Report of Surveys of Razor Clams (*Ensis arcuatus, Ensis siliqua and Ensis Ensis*) off the West coast of Ireland in 2016

Final Report

Inshore Fisheries Team

Fisheries Ecosystems Advisory Services

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Contents

Summary

Razor clam (*Ensis* spp.) beds were surveyed at 12 locations off the west coast of Ireland in 2016. Survey locations were based on information compiled from industry early in 2016. Razor clams occurred in all 12 locations. *Ensis arcuatus* was the dominant species although *Ensis siliqua* was also strongly represented in some locations. The catch rates and derived estimates of densities and biomass are sufficient to support commercial fisheries in all areas. In order to provide guidance on the likely level of fishing that could be supported speculative annual total allowable catches (TACs) are indicated using various assumptions relating to sustainable harvest rates.

Total biomass in the surveyed areas was 933t (*E. arcuatus*), 136t (*E. siliqua*) and 41t (*Ensis* spp). Biomass, including areas of likely distribution beyond the limits of the surveyed areas and based on presence of suitable habitat contiguous with the survey area, was 1509t (*E. arcuatus*), 264t (*E. siliqua*) and 53t (*Ensis* spp.). Taking all areas together, including existing fisheries in Clifden and Iniskea Is., the likely annual combined TACs are 233t for *E. arcuatus*, 34t for *E. siliqua* and 10.3t for *Ensis* spp.

Developing fisheries in unexploited stocks or in stocks that have not been fished for over 15 years should proceed cautiously. Advice should be based on a monitoring programme that would provide information on changes in biomass, size and age structure and recruitment. Overcapitalisation should be avoided given that some adaptive management will be needed in the initial years of any new fisheries depending on the response of stocks to fishing and until sustainable harvests are known.

Introduction

Early in 2016 the putative distribution of razor clams off the west coast of Ireland was mapped based on information from fishermen who had fished these stocks in the 1990s and from other fishermen who had more recent knowledge of the location of commercially viable razor clam beds (Marine Institute 2016). Interest in fishing these stocks has increased recently because of high fishing pressure on stocks in the Irish Sea and strong market demand.

The Inshore Management Group (IMG), comprising the Department of Agriculture Food and Marine and Marine Agencies, identified a protocol by which razor clam stocks that had not been fished for a number of years could potentially be re-opened and fished sustainably (Marine Institute 2015). This protocol included provision for a preliminary assessment of stock distribution and biomass which could be used to prioritise areas for new fisheries based on economic potential and whether the stock existed within an existing classified production area for bivalve molluscs or not. If it was decided to open areas to fishing then a management plan was also to be agreed prior to opening and the measures in the plan would be proportional to the risk of overexploitation or escalation of fishing of the stock considering its location and proximity to other razor clam fisheries or to vessels which were equipped to fish for razor clams and the cost:earnings ratio for these fisheries.

To inform the protocol and the prioritisation of areas that could potentially be opened to fishing MI undertook a number of razor clam surveys during 2016. The surveys provide information on species composition (there are 3 species of *Ensis* spp. in the survey data), spatial distribution, biomass, size composition and indications of age and growth. Preliminary and speculative annual TAC scenarios

are indicated, based on harvest rates that are thought to be sustainable, in order for the authorities and industry to evaluate the fishery and economic potential that could accrue from opening these areas to fishing. The speculative TACs proposed will need to have a firmer basis and the stocks will need to be monitoring annually if they are opened to fishing.

Existing razor clam fisheries

The main Razor clam fishery in Irish waters has, since the mid-1980s, been for *Ensis siliqua* in the north Irish Sea and since 2010 off the east Wexford coast. Annual landings are approximately 1000 tonnes and involve about 70 vessels. Annual first sale value is approximately €6m and is increasing due to stronger market prices even if landings are stable. Fisheries for *Ensis arcuatus* occur in Clifden Bay Co. Galway and since 2016 at the Iniskea Is in County Mayo. Landings from these two locations do not exceed 50 tonnes per annum. Fisheries for *Ensis* spp. did occur in a number of other areas on the west coast in the 1990s but due to poor market conditions and overexploitation these fisheries did not continue. Records and data from these small scale local fisheries on the west coast in the 1990s are poor or non-existent. However, the memory and knowledge of fishermen who participated in these fisheries has been valuable in identifying the locations where they occurred and what the future potential might be as outlined in Marine Institute (2016). This information has also been used by the Regional Inshore Fisheries Forums (RIFFs) to set the priorities for surveys in 2016 as reported here.

Surveys in 2016

Locations

Surveys were completed in areas shown in Table 1 and Figure 1. More than one area (razor clam bed) was surveyed in some locations. In inner Bantry Bay discrete areas in Bearhaven and in Adrigole Hbr were surveyed. In north west Donegal Gweedore Bay, Cruit Bay and Rutland sound were surveyed. At Clifden the main Bay and an area north of Turbot Island were surveyed. A number of beds were sampled at the approaches to Killary Hbr., North and south shores of Ballinakill Bay and south and east of Inisbofin and south of Iniskea Is. Ten tows were taken east of Inisturk opportunistically by one of the survey vessels on passage. A total of 274 stations were sampled between April and November 2016.

Three commercial vessels were used for survey; the MFV Lantern (Clifden Bay and Iniskeas), the MFV William B (Bearhaven and Adrigole) and the MFV Rosanne (all other surveys).

Table 1. Locations of Razor clam surveys in 2016 and number of dredge tows taken per survey.

County	Location	Number of tows	Dredge type	Dredge width	Month
Cork	Bearhaven	33	Water jets	1m width	July
Cork	Adrigole Hbr	8	Water jets	1m width	July
Donegal	Gweedore Bay	23	Water jets	1m width	October
Donegal	Cruit Bay	10	Water jets	1m width	October
Donegal	Rutland Sound	53	Water jets	1m width	October
Galway	Ballinakill Bay	18	Water jets	1m width	September

Galway	Clifden Bay	33	Propeller	0.56m width	April
Galway	Turbot Is. Clifden	7	Propeller	0.56m width	April
Galway	Inisbofin	9	Water jets	1m width	September
Galway	Inisturk	10	Water jets	1m width	November
Galway	Killary Approaches	36	Water jets	1m width	October
Mayo	Broadhaven Bay	22	Water jets	1m width	July
Mayo	Iniskea Is.	12	Propeller	0.56m width	July

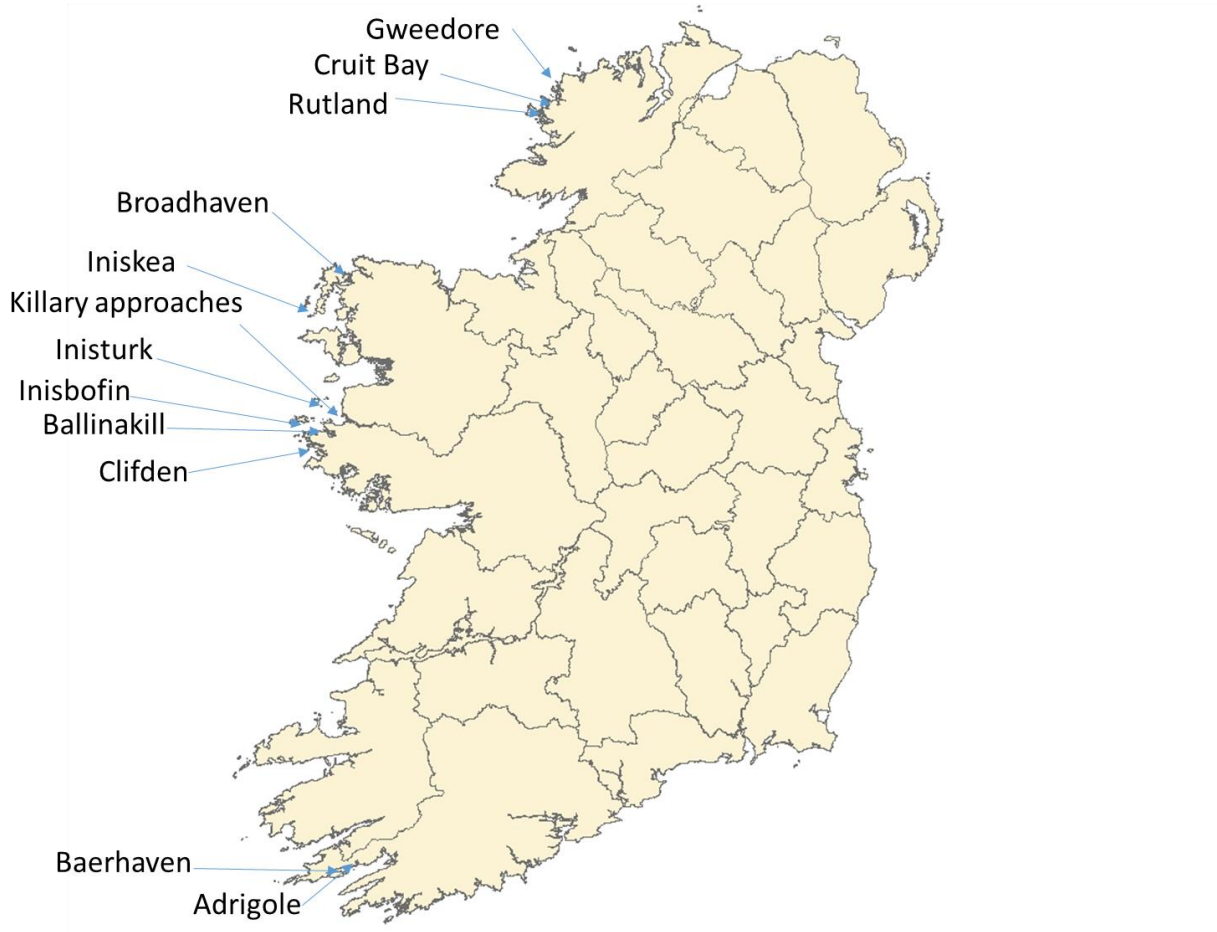


Figure 1. Locations of razor clam surveys off the west coast of Ireland in 2016.

Methods

Survey

Dredges using hydraulically pressurised water jets, to dislodge sediments and razor clams in front of the dredge, were used at all locations except Clifden Bay and Iniskea Is. where a smaller dredge with a propeller attached in front of the dredge was used (Table 1). The water pressure and angle of the water jets (or speed and angle of propeller) are important in enabling penetration of the dredge into the sediment to a depth of approximately 25cm and ideally need to be adjusted in relation to the compactness and grain size of the sediment. This was not possible during the limited time available for surveys and catchability in the surveys is expected to be lower than that during commercial operations where fine scale adjustments of gear for different ground types would be standard practice. Poor penetration of the sediment is indicated by a high proportion of broken clams in the

catch. Typically the propeller dredge is used in loose sand where *E. arcuatus* can occur in high densities and the water jet dredge is used in compacted sandy mud or mixed sediments where *E. siliqua* is more common.

There was no formal survey design or pre-defined stations as the distribution and extent of clam beds prior to survey was speculative. Admiralty chart depth contours and aerial imagery from google maps combined with the information presented in the initial mapping exercise completed earlier in 2016 (Marine Institute 2016) were used to infer possible extent of individual clam beds. Typically the razor clam beds occurred on shallow sub-tidal sand banks visible from aerial imagery. In other locations this was not clear and station positions were exploratory.

At each station the dredge was towed for 3-5minutes. Tow path and length of tow was recorded using a Trimble® GPS Survey Unit or in the case of Inisbofin and Ballinakill surveys the GPS position at start and end of the tow was recorded from the vessel GPS plotter. Tow length was typically within the range 20-60m.

At each station the total number and weight of *E. arcuatus, E. siliqua* and *E. Ensis* in the catch was estimated. *E. Ensis* was uncommon. Species were not distinguished in the Bearhaven and Adrigole surveys although *E. siliqua* was dominant. No size measurements were taken at Inisturk. The presence of other species of bivalve was recorded and in some cases these were enumerated. Either the entire catch or a sub-sample of razor clams was measured at each station.

Data analysis

The area surveyed was defined by the distribution of the stations using the α-shape function (van Kreveld et al 2011), implemented in the R package alphahull, to define the boundaries of the surveyed area. Sampling was generally not sufficient to identify the boundaries of the beds which would require sampling until zero catches were systematically found in all directions from the centre of the bed. The results are presented, therefore, both for the area represented by the survey (survey area) and secondly for the area over which razor clams are likely to be distributed (extrapolated area or likely distribution area) where it is clear that the habitat (shallow water sandbanks) also extends beyond but is contiguous with the survey area. The space between the survey area and the extrapolated area is, therefore, not supported by sample data as such but is an inferred distribution given that similar habitat to that in the survey area seems available. The mathematical interpolation of the survey data is extended out to the edges of this likely distribution area.

The number and weight of razor clams per sample were standardised to density and weight per square meter (using the swept area estimate for each dredge haul; dredge width * distance towed). No adjustments for catchability (gear efficiency) were included in reported density or biomass except in the case of areas where there are established fisheries and where the Skippers have adjusted gear to optimise catches. In these cases (Clifden Bay and Iniskea Is) gear efficiency is adjusted to 90%. The reported figures for all other areas assume a dredge efficiency of 100% which is unrealistic. The reported biomasses are therefore minimum estimates to varying degrees depending, as reported above, on how well the dredge worked in particular sediments.

Densities and biomass per unit area were mapped and interpolated using an Inverse Distance Weighting (IDW) algorithm in R. This interpolation method averages the values of sample data points in the vicinity of each cell in the raster surface being estimated. A power value in the interpolation

can be used to control the weighting of points based on geographic distance from the point being calculated. Specifying low power, such as 2 in the present case, gives more influence to distant points and a smoother surface.

Density contours were drawn at intervals to reflect the range in density and biomass over the survey area. The geographic area within each contour was calculated.

Total weight and number of razor clam was estimated directly at each station where possible. Where sub-sampling was required the weight of measured razor clams was calculated by converting shell length to weight using a length weight relationship estimated for clams at Inishkea and Killary for *E. arcuatus* and Broadhaven Bay for *E. siliqua*. The sample weight was raised to total catch weight and total catch numbers.

The estimated individual weight data for razor clams were used to estimate the weight of the catch by station and the mean±s.d. of the weight of each species of razor clams among stations within each contour. When a catch weight was available, the biomass density and its confidence interval were directly estimated by stratum based on biomass densities calculated at the stations.

Alternatively, when only density and mean individual weight were available – or the catch weight was deemed unreliable – the mean biomass density of razor clams (BD_c) and its confidence limits per square meter within the contour was calculated as

$$BD_c = (D \pm d) * (W \pm w) = D * W \pm ((D * W) * \sqrt{d^2 / D^2 + w^2 / W^2})$$

where D is average density of razor clams at stations within the contour, d is the confidence limits for the average density, W is the mean weight of razor clams at stations within the contour and w is the confidence limit for the mean weight.Total biomass within each contour (B_c) was calculated from the product of the mean biomass density within the contours and the geographic area encompassed by the contours.

$$B_c = BD_c * A_c \pm CL_{BDc} * A_c$$

where BD_c is the biomass per square meter within a contour area, A_c is the area encompassed by the contour, CL_{BDc} is the confidence limit for the biomass per square meter within the contour area as calculated above. Finally the total biomass was obtained by summing the biomass estimates for all contours

$$B = \sum_{c=1}^{n} (B_c)$$

Confidence limits for total biomass, being non-additive, were combined across strata using the method of Cochran (1977, p. 95) adapted to fish surveys by Rätz (1996).

Alternatively, when the above method was not suitable (providing unreliable estimates with very wide confidence intervals), the mean biomass by strata was modelled using a Bayesian framework adjusted on biomasses at stations, calculated as $BD_s = D_s \times \overline{W_s}$, were D_s is the density of individuals at the station *s* and $\overline{W_s}$ the mean weight of individual at this same station. Different

distributions of biomass densities among strata – Normal and Log Normal – were tested and the goodness of fit compared using the DIC to retain the best model. Results from the Bayesian method are not reported here.

Within this framework, mean biomass multiplied by stratum surface areas and summed over strata provide an estimate of the distribution of the total biomass, from which a range of credible values for 95% confidence interval could be derived.

Results

Summary statistics

E. arcuatus was the dominant species in all surveys other than in the approaches to Killary Harbour, comprising 94% by number and 91% by weight of all clams identified to species (Table 2, Figure 2). The total surveyed area was 8.78km^2 and the total likely distribution area was 12.79km^2.

Table 2. Ensis species composition in surveys by number and weight

	Sample size		Proportion	
Species	Number	Weight	Number	Weight
Ensis arcuatus	33366	761	0.94	0.91
Ensis Ensis	62		0.01	0.01
Ensis siliqua	2024	73	0.06	0.09
Ensis spp.	4966	191	0.12	0.23
Total	40419	1025		

Nominal catches of *E. arcuatus* per 3-5min tow ranged from 30-662 individuals and 1-13.7kgs. Catches were highest at Clifden (Turbot Is) and Iniskeas which are currently commercially fished. Catches in inner Clifden Bay and Inisbofin averaged 298 and 244 individuals per tow and at Ballinakill Bay and Broadhaven Bay averaged 130 and 121 individuals per tow respectively. Lowest average catches of *E. arcuatus* occurred at Cruit Bay, Rutland sound and at the approaches to Killary.

Table 3. Mean number and weight (kgs) of catch of Ensis spp. per 3-5minute tow at survey locations.

Location	Mean No per tow	Mean No per tow	Mean No per tow	Mean kgs per tow	Mean kgs per tow	Mean kgs per tow
	E. arcuatus	*E. siliqua*	*Ensis* spp	*E. arcuatus*	*E. siliqua*	*Ensis* spp
Bearhaven			142.9			5.1
Adrigole Hbr			31.1			1.2
Gweedore Bay	81.6	11.6		2	0.6	
Cruit Bay	30.5	32.2		1.1	2	
Rutland Sound	46.9	5.3		1.3	0.3	
Ballinakill Bay	130.9	1.5		4	0.1	
Clifden Bay	298.4			7.4		
Turbot Is Clifden	662.1			13.7		
Inisbofin	244.9	3.2		7.7	0.3	
Inisturk						1.3
Killary Approaches	40.7	18.6		1.2	1.1	
Broadhaven Bay	121.9	20.3		4.2	0.1	
Iniskeas	593.2			9		

Figure 2. (a) Hydraulic razor clam dredge suspended on frame at stern of survey vessel. The sorting box is in foreground. (b) unsorted catch with sediment and bivalve shells (c) clean unsorted catch with E. arcuatus and heart urchin at Inisbofin (d) sorted catch of E. arcuatus from Ballinakill (e) E. arcuatus (top 3) and E. Ensis (bottom 2) from Killary.

Biomass assessments and possible TACs

Estimated biomass and annual possible TACs for each area are summarised in Table 4. A range of TAC possibilities are presented given the limited scope of the surveys, the inherent uncertainty in the biomass estimates and assuming sustainable annual harvest rates of 20-30%. The lowest expected TAC was estimated as a harvest rate of 20% of the lower 95% confidence interval for the biomass estimated in the surveyed area. The likely value is based on a 25% harvest rate of the average biomass estimated from the survey area and the maximum expected TAC was calculated from the upper 95% confidence interval of the extrapolated area over which razor clams may be distributed beyond but contiguous with the surveyed area. All these estimates and the sustainable harvest rate, would need to be confirmed by more extensive surveys if the areas are opened to fisheries. Variation in dredge efficiency has not been accounted for in the estimates other than application of an efficiency of 90% for beds that are already opened to fishing (Clifden and Iniskeas) and where the gear has been optimised for operation in these areas. In other surveys the gear efficiency is likely to have been lower than 90% and the biomass and TAC options are, therefore, likely to underestimates.

Except in the Killary Approaches where *E. siliqua* is the dominant species in terms of biomass (likely TAC of about 15t), most beds are dominated by *E. arcuatus*. Total biomass in the surveyed areas are 933t (*E. arcuatus*), 136t (*E. siliqua*) and 41t (*Ensis* spp). Extrapolated or potential biomass including areas of likely distribution beyond the limits of the surveyed areas are 1509t (*E. arcuatus*), 264t (*E. siliqua*) and 53t (*Ensis* spp.)

The likely annual TACs for *E. arcuatus* range from 1.9t in Cruit Bay (small bed of about 0.25 km^2) to about 58t in Clifden Bay and 45t in Rutland sound. Taking all areas together, including existing fisheries in Clifden and Iniskeas, the likely annual combined TACs are 233t for *E. arcuatus*, 34t for *E. siliqua* and 10.3t for *Ensis* spp.

More detailed accounts of each area are presented below.

Precaution in evolving to sustainable TACs

The sustainability of the TACs options outlined in this report is unknown. Most of these stocks are unexploited and the survey data provides the first estimates for virgin biomass i.e. biomass of an unfished stock that may be at equilibrium with respect to mortality, recruitment and age structure. There are some theoretical methods to estimate maximum sustainable yields in these situations but their utility may be limited in this case. Any fishery development strategy evolving from an unexploited status to maximum sustainable yield (represented by harvest rate of 20-30% as assumed here) makes a number of assumptions about the stocks response to exploitation (Die and Caddy 1997). In the case of razor clam stocks the response to exploitation and generation of surplus production which could be harvested could include

- Increased recruitment of juveniles due to reduced competition for space and reduced cannibalism of settling larvae by adults. This is a common response in infaunal bivalve species
- Increased growth rate if growth is density dependent
- Reduced growth rate due to gear contact
- Increased ‘unobserved’ mortality due to contact with fishing gear

- Changes in species composition, diversity and dominance in the habitat which may affect recruitment of Ensis spp.

In some beds at least there are indications of missing year classes indicating that recruitment is not annual or that there are episodic mortality events perhaps due to effects of harmful algal blooms. Forecasting sustainable harvest rates in these situations is problematic. Stocks with missing age classes may not support annual fisheries.

Some stocks (Clifden Bay) have been fished for over 15 years and seem stable although this sustainable fishing period followed from previous fisheries which led to significant depletion in biomass. Stock recovery occurred. Annual harvest rate in this stock in the past 15 years, presuming that there have been no major annual fluctuations in stock biomass, however, appear to have been about 13% which is lower than the proposed likely TACs of 20-30% of biomass suggested above. Theoretically also if MSY = $0.5MB_0$ (Gulland's formula), where B_o is the unexploited biomass and M is natural mortality rate of 0.2, then the TACs proposed above are also too high. However, cockle stocks in Ireland and elsewhere and where the biological processes are similar to that of Razor clams, have been exploited sustainably using harvest rates of 20-30% per annum. The relation between size at maturity and size at recruitment to the fishery is an important consideration here. For razor clams the market size of 120-130mm is well above the size at maturity which is likely to be less than 100mm thereby protecting spawning potential even when fishing mortality is high (provided fishing effects on clams under 100mm is low). In addition the biomass estimates reported here are minimum estimates considering that the dredge efficiency was assumed to be 100%.

The most appropriate approach to developing new fisheries, and consistent with existing codes of conduct for new fisheries, is to ensure a monitoring programme exists, that over investment (capitalisation) does not develop and to have prior agreement between industry and authorities of the need to be adaptive in response to monitoring data.

A monitoring programme for these fisheries will need to include, in the initial years of fishery development at least, annual estimates of biomass and size structure and recording of all landings. These data will also increase knowledge of the recruitment process and age structure from which more direct estimates of mortality can be derived. Fishing performance indicators such as catch per dredge hour could eventually substitute for survey data as an index of biomass if data quality was sufficient.

Table 4. Biomass estimates for Ensis spp. in each surveyed area. The assessed biomass is based on the survey data applied to the area surveyed. The potential biomass is based on the survey data applied to a larger area (in some cases) where suitable habitat seems available and is contiguous with the surveyed area and given that the surveys did not identify the boundaries of the beds. The lowest expected TAC is based on the lower 95% confidence limit for the assessed biomass and a 20% annual harvest rate. The likely TAC is based on a 25% harvest rate of the average assessed biomass. The maximum TAC is based on a 30% harvest rate of the average potential biomass. The areas (km^2) contained by the surveys and the likely areas of distribution of Razor clams, given available habitat and depth in each area, are indicated.

Species	Location	Assessed biomass (t) ± 95% CI		Potential biomass (t) ± 95% CI		Lowest expected TAC (t)	Likely TAC (t)	Maximum expected TAC (t)	Survey area (km^2)	Distribution area (km^2)
E. arcuatus	Gweedore Bay	69.09	± 21.59	140.29	± 43.29	9.5	17.27	55.07	1.21	2.54
	Cruit Bay	7.53	± 4.53	11.68	± 7.07	0.6	1.88	5.63	0.25	0.38
	Rutland Sound	178.07	± 37.00	210.79	± 43.34	28.21	44.52	66.71	3.57	4.55
	Ballinakill Bay	111.36	± 90.38	162.26	± 137.01	4.2	27.84	89.78	0.28	0.36
	Clifden Bay	230.55	± 14.53	365.83	± 21.71	43.2	57.64	116.26	0.45	0.75
	Turbot Island Clifden	63.91	± 6.89	143.86	± 15.82	11.4	15.98	47.9	0.07	0.16
	Inisbofin	72.39	± 39.81	126.4	± 69.18	6.52	18.1	58.67	0.26	0.46
	Killary Approaches	46.95	± 17.74	96.78	± 33.73	5.84	11.74	39.15	0.86	1.34
	Broadhaven Bay N	46.41	± 34.69	46.41	± 34.69	2.34	11.6	24.33	0.355	0.355
	Broadhaven Bay S	30.18	± 12.54	30.18	± 12.54	3.53	7.55	12.82	0.91	0.91
	Iniskeas	76.63	± 14.97	202.71	± 40.57	12.33	19.16	72.98	0.178	0.46
	Sub-total	**933.1**		**1537.19**		**127.7**	**233.3**	**589.3**		
E. siliqua	Gweedore Bay	14.21	± 3.06	35.01	± 7.54	2.23	3.55	12.77		
	Cruit Bay	12.85	± 4.73	20.2	± 7.48	1.62	3.21	8.3		
	Rutland Sound	23.02	± 4.05	34.7	± 6.1	3.79	5.76	30.71		
	Ballinakill Bay	3.06	± 2.35	3.51	± 2.71	0.14	0.77	1.87		
	Inisbofin	0.33	± 0.28	0.8	± 0.45	0.01	0.08	0.38		
	Killary Approaches	60.01	± 13.85	95.32	± 23.24	9.23	15	35.57		
	Broadhaven Bay N	5.32	± 1.55	5.32	± 1.55	0.75	1.33	2.06		
	Broadhaven Bay S	17.18	± 10.64	17.18	± 10.64	1.31	4.3	8.35		
	Sub-total	**136**		**212.04**		**19.1**	**34**	**100**		

Ensis spp.	Adrigole Harbour	2.23	± 1.75	10.9	± 8.64	0.1	0.56	5.86	0.043	0.176
	Bearhaven	39.05	± 16.69	42.11	± 18.15	4.47	9.76	18.08	0.175	0.182
	Inisturk				10			3.3	0.17	0.17
	Sub-total	**41.3**		**53**		**4.6**	**10.3**	**23.9**		
Totals		**1110**		**1826**		**151**	**278**	**713**	**8.781**	**12.793**

Survey reports

Bearhaven – Co. Cork

This bed was surveyed on July the 27th and 29th, aboard MFV William B using a hydraulic dredge (Figure 3 - Figure 5). The area over which the main razor clam (*Ensis* spp.) bed is distributed was not well covered by the survey and the area of the clam bed and biomass estimate are therefore significantly underestimated. Gear efficiency may have been low to moderate. There were large volumes of shell and mixed sediments in the catch which increased catch sorting time. Compacted muds occurred in deeper areas and could not be fished. The sampled area per station varied from 10m^2 to 54m^2 depending on the length of each dredge haul. 28 dredge hauls were completed in Bearhaven, between Kealamullagh Point and Pipers Point to the west of the Sound and between Fort Point and Naglas Point on the eastern side, where densities ranged from 0-44.9 razors m^{-2}. However, only one station returned a density of 44.9 razors.m^{-2}, with the majority ranging from 0-16.5 razors.m^{-2}.

A total of 1,364 razor clams were measured from Bearhaven. The majority of razor clams observed were *E. siliqua*, however *E. arcuatus* were also observed during the survey. The ratio of *E. siliqua* to *E. arcuatus* was not recorded, therefore the biomass estimate includes both species. The total biomass was estimated to 39±17 tonnes (Table 5 - Table 6).

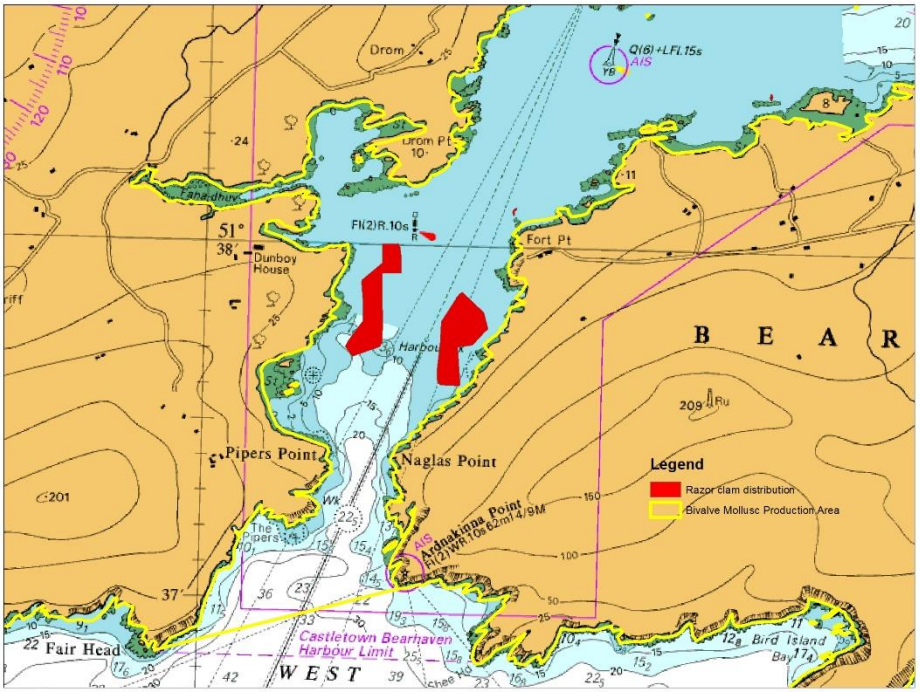


Figure 3. Survey distribution area of Ensis spp. in Bearhaven

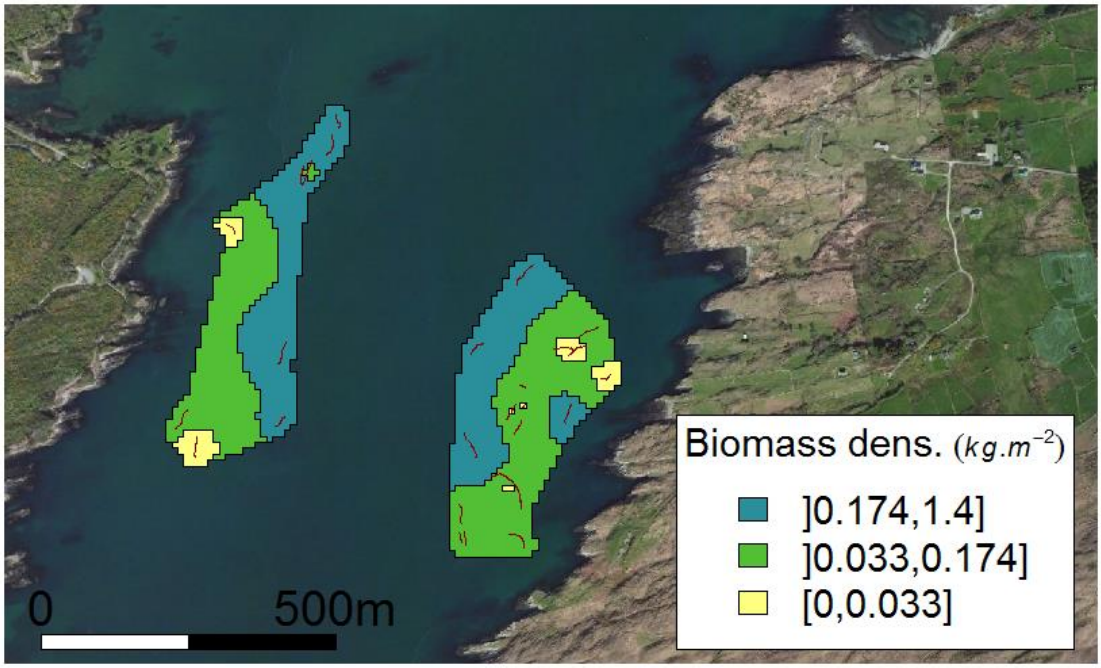


Figure 4. Distribution of biomass of Ensis spp. over the surveyed zone in Bearhaven.

Table 5. Stratified biomass assessment summary for Ensis spp. over the surveyed zone in Bearhaven.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass (g.m^{-2})	95% CL Biomass (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.033]	9500	8	13.72	8.23	0.13	0.08
]0.033,0.174]	91300	9	46.90	20.73	4.28	1.89
]0.174,1.4]	74600	10	464.27	222.34	34.63	16.59
Total	**0.175 km²**	**27**	**222.62**	**95.18**	**39.05**	**16.69**

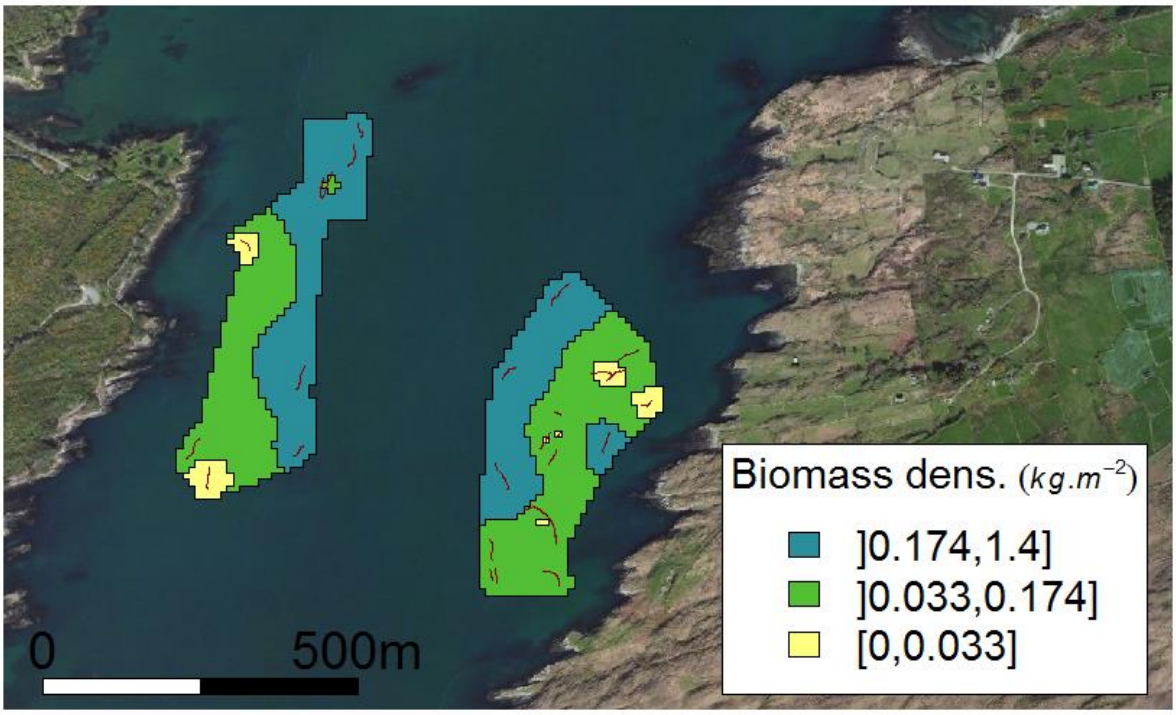


Figure 5. Biomass density of Ensis spp. over the extended survey zone (potential distribution) in Bearhaven.

Table 6. Stratified biomass assessment summary for Ensis spp. over the extended survey zone (potential distribution) in Bearhaven.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.033]	9500	8	13.72	8.23	0.13	0.08
]0.033,0.174]	91300	9	46.90	20.73	4.28	1.89
]0.174,1.4]	81200	10	464.27	222.34	37.70	18.05
Total	**0.182 km²**	**27**	**231.38**	**99.74**	**42.11**	**18.15**

Adrigole Harbour – Co. Cork

This bed was surveyed on July the 28th aboard MFV William B (Figure 6 - Figure 8). Due to difficulties in tuning the dredge for this kind of ground, the bed couldn't be explored extensively. Eight hauls were taken. Mussel lines are present immediately west and north west of the bed. Razor densities in this area ranged from 0-4.3m^{-2}. A total of 242 razor clams were measured. The majority of razor clams observed were *E. siliqua*, along with some *E. arcuatus*. A biomass of 2.2±1.8 tonnes was estimated. Extrapolating to the potential extent of the bed, the biomass was 10.9±8.6 tonnes (Table 7 - Table 8).

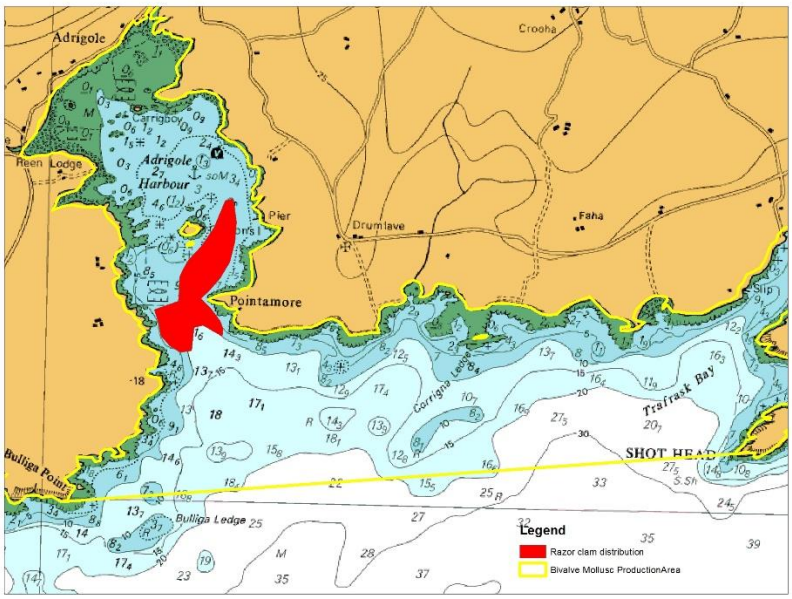


Figure 6. Likely distribution area of Ensis spp. in Adrigole Hbr.

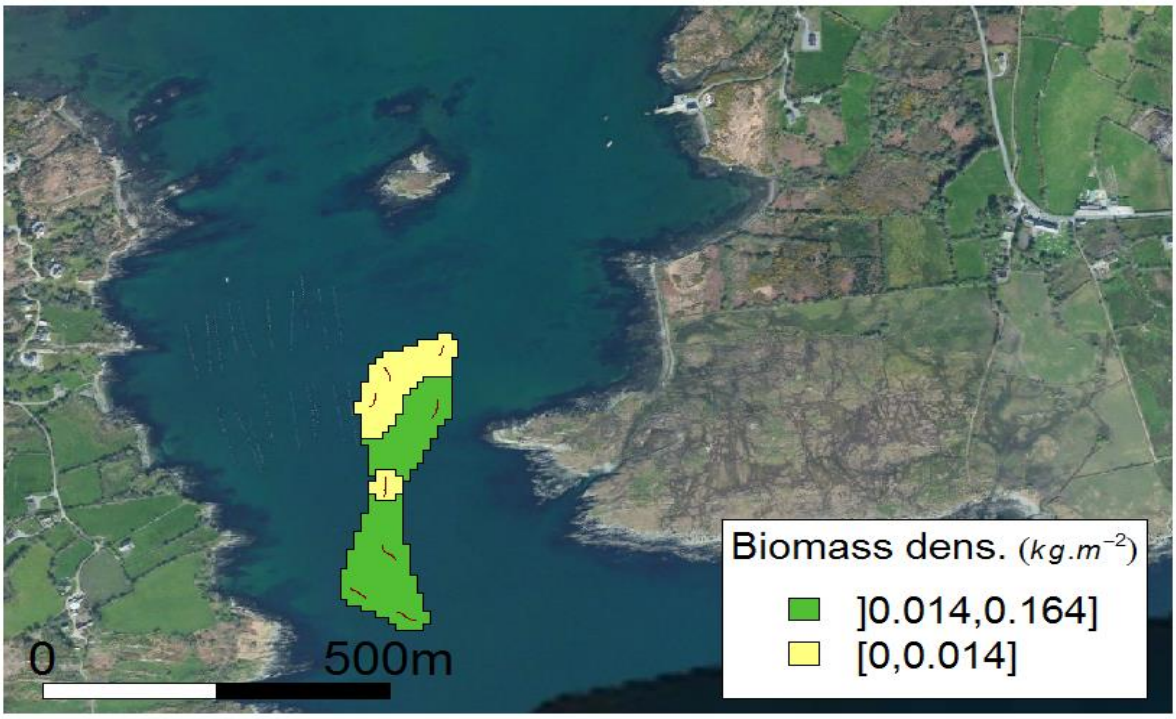


Figure 7. Biomass density of Ensis spp. over the surveyed zone in Adrigole Harbour. Mussel long lines are visible to the west of the survey area.

Table 7. Stratified biomass assessment summary for Ensis spp. over the surveyed zone in Adrigole Harbour.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.014]	14200	4	2.29	4.48	0.03	0.06
]0.014,0.164]	28400	4	77.34	61.74	2.20	1.75
Total	**0.043 km²**	**8**	**52.32**	**41.19**	**2.23**	**1.75**

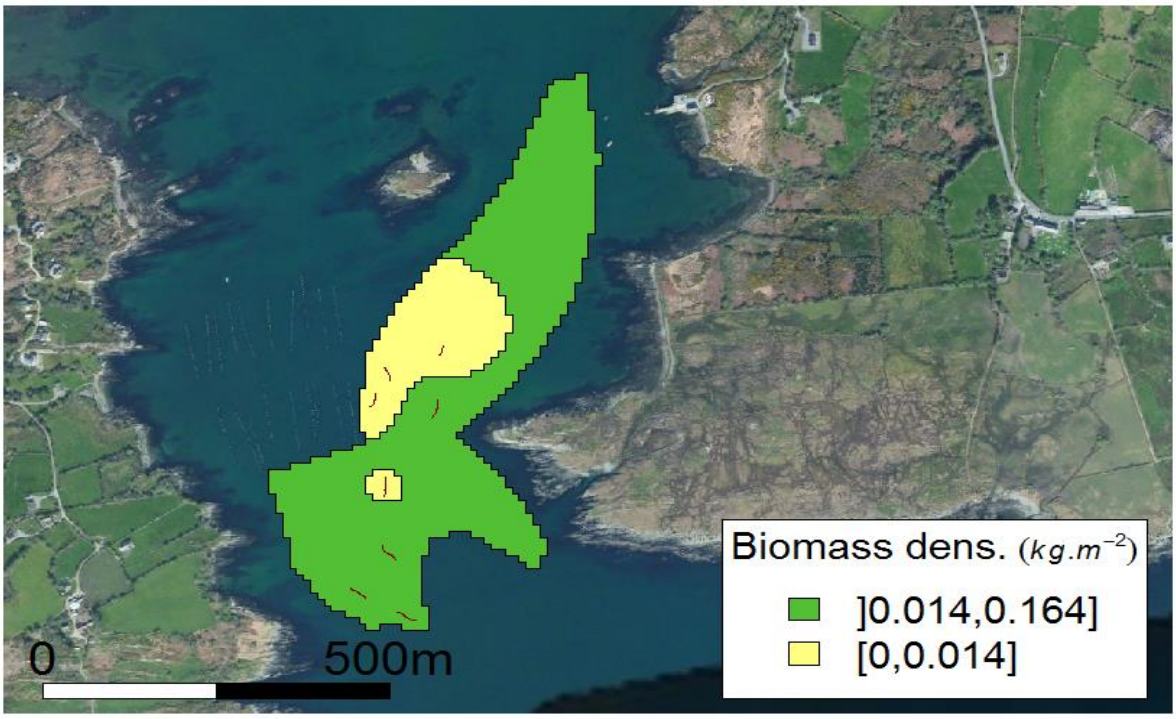


Figure 8. Distribution of biomass of Ensis spp. over the extended survey zone (potential distribution) in Adrigole Harbour.

Table 8. Stratified biomass assessment summary for Ensis spp. over the extended survey zone (potential distribution) in Adrigole Harbour.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.014]	36000	4	2.29	4.48	0.08	0.16
]0.014,0.164]	139900	4	77.34	61.74	10.82	8.64
Total	**0.176 km²**	**8**	**61.98**	**49.11**	**10.90**	**8.64**

Gweedore Bay – Co. Donegal

This bed was surveyed on October the 14th aboard MFV Rosanne using a hydraulic dredge (Figure 9 - Figure 15). Dredge efficiency may have been low to moderate as there was a significant proportion of razors in the catch that had been cut by the dredge. Both species were present, with a dominance of *E. arcuatus*. The total biomass of *E. arcuatus* was estimated at 69±22 tonnes (140±43 for the extended area) and total biomass for *E. siliqua* was 14.2±3.1 tonnes (35±7.5 for the extended area) (Table 9 - Table 12).

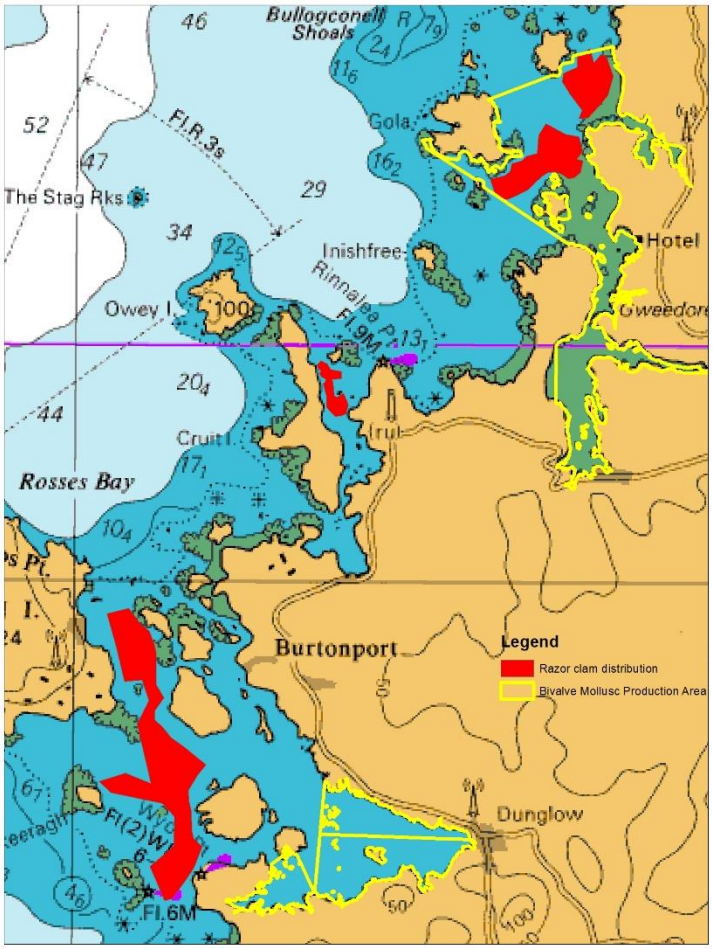


Figure 9. Likely distribution area of Ensis spp. in Gweedore Bay, Cruit Bay and Rutland Sound Donegal. Existing classified production areas for bivalve molluscs are shown

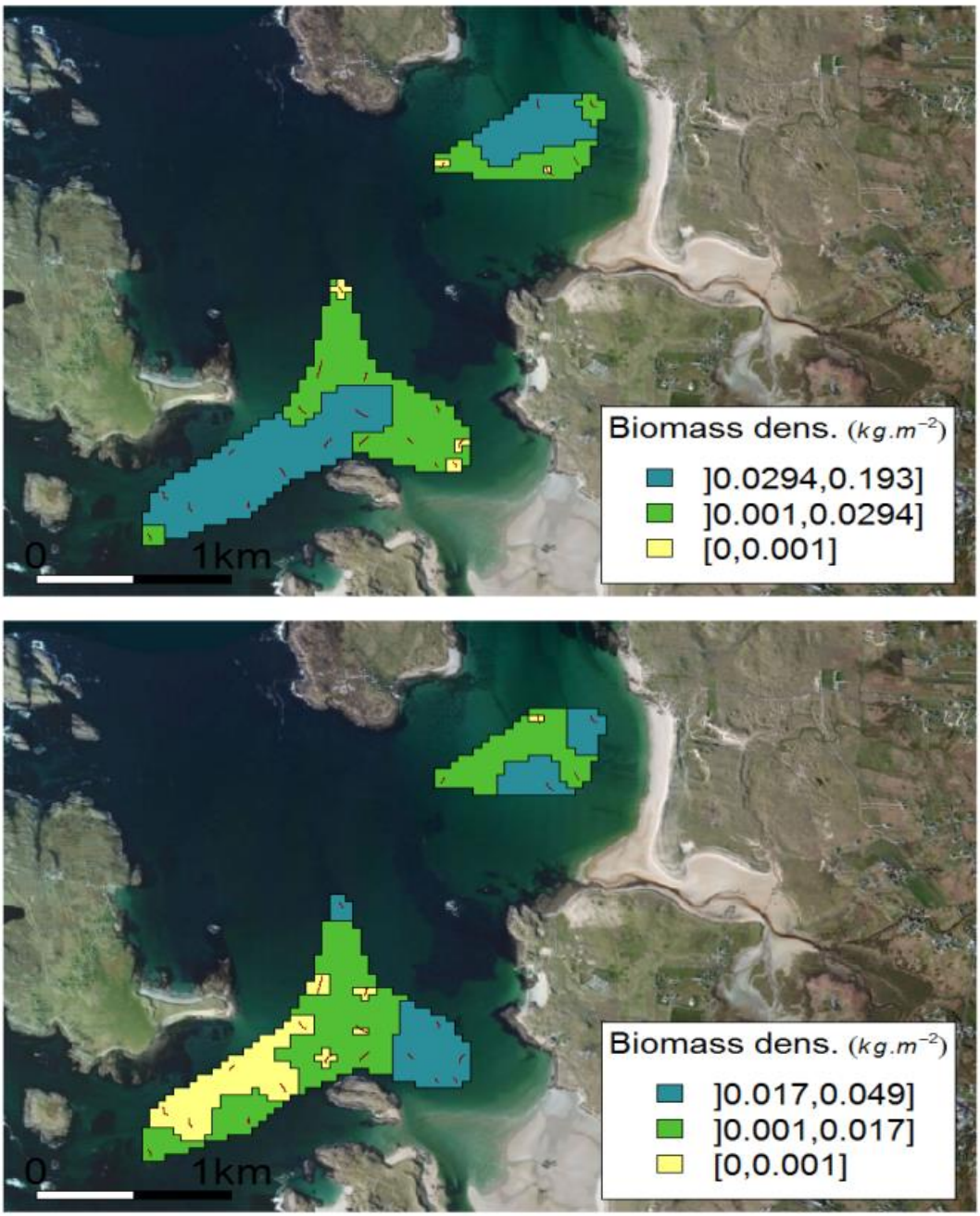


Figure 10. Biomass density of E. arcuatus (top) and E. siliqua (bottom) over the surveyed zone in Gweedore Bay.

Table 9. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in Gweedore Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.001]	24000	5	0.23	0.28	0.01	0.01
]0.001,0.0294]	532800	10	8.12	5.16	4.33	2.75
]0.0294,0.193]	656000	8	98.71	32.65	64.76	21.42
Total	**1.213 km²**	**23**	**56.97**	**17.80**	**69.09**	**21.59**

Table 10. Stratified biomass assessment summary for E. siliqua over the surveyed zone in Gweedore Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.001]	262400	10	0.00	0.00	0.00	0.00
]0.001,0.017]	652800	5	7.09	2.78	4.63	1.81
]0.017,0.049]	297600	8	32.19	8.29	9.58	2.47
Total	**1.213 km²**	**23**	**11.72**	**2.52**	**14.21**	**3.06**

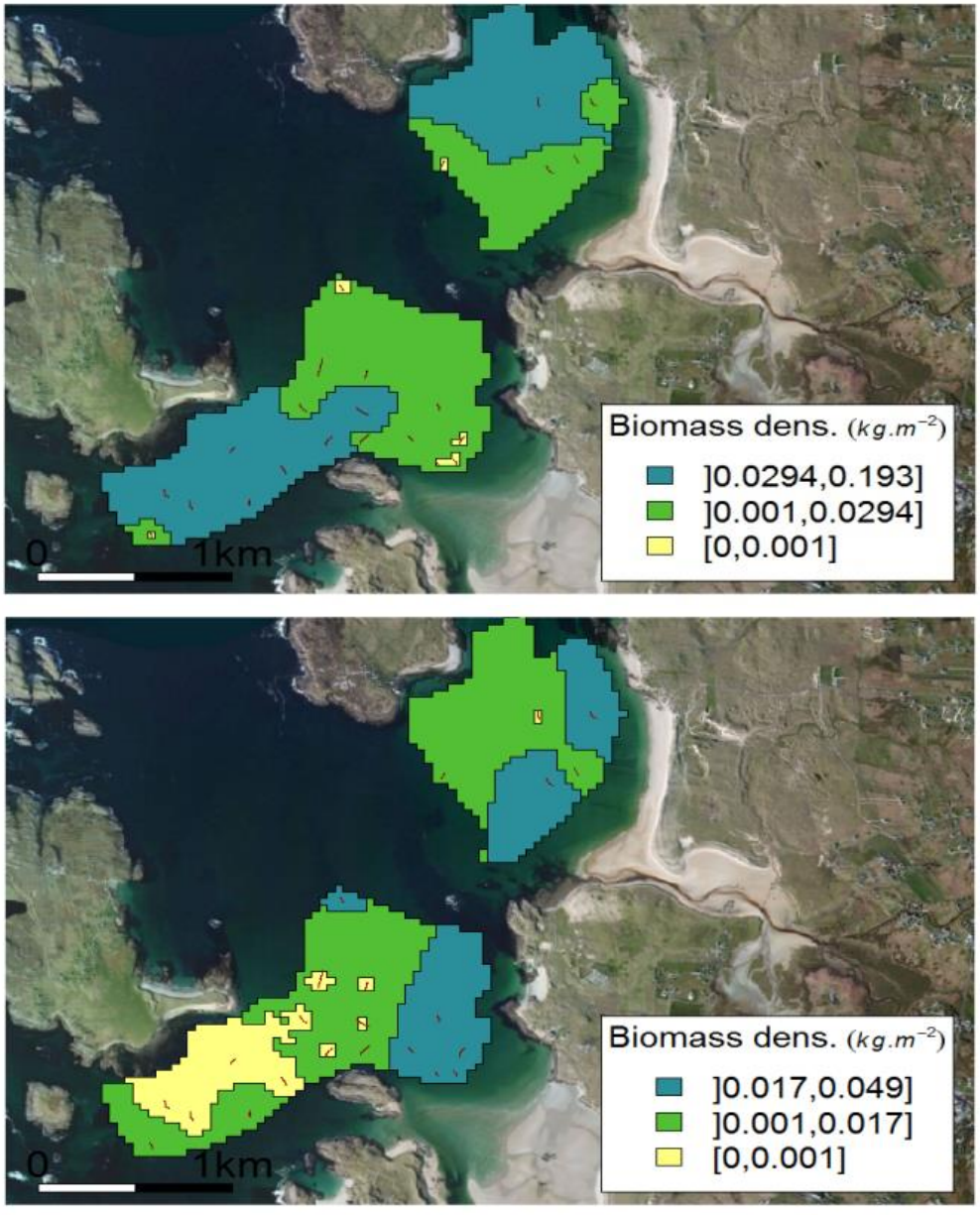


Figure 11. Distribution of biomass of E. arcuatus (top) and E. siliqua (bottom) over the extended survey zone (potential distribution) in Gweedore bay.

Table 11. Stratified biomass assessment summary for E. arcuatus over the extended survey zone (potential distribution) in Gweedore Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.001]	22400	6	0.23	0.28	0.01	0.01
]0.001,0.0294]	1214400	9	9.00	5.43	10.93	6.60
]0.0294,0.193]	1310400	8	98.71	32.65	129.35	42.78
Total	**2.547 km²**	**23**	**55.08**	**16.99**	**140.29**	**43.29**

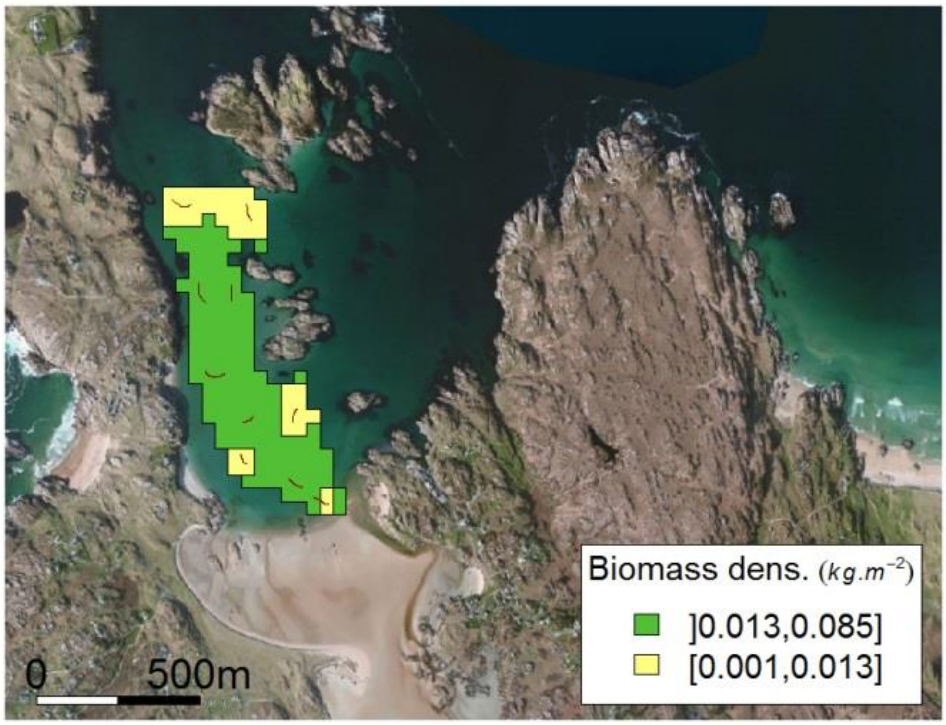
Table 12. Stratified biomass assessment summary for E. siliqua over the extended survey zone (potential distribution) in Gweedore Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.001]	385600	10	0.00	0.00	0.00	0.00
]0.001,0.017]	1377600	5	7.09	2.78	9.77	3.82
]0.017,0.049]	784000	8	32.19	8.29	25.23	6.50
Total	**2.547 km²**	**23**	**13.74**	**2.96**	**35.01**	**7.54**

Cruit Bay – Co. Donegal

This bed was surveyed on October the 13th aboard MFV Rosanne using a hydraulic dredge. Dredge efficiency may have been low to moderate as there was a significant proportion of razors in the catch that had been cut by the dredge.

Both species were present. *E. siliqua* was dominant. The total biomass of *E. arcuatus* was estimated at 7.5±4.5 tonnes (11.7±7.1 for the extended area) and total biomass for *E. siliqua* was 12.9±4.7 tonnes (20.2±7.5 for the extended area) (Table 13 - Table 16).



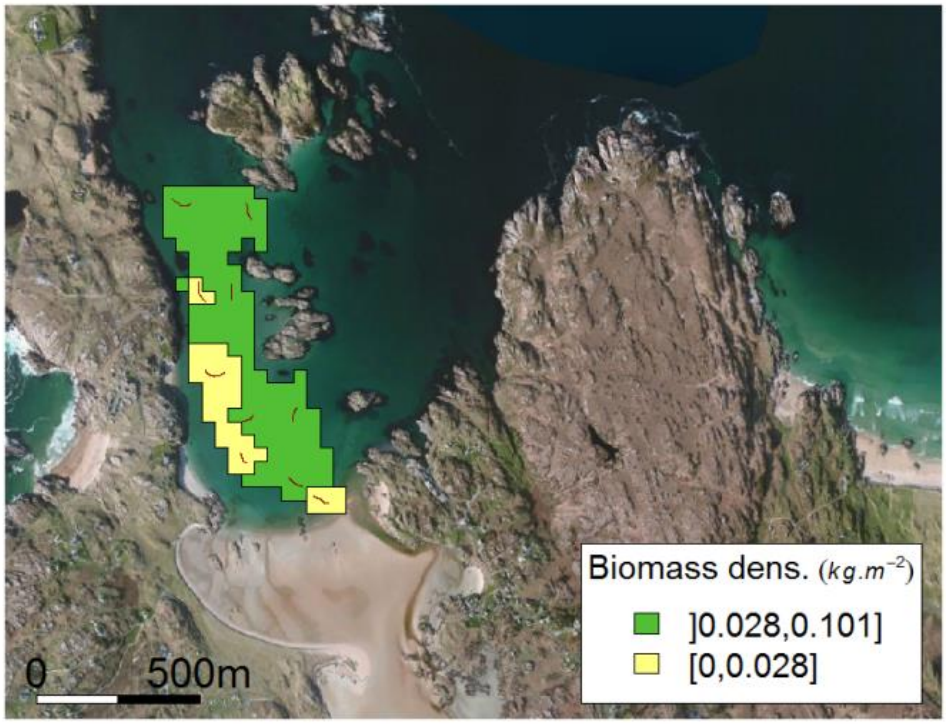


Figure 12. Distribution of biomass of E. arcuatus (top) and E. siliqua (bottom) over the surveyed area in Cruit Bay.

Table 13. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in Cruit Bay.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.001,0.013]	64000	5	6.40	2.84	0.41	0.18
]0.013,0.085]	188800	5	37.69	23.99	7.12	4.53
Total	**0.253 km²**	**10**	**29.77**	**17.93**	**7.53**	**4.53**

Table 14. Stratified biomass assessment summary for E. siliqua over the surveyed zone in Cruit Bay.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.028]	60800	4	9.48	7.21	0.58	0.44
]0.028,0.101]	192000	6	63.90	24.52	12.27	4.71
Total	**0.253 km²**	**10**	**50.81**	**18.70**	**12.85**	**4.73**

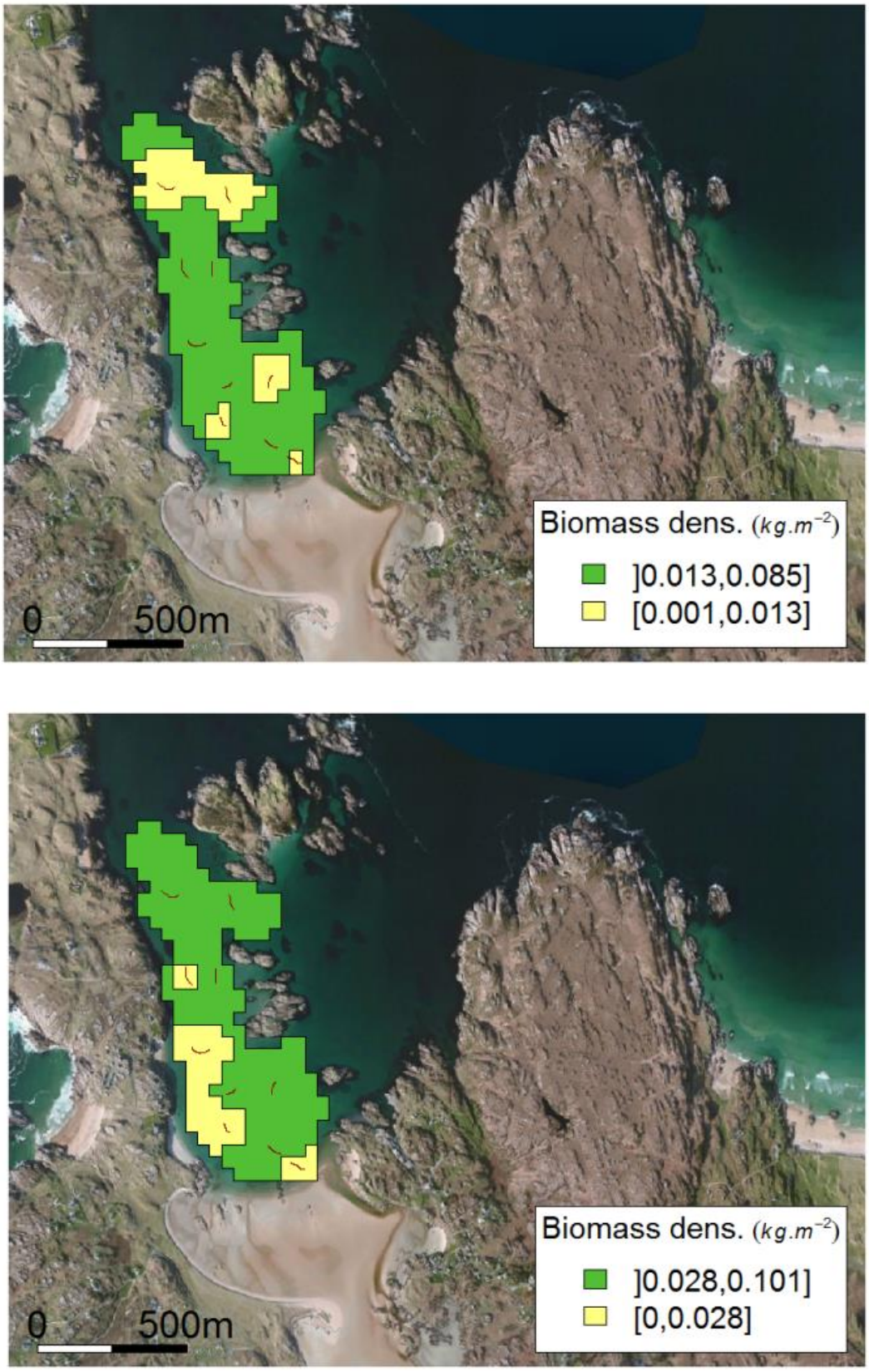


Figure 13. Distribution of biomass of E. arcuatus (top) and E. siliqua (bottom) over the extended area (potential distribution) in Cruit bay.

Table 15. Stratified biomass assessment summary for E. arcuatus over the extended survey zone (potential distribution) in Cruit Bay.

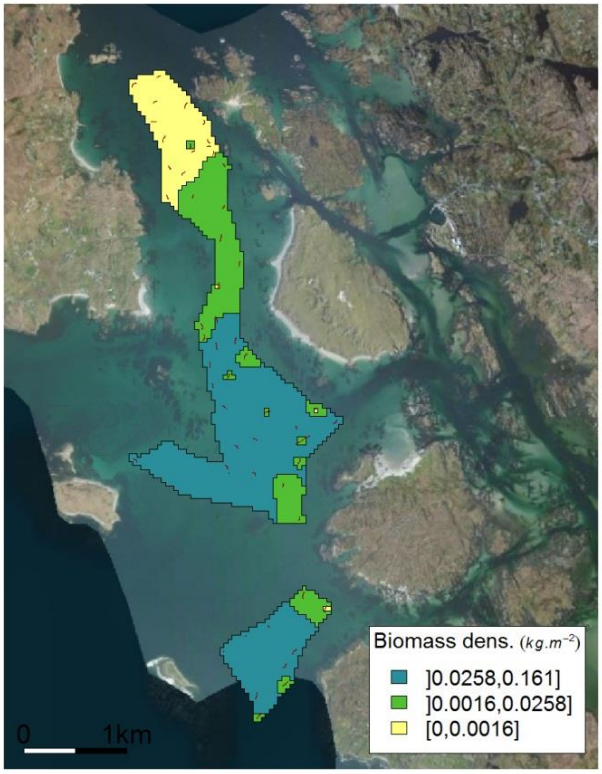
Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.001,0.013]	91200	5	6.40	2.84	0.58	0.26
]0.013,0.085]	294400	5	37.69	23.99	11.10	7.06
Total	**0.386 km²**	**10**	**30.29**	**18.33**	**11.68**	**7.07**

Table 16. Stratified biomass assessment summary for E. siliqua over the extended survey zone (potential distribution) in Cruit Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.028]	81600	4	9.48	7.21	0.77	0.59
]0.028,0.101]	304000	6	63.90	24.52	19.43	7.45
Total	**0.386 km²**	**10**	**52.39**	**19.39**	**20.20**	**7.48**

Rutland Sound – Co. Donegal

This bed was surveyed on October the 12th and 13th aboard MFV Rosanne using a hydraulic dredge. Dredge efficiency was probably low to moderate given the prevalence of razor clams that were cut by the dredge. This was the largest bed surveyed in Donegal. Both species were present with a clear dominance of *E. arcuatus*, except in the Northern part. The biomass of *E. arcuatus* was estimated to be 178±37 tonnes. The biomass of *E. siliqua* was estimated to 23±4.1 tonnes (Table 17 - Table 20).



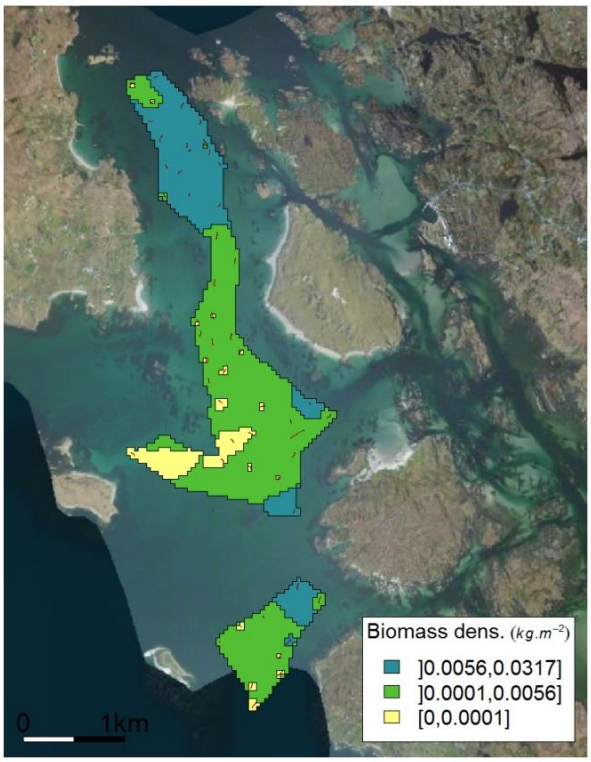


Figure 14. Biomass density of E. arcuatus (top) and E. siliqua (bottom) over the surveyed area in Rutland Sound.

Table 17. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in Rutland Sound.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0016]	579200	17	0.38	0.25	0.22	0.14
]0.0016,0.0258]	886400	18	8.73	3.72	7.74	3.30
]0.0258,0.161]	2113600	18	80.48	17.43	170.11	36.85
Total	**3.579 km²**	**53**	**49.75**	**10.34**	**178.07**	**37.00**

Table 18. Stratified biomass assessment summary for E. siliqua over the surveyed zone in Rutland Sound.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0001]	310400	20	0.00	0.00	0.00	0.00
]0.0001,0.0056]	2224000	15	1.95	0.91	4.34	2.03
]0.0056,0.0317]	1044800	17	17.88	3.35	18.68	3.51
Total	**3.579 km²**	**52**	**6.43**	**1.13**	**23.02**	**4.05**

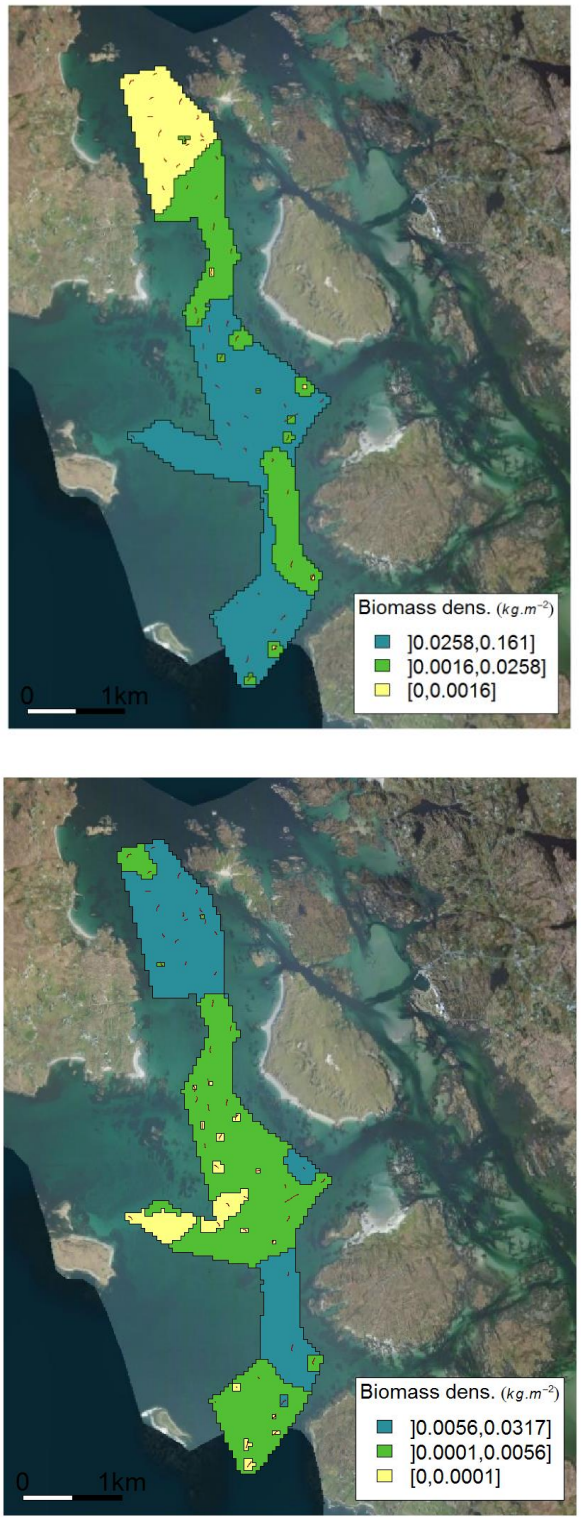


Figure 15. Distribution of biomass of E. arcuatus (top) and E. siliqua (bottom) over the extended survey zone (potential distribution) in Rutland Sound.

Table 19. Stratified biomass assessment summary for E. arcuatus over the extended survey zone (potential distribution) in Rutland Sound.

Strata	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0016]	822400	18	0.36	0.24	0.30	0.20
]0.0016,0.0258]	1262400	17	9.24	3.80	11.67	4.80
]0.0258,0.161]	2470400	18	80.48	17.43	198.83	43.07
Total	**4.555 km²**	**53**	**46.28**	**9.51**	**210.79**	**43.34**

Table 20. Stratified biomass assessment summary for E. siliqua over the extended area (potential distribution) in Rutland Sound.

Strata	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0001]	316800	18	0.00	0.00	0.00	0.00
]0.0001,0.0056]	2539200	17	1.72	0.86	4.37	2.18
]0.0056,0.0317]	1699200	17	17.88	3.35	30.37	5.70
Total	**4.555 km²**	**52**	**7.63**	**1.34**	**34.75**	**6.10**

Ballinakill Bay – Co. Galway

This bed was surveyed on September the 14th, aboard MFV Rosanne using a hydraulic dredge (Figure 16 - Figure 18). Dredge efficiency was high in the relatively clean loose sand especially on the north shore. Catches were clean with little dead shell or by-catch. Mixed sediments occurred on the south shore. Mud substrates in the middle channel of the Bay are devoid of razor clams. Biomass ranged from 0.1-2.93kgs.m^{-2}. A total of 886 *E. arcuatus* were measured. Average size was 131±17mm. A total of 28 *E. siliqua* had an average shell length of 174±28mm. Biomass of *E. arcuatus* was estimated to be 111±90t and 3t for *E. siliqua* in the surveyed area. Biomass in the extended area was 162±137t for *E. arcuatus* and 3.5t for *E. silique* (Table 21 - Table 24).

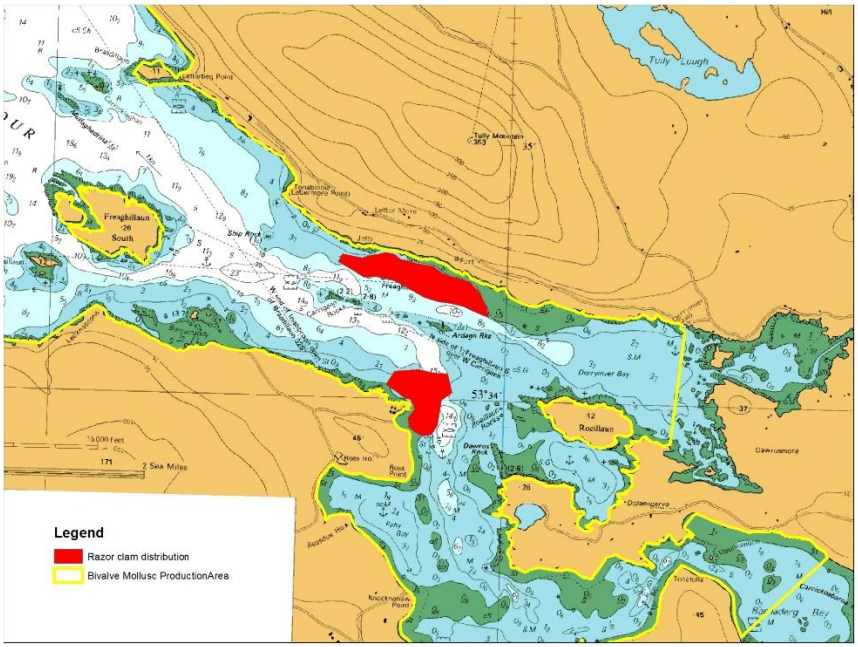
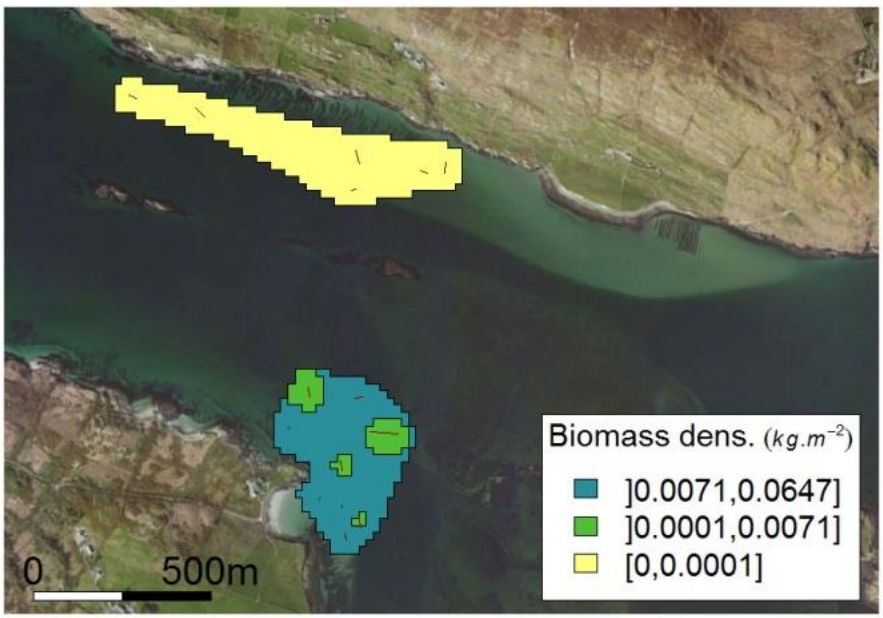


Figure 16. Likely distribution area of Ensis spp. in Ballinakill Bay.



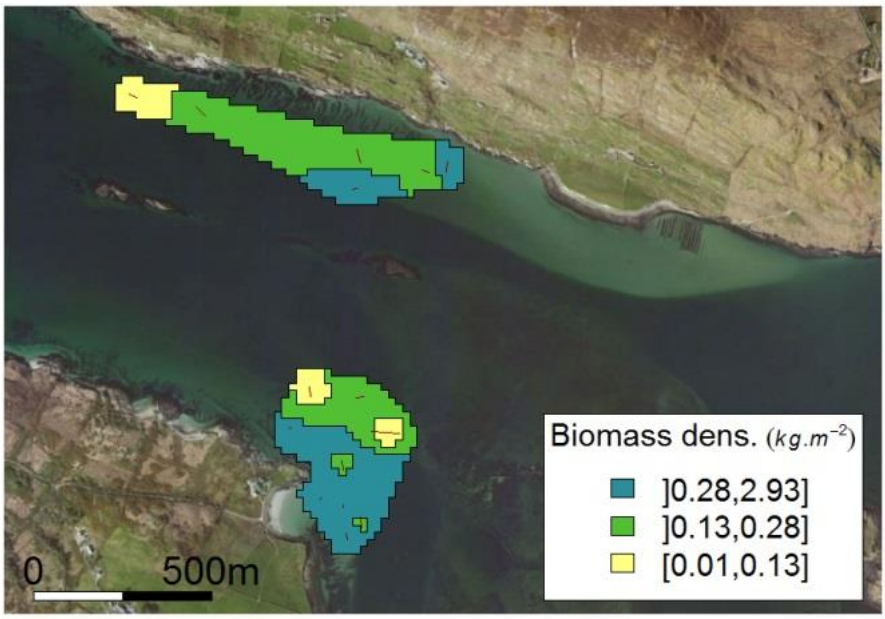


Figure 17. Biomass density of E. arcuatus (top) and E. siliqua (bottom) over the surveyed zone in Ballinakill Bay.

Table 21. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in Ballinakill Bay.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.01,0.13]	31200	3	23.05	5.92	0.72	0.18
]0.13,0.28]	140400	6	168.60	40.37	23.67	5.67
]0.28,2.93]	107600	6	808.24	838.34	86.97	90.20
Total	**0.279 km²**	**15**	**398.84**	**323.72**	**111.36**	**90.38**

Table 22. Stratified biomass assessment summary for E. siliqua over the surveyed zone in Ballinakill Bay.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0001]	142400	6	0.00	0.00	0.00	0.00
]0.0001,0.0071]	24000	4	1.83	2.42	0.04	0.06
]0.0071,0.0647]	112800	5	26.71	20.87	3.01	2.35
Total	**0.279 km²**	**15**	**10.95**	**8.43**	**3.06**	**2.35**

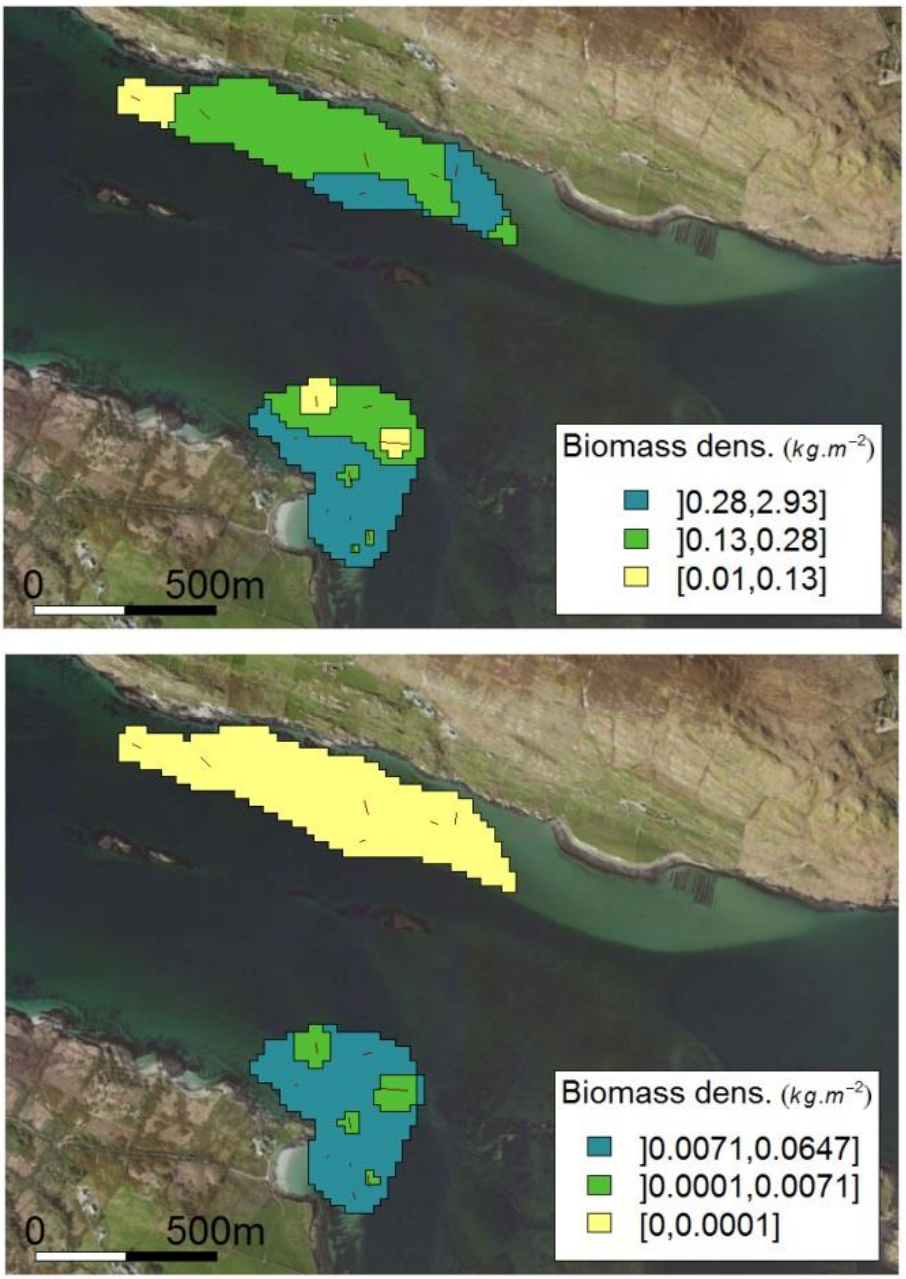


Figure 18. Biomass density of E. arcuatus (top) and E. siliqua (bottom) over the extended survey zone (potential distribution) in Ballinakill Bay.

Table 23. Stratified biomass assessment summary for E. arcuatus over the extended survey zone (potential distribution) in Ballinakill Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.01,0.13]	31200	3	23.05	5.92	0.72	0.18
]0.13,0.28]	194000	7	183.12	44.43	35.53	8.62
]0.28,2.93]	137600	5	915.84	993.73	126.02	136.74
Total	**0.363 km²**	**15**	**447.25**	**377.64**	**162.26**	**137.01**

Table 24. Stratified biomass assessment summary for E. siliqua over the extended survey zone (potential distribution) in Ballinakill Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0001]	209200	6	0.00	0.00	0.00	0.00
]0.0001,0.0071]	24000	4	1.83	2.42	0.04	0.06
]0.0071,0.0647]	129600	5	26.71	20.87	3.46	2.70
Total	**0.363 km²**	**15**	**9.66**	**7.46**	**3.51**	**2.71**

Clifden Bay – Co.Galway

This bed was surveyed on April the 26th and completed on May the 16th aboard MFV Lantern using a 0.56m wide dredge with propeller rather than hydraulically driven water jets (Figure 19 - Figure 21). The area has been fished annually for many years. The survey data has been tuned to a high gear efficiency of about 90%. *E. siliqua* is not present in commercial quantities in the area. Over 3000 *E. arcuatus* were measured. Average size was 116±30mm. Biomass was estimated to be 230±14t in the survey area and 365±21t in the extended area (Table 25 - Table 26).

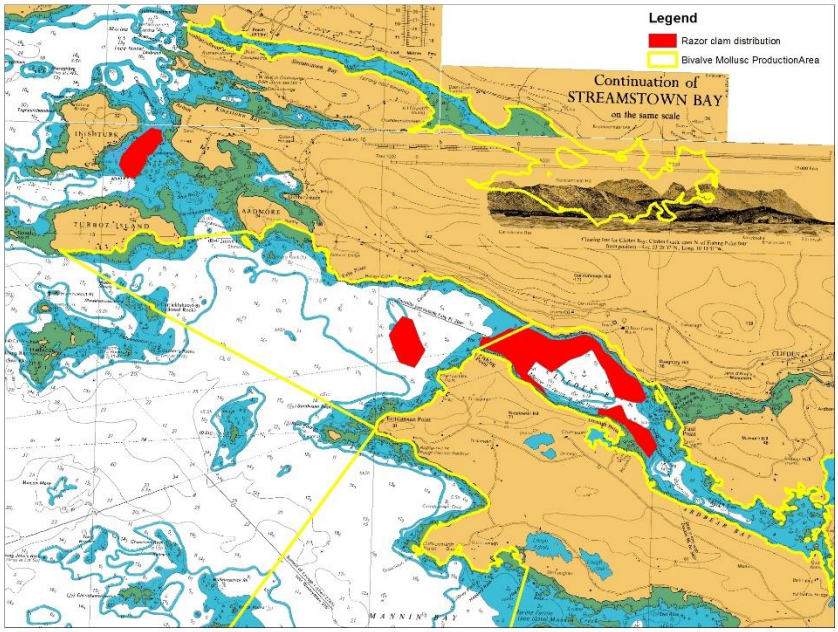


Figure 19. Likely distribution area of Ensis spp. in Clifden Bay and Turbot Island

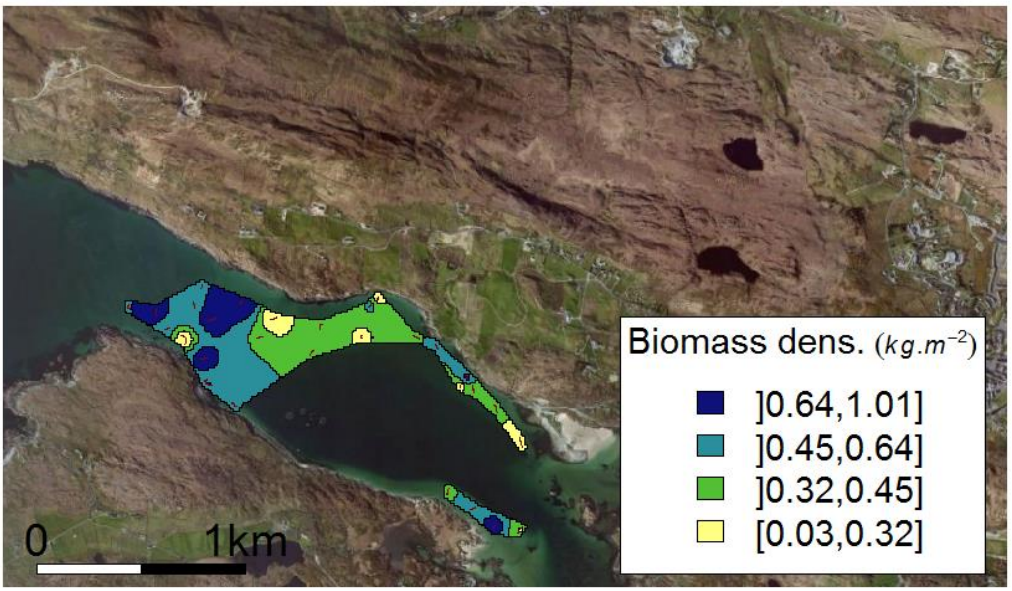


Figure 20. Biomass density of E. arcuatus over the surveyed zone in Clifden Bay. The biomass is corrected assuming a gear efficiency of 90%. Salmon farm cages are visible off the south shore.

Table 25. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in Clifden Bay. The biomass is corrected assuming a gear efficiency of 90%.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.03,0.32]	37300	7	200.00	75.18	7.46	2.80
]0.32,0.45]	168300	8	401.66	28.27	67.60	4.76
]0.45,0.64]	175600	6	553.90	65.97	97.26	11.58
]0.64,1.01]	73000	6	797.64	93.42	58.23	6.82
Total	**0.454 km²**	**27**	**507.60**	**31.99**	**230.55**	**14.53**

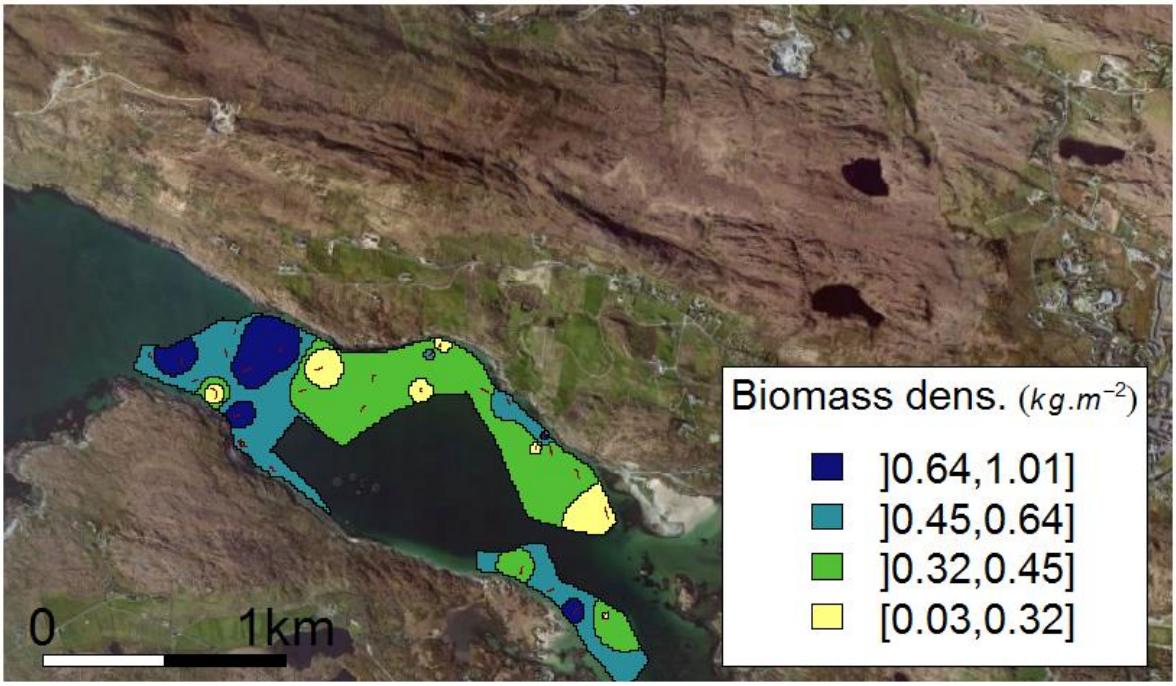


Figure 21. Distribution of biomass of E. arcuatus over the extended survey zone (potential distribution) in Clifden Bay. The biomass is corrected assuming a gear efficiency of 90%.

Table 26. Stratified biomass assessment summary for E. arcuatus over the extended survey zone (potential distribution) in Clifden Bay. The biomass is corrected assuming a gear efficiency of 90%.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.03,0.32]	70100	7	200.00	75.18	14.02	5.27
]0.32,0.45]	340500	8	401.66	28.27	136.77	9.62
]0.45,0.64]	248700	6	553.90	65.97	137.75	16.41
]0.64,1.01]	96900	6	797.64	93.42	77.29	9.05
Total	**0.756 km²**	**27**	**483.78**	**28.71**	**365.83**	**21.71**

Turbot Island Clifden – Co. Galway

This bed was surveyed on May the 16th, aboard MFV Lantern (Figure 22 - Figure 23). As for Clifden Bay, the bed has been fished annually for many years and dredge efficiency is assumed to be high. Survey data were corrected assuming a dredge efficiency of 90%. *E. siliqua* is not present. Average size of 1264 measured *E. arcuatus* was 111±32mm. Biomass was 63±6t in the survey area and 143±15t in the extended area (Table 27 - Table 28).

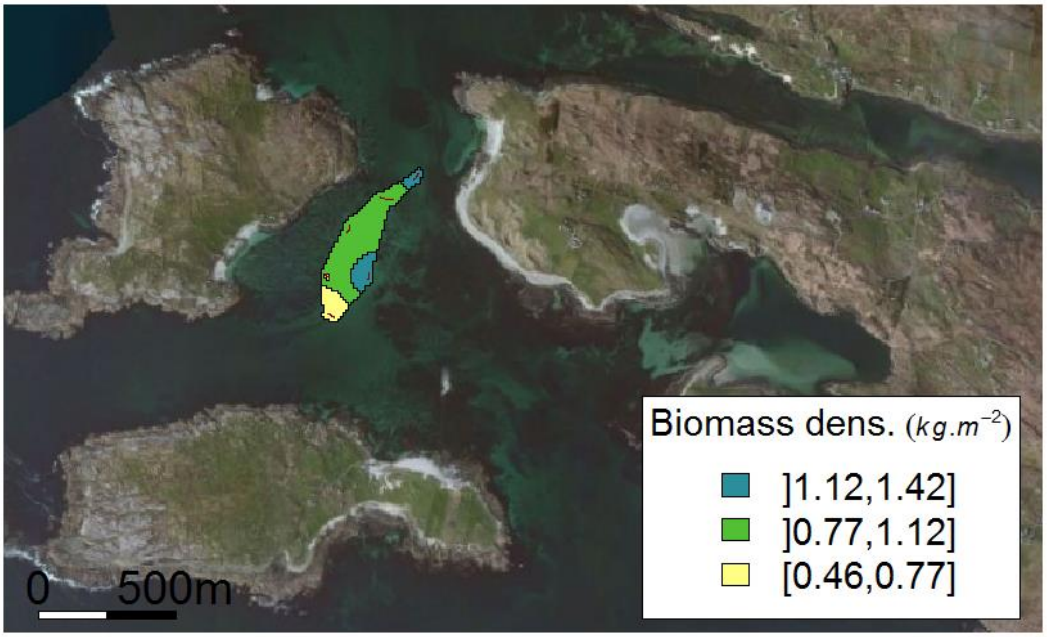


Figure 22. Biomass density of E. arcuatus over the surveyed zone in Turbot Island. The biomass is corrected assuming a gear efficiency of 90%.

Table 27. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in Turbot Island. The biomass is corrected assuming a gear efficiency of 90%.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.46,0.77]	9200	2	614.58	300.99	5.65	2.77
]0.77,1.12]	49500	2	845.59	124.67	41.86	6.17
]1.12,1.42]	12100	2	1,355.47	109.40	16.40	1.32
Total	**0.071 km²**	**6**	**902.72**	**97.35**	**63.91**	**6.89**

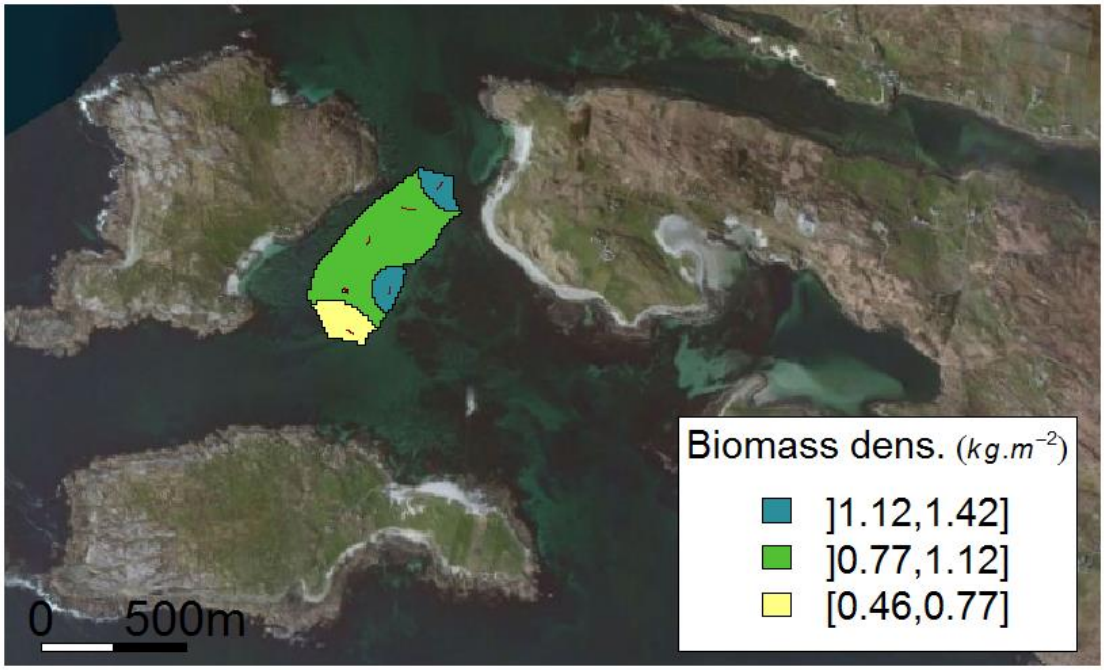


Figure 23. Biomass density of E. arcuatus over the extended survey zone (potential distribution) in Turbot Island. The biomass is corrected assuming a gear efficiency of 90%.

Table 28. Stratified biomass assessment summary for E. arcuatus over the extended survey zone (potential distribution) in Turbot Island. The biomass is corrected assuming a gear efficiency of 90%.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.46,0.77]	21400	2	614.58	300.99	13.15	6.44
]0.77,1.12]	113700	2	845.59	124.67	96.14	14.18
]1.12,1.42]	25500	2	1,355.47	109.40	34.56	2.79
Total	**0.161 km²**	**6**	**895.77**	**98.49**	**143.86**	**15.82**

Inisturk – Co. Mayo

10 tows were taken opportunistically by the MFV Roseanne on passage from Killary to Blacksod on Nov 7th (Figure 24). *Ensis* were not identified to species. Average catch was 1.3kg per 3 min tow. The bed is at least 0.335km^2 in area. Dredge efficiency was deemed to be low especially in deeper water to the east of the area. Data is insufficient for estimation of biomass. However, if the swept area per tow is assumed to be 30m^2 then given the area encompassed by the survey points and the average catch per tow suggests a biomass of 15 tonnes.

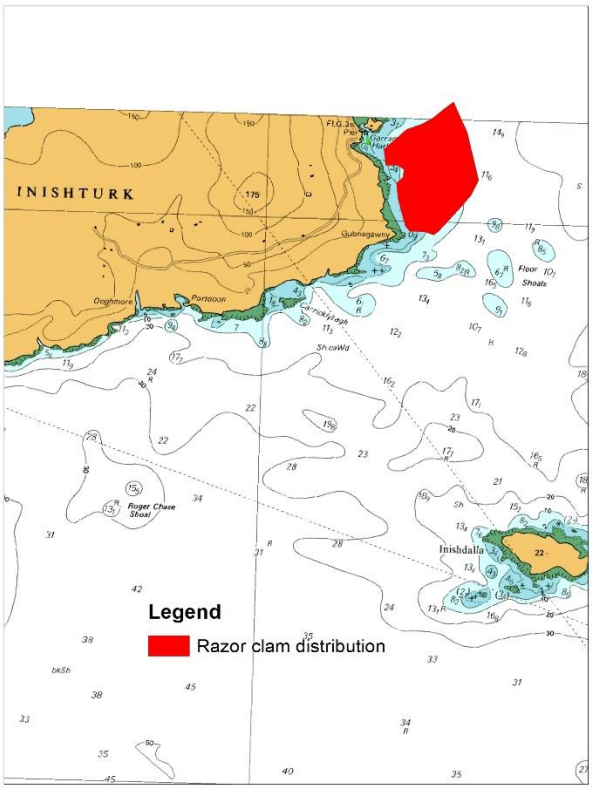


Figure 24. Likely distribution area of Ensis spp. at Inisturk.

Inisbofin – Co. Galway

This bed was surveyed on September 15th aboard MFV Rosanne using a hydraulic dredge (Figure 25 - Figure 27). Dredge efficiency was probably high given the clean sand substrate. Some tows were taken in a separate area east of the Island and although razor clams are present the ground is too stony to fish. 220 *E. arcuatus* that were measured had an average length of 131±25mm. 26 *E. siliqua* had an average length of 198±13mm. Biomass of *E. arcuatus* was estimated to be 72±39t in the surveyed area and 126±69t in the extended area (Table 29 - Table 32).

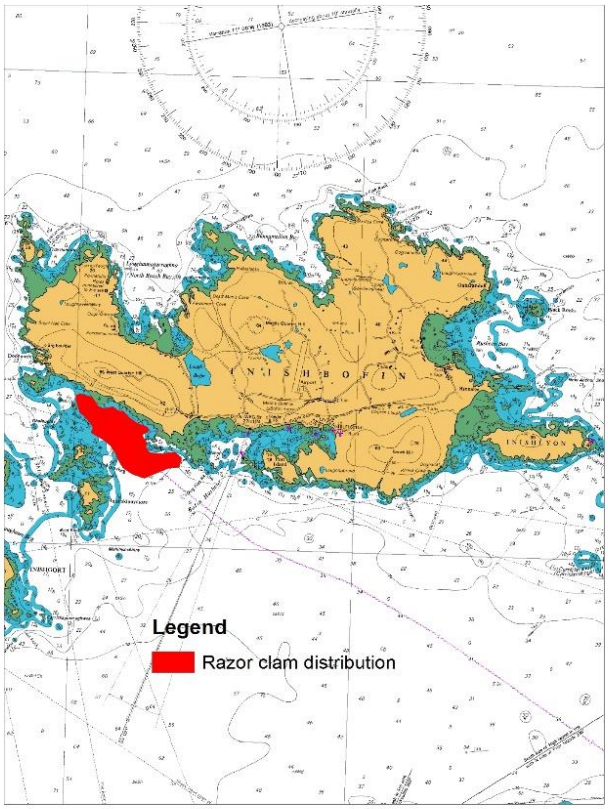


Figure 25. Likely distribution area of Ensis spp. at Inisbofin

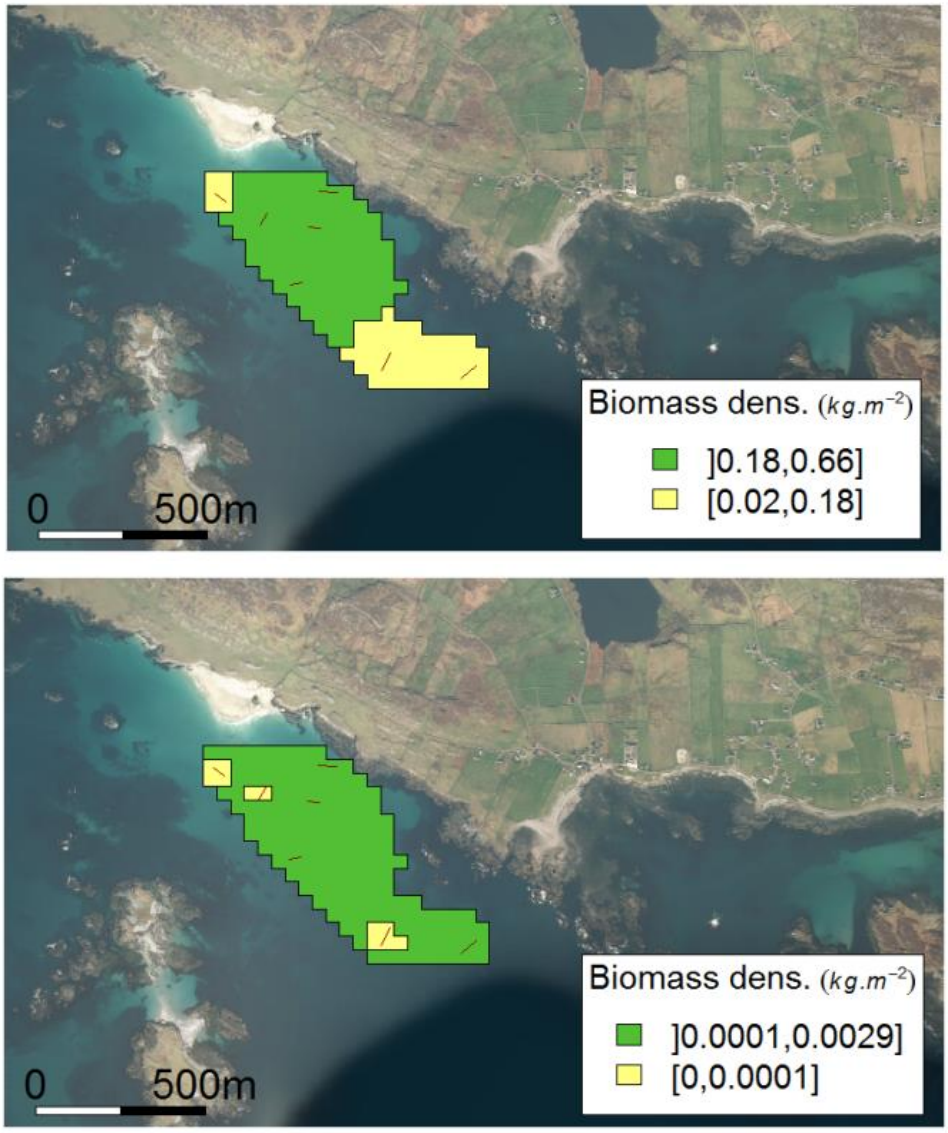


Figure 26. Biomass density of E. arcuatus (top) and E. siliqua (bottom) over the surveyed zone at Inisbofin.

Table 29. Stratified biomass assessment summary for E. arcuatus over the surveyed zone at Inisbofin.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.02,0.18]	81600	3	59.57	44.60	4.86	3.64
]0.18,0.66]	176000	4	383.68	225.25	67.53	39.64
Total	**0.258 km²**	**7**	**281.01**	**154.54**	**72.39**	**39.81**

Table 30. Stratified biomass assessment summary for E. siliqua over the surveyed zone in Inisbofin.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0001]	17600	3	0.00	0.00	0.00	0.00
]0.0001,0.0029]	240000	4	1.38	1.16	0.33	0.28
Total	**0.258 km²**	**7**	**1.28**	**1.08**	**0.33**	**0.28**

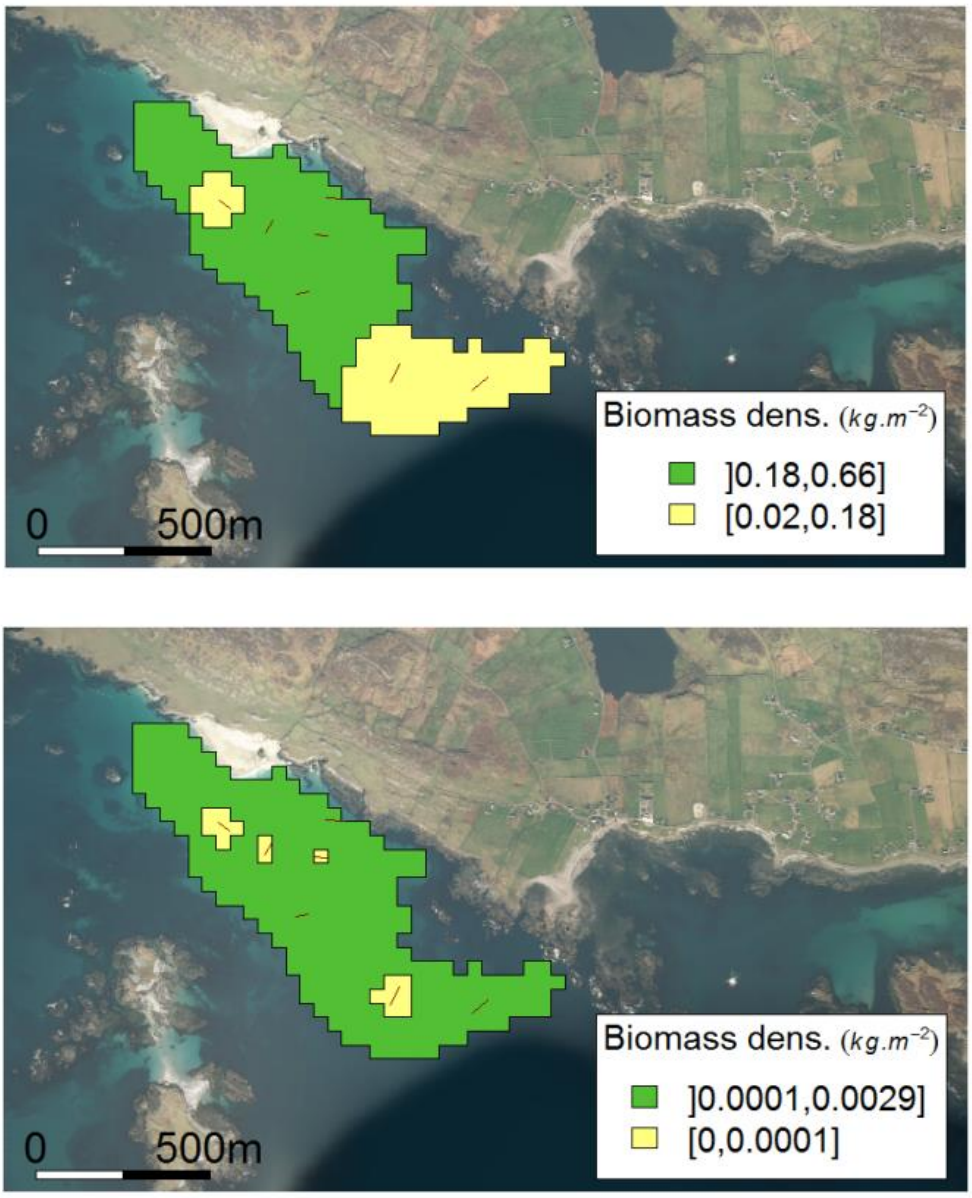


Figure 27. Biomass density of E. arcuatus (top) and E. siliqua (bottom) over the extended survey zone (potential distribution) at Inisbofin.

Table 31. ***Stratified biomass assessment summary for E. arcuatus over the extended survey zone (potential distribution) at Inisbofin.***

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.02,0.18]	153600	3	59.57	44.60	9.15	6.85
]0.18,0.66]	305600	4	383.68	225.25	117.25	68.84
Total	**0.459 km²**	**7**	**275.27**	**150.64**	**126.40**	**69.18**

Table 32. ***Stratified biomass assessment summary for E. siliqua over the extended survey zone (potential distribution) at Inisbofin.***

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0001]	25600	4	0.00	0.00	0.00	0.00
]0.0001,0.0029]	433600	3	1.83	1.03	0.80	0.45
Total	**0.459 km²**	**7**	**1.73**	**0.98**	**0.80**	**0.45**

Killary Approaches – Co. Galway

This bed was surveyed on November the 2nd aboard MFV Rosanne (Figure 28 - Figure 30). No catch weight by tow was available for this survey. Biomass was consequently assessed on the only basis of density (individuals·m^{-2}) and mean weight calculated from the size distribution and a weight-length relationship. Razor clams occur in a number of areas in the approaches to Killary Harbour. Some patches are quite small. Average size of 445 *E. arcuatus* was 130±25mm. Average size of 341 *E. siliqua* was 162±36mm. Biomass of *E. arcuatus* was estimated at 46±17t in the surveyed area and 96±33t in the extended area. Biomass of *E. siliqua* was 60±13t in the survey area and 95±23t in the extended area (Table 33 - Table 36).

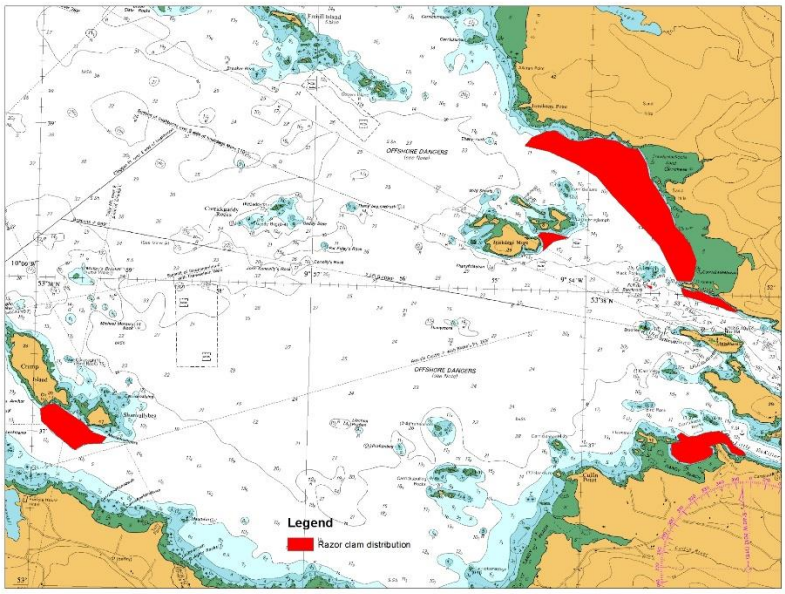


Figure 28. Likely distribution area of Ensis spp. at approaches to Killary

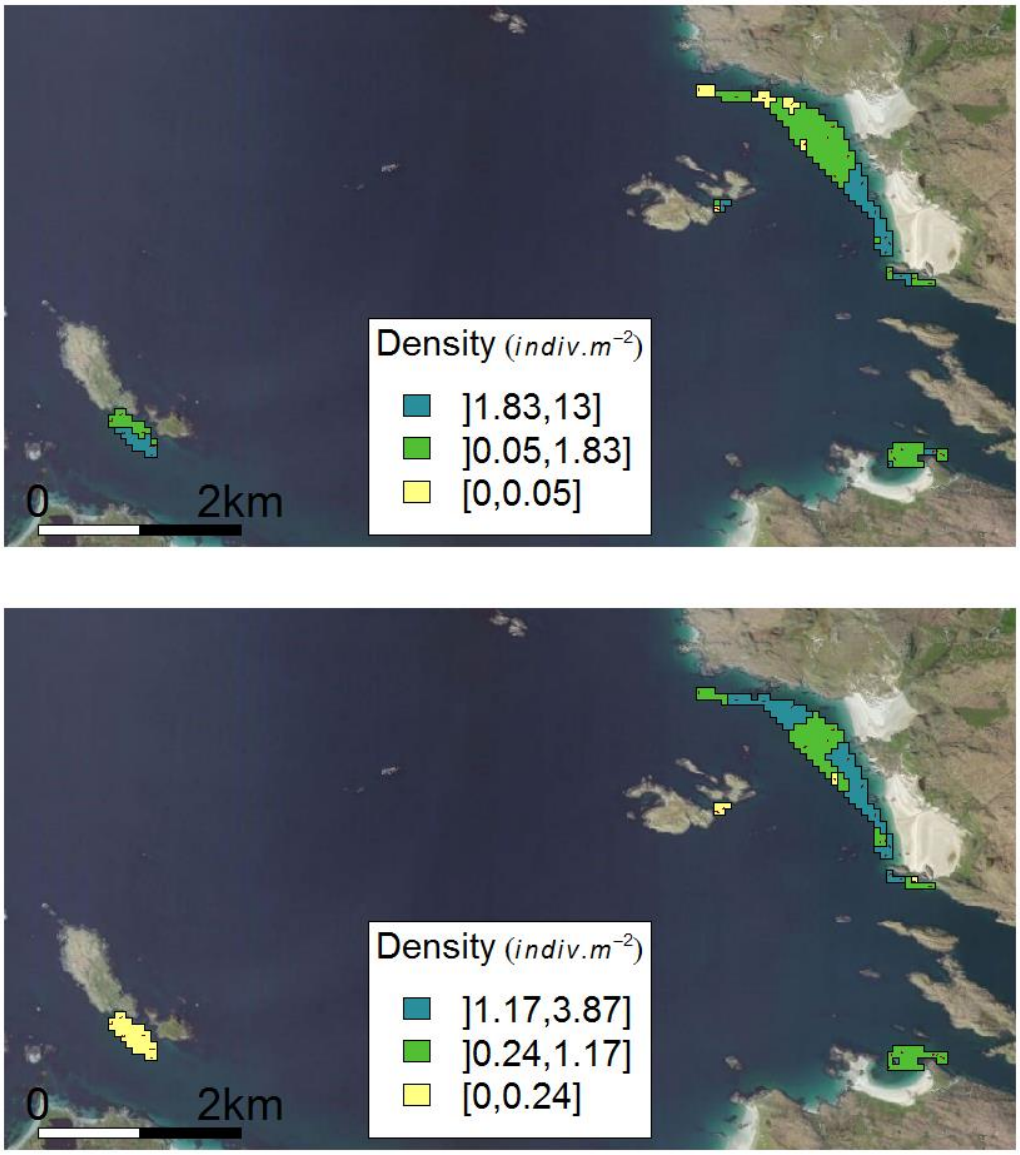


Figure 29. Biomass density of E. arcuatus (top) and E. siliqua (bottom) over the surveyed zone in Killary Approaches.

Table 33. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in Killary Approaches.

Strata (kg.m^{-2})	Area (m^2)	N	Mean density (m^{-2})	95% CL density (m^{-2})	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.05]	79200	5	0.000	0.000	0.00	0.00	0.00	0.00
]0.05,1.83]	547200	17	0.349	0.244	10.74	7.56	5.88	4.14
]1.83,13]	237600	12	5.550	2.308	172.87	72.62	41.07	17.25
Total	**0.864 km²**	**34**	**1.747**	**0.653**	**54.34**	**20.54**	**46.95**	**17.74**

Table 34. Stratified biomass assessment summary for E. siliqua over the surveyed zone in Killary Approaches.

Strata (kg.m^{-2})	Area (m^2)	N	Mean density (m^{-2})	95% CL density (m^{-2})	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.24]	151200	10	0.018	0.030	0.70	1.22	0.11	0.18
]0.24,1.17]	370800	13	0.608	0.195	28.67	9.77	10.63	3.62
]1.17,3.87]	342000	11	2.183	0.579	144.07	39.09	49.27	13.37
Total	**0.864 km²**	**34**	**1.129**	**0.244**	**69.45**	**16.03**	**60.01**	**13.85**

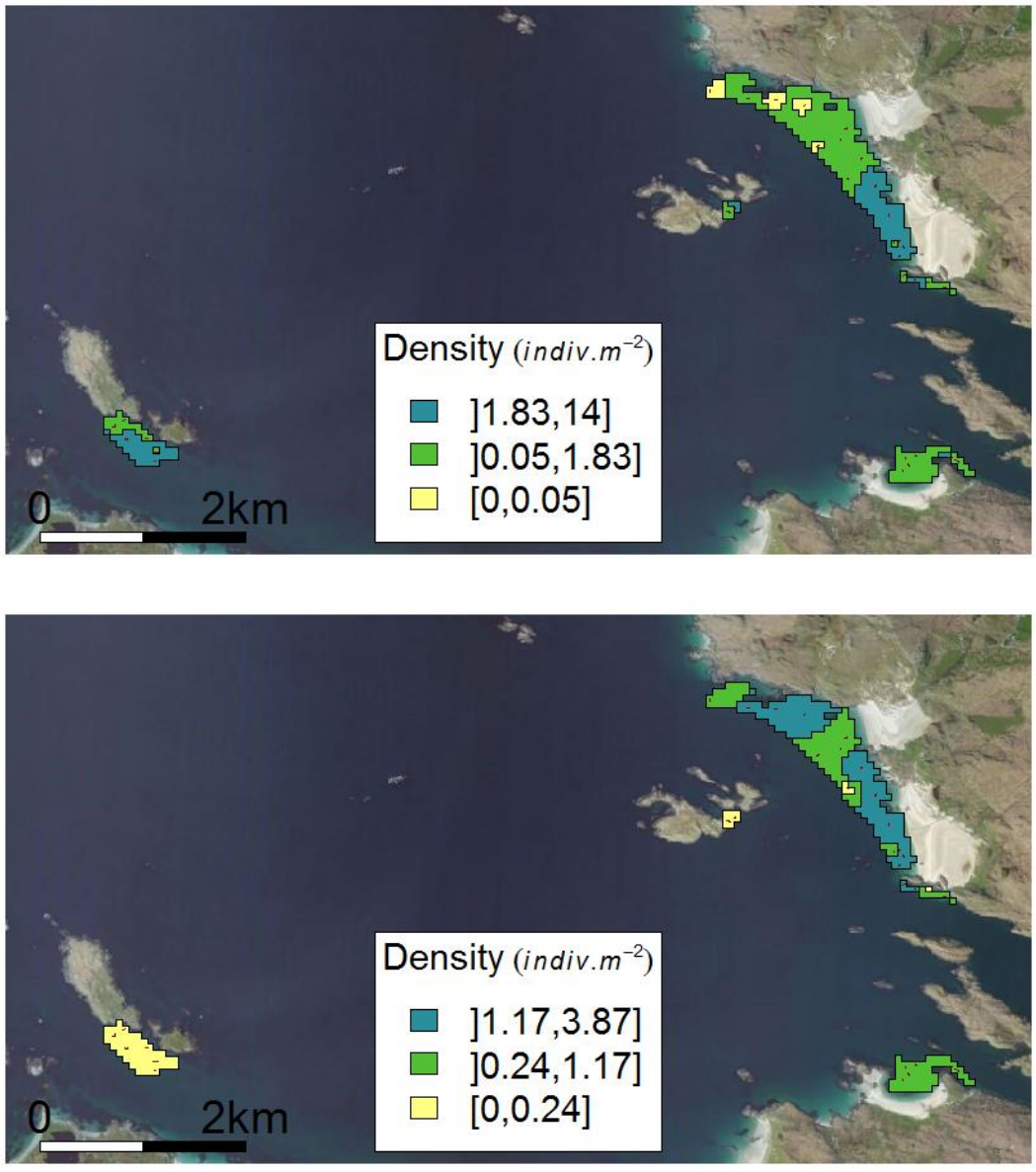


Figure 30. Biomass density of E. arcuatus (top) and E. siliqua (bottom) over the extended survey zone (potential distribution) at Killary Approaches.

Table 35. Stratified biomass assessment summary for E. arcuatus over the extended survey zone (potential distribution) in Killary Approaches.

Strata (kg.m^{-2})	Area (m^2)	N	Mean density (m^{-2})	95% CL density (m^{-2})	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.05]	97200	4	0.000	0.000	0.00	0.00	0.00	0.00
]0.05,1.83]	842400	20	0.402	0.275	12.26	8.44	10.33	7.11
]1.83,14]	406800	9	6.799	2.545	212.51	81.04	86.45	32.97
Total	**1.346 km²**	**33**	**2.306**	**0.788**	**71.88**	**25.05**	**96.78**	**33.73**

Table 36. Stratified biomass assessment summary for E. siliqua over the extended survey zone (potential distribution) in Killary Approaches.

Strata (kg.m^{-2})	Area (m^2)	N	Mean density (m^{-2})	95% CL density (m^{-2})	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.24]	237600	10	0.018	0.030	0.70	1.22	0.17	0.29
]0.24,1.17]	547200	12	0.574	0.201	23.13	8.63	12.66	4.72
]1.17,3.87]	561600	11	2.172	0.587	146.90	40.52	82.50	22.76
Total	**1.346 km²**	**33**	**1.142**	**0.258**	**70.80**	**17.26**	**95.32**	**23.24**

Broadhaven Bay – Co. Mayo

The two beds were surveyed on July 28th aboard MFV Rosanne using a hydraulic dredge (Figure 31 - Figure 32). The sampled area per tow varied from 16m^2 to 147m^2 depending on the length of each dredge haul. A total of 22 dredge hauls were completed; 13 North of Ballyglass pier, in the area delimited by the North of the pier and the Broadhaven lighthouse, where densities of *E. arcuatus* ranged from 0.1-21.7m^{-2} and 0-1.0m^{-2} for *E. siliqua*. A further 9 hauls were undertaken in the area South of the pier. Razor densities in this area ranged from 0.0-4.6 m^{-2} (*E. arcuatus*) and 0.0-0.95 m^{-2} (*E. siliqua*). The total area encompassed by the survey extends over 0.35 km^2 in the North and 0.92km^2 in the South. However, razor clams probably occur in a larger area though it is believed that the limits of the exploitable bed were mostly encompassed in the surveyed area.

A total of 1,063 razor clams were measured; 722 in the North (541 *E. arcuatus*, 181 *E. siliqua*) and 341 (264 *E. arcuatus*, 77 *E. siliqua*) in the South. The ratio of *E. siliqua* to *E. arcuatus* caught (in number) was 0.16 in the North bed and 0.22 in the South bed. Average size of E. arcuatus and E. silique was 133±27 and 162±34 respectively.

The biomass for *E. arcuatus* was estimated to be 46±35 tonnes in the North of Ballyglass pier and 30±13 tonnes in the South bed. However, the biomass in the Northern bed is very uncertain, as shown by the wide confidence interval. Biomass estimates for *E. siliqua* were of 5.3±1.6 tonnes in the North of Ballyglass pier and 17.2±10.6 tonnes in its South. The biomass estimates in the South bed are probably overestimated as the interpolated area is crossed by a deep channel (Table 37 - Table 40).

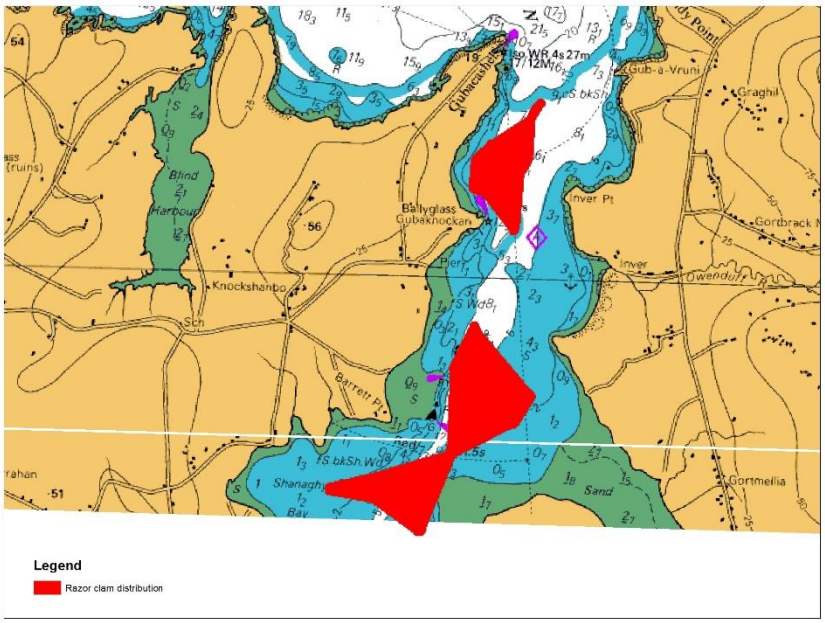


Figure 31. Likely distribution area of Ensis spp. at Broadhaven Bay

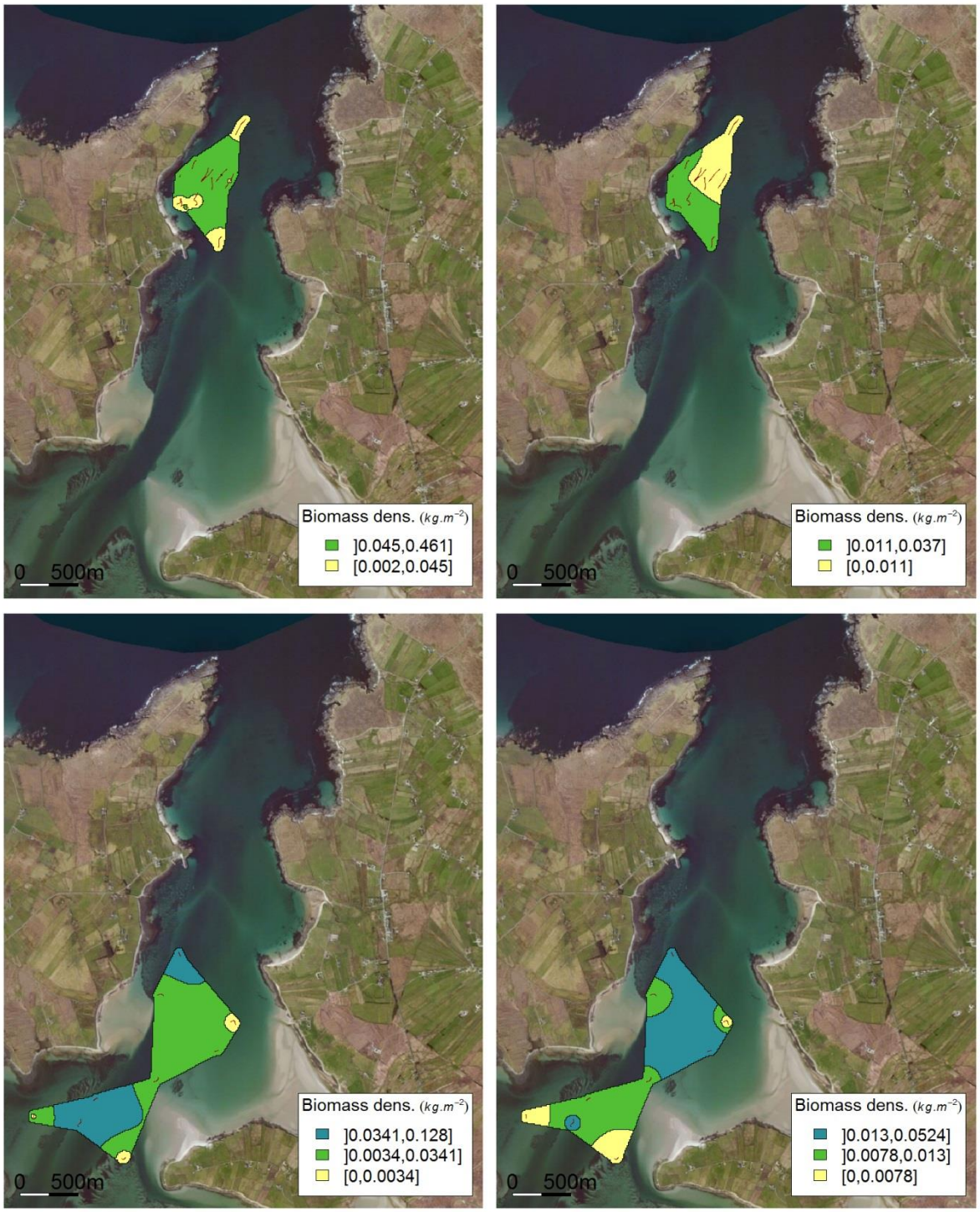


Figure 32. Biomass density of E. arcuatus (left) and E. siliqua (right) over the surveyed zone in the Northern (top) and Southern beds (bottom) in Broadhaven Bay.

Table 37. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in the North of Broadhaven Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0.002,0.045]	73200	7	22.71	11.38	1.66	0.83
]0.045,0.461]	281500	6	158.95	123.18	44.74	34.68
Total	**0.355 km²**	**13**	**130.84**	**97.79**	**46.41**	**34.69**

Table 38. Stratified biomass assessment summary for E. siliqua over the surveyed zone in the North of Broadhaven Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.011]	157200	6	0.12	0.24	0.02	0.04
]0.011,0.037]	197500	7	26.85	7.83	5.30	1.55
Total	**0.355 km²**	**13**	**15.01**	**4.36**	**5.32**	**1.55**

Table 39. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in the South of Broadhaven Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0034]	28000	3	1.57	1.76	0.04	0.05
]0.0034,0.0341]	580200	3	4.99	1.34	2.90	0.78
]0.0341,0.128]	306800	3	88.77	40.78	27.24	12.51
Total	**0.915 km²**	**9**	**32.98**	**13.70**	**30.18**	**12.54**

Table 40. Stratified biomass assessment summary for E. siliqua over the surveyed zone in Broadhaven Bay.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.0078]	105100	3	2.13	4.17	0.22	0.44
]0.0078,0.013]	358100	3	11.18	1.71	4.00	0.61
]0.013,0.0524]	451800	3	28.67	23.50	12.95	10.62
Total	**0.915 km²**	**9**	**18.77**	**11.63**	**17.18**	**10.64**

Iniskea Is – Co. Mayo

This bed was surveyed on July 27th aboard MFV Lantern using a propeller dredge (Figure 33 - Figure 35). *E. siliqua* is not present in this bed. Dredge efficiency is assumed to be 90% given the gear has been tuned for commercial fishing in this area. The extended or potential distribution area was derived from iVMS data from commercial vessels fishing in the area in 2016 and provides strong supporting information that the bed extends beyond the surveyed area.

The total biomass of clams was estimated to be 77±15t when a deep tow carried out in the South-East of the area is included. If the area is extended to that covered by the VMS data, the biomass estimate was 203±41 tonnes (Table 41 - Table 42).

The average shell length of *E. arcuatus* was 103mm compared to 123mm in a separate survey completed in Oct 2015. This difference is due to a combination of higher numbers of clams between 70-90mm and a smaller number of clams >140mm in the 2016 survey compared to the 2015 survey (lower numbers of large clams in the catch in 2016). Approximately 29% of clams were over 130mm compared to 59% in Oct 2015. Ten tonnes of razor clams were landed by the fishery between the surveys.

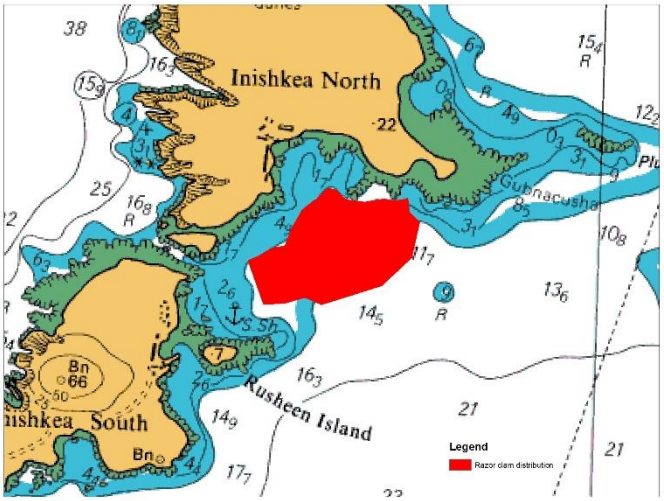


Figure 33. Likely distribution area of Ensis spp. at Iniskea Is.

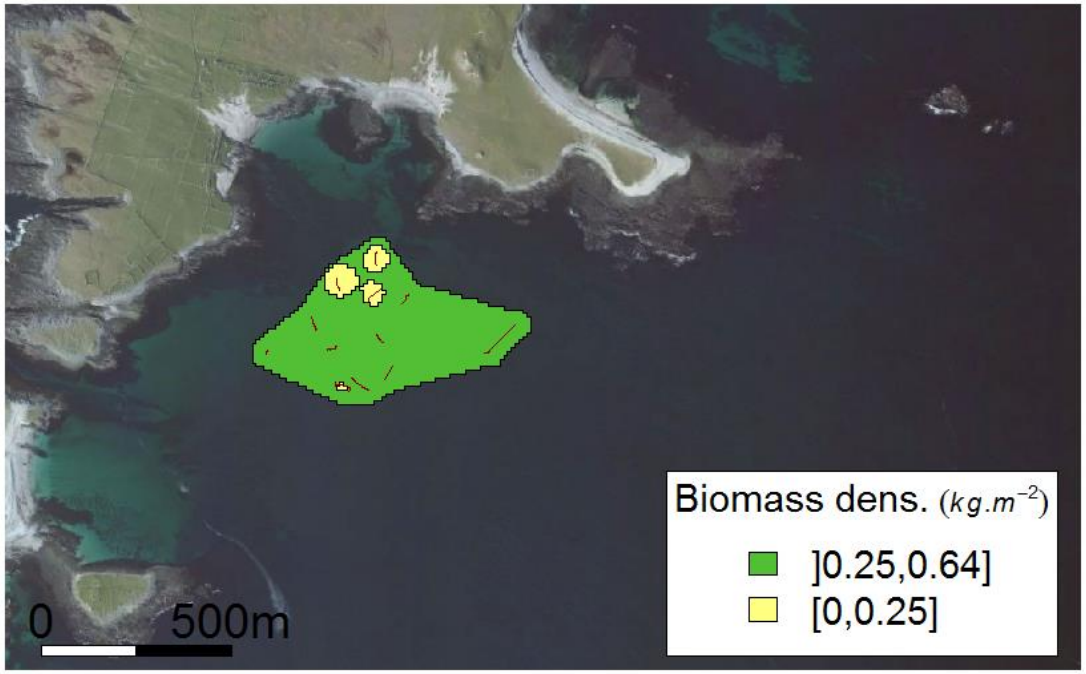


Figure 34. Biomass density of E. arcuatus over the surveyed zone in Iniskeas.

Table 41. Stratified biomass assessment summary for E. arcuatus over the surveyed zone in Iniskeas.

Strata (kg.m^{-2})	Area (m^2)	N	Biomass density (g.m^{-2})	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.25]	13600	4	213.97	27.73	2.91	0.38
]0.25,0.64]	164700	8	447.58	90.87	73.72	14.97
Total	**0.178 km²**	**12**	**429.76**	**83.97**	**76.63**	**14.97**

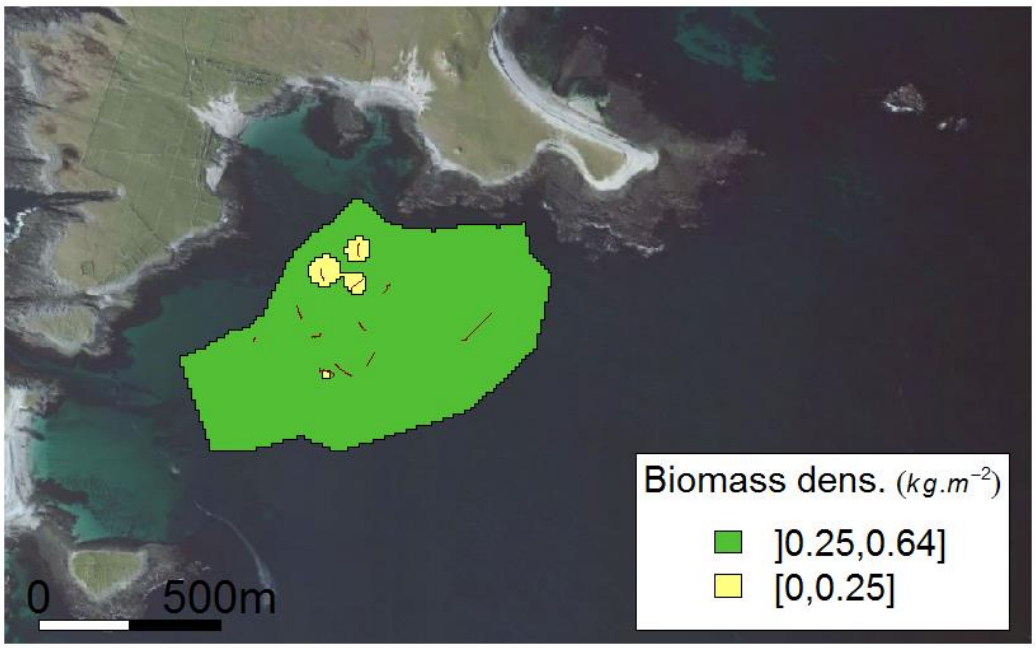


Figure 35. Biomass density of E. arcuatus over the extended survey zone (potential distribution) in Iniskeas.

Table 42. Stratified biomass assessment summary for E. arcuatus over the extended survey zone (potential distribution) in Iniskea Is.

Strata ($kg.m^{-2}$)	Area (m^2)	N	Biomass density ($g.m^{-2}$)	95% CL Biomass density (±)	Biomass (tonnes)	95% CL Biomass (±)
[0,0.25]	13600	4	213.97	27.73	2.91	0.38
]0.25,0.64]	446400	8	447.58	90.87	199.80	40.56
Total	**0.460 km²**	**12**	**440.68**	**88.19**	**202.71**	**40.57**

Size and growth

Length-weight

The relationship between shell length and weight was established using data from Broadhaven for *E. arcuatus* and *E. siliqua*. Although *E. siliqua* reaches a larger size than *E. arcuatus* the relationship between shell length and weight is very similar in the two species. These relationships may vary seasonally. Average weight at minimum legal landing of 100mm is approximately 10g and at the market size of 130mm is approximately 24g. Weight at 200mm which is towards the maximum size for *E. siliqua* is almost 100g (Figure 36).

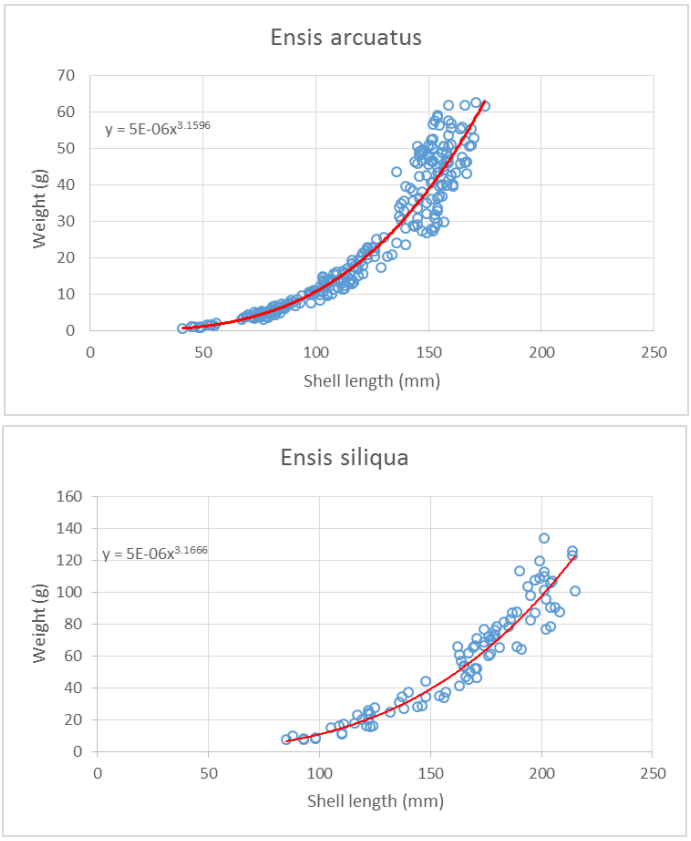


Figure 36. Length weight relationship for E. arcuatus and E. siliqua. Data combined from a number of areas.

Age and growth

It is not possible to reliably estimate age of Ensis spp. directly from external shell marks although growth curves have been estimated in other studies from shell sections. Some information on age and growth can be extracted from the size distributions where a mix of distributions representing putative age classes is evident. Extracting the modal size from these distribution mixtures gives an indication of growth rate for E. arcuatus (Figure 37). Age at minimum legal size seems to be approximately 3yrs while age at market size of 130mm may be 5yrs. Age at minimum legal size is similar to that reported by Robinson and Richardson (1998) in the UK. More information on age and growth could be obtained from seasonal sampling.

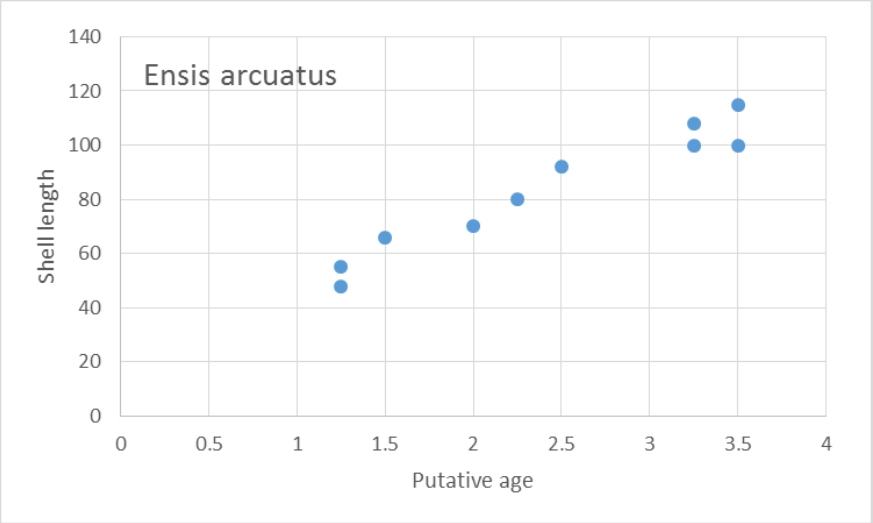


Figure 37. Putative age of E. arcuatus derived from obvious modes in the size distribution data from a number of survey areas and scaled to size at age data from Robertson and Richardson (1998). This assumes birth dates and growth rate are similar across areas and also similar to the areas in the UK sampled by Robertson and Richardson (1998).

Size distributions

In all surveyed areas, except for those recently exploited, the size distribution is dominated by size classes above the minimum size, which is consistent with expectations for moderate or fast growing species with a low natural mortality and no fishing mortality (Table 43, Figure 38 - Figure 49). Growth in shell length slows with age and if natural mortality is low a number of age classes accumulate in the upper size classes. Most of the biomass in unexploited stocks also occurs in the size classes above the MLS as weight increases with the cube of length.

Although age and growth is uncertain the size distributions are indicative of how regular recruitment is in the different locations and whether year classes are likely to be missing or not. Regular recruitment would infer that such populations would be more resilient to fishing mortality and be able to support annual fisheries than if recruitment was very irregular. The dredges used in the surveys are unlikely to select for 0+ age razor clams and there is incomplete selection for 1+ year old clams (the selection occurs through the bars of the dredge which have a 10mm spacing between them or through the square meshes of the dredge cage). The size distribution data shown for each site below indicate that there are likely to be missing year classes in most areas or else growth rate is much higher than reported in the literature for other stocks in the UK and Europe. This is unlikely. The shape of the size distribution could be used to provide short term forecasts of biomass available to future fisheries if growth rate and natural mortality estimates were improved.

Table 43. Average (±standard deviation) shell length of E. arcuatus, E. siliqua and Ensis spp. for all survey locations

	E. arcuatus			*E. siliqua*			*Ensis spp.*		
		Shell Length			Shell Length			Shell Length	
Location	N	Mean	S.d.	N	Mean	S.d.	N	Mean	S.d.
Adrigole Harbour	0			0			242	137.5	18.4
Bearhaven	0			0			1364	135.0	25.0
Ballinakill Bay	886	131.8	17.4	28	174.3	28.6	0		
Broadhaven Bay	805	133.9	27.0	258	162.5	34.7	0		
Clifden Bay	3084	116.5	30.1	0			0		
Cruit Bay	238	142.4	23.0	164	175.5	26.3	0		
Gweedore Bay	637	123.5	29.1	149	148.2	44.1	0		
Inisbofin	220	131.8	25.7	26	198.3	13.9	0		
Iniskeas	1364	103.8	33.4	0			0		
Killary Approaches	445	130.2	25.1	341	163.0	36.3	0		
Rutland Sound	1472	130.9	26.1	132	165.1	30.3	0		
Turbot_Clifden	1264	111.8	32.2	0			0		

Bearhaven – Co. Cork

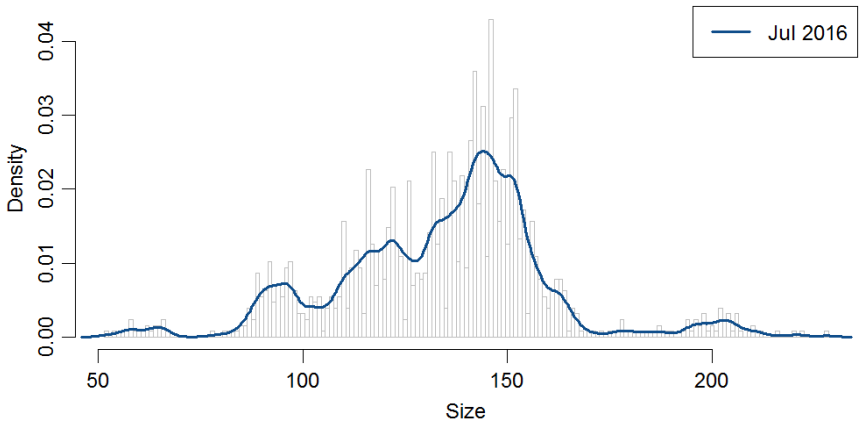


Figure 38. Size distribution of Ensis spp. in Bearhaven, July 2016. Bars are data on numbers by size. Blue line is a smoothed function of the size data. Data scaled so that the area underneath the smoothed function sums to 1.

Adrigole Harbour – Co. Cork

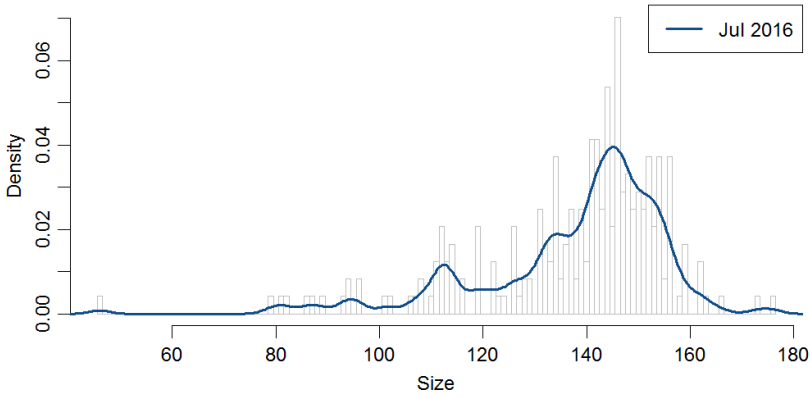


Figure 39. Size distribution of Ensis spp. in Adrigole Harbour, July 2016.

Gweedore Bay – Co. Donegal

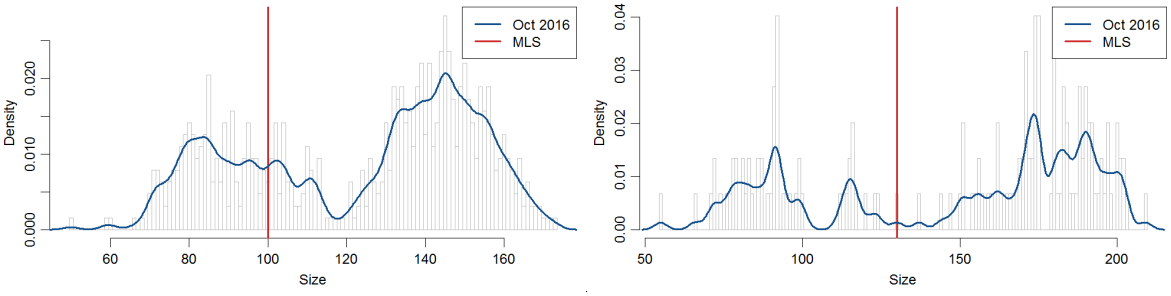


Figure 40. Size distribution of E. arcuatus (left) and E. siliqua (right) in Gweedore Bay, October 2016. MLS: minimum landing size.

Cruit Bay – Co. Donegal

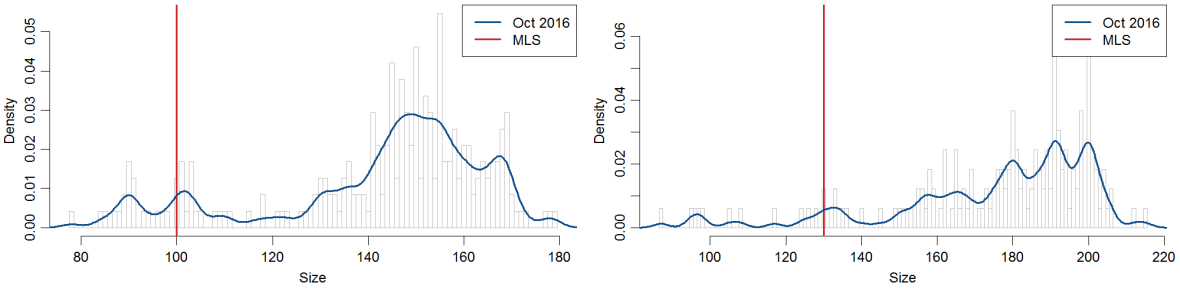


Figure 41. Size distribution of E. arcuatus (left) and E. siliqua (right) in Cruit Bay, October 2016. MLS: minimum landing size.

Rutland Sound – Co. Donegal

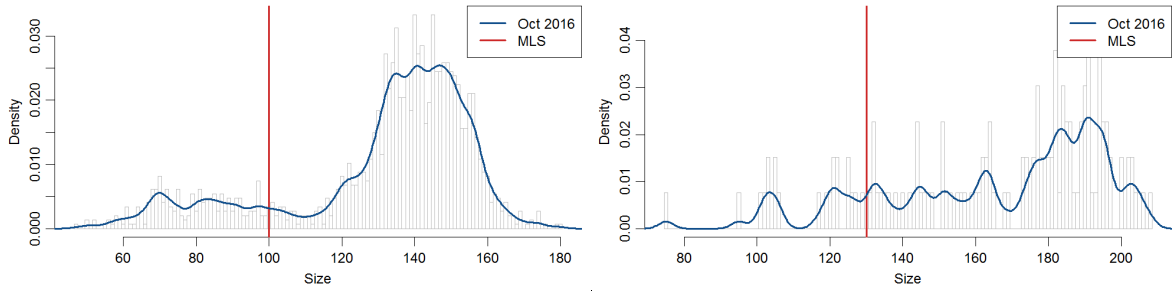


Figure 42. Size distribution of E. arcuatus (left) and E. siliqua (right) in Rutland Sound, October 2016. MLS: minimum landing size.

Ballinakill Bay – Co. Galway

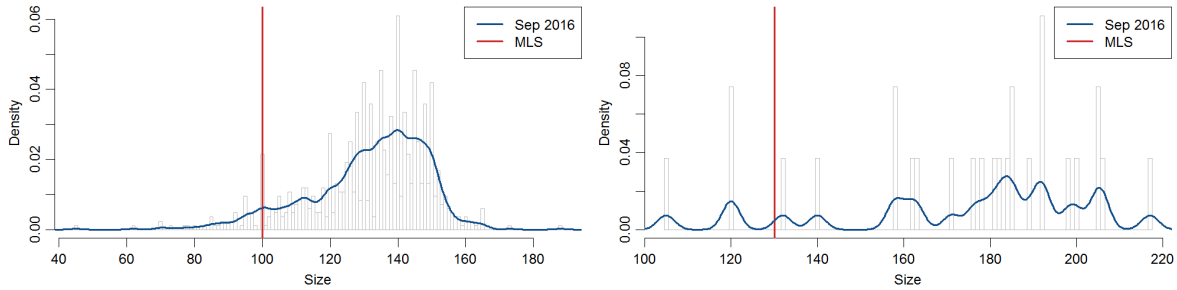


Figure 43. Size distribution of E. arcuatus (left) and E. siliqua (right) in Ballinakill Bay, September 2016. MLS: minimum landing size.

Clifden Bay – Co.Galway

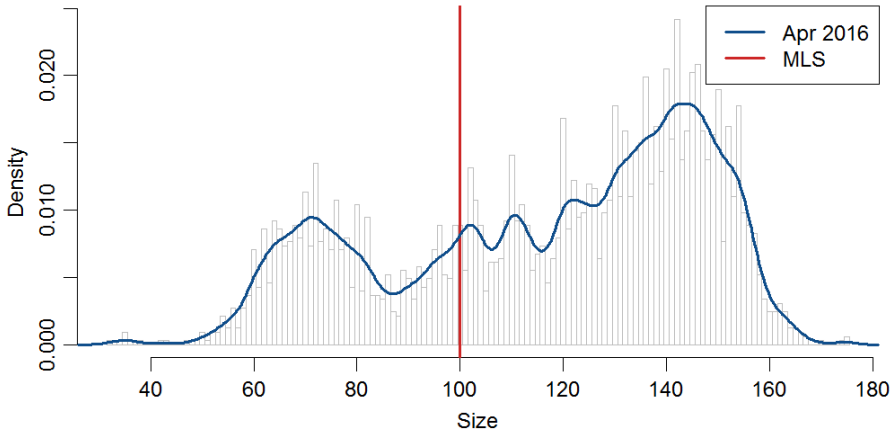


Figure 44. Size distribution of E. arcuatus in Clifden Bay, April 2016. MLS: minimum landing size.

Turbot Island Clifden – Co. Galway

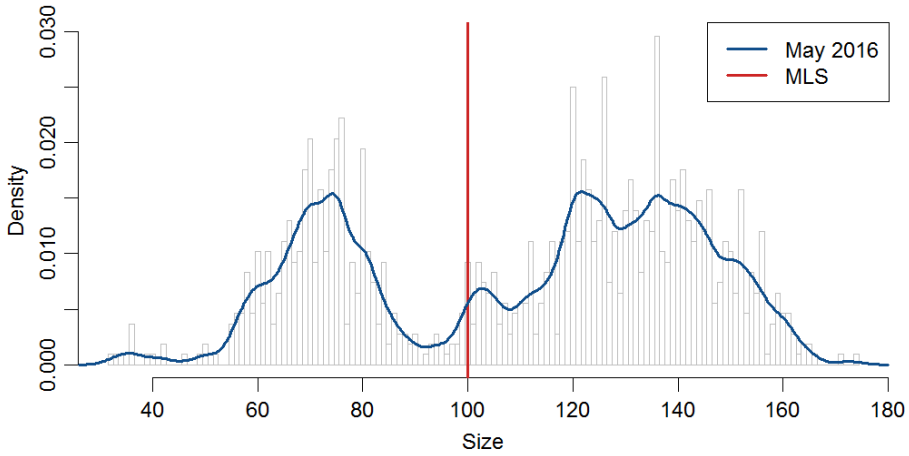


Figure 45. Size distribution of E. arcuatus in Turbot Island, Clifden, April 2016. MLS: minimum landing size.

Inisbofin – Co. Galway

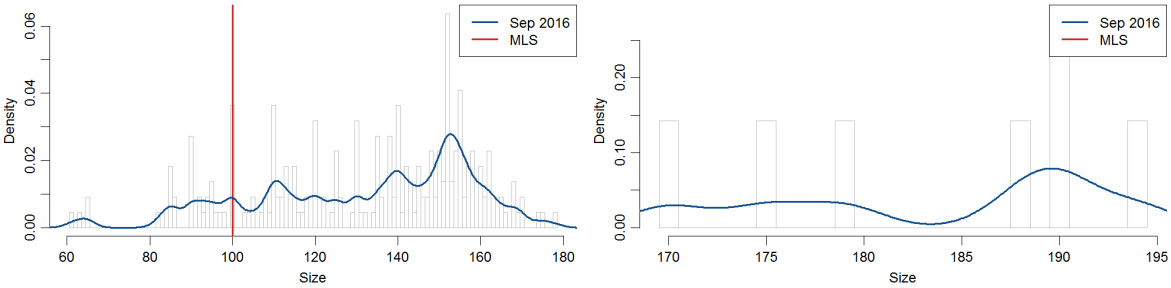


Figure 46. Size distribution of E. arcuatus (left) and E. siliqua (right) in Ballinakill Bay, October 2016. MLS: minimum landing size.

Killary Approaches – Co. Galway/Mayo

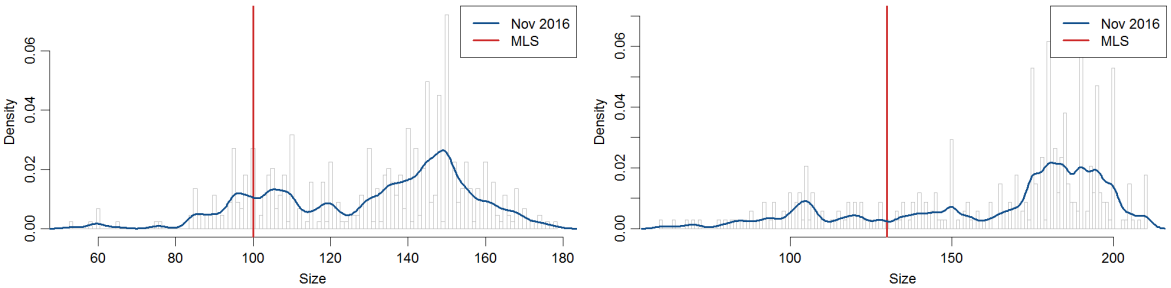


Figure 47. Size distribution of E. arcuatus (left) and E. siliqua (right) in Killary Approaches, October 2016. MLS: minimum landing size.

Broadhaven Bay – Co. Mayo

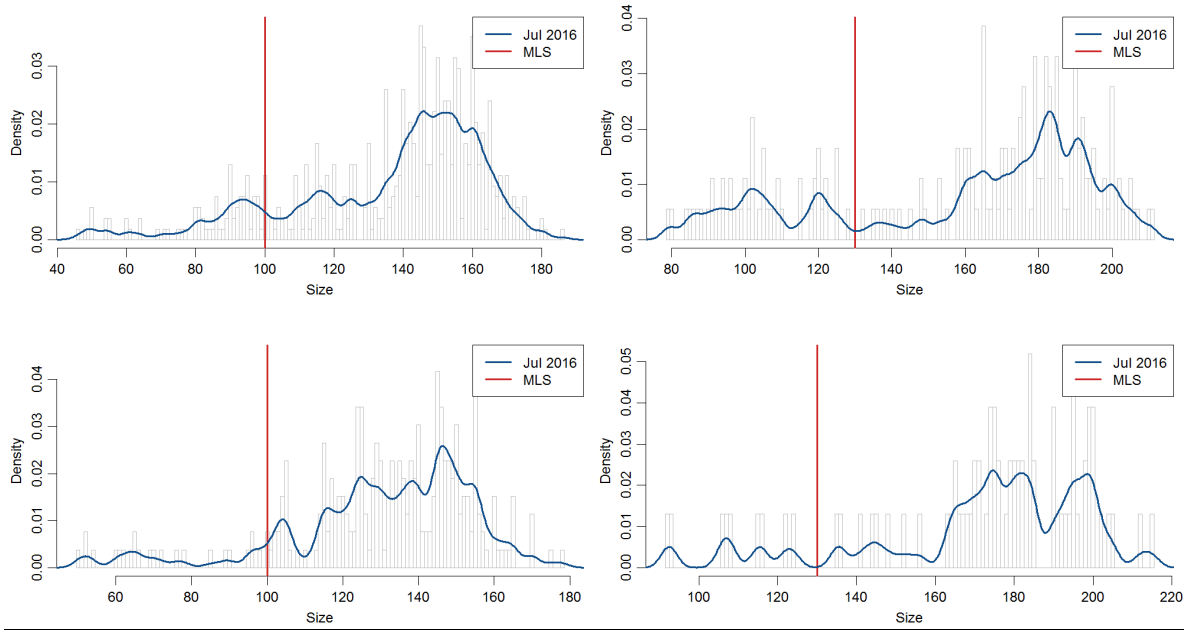


Figure 48. Size distribution of E. arcuatus (left) and E. siliqua (right) in the Northern (top) and Southern (bottom) beds in Broadhaven Bay, July 2016. MLS: minimum landing size.

Iniskea Is. – Co. Mayo

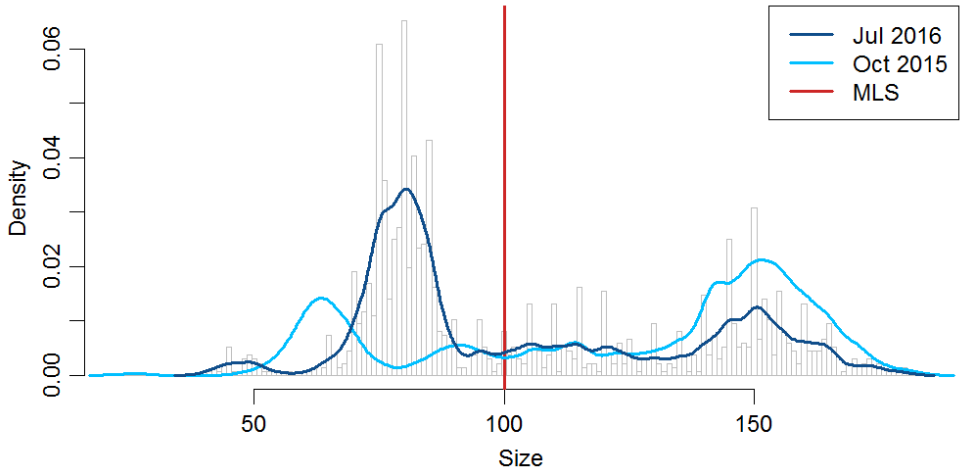


Figure 49. Size distribution of E. arcuatus in Iniskea Is. July 2016 and comparison with the size distribution observed in the same location in October 2015. MLS: minimum landing size.

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