Aln Estuary Fish Survey Report (2015 - 2023)

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Summary

The purpose of the biannual Aln Estuary fish survey is to understand the fish species present in the Estuary and the role it plays as an important spawning and nursery ground for North Sea fish species. The surveys help to identify species abundance of fish communities present at each survey site. Additional data is collected on the physio-chemical properties of the estuary, in the form of temperature and salinity. The fish surveys are based on the Environment Agency Transitional and Coastal Monitoring (TrAC) method. Over eight years 7,473 fish have been recorded, of which 4,689 (63%) have been measured. The 2023 results were compared with previous years to evaluate the significance of the site as a nursery and monitor for any temporal changes.

Key results for the 2023 survey are:

- In total 13 were identified to species level and two to genus level. In Spring 10 species and two genus were identified and in Autumn 11 species and one genus.
- All identified commercial species measured were representative of juvenile sizes, except the trout, 22% of lesser and 7% of greater sandeels, which were recorded as adults.
- The most abundant species recorded was the Atlantic herring (n=706), representing the highest recorded species abundance in one sample.

Overall key results (2015 – 2023) are:

- Site fidelity has been exhibited by six species which have consistently been recorded every year. Five species have only been recorded once.
- The highest abundances recorded are lesser sandeel (n=2,102), Atlantic herring (n=1,851) followed by goby spp. (n=1,347). These account for 73% of the total number of all individuals recorded.
- Inter-annual species richness has not varied much (Sorensen Index Similarity score 90% - 64%), however their associated population dynamics have fluctuated more widely, both inter and intra- annually (Bray Curtis Index Similarity Score 80% - 16%).

Acknowledgments

NIFCA would like to express their sincere appreciation to all the volunteers who have given their time to assist in the collection of data. Without their help, it would not be possible to complete this survey.

Introduction

The Aln Estuary Marine Conservation Zone (MCZ) is the smallest designated MCZ in the UK, covering an area of 38.5 hectares. The site designated in 2013 extends from the upper tidal limit at Lesbury to the estuary mouth adjacent to Alnmouth, on the Northumberland Coast (Figure 1). The estuary harbour is used to anchor small pleasure and fishing boats and is a popular destination for tourists and recreational sea anglers.

The Aln estuary is designated as a protected marine area for a variety of habitats including intertidal mud, sheltered muddy gravels, coastal saltmarshes and saline reedbeds, as well as estuarine rocky habitats (Net Gain, 2011). These habitats can act as spawning and nursery areas for fish species and support migratory and over-wintering birds. Under section 154 of the Marine and Coastal Access Act (MaCAA) NIFCA have a responsibility to manage MCZs and ensure the conservation objectives of MCZs are met and furthered. Given this MCZs estuarine location, the Environment Agency (EA) carry out monitoring for Water Framework Directive (WFD) compliance.

The TrAC fish surveys focus on collecting juvenile abundance data that can be used to determine if the estuary acts as important nursery fish grounds. According to Heupel *et al*. (2007), nursery grounds are identified by: (1) greater site fidelity (2) the area is used frequently every year and (3) higher juvenile abundances are recorded compared to other areas. Another factor to consider is the estuary depth; it is thought that small fish including juveniles are most abundant in shallow areas because these habitats enhance survivorship and growth (Manderson *et al.*, 2004). However, some predators are not limited to deep water by body size or behaviour (Manderson *et al.*, 2004; Linehan *et al.*, 2001).

NIFCA conducted a pilot juvenile/small fish survey at the estuary in May 2012 to gain further knowledge of the estuary (pre-designation) and because of the potential importance of the site for juvenile fish. Since 2015 NIFCA have carried out biannual surveys (in late spring and early autumn) to gain more information of fish population dynamics. There was a break in surveys in 2020 due to the covid-19 pandemic.

This report analyses the fish survey data collected in 2023 and applies the findings to earlier surveys identifying any possible trends for this ecologically important habitat.

Methods

Study Site

The study site is located on the Aln Estuary which is located along the Northeast coast of Northumberland (Figure 1). Two types of nets are deployed to encompass a 24-hour sampling regime. Three seine nets and two fyke nets were deployed at the mouth of the estuary, below the anchorage and an upstream location. These sites allow for the greatest range of species to be sampled as the salinity and habitat types varies between sites.

Survey Methodology

Two-day surveys for the collection of fish species presence were conducted on 15th and 16th May and 25th and 26th September 2023 to coincide with the spring and autumn migration of juvenile fish species (Ibbotson *et al*., 2013).

For the seine net survey, an estuary seine net 43m in length and 4m in depth (210/12 with 6.5mm and 14mm mesh size), with floats on the head rope and no lead weights on the footrope was deployed from the boat. The first tow line was fastened ashore, and the net set in a wide arc returning to the shore (FAO, 2013). The seine net is then pulled ashore by the survey team (Environment Agency, 2011) ensuring that the ground rope is in permanent contact with the estuary bed to create a barrier to prevent fish from escaping the seine net (FAO, 2013).

For the fyke survey, the two fyke nets consist of interconnecting nets held open by metal rings with a one-way entry to trap fish. They comprise of a 10- & 14-mm mesh size, 100 cm depth x (2 x 5.3m) in length and is connected by a 10-metre centre leader net. The fyke net opening (mouth) is attached to the leader that gathers and directs fish into the mouth and then through the interconnecting nets into the fyke's 'cod-end'. The first end of the fyke net was positioned upstream of the site with the net being lowered into the water downstream on an approximate angle of 30º. Once the full net and weights were submerged, the nets were then pulled taught using the buoy rope.

Day One: The two fyke nets are set at two locations in the estuary using a small boat at mid-tide (locations were selected based on depth to prevent exposure at low tide) and were left to soak for 24 hours. Seine net surveys were then conducted at the two sites downstream, each location was surveyed twice.

Day Two: The fyke nets were recovered at mid tide using the boat and seine netting using the same methodology as the previous day was carried out at the third site further upstream.

For all surveys the species caught were removed from the nets and placed into buckets of oxygenated water (collected at each site). Fish species were identified to species level where possible, using the Environment Agency 2009 manual "Key to the marine and freshwater fishes of Britain and Ireland". For individuals not possible to identify to species level, they were identified to the furthest point possible e.g. Genus level, pipefish spp. The first 50 individuals were measured from mouth to tail to the nearest millimetre using a fish measuring board (Figure 2). Once all the fish from the sample had been recorded, all the fish were returned to the estuary. For the seine net sampling, the fish were returned once the second net had been set, to avoid catching them again and duplication of the results. Temperature and salinity values were recorded using a thermometer and salinity refractometer at each location at the time of sampling.

The survey has been running from 2012 but usable data for fish abundance and length are only available from 2015 onwards and for abiotic conditions from 2019 onwards. For consistency, only data from biannual surveys from 2015 were analysed for annual comparisons of surveys.

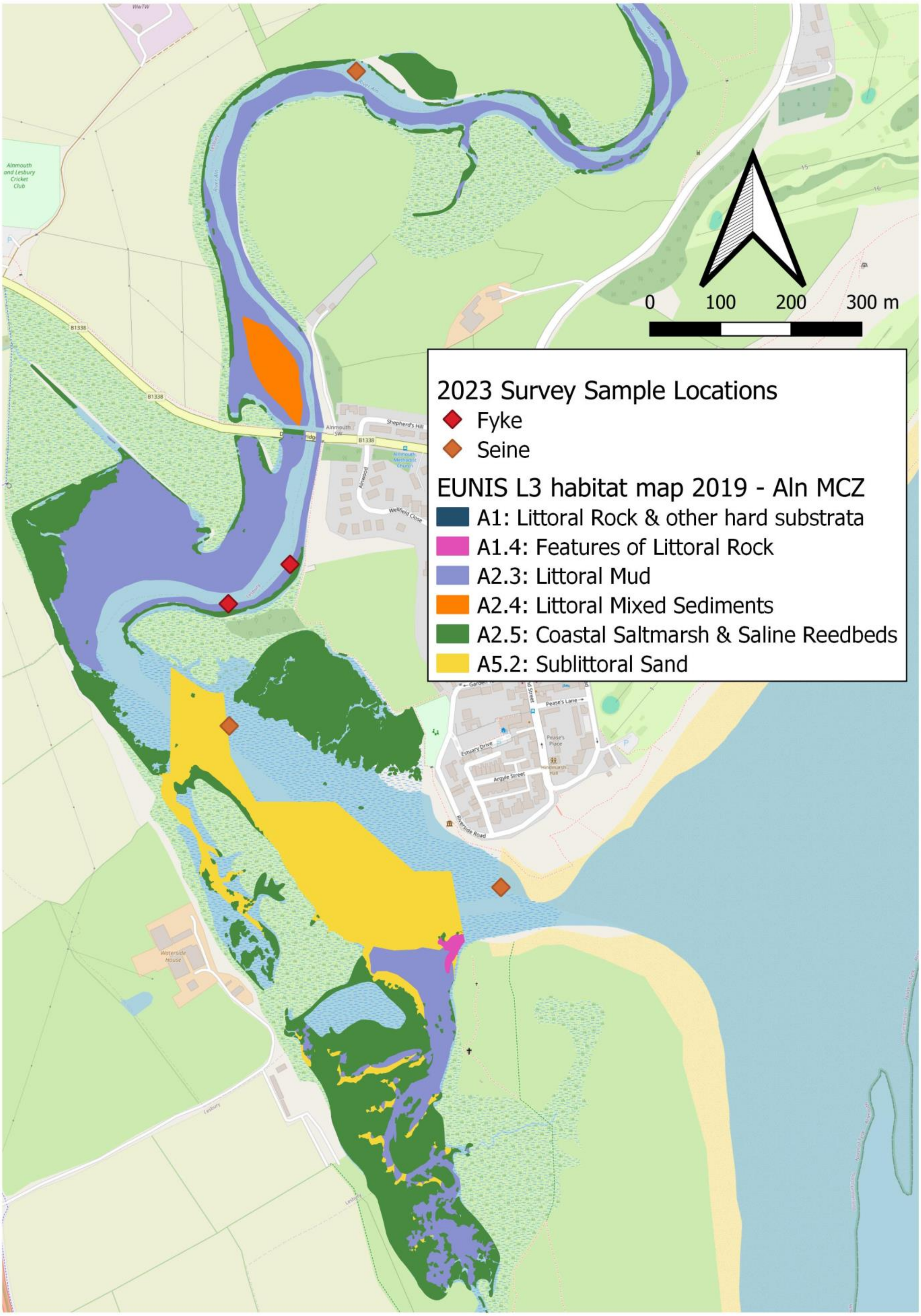


Figure 1 | Aln estuary MCZ EUNIS L3 habitat classification (Pre 2022 Review) & seine and fyke net survey points for 2023.

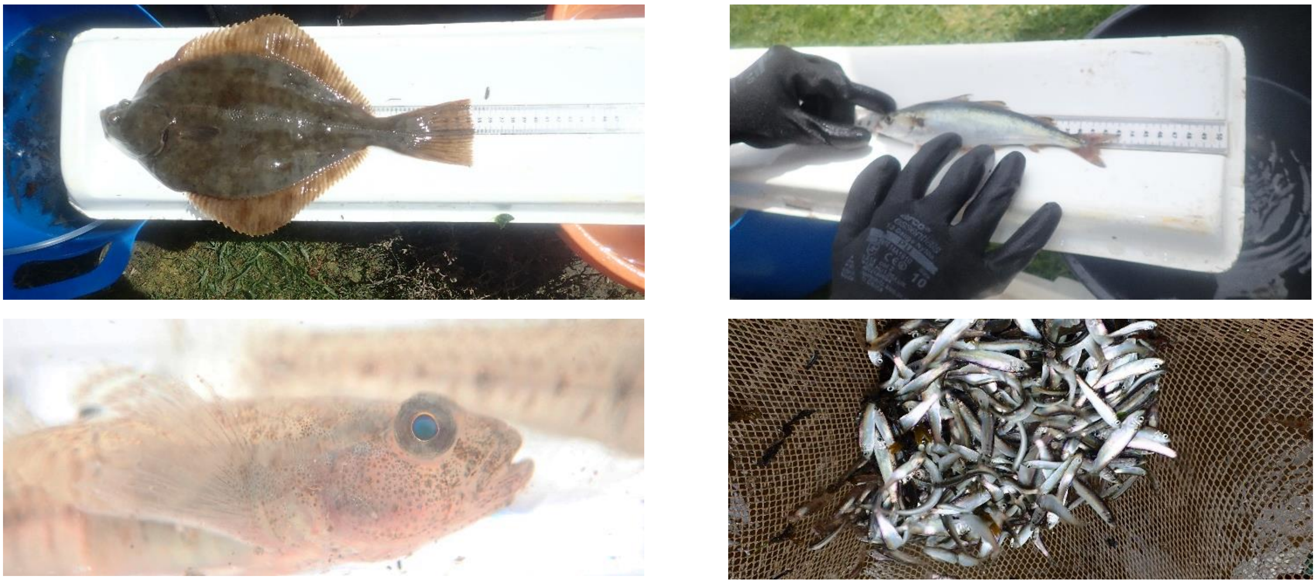


Figure 2 | Species recorded during the 2023 Aln Estuary fish survey. From top left going clockwise: flounder, saithe, goby spp., herring.

Results

Aln Survey (2023)

A total of 1,493 individuals were collected and 643 individuals measured during the Aln Estuary 2023 surveys. Thirteen species were identified to species level and two to genus level, a flatfish species, and goby spp. The flatfish species were unable to be identified due to their minute size (19mm - 34mm) and lack of distinctive markings but were most likely juvenile flounders. For the goby spp., despite several common gobies (*Pomatoschistus microps*) being identified during the 2023 survey, other individuals were not distinguished from the closely related sand goby (*Pomatoschistus minutus*). Therefore, due to the disparity in the recording for these species in this survey and throughout the eight years of surveying, all gobies' species have been grouped to genus level for this report to allow a comparative analysis.

Fish Abundance

Overall, fish abundance during 2023 (Figure 3) was dominated by Atlantic herring, *Clupea harengus,* (n= 706, 47%), followed by goby spp., (n = 356, 23%), an unidentified flatfish (n= 161, 10%) and lesser sandeel *Ammodytes tobianus* (n = 106, 7%). Of these species, 100% of herring and 85% of goby spp. were caught during the Autumn survey, and 100% of the unidentified flatfish and 87% of the lesser sandeel were recorded in Spring. Commercial species represented 84% of the fish in the sampling, with European eel exclusively caught during the autumn survey and Atlantic salmon and sea trout during the spring survey. Most of the fish were caught in the Autumn survey (n= 1,143, 76%) with the 'upper' sampling site recording the highest number of individuals for both Spring (n= 218, 60%) and Autumn (n= 948, 82%).

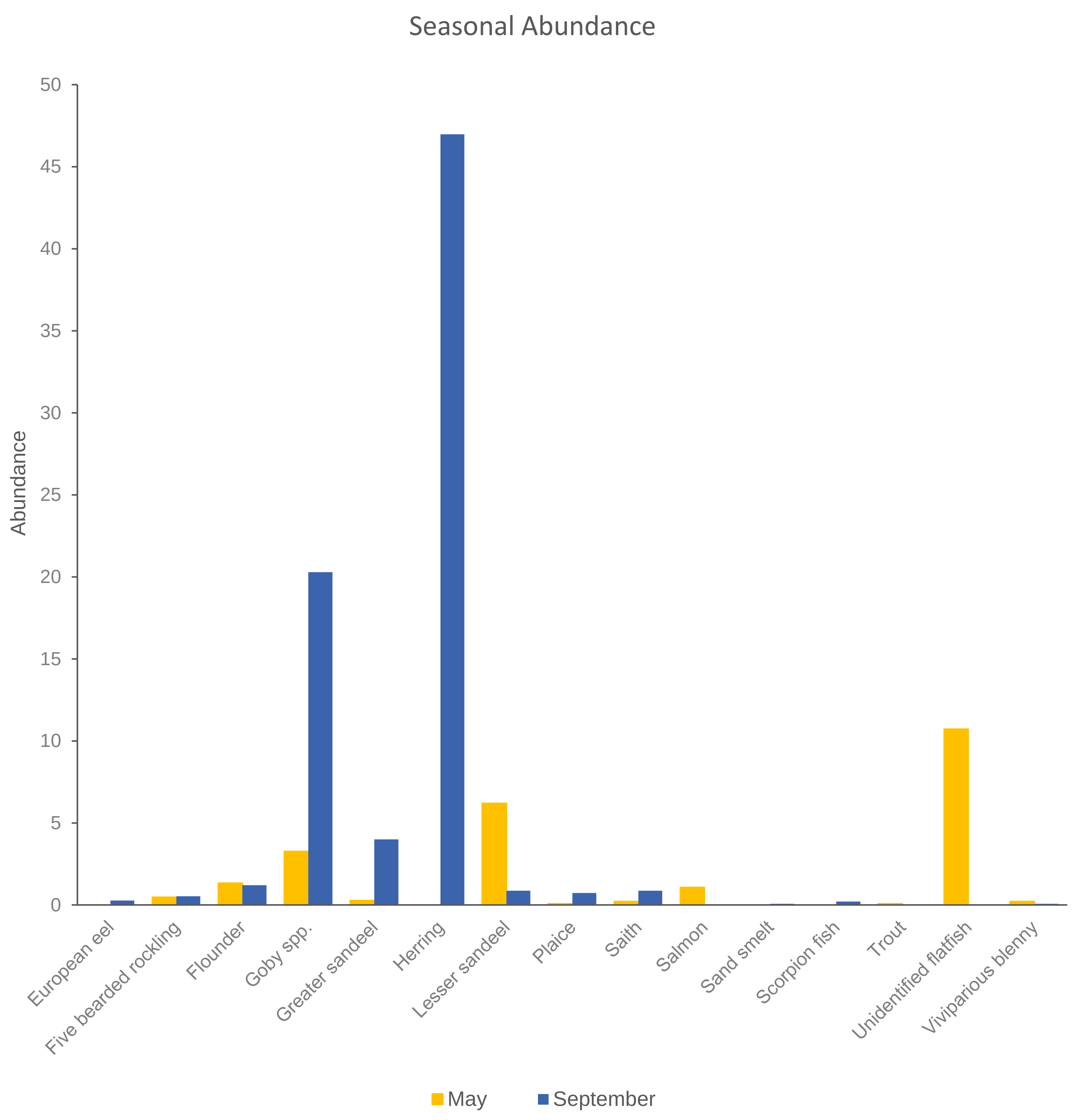


Figure 3 | The seasonal abundance of the recorded species caught in the 2023 Aln Estuary surveys.

Mean Length

The results of individual commercial species (including the unidentified flatfish) are summarised in Table 1, and non-commercial in Table 2. All the commercial individuals measured were juveniles except for the one trout measured and the lesser and greater sandeels, with 22% and 7% recorded as adults, respectively. Except for trout, the rolling means (2015 – 2023) of the measured lengths for all commercial species are below the species' size of maturity.

Table 1 | Total catch, mean length, and size at maturity for species important for commercial fishing during the 2023 Aln Estuary surveys.

Species	Number caught	Mean length (mm)	Rolling mean length (mm)	Size of maturity (mm)	Reference
European flounder (*Platichthys flesus*)	38	161	72	300	MSEP (2014)
Lesser sandeel (*Ammodytes tobianus*)	106	112	114	130	Environment Agency (2009)
Atlantic herring (*Clupea harengus*)	706	77	62	175	Ellis et al. (2012); ICES (2009)
Salmon (*Salmo salar*)	16	168	168		Unavailable for region
Plaice (*Pleuronectes platessa*)	12	64	66	350	MSEP (2014)
Saithe (*Pollachius virens*)	16	168	153	554	Jennings et al. (1998)
European eel (*Anguilla anguilla*)	4	326	337	450 - 650	https://www.fishbase.se/summary/Anguilla-anguilla.html
Greater sandeel (*Hyperoplus lanceolatus*)	64	103	126	130	Ellis et al. (2012); ICES (2009)
Trout (*Salmo trutta*)	1	276	188	177 - 228	Taube (1976)
Unidentified flatfish	161	24.5	24.5	-	
Total	963				

Table 2 | Total catch and mean length for the non-commercially important species during the 2023 Aln Estuary surveys.

Species	Number caught	Mean length (mm)	Rolling mean length (mm)
Goby spp. (Common & Sand goby (*Pomatoschistus microps/ minutus*))	356	53	51
Viviparious blenny (*Zoarces viviparus*)	4	210	209
Sand smelt (*Atherina presbyter*)	1	78	67
Five bearded rockling (*Ciliata mustela*)	15	151	156
Scorpion fish (*Scorpaenidae* sp.)	3	80	76.1
Total	476		

Aln Surveys (2015-2023)

Over eight years 16 surveys have been carried out consisting of 96 seines and 32 fykes from the four sites within the Aln Estuary. A total of 7,483 fish have been caught, of which 4,689 (62%) have been measured, which consisted of a total of 20 species, two genus and one unidentified species.

Species Richness

Species richness was recorded highest in the years 2015 and 2022 with 15 species and goby spp. identified in both years, of which 10 (63%) were represented as commercially important species. The lowest species richness was recorded in 2018, with 10 species identified in addition to goby spp. Despite recording the lowest species richness, commercially important species still represented most species caught with seven commercial species (64%) identified (Figure 5).

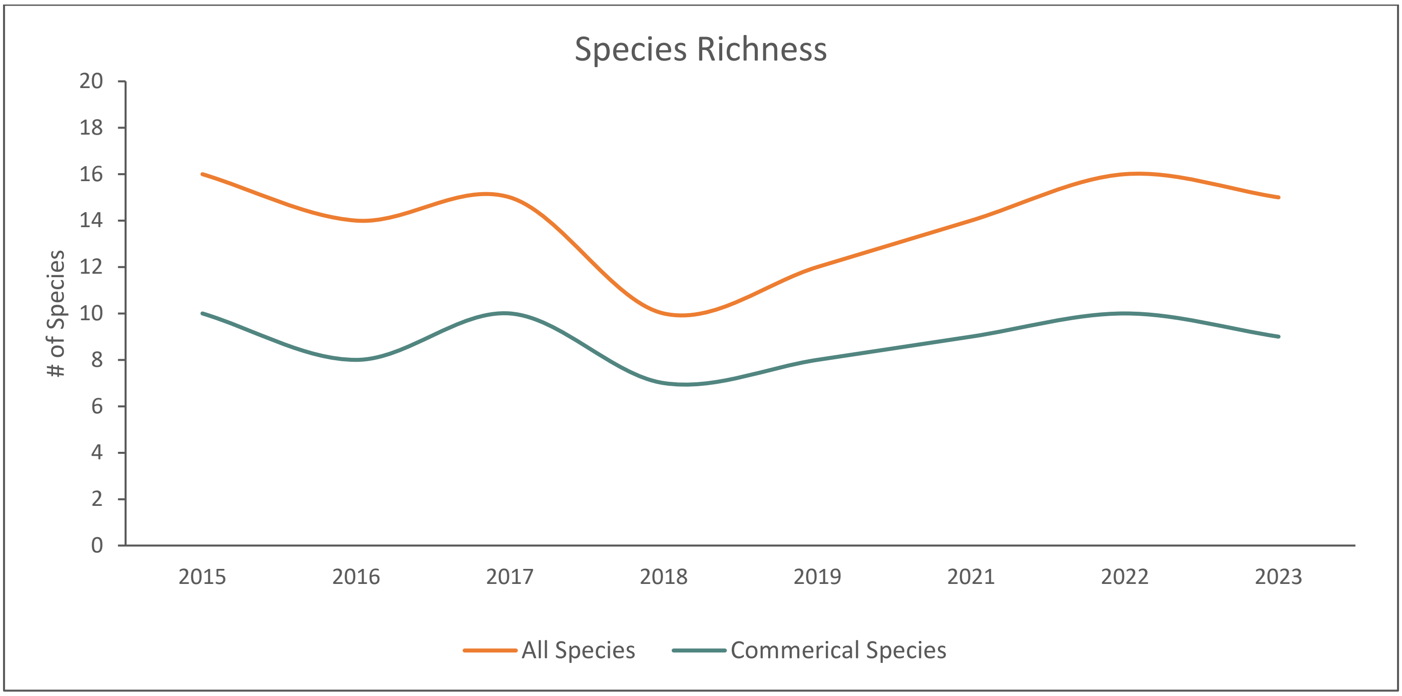


Figure 4 | Species richness for total number of species and commercial species recorded annually during the Aln estuary survey.

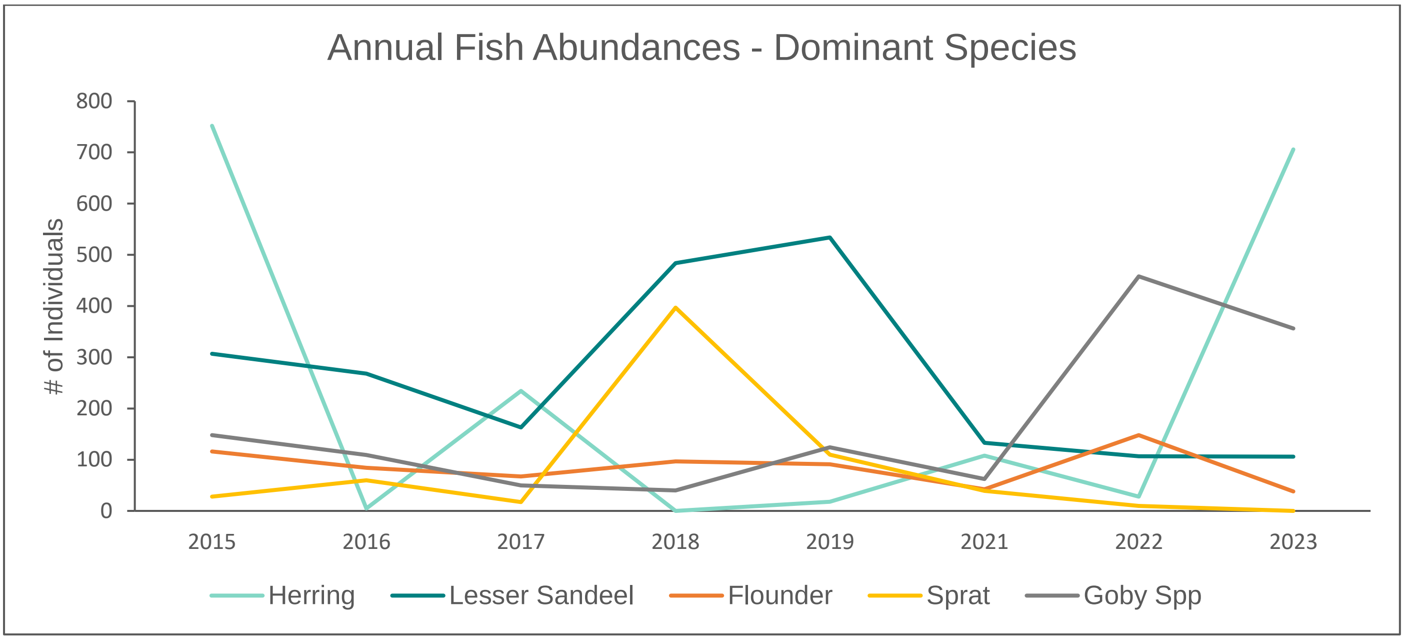
The inter-annual variation of species richness (based on Sorensen Index score for species presence/ absence) reveals a high similarity (Table 3), with the overall average score as 79% indicating a relatively stable species presence throughout the eight years. The highest similarity was recorded between the years 2017 and 2015 (90%), and the lowest both in 2018 with 2019 and 2023 (64%).

Table 3 | Sorensen Index showing the species richness similarity comparison between each annual survey. Highlighted scores represent the highest (Green) and lowest (Red) scores.

	2015	2016	2017	2018	2019	2020	2021	2022	2023
2015	-	-	-	-	-	-	-	-	-
2016	87%	-	-	-	-	-	-	-	-
2017	90%	83%	-	-	-	-	-	-	-
2018	77%	83%	72%	-	-	-	-	-	-
2019	79%	77%	89%	64%	-	-	-	-	-
2020	-	-	-	-	-	-	-	-	-
2021	73%	79%	76%	75%	77%	-	-	-	-
2022	81%	87%	84%	77%	79%	-	84%	-	-
2023	71%	69%	73%	64%	74%	-	71%	77%	-

Fish Abundance

The most dominant species recorded throughout all surveys are the lesser sandeel (n=2,102), Atlantic herring (n=2,075) followed by goby spp. (n=1,347), accounting for 73% of the total number of individuals recorded (Figure 6a). The lesser sandeel was the most recorded species in the years 2016, 2018, 2019 and 2021, and has consistently been recorded as one of the most dominant species in every other year. Other species recorded every year but not necessarily in high abundance are the goby spp., Atlantic herring, European flounder, saithe and European eel (Figure 6). The least recorded species are salmon (2023), thick- lipped grey mullet (2022), four-bearded rockling (2021), a pipefish spp. (2016) and dab (2015), having only been recorded once during the eight years. Despite being recorded in every other annual survey; sprat was not observed in any of the survey samples in 2023.



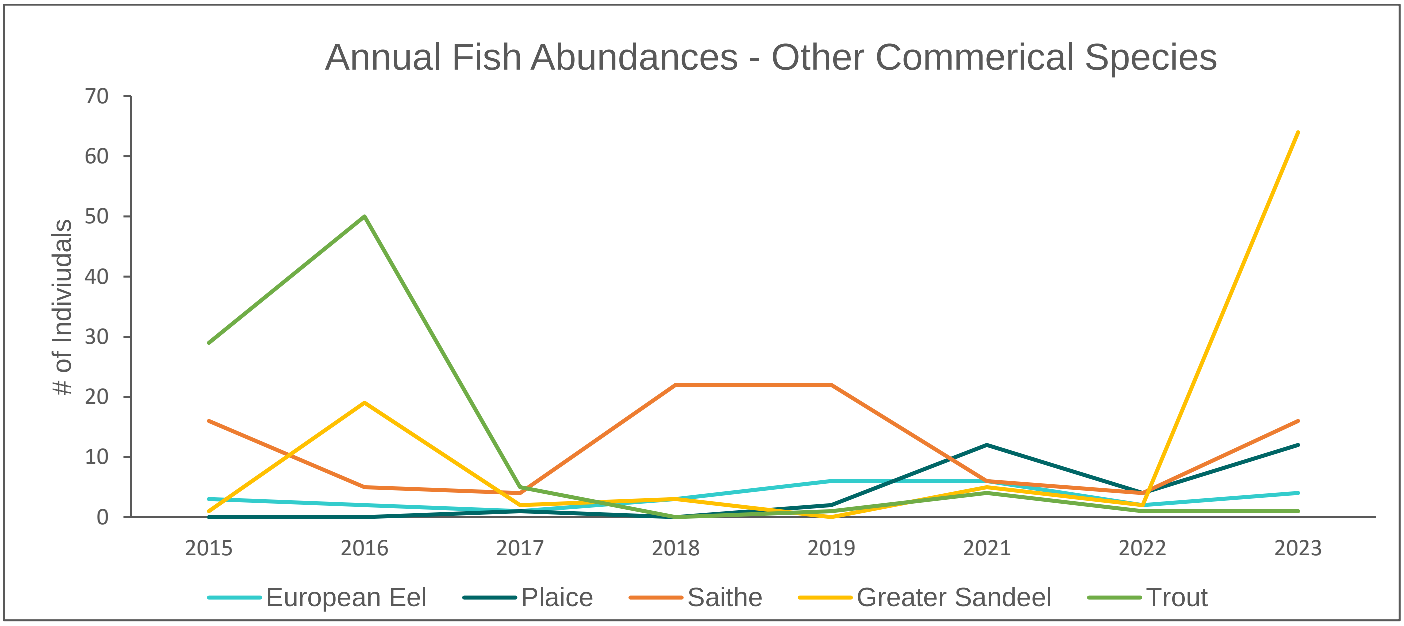


Figure 5 | Total fish abundance for (top) most dominant species, herring, lesser sandeel and goby spp. recorded for the 2015-23 Aln estuary surveys**,** (bottom) other commercially important species for the 2015-23 Aln estuary surveys.

After several years of recorded low abundances, the 2023 herring sample represents the largest number of individuals caught for one species in a single seine sample to date (n= 706). This is also the second largest annual abundance recorded for a species; the largest also being herring, caught across multiple seine samples in 2015 (n= 752). The lesser sandeel and herring exhibit opposing fluctuations in their abundances, as in the years of recorded high abundances (for the lesser sandeel 2018 & 2019 and herring 2015 & 2023), the other species have exhibited lower than average abundances.

For flatfish species, the 2023 abundance of flounder was the lowest recorded over the survey timeframe (n=38), proceeding its highest recorded abundance in 2022 (n=148). Despite the low abundance numbers, plaice recorded its highest abundance again (n=12), as previously recorded in 2021. Although the abundances of the identified flatfish species were low, it is highly likely that the unidentified flatfish species was representative of either Flounder or Plaice, which was the highest abundance recorded of a flatfish species during the eight-year survey.

The inter-annual variation of species diversity (using the Bray Curtis Index score for similarity) calculated for species presence and their associated abundances revealed a much wider variation compared to species richness (Table 4). The highest similarity was calculated as 80% between 2018 to 2019 and the lowest of 16% between 2018 to 2023. Of note is the high Bray Curtis similarity score between 2018 and 2019, which is also the same years which scored the lowest Sorensen Index score (64%). Despite these years sharing the least species recorded in common between the years, the species which were present had similar abundances within the samples collected.

Table 4 | Bray- Curtis Index showing the species population similarity for species composition & abundance comparison between each annual survey. Highlighted percentages represent the highest (Green) and lowest (Red) scores.

	2015	2016	2017	2018	2019	2020	2021	2022	2023
2015	-	-	-	-	-	-	-	-	-
2016	53%	-	-	-	-	-	-	-	-
2017	56%	55%	-	-	-	-	-	-	-
2018	42%	56%	37%	-	-	-	-	-	-
2019	59%	71%	45%	80%	-	-	-	-	-
2020	-	-	-	-	-	-	-	-	-
2021	49%	58%	75%	38%	56%	-	-	-	-
2022	50%	48%	41%	33%	58%	-	55%	-	-
2023	71%	28%	43%	16%	26%	-	36%	48%	-

Salinity and Temperature

The 2023 salinity and temperature readings taken at each sampling site are presented in Table 5. As expected, the salinity levels are lower at the survey point furthest upstream compared to closest to the mouth of the estuary. The salinity range across all sites was slightly greater in Spring (25 parts per thousand (ppt) – 38ppt) compared to Autumn (26ppt – 36ppt), and hence their overall associated averages, in Spring 33ppt compared to Autumn 31.8ppt. Water temperature was fairly uniform across the sample points with an overall mean of 11.5°C for Spring (11 - 13°C) and 14.3°C for Autumn (14-15°C).

Table 5 | Salinity and temperature values across the Aln estuary survey points recorded during the 2023 Aln Estuary surveys.

Survey Point	Temperature (C°)		Salinity (ppt)	
	Spring	Autumn	Spring	Autumn
Fyke	13	14	32	30
Seine - mouth	11	15	38	36
Seine - mid	11	14	37	35
Seine - upper	11	14	25	26
Mean value	**11.5**	**14.3**	**33**	**31.8**
Rolling Mean (2019 – 2023) *	**11.9**	**13.5**	**26.1**	**29.0**

**Data from 2015 to 2018 was not included as abiotic parametric data was not consistently collected across all sites. 2020 is omitted as no survey was conducted.*

In comparison to the previous years' (2019 – 2023)*, the 2023 temperature averages are fairly consistent, varying only -0.4°C for Spring and +0.8°C for Autumn from the rolling means. The 2023 salinity readings revealed a greater difference from the rolling means, with a +6.9ppt and +2.8ppt average increase for Spring and Autumn respectively. These inter-annual differences for salinity are more apparent across the sample sites during the Spring surveys than the Autumn (Figure 7) and are possibly caused from an increase period of rainfall.

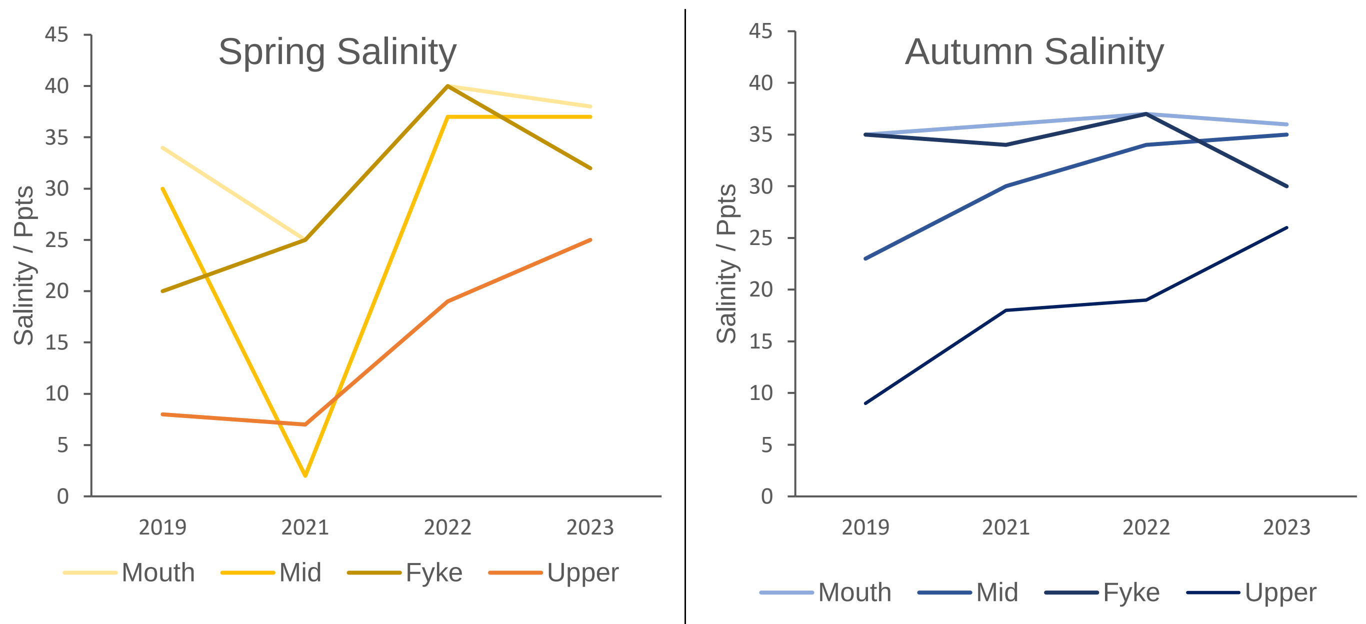


Figure 6 | Salinity measurements taken from each sampled site per year for Spring (left) and Autumn (right) surveys.

Discussion

The most abundant and significant species recorded in the 2023 Aln Estuary surveys, are examined further for their use of its habitats and its relative function and importance to the species.

Atlantic herring (*Clupea harengus*) is a pelagic species with stocks distributed across the northwestern and northeastern Atlantic. Not only an important prey species for cod, whiting, mackerel, sea birds and mammals, this species has significant commercial value (outside the NIFCA district) in the North Sea. However, its population has suffered substantial instabilities resulting from heavy exploitation and recruitment failures (Dickey-Collas *et al.*, 2010). Since the fishery closure between 1977 to 1981 the population has recovered and is considered sustainably harvested within its managed precautionary stock limits. Despite this the population is viewed as declining within the limits, with research linking recruitment failures to climatic factors, such as SST and lower food availability (Payne *et al.,* 2009).

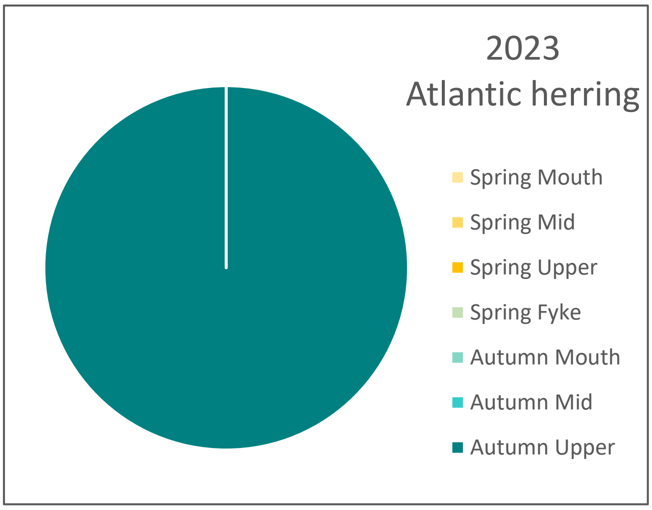


Figure 7 | Distribution & seasonality of Atlantic herring recorded during the 2023 surveys.

The North Sea Atlantic herring stock is made up of four components, with one of their spawning grounds identified off the coast of Northumberland (Coull *et al.,* 1998). Atlantic herring spawn at different times of the year, and the North Sea stock are primarily Autumn (as opposed to Spring) spawners, taking place between August and October (Henderson 2014). Spawning occurs at a depth of 10 – 80m, with females laying eggs on gravel or coarse sediment habitats, and the males spraying milt above. Once hatched the larvae drift towards the eastern North Sea coastline to their inshore nursery grounds (thefishsite 2010), usually estuaries, and remain for up to two years before migrating offshore (ices.dk). At the time of their first spring, the Autumn spawned herring reach about 50mm in length (Stevenson & Scott 2005). The populations present in the Aln Estuary are consistent with originating from the previous autumn's spawn, measuring an overall average of 50mm in the Spring survey and 65mm in the Autumn survey. These measurements are well below the size of maturity (Figure 9), highlighting the significance of this site as a nursery ground for the North Sea Atlantic herring stocks.

During 2023, all juvenile Atlantic herring were caught in the upper sampling site during the Autumn survey (Figure 8). This is generally consistent with previous years' surveys with the majority of all the herring caught (60%) in the upper Autumn samples. Fish surveys conducted in other estuaries have found high abundances of juvenile herring utilising saltmarsh and muddy sediment habitats for shelter and food availability (Green *et al.,* 2012, Stamp *et al.,* 2022), and these habitats are located within the upper sampling site of the Aln Estuary survey. Research for the salinity tolerance of herring have shown that juveniles have a wider tolerance of salinities, which is narrowed as they mature to migrate back to the marine environment as adults (Stevenson & Scott 2005). This ontogenetic shift is not exhibited in the Aln Estuary Atlantic herring population as the largest individuals (>100mm) have been recorded at the mouth (n=6) and upper (n= 16) sites and is likely to be nearer the onset of maturity.

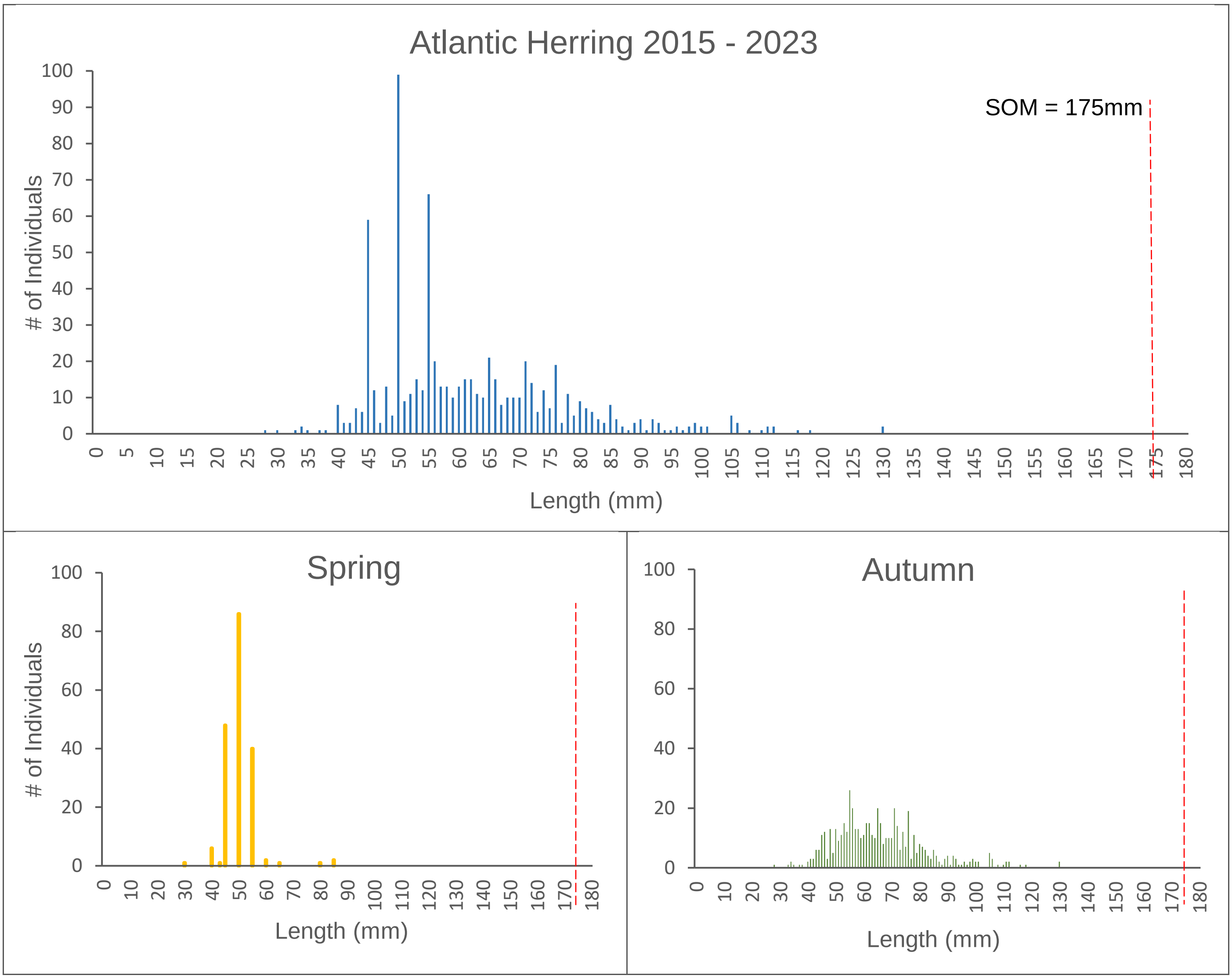


Figure 8 | Size distribution bar graphs for Atlantic herring showing all individuals measured 2015 – 2023 (top), all measured during spring surveys (bottom left), and all measured during autumn surveys (bottom right). Red dash line represents size of maturity.

There are two types of **lesser sandeel** that are commonly found across the North Sea, *Ammodytes tobianus* and *Ammodytes marinus*. *A. tobianus* is found in intertidal waters and is the species recorded within the Aln Estuary. *A. marinus* is found in deeper waters from 20m to 80m depth and up to March 2024 (prior to the ban), supported a large fishery in the English waters of the North Sea. The lesser sandeel can be found close to clean, fine sand, in which it burrows overnight, and swims over in a head-down posture during the daylight. They are considered to be the most important of the forage fish species in the North Sea (Engelhard *et al.,* 2014), a high energy mid-trophic species that transfer zooplankton energy further up the chain to important piscivorous fish species (e.g. mackerel, whiting, Atlantic cod) and protected species of sea birds (MCCIP 2018). Their position within the food web creates high spatial and temporal variability because their abundance can be controlled by food availability and/or intensity of predation (Frederiksen et al., 2007).

As in 2022, the lesser sandeel was the fourth most abundant species recorded in the 2023 Aln estuary survey, with the majority caught during the spring survey (87.7%). The seasonal abundance disparity correlates with the spawning period of January-February and possibly the onset of their winter hibernation period, when the lesser sandeels bury themselves in sandy sediments. In 2023, no sandeels were caught in the upper survey sites (Figure 10), which follows the spatial trend that the majority of lesser sandeels are caught in the mouth and mid survey sites (84.7%).

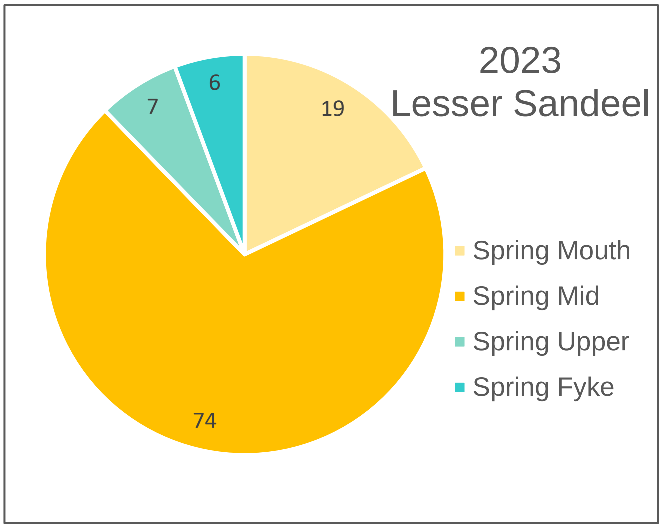
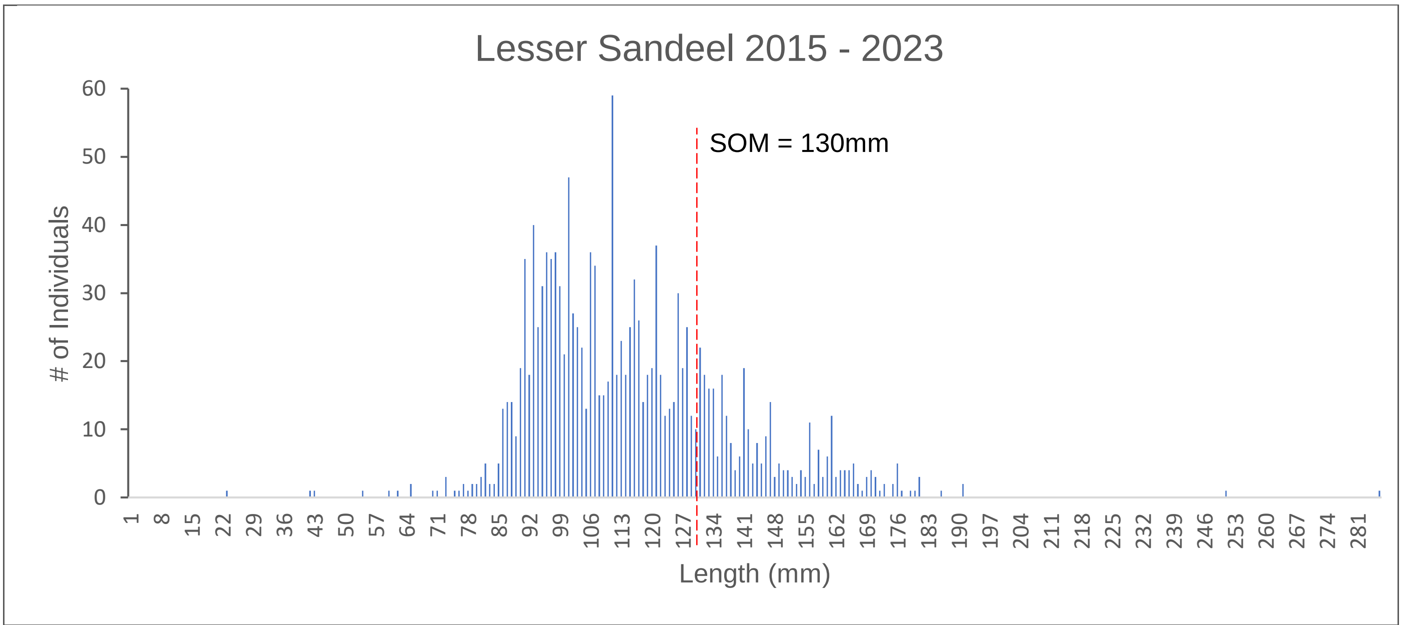


Figure 9 | Distribution & seasonality of lesser sandeel recorded during the 2023 surveys.

This distribution is most likely driven by the species habitat preference for sandy sediment habitats (Régnier *et al.*, 2018 & Holland *et al.*, 2005), which are located towards the mouth of the estuary.

The lesser sandeel's size of maturity is 130mm. In the 2023 survey, the average length of the individuals measured was 112mm, with a rolling mean of 114mm, both below the size of maturity. Furthermore, of the 1,428 individuals measured from the 2,102 counted, 1,109 were measured below 130mm and 319 above (Figure 11), highlighting the importance of this site for lesser sandeel's juvenile development.



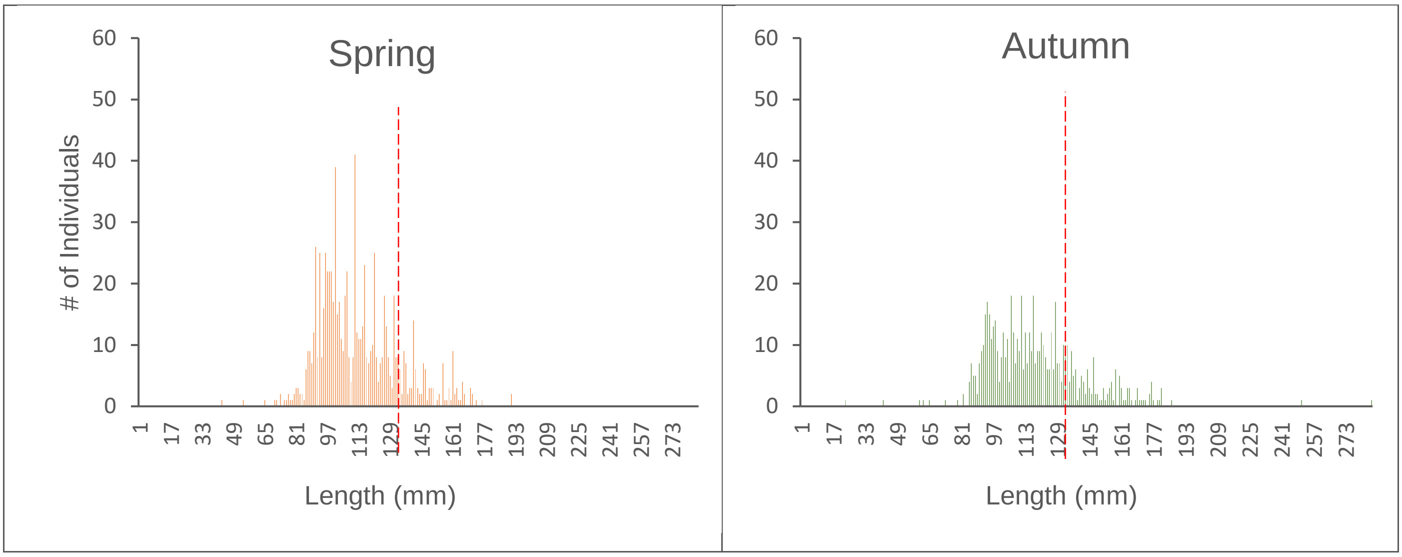


Figure 10 | Size distribution bar graphs for Lesser sandeel showing all individuals measured 2015 – 2023 (top), all measured during spring surveys (bottom left), and all measured during autumn surveys (bottom right). Red dash line represents size of maturity.

European flounder (*Platichthys flesus*) is an important fish species in estuarine communities and a popular sport fish for angling. It is a bottom dwelling flatfish most commonly found within 50m of the shore in estuaries and other low-salinity waters. Although often found in freshwater, adults return to deeper marine water (20-50m) to breed during the spawning period January to June. Males reach maturity at approximately 110 mm and females at 170 mm (Summers 1979; Bos 1999; Drevs et al.,1999); however, age at maturity will almost certainly differ between populations, particularly those with decreased numbers or those heavily fished.

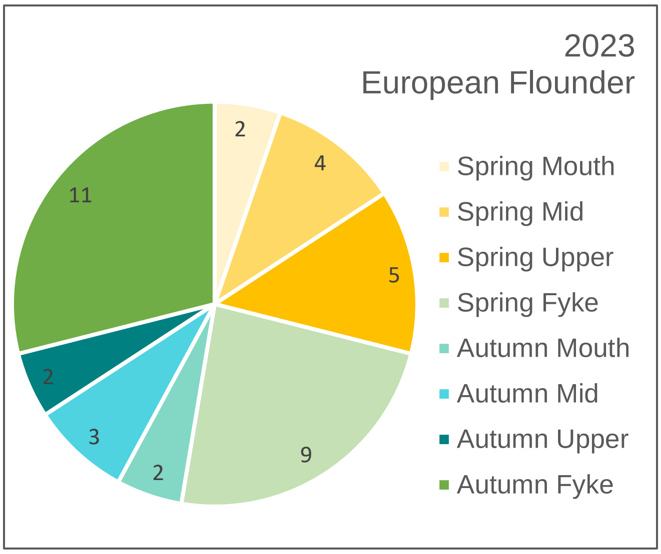


Figure 11 | Distribution & seasonality of European flounder recorded during the 2023 surveys.

Flounders have been observed in every year surveyed and were recorded at every sampling site during the 2023 survey (Figure 12), with 71.2% caught during the Spring. Since 2015, 683 individuals have been recorded, 87% and 79% measuring below the female and male maturity size respectively (Figure 13), exhibiting a predominantly juvenile population and a minor adult resident assemblage present in the Aln Estuary. Evaluation of the average length per season for each site survey provides an insight to this species spatial and temporal demographic distribution within the Aln Estuary. For both the Spring and Autumn surveys, the upper site had the lowest average size in comparison across all site's sampled for that season, with Spring consisting of the smallest individuals (average = 39mm). These trends combined with the species' spawning period from January to June, infer that the youngest individuals inhabiting the Aln Estuary are located at the upper site in spring and then migrate downstream as they mature. If following this ontogenetic trend, it would also suggest that the unidentified flatfish recorded in the upper sample site during the spring 2023 survey were European Flounders

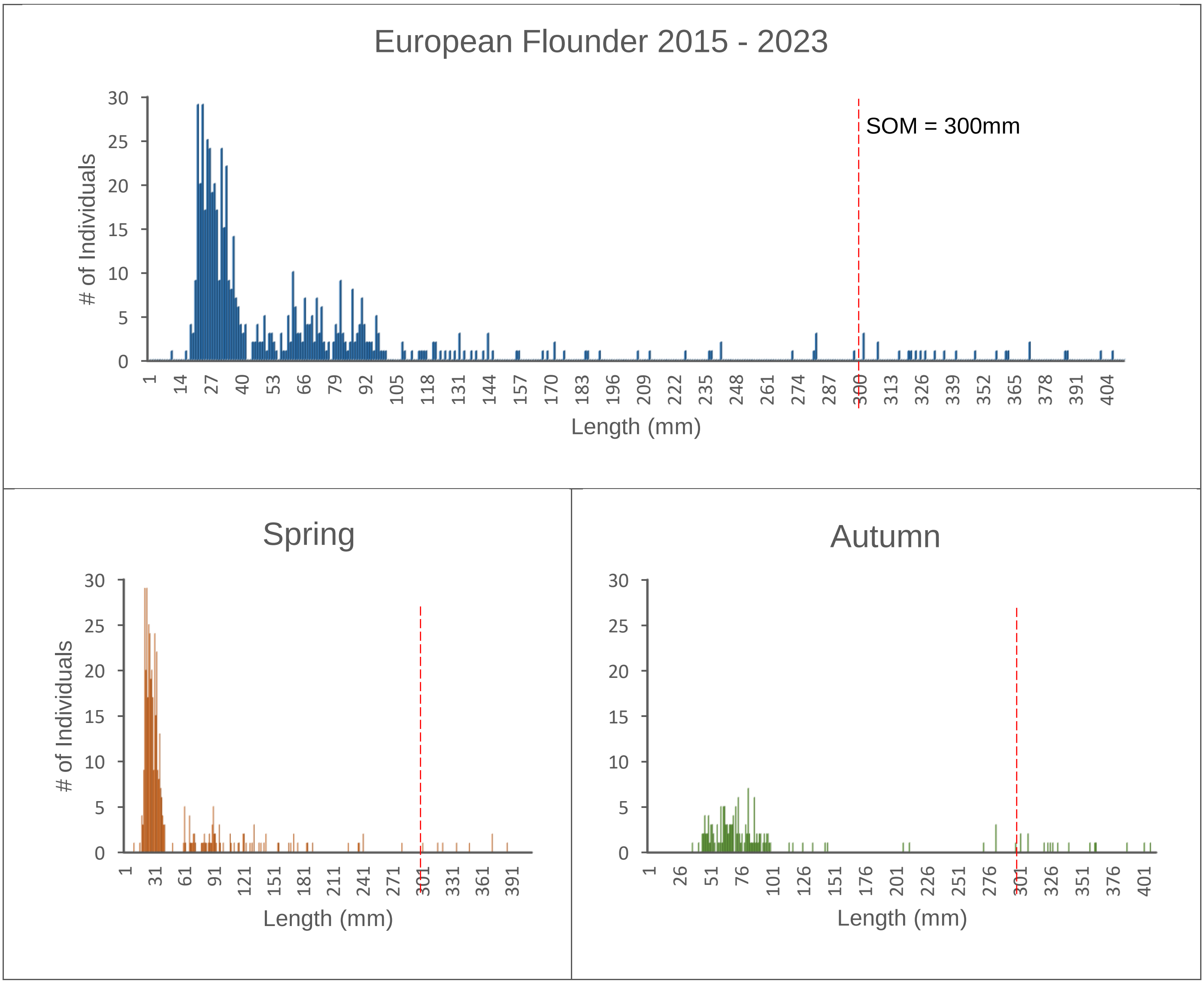


Figure 12 | Size distribution bar graphs for European flounder showing all individuals measured 2015 – 2023 (top), all measured during spring surveys (bottom left), and all measured during autumn surveys (bottom right). Red dash line represents size of maturity.

The **common** (*Pomatoschistus microps*) and the **sand goby** (*Pomatoschistus minutus*) are small goby species, considered abundant across the coastline of the UK. Both occupy similar ecological niches, found in coastal waters, tide-pools, lagoons, saltmarshes, and estuaries, with a preference for sandy or muddy sediment bottoms. They feed on polychaetes and amphipods, and although not an important commercial species, are a significant prey species to other fish and bird species. They have

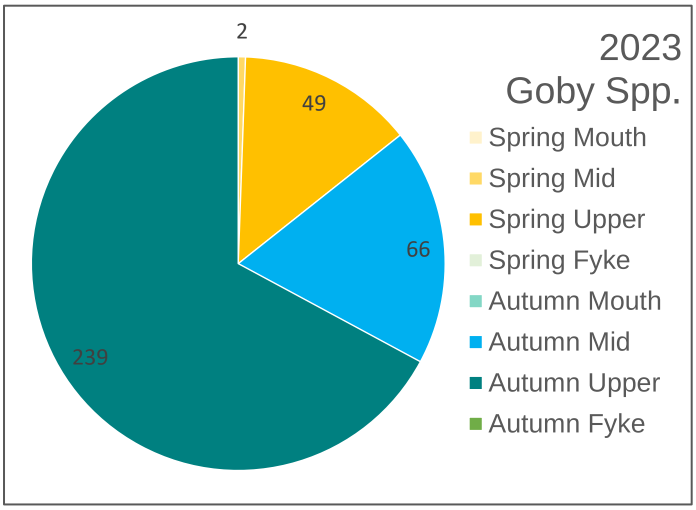


Figure 13 | Distribution & seasonality of goby spp. recorded during the 2023 surveys.

a lifespan up to one to two years, with both species maturing at seven to 12 months, 40mm in length (Riley 2007, Riley 2003). However, despite both having the same size of maturity, each have different growth length maximums, for sand gobies <100mm, and common gobies <64mm (Riley 2007, Riley 2003). They also have contrasting spawning periods; sand gobies are summer spawners, June to August and common gobies winter spawners, February to September (Riley 2007, Riley 2003).

Over the eight years of surveying, 738 gobies have been measured, ranging from 25mm to 82mm in length (Figure 15), with an average of 51mm. Only 7% of all the individuals measured were below 40mm, meaning that 93% of our samples consisted of mature individuals and present a resident assemblage within the Aln Estuary.

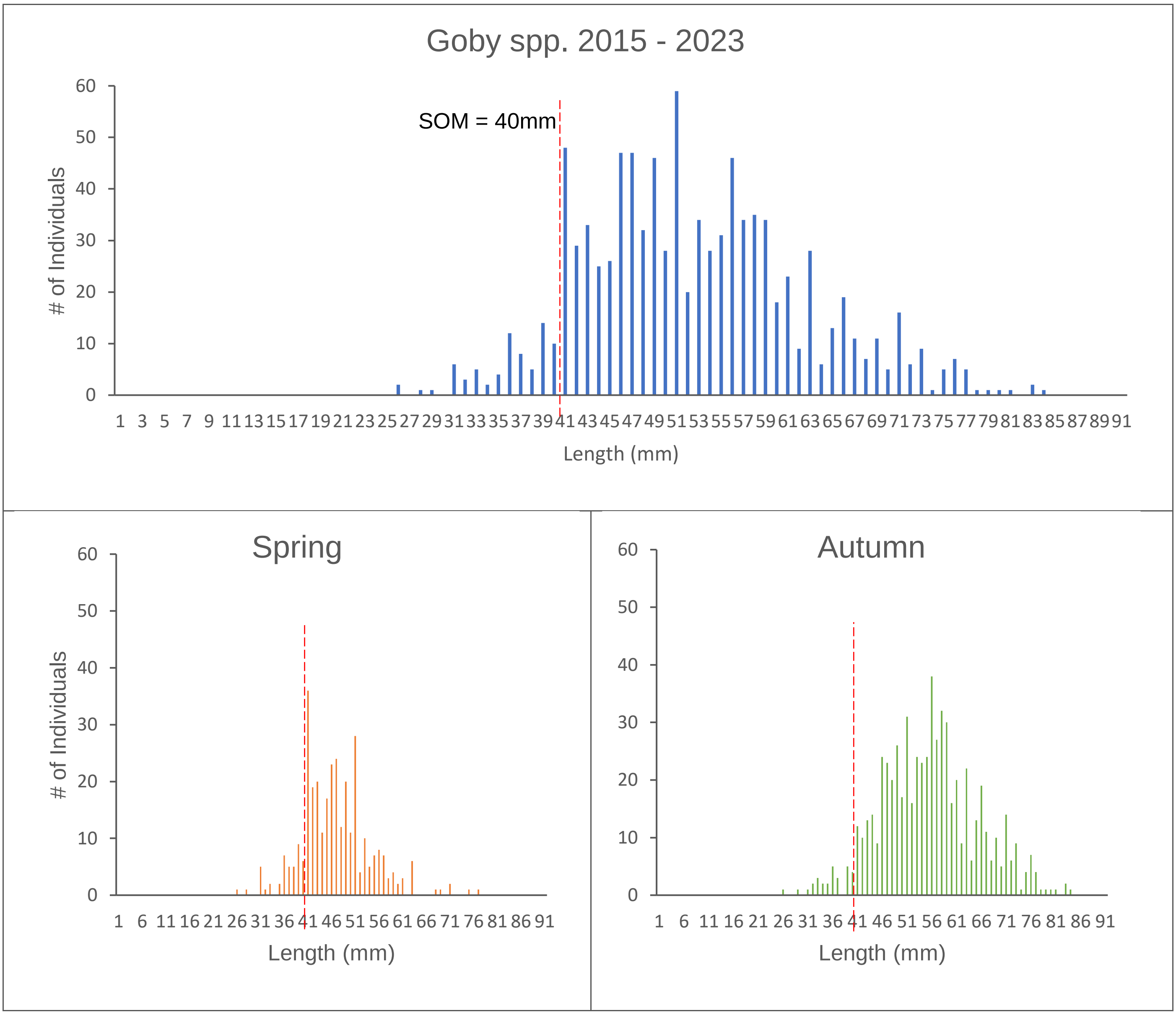


Figure 14 | Size distribution bar graphs for goby spp. showing all individuals measured 2015 – 2023 (top), all measured during spring surveys (bottom left), and all measured during autumn surveys (bottom right). Red dash line represents size of maturity.

The **European eel** (*Anguilla anguilla*) was classified as Critically Endangered by the International Union for Conservation of Nature (IUCN) in 2008, after it was determined that recruitment for this species had dramatically declined (~95%) since the 1980s (ICES, 2019). The Eels (England and Wales) Regulation (2009) were implemented to help the recovery of the stock with a permitted fishery, closed seasons, and unobstructed passage of eels in rivers and estuaries. The species has a complex life cycle, which includes a significant period of their adult lives spent in fresh or estuarine waters at the yellow eel life stage (up to 50 years) followed by the final silver eel life stage before spawning migration to the Sargasso Sea in the Atlantic Ocean (Westerberg *et al.,* 2018). Recent tracking research by Wright *et al.,* (2022) has recorded slower than previously calculated migration speeds. It was originally calculated as six months; however, it is impossible to cross the Atlantic at the speeds recorded in that timeframe. Instead, it supports an 18month migration which co-insides with the spawning period, beginning December, peaking February/ March and ending in May.

In total, 27 European eels have been caught from the Aln Estuary surveys from 2015 to 2023, and although observed in low numbers they have been recorded every year. The greatest number of individuals caught in the annual surveys were six in 2019 and 2021, and the least was one in 2017. European eels become inactive during the winter months, staying dormant in mud burrows from November/ December until April/ May, initiated by changes in the photoperiod (Rohtla *et al.,* 2022) and/ or changes in temperature (Westerberg & Sjöberg 2014). All but one individual has been recorded during the Autumn survey, which could be attributed to this dormant period. Interestingly the only individual recorded during the Spring was also the only eel to be caught at the upper site in the seine net. As a nocturnal species lying inactive during the day under rocks, in weeds or muddy sediments, all others have been recorded from the fyke nets left to soak overnight.

The lengths of each life stage vary significantly throughout their distribution, influenced by latitude and populations density, with the range's extremes recorded as 54mm to 92mm for glass eels, up to 69mm and 1,330mm for yellow eels and 210mm to 1,480mm for male silver eels and 264mm to 1,010mm for females (Dekker *et al.,* 1998). The lengths of the eels caught in the Aln Estuary range from 241mm to 460mm (Figure 16), which indicate these individuals are at either their mid to late yellow eel or at very beginning of the silver eel life stage. The continuous presence of European eels throughout the Aln Estuary surveys indicates that it provides essential stable habitat for European eels as they develop during their long yellow eel life stage, before maturing and embarking on their long migration back to their breeding grounds.

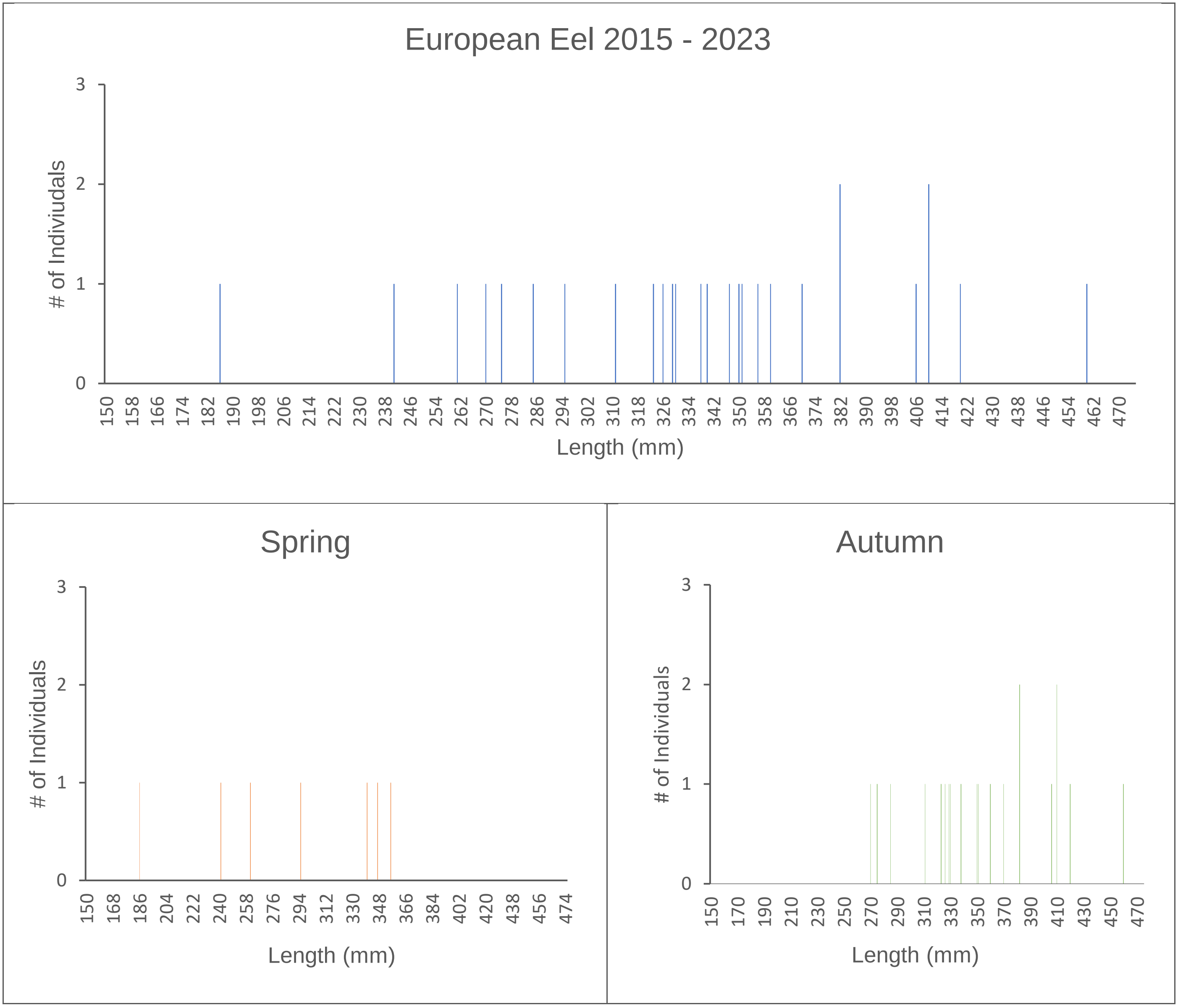


Figure 15 | Size distribution bar graphs for European eel showing all individuals measured 2015 – 2023 (top), all measured during spring surveys (bottom left), and all measured during autumn surveys (bottom right)

Aln Survey (2015-2023)

Species Richness

In total 20 species have been identified and recorded to individual species level across eight years of surveying. Other individuals were identified to genus level for a pipefish, a flatfish, and goby species. For the latter, two species of gobies have been identified as present throughout the Aln Estuary surveys, the common and the sand goby. Five of the 20 identified species have been recorded each year, along with goby spp. (common and/or sand) and six species have only been recorded once. Annual variation of species richness is low, with 10 to 15 species recorded each year and Sorensen Index similarity scores ranging between 90% - 64%, indicating a stable fish assemblage. The lowest number of species were recorded in 2018 (n=10) and could be related to the 'Beast from the East' storms in February of that year. Only five species were recorded during the spring survey, which were common and sand goby, greater and lesser sandeel and flounder and represents the lowest number of species recorded in any seasonal survey. Other variations in species richness could be linked to changes in the physio-chemical environment (Whitfield 2021), discussed further under 'Salinity and Temperature' below. Additionally, species richness will be linked to fish identification experience and staff; with little opportunity to practice using the fish identification skills between surveys it is important that surveyors attend identification refresher courses, and that consistent staff complete the surveys. This is evident in the immediate surveys proceeding fish identification training, with an increase in the ability to distinguish goby species.

Fish Abundance

Despite the Aln Estuary exhibiting a low species richness variation inter-annually, their associated population dynamics is much more variable inter and intra-annually, with similarity scores of Bray Curtis Index ranging from 80% to 16%. The highest abundant species recorded is the lesser sandeel and Atlantic herring, exhibiting opposing fluctuation in species dominance. Seasonal abundance variations are evident with Autumn surveys generally recording higher numbers of Atlantic herring, goby spp. and European eels and Spring surveys recording higher numbers of flounders. Lesser sandeels exhibit less of a seasonal variation but do show a stronger spatial abundance variation with most individuals recorded at the mouth and mid survey sites. In contrast, juvenile Atlantic herring recorded in high abundances at the upper sampling site. These spatial differences in species abundance are most likely driven by species habitat preference; lesser sandeels preferring sandy sediment seabeds for burrowing and juvenile herring muddy, saltmarsh habitat for shelter and food availability. Furthermore, it does not suggest that spatial conflict between the two major species is the cause for their opposing dominance.

Salinity and Temperature

Estuarine habitats have highly varied physio-chemical environments (Whitfield & Elliott 2005) and as such research has been carried out to try and determine if and what factors influence estuarine fish assemblage composition and abundances. Four factors believed to be primarily drivers are salinity, temperature, turbidity (Whitfield 2021) and dissolved oxygen (Marshall & Elliott 1998). Research by Marshall and Elliott (1998) of these drivers on fish assemblages in the Humber Estuary concluded that temperature was the primary influence for abundances and salinity for species richness.

Water temperature is a good indicator of estuary health. Dissolved oxygen is critical for the animals and plants that live in the water. The higher the water temperature the less oxygen can be dissolved. Therefore, seasonal changes are an important indicator of habitat quality for many estuarine species, as well as determining species distribution as defined by their temperature tolerances. At present the temperatures recorded in the Aln Estuary have been fairly uniform, ranging from 10.5°C to 15.5°C, and as such exhibit no trend between temperature, species richness and abundance. It is possible that no trend has been identified due to the narrow range in temperatures exhibited in the Estuary, however, data will continue to be collected to increase our dataset and examine possible impacts.

Within an estuary the salinity varies horizontally and vertically, influenced by river flow, rainfall, air temperature and tidal regime. As in other estuaries the Aln Estuary salinity levels are highest at the mouth, with an overall average 35.1ppt, which is in line with the salinity of the North Sea, 35 ppt (ICES, 2021). Moving upstream the salinity declines with overall averages 28.5ppt and 15.25ppt at the mid and upper sampling sites respectively. Lower than average levels were recorded at all sites in the 2021 spring survey with the 25ppt, 2ppt and 7ppt recorded at the mouth, mid and upper sampling sites. Although these extremely low salinities did not reveal any changes to species richness, the species abundances were the lowest recorded in spring (n = 96, 2015 – 2023 average = 376) during the eight years surveying, suggesting that salinity strongly influences the fish abundances within the Aln Estuary. However, at other surveys sites where salinity levels have measured below 10ppt its effect for reducing fish abundances is less evident, with abundances of 66, 283 and 408 recorded in the upper sampling site for salinities of 8ppt, 9ppt and 10ppt respectively. All organisms have unique tolerance and responses to salinity changes and as some species distribution is determined by habitat preference (e.g. lesser sandeel and sandy sediments), more data is required to identify impacts of salinity on the fish site specific assemblages (Marshall & Elliot 1998). The reasons for these lower-than-average salinity readings are unknown but could be due to increased rainfall and consequently an increased riverflow influence or a data collection error. To increase our confidence to a reason, examining the climatic data for rainfall and air temperature for the region during the month of the surveys could provide a more in-depth understanding of the local climatic conditions effect on the Aln Estuary environment and the subsequent impact on the fish assemblages.

Conclusions & Recommendations

The results from the 2023 Aln Estuary survey continue to evidence the importance of the Aln Estuary MCZ habitats as a nursery ground for fish assemblages, most notedly for the commercial species, the lesser and greater sandeel, Atlantic herring, European flounder, and European eel. The mosaic of habitats within the Aln estuary facilitates a diversity of juvenile species to inhabit the small MCZ, with juvenile Atlantic herring and European flounders showing a preference for the saltmarsh and juvenile lesser and greater sandeels a preference for the sublittoral sand habitats. The continued recording of high abundances, low variation in species richness and six species consistently recorded every year supports that conditions in the MCZ are stable and the site is achieving its conservation objective to 'Maintain in favourable condition'.

Less certain are the factors affecting the fluctuating population dynamics between the species. To date, physio- chemical data in the form of temperature and salinity have been collected sparsely since 2015 with variations in the equipment used and have yet to reveal any associated trends. This could be due to the Aln estuary exhibiting a low temporal and spatial range of temperatures, well within tolerance for the species present or external factors to the Aln estuary, such offshore impacts on spawning grounds. Salinity readings for the Aln estuary have fluctuated much more widely but have yet to reveal any consistent correlations with species richness and associated their abundances.

NIFCA surveys will continue to provide a baseline count of juvenile species at the sampling sites, which will be used to monitor the status of the commercially and recreationally important juvenile fish species, along with the collection of temperature and salinity. To compliment the physio-chemical collected, sourcing online climate data (e.g. rainfall) for a week prior to the survey could greater our understanding for fluctuations in salinity, in addition to the influence of climate change on the estuary and subsequent suitability of the habitat for juvenile development. It is recommended that surveyors continue to revise their fish ID and utilise training tools and guides available, in particular having a field guide distinguishing key differences between sand and common gobies.

References

- Bos, A.R., (1999) Tidal transport of flounder larvae (Pleuronectes flesus) in the Elbe River, Germany. *Archive of Fish. and Mar. Research*. 47; 47-60
- Coull, K.A., Johnstone, R., and S.I. Rogers. (1998) Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd.
- Dekker W., van Os B. & van Willigen J (1998) ‘Minimal and maximal size of eel’ *Bulletin Français de la Pêche et de la Pisciculture* 349: 195-197 http://www.kmae-journal.org
- Dickey-Collas, Mark & Nash, Richard & Brunel, Thomas & van Damme, Cindy & Marshall, C. & Payne, Mark & Corten, Ad & Geffen, Audrey & Peck, Myron & Hatfield, Emma & Hintzen, Niels & Enberg, Katja & Kell, Laurence & Simmonds, E. (2010) Lessons learned from stock collapse and recovery of North Sea herring: A review. *ICES Journal of Marine Science.* 67. 1875-1886.
- Drevs, T., Kadakas, V., Lang, T., & Mellergaard, S., (1999) Geographical variation in the age/length relationship in Baltic flounder (Platichthys flesus). *ICES J. of Mar. Sci*. 56; 134-137
- Engelhard, G. H., Peck, M. A., Rindorf, A., Smout, S. C., van Deurs, M., Raab, K., Andersen, K. H., Garthe, S., Lauerburg, R. A. M., Scott, F., Brunel, T., Aarts, G., van Kooten, T., and Dickey-Collas, M. (2013) Forage fish, their fisheries, and their predators: who drives whom? *ICES Journal of Marine Science*, 71: 90–104
- Environment Agency (2011) Seine netting for monitoring fish. Operational instruction 145.
- FAO (2013) Fishing Gear Types. Beach Seine Nets. http://www.fao.org/fishery/geartype/202/en [Accessed: 08/11/2021].
- Frederiksen, M., Furness, R.W. and Wanless, S., (2007) Regional variation in the role of bottom-up and top-down processes in controlling sandeel abundance in the North Sea. *Marine Ecology Progress Series*, 337, pp.279-286
- Green B.C, Smith D.J., Grey J. & Underwood G.J.C. (2012) High site fidelity and low site connectivity in temperate saltmarsh fish populations: a stable isotope approach. *Oecologia* 168:245-255

- Henderson P.A. (2014) Identification Guide to the Inshore Fish of the British Isles. Pisces Conservation Ltd p.67
- Heupel, M.R., Carlson, J.K. and Simpfendorfer, C.A. (2007) Shark nursery areas: concepts, definition, characterization and assumptions. *Marine Ecology Progress Series*, 337: 287–297.
- Holland, Gayle & Greenstreet, Simon & Gibb, Iain & Fraser, Helen & Robertson, Michael. (2005). Identifying sandeel Ammodytes marinus sediment habitat preferences in the marine environment. Marine Ecology-progress Serie. *MAR ECOL-PROGR SER*. 303. 269-282. 10.3354/meps303269
- Ibbotson A.T., Riley W.D., Beaumont W.R., Cook A.C., Ives M.J., Pinder A.C. & Scott L.J. (2013) The source of autumn and spring downstream migrating juvenile Atlantic salmon in a small lowland river. *Ecol Freshw Fish* 22:73–81.
- Ices.dk ICES FishMap Species factsheet – herring. https://www.ices.dk/about-ICES/projects/EU-RFP/EU%20Repository/ICES%20FIshMap/ICES%20FishMap%20species%20factsheet-herring.pdf (Accessed 19 March 2024)
- ICES. 2019. European eel (Anguilla anguilla) throughout its natural range. In Report of the ICES Advisory Committee. ICES Advice 2019, ele.2737.nea. 10.17895/ices.advice.4825.
- ICES. 2021. ICES Report on Ocean Climate. Available at: ICES Oceanography - IROC (Accessed 9 May 2022).
- Linehan J.E., Gregory R.S. & Schneider D.C., (2001) Predation risk of age-0 cod (Gadus morhua) relative to depth and substrate in coastal waters. *Journal of Experimental Marine Biology Ecology*: 263: 25– 44.
- Manderson J.P., Pessutti J., Hilbert J.G. & Juanes F. (2004) Shallow water predation risk for a juvenile flatfish (winter flounder; Pseudopleuronectes americanus, Walbaum) in a northwest Atlantic estuary. *Journal of Experimental Marine Biology and Ecology*: 304: 137-157.
- Marshall S. & Elliott M. (1998) Environmental influences on the fish assemblage of the Humber estuary, UK. *Estuarine, Coastal and Shelf Science* 46(2), pp.175-184.
- MCCIP (2018) Climate change and marine conservation: Sandeels and their availability as seabird prey. Eds. Wright P, Regnier T, EerkesMedrano D and Gibb F MCCIP, Lowestoft, 8pp. doi: 10.14465.2018.ccmco.006-sel
- MSEP (2014) The Marine Socio-Economics Project. Recreational Sea Angling (RSA): Minimum Landing Sizes (MLS). Available at: http://www.mseproject.net/newsletter/doc_download/136-2-minimumlanding-sizes [Assessed: 14/01/2016].
- Net Gain (2011) Final recommendations. Submission to Natural England & JNCC, Version 1.2 Hull: Net Gain.
- Payne M.R., Hatfield E.M.C., Dickey- Collas M., Falkenhaug T., Gallego A., Gröger J., Licandro P., Llope M., Munk P., Röckmann, Schmidt J.O. & Nash R.D.M. (2009) Recruitment in a changing environment: the 2000s North Sea herring recruitment failure. *ICES Journal of Marine Science* 66:2 pp272-277 doi.org/10.1093/icesjms/fsn211
- Riley K. (2003) *Pomatoschistus microps* Common goby. In Tyler-Walters H. and Hiscock K. *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 24-04-2024]. Available from: https://www.marlin.ac.uk/species/detail/1202
- Riley K. (2007) *Pomatoschistus minutus* Sand goby. In Tyler-Walters H. and Hiscock K. *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 24-04-2024]. Available from: https://www.marlin.ac.uk/species/detail/1204
- Régnier T., Gibb F. M. & Wright, P. J. (2018) Temperature effects on egg development and larval condition in the lesser sandeel, *Ammodytes*

marinus. *J. Sea Res.* 134, 34–41. doi: 10.1016/j.seares.2018.01.003

- Rohtla M., Moland E., Skiftesvik A.B., Thorstad E.B., Bosgraaf S., Olse E.M., Browman H.I. & Durif C.M.F. (2022) Overwintering behaviour of yellow-stage European eel (*Anguilla anguilla*) in a natural marine fjord system *Estuarine, Coastal and Shelf Science* 276 108016
- Stamp T., West E., Robbins T., Plenty S. & Sheehan E. (2022) Large-scale historic habitat loss in estuaries and its implications for commercial and recreational fin fisheries *ICES Journal of Marine Science* 79:1981-1991
- Stevenson D.K & Scott M.L. (2005) Essential fish habitat source document. Atlantic Herring, *Clupea harengus,* Life History and Habitats Characteristics *NOAA technical memorandum NMFS-NE*; 192
- Summers, R.W. (1980) The diet and feeding behaviour of the flounder Platichthys flesus (L.) in the Ythan estuary, Aberdeenshire, Scotland. *Est. Coast. Shelf Sci*. 11; 217-232
- Taube C.M. (1976) Sexual Maturity and Fecundity in Brown Trout of the Platte River, Michigan *Transactions of the American Fisheries Society* doi.org/10.1577/1548-8659(1976)105<529:SMAFIB>2.0.CO;2
- The Fish Site (2010) Available at: https://thefishsite.com/articles/herring-stocks-in-the-north-sea (Accessed: 11 Nov 2021).
- Westerberg H. & Sjöberg N (2015) Overwintering dormancy behaviour of the European eel (*Anguilla anguilla* L.) in a large lake. *Ecology of Freshwater Fish 24*:532-543
- Westerberg H., Miller M.J., Wysujack K., Marohn L., Freese M., Pohlmann J.D., Watanabe S., Tsukamoto K. & Hanel R. (2018) Larval abundance across the European eel spawning area: An analysis of recent and historic data. *Fish & Fisheries*. 19: 890–902.
- Whitfield A.K. & Elliott M. (2005) Fishes as indicators of environmental and ecological changes within estuaries: a review of progress and some suggestions for the future. *Journal of Fish Biology* 61: 229-250
- Whitfield A.K. (2021) Estuaries- how challenging are these constantly changing aquatic environments for associated fish species? *Environmental Biology of Fishes* 104:517-528
- Wright R.M., Piper A.T., Aarestrup K., Azevedo J.M.N., Cowan G., Don A., Gollock M., Rodriguez Ramallo S., Velterop R., Walker Westerberg H & Righton D. (2022) First direct evidence of adult European eels migrating to their breeding place in the Sargasso Sea. *Scientific Reports* 12:15362