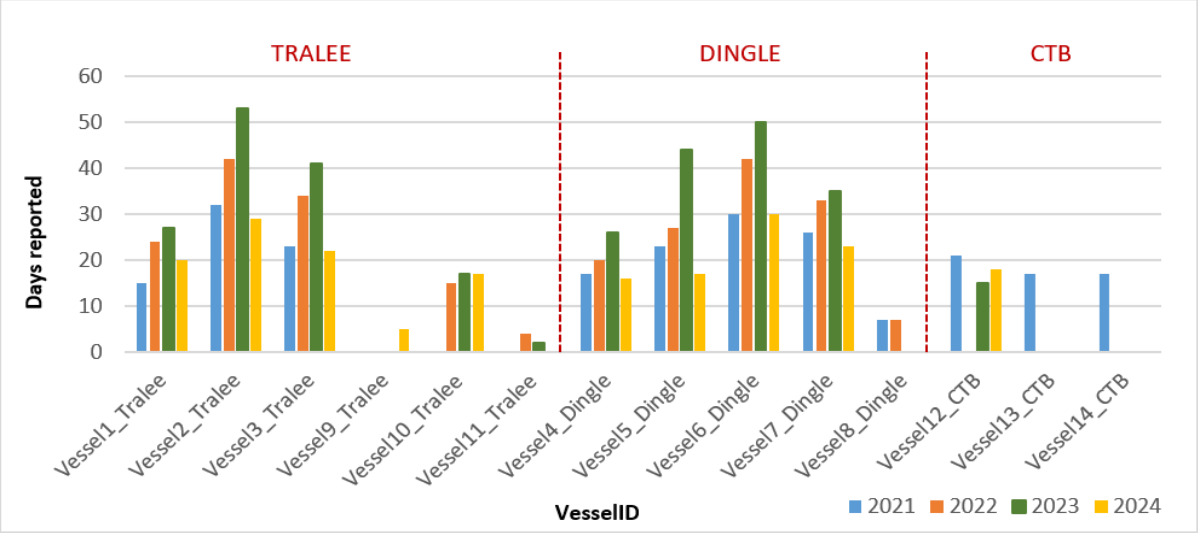


Figure 2. Number of fishing days for which data were reported by skippers and observers per vessel and year 2021-2024.

Table 1. Number of skipper and observer trips reported by year and fleet.

	Self-sampling					Observers				
Area/Year	2021	2022	2023	2024	**Total**	2021	2022	2023	2024	**Total**
Tralee	64	89	111	64	**328**	6	11	10	7	**34**
Dingle	92	104	146	76	**418**	4	18	9	10	**41**
Total	156	193	257	140	**746**	10	29	19	17	**75**

Raising procedures

To estimate total fishing effort, catch, and bycatch of the fleets, a two-step raising procedure were applied to the sample data. The proportion of the total fishing days for which effort, catch and bycatch were reported by skippers and observers was raised using the iVMS data, from which the total number of fishing days at sea can be accurately estimated.

Data reported by the contracted vessels represented a sub-set of their total fishing activity. This included vessels that were only using tangle nets, that reported data consistently across years (to allow temporal trend analysis), and that had iVMS on board. Those vessels which used mixed gears, including pots for lobsters and crabs, top entry pots for spider crabs and gill nets for pollack, were not included in this raising step. Based on these criteria, reported effort, catch and bycatch were raised to vessel level for three vessels from the Tralee area and four vessels from the Dingle area using an Individual Raising Factor (IRF) calculated as Reported Days / iVMS Days (Table 2). The average

proportion of fishing days of these vessels that were sampled was 0.34, equivalent to a raising factor of ~3. Methods to estimate days at sea from iVMS data are described below.

Table 2. Annual Individual Raising Factor (IRF) by vessel level to estimate total fleet level effort, catch and bycatch.

Individual Raising Factor: contracted vessel activity to total estimation				
Vessel	**2021**	**2022**	**2023**	**2024**
Vessel1_Tralee	0.26	0.32	0.36	0.34
Vessel2_Tralee	0.21	0.30	0.36	0.20
Vessel3_Tralee	0.20	0.28	0.35	0.18
Vessel1_Dingle	0.17	0.24	0.24	0.18
Vessel2_Dingle	0.26	0.36	0.48	0.29
Vessel3_Dingle	0.42	0.71	0.58	0.60
Vessel4_Dingle	0.25	0.55	0.51	0.35

A second raising procedure was used to estimate the fleet level fishing effort, catch and bycatch for Tralee and Dingle vessels separately. Firstly, landings of non-contracted vessels were estimated from logbooks and sales notes. Vessels landing more than 100 kg of crayfish per year were considered netters and included in the analysis. The crayfish landings per unit effort ($LPUE.kg^{-1}.nmnet^{-1}$) of contracted tangle net vessels were used to estimate the effort (miles of net) of these non-contracted vessels, and contracted vessels that did not meet the criteria used in the first raising procedure but landed more than 100 kg of crayfish annually. Effort for these vessels was estimated from their known landings using LPUE. The Fleet-Level Raising Factor (FRF) was then calculated as ($Effort_{contracted\ vessels}$ + $Effort_{non\text{-}contracted\ vessels}$) / $Effort_{contracted\ vessels}$. This FRF, representing the additional proportion of effort contributed by vessels not included in the first raising step, was then applied to the contracted vessels catch and bycatch raised estimates to provide estimate of total fleet catch and bycatch (Table 3). Contracted vessels accounted for the majority of fishing effort in Tralee across all years, covering approximately 98% in 2021-2022, 92% in 2023, and 70% in 2024. The coverage in Dingle was more variable, ranging from about 50% in 2021 to 87% in 2023, before decreasing to 60% in 2024.

Table 3. Annual Fleet-Level Raising Factor (FRF) by vessel group to estimate total fleet effort, catch and bycatch from raised contracted vessel data.

Fleet-Level Raising Factor: contracted vessel activity to fleet activity				
Vessel group	**2021**	**2022**	**2023**	**2024**
Tralee	1.0126 (98.8%)	1.0267 (97.4%)	1.0837 (92.3%)	1.4326(69.8%)
Dingle	2.0008 (50%)	1.7455 (57.3%)	1.146 (87.3%)	1.6699 (59.9%)

Estimation of total effort (days at sea) by year and vessel group

The total annual days at sea for each contracted vessel were estimated using a combination of the iVMS data and supplementary trip log data (the days the vessels were contracted and involved in data collection on catch and bycatch in tangle nets). iVMS data were filtered to exclude days when the vessels remained at the pier for the entire day or were participating in specific surveys, not involving tangle nets, contracted by the Marine Institute. We also accounted for periods without iVMS coverage. During the main fishing season iVMS was generally available 100% of the time but battery depletion in the iVMS devices reduced coverage in late autumn. Trip log data serves as a supplementary source to cover periods not recorded by the iVMS. The total day at sea was therefore estimated from iVMS days at sea + trip log data when iVMS was not available. iVMS, however, accounted for close to 100% of activity of the vessels.

Data on fishing effort are reported here from April 2021 to December 2024. Little fishing occurs from January to March. However, the iVMS trackers were not installed on the vessels until August 2021,

resulting in no data for the period April to July 2021. To account for this missing data and estimate the days at sea during this period, the logbook data for vessels over 10 meters were compared to the iVMS data from August to November 2021, when both data sources were available. This comparison indicated the level of discrepancy between the two datasets (i.e., how much more the iVMS data reported in comparison to the logbook data). This ratio was then applied to adjust the logbook effort estimates for April to July 2021.

In the case of vessels under 10m in length, that do not report logbook data, the average number of days at sea from the iVMS data for April to July across the years 2022-2024 was calculated. This average was used to estimate effort for the same months in 2021, assuming similar levels of vessel activity across years.

Results

National and regional trends in crayfish landings

Long term landings data for crayfish show peaks and troughs indicative of boom and bust fisheries since the 1920s. Landings were higher, than they are currently, from the 1950s-1990s (Figure 3). Landings increased significantly from lows of 10-30 tonnes annually during 2014-2020 to 50 tonnes in 2021 and to 70-83 tonnes in the period 2022-2024.

The number of vessels targeting crayfish also increased in the period 2021-2024 (Figure 4, Figure 5). Targeting vessels were defined as vessels landing more than 100kgs per year, which likely indicates the use of tangle nets. While small quantities of crayfish may be caught in pots, any significant landings by vessel indicates the use of tangle nets. Increased targeted effort on crayfish occurred in Kerry and Cork in particular and also in Mayo and Galway during 2021-2024. Targeted fishing effort also occurred in Waterford from 2021 and Wexford from 2023. Historically, there were significant landings of crayfish into ports in these areas. County Kerry accounted for more than half the national landings of crayfish in recent years.

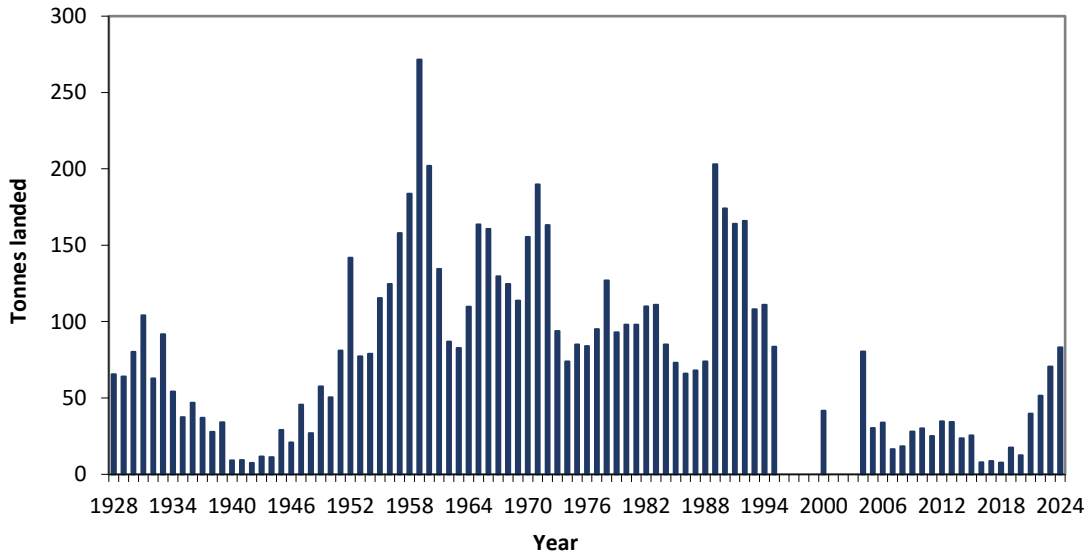


Figure 3. Annual landings (tonnes) of crayfish into Ireland 1928-2024.

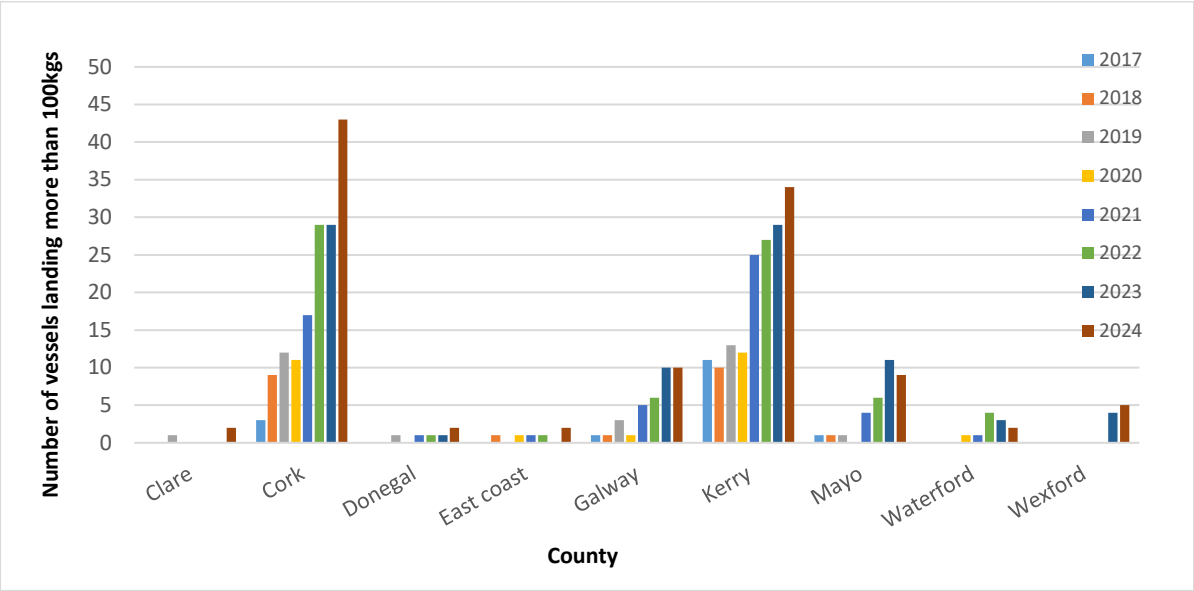


Figure 4. Annual number of vessels targeting crayfish (taken as >100kg per annum) by county 2017-2024.

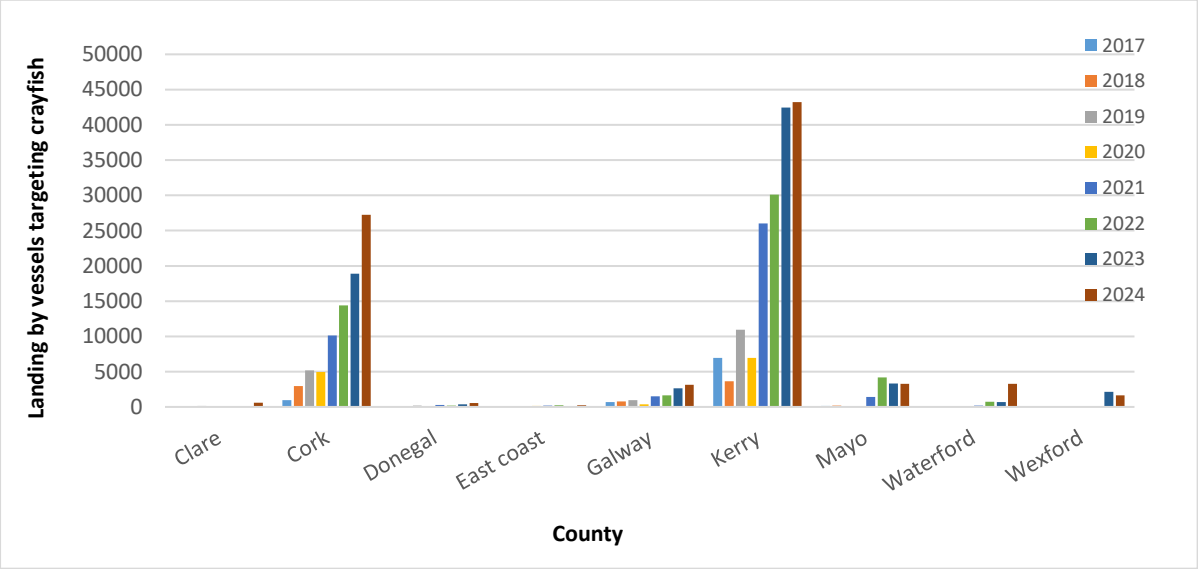


Figure 5. Annual landings by vessels targeting crayfish (taken as >100kg per annum) by county 2017-2024.

Comparison of data reported by Skippers and Observers

The number of trips reported by observers was 10% of the number reported by skippers. The correspondence between observer and skipper data was not fully examined and is difficult to compare in the case of bycatch given these data are zero inflated. Both data sets are combined in the analysis and estimates provided in this report. Observers reported higher crayfish catches in several months for both the Dingle and Tralee fleets (Figure 6). This may be due to underestimation of discards in skipper reported data, as previously observed in Irish lobster fisheries (unpublished data). Seal and skate CPUE reported by observers was significantly higher in two months across the four-year period but not reported by observers in many months when it was reported by skippers.

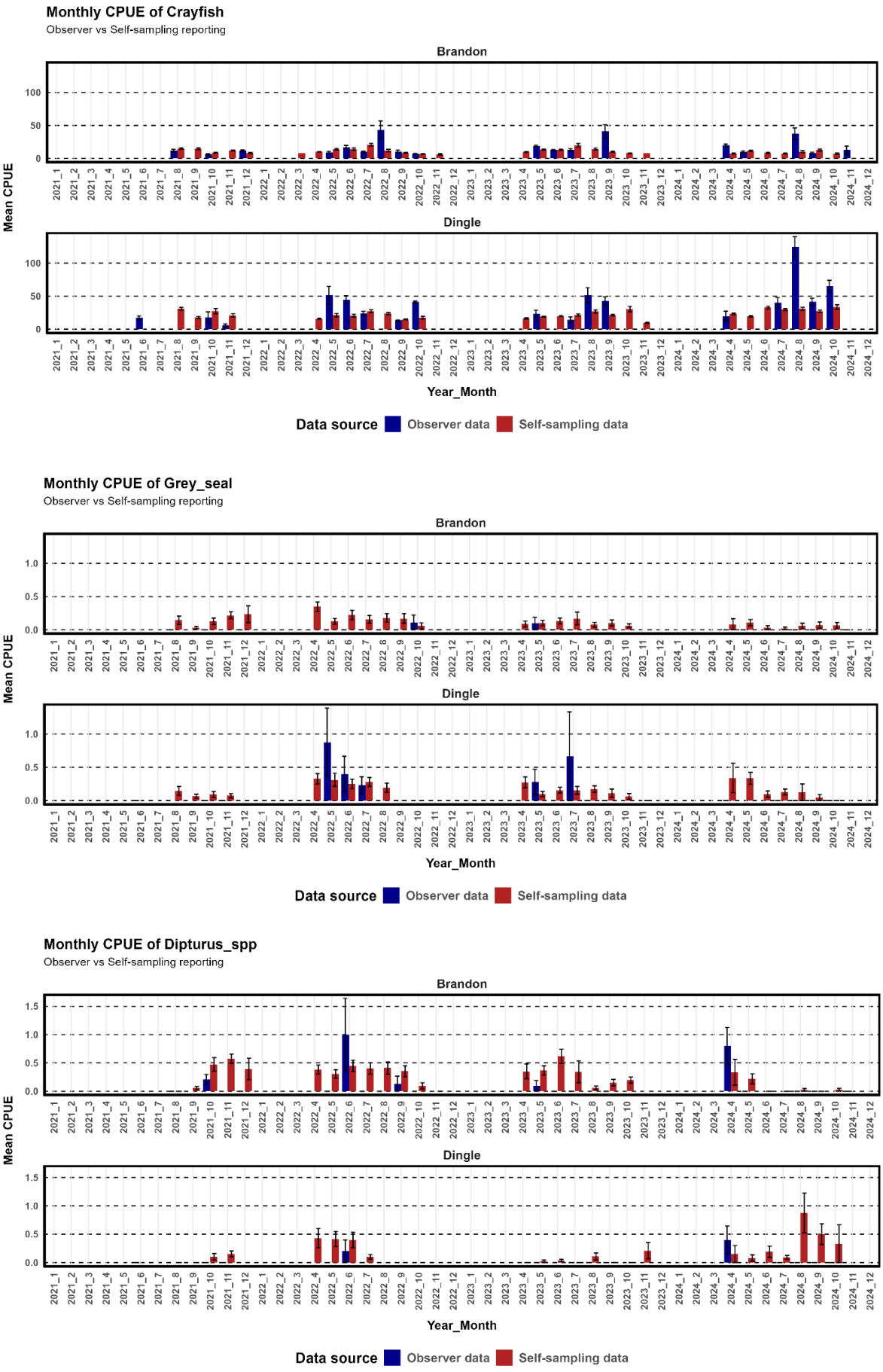


Figure 6. Monthly CPUE of crayfish, grey seals and flapper skates in Dingle and Tralee fleets reported separately by skippers and observers.

Data reported by contracted vessels

Days at sea by vessel group 2021-2024

The Tralee group of vessels reported data for 362 days while the Dingle group reported 459 days over the four years (Table 4).

Table 4. Number of days reported by year by each vessel group in Tralee Bay and Dingle Bay areas.

Vessel Group	2021	2022	2023	2024	Total days reported
Tralee	70	100	121	71	**362**
Dingle	96	122	155	86	**459**

Fishing effort (miles of net) by year and vessel group

The Tralee vessel group reported higher fishing effort across all years compared to Dingle group. Over the four years, the total reported effort for Tralee vessels was 1,367 miles, while Dingle vessels reported 874 miles. Effort per year was lower in the Dingle group (Table 5).

Table 5. Number of miles of net reported by year and vessel group in Tralee Bay and Dingle Bay areas.

	Total miles of net	Mean ± SD (number per vessel group)
2021_Tralee	273	91 ± 66
2022_Tralee	374	125 ± 90
2023_Tralee	440	147 ± 112
2024_Tralee	280	93 ± 53
TOTAL_Tralee	**1,367**	
2021_Dingle	163	41 ± 17
2022_Dingle	238	59 ± 27
2023_Dingle	316	79 ± 45
2024_Dingle	157	39 ± 12
TOTAL_Dingle	**874**	

Catches of crayfish and lobster by year and vessel group

Contracted vessels reported significant catches of crayfish but low number of lobsters in the targeted catch. Over 14000 and 19000 crayfish were reported by the Tralee and Dingle vessels respectively compared to ~400 and ~1700 lobster in each vessel group. This equated to 14-15 tonnes of crayfish and 0.2-1.7 tonnes of lobster (Table 6). These are unraised estimates and indicate the sampling effort of the skippers and observers.

Table 6. Reported catches of crayfish and lobster (numbers, kgs) by vessel group and year. Values represent total catch and mean ± SD per vessel. These data are not raised to total vessel activity.

	Total Cray Catch No	Mean ± SD (number per vessel)	Total Cray Catch Kgs	Mean ± SD (kgs per vessel)
2021_Tralee	2,836	945 ± 483	2,876	959 ± 356
2022_Tralee	4,024	1,341 ± 360	4,018	1,339 ± 509
2023_Tralee	4,838	1,613 ± 776	4,742	1,581 ± 981
2024_Tralee	2,553	851 ± 212	2,242	747 ± 287
TOTAL_Tralee	**14,251**		**13,878**	
2021_Dingle	3,101	775 ± 144	2,371	593 ± 129
2022_Dingle	5,040	1,260 ± 424	4,022	1,006 ± 321
2023_Dingle	6,645	1,661 ± 839	5,286	1,321 ± 675
2024_Dingle	4,483	1,121 ± 204	3,565	891 ± 134
TOTAL_Dingle	**19,269**		**15,244**	

	Total Lobster Catch No	Mean ± SD (number per vessel)	Total Lobster Catch Kgs	Mean ± SD (kgs per vessel)
2021_Tralee	46	945 ± 483	26	9 ± 7
2022_Tralee	157	52 ± 27	107	36 ± 5
2023_Tralee	134	45 ± 38	81	27 ± 12
2024_Tralee	56	19 ± 14	38	13 ± 12
TOTAL_Tralee	**393**		**252**	
2021_Dingle	343	86 ± 45	340	85 ± 46
2022_Dingle	546	137 ± 86	531	133 ± 93
2023_Dingle	628	157 ± 182	612	153 ± 198
2024_Dingle	281	70 ± 51	238	59 ± 47
TOTAL_Dingle	**1,798**		**1,721**	

Size composition of crayfish by year and vessel group

Approximately 67% of the crayfish caught in Tralee were above the MLS, compared to only 38% in Dingle (Figure 7). This difference suggests a variation in the size composition of crayfish populations between the two study areas. It is unlikely to be due to different selectivity as the fishing gear used in each area is similar.

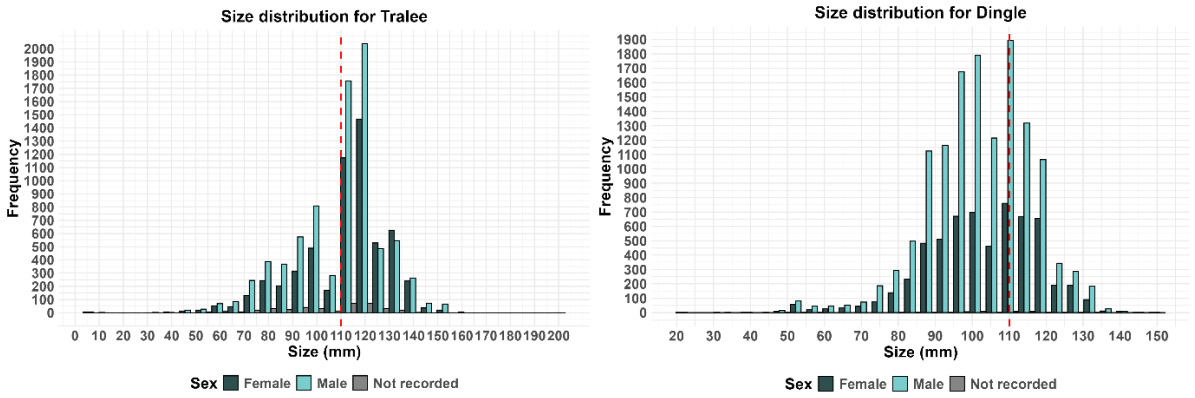


Figure 7. Size distribution of crayfish for Tralee (left) and Dingle (right) 2021-2024.

Total reported crayfish landings in Tralee and Dingle increased from 2021 to a peak in 2023 and dropped in 2024. Tralee generally reported higher crayfish landings than Dingle, particularly in 2022-2023. The mean number of crayfish landed per vessel in Tralee ranged from 490 to 1,133 individual annually. In Dingle, mean landings per vessel were lower, ranging from 263 to 662 individuals annually. The reported lobster landings were higher in Dingle than in Tralee across all years (Table 7).

Table 7. Reported landings of crayfish and lobster (numbers, kgs) by vessel group and year. Values represent total catch and mean ± SD per vessel. These data are not raised to total vessel activity.

	Total Cray Landed No	Mean ± SD (number per vessel)	Total Cray Landed Kgs	Mean ± SD (kgs per vessel)
2021_Tralee	1,883	628 ± 302	2,354	784 ± 265
2022_Tralee	2,763	921 ± 393	3,376	1,125 ± 507
2023_Tralee	3,400	1,133 ± 823	3,939	1,313 ± 975
2024_Tralee	1,470	490 ± 260	1,629	543 ± 319
TOTAL_Tralee	**9,516**		**11,298**	
2021_Dingle	1,050	263 ± 129	1,115	279 ± 147
2022_Dingle	1,985	496 ± 218	2,094	523 ± 206
2023_Dingle	2,649	662 ± 391	2,798	699 ± 396
2024_Dingle	1,690	423 ± 48	1,845	461 ± 31
TOTAL_Dingle	**7,374**		**7,852**	

	Total Lobster Landed No	Mean ± SD (number per vessel)	Total Lobster Landed Kgs	Mean ± SD (kgs per vessel)
2021_Tralee	30	10 ± 7	20	6 ± 4
2022_Tralee	111	37 ± 12	76	25 ± 3
2023_Tralee	65	22 ± 9	48	16 ± 5
2024_Tralee	37	12 ± 10	25	8 ± 8
TOTAL_Tralee	**243**		**169**	
2021_Dingle	297	74 ± 42	275	69 ± 46
2022_Dingle	459	115 ± 68	415	104 ± 70
2023_Dingle	521	130 ± 149	479	120 ± 156
2024_Dingle	239	60 ± 47	197	49 ± 42
TOTAL_Dingle	**1,516**		**1,366**	

Crayfish catch rates

Trends in mean monthly catch rates of crayfish, standardised for net length, were inconsistent across years. In Tralee CPUE usually declined during the season but this was not generally the case in Dingle (Figure 8). Annual mean catch rates of crayfish, doubled during the period 2017-2024 in both Tralee and Dingle fleets (Figure 9).

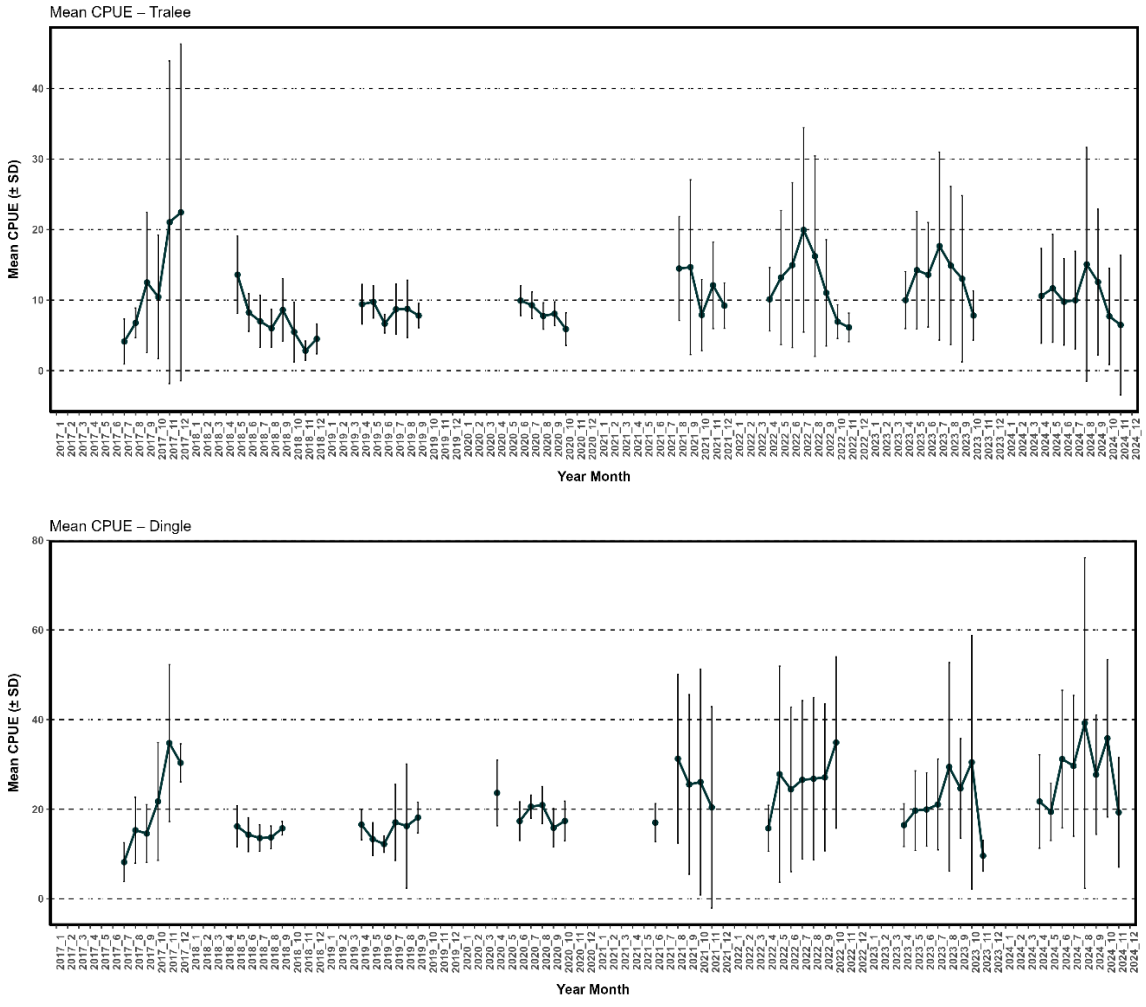


Figure 8. Monthly average (± standard deviation) catch rate of crayfish per nautical mile of net hauled 2017-2024 by vessel group and including all vessels reporting data.

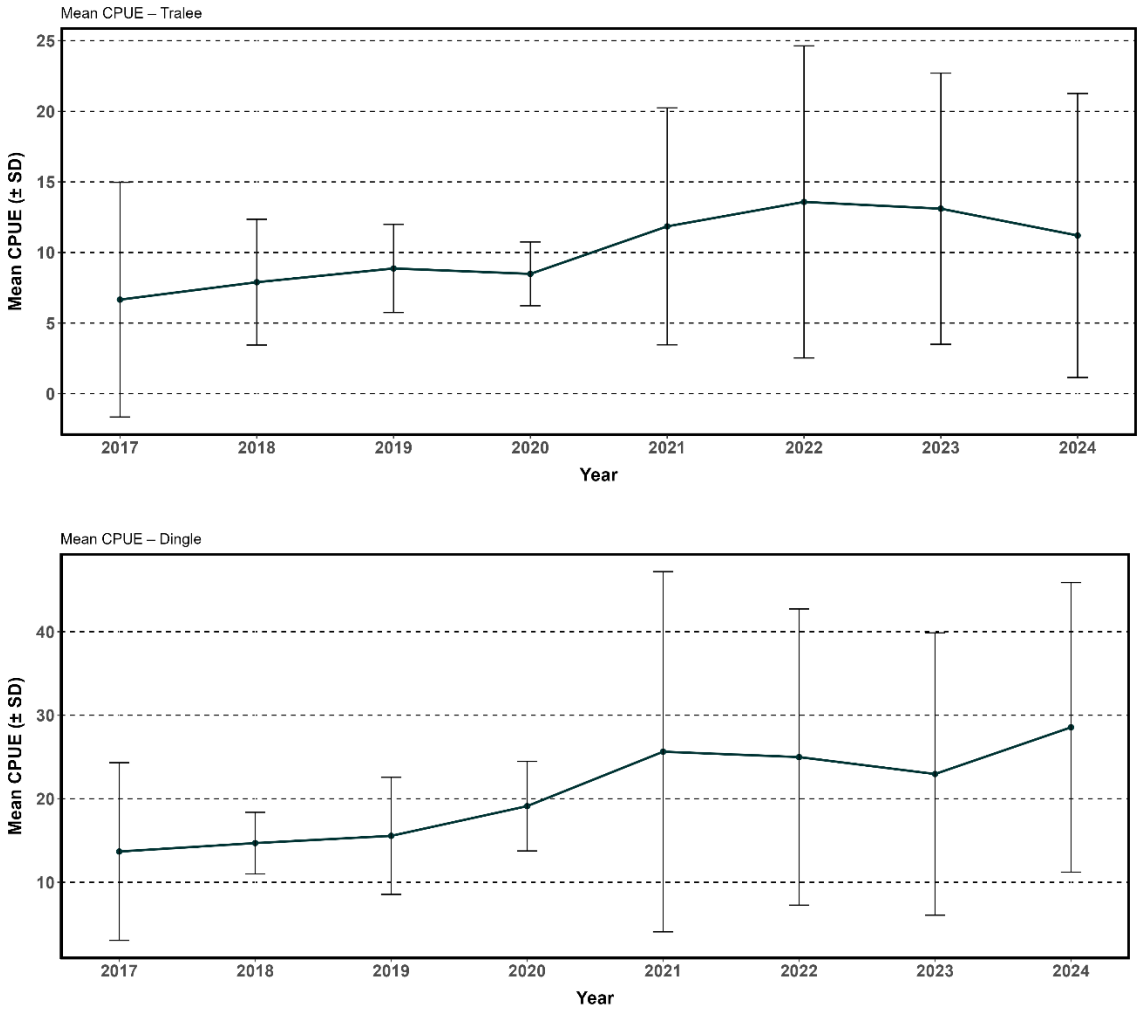


Figure 9. Annual average (± standard deviation) catch rate of crayfish per nautical mile of net hauled 2017-2024 by vessel group and including all vessels reporting data.

Crayfish mortality

Crayfish mortality in tangle nets averaged 7.2% over 2021-2024 in Dingle and Tralee areas combined. Mortality rates in Tralee were approximately double that of Dingle and were higher in 2021 and 2022 than in 2023 and 2024 (Table 8). Peak monthly mortality varied across years. Highest monthly mortalities were in Tralee in October 2021 and September 2022 (Figure 10). There was a positive correlation between the soak time of the nets and mortality rate although this relationship was very different in Tralee and Dingle. Dingle vessels used longer soak times but had lower mortality. Mortality increased more rapidly with soak time in Tralee (Figure 11). These differences may be accounted for by scavenging benthic amphipods and isopods (locally referred to as "skinners") which attack injured or stressed crayfish in the Tralee fishing area but are less prevalent in Dingle fishing grounds.

Table 8. Average annual mortality of crayfish in tangle nets in Dingle and Tralee areas.

Average % mortality	**Area**		
Year	**Dingle**	**Tralee**	**Combined average**
2021	6.15	11.25	8.70
2022	4.82	10.83	7.82
2023	2.72	9.55	6.13
2024	3.67	9.39	6.38
Overall average	**4.26**	**10.26**	**7.26**

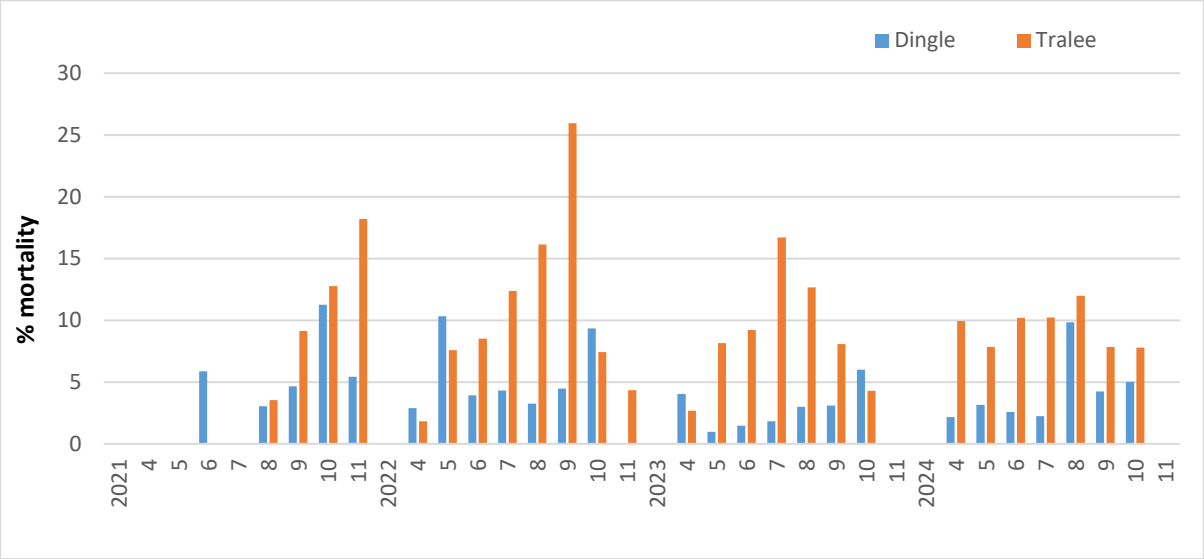


Figure 10. Monthly average mortality of crayfish in tangle nets in Dingle and Tralee areas.

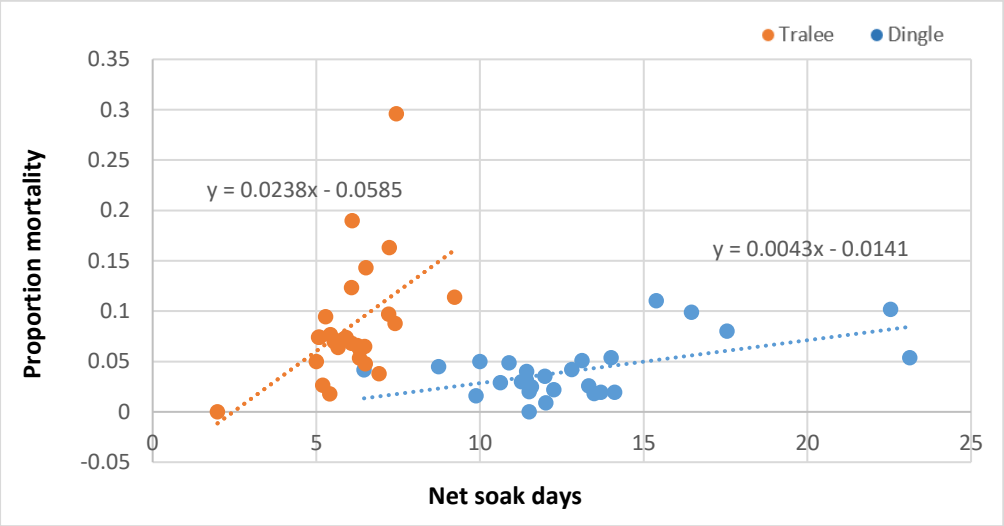


Figure 11. Relationship between tangle net soak time (days) and the proportion of crayfish dead in tangle net catches in Tralee and Dingle areas.

Catch and bycatch species composition by year and fleet area

In Dingle, crayfish were the most common species caught in tangle nets across all years, followed by spider crab and brown crab. In Tralee, crayfish was the second most common species caught after spider crab. Low numbers of lobster were caught although these areas support targeted pot fisheries for lobster. Commercial fish caught in tangle nets included turbot, monkfish, pollack, spurdog and thornback rays along with low numbers of spotted and blonde rays. These fish are generally lost or damaged due to skinners and seal depredation before nets are hauled which reduces or negates the value of the catch. Other non-commercial species are caught including protected species such as grey seal and critically endangered species such as angel shark and skate (Table 9 and Table 10).

Table 9. Catch and bycatch species composition (numbers) reported in tangle nets in Tralee (T) and Dingle (D) vessels for 2021-2024. Tralee vessels fish west of Tralee Bay and Brandon Bay while Dingle vessels fish mainly around the Blasket Islands and outer Dingle Bay. These data are not raised to total vessel or fleet activity.

Species	2021_T	2022_T	2023_T	2024_T	Total_T	2021_D	2022_D	2023_D	2024_D	Total_D
Spider Crab (*Maja brachydactyla*)	4,551	5,878	7,044	5,085	**22,558**	1,549	2,287	3,200	4,044	**11,080**
Crayfish (*Palinurus elephas*)	3,119	4,311	5,180	2,710	**15,320**	3,254	5,131	6,737	4,530	**19,652**
Brown Crab (*Cancer pagurus*)	2,525	3,231	3,383	1,784	**10,923**	2,076	2,555	3,584	2,328	**10,543**
Lobster (*Homarus gammarus*)	71	169	141	60	**441**	391	544	645	288	**1,868**
Pollack (*Pollachius pollachius*)	232	578	715	340	**1,865**	67	178	142	109	**496**
Monkfish (*Lophius spp*)	158	209	228	164	**759**	44	95	144	88	**371**
Turbot (*Scophthalmus maximus*)	63	141	181	74	**459**	10	31	51	27	**119**
Black Pollack (*Pollachius virens*)	0	16	0	0	**16**	0	6	0	1	**7**
Spurdog (*Squalus acanthias*)	1,621	1,949	2,327	1,046	**6,943**	129	146	179	57	**511**
Thornback (*Raja clavata*)	219	438	562	218	**1,437**	44	87	188	86	**405**
Dog fish (*Scyliorhinus spp*)	260	287	410	258	**1,215**	150	241	222	124	**737**
Spotted Ray (*Raja montagui*)	178	295	139	74	**686**	9	3	2	3	**17**
Flapper Skate (*Dipturus spp*)	83	122	106	20	**331**	12	47	13	29	**101**
Blonde Ray (*Raja brachyura*)	33	54	111	56	**254**	23	114	126	62	**325**
Grey Seal (*Halichoerus grypus*)	34	66	38	14	**152**	19	71	54	27	**171**
Tope (*Galeorhinus galeus*)	26	26	52	8	**112**	5	9	17	11	**42**
Painted Ray (*Raja microocellata*)	54	16	8	0	**78**	0	0	32	6	**38**
Sting Ray (*Dasyatis pastinaca*)	22	26	22	1	**71**	1	1	8	0	**10**
Angel Shark (*Squatina squatina*)	0	16	3	2	**21**	0	0	0	0	**0**
Undulate Ray (*Raja undulata*)	3	11	0	0	**14**	0	0	0	1	**1**
Harbour porpoise (*Phocoena phocoena*)	0	0	0	0	**0**	0	1	0	0	**1**
Common dolphin (*Delphinus delphis*)	0	0	1	0	**1**	0	0	0	0	**0**
Risso's dolphin (*Grampus gripeus*)	0	1	0	0	**1**	0	0	0	0	**0**
TOTAL	13,252	17,840	20,651	11914	**63,657**	7,783	11,547	15,345	11,821	**46,496**

Table 10. Rates of catch and bycatch (numbers.100nm of net) per species reported in tangle nets in Tralee (T) and Dingle (D) vessels for 2021-2024. Tralee vessels fish west of Tralee Bay and Brandon Bay while Dingle vessels fish mainly around the Blasket Islands and outer Dingle Bay. These data are not raised to total vessel or fleet activity.

Species	2021_T	2022_T	2023_T	2024_T	Total_T	2021_D	2022_D	2023_D	2024_D	Total_D
Spider Crab (*Maja brachydactyla*)	1,663.99	1,572.46	1,598.66	1,813.80	**6,648.90**	950.60	960.92	1,011.54	2,565.99	**5,489.05**
Crayfish (*Palinurus elephas*)	1,140.40	1,153.26	1,175.62	966.65	**4,435.93**	1,996.93	2,155.88	2,129.60	2,874.37	**9,156.78**
Brown Crab (*Cancer pagurus*)	923.22	864.34	767.78	636.35	**3,191.69**	1,274.01	1,073.53	1,132.92	1,477.16	**4,957.62**
Lobster (*Homarus gammarus*)	25.96	45.21	32.00	21.40	**124.57**	239.95	228.57	203.89	182.74	**855.15**
Pollack (*Pollachius pollachius*)	84.83	154.62	162.27	121.28	**523.00**	41.12	74.79	44.89	69.16	**229.96**
Monkfish (*Lophius spp*)	57.77	55.91	51.75	58.50	**223.92**	27.00	39.92	45.52	55.84	**168.27**
Turbot (*Scophthalmus maximus*)	23.03	37.72	41.08	26.40	**128.23**	6.14	13.03	16.12	17.13	**52.42**
Black Pollack (*Pollachius virens*)	0.00	4.28	0.00	0.00	**4.28**	0.00	2.52	0.00	0.63	**3.16**
Spurdog (*Squalus acanthias*)	592.69	521.39	528.12	373.11	**2,015.30**	79.17	61.34	56.58	36.17	**233.26**
Thornback (*Raja clavata*)	80.07	117.17	127.55	77.76	**402.55**	27.00	36.55	59.43	54.57	**177.55**
Dog fish (*Scyliorhinus spp*)	95.06	76.78	93.05	92.03	**356.92**	92.05	101.26	70.18	78.68	**342.17**
Spotted Ray (*Raja montagui*)	65.08	78.92	31.55	26.40	**201.94**	5.52	1.26	0.63	1.90	**9.32**
Flapper Skate (*Dipturus spp*)	30.35	32.64	24.06	7.13	**94.18**	7.36	19.75	4.11	18.40	**49.62**
Blonde Ray (*Raja brachyura*)	12.07	14.45	25.19	19.98	**71.68**	14.11	47.90	39.83	39.34	**141.18**
Grey Seal (*Halichoerus grypus*)	12.43	17.66	8.62	4.99	**43.71**	11.66	29.83	17.07	17.13	**75.69**
Tope (*Galeorhinus galeus*)	9.51	6.96	11.80	2.85	**31.12**	3.07	3.78	5.37	6.98	**19.20**
Painted Ray (*Raja microocellata*)	19.74	4.28	1.82	0.00	**25.84**	0.00	0.00	10.12	3.81	**13.92**
Sting Ray (*Dasyatis pastinaca*)	8.04	6.96	4.99	0.36	**20.35**	0.61	0.42	2.53	0.00	**3.56**
Angel Shark (*Squatina squatina*)	0.00	4.28	0.68	0.71	**5.67**	0.00	0.00	0.00	0.00	**0.00**
Undulate Ray (*Raja undulata*)	1.10	2.94	0.00	0.00	**4.04**	0.00	0.00	0.00	0.63	**0.63**
Harbour porpoise	0.00	0.00	0.00	0.00	**0.00**	0.00	0.42	0.00	0.00	**0.42**
Common dolphin	0.00	0.00	0.23	0.00	**0.23**	0.00	0.00	0.00	0.00	**0.00**
Risso's dolphin	0.00	0.27	0.00	0.00	**0.27**	0.00	0.00	0.00	0.00	**0.00**
TOTAL	4,845	4,772	4,686	4,249	**18,554**	4,776	4,851	4,850	7,500	**21,979**

Raised effort, catch and landings of contracted vessels

iVMS data and distribution of fishing

iVMS provided data on the location and speed of vessels every 10 minutes when the vessel was at sea and every hour when the vessel was in port. iVMS units remained continuously active ('always on'), providing accurate information on the days at sea (equivalent to fishing days at sea) for each vessel, as well as high-resolution spatial data for mapping the distribution of fishing activity (Figure 12).

A fishing trip was defined as activity at sea during any 24 hr period using the iVMS data. For each trip and vessel, the time difference (interval) between consecutive iVMS pings was calculated. A speed filter was applied to identify fishing activity. Records where the vessel speed was between 0 and 3 knots were considered indicative of fishing activity. This speed range was chosen based on known fishing behaviour where vessels typically move slowly while fishing.

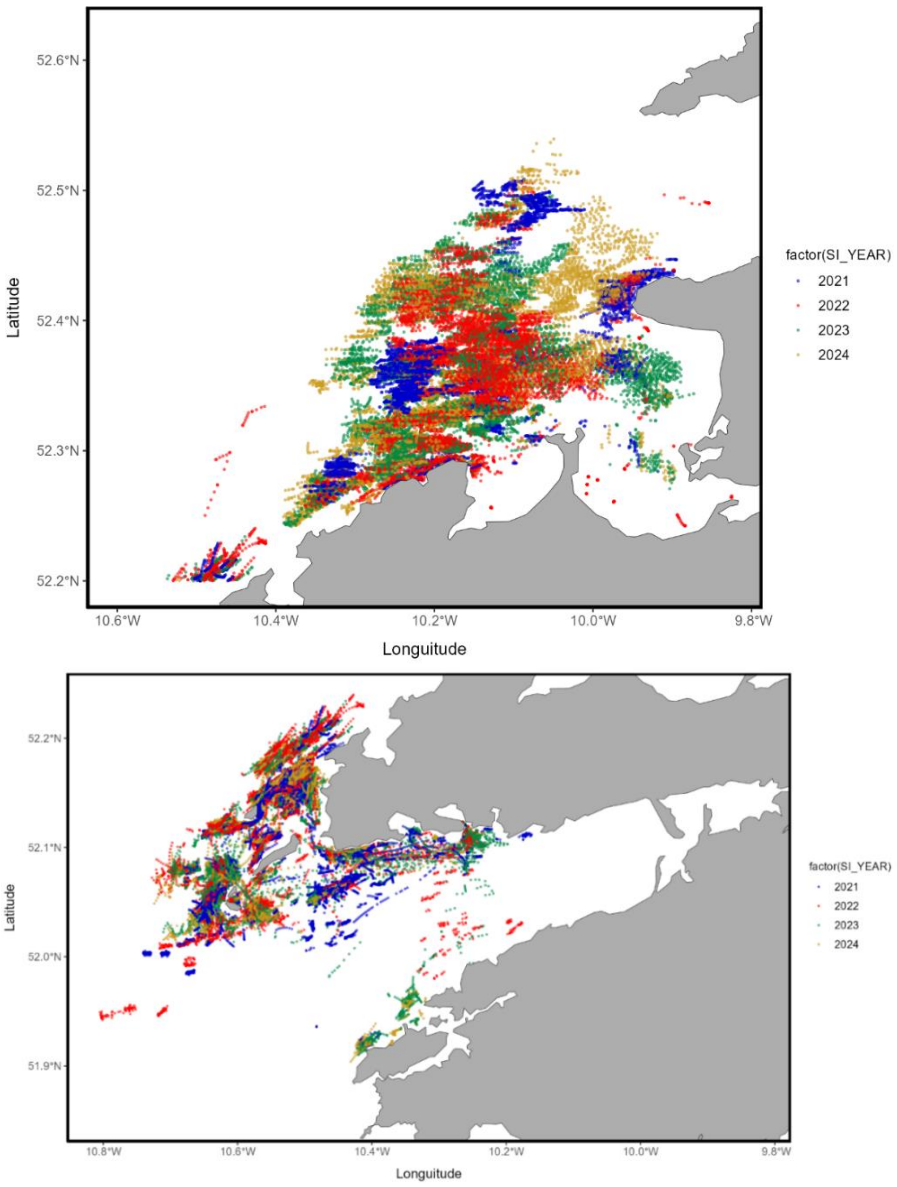
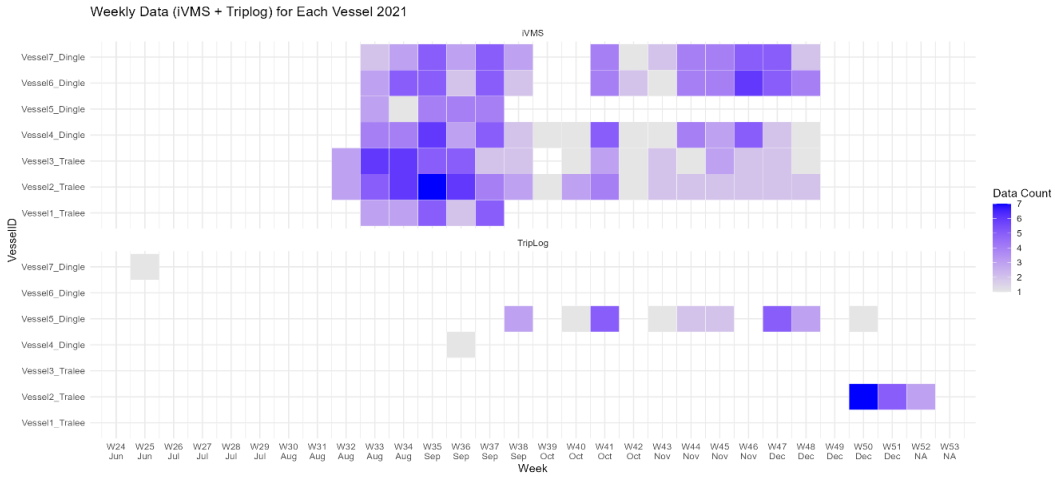
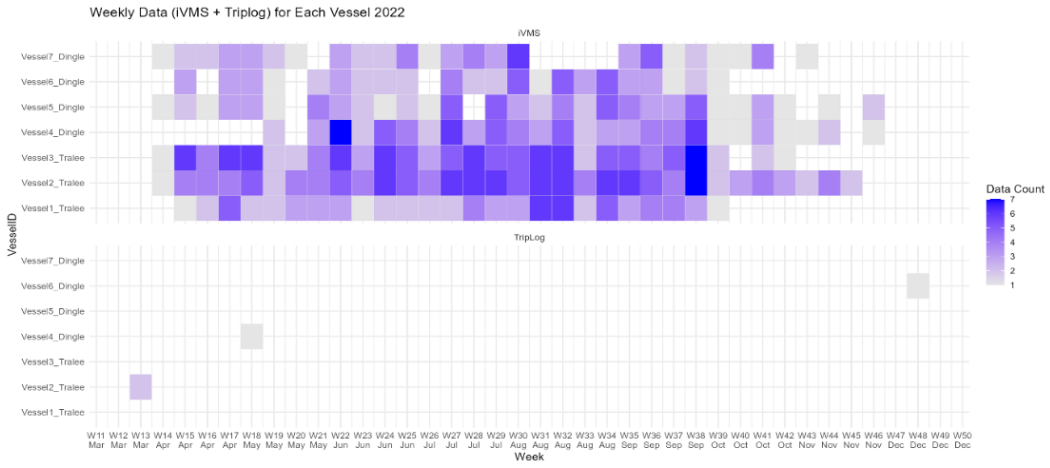


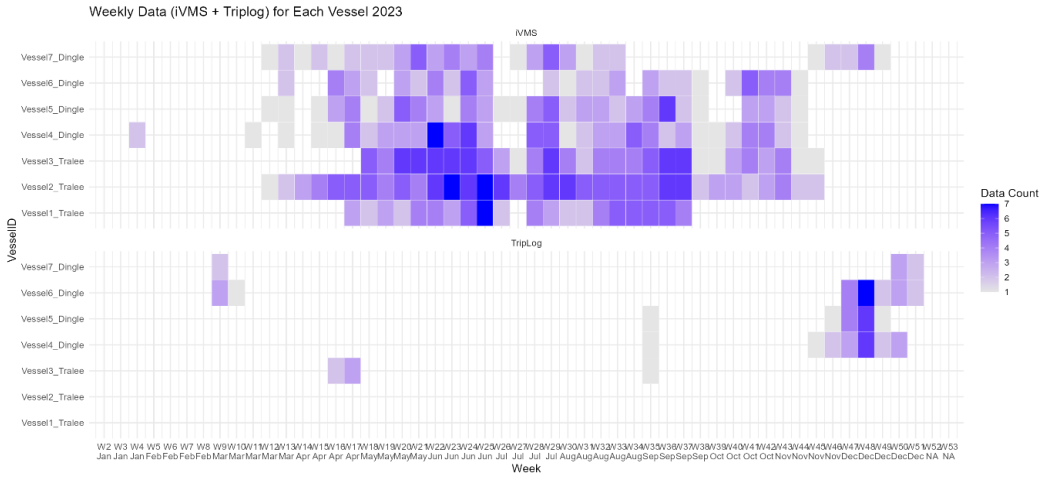
Figure 12. Distribution of fishing activity of the Tralee (above) and Dingle (below) vessel groups as estimated from iVMS data.

Days at sea per vessel per week was estimated (Figure 13). These data show variable effort levels across vessels and gaps associated with poor weather or for other operational reasons. The total days

at sea, during 2021-2024 and estimated from iVMS and trip log data as described in the methods section, was 1,331 and 1,246 days for the Tralee and Dingle vessels respectively (Table 11). The number of trips per month was higher in summer (Figure 14).







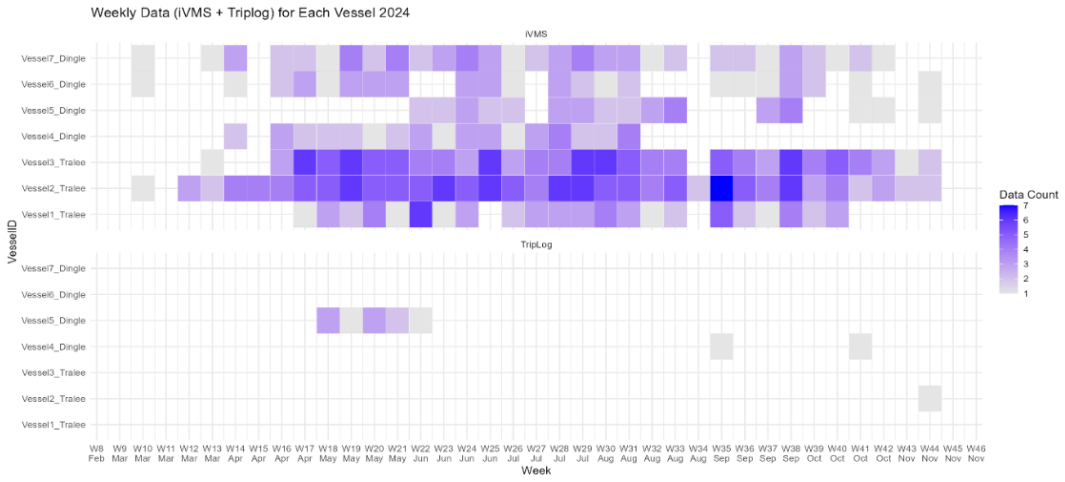
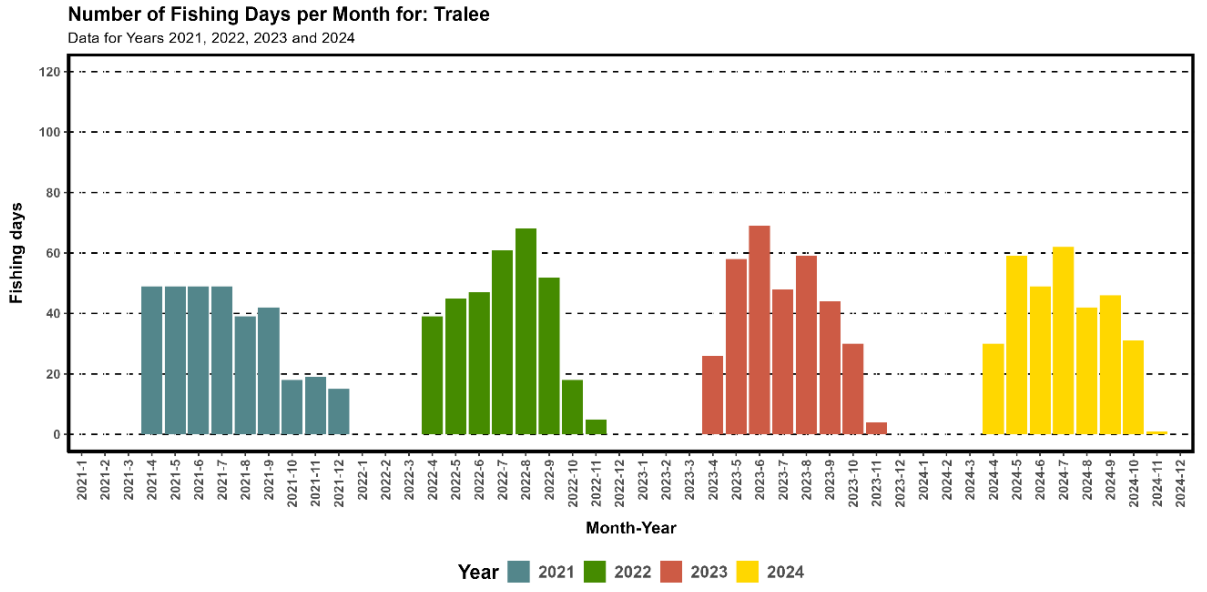


Figure 13. Estimated days at sea per week, year and vessel. iVMS days at sea are combined with the trip log data in the upper panels in each year. Trip logs without iVMS data are in the lower panels.

Table 11. Raised total days at sea per year and vessel group (Tralee, Dingle).

Vessel Group	2021	2022	2023	2024	Total
Tralee	329	335	340	327	**1,331**
Dingle	360	277	355	254	**1,246**



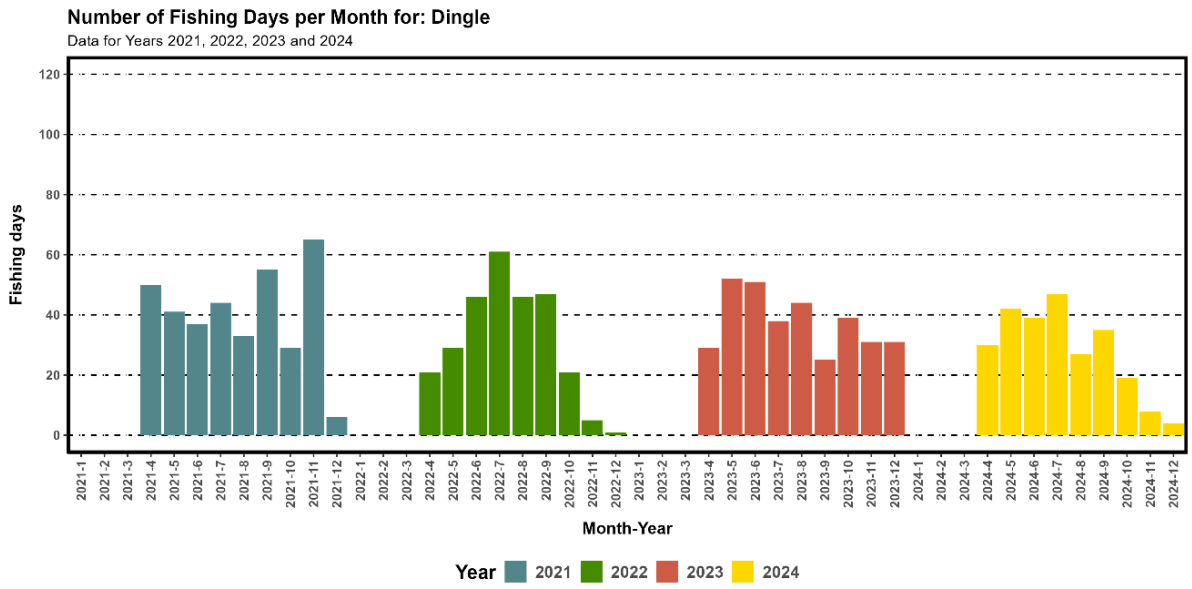


Figure 14. Raised monthly days at sea 2021-2024 of the Tralee and Dingle vessel groups.

Tralee vessels

Filtered iVMS records were mapped on a 500m x 500m grid. The total fishing effort (hours) for each grid cell was calculated by summing the time intervals between pings in each grid cell. Fishing activity was concentrated in the area west of Tralee Bay and south of Brandon Bay and during the months of April to Oct (Figure 15 and Figure 16).

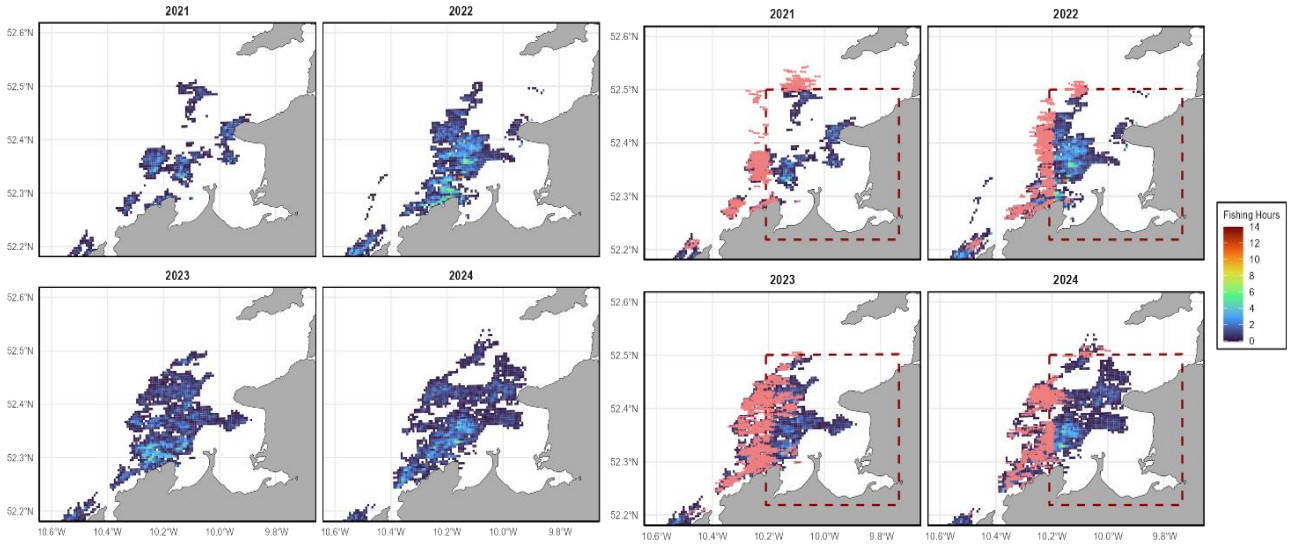


Figure 15. Spatial distribution of annual fishing hours for the Tralee vessel group 2021-2024. Locations for net hauls reported by skippers under contracted survey are shown in pink on the right panel. The dotted red line is an area closed to tangle nets.

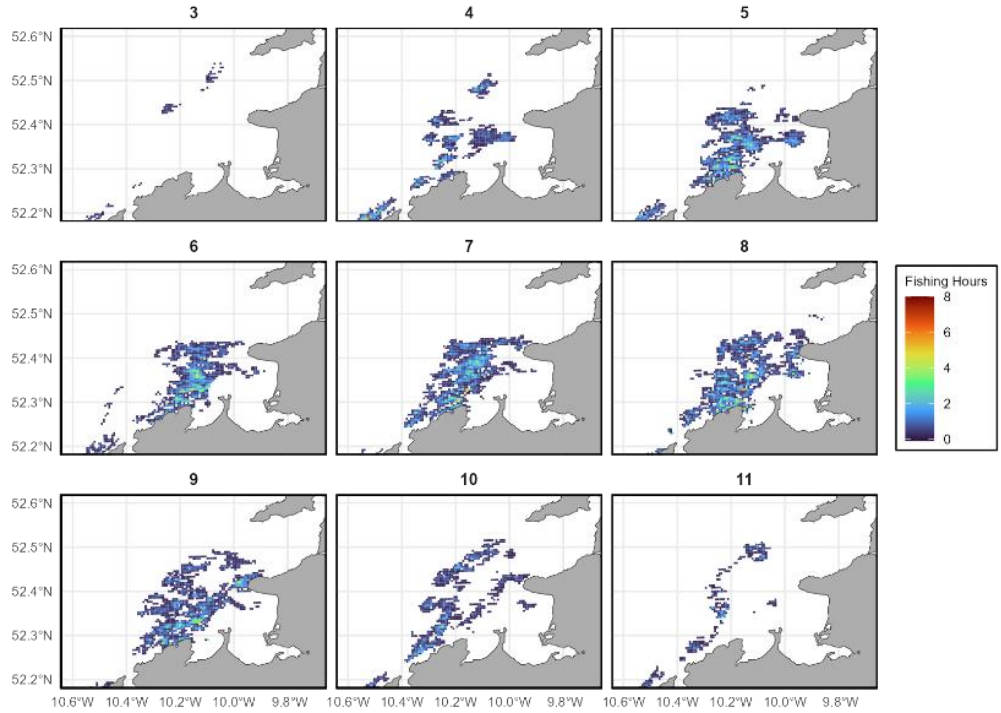


Figure 16. Spatial distribution of fishing activity by month for the Tralee Bay vessel group.

Dingle vessels

Fishing activity was concentrated around the Blasket Islands during the months of April to November (Figure 17 and Figure 18).

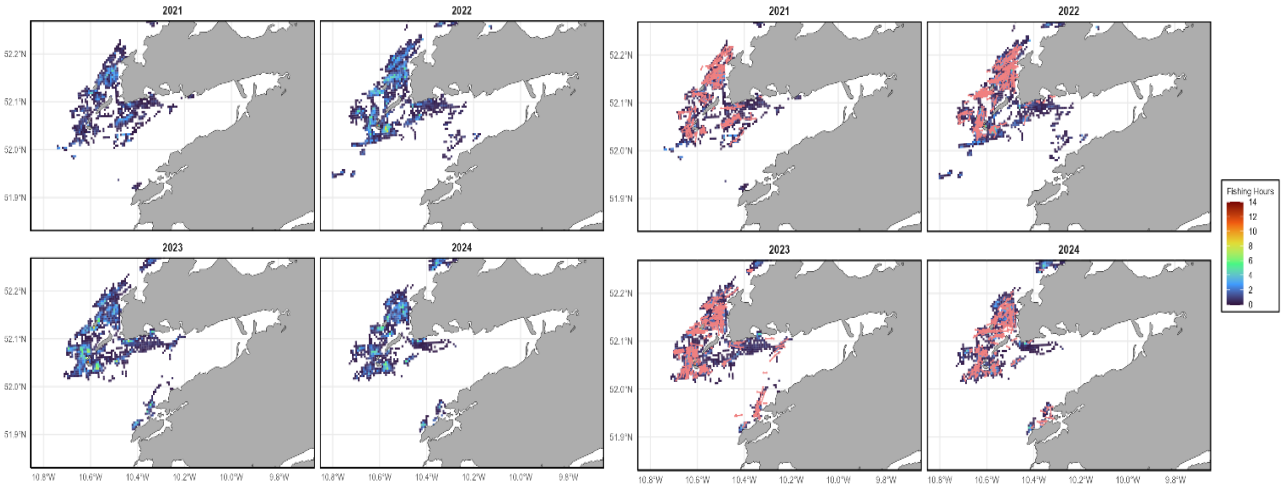


Figure 17. Spatial distribution of annual fishing hours for the Dingle vessel group 2021-2024. Locations for net hauls reported by skippers under contracted survey are shown in pink on the right panel.

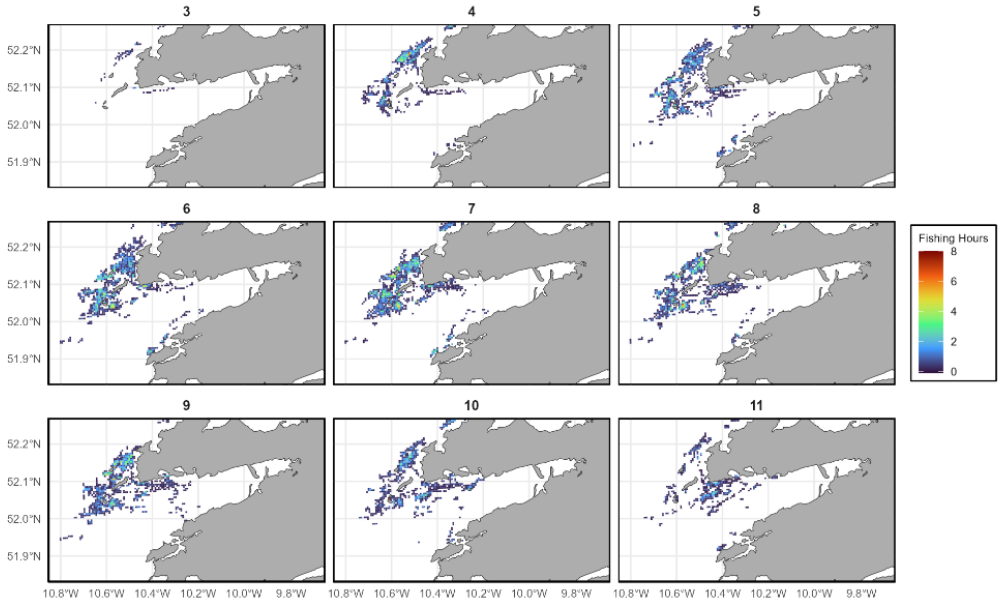


Figure 18. Spatial distribution of fishing activity by month for the Dingle Bay vessel group.

Comparison of landings and days at sea estimated from contracted reported data and iVMS to logbook declarations and sales notes

As described above, iVMS data provides direct evidence of how many days a vessel is fishing at sea. These data provide a census of fishing activity and were used to generate raised estimates of total landings and fishing effort by raising the reported data (contracted days when catch and bycatch were reported by observers or skippers) to the total number of iVMS days at sea. The resulting estimates were then compared with similar information from logbook declarations and sales notes. Logbook declarations by vessels over 10m provide estimates of days at sea and landings, while sales notes provide data on the volume and value of landings by vessel.

Days at sea per vessel and year, estimated from logbook declarations, ranged from 21 to 68% of the iVMS days reported (Table 12, Figure 19). Sales notes captured 11% to 87% of the estimated landings per vessel (Table 13). Some vessels were particularly poorly represented in both logbook declarations and sales note data. The number of sales is not representative of the number of days at sea, as catches are often accumulated over several days prior to sale. The average ratio of 6 between sales and fishing days is consistent with weekly sales patterns. The sales notes were, therefore, not used to compare days at sea with iVMS data for vessels under 10m.

Table 12. Landings of crayfish and days at sea per year and vessel group for Tralee and Dingle vessels over 10m in length estimated from logbook declarations. To preserve anonymity, data for Tralee are not shown as only 1 vessel reported declarations.

VesselID	Total Cray Landed Kgs	Mean ± SD (kgs per vessel)	Total Days at Sea	Mean ± SD (days per vessel)
2021_Tralee				
2022_Tralee				
2023_Tralee				
2024_Tralee				
TOTAL_Tralee				
2021_Dingle	7,153	1,788 ± 300	168	42 ± 17
2022_Dingle	7,386	1,846 ± 568	248	62 ± 40
2023_Dingle	8,131	2,033 ± 65	209	52 ± 17
2024_Dingle	6,081	1,520 ± 607	181	45 ± 17
TOTAL_Dingle	**28,751**		**806**	

Table 13. Landings of crayfish per year and vessel group for Tralee and Dingle vessels under 10m in length estimated from sales note data.

	Total Cray Landed Kgs	Mean ± SD (kgs per vessel)
2021_Tralee	4149	2074 ± 1,861
2022_Tralee	1735	867 ± 1,178
2023_Tralee	4757	1585 ± 189
2024_Tralee	6056	2018 ± 1,184
TOTAL_Tralee	**16,697**	
2021_Dingle	1222	611 ± 846
2023_Dingle	3076	769 ± 479
2024_Dingle	3519	879 ± 617
TOTAL_Dingle	**8,534**	

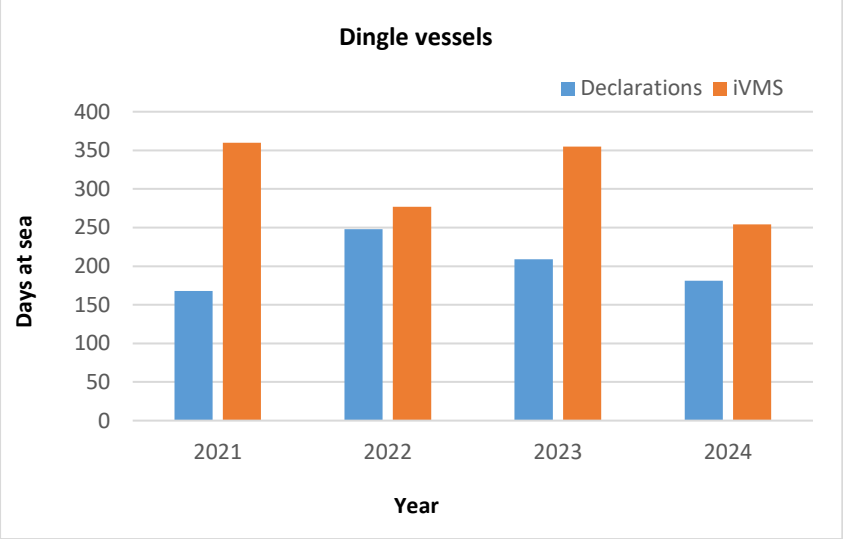


Figure 19. Annual days at sea for the contracted Dingle vessels estimated from iVMS data and logbook declarations.

Raised tangle net effort by year and vessel group

While the total number of days at sea was similar for both areas, the estimated fishing effort based on miles of net hauled was considerably higher in Tralee. The Tralee's vessels hauled an estimated 5,239 nm of net compared to 2,307 nm for Dingle vessels (Table 14). Annually, the estimated miles of net hauled in Tralee ranged from 1,241 nm to 1,393 nm, while in Dingle, it ranged from 498 nm to 689 nm.

Table 14. Raised total miles of net hauled per year and vessel group (Tralee, Dingle).

Vessel Group	2021	2022	2023	2024	Total miles of net
Tralee	1,334	1,271	1,241	1,393	**5,239**
Dingle	581	539	689	498	**2,307**

Raised catch of contracted vessels

Catches of crayfish per vessel group varied from 11,351 to over 16,000 crayfish and between 9-13.5 tonnes annually. Lobster catches were much lower amounting to 0.1-1.2 tonnes per year for all vessels (Table 15).

Table 15. Raised total catches (numbers, kgs) of crayfish and lobster by contracted vessels in Dingle and Tralee fleets for years 2021-2024.

	Total Cray Catch No	Mean ± SD (number per vessel)	Total Cray Catch Kgs	Mean ± SD (Kg per vessel)
2021_Tralee	13,624	4,541 ± 2,650	13,598	4,532 ± 2,049
2022_Tralee	13,483	4,494 ± 1,373	13,489	4,496 ± 1,829
2023_Tralee	13,581	4,527 ± 2,198	13,323	4,441 ± 2,772
2024_Tralee	11,351	3,784 ± 1,392	10,209	3,403 ± 1,812
TOTAL_Tralee	**52,039**		**50,619**	
2021_Dingle	12,103	3,026 ± 1,173	9,341	2,335 ± 985
2022_Dingle	12,932	3,233 ± 1,796	10,315	2,579 ± 1,409
2023_Dingle	16,310	4,077 ± 2,334	12,879	3,220 ± 1,788
2024_Dingle	15,891	3,973 ± 2,596	12,576	3,144 ± 1,938
TOTAL_Dingle	**57,236**		**45,111**	
	Total Lobster Catch No	**Mean ± SD (number per vessel)**	**Total Lobster Catch Kgs**	**Mean ± SD (Kg per vessel)**
2021_Tralee	228	76 ± 73	128	43 ± 35
2022_Tralee	534	178 ± 103	358	119 ± 24
2023_Tralee	378	126 ± 110	228	76 ± 33
2024_Tralee	238	79 ± 64	143	48 ± 32
TOTAL_Tralee	**1,377**		**857**	
2021_Dingle	1,288	322 ± 171	1,264	316 ± 160
2022_Dingle	1,155	289 ± 90	1,093	273 ± 99
2023_Dingle	1,264	316 ± 288	1,194	298 ± 319
2024_Dingle	817	204 ± 139	663	166 ± 109
TOTAL_Dingle	**4,524**		**4,214**	

Raised landings of contracted vessels

Landings were defined as those crayfish or lobster that were legal sized in the reported data and raised to the total days at sea. Total landings of crayfish ranged from 4,000 to over 9,000 crayfish and 4.4-11.3 tonnes per year per vessel group (Table 16). Using unit monthly prices from sales note data (Figure 20, Figure 21) the total value of the landings per vessel group ranged from €270,000 to €422,000 per year in Tralee and from €165,000 to €233,000 per year in Dingle. Lobster landings by comparison were only €1,500-4,000 per year in Tralee and €8,000-16,000 per year in Dingle (Table 17).

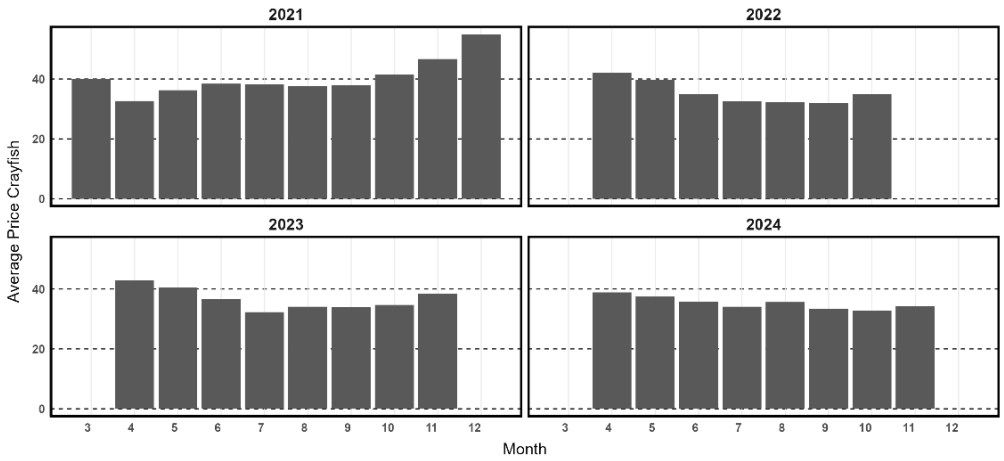
Table 16. Raised total landings (numbers, kgs) of crayfish and lobster for contracted vessels in Dingle and Tralee fleets for years 2021-2024.

	Total Cray Landed No	Mean ± SD (number per vessel)	Total Cray Landed Kgs	Mean ± SD (Kg per vessel)
2021_Tralee	8,951	2,984 ± 1626	11,029	3,676 ± 1,532
2022_Tralee	9,282	3,094 ± 1391	11,346	3,782 ± 1,787
2023_Tralee	9,559	3,186 ± 2322	11,073	3,691 ± 2,749
2024_Tralee	6,842	2,281 ± 1539	7,603	2,534 ± 1,844
TOTAL_Tralee	**34,634**		**41,051**	
2021_Dingle	4,116	1,029 ± 596	4,418	1,104 ± 679
2022_Dingle	5,016	1,254 ± 746	5,334	1,333 ± 768
2023_Dingle	6,168	1,542 ± 821	6,529	1,632 ± 839
2024_Dingle	5,678	1,419 ± 693	6,213	1,553 ± 740
TOTAL_Dingle	**20,978**		**22,494**	

	Total Lobster Landed No	Mean ± SD (number per vessel)	Total Lobster Landed Kgs	Mean ± SD (Kg per vessel)
2021_Tralee	147	49 ± 36	95	32 ± 21
2022_Tralee	374	125 ± 49	254	85 ± 15
2023_Tralee	182	61 ± 25	135	45 ± 14
2024_Tralee	150	50 ± 40	95	32 ± 25
TOTAL_Tralee	**853**		**579**	
2021_Dingle	1,110	278 ± 151	994	248 ± 131
2022_Dingle	978	245 ± 65	864	216 ± 66
2023_Dingle	1,039	260 ± 235	928	232 ± 252
2024_Dingle	672	168 ± 117	523	130 ± 87
TOTAL_Dingle	**3,799**		**3,309**	

Table 17. Raised value (€) of total landings of crayfish and lobster for contracted vessels in Dingle and Tralee fleets for years 2021-2024.

	Crayfish Landed Value (€)	Mean ± SD (value per vessel)
2021_Tralee	€422,000	€141,000 ± 67,000
2022_Tralee	€415,000	€138,000 ± 68,000
2023_Tralee	€398,000	€133,000 ± 98,000
2024_Tralee	€270,000	€90,000 ± 66,000
TOTAL_Tralee	**€1,505,000**	
2021_Dingle	€165,000	€41,000 ± 25,000
2022_Dingle	€191,000	€48,000 ± 27,000
2023_Dingle	€233,000	€58,000 ± 30,000
2024_Dingle	€219,000	€55,000 ± 26,000
TOTAL_Dingle	**€808,000**	
	Lobster Landed Value	**Mean ± SD (value per vessel)**
2021_Tralee	€1,500	€505 ± 346
2022_Tralee	€4,000	€1,000 ± 248
2023_Tralee	€2,000	€718 ± 228
2024_Tralee	€1,500	€508 ± 411
TOTAL_Tralee	**€9,000**	
2021_Dingle	€16,000	€4,000 ± 2,100
2022_Dingle	€14,000	€3,500 ± 1,000
2023_Dingle	€15,000	€3,700 ± 4,000
2024_Dingle	€8,000	€2,100 ± 1,400
TOTAL_Dingle	**€53,000**	



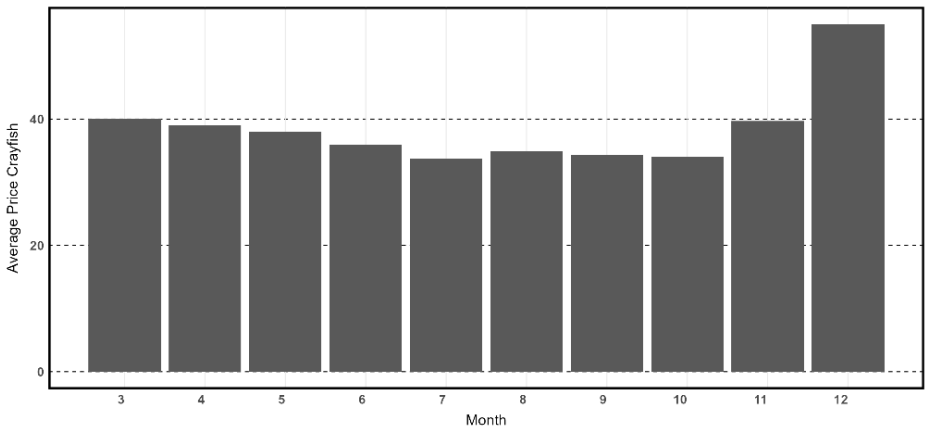


Figure 20. Month by year and average monthly prices across all years per kg at first sales for crayfish sourced from sales note data.

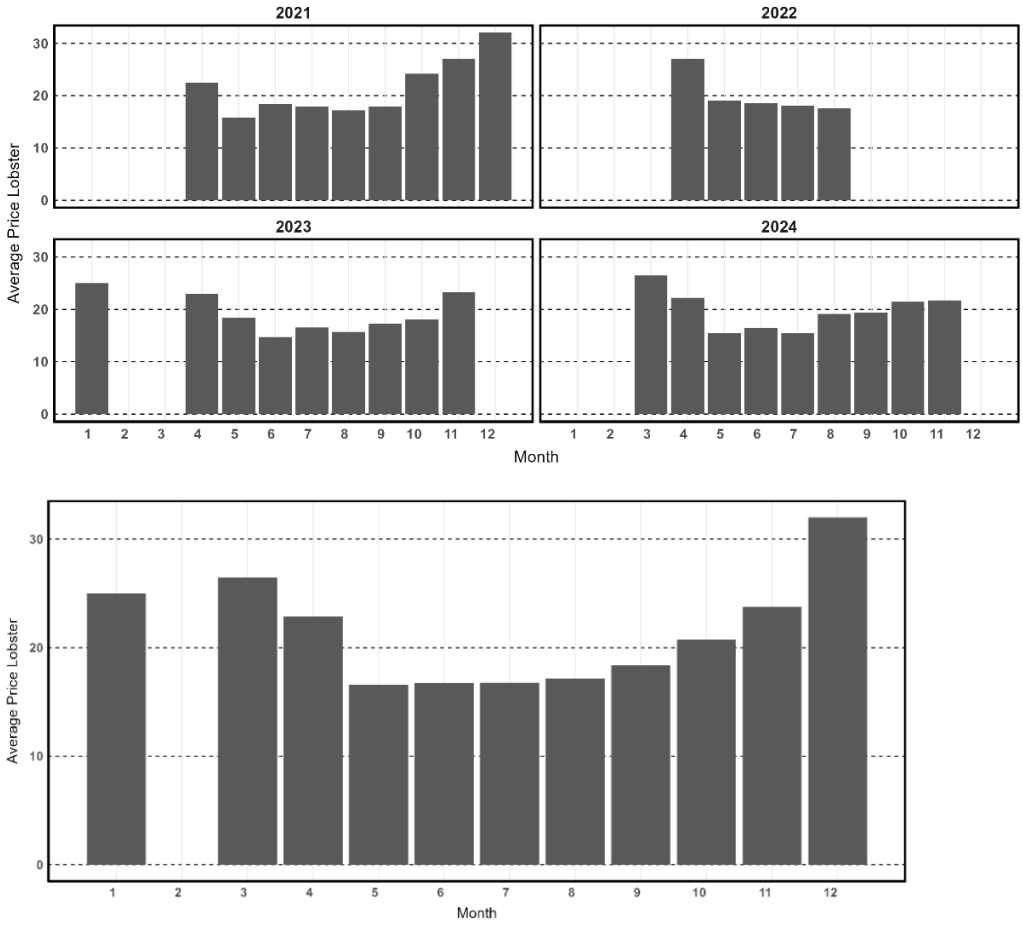


Figure 21. Month by year and average monthly prices across all years per kg at first sales for lobster sourced from sales note data.

Raised bycatch of contracted vessels by year and vessel group

Total numbers by species in the catch and bycatch reported data of contracted vessels were raised to total annual activity of the vessels using the ratio of reported contracted days to total iVMS active days (Table 18). The differences in catch profile of the two fleets for contracted days are further emphasised by the raising factors. Higher numbers of spider crab, brown crab, pollack, monkfish, turbot, spurdog, thornback ray, spotted ray flapper skate, tope, painted ray, sting ray, angel shark (none reported in the Dingle fleet), undulate ray and grey seal are caught by the Tralee Bay fleet.

Table 18. Estimated total catch and bycatch per species and year for Tralee (T) and Dingle (D) contracted vessels.

Species	2021_T	2022_T	2023_T	2024_T	Total_T	2021_D	2022_D	2023_D	2024_D	Total_D
Spider Crab (*Maja brachydactyla*)	21,790	19,410	19,737	21,933	**82,869**	5,576	5,224	7,003	9,553	**27,357**
Crayfish (*Palinurus elephas*)	15,017	14,456	14,527	11,982	**55,983**	12,746	13,295	16,629	16,129	**58,799**
Brown Crab (*Cancer pagurus*)	12,221	10,845	9,487	7,839	**40,392**	7,638	6,191	8,375	7,261	**2,9464**
Lobster (*Homarus gammarus*)	355	575	398	259	**1,587**	1,460	1,158	1,297	837	**4,752**
Pollack (*Pollachius pollachius*)	1,145	1,986	2,019	1,675	**6,825**	243	378	296	308	**1,225**
Monkfish (*Lophius spp*)	773	715	643	826	**2,956**	162	163	290	211	**826**
Turbot (*Scophthalmus maximus*)	308	478	510	358	**1,654**	34	56	110	75	**275**
Black Pollack (*Pollachius virens*)	0	56	0	0	**56**	0	10	0	3	**13**
Spurdog (*Squalus acanthias*)	8,044	6,790	6,581	4,905	**26,320**	391	230	312	117	**1,049**
Thornback (*Raja clavata*)	1,039	1,478	1,577	1,034	**5,128**	119	170	331	170	**790**
Dog fish (*Scyliorhinus spp*)	1,261	957	1,146	1,070	**4,434**	532	609	549	461	**2,151**
Spotted Ray (*Raja montagui*)	859	991	391	367	**2,607**	46	6	6	11	**69**
Flapper Skate (*Dipturus spp*)	413	426	302	109	**1,250**	41	90	24	64	**220**
Blonde Ray (*Raja brachyura*)	160	180	312	269	**921**	98	228	247	156	**729**
Grey Seal (*Halichoerus grypus*)	166	224	107	56	**554**	46	140	102	68	**355**
Tope (*Galeorhinus galeus*)	124	87	145	26	**382**	13	14	32	21	**80**
Painted Ray (*Raja microocellata*)	260	54	22	0	**336**	0	0	55	10	**65**
Sting Ray (*Dasyatis pastinaca*)	106	87	62	5	**260**	2	2	14	0	**18**
Angel Shark (*Squatina squatina*)	0	56	8	10	**74**	0	0	0	0	**0**
Undulate Ray (*Raja undulata*)	14	37	0	0	**51**	0	0	0	3	**3**
Harbour porpoise (*Phocoena phocoena*)	0	0	0	0	**0**	0	2	0	0	**2**
Common dolphin (*Delphinus delphis*)	0	0	3	0	**3**	0	0	0	0	**0**
Risso's dolphin (*Grampus gripeus*)	0	4	0	0	**4**	0	0	0	0	**0**
TOTAL	64,055	59,890	57,978	52,722	**234,645**	29,149	27,966	35,674	35,456	**128,244**

Raised (to fleet level) estimates of catch and bycatch by year and area

Not all vessels using tangle nets in the Dingle and Tralee fleets were contracted to report data. Using raising procedures described above the total fishing effort, catch and bycatch of vessels reporting data was raised to fleet level to include all vessels in the Dingle and Tralee tangle net fleets (Table 19, Table 20). These raised data are the first to provide reliable (low raising factors) estimates of fleet level

bycatch of protected and endangered species that are caught by tangle nets annually from Dingle Bay north to Kerry Head.

Table 19. Total fishing effort (miles of nets) for Tralee and Dingle vessels. These are estimates raised to fleet level.

Vessel Group	2021	2022	2023	2024	Total miles of net
Tralee	1,351	1,305	1,345	1,995	**5,996**
Dingle	1,164	942	790	831	**3,727**

Table 20. Total catch and bycatch per species and year for Tralee (T) and Dingle (D) vessels. These are estimates raised to fleet level for all vessels identified as fishing with tangle nets in the Dingle and Tralee Bay area fishing grounds.

Species	2021_T	2022_T	2023_T	2024_T	Total_T	2021_D	2022_D	2023_D	2024_D	Total_D
Spider Crab (*Maja brachydactyla*)	22,065	19,928	21,390	31,422	**94,805**	11,157	9,119	8,026	15,954	**44,255**
Crayfish (*Palinurus elephas*)	15,207	14,842	15,744	17,167	**62,960**	25,504	23,206	19,057	26,934	**94,702**
Brown Crab (*Cancer pagurus*)	12,376	11,135	10,281	11,231	**45,022**	15,282	10,806	9,598	12,126	**47,812**
Lobster (*Homarus gammarus*)	359	590	432	371	**1,752**	2,921	2,021	1,487	1,397	**7,827**
Pollack (*Pollachius pollachius*)	1,160	2,039	2,188	2,399	**7,786**	487	660	339	515	**2,000**
Monkfish (*Lophius spp*)	783	734	696	1,183	**3,396**	324	284	332	352	**1,293**
Turbot (*Scophthalmus maximus*)	312	491	553	512	**1,868**	69	98	126	126	**417**
Black Pollack (*Pollachius virens*)	0	57	0	0	**57**	0	18	0	5	**23**
Spurdog (*Squalus acanthias*)	8,146	6,971	7,133	7,027	**29,276**	782	401	358	195	**1,735**
Thornback (*Raja clavata*)	1,052	1,518	1,709	1,482	**5,760**	239	297	380	283	**1,199**
Dog fish (*Scyliorhinus spp*)	1,277	983	1,242	1,533	**5,035**	1,065	1,063	629	769	**3,527**
Spotted Ray (*Raja montagui*)	870	1017	423	525	**2,835**	93	10	7	19	**128**
Flapper Skate (*Dipturus spp*)	418	437	328	156	**1,338**	82	158	28	106	**374**
Blonde Ray (*Raja brachyura*)	162	185	338	385	**1,070**	196	398	283	261	**1,138**
Grey Seal (*Halichoerus grypus*)	168	230	116	80	**595**	91	245	116	113	**566**
Tope (*Galeorhinus galeus*)	126	89	158	37	**409**	27	25	37	35	**123**
Painted Ray (*Raja microocellata*)	263	55	24	0	**343**	0	0	63	17	**80**
Sting Ray (*Dasyatis pastinaca*)	107	90	67	7	**271**	5	3	16	0	**24**
Angel Shark (*Squatina squatina*)	0	57	9	15	**81**	0	0	0	0	**0**
Undulate Ray (*Raja undulata*)	15	38	0	0	**53**	0	0	0	5	**5**
Harbour porpoise (*Phocoena phocoena*)	0	0	0	0	**0**	0	3	0	0	**3**
Common dolphin (*Delphinus delphis*)	0	0	3	0	**3**	0	0	0	0	**0**
Risso's dolphin (*Grampus gripeus*)	0	4	0	0	**4**	0	0	0	0	**0**
TOTAL	64,864	61,489	62,835	75,533	**26,4721**	58,323	48,815	40,883	59,211	**207,232**

Reported elasmobranch bycatch

Elasmobranch bycatch was reported by all contracted vessels between 2021 and 2024 and is reported below without raising.

Sensitivity of elasmobranchs to fishing mortality

Sharks, skates and rays have biological characteristics that make them highly vulnerable to depletion. This has led to dramatic population declines in the northeast Atlantic over the past century and locally in Tralee Bay in the case of angel shark. These species are typically long lived, slow growing, late maturing, have protracted breeding cycles and often produce very few offspring, resulting in very low population growth rates and limited capacity to recover from overfishing and other threats such as pollution or habitat destruction (Ellis *et al.* 2008). Extinction risk is inversely related to the intrinsic rate (r) of population increase and total mortality should not exceed r if population decline is to be prevented. Age at maturity for flapper skate for instance may be as high as 21 years (Régnier *et al*. 2021) suggesting that such species are very sensitive to fishing or other sources of mortality as the cumulative mortality prior to maturity may result in very few individuals reaching maturity.

Their large size, unique morphology and aggregating nature also make them more susceptible to catch in entangling nets. Additionally, the high mobility and migrations of many species, incorporates another level of complexity to their assessment and highlights the need for proper knowledge of stock structure and dynamics to enable effective management. Elasmobranch fisheries assessment is complicated further by the problem of identification of landings to species level. This data deficiency represents a significant barrier to developing dedicated action plans and implementing effective management measures (Régnier, 2024). Designing spatial management strategies, requires detailed knowledge of habitat use, species distribution, and the identification of areas of high vulnerability.

Status of elasmobranchs that occur in Irish waters

Ireland's waters contain a wide variety of shark (38 species), skates and rays (32 species) and chimaeras (7 species) (Varian, 2011; Clarke *et al*. 2016). Tralee Bay supports a high diversity of these elasmobranch species, some of which are now critically endangered or endangered in Ireland, the Atlantic region and globally (Table 21).

The status of some species has changed since the last IUCN assessment. For instance, spurdog has recovered to the extent that there is now a fisheries quota for the species.

Elasmobranchs bycatch data from the crayfish fishery is used below to estimate the distribution and relative abundances of 11 species in the southwest coast of Ireland: angel shark, flapper skate, tope, spurdog, dogfish, undulate ray, stingray, blonde ray, thornback ray, painted ray and spotted ray. There were no records of cuckoo ray or white skate although these species were recorded in the area in 2018-2019.

Table 21. Conservation status listing of Elasmobranch species.

Species	IUCN Global Redlist	Irish Redlist	European Redlist	NE Atlantic Redlist
Thornback Ray (*Raja clavata*)	Near threatened	Least concern	Near threatened	Near threatened
Painted Ray (*Raja microocellata*)	Least concern	Least concern	Near threatened	Near threatened
Stingray (*Dasyatis Pastinaca*)	Data deficient	Endangered	Least concern	Least concern
Undulate Ray (*Raja undulata*)	Endangered	Endangered	Near threatened	Endangered
Blonde Ray (*Raja brachyura*)	Near threatened	Near threatened	Near threatened	Near threatened
Spotted Ray (*Raja montagui*)	Least concern	Least concern	Least concern	Least concern
Spurdog (*Squalus acanthias*)	Endangered	Vulnerable	Endangered	Critically endangered
Angel Shark (*Squatina squatina*)	Critically endangered	Critically endangered	Critically endangered	Critically endangered
Flapper Skate (*Dipturus spp*)	Critically endangered	Critically endangered	Critically endangered	Critically endangered
Tope (*Galeorhinus galeus*)	Critically endangered	Vulnerable	Vulnerable	Data deficient
Dogfish (*Scyliorhinus spp*)	Near threatened	Least concern	Near threatened	Near threatened
White skate (*Rostroraja alba*)	Endangered	Critically endangered	Critically endangered	Critically endangered
Cuckoo ray (*Leucoraja naevus*)	Least concern	Vulnerable	Least concern	Least concern

Critically endangered species - Angel Shark (*Squatina squatina*) and Flapper Skate (*Dipturus spp*)

A total of 444 Flapper skate and 22 angel sharks were observed and reported in contracted data during 2021-2024. The catches of flapper skate in 2021 peaked in November, while in 2022-2024 the catches were higher during the spring. The catches of angel shark reached the maximum number in August-September 2022 when 6 individuals were reported (Figure 22). Incidental bycatch of Angel sharks was also reported in inner Tralee Bay over the oyster beds east of Fenit. Two were captured and released from oyster dredges in autumn of 2024.

The proportion of zero hauls for angel shark and flapper skate was consistently high throughout the year, indicating that these species were rarely encountered. When present, mean catch size was low, around 1–1.5 individuals per haul (Figure 23, Figure 24).

Spatial distribution of angel shark bycatch was concentrated in a few specific locations. Most of the reported catches were northwest of Tralee Bay, with 1 record (no location) in the Dingle area. Flapper skate show a much broader spatial distribution from Kerry Head south to the Blaskets and Dingle Bay (Figure 25).

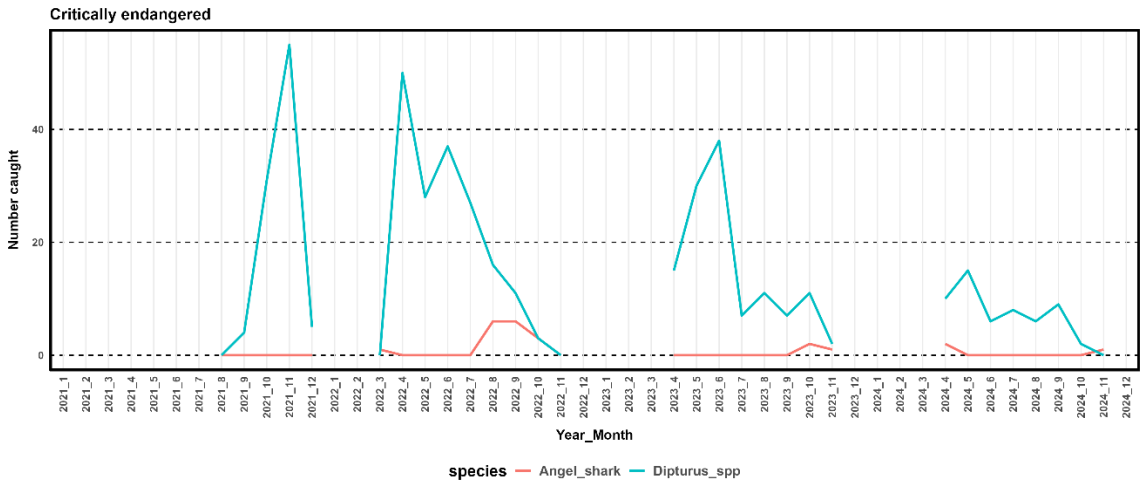


Figure 22. Numbers of flapper skate (Dipturuss spp) and angel shark reported by skippers and scientific observers monthly during 2021-2024.

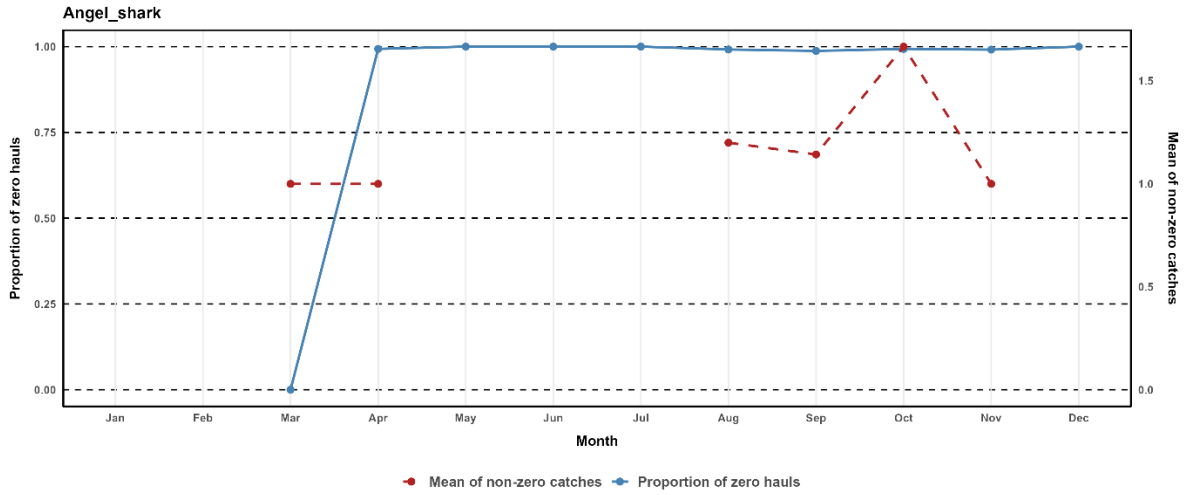


Figure 23. Proportion of hauls with zero bycatch and the mean number of angel shark in hauls where they were encountered per month (all years combined).

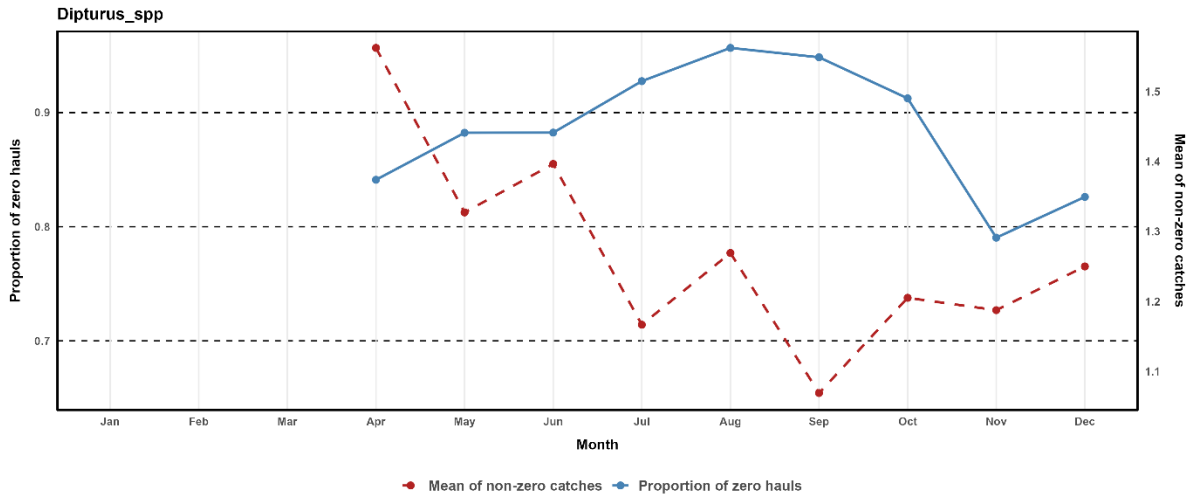


Figure 24. Proportion of hauls with zero bycatch and mean number of flapper skate (Dipturus spp) in hauls where they were encountered per month (all years combined).

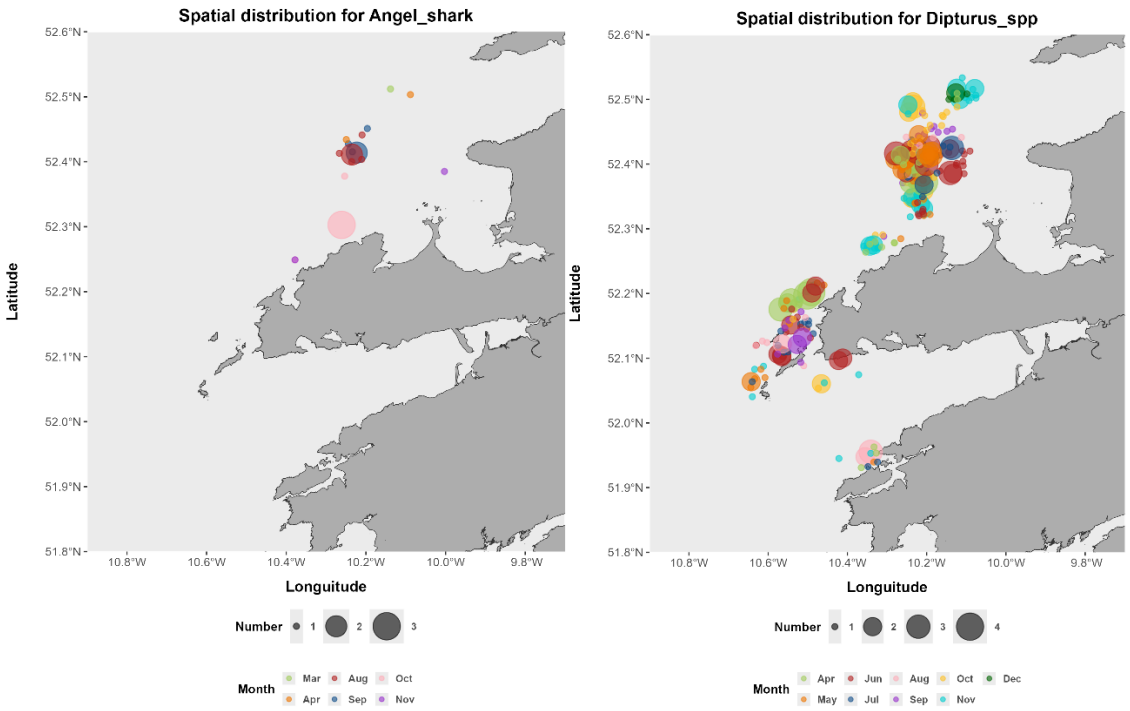


Figure 25. Spatial distribution of reported captures of flapper skate (Dipturus spp) and angel shark by month.

The significance of Angel shark bycatch

Angel shark continue to suffer fishery bycatch mortality in Tralee Bay which holds the last remnant populations of this species in the NE Atlantic. There is a high risk of extinction of this species at local, NE Atlantic and global level if bycatch continues. The Canary Islands is a remaining hotspot for the species in the Atlantic. Historically, and until the 1980s, Tralee Bay (Shepherd *et al*. 2019) was an important and well-known centre of distribution in Irish waters. It supported an economically important recreational angling sector in inner Tralee Bay. The species also occurred in Clew Bay and Galway Bay and in the Irish Sea in Cardigan Bay (Hiddink *et al*. 2019). The species is a prohibited species in the common fisheries policy meaning that it must be released immediately when captured. However, this protection is not sufficient for critically endangered species where the process of capture can lead to mortality and where the size of the extant population may be extremely low. Although at least some angel shark caught were released alive (two were tagged with satellite tags) the proportion killed in tangle nets is probably high given the long net soak times used in the tangle net fishery.

The significance of flapper skate bycatch

Critically endangered flapper skate is captured in a number of fishing gears in Irish waters including bottom trawls and bottom set nets and is targeted (catch and release) by recreational anglers. Post release survival depends on physical trauma and physiological stress associated with capture. Capture in tangle nets with multiple day soak times may cause injury and mortality. In outer Tralee Bay injured and stressed fish are often killed by scavenging peracarid crustaceans. Depleted populations of skate cannot sustain significant fishing mortality at local level (given high site fidelity) or over wider geographic areas given their life history and in particular high age at maturity.

Habitat requirements, especially for egg laying, and the mobility and relative site fidelity of mature female skate are important considerations for conservation management of skate. There is an inverse relationship between body size and water depth, and skate move into shallow (25-75m) water over winter months. Large female skate migrate to these shallow waters for egg laying (Thorburn *et al*. 2021). Tangle net bycatch on large skate may, therefore, have significant negative effects on the

number of spawning skate. Removal of fishing pressure in marine protected areas for skate in Scotland has led to significant recovery of the species in these areas as skate in these sites show high site fidelity (Régnier *et al*. 2024).

Endangered species - Sting Ray (*Dasyatis pastinaca*) and Undulate Ray (*Raja undulata*)

A total of 83 stingrays and 16 undulate rays were reported during 2021-2024. Stingray was caught more frequently than undulate ray. Catches of undulate ray were generally low throughout 2021-2024, with a peak of 11 individuals caught in April 2022. None were reported in 2023, and one individual was caught in August 2024 (Figure 26).

The proportion of zero hauls was close to 1 throughout the year. When present, stingray showed slightly higher variability in mean catch size (1.0-1.8 individuals) across April-June and August-December, whereas undulate ray occurred only sporadically with consistently low catch numbers (Figure 27, Figure 28)

Catches of both species were concentrated mainly in the northwest of Tralee Bay (Figure 29).

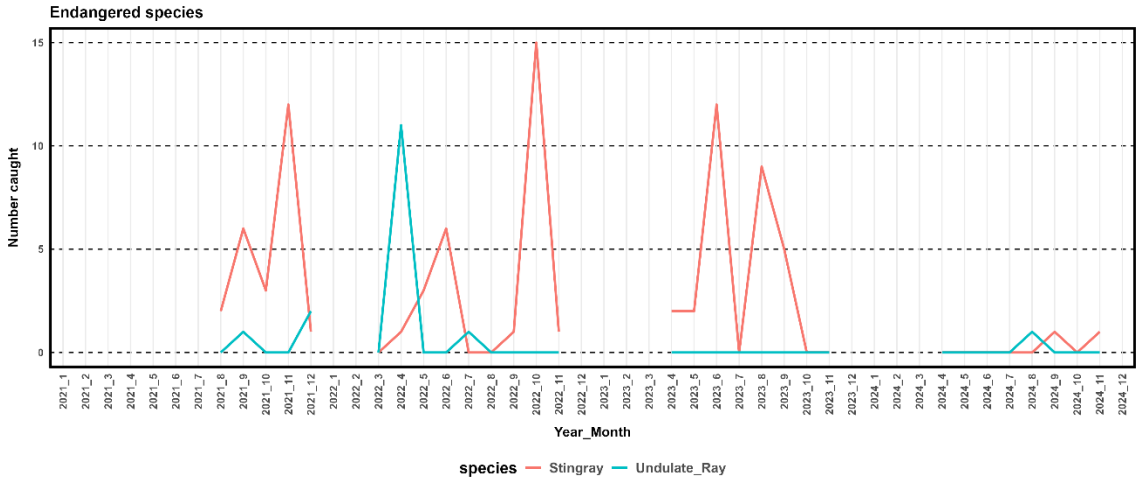


Figure 26. Numbers of sting ray and undulate ray reported by skippers and scientific observers monthly during 2021-2024.

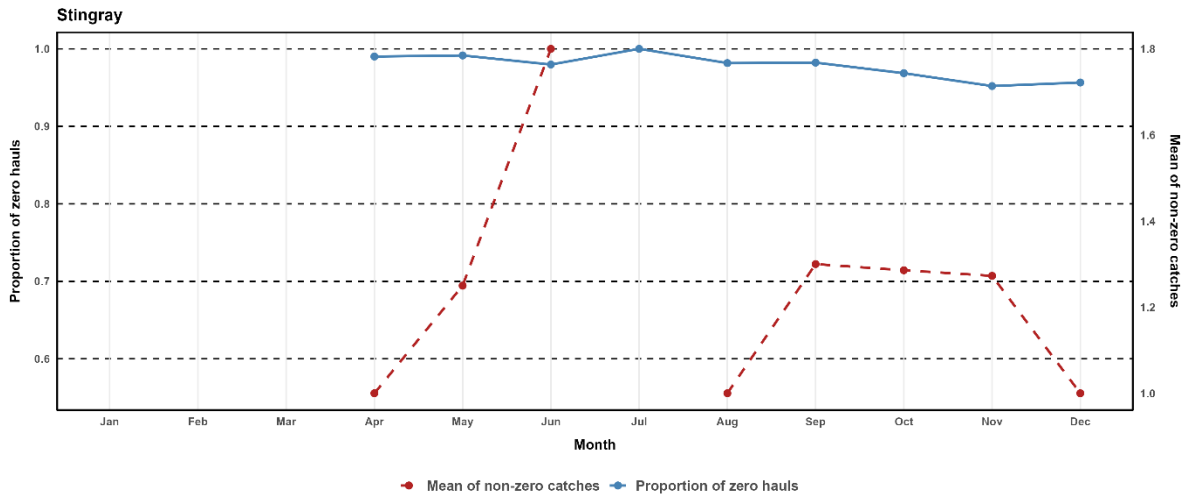


Figure 27. Proportion of hauls with zero bycatch and mean number of stingray in hauls where they were encountered per month (all years combined).

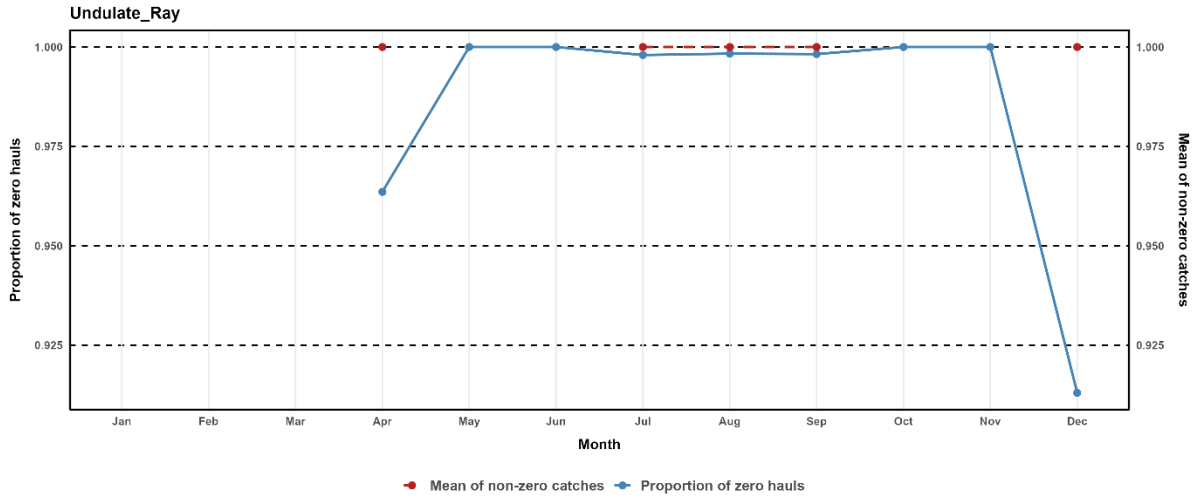


Figure 28. Proportion of hauls with zero bycatch and mean number of undulate ray in hauls where they were encountered per month (all years combined).

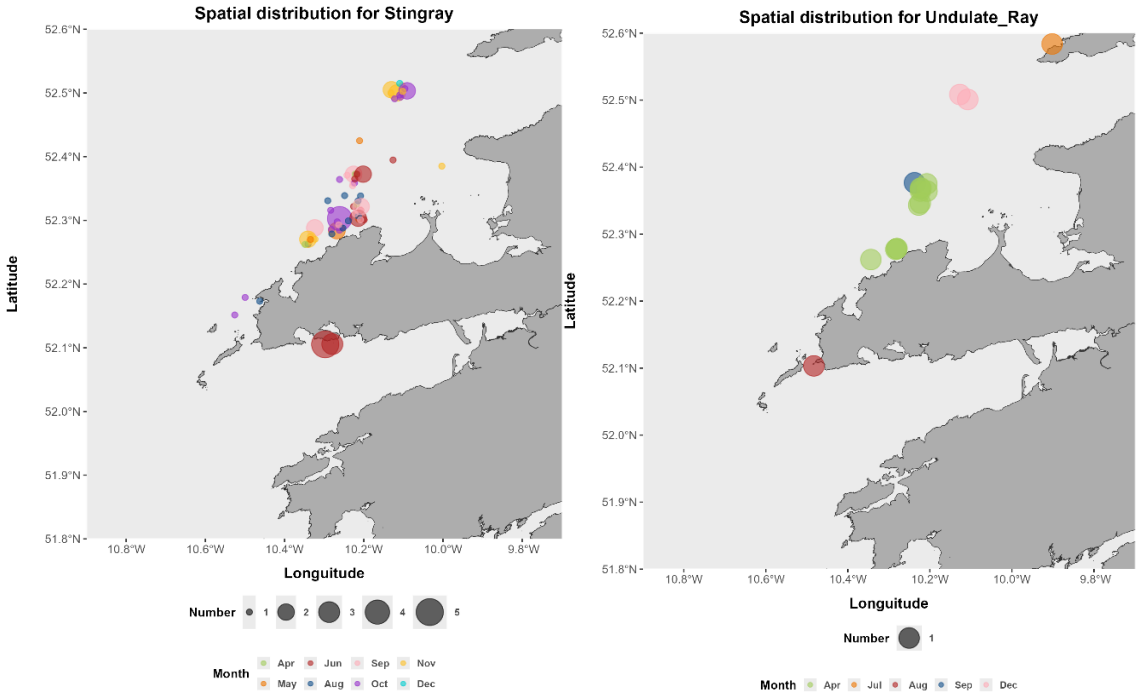


Figure 29. Spatial distribution of reported captures of sting ray and undulate ray by month.

Vulnerable species - Spurdog (*Squalus acanthias*) and Tope (*Galeorhinus galeus*)

A total of 7,613 spurdog and 158 tope were reported caught during 2021-2024. Both species were present from April to November. The number of spurdog was higher in 2021-2023 than in 2024 (Figure 30).

Spurdog was present throughout the year, with mean non-zero catch peaking in late summer and declining towards winter (Figure 31). There was a high percentage of zero hauls for Tope throughout the year while mean non-zero catches increased steadily from spring, peaked in summer, and dropped in December (Figure 32).

Catches of both species were highest along the north coast of the Dingle peninsula (Figure 33).

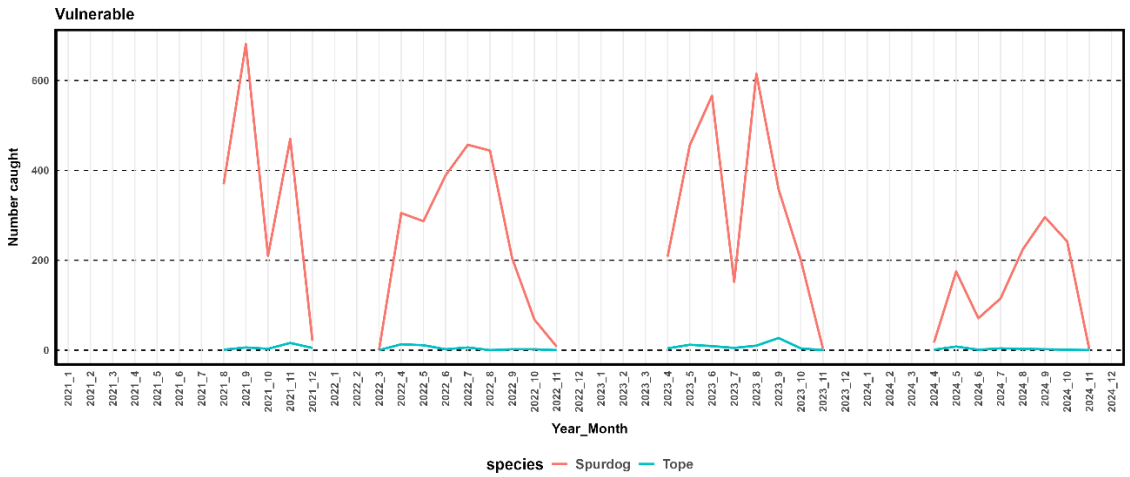


Figure 30. Numbers of spurdog and tope reported by skippers and scientific observers monthly during 2021-2024.

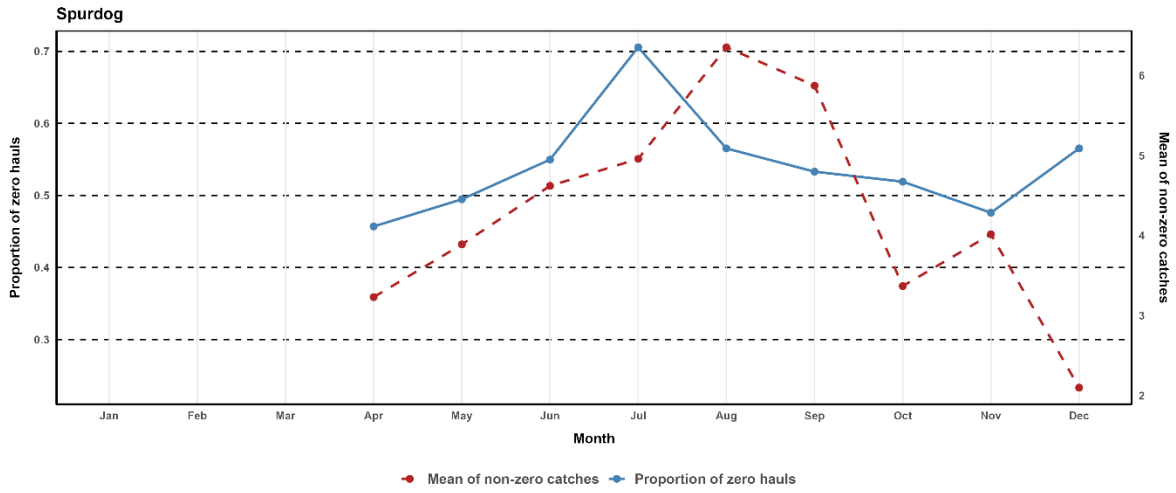


Figure 31. Proportion of hauls with zero bycatch and mean number of spurdog in hauls where they were encountered per month (all years combined).

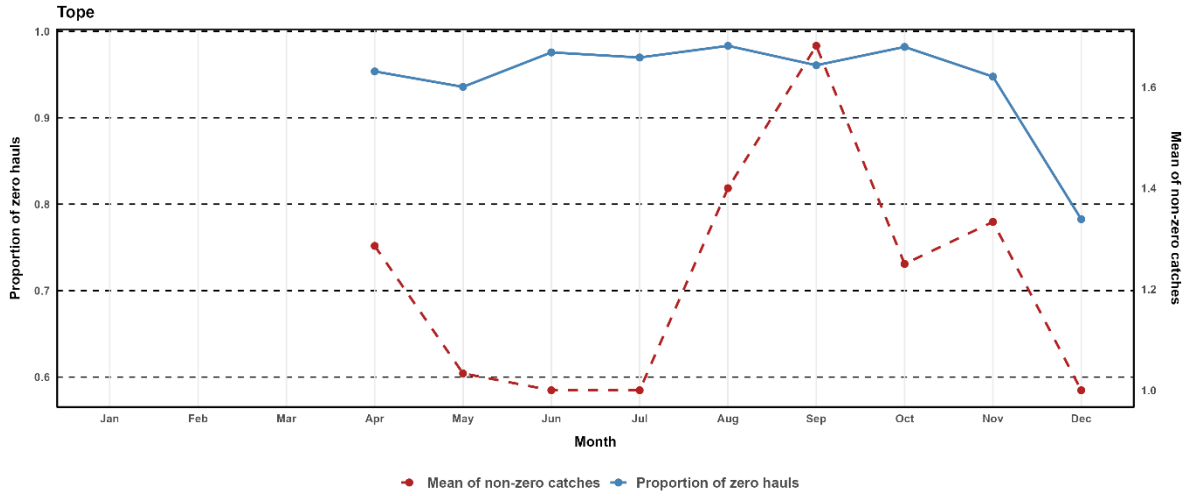


Figure 32. Proportion of hauls with zero bycatch and mean number of tope in hauls where they were encountered per month (all years combined).

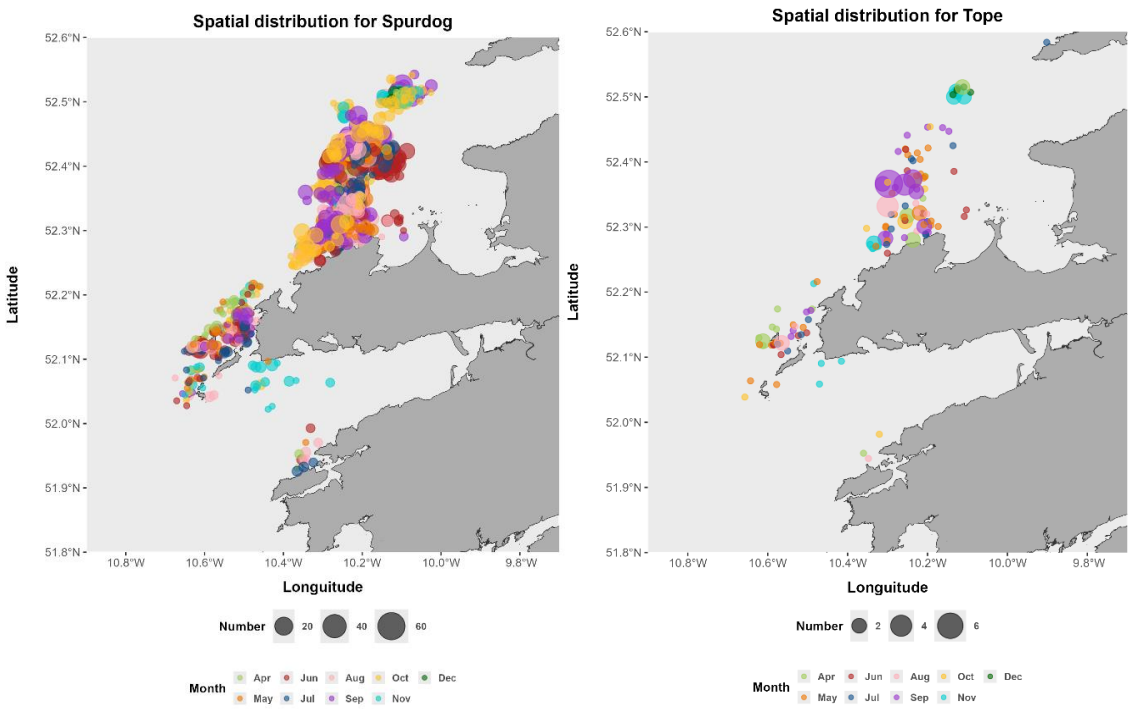


Figure 33. Spatial distribution of reported captures of spurdog and tope by month.

Near threatened species - Blonde Ray *(Raja brachyura)*

Blonde ray were reported as bycatch in most of the area where tangle nets were fished. A few catches were observed south of Dingle Bay. Higher number of individuals were caught during April-August. The mean of non-zero catches peaked in June with a second peak in October (Figure 34, Figure 35, Figure 36).

Figure 34. Numbers of blonde ray reported by skippers and scientific observers monthly during 2021-2024.

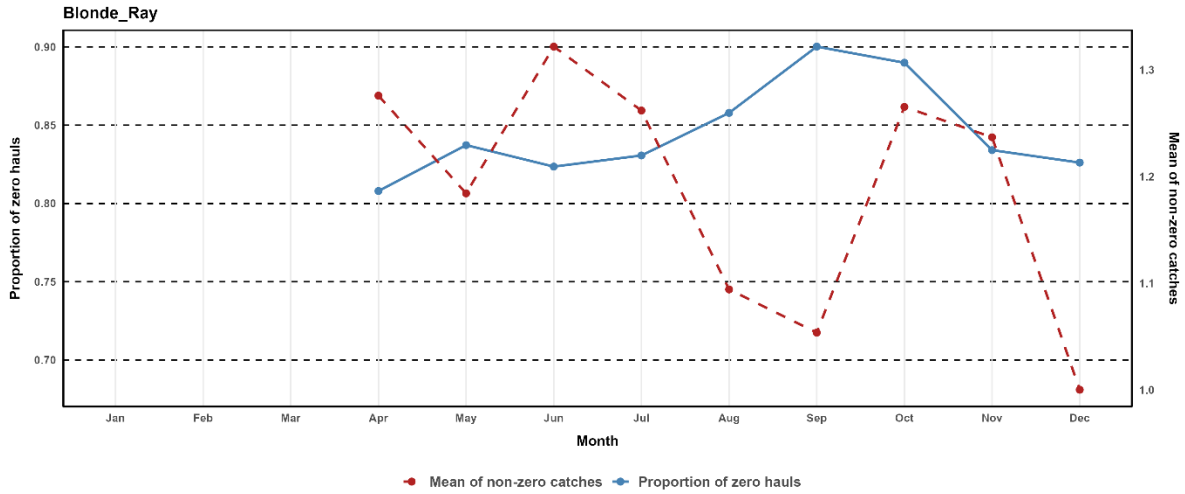


Figure 35. Proportion of hauls with zero bycatch and mean number of blonde ray in hauls where they were encountered per month (all years combined).

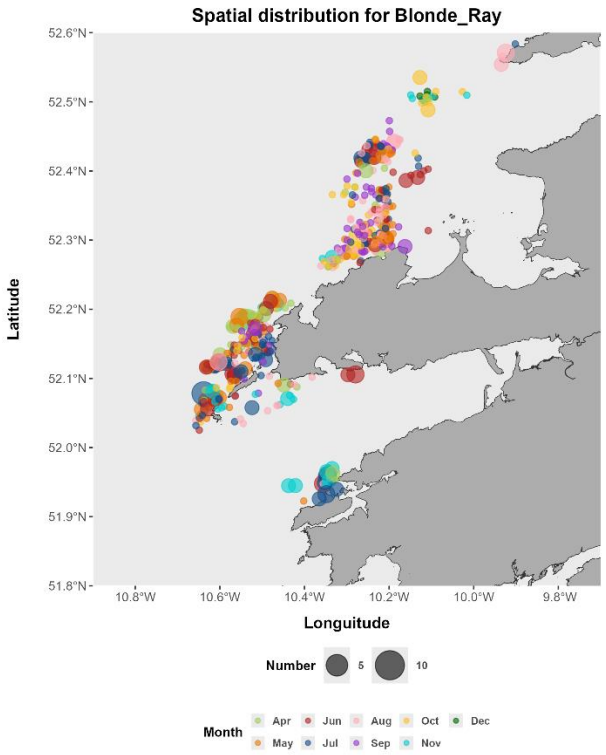


Figure 36. Spatial distribution of reported captures of blonde ray by month.

Species of least concern – Dogfish (*Scyliorhinus spp*), Thornback Ray (*Raja clavata*), Spotted Ray (*Raja montagui*) and Painted Ray (*Raja microocellata*)

Dogfish, thornback ray, spotted ray and painted ray were reported in all months April-November and throughout the fishing area. Thornback ray and dogfish were reported in higher numbers (Figure 37, Figure 38, Figure 39, Figure 40, Figure 41, Figure 42).

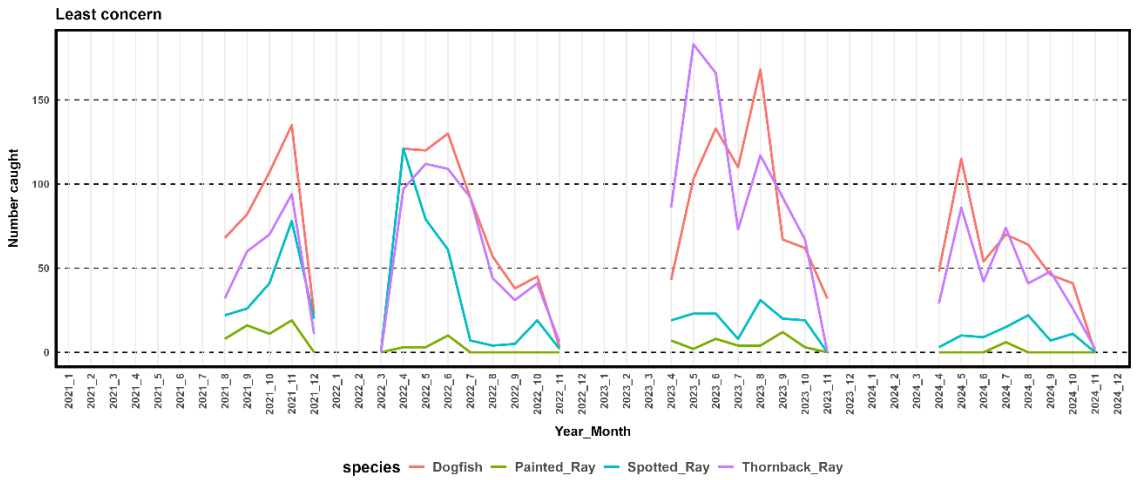


Figure 37. Numbers of dogfish, spotted ray, thornback ray and painted ray reported by Skippers and scientific observers monthly during 2021-2024.

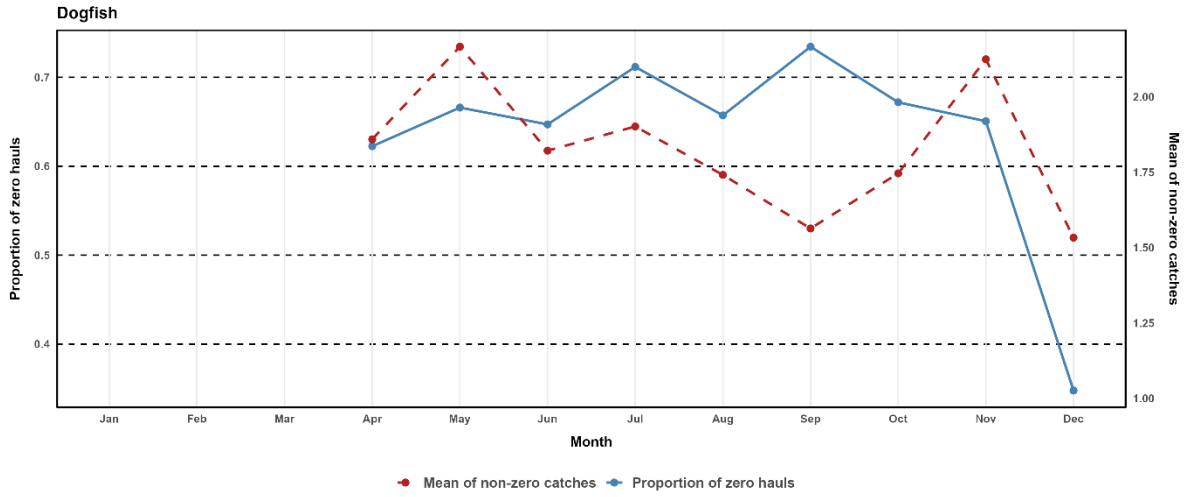


Figure 38. Proportion of hauls with zero bycatch and mean number of dogfish in hauls where they were encountered per month (all years combined).

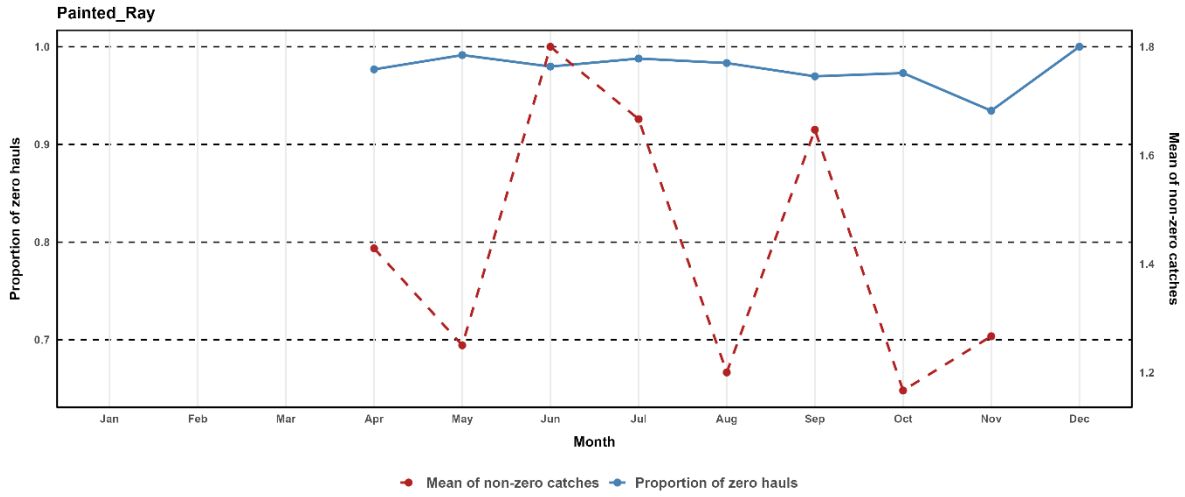


Figure 39. Proportion of hauls with zero bycatch and mean number of painted ray in hauls where they were encountered per month (all years combined).

Figure 40. Proportion of hauls with zero bycatch and mean number of spotted ray in hauls where they were encountered per month (all years combined).

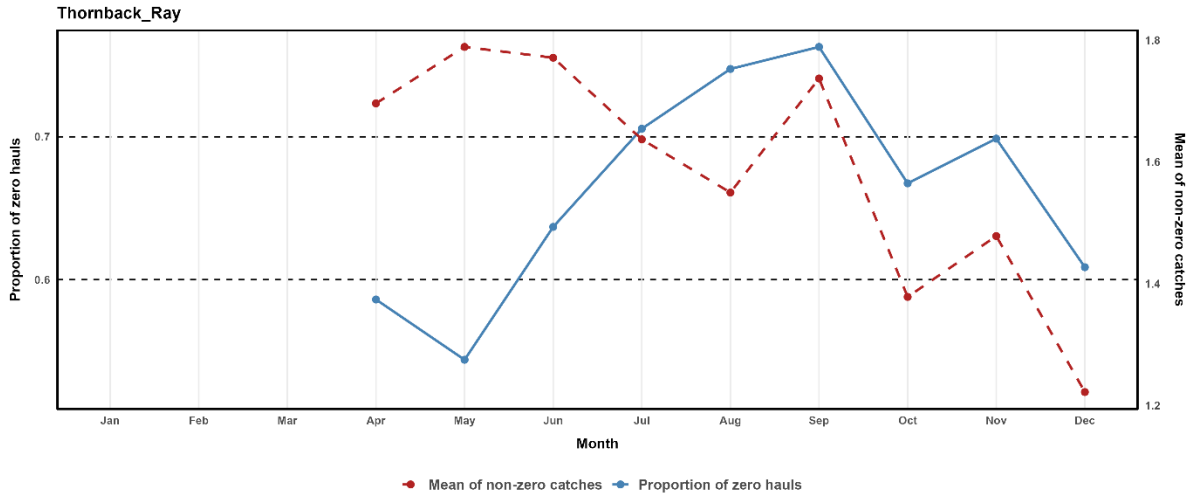


Figure 41. Proportion of hauls with zero bycatch and mean number of thornback ray in hauls where they were encountered per month (all years combined).

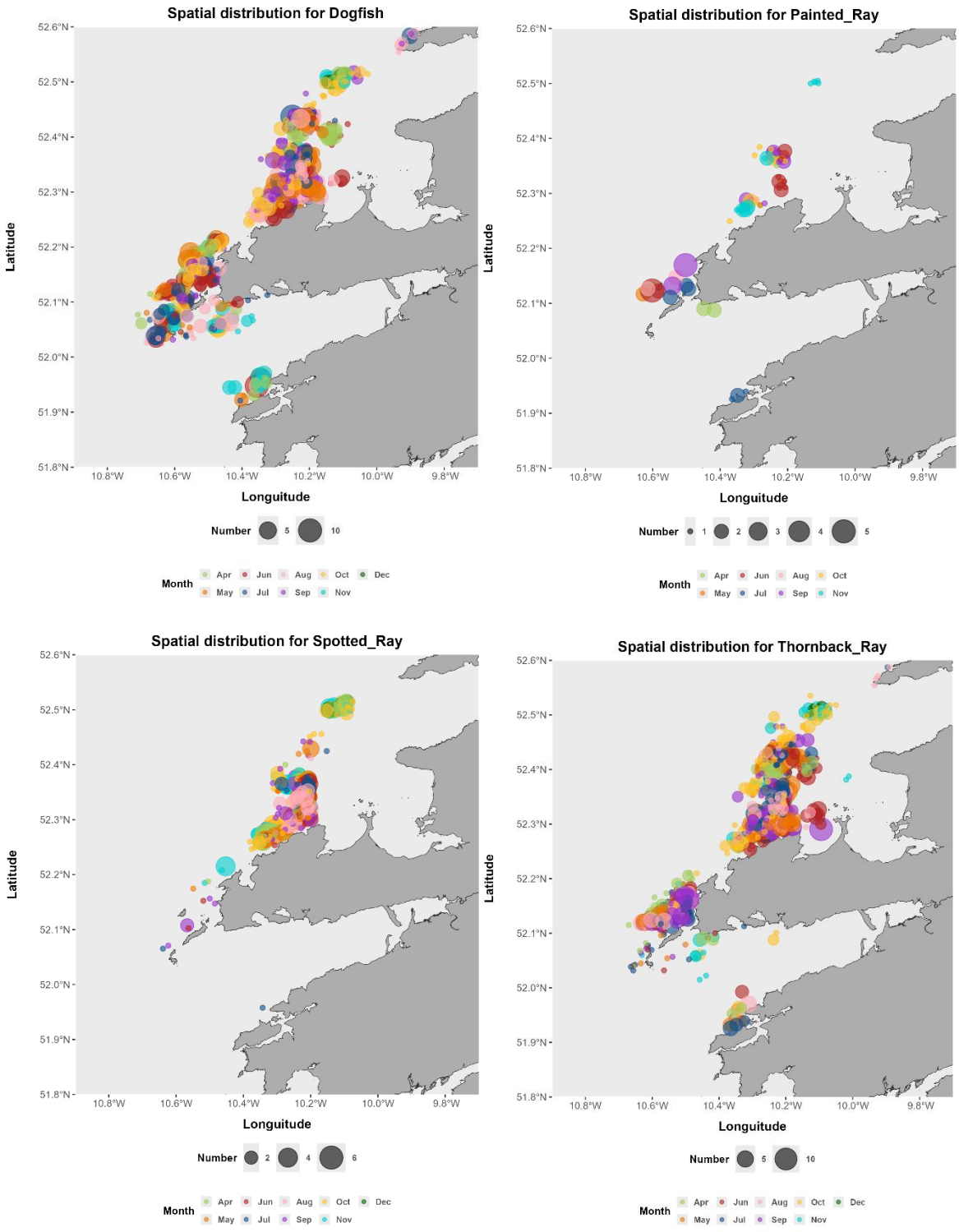


Figure 42. Spatial distribution of reported captures of dogfish, spotted ray, thornback ray and painted ray by month.

Grey seal bycatch

A total of 331 grey seals were observed in bycatch during 2021-2024 by skippers and observers. Grey seals were caught in all months when the fishery operated but bycatch peaked in April and declined during the summer (Figure 43). The mean of non-zero catches remained stable throughout the year at about one seal per haul (Figure 44).

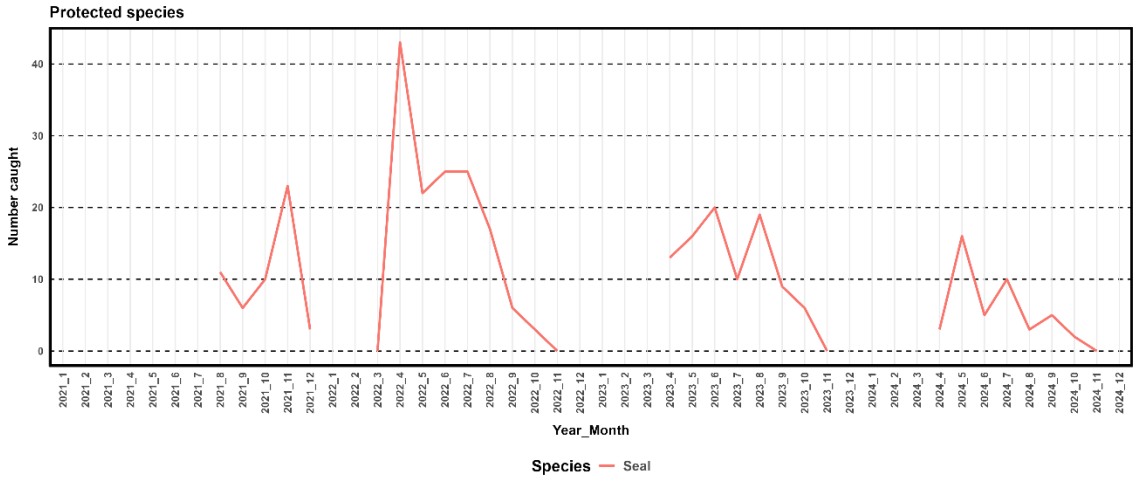


Figure 43. Numbers of grey seals reported by Skippers and scientific observers monthly during 2021-2024.

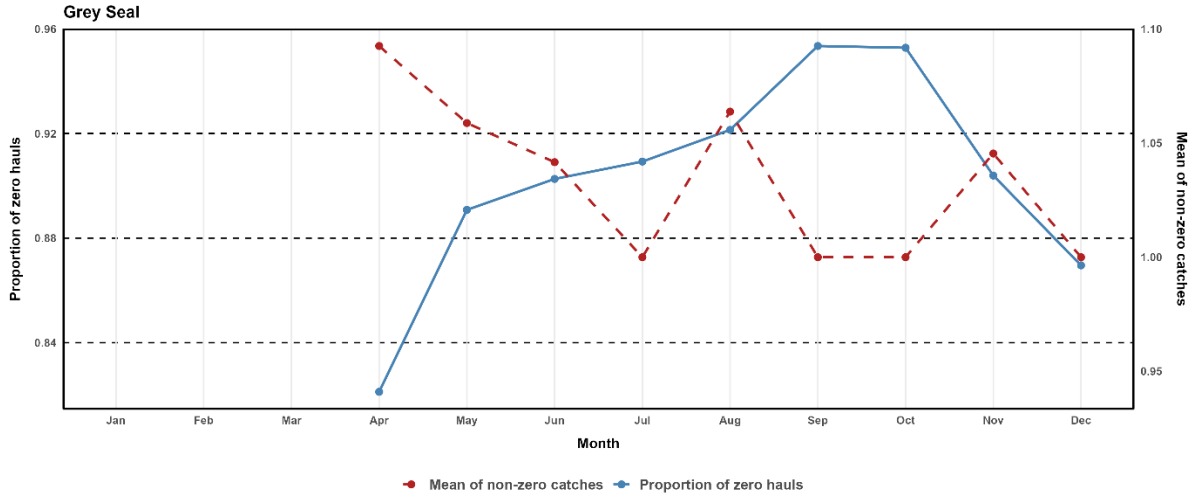


Figure 44. Proportion of hauls with zero bycatch and mean number of grey seals in hauls where they were encountered per month (all years combined).

The number of seals caught relative to net soak time peaked at between 6-8 days net soak. Lower bycatch at long soak times is presumably due to loss of seal carcasses from the nets during soak or during hauling (Figure 45).

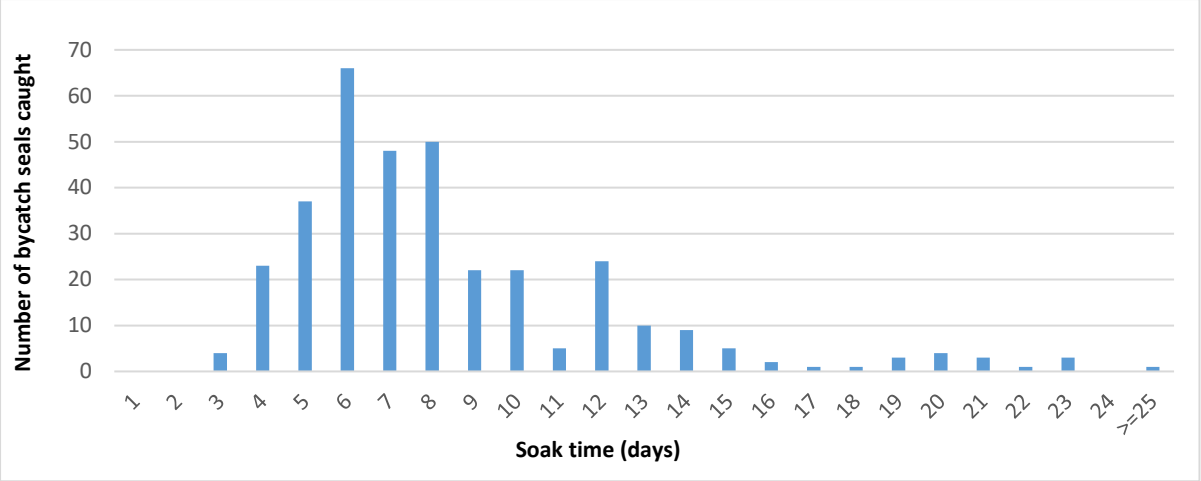


Figure 45. Bycatch of grey seal relative to soak time of tangle nets.

The proportion of hauls with seals averaged 7.5% in the Tralee fleet and 13.5% in the Dingle fleet (Table 22).

Grey seals were captured as bycatch in most of the area where fishing events occur (Figure 46). However, the probability of capture was higher within 10km of the main haul-out site on the Great Blasket Islands. There was a relationship between the probability of bycatch and the proportion of the total bycatch taken relative to the distance between the fishing activity and the haul out site (Table 23, Figure 47). Forty two % of seals were caught within 10km of the haul out site although only 27% of hauls were taken in that area. Of the 314 hauls with seal bycatch 96% involved a single seal, 4% had 2 seals and 1 event had 3 seals. These data were also used to estimate the spatial risk of bycatch by Murphy *et al*. (2025). Bycatch risk was higher where suitable habitat for seals overlapped with high levels of fishing activity.

Table 22. Proportion of net hauls with and without seals annually in the Dingle and Tralee fleets.

	Proportion of net hauls with seals	Proportion of net hauls without seals
Tralee		
2021	8.82	91.18
2022	12.04	87.96
2023	5.65	94.35
2024	3.58	96.42
Average	7.53	92.47
Dingle		
2021	7.93	92.07
2022	20.83	79.17
2023	12.59	87.41
2024	10.84	89.16
Average	13.48	86.52

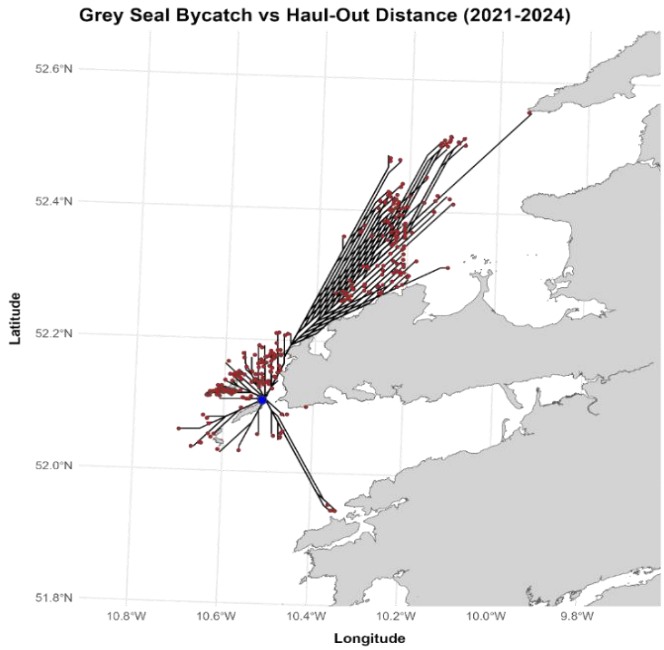


Figure 46. Location of bycatch of grey seal (red points) relative to straight line distance to the Blasket Island seal haul out (blue point).

Table 23. Bycatch of grey seal, probability of catch and proportion of total captured relative to distance from the Blasket Island haul out site.

Distance from haul out site	Net hauls	% of hauls	All seals	1 seal	2 seals	3 seals	Probability of capture	Proportion captured
0-5	192	5.46	35	33	2	0	18.23	11.15
5-10	752	21.40	113	110	3	0	15.03	35.99
10-20	344	9.79	12	10	1	1	3.49	3.82
20-30	473	13.46	45	43	2	0	9.51	14.33
30-40	1072	30.51	80	77	3	0	7.46	25.48
40-50	512	14.57	16	16	0	0	3.13	5.10
50-60	157	4.47	12	12	0	0	7.64	3.82
60-70	12	0.34	1	0	1	0	8.33	0.32
TOTAL	**3514**		**314**	**301**	**12**	**1**		

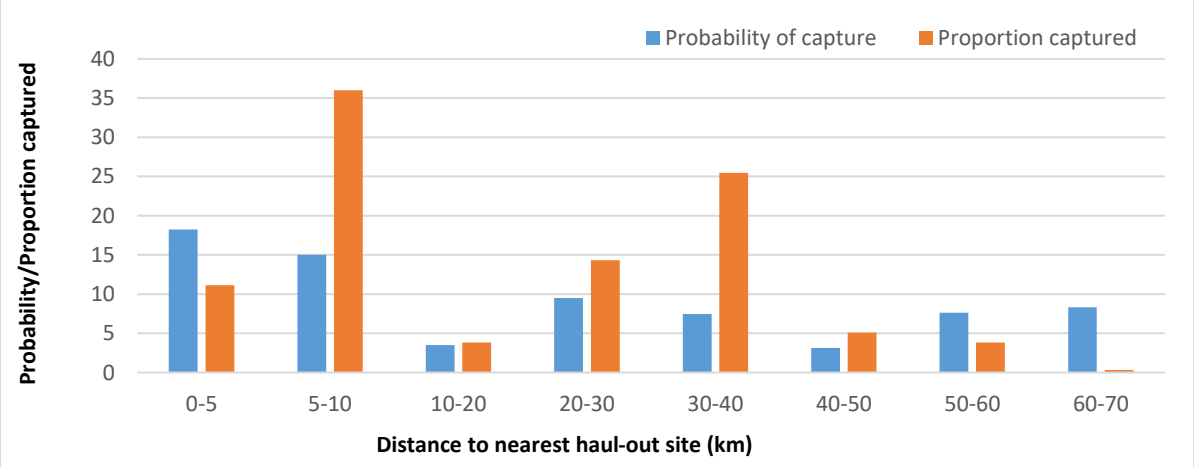


Figure 47. Probability of capture and proportion of total seals captured relative to distance to the Blasket Island haul out site. Probability of capture is the number of hauls with bycatch relative to the total number of hauls taken within a given distance category to the haul out.

Annual mean (± 90% confidence limits, CL) estimates for total seal bycatch, per nautical mile of net reported by observers and skippers and raised to total estimated fleet activity, varied from 239 to 480 individuals annually (Table 24).

Confidence limits were estimated using a bootstrap approach, in which the reported haul data was randomly resampled with replacement 1,000 times. The 5th and 95th percentiles of the resulting distribution of bycatch estimates were taken as the bounds of the 90% confidence interval.

Table 24. Fleet level seal bycatch estimates with 90% confidence intervals (CI).

Fleet level seal bycatch estimates			
Year	Estimate	Lower CI	Upper CI
2021	269	209	329
2022	480	415	553
2023	239	197	280
2024	244	186	308

The significance of grey seal bycatch

Bycatch estimates provided above are within the range of modelled estimates of Luck *et al*. (2019, 2020) for annual total seal bycatch in the entire Irish EEZ of between 202 (90% CI: 3-433) and 349 (90% CI: 6-833). The data indicates that very high fleet specific localised bycatch possibly accounts for a high proportion of total fishery seal bycatch, highlighting the importance of concentrating data collection in these areas to obtain accurate estimates of bycatch.

Fishing with large mesh tangle nets also occurs in proximity to other seal haul out sites in Ireland including west of Mayo (the Iniskeas SAC), Connemara and west Galway (Slyne Head, Duvillaun Is and Inisbofin and Inisark SACs) and on the south coast (Roaringwater Bay SAC). Although factors other than distance to haul out influence catch rate, the presence of large mesh set net fisheries in such locations probably constitute a high risk of seal bycatch.

Grey seals are listed in Annex II of the Habitats Directive. Although the species is wide ranging in the marine environment, the Directive establishes SACs to protect them. Grey seals use specific sites for breeding, moulting and resting, and have some degree of fidelity to these areas while also undertaking large scale migrations and foraging movements in open water (Cronin *et al*. 2013).

Nine SACs are designated for grey seal on the coast of Ireland, one of these is the Blasket Islands (NPWS 2014). The conservation objectives for grey seal at these sites (and which includes activities outside the sites that could impact grey seal populations) have explicit targets; breeding and haul out sites should be conserved, and human activities should not adversely affect grey seal populations at the sites.

Population estimates in 2005 and 2012, and anecdotal information on the rate of encounter between seals and fishing vessels all indicate that the number of grey seals in Irish waters and at breeding and haul out colonies is increasing. The population of grey seal on all coasts was estimated to be between 7000-9000 individuals prior to 2013 (O'Cadhla *et al*. 2013). The Blasket Island population increased from 648-833 seals in 2005 (O'Cadhla *et al*. 2007) and to 1099-1413 in 2012 (O'Cadhla *et al*. 2013), representing a 4% increase per annum. There are no more recent estimates.

This increase of 4% per annum is lower than the maximum density independent potential population rate of increase of 10% when constrained by life history parameters only. Annual bycatch of 239 to 480 seals close to the Blasket Islands haul out site would lead to extinction of the population (1099-

1413 seals in 2012) if it was not sub-vented by inward migration. Furthermore, Harding *et al*. (2007) showed that hunting levels (equivalent to bycatch), that are in proportion to population size, pose a much higher risk to seal populations than hunting a fixed number.

The bycatch in the tangle net fishery is likely to be in proportion to the population size rather than a fixed number, as encounter rates with fishing gear are expected to increase in proportion to population size. Cosgrove *et al*. (2016) also found positive correlations between catches of crayfish and monkfish and seal bycatch, suggesting that productive, well managed fisheries may be associated with higher bycatch, food subvention and potentially lead to increase in attractiveness of such areas for seals. High depredation rates of monkfish and pollack occur in tangle nets and gill nets, respectively, in the Blasket Island area (Cronin *et al*. 2014).

Acoustic telemetry data shows extensive migrations of grey seal from French and Scottish populations to Irish waters (Cronin *et al*. 2011; Murphy *et al.* 2025), which may explain the resilience of seals at the Blasket Island haul out and surrounding area to high bycatch mortality. Inward migration to the area is contingent in that case on the maintenance of productive seal populations elsewhere. Recent genetic data (Steinmetz *et al.* 2024) show that seals from Ireland are part of a single interbreeding population, with southwest England being a source of migrants to Ireland, and the southern North Sea (Germany, Denmark) either serving as an additional source or sharing a common source of migrants to the island of Ireland. Based on this genetic structure in the Northeast Atlantic, the island of Ireland, southwestern UK (Cornwall) and France are proposed as a single management unit.

Effective management of seal bycatch and other pressures throughout this region, particularly in areas where seals occur in high numbers and are exposed to high risk or mortality, is therefore essential for maintaining seal populations. The Blasket Islands and other important haul out sites in Ireland are critical locations for proactive management and conservation efforts. Murphy *et al*. (2025) model the spatial distribution of risk of bycatch based on bycatch data and fleet activity reported here which can be used for spatial management approaches to reducing seal bycatch.

Discussion and conclusions

Catches of commercial species and unintended bycatch of non-commercial species were estimated for the tangle net fishery targeting crayfish (*Palinurus elephas*) in north Kerry. The unintended bycatch included endangered, threatened and protected species. Enhanced monitoring of the fishery was enabled through a combination of contracted skipper self-reporting, scientific observer coverage, and by monitoring of vessel activity using vessel monitoring systems (iVMS). All of the main vessels operating in the area were included. The iVMS data provided, for the first time, a census of fishing activity of vessels reporting catch and bycatch data. Crayfish catch rate data was used to estimate the likely fishing effort of vessels that were not monitored, based on their reported crayfish landings, and to raise catch and bycatch to fleet level.

Crayfish catch rates increased during the period 2017-2024. National landings also increased from less than 10 tonnes to 83 tonnes (valued at €2.9million per annum) during that period. The increase in catch rates likely reflects higher stock levels, although it may also be influenced by the increased use of ground discrimination software on board vessels. Higher catch rates have also been reported in southwest England, the Scilly Isles and northern France in recent years and points to a probable increase in recruitment of crayfish across this region. Tagging data from France and Ireland (Shellfish stocks and fisheries review 2023) also shows recruitment of sub-adult crayfish from France and the Celtic Sea onto Irish coastal reef habitat and, therefore, some connectivity across this region. However, tagging data for the southwest coast of Ireland (reported elsewhere) also shows high levels of residency of larger size classes of crayfish on Irish coastal reef habitat.

Increased catch rates have also attracted new effort into the fishery, both locally (on the southwest and south coast) and nationally. The number of vessels landing and selling more than 100kg of crayfish increased from 10 to 108 between 2014 and 2024. These trends are unsurprising for this fishery given that the value per individual fish is between €40-80 and any indication that stocks are increasing attracts significant attention from fishermen. The investment and operating costs by comparison are not that high; tangle nets can be soaked for several days while the vessels tend to pots or other gear. The main cost is annual replacement and mounting of gear which is usually done during the winter. The fishery is, therefore, prone to boom and bust cycles. The scope to build and maintain stocks at a high level that would make fishing with pots viable is also less likely to happen in this scenario.

There was significant geographic variability in bycatch rates of some species, even within the relatively small project area. This finding has important implications for assessing bycatch over larger spatial scales where data support may be limited, and care should be taken when extrapolating between areas. In the case of grey seals, bycatch variability was driven by the degree to which fishing occurs in areas where seals are more likely to occur such as areas close to haul out locations.

The study highlights two main issues that need to be resolved in order to ensure a sustainable and viable fishery for crayfish. The first concerns the increase in fishing effort and landings, which is likely to continue given the current pressures on other fisheries targeted by the inshore fleet in Ireland. The diversity of fishing opportunity available to the fleet has declined in recent decades and continues to do so. Targeting of crayfish with tangle nets is an attractive option given the high market value for this species. Although the minimum conservation reference size (MCRS) of 110mm helps protect spawning potential, the rate of removal or exploitation rate of crayfish over 110mm needs to be managed if the fishery is to remain viable. Also, given that tangle net fishing also causes mortality of crayfish, including those less than 110mm, the effectiveness of the MCRS is compromised.

The second obvious issue with the tangle net fishery is the bycatch of critically endangered and protected species. Although the number of individuals of some species such as angel shark reported in bycatch was low it is still problematic. This species was once common in the area and supported a lucrative recreational angling sector in inner Tralee Bay. The current population, as reflected in the bycatch, is highly depleted relative to historic levels and there is a risk of local extinction. Although the species is prohibited from retention on board vessels (Regulation (EU) 2019/124) and must be released immediately if caught, this does not protect it from fishing mortality in static net fisheries, given that a proportion of those fish are dead when the fishing gear is hauled. There are probably no safe bycatch limits at this point for this species given that it is already critically endangered (Hiddink *et al*. 2019; Shepherd *et al*. 2019). Tangle netting is prohibited in Tralee Bay (SI 233/2006) to protect angel shark and other endangered species. This closed area, however, does not protect fish during transit to and from the bay, particularly along the seaward boundary, where most tangle net fishery operates.

Transitioning from tangle nets to alternative fishing gears such as pots, which eliminate bycatch, is a potential solution for the crayfish fishery. Trials with different pot designs have been ongoing in the study area since 2022. Development of a viable pot fishery for crayfish remains a key objective in securing a sustainable future for the fishery.

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