Marine Institute
Project Ref: ITT17-020

To identify spawning, nurseries and essential habitat of endangered skates off the west coast of Ireland.

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Marine Dimensions

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Acknowledgements

We are most grateful to all those dedicated volunteer observers who have kindly submitted their observations of shark and ray eggcases on beaches around Ireland to Purse Search Ireland in order to inform fisheries conservation management.

1.0 INTRODUCTION

1.1 Project background

The key importance of Irish coastal waters for endangered skates (and the skate-like Angel Shark) has now been established with the recent Red List of Irish Elasmobranchs, published by the National Parks and Wildlife Service, and recent advice from the International Council for the Exploration of the Seas (Clarke *et al*., 2016). The threats to these species in the area are largely due to by-catch in commercial fisheries. The species in question are the White Skate, *Rostroraja alba*, Common Skates , ie. Flapper Skate, *Dipturus intermedia*, and Blue Skate, *Dipturus flossada* (aka *Dipturus batis*), Undulate Ray, *Raja undulata*, Common Stingray, *Dasyatis pastinaca,* and Angel Shark, *Squatina squatina*.

A recital of the Council of the European Union, December 2016, stated that *"the current system of management of skates and rays under generic TACs could be improved to fully address the need to sustainably manage vulnerable species and data limited stocks and allow for the sustainable exploitation of commercially important species.*" Furthermore, Ireland has an obligation to achieve good environmental status under the meaning of the Marine Strategy Framework Directive. In recognition of these objectives, the Marine Institute has initiated a project to improve the knowledge base for sustainable management and conservation of these endangered species.

The main Actions are as follows:

1. Conduct periodic eggcase surveys over a 12-month cycle of the two main centres of population viz. Tralee Bay and Inner Galway Bay using an appropriate survey design.

2. Archive and collate data collected.

3. Collate records of eggcases by species, date and location and hydrographic conditions, and – as appropriate – survey effort per site.

4. Produce a report with details of the abundance and distribution of eggcases per month throughout the year in each area.

5. Include in the report, analysis of the local distribution of these eggcases within each bay, and likely spawning sites.

6. Present and discuss the results in the context of existing knowledge of the distribution and abundance of these species and their eggcases in Irish waters.

1.2 Objective

The objective of the project is to collect, collate and report the essential habitat, spawning and nursery sites for these endangered skates off the west coast of Ireland.

1.3 Outputs

The following are the overall outputs of the project:

1. Reports on essential habitats, spawning and nursery grounds as a basis of advice for management and conservation.

2. Spatially explicit database of recordings of eggcases by species, area and time.

3. Elucidate extent of spawning season in fine local detail in verified hotspots.

4. Public outreach through stakeholder interaction, traditional and social media, and through dissemination of scientific results that furthers the four aims of the project.

5. Discussion of the results in the context of early work on the subject.

Marine Dimensions has been the service provider contracted (as of 19th November, 2018) to provide services relating to the outputs listed above.

1.4 Scientific team

Marine institute	Dr Maurice Clarke	Project Director
Marine Dimensions	Dr Sarah Varian	Project Coordinator
	Eleanor Turner	Research and Outreach Officer
	Emma White	Research and Outreach Officer
	Paul Cuddihy	GIS consultant, web developer
	Galway Atlantaquaria	Outreach partner, Galway Bay
	Sea Synergy	Outreach partner, Tralee Bay

2.0 METHODS

2.1 Survey design, methodology and approach

Three types of survey techniques have been used to identify and monitor sites of interest for the purpose of achieving the objectives of the present study, including citizen science surveys, exploratory surveys and indicator site surveys.

Citizen science surveys incorporate casual observations by members of the public, validated by scientists (Section 2.2.1, Table 1), which are then followed up on by biologists conducting semi quantitative exploratory surveys at and around the sites highlighted by citizens (Section 2.2.2). Indicator site surveys are then conducted at specific shoreline segments which have been identified as being suitable for quantitative assessment and long term monitoring, including evaluation of seasonality and environmental parameters (Sections 2.2.3).

The indicator site selection is based on results obtained from evaluation of sites through application of the Nursery Hotspot Indicator (NHI) Index (Table 2). The application of a particular survey technique in relation to investigation of a site or region of interest is also informed by several criteria, including availability of scientific information, species richness and capacity in terms of resources.

Because the three techniques differ in terms of scope, affordability and scientific rigour, they are considered to be most effective when considered together through a combined approach. This is especially true for a broad scale nationwide survey such as the Endangered Skates Project, which aims to monitor the health and recovery of several subpopulations of rare and threatened species long term.

2.2 Survey techniques

2.2.1 *Citizen science surveys*

Citizen science surveys are carried out by volunteer observers participating in Purse Search Ireland, the nation's Shark and Ray Eggcase Sightings Scheme. Sightings are for the most part incidental, eg. a member of the public happens upon an eggcase while out on a beach walk with family (Table 1), and although this presents difficulties for collation of zero sightings data, it is a very useful and affordable method for surveying the presence of a rare species over a large area. Citizen science is therefore the preferred method for identifying and flagging areas for further investigation by scientists. The Purse Search programme also serves as a public engagement project in relation to awareness of endangered species of shark and ray in Ireland.

The following variables are collated for the project from Purse Search following verification through provision of a photograph or sample:

- Presence and number of eggcases by skate species
- Observation date

- Sighting location

2.2.2 *Exploratory surveys*

Exploratory surveys are designed to investigate sites flagged by citizen scientist observations with a view to identifying indicator sites that may be used to monitor nursery areas on a long-term basis.

The surveys are semi quantitative, with biologists recording the number and species of skate eggcases along the strand line of a segment of shoreline. The scientists search an area of approximately 3 metres either side of the upper strand line, as well as an area of 3m before the dunes at the back of the beach, as they proceed to a marked end point. The surveyors then return to the starting point, searching for eggcases along the lower strand line. The beach is searched thoroughly by one or more surveyors.

The survey start point is generally located at the entrance to the beach, while the end point is frequently determined by the topography, eg. a river or rocky outcrop may act as a barrier at either end of the beach. In cases where the beach is more than 1km long, more than one segment survey may be carried out. Start time and end time is also recorded, with survey effort calculated as the beach area surveyed in metres squared per minute.

Variables recorded for the exploratory programme include the following:

- Survey date
- Survey start and end time
- Location, ie. latitude and longitude for survey start and end points
- Presence and number of eggcases by skate species
- Survey effort in metres squared per minute

2.2.3 *Indicator site surveys*

The indicator site survey technique is more discreet and refined than the exploratory survey technique, as it focuses on a finite area of the upper shore where stranded eggcases tend to be concentrated. The surveys are quantitative, with biologists recording the number of eggcases by skate species along the upper strand line of a segment of shoreline. The surveyor searches an area 5m before the dunes at the back of the beach, proceeding to the marked end point. The biologist then returns to the starting point, searching for eggcases 5 metres either side of the upper strand line.

No more than one observer carries out the indicator site survey and effort is calculated as the beach area surveyed in metres squared per minute.

Variables recorded for the quantitative programme include the following:

- Survey date

- Survey start and end time
- Location, ie. latitude and longitude for survey start and end points
- Presence and number of eggcases by skate species
- Survey effort in metres squared per minute

The following environmental parameters are also recorded for each site:

- Wind strength

  Wind strength is calculated as the mean speed in kilometres per hour recorded over the 7 days prior to and including the survey date (according to timeanddate.com which takes data from Custom Weather). This parameter provides an indication of sea state and local hydrographic conditions in the area, where strong winds are considered to be more likely to influence the deposition of eggcases on the strand line.

- Seaweed cover

  The degree to which seaweed cover might obscure eggcase sightings is assessed by the surveyor as an estimate of percentage cover in the survey area. Surveyors do not remove or disturb seaweed on the strand line through the course of the surveys.

- Tidal range

  Tidal range provides an indication of local hydrographic conditions in the area, where spring tides with a high tidal range are considered to be more likely to influence the deposition of eggcases on the strand line. Tidal range is calculated as the mean range in metres over the 7 days prior to and including the survey date.

- Eggcase condition

  Condition of the eggcases is recorded in order to provide an indication of how recently the eggcase has been deposited on the shoreline. A scale of 1-3 is applied as follows:

Eggcase Stage	Eggcase State
1	Eggcase is still moist, soft and pliable. Hatchling slit opens easily when sides of the case are squeezed between thumb and forefinger. There may be signs of the embryo or embryonic tissue in the case which have not yet decomposed.
2	Eggcase is dry but soft and pliable. Hatchling slit does not open easily when sides of the case are squeezed between thumb and forefinger. If present, embryo or embryonic tissue have already started decomposing or have decomposed.
3	Eggcase is dry, hard and rigid. Hatchling slit does not open when sides of case are squeezed between thumb and forefinger. It is not possible to determine whether the embryo or embryonic tissue are present as the case cannot be opened.

If there are signs of a skate embryo or embryonic tissue in an eggcase which have not yet decomposed, a sample of tissue is preserved for DNA analysis. If in tact, embryos are preserved by freezing to allow examination of morphometrics at a later stage.

- Seawater temperature

  Sea surface temperature is recorded by the biologist at the survey site using a thermometer on the day of the survey.

- Beach substrate type

  Beach substrate type is recorded by the biologist on the day of the survey.

- Subtidal substrate type

  Subtidal substrate type extending from low water mark to 100m is noted through reference to scientific literature for the area.

- Citizen science

  Citizen science is considered to be an important parameter as the removal of eggcases at indicator sites by volunteer observers could potentially skew survey results. Sightings submitted by citizen scientists for Tralee Bay and Galway Bay are therefore examined for site overlap.

Table 1: The three phases of action experienced by volunteer observers participating in the Purse Search Shark and Ray Eggcase Sightings Scheme.

Phase	**Action**	**Outcome**
1. Education and outreach	Potential volunteer observers are informed about the project through: (a) school workshops (b) public outreach events (c) press and media coverage (d) flyers (e) website info (f) social media Observers are asked to report their observations online through the Purse Search project page at marinedimensions.ie. It is also requested that they post a sample or send a photograph of the purse on to the project scientists in order to confirm species identification.	Public awareness is raised. Approximately 10,000 people per year are informed through face to face events, with many more informed through press and media coverage.
2. Exploration and discovery	Volunteers discover purses either (a) incidentally on a beach walk or (b) intentionally through a beach survey	Learning is consolidated through outdoor exploration and discovery. Observations may or may not be reported to Marine Dimensions at this stage.
3. Reporting	Volunteers report the sighting online through a recording form or via land mail. The observation may be reported in one of three ways: (a) with no description, photo or sample of the purse, (b) with a description or photo of the purse, but no sample, (c) with a description and/or photo, and sample of the purse. Following receipt of the information, the project scientist e-mails the observer to give them the results of their report and to thank them for their participation.	The sightings are included in the Purse Search database and species identified are classified as either confirmed or unconfirmed, depending on the quality of information provided by the observer through actions (a)-(c): (a) is classified as unconfirmed, (b) may be classified as unconfirmed or confirmed, depending on the quality of information provided, (c) is classified as confirmed once the eggcase is in good condition.

Table 2: The Nursery Hotspot Indicator Index for threatened species of egglaying shark and ray, used to prioritise areas for further investigation and ongoing monitoring programmes conducted by scientists.

	Criterion	Score	Action
1	No elasmobranch eggcases reported through citizen science (Purse Search or Great Eggcase Hunt).	No score / no data	These sites may have been surveyed in a casual way by citizen scientists who have not reported the lack of sightings to project scientists. Casual surveys are bound to be carried out as a result of Purse Search outreach; however observers rarely report zero sightings. It is recommended that these areas are surveyed through follow up exploratory surveys conducted by biologists if they are adjacent to areas scoring 2 or more.
2	At least 1 elasmobranch eggcase reported through citizen science, but no threatened species.	0 points.	Continue to survey through citizen science.
3	Site has had at least 1 eggcase from at least 1 threatened species of shark or ray verified through citizen science.	1 point.	Follow up with an exploratory scientific survey.
4	Site has had at least 1 eggcase from at least 1 threatened species of shark or ray verified through exploratory surveys by biologists.	1 point.	If the site's total score is 1, conduct a repeat exploratory survey at a later date and continue to monitor with citizen science. If the score is 2, select site for further investigation and ongoing monitoring.
5	Site has had eggcases from the same species of threatened shark or ray verified through citizen science and recorded on more than one occasion (ie. on separate dates).	1 point	Follow up with exploratory survey, select for ongoing monitoring and more detailed quantitative investigation.
6	Site has had eggcases from 2 threatened species verified through citizen science or exploratory surveys.	1 point	Follow up with exploratory survey if necessary, select for ongoing monitoring and more detailed quantitative investigation.
7	Site has had eggcases from 3 threatened species verified through citizen science or exploratory surveys.	1 point	Follow up with exploratory survey if necessary, select for ongoing monitoring and more detailed quantitative investigation.
8	Site has had eggcases from 4 threatened species verified through citizen science or exploratory surveys.	1 point	Follow up with exploratory survey if necessary, select for ongoing monitoring and more detailed quantitative investigation.

Maximum total score is 6. Sites scoring 2 or above should be selected for ongoing monitoring and more detailed quantitative investigation. The higher the score, the higher the priority in terms of requirements for conservation management investment.

3.0 Results and Discussion

3.1 Site selection

3.1.1 *Sampling approach*

Survey sites were selected according to the approach outlined above in Section 2.1, incorporating evaluation of results obtained through application of the NHI Index and updated review of sightings reported in 2018 through the Purse Search Ireland project (Table 2, Figures 1-4). Specifications outlined by the Marine Institute in the project's Request for Tender document were also adhered to, with two key study areas, ie. Tralee Bay and Galway Bay, selected as a result.

The sampling approach may be considered to be stratified to an extent with Tralee Bay and Galway Bay treated as sub-populations. However, it should be noted that the sampling strategy is influenced by the investigation of seasonality, which requires each site in Tralee Bay to be sampled each month to explore eggcase beach deposition rates relative to season, regardless of each site's importance in terms of eggcase species counts relative to the overall count for the bay.

3.1.2 *Tralee Bay*

Of the 48 shoreline segments surveyed through exploratory surveys in 2017 (Marine Dimensions, 2017), 5 sites were identified as being suitable for long term monitoring and quantitative assessment as nursery indicator sites, including investigation of seasonality. The sites, which are based in Castlegregory, Camp, Derrymore, Fenit and Ballyheige (Figure 5), were subsequently surveyed on a monthly basis from January through December 2019 using the indicator site survey technique.

3.1.3 *Galway Bay*

Application of the NHI Index to citizen science sightings and exploratory survey data has not revealed any shorelines suitable for indicator site surveys in Galway Bay to date. However, a number of sites were considered to warrant further investigation through exploratory surveys as several citizens reported verified sightings of eggcases from endangered species at new locations around the bay in 2018. This included observations of White Skate, Flapper Skate and Undulate Ray eggcases. Exploratory surveys following up on citizen science sightings were subsequently carried out in order to establish whether there may be indicator sites that could be used for more quantitative investigations and long term monitoring (Figure 5).

A small number of other sites around the country, including Whitestrand in Co Clare and Falcarragh in Co. Donegal, have been identified as being suitable nursery indicator sites through application of the NHI Index. However, these sites have continued to be monitored through citizen science as the focus of the present study has been on Tralee Bay and Galway Bay.

Some sites have been highlighted that may be suitable for site indicator surveys, scoring above 4 with the NHI index. However, monitoring these sites using indicator

site surveys conducted by scientists was beyond the scope of this study; they continue to be monitored through citizen science.

Figure 1: Distribution of Undulate Ray, *Raja undulata*, eggcases around Ireland's coastline reported by volunteer observers through Purse Search Ireland from 2007 to 2018.

Figure 2: Distribution of White Skate, *Rostroraja alba*, eggcases around Ireland's coastline reported by volunteer observers through Purse Search Ireland from 2007 to 2018.

Figure 3: Distribution of Flapper Skate, *Dipturus intermedia*, eggcases around Ireland's coastline reported by volunteer observers through Purse Search Ireland from 2007 to 2018.

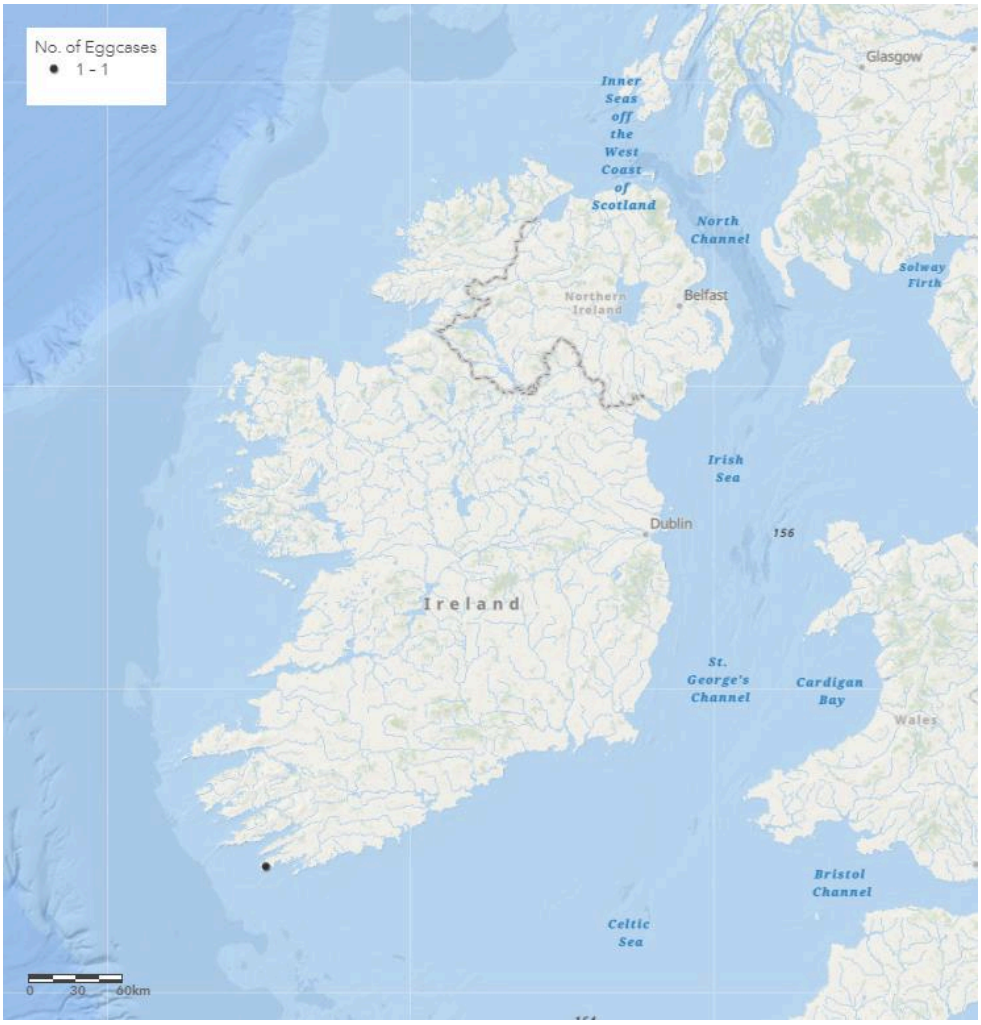

Figure 4: Distribution of Blue Skate, *Dipturus flossada*, eggcases around Ireland's coastline reported by volunteer observers through Purse Search Ireland from 2007 to 2018.

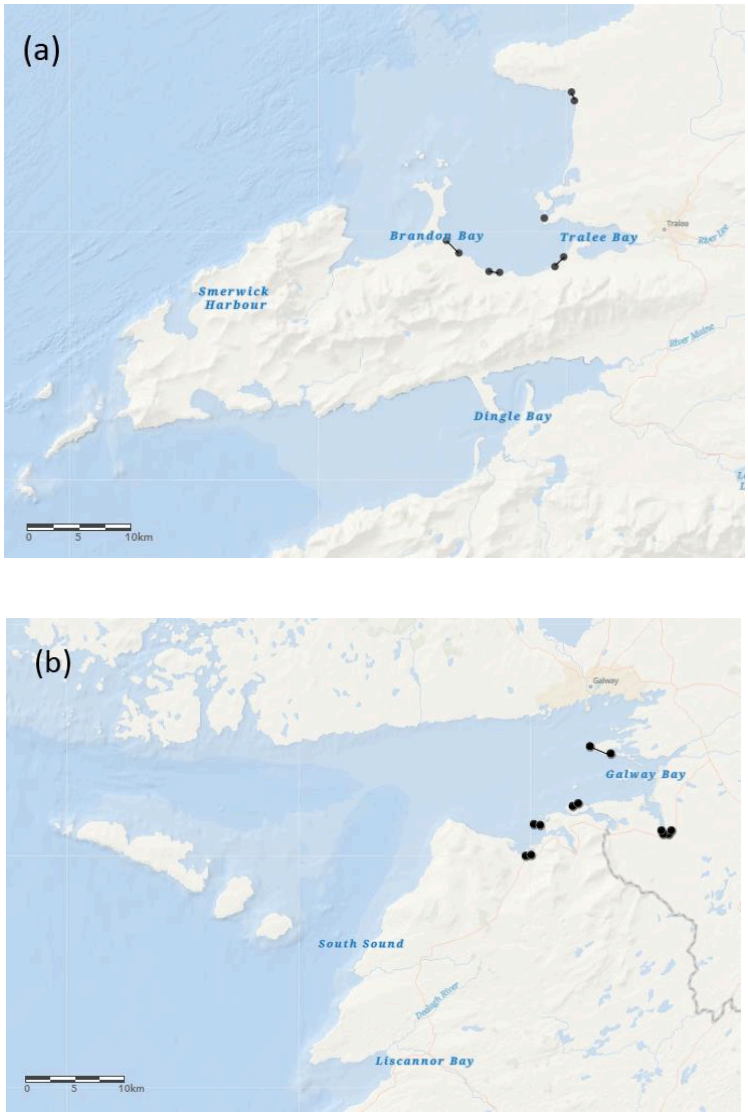

Figure 5: Location of (a), indicator site surveys carried out each month in Tralee Bay and (b), exploratory surveys following up on sites highlighted by citizen science in Galway Bay.

3.2 Effectiveness of quantitative survey programme: relationship with hydrographic factors

When the relative abundance of eggcases recorded at indicator sites was investigated relative to environmental parameters, a positive relationship with wind strength was noted (Figure 6). The influence of wind strength on seasonal variation in eggcase deposition and discard rates was subsequently considered in relation to use and interpretation of eggcase surveys as a means to monitor nursery areas.

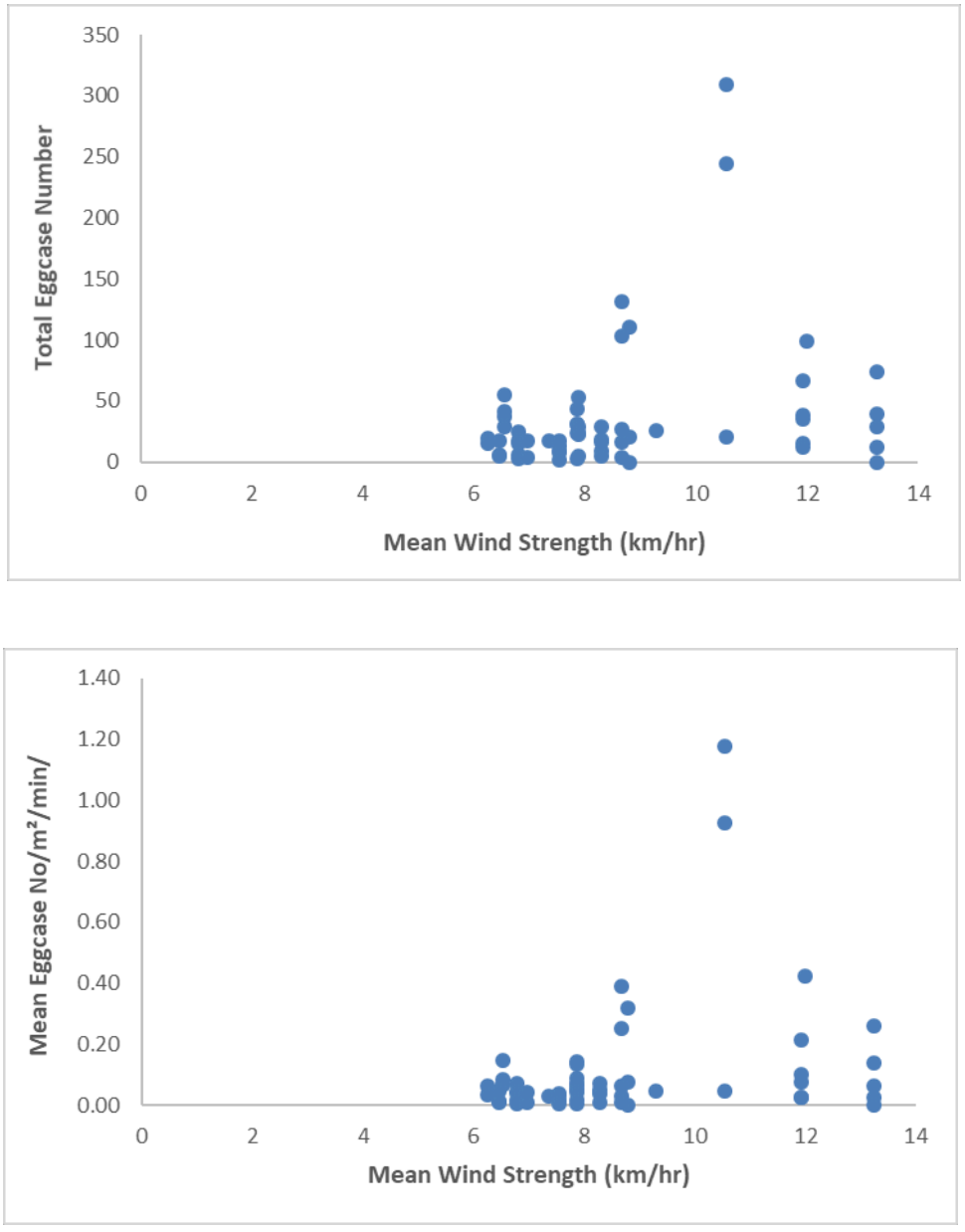

Figure 6: Total and mean (per m²/min) number of eggcases recorded on indicator site surveys relative to mean wind strength (km/hr).

3.3 Distribution and abundance of eggcases

3.3.1 *Geographical variation*

Distribution and abundance of eggcases reported by volunteer observers through Purse Search in 2018 were found to reflect ranges for all 4 species of endangered skate recorded through the citizen science project in previous years (Figures 1-4; Marine Dimensions, 2017).

Results also reflect distribution of adult skate recorded in inshore areas by the Irish Specimen Fish Committee and Inland Fisheries Ireland's long standing Sportfish Tagging Programme (Went, 1977; Wögerbauer *et al*., 2014). For example, verified sightings of eggcases from White Skate have only been recorded on beach strandlines in Tralee Bay, Galway Bay, West Clare and the Sligo/Leitrim coastline (Figure 2). Similarly, historical catches of adult White Skate were recorded in Tralee Bay, Galway Bay, Clew Bay and Enniscrone in Sligo (Went, 1977).

Eggcase sightings data for Flapper Skate and Undulate Ray also reflect distribution of recreational catches reported for these species, with Flapper Skate absent on the east coast in recent years and Undulate Ray eggcase sightings for the most part restricted to Tralee Bay (Figures 1 and 3; Wogerbauer *et al*., 2014).

Only one eggcase from the Blue Skate has been recorded nationwide (Figure 4); the single eggcase was sighted in Cork, reflecting the more southerly distribution of this species (Clarke *et al*., 2016).

3.3.2 *Local hotspots*

<u>Tralee Bay</u>

A total of 8 egglaying elasmobranch species were recorded in Tralee Bay through the course of this study, including 6 species of skate and 2 species of shark (Table 3). Undulate Ray was the most abundant species recorded on indicator site surveys (mean: 0.05/m²/min, ±SE: 0,01), while White Skate was the most scarce (mean: 0.0006/m²/min, ±SE: 0.0002). The bay is also reported to be a nursery area for other pup bearing species of elasmobranch, including Stingray and Angel Shark, making it the most important bay in Ireland in terms of shark and ray biodiversity (Marine Dimensions, 2017).

Table 3: Total number of eggcases identified for each species recorded on monthly indicator site surveys (n=60) in Tralee Bay in 2019 (± SE).

Species name	Common name	Eggcase No.	Mean Eggcase No/m²/min	S.E.
Raja undulata	Undulate Ray	1020	0.0529	0.0139
Dipturus intermedia	Flapper Skate	0	0	0
Dipturus flossada	Blue Skate	0	0	0
*Rostroraja alb*a	White Skate	14	0.0006	0.0002
Raja clavata	Thornback Ray	398	0.0220	0.0076
Raja montagui	Spotted Ray	194	0.0092	0.0021
Raja microocellata	Small Eyed Ray	93	0.0047	0.0015
Raja brachyura	Blonde Ray	25	0.0012	0.0004
Scyliorhinus canicula	Small Spotted Catshark	347	0.0149	0.0026
Scyliorhinus stellaris	Bull Huss	29	0.0013	0.0003
Unidentified Rajidae sp.		39	0.0018	0.0006

The number of eggcases identified on indicator site surveys (including total and mean per m² per minute) at each location within Tralee Bay is given in Table 4. Variation in mean eggcase number per m² per minute relative to indicator site surveyed for each species is also given in Figure 7.

The highest number of eggcases was recorded in the south of the bay, with a total of 847 eggcases and a mean of 0.23 eggcases/m²/min recorded at the Derrymore Island site (Table 4). Camp was the next most eggcase rich site, followed by Castlegregory, Fenit Island Road and Ballyheigue. Derrymore Island was also the most species rich site, with eggcases from 6 species of skate and 2 species of shark recorded on indicator site surveys in 2019 (Figure 7). Sites in the south of the bay were also the most important in terms of eggcase abundance for endangered species.

Table 4: Number of eggcases identified (including total and mean/m²/min) at each indicator site surveyed each month (n=60) in Tralee Bay in 2019.

Site name	Eggcase No.	Mean Eggcase No/m²/min	S.E.
Castlegregory	243	0.0431	0.0058
Camp	746	0.2054	0.0943
Derrymore Island	847	0.2280	0.0712
Fenit Island Road	215	0.0448	0.0109
Ballyheigue	108	0.0214	0.0071

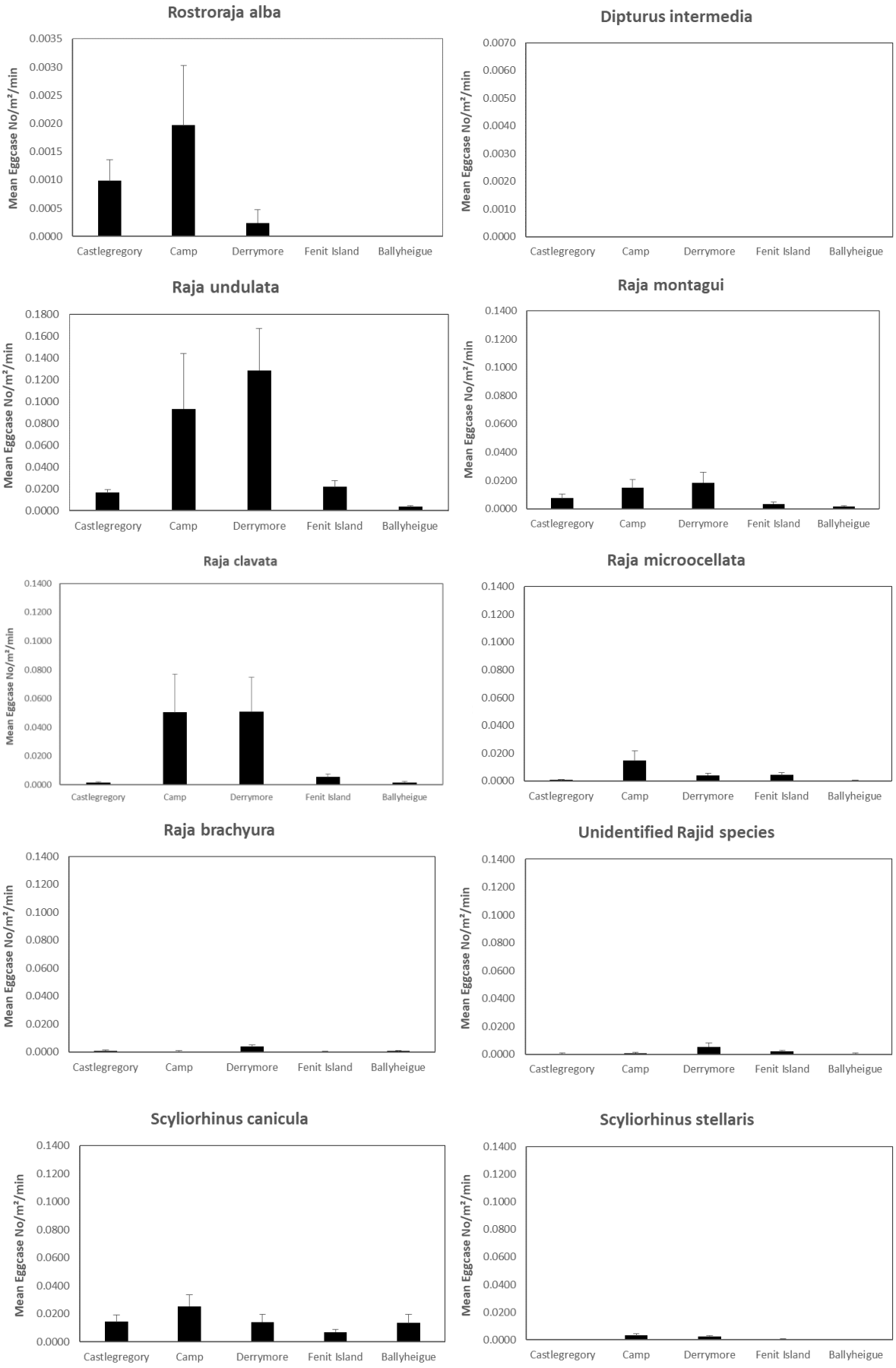

Figure 7: Variation in mean eggcase number per m² per minute for each species relative to indicator site surveyed in Tralee Bay in 2019 (± SE).

Galway Bay

Only 3 species of egglaying elasmobranch, ie Thornback Ray, Small Spotted Catshark and Bullhuss, were recorded on exploratory surveys carried out in Galway Bay (Table 5), although 6 species have been reported through citizen science (Figures 1-3, Marine Dimensions, 2017; Varian *et al*., 2010). In addition, no repeat records of endangered species were recorded at sites surveyed by scientists. A similar outcome was reported through the 2017 survey programme when scientists followed up on sightings of White Skate and Undulate Ray eggcases in south Galway Bay (Marine Dimensions, 2017). However, the occasional sightings of eggcases from White Skate (over a period of 25 years), Flapper Skate and Undulate Ray likely indicate the presence of spawning individuals, albeit in very low numbers. Observations of adult Stingray in the south of the bay have also been reported by citizen scientists (Marine Dimensions, 2017).

Table 5: Number of eggcases identified (including total and mean/m²/min) for each species recorded on exploratory surveys (n=6) carried out in Galway Bay in 2019.

Species name	Common name	Eggcase No.	Mean Eggcase No/m²/min	S.E.
Raja undulata	Undulate Ray	0	0	0
Dipturus intermedia	Flapper Skate	0	0	0
Dipturus flossada	Blue Skate	0	0	0
*Rostroraja alb*a	White Skate	0	0	0
Raja clavata	Thornback Ray	4	0.0097	0.0097
Raja montagui	Spotted Ray	0	0	0
Raja microocellata	Small Eyed Ray	0	0	0
Raja brachyura	Blonde Ray	0	0	0
Scyliorhinus canicula	Small Spotted Catshark	53	0.1173	0.0680
Scyliorhinus stellaris	Bull Huss	4	0.0095	0.0072
Unidentified Rajidae sp.		0	0	0

The scarcity of eggcase records makes it difficult to identify a site suitable for ongoing monitoring through indicator site surveys (Table 6); none of the sites surveyed through citizen science and/or the exploratory programme have scored more than 2 following application of the NHI Index (Table 2). It is there recommended that citizen science continue to be used to monitor the bay.

Table 6: Number of eggcases identified (including total and mean/m²/min) at each site surveyed on exploratory surveys (n=6) in Galway Bay in 2019.

Site name	Eggcase No.	Eggcase No/m²/min
Tawin Island	17	0.19
Aughinish	7	0.09
The Rine	36	0.53
Kinvara North	0	0
Kinvara South	0	0
Ballyvaughan	1	0.01

3.4 Extent of spawning season

3.4.1 *Undulate Ray*

There is a paucity of information on the reproductive ecology of Undulate Ray in general, especially in relation to populations inhabiting Irish waters. Available literature indicates that Undulate Ray breed seasonally between March and June in the north east Atlantic (Moura *et al*., 2008, Shark Trust, 2009), although a study by Coelho and Erzini (2006) in the south of Portugal has suggested that the species may breed during the winter in warmer waters. In 1997, a female Undulate Ray in the Benalmadena Sea Life Centre in Spain started laying eggs 25 days after mating, continuing for 77 days, during which time she laid 88 eggs. The incubation period for the first skate hatched was 91 days and it measured 14cm in length (De La Rosa, 1998, Shark Trust, 2009).

If we presume that the Undulate Rays in Tralee Bay are laying eggs from April to July (approximately one month after mating) with an incubation rate of approximately 3 months, one would expect to see hatchlings emerging from July-October, with higher numbers of eggcases discarded on the seabed during that time. Wind strength, along with local topographic conditions, would then likely determine how quickly, and to what extent, numbers of eggcases might be deposited on beaches as a result.

Figure 8 shows monthly variation in mean eggcase number per m² per minute for each species of elasmobranch recorded on indicator site surveys in Tralee Bay in 2019. It seems likely that eggcases discarded by hatchlings in July-October may have been accumulating on the seabed as monthly mean wind strengths were low in the summer and early autumn (< 8.5 km/hr). The sharp increase of eggcases recorded in November may then reflect the impact of stormy weather on the movement and subsequent deposition of cases that had been accumulating on the seabed.

Lower numbers of eggcases recorded in February through April may actually reflect reduced numbers of discarded eggcases, especially since very high wind strengths were recorded in February (mean: 13.25 km/hr). If this pattern follows the same trend

each year, ie. higher numbers of eggcases are deposited in the autumn/early winter as a result of (a), hatchling emergence discarding eggcases through July-Oct and (b), high wind strengths due to autumn storms and gales, it should be possible to use the beach eggcase surveys as a means of monitoring the health and recovery of the population. Likewise, any decrease in the numbers of eggcases recorded in the autumn, especially when recorded along side high mean wind strengths, would serve as a red flag in terms of nursery population decline.

However, clearly this method is based on a number of assumptions and it is essential that the monthly surveys are continued, preferably for at last 3 years, so that trends in association with wind strength and eggcase discards may be examined. Improved information in relation to Undulate Ray reproductive biology in Irish waters would also be useful. For example, a study could be carried out on egglaying rates and embryo incubation times for Undulate Rays kept in aquaria on the west coast of Ireland. Such information would allow further refining of likely egg deposition rates and emergence of hatchlings in Tralee Bay.

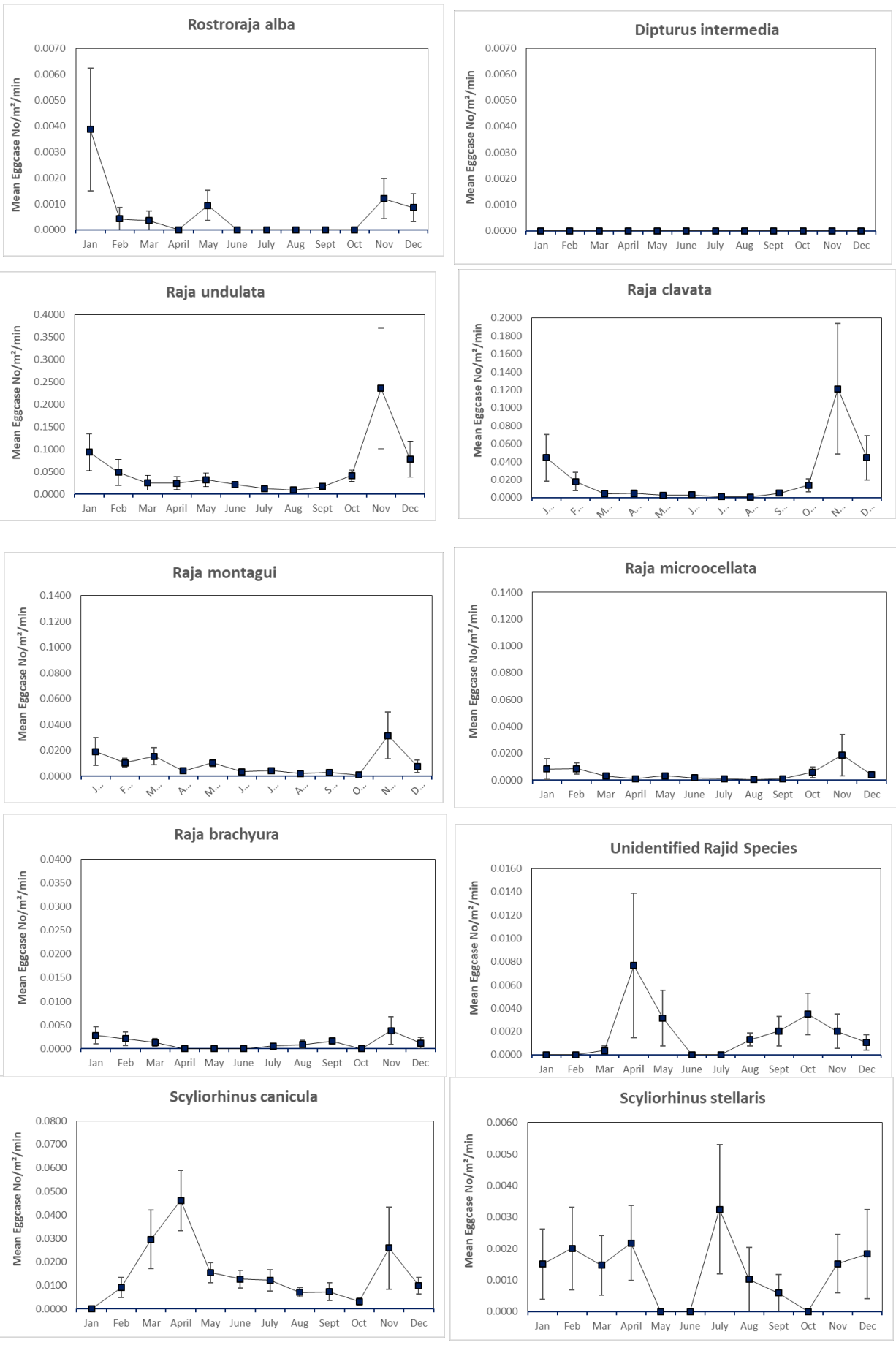

Figure 8: Monthly variation in mean eggcase number per m² per minute for each species of elasmobranch recorded on indicator site surveys in Tralee Bay in 2019 (± SE).

3.4.2 *White Skate*

Although there is a paucity of information on the reproduction of White Skate in general, a recent study in Tunisia by Kadri et al (2014) indicated that the species lays eggs year round. Other studies have also indicated egglaying rates of 55 – 156 ova per year, with eggcases ranging in length from 127.8-190.0 mm (when measured without horns) (Gordon *et al*., 2016). The incubation period appears to about 15 months (Clark, 1926; Dulvy *et al*., 2006; Shark Trust, 2009).

It is difficult to detect any trend in the extent of spawning season for the species in Tralee Bay and Galway Bay due to the low numbers of eggcases recorded (a total of 14 eggcases were recorded on 60 indicator site surveys) (Figure 8). The highest number of eggcases was recorded in January (n=6). However, an increase in eggcase numbers was also observed for other skate species at that time, indicating that the peak may be related to other factors, eg. there may have been a build up of eggcases over time due to lack of collections in the area prior to surveying.

Low numbers recorded through the summer also likely reflect hydrographic factors, similar to the Undulate Ray, with low wind strengths through these months (monthly mean <8.5) likely resulting in lower eggcase counts in general. White Skate eggcases have been reported year round through Purse Search, however, while Valentine, Galway Atlantaquaria's captive White Skate, was also observed laying eggs throughout the year (Noirin Burke, pers comm). It therefore seems most likely that hatchlings are emerging year round in both Tralee Bay and Galway Bay. Ongoing surveys could provide further elucidation of any trends in seasonality.

3.4.3 *Flapper Skate*

Female Flapper Skate are reported to lay up to 40 large eggs per year (Neal *et al*., 2008; Shark Trust, 2009), with capsules ranging in length from 150-200 mm (Shark Trust, 2019). Eggs are deposited during spring and summer months in the north east Atlantic (Clark, 1922), and may be left loose on a sandy or muddy seabed or occasionally secured between rocks (Neal *et al*., 2008; Shark Trust, 2009). Gordon et al (2016) state that no accurate information has been published regarding developmental time of this species, although previous studies have suggested an incubation period of 2-5 months depending on temperature (Clark, 1926; Neal *et al*., 2008; Shark Trust, 2009).

Although no Flapper Skate eggcases were recorded on indicator site and exploratory surveys conducted in Tralee Bay and Galway Bay, eggcases continue to be reported by citizen scientists on beaches around the country through Purse Search. However, it is difficult to determine any trends in seasonality due to the low numbers of eggcases recorded; only 35 eggcases have been recorded over a period of 11 years (2007-2018).

3.5 Public outreach

A comprehensive public outreach programme for Ireland's endangered skate and flat shark species has been continued, with key themes relating to White Skate, Flapper Skate and Undulate Ray worked into Marine Dimensions' existing shark and ray education and awareness programmes. This includes the following events and programmes:

3.5.1 *The Purse Search Ireland Programme*

Awareness continues to be raised for Ireland's egglaying sharks and rays through the Purse Search project (with emphasis on the endangered species considered in the present study) with numerous public engagement events (eg. libraries, festivals and schools) taking place around the country over the past year (eg. in Wexford, Donegal, Dublin, Wicklow, Clare and Limerick). The programme continues to be a very popular project with the public, demonstrating its potential both in terms of its ability to engage citizens, as well as its use as a method for highlighting areas of scientific interest. The programme also serves to enhance the profile of the EMFF project work, assisting with data collection and dissemination.

3.5.2 *The Marine Institute's Explorer's Education Programme*

Marine Dimensions joined the Marine Institute's Explorers Programme in 2018 as a new Outreach Centre for the east coast and a total of 20 education modules are now being to delivered to schools each year through the programme. The current contract for services runs through to 2020.

The other six regional Outreach Centres in the Programme (ie. Galway Atlantaquaria, Leave No Trace, Sea Synergy, Loophead Summer Hedge School, Cork Lifetime Lab and Oceanics Surf Ltd) were introduced to the endangered skates project through a seminar provided by Marine Dimensions in 2018, including the potential and benefits of incorporating citizen science as an activity on the Seashore Safari and Marine Project modules delivered through the programme. Since then, five of the six Centres have reported eggcase sightings to Marine Dimensions, three of which have included endangered skate species (ie. White Skate, Flapper Skate and Undulate Ray).

The inclusion of the Purse Search project in the Explorers Programme agenda has significantly increased the reach for the citizen science, as several Centres operate in regions (ie. Donegal, Sligo, Mayo, Galway and Cork) that have been identified as critical habitats for endangered skate species.

3.5.3 *The Agenda 21 Local Authority Education Programmes*

Marine Dimensions works closely with Local Authorities around Ireland, including Blue Flag Beach education and public outreach for the marine and coastal environment at the local level. Endangered skate species themes have been highlighted through these programmes since 2017.

3.5.4 *Other events and activities*

The project has also been highlighted through the following events:

- An *Understanding Sharks* day at Galway Atlantaquaria as part of European Maritime Day,
- Wexford Maritime Festival,
- Heritage Week library events in County Wicklow,
- SEAFEST (through the Explorers Programme stand).

Related outreach has also been conducted for Tralee Bay and Galway Bay by our project partners, Galway Atlantaquaria and Sea Synergy, through the Explorers Education Programme.

3.5.5 *Online Outreach*

The project has been promoted online through Marine Dimensions' website, marinedimensions.ie and social media channels, ie. Twitter, Facebook and Instagram.

4.0 CONCLUSIONS

Innovative methodologies have been developed that may be used to monitor, and raise awareness, for threatened species of egglaying skate and ray on an ongoing basis. It is hoped that we will now be able to further refine a sampling approach that includes robust, but low impact, survey techniques that may be used to monitor vulnerable species through an ongoing time series continuum.

Work to date has also demonstrated the importance of Tralee Bay and Galway Bay as critical habitats and potential refuges for several species of endangered skate and ray. It is recommended that Tralee Bay be prioritised for monitoring through ongoing monthly indicator site surveys, due to suitability of sites for monitoring local and seasonal variation in eggcase abundance. The low numbers of eggcases from endangered skate species recorded on beaches in Galway Bay makes it more suitable for monitoring through citizen science.

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6.0 ADDENDUM

Additional surveys of eggcase distribution and abundance at indicator sites in Tralee Bay were commissioned by the Marine Institute in January in order to maintain continuity in the data time series necessary for effective long term monitoring. The data is being made available as an additional output.