UNIVERSITY OF PLYMOUTH

The Ecology and Distribution of European Bass (Dicentrarchus labrax) in the South West UK

MPhil – PhD transfer report

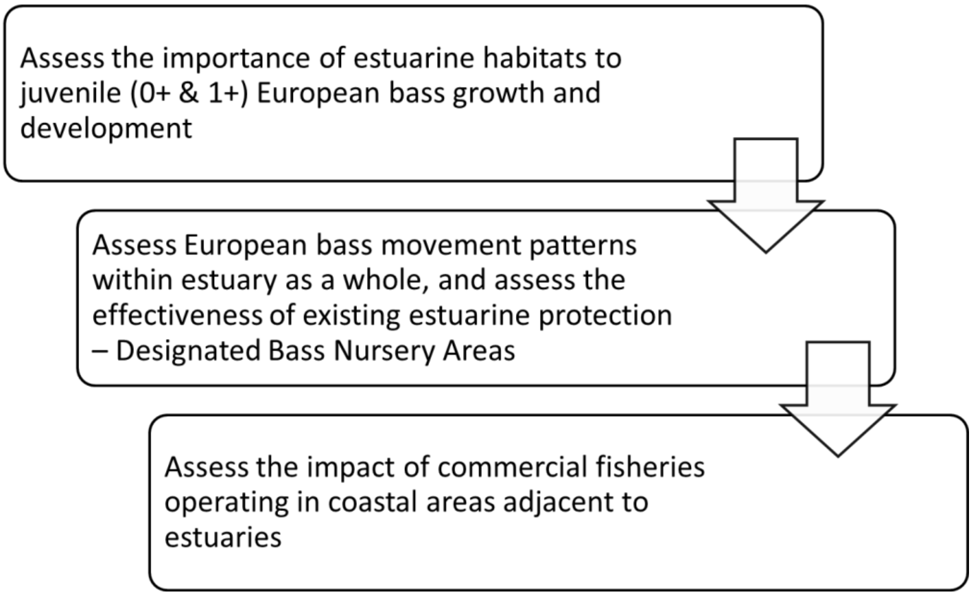
Thomas Stamp

PhD Summary

The current PhD has been co-supervised and co-funded between university Plymouth and the Devon and Severn Inshore Fisheries and Conservation Authority (D&S IFCA). In response to the rapid decline of the North Atlantic European bass (*Dicentrarchus labrax*) stock, the D&S IFCA are interested in investigating methods for localised/regional management actions which could benefit the stock at large.

It has been identified that estuaries are critical ecosystems for European bass, both as nursery habitats for juveniles and feeding habitat for "large" adults. From a management perspective, estuaries are spatially explicit and easily identifiable. There are also numerous current legislative tools which protect both estuarine habitats, and specifically protect bass whilst within estuaries. Therefore, by reviewing the efficacy of these management measures at protecting European bass, it may provide a cost effective mechanism to deliver practical localised management for European bass.

The primary research aims of the PhD are as follows:



This report is intended to provide an overview of the PhD structure, summary of results so far and planned future work.

Contents

1- The importance of incorporating protection of estuaries within European bass management (Literature Review)

1.1 - Introduction

Figure 1 - European bass (Image captured by K. Stephenson - D&S IFCA)

European bass (Figure 1) (*Dicentrarchus labrax*) is a commercially and recreationally important finfish species commonly found in estuaries and coastal water throughout the north east Atlantic and Mediterranean Sea (Pickett & Pawson, 1994; Garcia *et al.,* 1997). Since 2010, the International Council for Exploration of the Seas (ICES) has reported a dramatic decline in the North Atlantic stock, which since 2016 has fallen below "safe biological limits", a threshold known as B_{lim}. As a result ICES suggested an 80% reduction of commercial landings from 2013-2015, and a complete moratorium for both commercial and recreational fisheries in 2017 and 2018 (ICES, 2016 & 2017). In response to ICES advice the European Commission (EC) implemented a number of strict emergency "Technical Conservation Measures" which, from 2015-2017, have imposed restrictions such as; banning targeted pelagic trawling during spawning periods, imposing restrictions on commercial and recreational landings, and increasing the minimum landing size to 42cm total length (Ares, 2016).

The decline in north Atlantic European bass stock is not fully understood, however it has likely been affected by many contributory factors, which relate to; increasing fishing effort, a lack of responsive fisheries management, life history characteristics of European bass and anthropogenic impacts on habitats which European bass exploit. This review is intended to provide a summary of these factors and highlight the relevance for holistic management which focuses on both fisheries extraction but also the habitat requirements of European Bass.

1.1.a - Distribution and life history

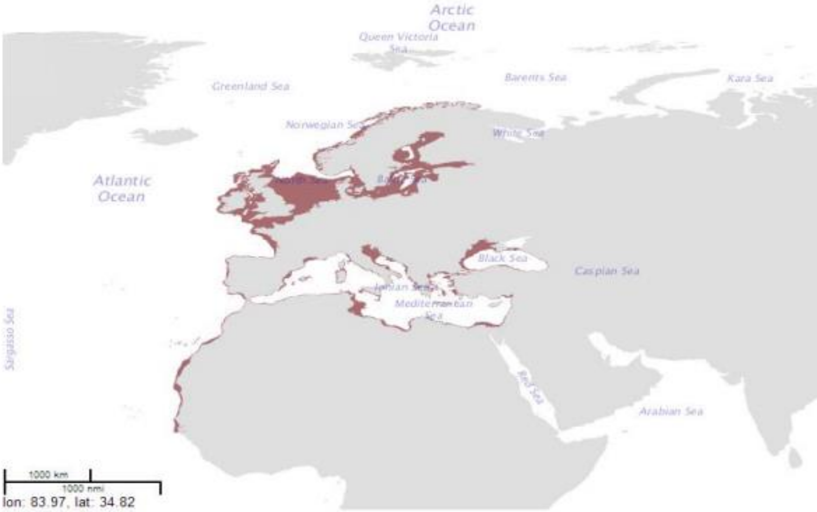


Figure 2 - Native distribution of European bass (Carol et al., 2016)

European bass (*Dicentrarchus labrax*) is native to the North East Atlantic and Mediterranean Sea (Figure 2) (Pickett & Pawson, 1994; Carol et al., 2016). They are however thought to be cold temperature limited at northern latitudes, therefore, significant fisheries are only viable below 53°N in the North Sea and 54°N in the Irish Sea (Pickett & Pawson, 1994; Vinagre *et al.,* 2012)(Figure 5).

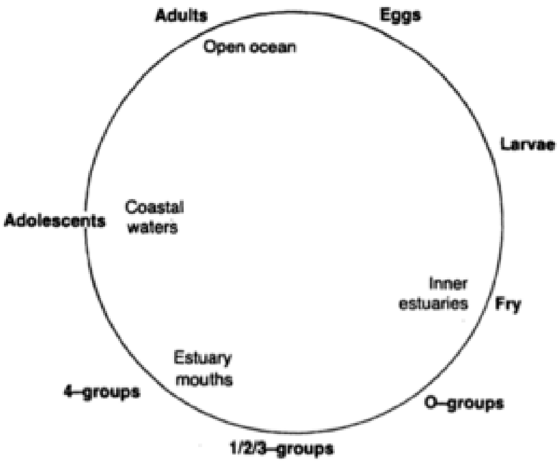


Figure 3 - The life cycle of European bass (*Dicentrarchus labrax*) (Image sourced from Pickett & Pawson, 1994)

Planktonic eggs are broadcast spawned into the water column and hatch within 6-9 days (Pickett & Pawson, 1994). The yolk sac is absorbed within 9-25 days, following which they most likely predate upon mobile zooplankton (Pickett & Pawson, 1994). From approximately May-June juvenile fish actively migrate into defined coastal nursery habitats, which in the UK largely take the form of estuaries on the east, south and west coast (Pawson *et al.,* 1987; Kelley, 1988; Pawson *et al*., 2007). Individuals are then thought to maintain residency or dependency to a specific nursery area for the first two-four years (Pawson *et al.,* 2007).

When residing within estuaries, saltmarsh habitats are known to play a key role for both refuge and nutrition (Kelley, 1988; Laffaille *et al.,* 2001; Green *et al.,* 2012; Fonseca *et al.,* 2011). In particular, Laffaille *et al.* (2001) & Fonseca *et al.* (2011) reported that 0+ European bass had fuller stomach when feeding in saltmarsh rather than within adjacent estuarine habitats. Furthermore, Laffaille *et al.* (2001) reported that when 0+ European bass were in estuaries but did not have access to intertidal saltmarsh habitat their diet was dominated by the mysid *Neomysis integer,* which feed predominantly on detritus from saltmarsh and terrestrial sources (Fockedey & Mees, 1999).

Using mark-recapture techniques Pawson *et al.* (1987) reported juvenile European bass (<32cm total length) generally remained within 16km of their host nursery area. However, adolescent European bass (32-42cm total length) are thought to disperse more widely. Greater dispersion from the host nursery habitat during "adolescence" has been reported by other authors (Kelley, 1988; Pickett & Pawson, 1994), who have suggested that individuals are seeking coastal or estuarine feeding locations to which they maintain residency during summer months (Pawson *et al.,* 1987; Cambiè *et al.,* 2016; Doyle *et al.,* 2017).

European bass display sexual dimorphism with females achieving sexual maturity at a greater size and later age than males (Kennedy & Fitzmaurice, 1972 from Cambie *et al.,* 2016). In English and Welsh waters, it has been reported by Pawson & Pickett (1996); Carroll *et al.* (2014) & Cambie *et al.* (2016) the majority of females (50% of the population) do not achieve sexual maturity until 39-42cm (total length), whereas males can achieve sexual maturity at 32-35cm (total length). From early winter, sexually mature individuals will begin migrating to offshore spawning locations which in the UK are thought to occur in the English Channel and Celtic Sea (Pickett & Pawson, 1994).

Spawning is regionally and annually variable, however in the UK spawning aggregations occur in offshore locations from early February (Pickett & Pawson, 1994) to June (Jennings & Pawson, 1992). The timing of spawning is thought to be temperature dependent, Thompson & Harrop (1987) suggested in the English Channel European bass spawn mainly within a temperature range of 8.5-11°C, However Pawson et al. (1987) suggested the progression of European bass spawning closely follows the incursion of the 9°C isotherm (Pawson *et al.,* 1987).

Following spawning, adults migrate inshore and display high inter-annual site fidelity/residency to specific coastal or estuarine feeding locations (Cambiè *et al.,* 2016; Doyle *et al.,* 2017), however migrate offshore to spawn each successive winter (Pickett & Pawson, 1994).

1.1.b - North Atlantic stock identity and status

Various authors (Child, 1992; Castilho & McAndrew, 1998; Patarnello *et al.,* 1993; Garcia *et al.,* 1997) have used different genetic techniques to assess stock differentiation throughout the geographic range of European bass. While Mediterranean populations appear to be genetically separated into several sub-basins, it is thought there is high gene flow across the North Atlantic (Fritsch *et al.,* 2007). Despite various tagging and stable isotope approaches which provide evidence for geographically/regionally distinct movement and feeding groups (Fritsch *et al.,* 2007; Cambiè *et al.,* 2016), little evidence has been found for genetically distinct populations of European bass in the north Atlantic (Fritsch *et al.,* 2007). Due to a lack of evidence from genetic studies, at IBP-NEW 2012 it was agreed by the European Commission that European bass in the North Sea, Irish Sea, Channel and Celtic Sea (ICES divisions; 4b & c, 7.a, 7.d-h) would be treated as one functional stock (ICES WGCSE, 2016). The remainder of this review will focus on this north Atlantic European bass stock (ICES divisions; 4.b-c, 7.a and 7.d-h), and not provide any information on other populations/stocks.

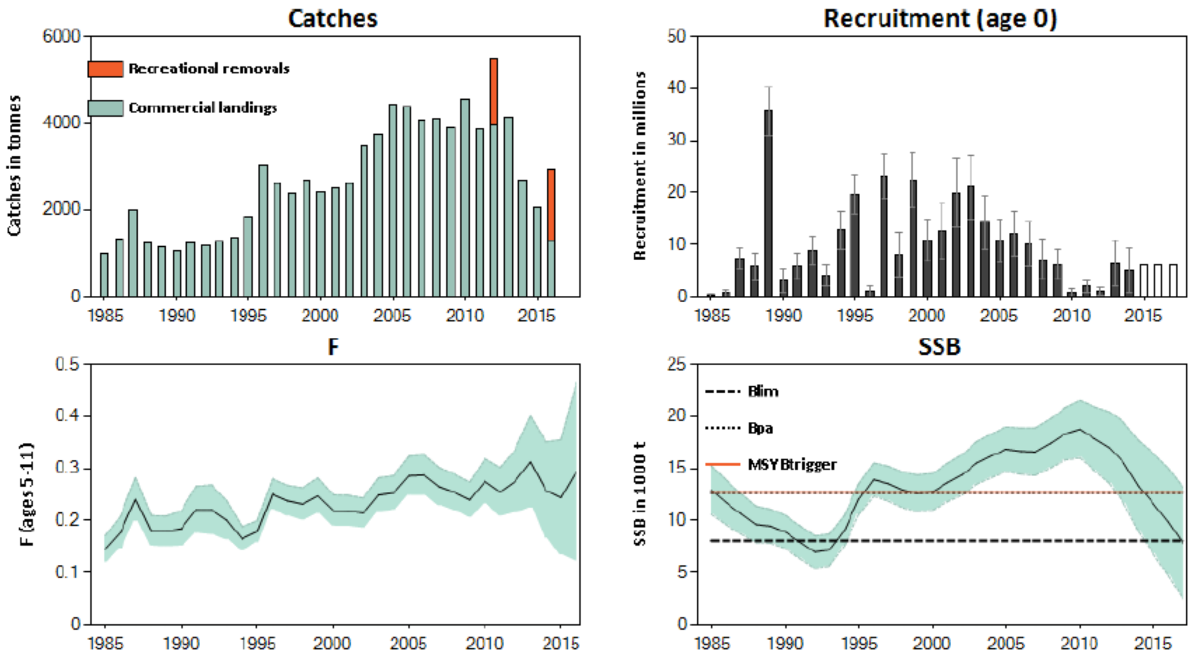


Figure 4 – Seabass in ICES statistical rectangles 4.b-c, 7.a, and 7.d-h. Summary of stock assessment (weight in thousand tonnes). Total landings (commercial landing and estimated recreational removals, available for 2012 and 2016, taking mortality or released fish into account). Fish mortality is shown for the combined commercial and recreational fisheries. Predicted recruitment vales are not shaded. Recruitment, F, and SSB are shown with 95% confidence intervals. Image sourced from ICES, 2017

Since 2010, ICES reported the north Atlantic European Bass stock had dramatically declined. This is measured by recording the number of sexually mature individuals within the population, otherwise known as the Spawning Stock Biomass (SSB). In 2018, ICES estimates the SSB is approximately 64% lower than in 2010 (2010 – 18215 tonnes; 2018 – 6414 tonnes; ICES, 2017), and is now below what is termed “safe biological limits”, a threshold called “B_{lim}” (Figure 4 – bottom right) (ICES, 2016). Below the B_{lim} threshold or reference point, reproduction and hence recruitment is at significant risk of being impaired (ICES, 2015) and ability of the stock to recover is in serious jeopardy (Williams & Carpenter, 2016).

European bass is not managed under the Common Fisheries Policy (see section 1.2.a) and therefore no quota is specified for commercial fisheries. Either because access to other quota species is limited or because European bass represent a lucrative alternative, commercial fishing pressure has remained above Maximum Sustainable Yield (MSY) thresholds for the past 30 years (Williams & Carpenter, 2016). Furthermore, recruitment has been extremely poor since 2010 (Figure 4) (Williams & Carpenter, 2016; ICES, 2016). It is therefore thought that an unsustainable increase in fishing effort and fishing mortality, combined with poor recruitment are thought to be the primary cause for the decline in the North Atlantic stock (Williams & Carpenter, 2017).

1.1.c - Commercial fisheries

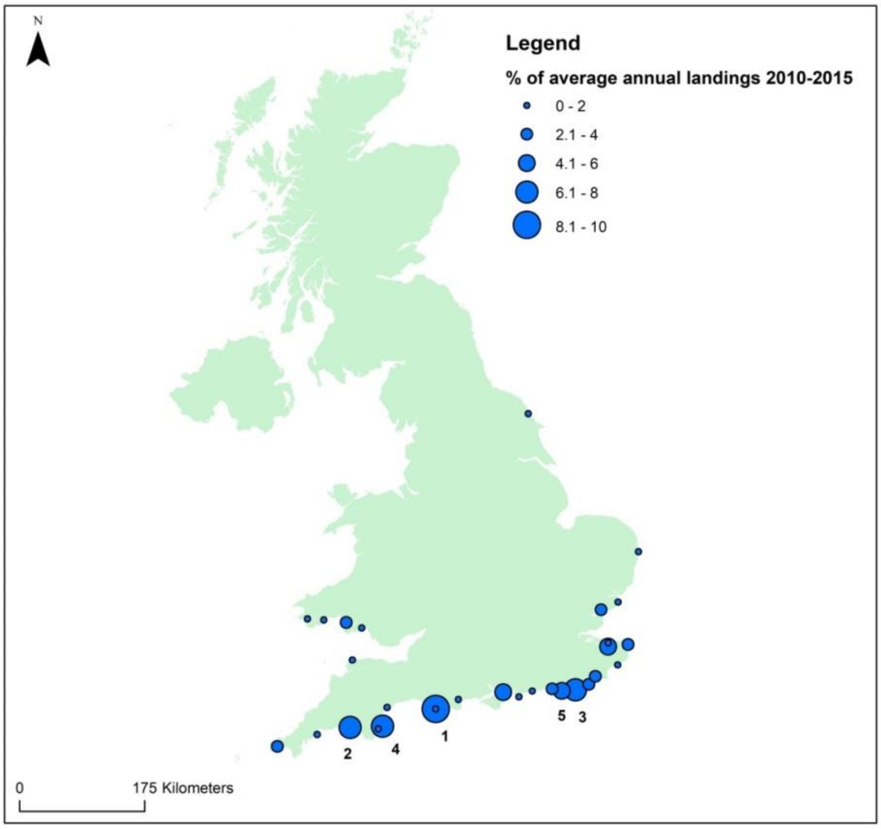
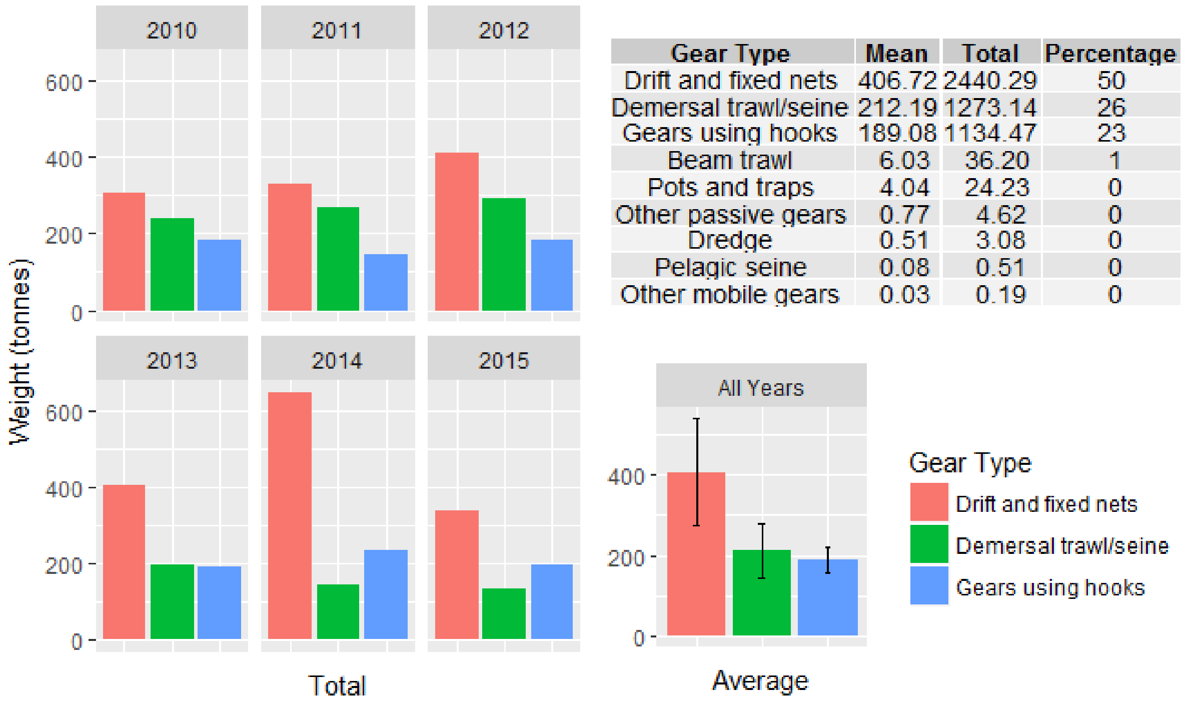


Figure 5 - Commercial landings of European bass by UK registered vessels within UK ports. The size of each circle is proportional to the amount of catch landed within each port. Numbered ports indicate the 5 largest ports in terms of European Bass landings. 1) Weymouth; 2) Plymouth; 3) Eastbourne; 4) Brixham; 5) Shoreham

In the UK, European bass is predominantly landed into ports along the south east, south and southwest coast of England and Wales (Figure 5). From 2010-2015, the 5 most significant UK ports in regard to the average first sale value of UK registered vessels landings where; 1) Weymouth - £516,731.45; 2) Plymouth £464,478.42; 3) Eastbourne - £438,992.10; 4) Brixham - £357,734.00; 5) Shoreham - £289,667.20. From 2010-2015, the first sale value of landed European seabass was worth an average of £5,994,616.99 per year to UK registered vessels. However, following re-sale the fishery is worth an estimated £35million per year to the UK economy (Barclay, 2011 from Caroll *et al.,* 2014).

Typically the commercial European bass fishery is seasonal, with the majority of landings occurring in summer and autumn (Carroll *et al.,* 2014), however, some fishing fleets from; UK, France, Spain and Portugal fished European bass all year (Carroll *et al.,* 2014; Williams & Carpenter, 2016). European bass is landed via a number of fishing techniques (Figure 6). The relative importance of each fishing technique is variable across the UK, however in terms of total landings from UK registered vessels the most significant methods are defined by the Marine Management Organisation (MMO) as; 1) Drift and fixed nets; 2) Demersal trawl/seine; 3) Gear using hooks (MMO, 2016).



Gear Type	Mean	Total	Percentage
Drift and fixed nets	406.72	2440.29	50
Demersal trawl/seine	212.19	1273.14	26
Gears using hooks	189.08	1134.47	23
Beam trawl	6.03	36.20	1
Pots and traps	4.04	24.23	0
Other passive gears	0.77	4.62	0
Dredge	0.51	3.08	0
Pelagic seine	0.08	0.51	0
Other mobile gears	0.03	0.19	0

Figure 6 - European Seabass landings by weight (tonnes), total for each year 2010-2015 (left), and, average for all years combined left. Data sourced from Marine Management Organisation (MMO) landing statistics. Data is for UK registered vessels- England; Guernsey; Isle of Man; Jersey; Northern Ireland; Scotland; Wales

1.1.d - Recreational fisheries

European bass is a highly prized recreational sport fish, famed for its "fighting prowess". In 2012, there were an estimated 884,000 sea anglers in the UK which spent an estimated £831 million that year on direct expenses incurred whilst angling e.g. petrol, accommodation and subsistence (Armstrong *et al.,* 2013; Ares, 2016). More specifically, the recreational sport fishery for European bass has been estimated to be worth £100 - £200 million per year to coastal economies of the UK (B.A.S.S, 2004 from Ares *et al.,* 2016; Caroll *et al.,* 2014; MRAG, 2014). It has therefore been suggested that the recreational fishery is far more economically valuable than the commercially fishery (MRAG, 2014).

In 2012, the UK government launched the Sea Angling 2012 project (see Armstrong *et al.*, 2013); which aimed to estimate the number of recreational sea angler in the UK, and assess their impact on marine fish populations. Armstrong *et al. (*2013) reported that in 2012 recreational sea anglers were landing/keeping an estimated total of 230-440tonnes of European bass in England. Which when compared to commercial landings into UK ports from the same time period (897tonnes), Recreational sea anglers were estimated to remove approximately 25-49% of the total UK commercial catch (Table 1). Armstrong *et al.* (2013) did emphasize that the point estimates quoted above represent the extreme values from several different analysis techniques, and that the values should be interpreted with caution.

Table 1 – Estimated European Seabass removal from recreational angling in England, France & the Netherlands compared to commercial landings in 2012 (Armstrong *et al.,* 2012)

Country	Recreational fishery: annual kept catch 2012 (tonnes)	Commercial fishery landings 2012 (tonnes)	Percentage of recreational removal to commercial
England	230-440	897 (UK total)	25-49%
France	940	2,492	37%
Netherlands	128	372	34%
Total	1,300-1,510	4,060 (all countries)	32-37%

The estimates produced by Armstrong et al., (2013) have been widely disputed by a number of recreational sea angling enthusiast groups (Angling Trust, 2018). However, the recreational European bass fishery is now regulated by Technical Conservation Measures (TCMs) introduced in 2015 by the European Commission. From 2016 – 2018 a similar project called the Sea Angling Diary has been conducted by the Centre for Environment, Fisheries, Aquaculture Science (CEFAS). Within the Sea Angling Diary Project, recreational sea anglers are encouraged to record their catch data on an online portal, as well as extra information which estimates the value of recreational fishing to local economies. The results from the Sea Angling Diary have not yet been made publicly accessible.

1.2 - Management of the North Atlantic European bass stock

The International Council for Exploration of the Seas (ICES) provides marine policy and fisheries management advice to regulating bodies across the; North Atlantic, Mediterranean sea, Black Sea, and the North Pacific Ocean. For the purposes of simplifying management advice, ICES split regions into "Statistical rectangles". These statistical rectangles are then often incorporated into the management measures imposed by regulators such as the European Commission.

In regard to the North Atlantic Bass stock, this refers to European bass which are captured within the following ICES statistical rectangles:

Table 2 – designations and common names of ICES statistical rectangles relevant to management of North Atlantic European bass stock

ICES Statistical Rectangle ID	ICES Statistical Rectangle Name
4.b & 4.c	North Sea
7.a	Irish Sea
7.b & 7.c	West Ireland
7.d & 7.e	English Channel
7.f & 7.g	Celtic Sea
7.h, 7.j & 7.k	South West Approaches

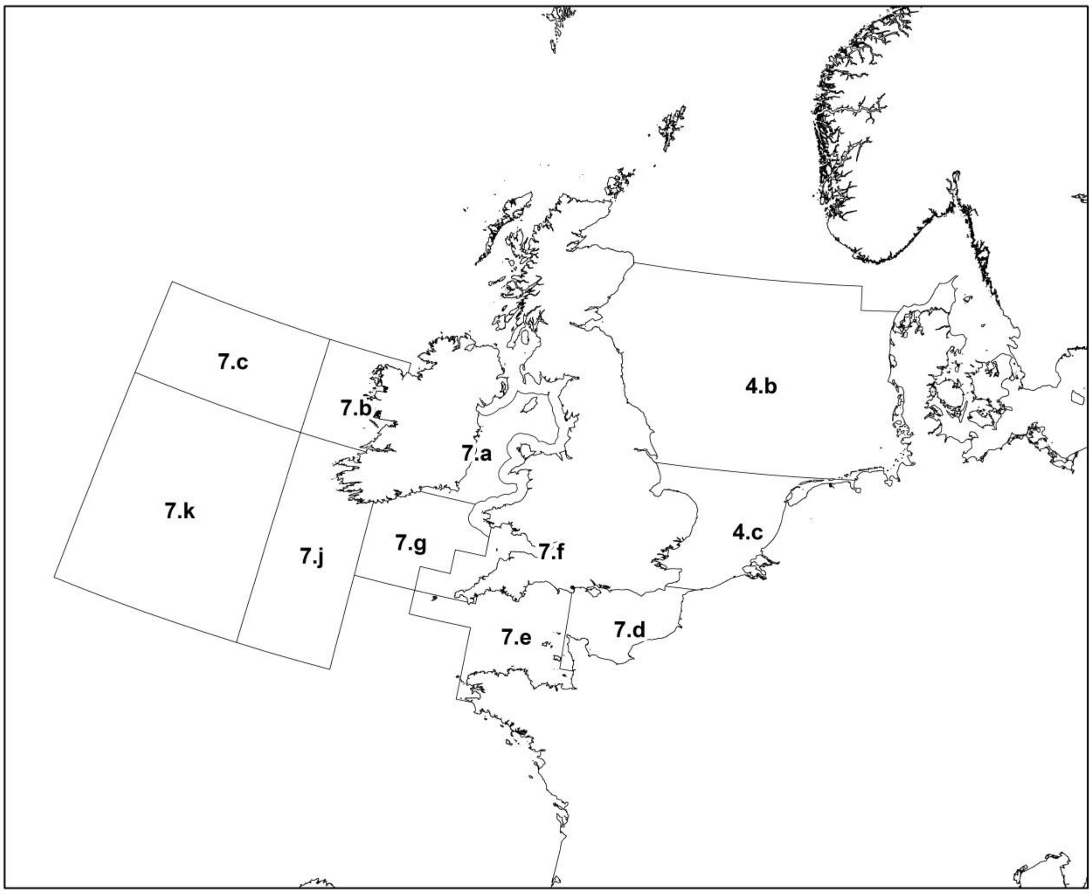


Figure 7 – Distribution of ICES statistical rectangles relevant to management of North Atlantic European bass stock

1.2.a - European Commission – Emergency Technical Conservation Measures

Unlike many other fisheries within the territorial waters of the European Union, there is currently no Fisheries Management Plan for European bass (Ares, 2016). Commercial and Recreational fisheries are instead largely regulated by emergency Technical Conservation Measures (TCM), introduced by the European Commission in 2015. These TCMs are annually reviewed in relation to advice from ICES and the requirements of each member state's commercial and recreational fishing operations. At the time of writing no TCMs have been published for the 2018 fishery, however the 2017 measures are listed below (MMO, 2017).

Closure of targeted pelagic trawling of spawning aggregations: 1st January – 30th June

In 2015, the European Commission imposed a ban on pelagic trawl fishing which targeted spawning aggregations of European bass. This was a major targeted winter fishery in offshore areas in the western Channel and approaches, including off North Devon and Cornwall (Pickett & Pawson, 1994). The 2017 TCM states that from the 1st January – 30th June 2017 Bass may be retained only when caught with demersal trawls and when up to 1% of the catch retained on board is bass. There are also restrictions for other fishing gears:

Sea Area	ICES Division	Demersal trawls and seines	Fixed Nets, Hooks and lines	All other gear types (including drift nets)
North Sea	4.b, 4.c	Up to 1% bass by-catch	1,300kg bass per vessel per month except February and March	All bass catches prohibited
English Channel	7.d, 7.e	Up to 1% bass by-catch	1,300kg bass per vessel per month except February and March	All bass catches prohibited
Celtic Sea	7.f, 7.g*	Up to 1% bass by-catch	1,300kg bass per vessel per month except February and March	All bass catches prohibited
Irish Sea	7.a*	Up to 1% bass by-catch	1,300kg bass per vessel per month except February and March	All bass catches prohibited
South West Approaches	7.h	Up to 1% bass by-catch	1,300kg bass per vessel per month except February and March	All bass catches prohibited

* Inside 12nm limit only

Restrictions on summer commercial and recreational fisheries

From the 1st July-31st December 2017 the following catch restrictions apply:

Sea Area	ICES Division	Demersal trawls and seines	Fixed Nets, Hooks and lines	All other gear types (including drift nets)
North Sea	4.b, 4.c	1,000kg bass per vessel per month	1,300kg bass per vessel per month	1,000kg bass per vessel per month
English Channel	7.d, 7.e	1,000kg bass per vessel per month	1,300kg bass per vessel per month	1,000kg bass per vessel per month
Celtic Sea	7.f, 7.g*	1,000kg bass per vessel per month	1,300kg bass per vessel per month	1,000kg bass per vessel per month
Irish Sea	7.a*	1,000kg bass per vessel per month	1,300kg bass per vessel per month	1,000kg bass per vessel per month
South West Approaches	7.h	1,000kg bass per vessel per month	1,300kg bass per vessel per month	1,000kg bass per vessel per month
* Inside 12nm limit only				

From the 1st January-30th June 2017 all recreational fishing shall be catch and release, except in west Ireland (ICES: 7.j, 7.k) where 1 bass per fishermen per day is permitted.
From the 1st July – 31st December 2017 1 bass per fishermen per day is permitted in all areas.

Increase in minimum landing size from 36cm to 42cm – Introduced in 2015

In 2015, the minimum landing size was increased from 36cm to 42cm (total length) to allow females the opportunity to reach sexual maturity and spawn prior to harvesting (Ares, 2016). Accompanying the increase in minimum landing size were complimentary increases in the minimum mesh sizes to 90mm for gill, tangle drift, trammel and any other enmeshing nets (Ares, 2016).

Area closure – Introduced for Irish vessels from 1990 but extended to all EU vessels in 2015

In 1990, a closed area was designated from which Irish vessels were prohibited to land European bass from the area of the Celtic Sea, Irish Sea, south of Ireland and west of Ireland (ICES areas 7a, b, c, g, j, k outside the UK 12 mile zone) (ICES, 2013). In 2015, the European Commission introduced further measures which prohibited any European Union vessel from landing European bass from within this area.

The current TCM states, European Bass cannot be caught, retained, transferred from one ship to another or landed in the following areas; 1) the South west approaches (ICES 7.b, 7.c, 7.j and 7.k), 2) Irish or Celtic Sea (outside the 12 nautical mile limit of ICES 7.g and 7.a).

1.2.b - UK Legislation – Designated Bass Nursery Areas

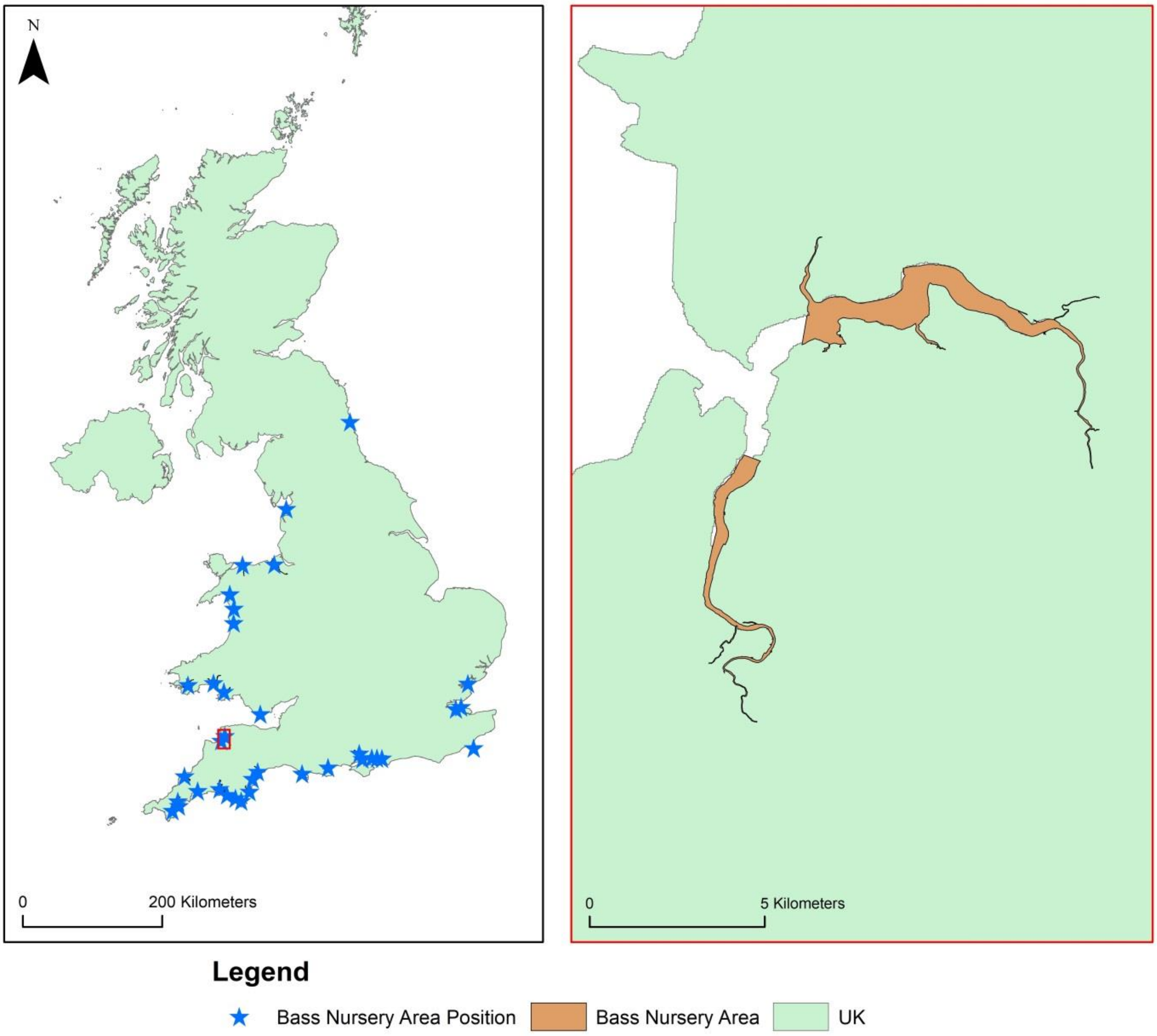


Figure 8 – Designated Bass Nursery Areas (BNAs) in England and Wales (Left). Taw & Torridge designated bass nursery area, Devon (Right)

In 1990, the Ministry of Agriculture, Fisheries and Food (MAFF) introduced legislation in England and Wales to protect juvenile European bass from commercial fishing. Through the *Bass (Specified Areas) (Prohibition of Fishing) (Variation) Order 1999,* 37 Bass Nursery Areas (BNAs) were designated largely in estuaries on the east, south and southwest coast of England and Wales (Figure 7). Within BNAs; fishing for any sea fish species using sand-eels is prohibited; and targeted commercial fishing for European bass from a vessel is prohibited for all or part of the year (MAFF, 1990). Management of each BNA is the responsibility of the local Inshore Fisheries Conservation Authority (IFCA), which may also have additional local by-laws which prohibit certain activities within or adjacent to estuaries or BNAs.

While BNAs do provide protection for the direct commercial removal of under-sized/immature European bass from nursery areas, the effectiveness of BNAs has not been formally assessed. A major potential issue is that BNA boundaries may not be relevant to the movement and/or behaviour of juvenile European bass. This is most likely due to the impracticalities and financial expense involved in assessing movement patterns of juvenile European bass within estuaries.

However, anecdotal reports from commercial and recreational fishermen have stated that at specific states of the tide fish aggregate around the mouths of estuaries/BNAs (Labistour, Torridge estuary harbour master *pers comms,* 2017). As evidenced by the Taw/Torridge BNA (Figure 7 – right), areas where bass aggregate close to estuaries often unprotected. It is therefore possible that juvenile/immature European bass are vulnerable to capture when in close proximity to BNA boundaries.

1.3 – Conservation and management knowledge gaps

The International Council for Exploration of the Seas (ICES) have recommended numerous research areas/knowledge gaps, which could aid management of the North Atlantic stock (see ICES, 2016). These research areas include, defining; stock identities with the North Atlantic; Recreational fisheries impact; Discard survival from numerous fishing activities; Recruitment dynamics (ICES, 2016). A number of these areas are currently being addressed by both academic and government bodies in the UK and France.

While these research areas are critical to the future success of North Atlantic European bass management, little attention is given to the habitat requirements of the fishery. ICES (2016) stated that poor recruitment since 2009 is likely a high contributing factor to the current decline in SSB. Therefore, research attention should also be paid to preserving recruitment pathways (though habitat provision), as well reviewing the efficacy of existing legalisation that protects European bass whilst exploiting those habitats (e.g. Designated Bass Nursery Areas).

The Devon and Severn Inshore Fisheries and Conservation Authority (D&S IFCA), a regional fisheries body in the UK, have argued that regional management of European bass could be complimentary to an overarching management policy (Ross, 2015). The remainder of this review will provide supporting evidence for regional fisheries management of European bass, which focus on protection of estuaries as essential habitat. Striped bass (*Morone saxatilis*) fisheries management will also be used as a comparative case study to demonstrate alternative management strategies and the role of habitat protection.

1.4 - Life history traits which increase the vulnerability of European bass to over exploitation

A number of life history traits increase the vulnerability of European bass to over-exploitation, these primarily include; spawning aggregations; philopatry/fidelity to feeding grounds; and dependence on estuarine habitats which are highly influenced by environmental fluctuations and anthropogenic activity. This review will focus on philopatry/fidelity to feeding grounds and dependence on estuarine habitats.

The formation of spawning aggregations is a major vulnerability within the life history of European bass. The European Commission have however introduced Emergency Technical Conservation Measures to protect European bass during spawning periods. Therefore, spawning aggregations will not be discussed further.

1.4.a - Philopatry/fidelity to feeding grounds

Mark Re-capture (Pawson *et al.,* 1987) and Data Storage (DS) tagging (CEFAS & IFREMER pers comms. 2017) have shown that during winter sexually mature European bass make large migrations to spawning areas in the Bay of Biscay, English Channel and Celtic Sea (Fritsch *et al.,* 2007). Adolescent European bass are also thought to disperse widely from their host nursery area in search of defined coastal feeding locations (Pawson *et al.,* 1987). However, during summer adults are known to display residency to specific summer feeding locations (Pawson *et al.,* 1987; Pickett *et al.,* 2004; Fritsch *et al.,* 2007; Green *et al.,* 2012; Pawson *et al.,* 2007; Pawson et al., 2008; Cambiè *et al.,* 2016; Doyle *et al.,* 2017). From a management perspective, philopatry is an important behavioural trait because it decreases mixing/movement within the population, and therefore increases the vulnerability of European bass to local population declines (Ares *et al.,* 2016).

From the 1980s to 2000s numerous mark recapture studies were published (Pawson *et al.,* 1987; Pickett *et al.,* 2004; Fritsch *et al.,* 2007; Pawson *et al.,* 2007). European bass were captured and a numbered ID tag attached to each individual, a number of these fish were re-captured and movement patterns were inferred between capture and re-capture locations. These studies demonstrated that, whilst regionally variable, in general tagged adult and juvenile European bass were captured within 16km from their respective tagging locations and therefore were not thought to disperse widely from defined nursery grounds (when juvenile), or summer feeding grounds (when mature).

Doyle *et al.* (2017) furthered these observations; acoustic telemetry was used to track 30 individual adult European bass (>42 cm total length) within Cork Harbour, Ireland. All tagged fish were highly resident to both the harbour as a whole (average residence time – 167 days), but also maintained residence at specific locations within harbour. All tagged fish left Cork Harbour for the winter spawning migration, however, of the 30 tagged fish 24 returned to the same area within the harbour that they occupied prior to the winter migration, demonstrating that European bass display inter-annual site fidelity. Acoustic telemetry studies conducted on the closely related Striped bass (*Morone saxatilis*) in the USA have also found similar patterns, where individuals maintain a high affinity to specific summer feeding grounds over multiple years (Ng *et al.,* 2007).

Cambiè *et al.,* (2016) used the stable isotope ratios (δ13C and δ15 22N) to assess connectivity and movement of European bass across Wales, UK. The last growing segment of the scales from 189 individual European bass were removed, and their stable isotope (δ13C and δ15 22N) signatures calculated. The last growth segment of the scales was removed because their isotopic signature will be representative of the region that each fish inhabited in the latest growth season. The results indicated geographic segregation into 2 distinct feeding regions, with individual European bass captured from North and mid wales having distinct isotopic signatures from those captured in south wales.

1.4.b - Dependence on estuarine habitats

It is well cited that juvenile European bass are highly dependent on defined coastal nursery areas, which in the UK largely take the form of estuaries on the east, south and west coast (Kelley, 1988). In particular, Kelley (1988); Laffaille *et al.* (2001); Fonseca *et al.* (2011); Green *et al.* (2012) stressed the importance of saltmarsh to 0+ European bass nutrition. Laffaille *et al.* (2001) & Fonseca *et al.* (2011) reported that on average 33-38% of 0+ European bass entering saltmarsh have empty stomachs, whereas when leaving saltmarsh 93-98% of individuals have full stomachs. It was estimated that in the brief 1-2 hour tidal submersion of these saltmarshes the fish had consumed an estimated 8% of their total body weight (Laffaille *et al.,* 2001). Laffaille *et al.* (2001) also reported that when 0+ European bass were in estuaries in Mount St Michaels Bay, France, but did not have access to intertidal saltmarsh habitat, their diet was dominated by the mysid *Neomysis integer,* which feed predominantly on detritus from saltmarsh and terrestrial sources (Fockeday & Mees, 1999). These results suggest that saltmarsh provide an essential habitat for European bass, both via direct consumption of resident invertebrates and indirectly via detrital production to estuaries at large.

Green *et al.* (2012) and Doyle *et al.* (2017) also suggested that not only do specific habitats contribute significantly to European bass nutrition, but that both 0+ and mature (>42cm total length) European bass may display high site fidelity to specific locations within estuaries. Green *et al.* (2012) used a stable isotope technique to identify the isotopic signature of 5 saltmarsh sites within the Blackwater-Colne and Stour-Orwell estuary complexes, Essex. Specimens were collected from numerous trophic levels- primary producers and detritus e.g. *Spartina anglica*; secondary consumers e.g. *Carcinus maenus*; and the dominant fish species e.g. 0+ European bass. At each trophic level site specific isotopic signatures were evident, and provided evidence that 0+ European bass as well as other estuarine fish species; e.g. Common Goby (*Pomatoschistus microps*) may have highly localized movement within estuaries.

Cambiè *et al.* (2016) also reported that all European bass >50cm total length, captured as part of the study, had an estuarine isotopic signature (low δ13 C). These results indicate that these individual fish may preferentially feed within estuaries for an extended period of time, possibly over the entire summer feeding season. Cambiè *et al.* (2016) therefore suggested that if protecting large individuals (e.g. large spawners) was identified as a management target, an effective method to achieve this goal would be to afford estuaries higher protection.

1.5 - The requirement to protect Essential Fish Habitat (ESH) for European bass

Essential Fish Habitat (ESH) is a general term for a particular habitat which provides a critical ecosystem service to commercially important fish species; i.e. habitats that are necessary for fish; spawning, breeding, feeding, or growth to maturity (NOAA, 2018). Estuaries have been identified as an ecosystem which provides key nursery and feeding habitats for juvenile and adult European bass (Pickett & Pawson, 1994; Cambie *et al.,* 2016; Doyle *et al.,* 2017). Estuarine habitats, e.g. saltmarsh, are however in state of decline across Europe (Colcough *et al.,* 2005), and therefore the provision of ESH for European bass is likely to be decreasing.

1.5.a - Estuarine habitat decline

Estuaries in northern Europe are typically highly adapted by anthropogenic activities (Airoldi *et al.,* 2008); both by the direct removal or adaptation of intertidal habitat, and indirectly through management of adjacent land causing the introduction of alien/harmful substance e.g. sewage effluent or agricultural pesticides. It is now estimated that as much as 85% of UK estuaries have been affected by land reclamation, with the loss of intertidal habitat ranging from 25-80%, and predicted to continue at a rate of 0.2-0.7% per year (Kelley, 1988; Lotze *et al.,* 2006; Airoldi & Beck, 2007; Mossman *et al.,* 2012). Furthermore, it is predicted that as a result of sea level rise and coastal squeeze 2% of UK saltmarsh is lost each year (Dixon *et al.,* 1998; Colclough *et al.,* 2005).

The full scale of intertidal habitat loss is difficult to quantify, as limited records exist which detail the historic extent of habitats. However, as part of the Environment Agency Water Framework Directive assessment of saltmarsh habitat in England and Wales, the “historical” extent of saltmarsh (Figure 9) is estimated and compared to current extent. This is achieved by; digitising “first epoch” Ordinance Survey (OS) maps (1843-1893), areas identified as saltmarsh and grazing marsh were then spatially defined. When the area of historic saltmarsh and grazing marsh are combined and compared to the current saltmarsh extent, it is estimated that 63.91% saltmarsh habitat has been historically lost in England and Wales (Table 3).

Historical landclaim was also estimated by the Environment Agency using LiDAR, this was defined as land below the highest astronomical tide that is adjacent to coastal water and located behind an artificial flood defence. The LiDAR landclaim estimate represents the potential intertidal habitat which could be colonised by saltmarsh. It has been suggested that fully functioning saltmarsh will occupy between 25-50% of the suitable intertidal area (De Jong, 2004; Dijkema *et al.,* 2004 from WFD UKTAG). If the landclaim estimate is compared to current saltmarsh extent, it is estimated that 18.4-67.36% saltmarsh habitat has been historically lost in England and Wales (Table 3).

There is considerable uncertainty surrounding estimated intertidal habitat loss, for example some older OS maps do not include all saltmarsh habitats, or include freshwater marsh as saltmarsh. It is also uncertain if “grazing marsh” is a salt or fresh water habitat. Furthermore, a lack of historical records detailing saltmarsh habitat extent (pre 1843) mean that land claim estimates derived from LiDAR data cannot be validated. Despite these caveats it is likely that substantial loss of intertidal habitat has occurred historically in the UK, and is likely to be compounded by modern human activities.

Table 3 – Estimated extent of historical saltmarsh and landclaim in England and Wales, when compared to the current extent of Saltmarsh. Data provided by the Environment Agency.

Habitat Name		Extent (km2) - England and Wales	% extent of current saltmarsh - England and Wales: 405.2173km^2	Estimated % loss of saltmarsh - England and Wales
Current saltmarsh extent - England and Wales (2006-2009)		405.2176		
Historic saltmarsh		259.743	156	+56
Grazing marsh		862.913	47	-53.04
Historic saltmarsh and grazing marsh		1122.656	36	-63.91
Estimated landclaim	100%	2482.87	16	-83.68
	50%	1241.435	33	-67.36
	25%	496.57	82	-18.40

Activities such as sheep grazing, or introduction of sewage effluent are thought to have a significant negative effect on the feeding success and survival of 0+ European bass. Laffaille *et al.* (2000) reported that sheep grazing on intertidal saltmarsh reduced 0+ European bass prey availability by approximately 25-40% when compared to un-grazed saltmarsh. Kelley (1988) also argued that pollution events would have a significant negative impact on 0+ European bass survival. For example, during 1984 a major 2 month drought occurred in the southwest UK. In the river Camel & Taw a pronounced reduction in freshwater flow, with no complimentary reduction in toxic effluent resulted in heavy pollution of upper estuaries and tributaries. As part of ongoing research into fish communities in these estuaries, Kelly (1988) noted the near absence of 0+ European bass, aswell as sand gobies (*Pomatoschistus minutus*), at locations where previously they were abundant. While no complimentary measurements of pollution levels were reported, Kelley (1988) suggested this reduction in fish abundance may be a result of the pollution event.

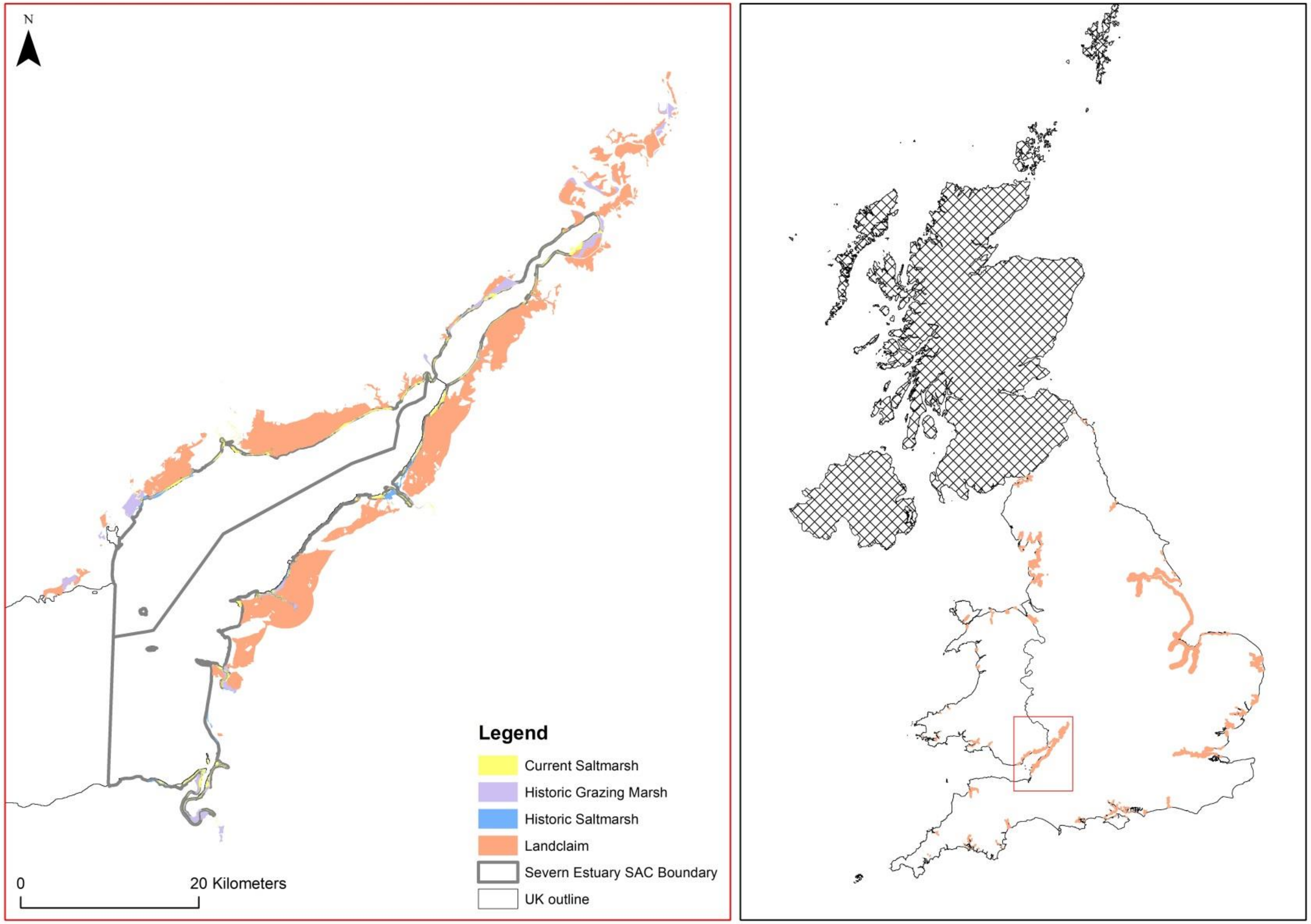


Figure 9 - Estimated extent of historical saltmarsh and landclaim in England and Wales, when compared to the current extent of Saltmarsh. Close up image of Severn Estuary (left) provided to demonstrate potential habitat loss at a local level. UK map (right) provided to show overall scale of potential habitat loss across England and Wales. Data provided by the Environment Agency.

1.5.b - Legislative protection for estuarine habitats

Estuaries and Saltmarsh are protected habitats within the European Union (EU), and can be designated for protection under the Habitats (Council Directive 92/43/EEC), and indirectly through the Birds Directive (Council Directive 2009/147/EC). UK national legislation also protect estuarine habitats, this includes Marine Conservation Zones (MCZs) designated under the Marine and Coastal Access Act, and Sites of Special Scientific Interest - SSSI. Estuaries (known as transitional waters) and saltmarsh habitat must also be monitored under the EU Water Framework Directive (Council Directive 2000/60/EC). These designations are however often very narrowly focussed, and very few protect habitats from a fisheries perspective. Furthermore, because a feature-based approach is currently applied, a wide range of exploitative activities, e.g. trawling, aggregate dredging, renewables development etc. are often permitted within their boundaries which may impact on the functionality of Essential Fish Habitats, even if there is no overall impact on site integrity (Roberts & Hawkins, 2012).

The latest overarching Habitats Directive Assessment submitted by the Joint Nature Conservation Committee (conducted in 2013) to the European Union, reported that at a UK level saltmarsh habitat was in either 'unfavorable, bad but stable' or 'unfavorable, bad but improving' status; and Estuaries as a whole were also deemed to be in "Bad and declining" condition (JNCC, 2013). The latest WFD assessments (conducted in 2016), reported that estuaries across the UK are predominantly in "Moderate" ecological status. WFD saltmarsh assessments indicated that waterbodies are predominantly in "Moderate" or "Good" ecological status. Estuarine fish assemblages are also assessed under the WFD, these were predominantly categorized as in "Good" ecological status. Despite the relatively high scores of estuaries, saltmarsh and estuarine fish assessments under the WFD, it has been reported by Best *et al.* (2007) that un-impacted estuaries are not available in the UK, and it is therefore uncertain how these scores compare to historical benchmarks.

The lack of robust protection for Essential Fish Habitat within the Natura 2000 network has however been recognized. As part of the Common Fisheries Policy Reform it has been proposed by the European Commission's Committee on Fisheries, that EU member states establish a network of marine reserves known as "Fish Stock Recovery Areas" (proposed under Amendment 68, Part 3, Article 7a) (Roberts & Hawkins, 2012).These areas are proposed to cover 10-20% of the territorial waters of EU member states to protect habitats which provide essential ecosystem services to commercially important fin and shell fish species. These areas could either add to the coverage of MPAs in the Natura 2000 network, or existing Natura 2000 sites could also be designated as "Fish Stock Recovery Areas" (Roberts & Hawkins, 2012. If achieved, this policy may be highly relevant to European bass conservation as estuarine Natura 2000 sites could be given higher protection for the purposes of protecting Essential Fish Habitat.

1.6 - Striped Bass (Morone saxatilis) fisheries management in Atlantic USA coastal states

1.6.a - Life history and fisheries management

Striped Bass (*Morone saxatilis*) is a closely related species to European bass, which has a native distribution along the east coast of the USA from St. Lawrence River, Canada to Northern Florida (ASMFC, 2018). Similar to European bass, Striped bass is a long lived species (max recorded age – 30 years Fiedler, 1991), which can reach a maximum size of ~81.88 lbs/37.14kg. When sexual maturity is achieved (approximately at age 6) females will spawn in freshwater habitats. Fertilised eggs drift downstream and metamorphose into larvae which remain within estuarine nursery areas for the 1st two-four years, after which the majority recruit into coastal populations which migrate northwards along the Atlantic USA coastline (ASMFC, 2018).

Striped bass has both an important commercial and recreational fishery throughout it's range, however as a result of overfishing and poor environmental conditions the fishery collapsed in the 1980s (ASMFC, 2018). As a result, in the 1980s a moratorium was imposed to encourage the fishery to recover. From 1982 recruitment steadily increased, and then from 1993-2004 there was a period of strong recruitment. Over the same time period the Spawning Stock Biomass (SSB) steadily increased, and the fishery is now open to both commercial and recreational fisheries. Currently the fishery is now deemed as "Not overfished nor experiencing overfishing".

Commercial and recreational Striped bass fisheries in US Atlantic states are regulated by a "complex" of management regimes (Murphy *et al.,* 2015). An overarching management body – The Atlantic Striped Bass Management Board of the Atlantic States Marine Fisheries Commission (ASMF), decides upon management strategies using guidelines within Amendment 6 to the Interstate Fishery Management Plan for Atlantic Striped Bass (February 2003)", and its subsequent addendums (Appendix I-IV) (ASMFC, 2018). This management plan is structured around the current status of the Spawning Stock Biomass (SSB), and sets biological reference points for Fishing mortality (known as "F") and population age structure. Individual states must then enforce the ASMF fisheries regulations, or implement alternatives which have equivalent biological reference points (Murphy *et al.,* 2015). The coast wide commercial quota is reviewed annually and based on target fishing mortality and Spawning Stock Biomass thresholds agreed by all relevant states. The quota allocated to each state is then based on the proportion of coast-wide catch each state achieved from 1972-1979 (known as the historical base period) (Table 4).

Table 4 – Historical bass period -Striped Bass (*Morone saxatilis*) commercial landings for USA Atlantic coastal states

State	Allocation (lbs)	State	Allocation (lbs)
Maine	250	New York	1061060
New Hampshire	5750	New Jersey	321750
Massachusetts	1159750	Delaware	193447
Rhode Island	243625	Maryland	131560
Connecticut	23750	Virginia	184853
		North Carolina	480480

1.6.b - Essential Fish Habitat protection – Striped bass

A key feature of Striped Bass Fishery Management Plans involves the restoration and maintenance of Essential Fish Habitat. Larval and juvenile striped bass are dependent on riverine and estuarine habitats which are vulnerable to anthropogenic disturbance (Hill *et al.,* 1989). Historically, practices such as channelization and land reclamation are also estimated to be responsible for a 50% reduction in coastal habitat, and are now thought to be the main physical threat to striped bass conservation and management (ASMFC, 2018). As a result, ASMF fisheries management plans feature identification and protection of ESH as a priority. Each state's jurisdictions are responsible for periodic review and monitoring of habitats essential for; spawning, nursery and wintering, as well as migratory corridors. This includes monitoring water and substrate quality, as well as monitoring human activities which could jeopardize striped bass habitat quality and extent (ASMFC, 2018).

Similar to Cambie et al., (2016), Baker *et al.* (2016) has also shown through stable isotope analysis that adult striped bass may also be highly dependent on estuaries as feeding habitats. 34 Striped bass ranging from 29.6-69.2 cm (total length) were collected from Plum Island estuary, Maussachusetts. Using stable isotope analysis, the contribution of different nutrient sources in the overall diet of these fish where investigated. The results suggested that approximately 44% of the Striped bass diet was ultimately derived from saltmarsh detritus. The authors recognized that the sample size was too small to base management decision for striped bass; however the results suggested that other than provision of nursery habitat saltmarsh habitat may also provide additional valuable feeding habitat.

1.6.c - Relevance of Striped Bass fisheries management to European Bass

The striped bass fishery experienced similar declines to the North Atlantic European bass fishery, however following implementation of a successful management strategy the striped bass fishery is now considered "recovered". It is likely that the success of striped bass management is dependent on a myriad of strategies which maintain the SSB, protect important/vulnerable life stages, protect supporting habitats, and also foster compliance from both the commercial and recreational fishing sectors.

European and striped bass are biologically and ecologically similar, management of striped bass fisheries may therefore have transferable strategies relevant to European bass. For example, the holistic nature of striped bass management recognizes that fisheries cannot be managed effectively by only regulating catch limits or minimum landing sizes. If essential habitats are degraded, management is not likely to provide adequate commercial or recreational fisheries (ASMFC, 2018).

1.7 - Discussion

ICES have reported a dramatic decline in North Atlantic European bass stock. The reason for the decline is not fully understood however is thought to be primarily a result of an unsustainable increase in fishing pressure and poor recruitment. Therefore, for future management it is crucial to focus on maintaining sustainable fishing mortality, but also provide protection to essential habitats which support juvenile fish populations.

The peer reviewed literature has provided evidence that estuaries provide critical ecosystem services as both a nursery habitat for juvenile, and feeding habitat for large sexually mature European bass. Despite legislative protection across Europe estuaries have been heavily impacted by human activities, resulting in large scale habitat loss and/or alteration. In lieu of pristine/ un-impacted estuarine habitats (Best *et al.,* 2007), the effect of this habitat loss on fish production is difficult to quantify however it is likely to have had substantial negative impacts (Mclusky *et al.,* 1992).

When European bass and Striped Bass (*Morone saxitilis*) management is compared, management of striped bass provides protection for essential spawning and nursery habitat, and migratory corridors. Not only is monitoring and protection of these essential habitats likely to support recruitment, but as demonstrated by Baker *et al.* (2016) & Cambie *et al.* (2016) may also provide substantial feeding opportunities for adults.

Within the UK, various legislative mechanisms are available which could aid the protection of estuarine habitats for the purposes of European bass conservation. Designated Bass Nursery Areas (BNA) provide protection for European bass from commercial fishing operations within estuaries. However, further research is required to assess if BNA boundaries are relevant to the movement and behaviour of the fish they protect. Modification of European and UK national legislation, such as the Habitats Directive and Marine and Coastal Access Act, could also be used to provide protection for the essential habitats which support fish production within designated Natura 2000 sites. However further work is required to; identify what aspects of estuarine habitats support European bass, as well as investigate potential mitigation measures for wide scale habitat loss.

1.8 - Conclusion and recommendations

The management and conservation of the North Atlantic European Bass stock faces many issues (please see Annex 1), however the protection of estuarine habitats may provide a positive impact on local European bass populations. Modern techniques, such as acoustic telemetry and stable isotope analysis, could provide improved knowledge of European bass behaviour and habitat use within estuaries. If necessary, regulators may then revise existing conservation or fisheries management legislation or develop new legislation mechanisms to provide a cost effective method to improve protection for essential habitats and offer protection for both juvenile and large adult European bass.

1.9 - References

1. Airoldi L, Balata D, Beck MW (2008) The gray zone: relationships between habitat loss and marine diversity and their applications in conservation. Journal of Experimental Marine Biology and Ecology 366:8-15
2. Ares E (2016) UK and European Sea bass conservation measures. House of Commons Library. House of Commons, UK Government
3. Armstrong M BA, Hargreaves J, Hyder K, Pilgrim-Morrison S, Munday M, Proctor S, Roberts A, Williamson K (2012) Sea Angling 2012 – a survey of recreational sea angling activity and economic value in England. DEFRA
4. ASMFC (2018) Atlantic Striped Bass - Fisheries Management Plan. Accessed 11/01/2018. http://www.asmfc.org/species/atlantic-striped-bass
5. Baker HK, Nelson JA, Leslie HM (2016) Quantifying striped bass (Morone saxatilis) dependence on saltmarsh-derived productivity using stable isotope analysis. Estuaries and coasts 39:1537-1542
6. Best M, Massey A, Prior A (2007) Developing a saltmarsh classification tool for the European water framework directive. Marine Pollution Bulletin 55:205-214
7. Cambiè G, Kaiser MJ, Marriott AL, Fox J, Lambert G, Hiddink JG, Overy T, Bennet SA, Leng MJ, McCarthy ID (2016) Stable isotope signatures reveal small-scale spatial separation in populations of European sea bass. Marine Ecology Progress Series 546:213-223
8. Carroll A (2014) Population Dynamics of the European Sea Bass (Dicentrarchus labrax) in Welsh Waters Master of Science, Bangor University, Bangor University
9. Castilho R, McAndrew B (1998) Population structure of seabass in Portugal: evidence from allozymes. Journal of Fish Biology 53:1038-1049
10. Child A (1992) Biochemical polymorphism in bass, Dicentrarchus labrax, in the waters around the British Isles. Journal of the Marine Biological Association of the United Kingdom 72:357-364
11. Colclough S, Fonseca L, Astley T, Thomas K, Watts W (2005) Fish utilisation of managed realignments. Fisheries Management and Ecology 12:351-360
12. Comission E (2016) CFP reform – the discard ban. Accessed 05/02/2017. https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/discards_en.pdf
13. Daw T, Gray T (2005) Fisheries science and sustainability in international policy: a study of failure in the European Union's Common Fisheries Policy. Marine Policy 29:189-197
14. Diodati PJ, Richards RA (1996) Mortality of striped bass hooked and released in salt water. Transactions of the American Fisheries Society 125:300-307
15. Dixon A, Leggett D, Weight R (1998) Habitat Creation Opportunities for Landward Coastal Re-alignment: Essex Case Studies. Water and Environment Journal 12:107-112
16. Doyle TK, Haberlin D, Clohessy J, Bennison A, Jessopp M (2017) Localised residency and inter-annual fidelity to coastal foraging areas may place sea bass at risk to local depletion. Scientific Reports 8
17. Fiedler K (1991) Lehrbuch der Speziellen Zoologie. Band II: Wirbeltiere. 2. Teil: Fische. D. Starck (ed.). Gustav Fischer Verlag:498
18. Fockedey, Mees (1999) Feeding of the hyperbenthic mysid Neomysis integer in the maximum turbidity zone of the Elbe, Westerschelde and Gironde estuaries. Journal of Marine Systems 22:207-228

19. Fonseca L, Colclough S, Hughes RG (2011) Variations in the feeding of 0-group bass Dicentrarchus labrax (L.) in managed realignment areas and saltmarshes in SE England. Hydrobiologia 672:15-31
20. Fritsch M, Morizur Y, Lambert E, Bonhomme F, Guinand B (2007) Assessment of sea bass (Dicentrarchus labrax, L.) stock delimitation in the Bay of Biscay and the English Channel based on mark-recapture and genetic data. Fisheries Research 83:123-132
21. Garcia de Leon F, Chikhi L, Bonhomme F (1997) Microsatellite polymorphism and population subdivision in natural populations of European sea bass Dicentrarchus labrax (Linnaeus, 1758). Molecular Ecology 6:51-62
22. Green BC, Smith DJ, Grey J, Underwood GJ (2012) High site fidelity and low site connectivity in temperate salt marsh fish populations: a stable isotope approach. Oecologia 168:245-255
23. Hill J, Evans JW, Van Den Avyle MJ (1989) Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Atlantic). Striped Bass. GEORGIA COOPERATIVE FISHERY AND WILDLIFE RESEARCH UNIT ATHENS
24. ICES (2016) ICES Advice on fishing opportunities, catch, and effort Celtic Seas and Greater North Sea ecoregions: Sea bass (Dicentrarchus labrax) in divisions 4.b–c, 7.a, and 7.d–h (central and southern North Sea, Irish Sea, English Channel, Bristol Channel, and Celtic Sea). In: ICES (ed) ICES Advice on fishing opportunities, catch, and effort Celtic Seas and Greater North Sea ecoregions
25. IFCA DS (2016) D&S IFCA outline of planned work relativing to European Sea Bass October 2015.
26. IFREMER (2017) BarGIP tagging project. In: 2017 PaIA (ed), Fort Lauderdale Convention Centre
27. Jennings S, Pawson M (1992) The origin and recruitment of bass, Dicentrarchus labrax, larvae to nursery areas. Journal of the Marine Biological Association of the United Kingdom 72:199-212
28. JNCC (2013) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC). Third Report by the United Kingdom under Article 17; H1130 Estuaries. JNCC
29. Kelley D (1988) The importance of estuaries for sea-bass, Dicentrarchus labrax (L.). Journal of Fish Biology 33:25-33
30. Khalilian S, Froese R, Proelss A, Requate T (2010) Designed for failure: a critique of the Common Fisheries Policy of the European Union. Marine Policy 34:1178-1182
31. Koukouras A (2010) Check-list of marine species from Greece. In: project AitfotEFP (ed). Aristotle University of Thessaloniki, Aristotle University of Thessaloniki
32. Laffaille P, Feunteun E, Lefeuvre J-C (2000) Composition of fish communities in a European macrotidal salt marsh (the Mont Saint-Michel Bay, France). Estuarine, Coastal and Shelf Science 51:429-438
33. Laffaille P, Lefeuvre J-C, Schricke M-T, Feunteun E (2001) Feeding ecology of o-group sea bass, Dicentrarchus labrax, in salt marshes of Mont Saint Michel Bay (France). Estuaries 24:116-125
34. Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, Kidwell SM, Kirby MX, Peterson CH, Jackson JB (2006) Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312:1806-1809

35. MAFF (1990) Bass Nursery Areas and Other Conservation Measures. Ministry of Agriculture, Fisheries and Food, Ministry of Agriculture, Fisheries and Food, Welsh Office Agriculture Office
36. McLusky DS, Bryant DM, Elliott M (1992) The impact of land-claim on macrobenthos, fish and shorebirds on the forth estuary, eastern Scotland. Aquatic conservation: marine and freshwater ecosystems 2:211-222
37. MMO (2017) Bass fishing guidance. Accessed 11/01/2018. https://www.gov.uk/government/publications/bass-fishing-guidance
38. Mossman HL, Davy AJ, Grant A (2012) Does managed coastal realignment create saltmarshes with 'equivalent biological characteristics' to natural reference sites? Journal of Applied Ecology 49:1446-1456
39. MRAG (2014) Defining the Economic and Environmental values of Sea Bass.
40. Murphy Jr RD, Scyphers SB, Grabowski JH (2015) Assessing Fishers' Support of Striped Bass Management Strategies. PloS one 10:e0136412
41. Ng CL, Able KW, Grothues TM (2007) Habitat use, site fidelity, and movement of adult striped bass in a southern New Jersey estuary based on mobile acoustic telemetry. Transactions of the American Fisheries Society 136:1344-1355
42. Patarnello T, Bargelloni L, Caldara F, Colombo L (1993) Mitochondrial DNA sequence variation in the European sea bass, Dicentrarchus labrax L.(Serranidae): evidence of differential haplotype distribution in natural and farmed populations. Molecular marine biology and biotechnology 2:333-337
43. Pawson M, Brown M, Leballeur J, Pickett G (2008) Will philopatry in sea bass, Dicentrarchus labrax, facilitate the use of catch-restricted areas for management of recreational fisheries? Fisheries Research 93:240-243
44. Pawson M, Pickett G (1996) The annual pattern of condition and maturity in bass, Dicentrarchus labrax, in waters around England and Wales. Journal of the Marine Biological Association of the United Kingdom 76:107-125
45. Pawson M, Pickett G, Kelley D (1987) The distribution and migrations of bass, Dicentrarchus labrax L., in waters around England and Wales as shown by tagging. Journal of the Marine Biological Association of the United Kingdom 67:183-217
46. Pawson M, Pickett G, Leballeur J, Brown M, Fritsch M (2007) Migrations, fishery interactions, and management units of sea bass (Dicentrarchus labrax) in Northwest Europe. ICES Journal of Marine Science: Journal du Conseil 64:332-345
47. Pickett G, Kelley D, Pawson M (2004) The patterns of recruitment of sea bass, Dicentrarchus labrax L. from nursery areas in England and Wales and implications for fisheries management. Fisheries Research 68:329-342
48. Roberts, Hawkins (2012) Establishment of Fish Stock Recovery Areas. European Parliment
49. Ross E (2015) Devon and Severn IFCA outline of planned work relating to European sea bass. Devon and Severn IFCA
50. Sissenwine M, Symes D (2007) Reflections on the common fisheries policy. Report to the general directorate for fisheries and maritime affairs of the European commission:75
51. Thompson BM, Harrop RT (1987) The distribution and abundance of bass (Dicentrarchus labrax) eggs and larvae in the English Channel and southern North Sea. Journal of the marine Biological Association of the United Kingdom 67:263-274

52. Trust A (2017) Bass ban sparks fury amongst sea anglers. Accessed 11/01/2018. http://www.anglingtrust.net/news.asp?section=29&itemid=4239#
53. Vinagre C, Máguas C, Cabral H, Costa M (2012) Food web structure of the coastal area adjacent to the Tagus estuary revealed by stable isotope analysis. Journal of sea research 67:21-26
54. WGCSE I (2016) Report of the Working Group for the Celtic Seas Ecoregion (WGCSE). Copenhagen, Denmark

2- Thesis structure

Estuaries represent essential habitat which support European bass at various life stages. In the UK there are a number of legislative instruments which currently protect European bass within estuaries, as well as protect the habitats they exploit. However, there remain a number of issues associated with substantial estuarine habitat loss, and uncertainty surrounding fish movement within and in close proximity to protected estuaries.

For purposes of fisheries management this thesis aims to review; how European bass utilize estuarine habitats, as well as identify how well European bass are protected from commercial fishing activities whilst within or in close proximity to estuaries;

- **Assessing variation in 0 group European bass growth to identify Essential Fish Habitat within UK estuaries (Section 3)**

Otolith microstructure will be used to assess how 0-group European bass growth varies with access to intertidal vs subtidal estuarine habitats. Saltmarsh is known to provide key feeding opportunities for European bass, however limited information can be found on how juvenile bass grow within other subtidal habitats.

- **The role of managed re-alignment schemes as compensatory fish habitat (Section 4)**

Managed Re-alignment is a mitigation measure to compensate for intertidal habitat loss. The chapter will assess differences in the fish community, aswell as fish diet and feeding success within Managed Re-alignment schemes when compared to natural saltmarsh.

- **Estuarine movement and habitat use characteristics of European Bass within Designated Bass Nursery Areas (Section 5)**

Designated Bass Nursery Areas are a form of spatial protection for European bass largely within estuaries on the east, south and west coast of England and Wales. It is however uncertain how effective spatial management is at protecting this fish species. Acoustic telemetry will be used to track 150 European bass within 3 designated Bass Nursery Areas.

- **Exploring alternate management options of static net fishing activities within close proximity to estuaries (Section 6)**

Static netting is a key fishing activity undertaken by the UK inshore commercial fishing fleet. As mitigation to reduce salmonid by-catch, within close proximity to estuaries static net headline depth must exceed 3m water depth. The Environment Agency however argues static net headline depth should exceed 5m. Reductions in headline depth to 5m may however have a significant negative impact on the ability of coastal net fishermen to catch target species, e.g. European bass.

Static nets with 3 and 5m headline depths will be deployed to assess differences in salmonid by-catch, aswell as catch rates of target species.

3- Assessing variation in 0 group European bass growth to identify Essential Fish Habitat within UK estuaries

3.1 - Background information

Essential fish habitat is a general term for a particular habitat which provides a critical ecosystem service to commercially important fish species; i.e. habitats that are necessary for fish; spawning, breeding, feeding, or growth to maturity (NOAA, 2018). Estuaries have been identified as an ecosystem which provides key nursery and feeding habitats for juvenile and adult European bass (Pickett & Pawson, 1994; Cambie *et al.,* 2016; Doyle *et al.,* 2017). Estuaries are however often highly urbanised ecosystems (Airoldi *et al.,* 2008), providing essential sheltered coastline for ports and major conurbations. As a result, the space/land which estuarine habitats occupy may be a prized commodity, or vulnerable to damaging human activities e.g. land reclaim, or boat anchoring. The value of these habitats in regard to fish production therefore needs to be assessed and documented for the purposes of spatial planning.

Numerous authors have stated the importance of saltmarsh as a feeding habitat for juvenile European bass (Kelley ; 1988; Laffaille *et al.,* 2000 & 2001; Fonseca *et al.,* 2011; Green *et al.,* 2012). The macro-tidal nature of estuaries within North East Atlantic Europe limits tidal submersion of intertidal habits, such as saltmarsh, to high springs tides which only occur ~2 weeks. A large tidal range also limits fish access to intertidal habitats to approximately 1-2 hours during each tide (Laffaille *et al.,* 2001). Despite limited access, it has been estimated that when exploiting intertidal saltmarsh 0+ European Bass can consume up to 8% of their body weight within a single tide (Laffaille *et al.,* 2001).

Laffaille *et al.* (2001) & Fonseca *et al.* (2011) suggest that European bass are voracious predators when exploiting saltmarsh. However, little information can be found which assess how European bass grow/develop when exploiting other sub-tidal estuarine habitats. It is therefore not well understood if estuaries as a whole provide equal feeding opportunities, or whether prey species consumed within specific habitats, e.g. saltmarsh, contribute proportionately more to growth. If European bass, and other fish species, are found to grow more when feeding in different habitats this could provide valuable justification for protection or management of habitats from a fisheries perspective.

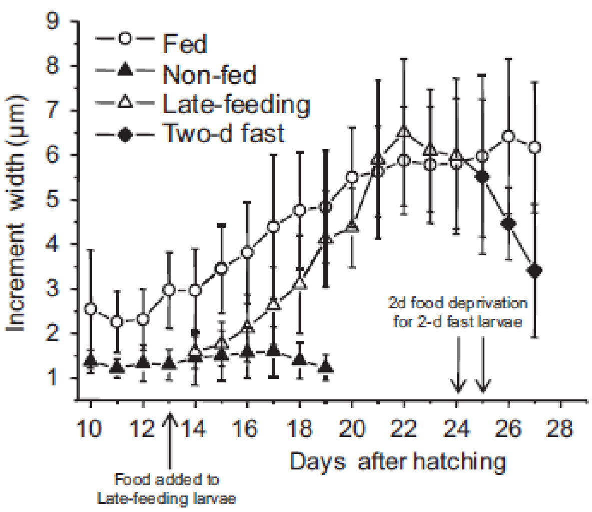


Figure 10 - Sagittal otolith growth increment widths from juvenile European bass following 4 feeding treatments (Agulera *et al.*, 2009)

Otoliths are calcified structures used for balance and/or hearing in all teleost fish (Campana, 1985; Stevenson & Campana, 1992). Similar to "tree rings" concentric bands are laid down at a daily and annual rate (Annual bands visible in figure 1), which can then be used to estimate growth (Campana, 1985). Aguilera *et al.* (2009) reported the width of daily growth increments in European bass otoliths was correlated to food availability/growth (Figure 8). 0+ European bass were exposed to different feeding treatments, when daily growth increments were analysed the increment width was larger when the fish was provided with larger amount of food. Furthermore, due to the chronological nature of increment deposition the addition of higher or lower food could be identified retrospectively.

As mentioned previously, high tidal range in north Europe limits fish access to intertidal habitats to during high spring tides. If fish growth disproportionately increases as a result of this discrete exposure to intertidal habitats, this may be reflected within daily otolith growth increments as demonstrated by Agulera *et al.* (2009). By identifying if fish growth varies in relation to access to intertidal habitats, this will provide more fine scale information on which to identify and protect Essential Fish Habitat.

3.1.a - Project Aims

The aim of this study is to analyse daily otolith growth increments from wild caught European bass, to assess if growth differs throughout the tidal cycle. During spring tidal cycles, European bass will have access to intertidal habitats, however during neap tidal cycles they do not. If prey availability or the nutrient content of prey, differs between intertidal or sub-tidal habitats this may be reflected in the growth and hence otolith increment widths of European bass.

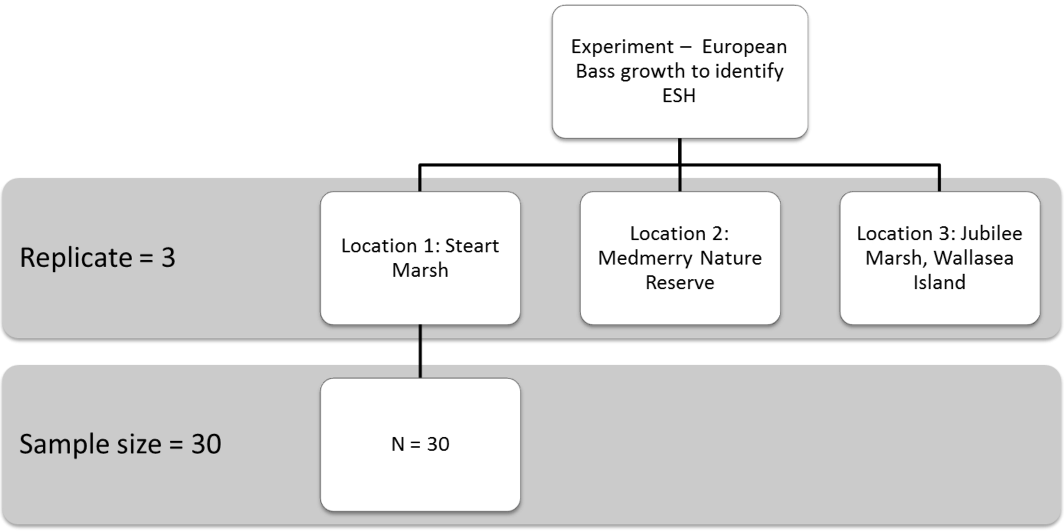
This will provide valuable evidence to local authorities, and protect site managers, to help inform the protection and potentially designation of Essential Fish Habitat.

3.1.b - Research question

1. Does 0+ European bass growth vary in relation to spring or neap tidal cycles?

3.2 - Method

From each of 3 locations in the UK; labelled in Figure 9 as; Steart Marsh, Medmerry Nature reserve, Jubilee Marsh, 0+ European bass will be collected from saltmarsh sites. The target number of fish per location is 30-40 individuals.



The sagittal otoliths will be removed from each individual. Each otolith will be cross sectioned through the nucleus. Cross sections will then be sanded until daily growth increments are visible under light microscopy. Otoliths will be photographed in high definition via a camera mounted microscope. Using image analysis software, daily growth increments will be marked and the distance between each mark measured.

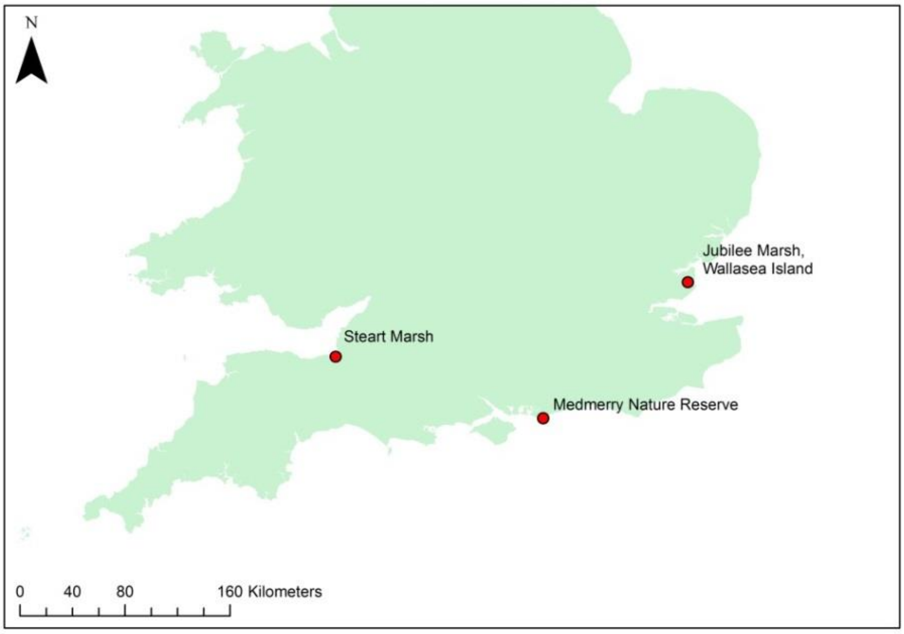


Figure 11- Proposed collection sites for 0+ European bassto assess variation in growth in relation to the tidal cycle.

3.3 - Progress to date

All sample sites were surveyed throughout the summer months in 2017. A total of 181 pairs of sagittal otoliths have been extracted from 0+ and 1+ European bass across these sample sites (table 3). Other species have also been preserved and otoliths potentially extracted, these include; Thin lip Mullet (*Chelon ramada*) and Goby species (*Pomatoschistus spp. & Gobius niger*).

Training has been undertaken at Bangor University to visualize daily growth rings and analyse the corresponding data. No samples have however been analysed to date.

Table 5 - Otoliths extracted from European bass from; Severn Estuary; Chichester Harbour; Essex Estuaries

Survey Location	Sample Site	Total
Medmerry Nature Reserve	East Head (natural	25
	Medmerry (MRAS)	6
	Pagham Harbour (natural)	44
Steart Marsh	Bridgwater Bay SSSI (natural)	12
	Huntspill Nature Reserve (Natural)	1
	Steart Marsh (MRAS)	18
Jubilee Marsh, Wallasea Island	Jubilee Marsh (MRAS)	16
	Paglesham Creek North (Natural)	20
	Paglesham Creek South (Natural)	39

3.4 - References

1) Aguilera B, Catalán IA, Palomera I, Olivar MP (2009) Otolith growth of European sea bass (Dicentrarchus labrax L.) larvae fed with constant or varying food levels. Scientia Marina 73:173-182
2) Airoldi L, Balata D, Beck MW (2008) The gray zone: relationships between habitat loss and marine diversity and their applications in conservation. Journal of Experimental Marine Biology and Ecology 366:8-15
3) Cambiè G, Kaiser MJ, Marriott AL, Fox J, Lambert G, Hiddink JG, Overy T, Bennet SA, Leng MJ, McCarthy ID (2016) Stable isotope signatures reveal small-scale spatial separation in populations of European sea bass. Marine Ecology Progress Series 546:213-223
4) Campana SE, Neilson JD (1985) Microstructure of fish otoliths. Canadian Journal of Fisheries and Aquatic Sciences 42:1014-1032
5) Doyle TK, Haberlin D, Clohessy J, Bennison A, Jessopp M (2017) Localised residency and inter-annual fidelity to coastal foraging areas may place sea bass at risk to local depletion. Scientific Reports 8
6) Fonseca L, Colclough S, Hughes RG (2011) Variations in the feeding of 0-group bass Dicentrarchus labrax (L.) in managed realignment areas and saltmarshes in SE England. Hydrobiologia 672:15-31
7) Green BC, Smith DJ, Grey J, Underwood GJ (2012) High site fidelity and low site connectivity in temperate salt marsh fish populations: a stable isotope approach. Oecologia 168:245-255
8) Kelley D (1988) The importance of estuaries for sea-bass, Dicentrarchus labrax (L.). Journal of Fish Biology 33:25-33
9) Laffaille P, Feunteun E, Lefeuvre J-C (2000) Composition of fish communities in a European macrotidal salt marsh (the Mont Saint-Michel Bay, France). Estuarine, Coastal and Shelf Science 51:429-438
10) Laffaille P, Lefeuvre J-C, Schricke M-T, Feunteun E (2001) Feeding ecology of o-group sea bass, Dicentrarchus labrax, in salt marshes of Mont Saint Michel Bay (France). Estuaries 24:116-125
11) NOAA (2018) Essential Fish Habitat. Accessed 01/16/2018. https://www.fisheries.noaa.gov/national/habitat-conservation/essential-fish-habitat
12) Pickett GD, Pawson MG (1994) Sea Bass: Biology, Exploitation and Conservation, MAFF Fisheries Laboratory Lowestoft, UK
13) Stevenson DK, Campana SE (1992) Otolith microstructure examination and analysis. Department of Fisheries and Oceans

4 - The role of managed re-alignment schemes as compensatory fish habitat

4.1 - Background information

Saltmarsh provides a critical nursery habitat for numerous commercially important fish species, e.g. European Bass. Saltmarsh as a habitat is however in a state of rapid decline across Europe, with the loss of intertidal habitat ranging from 25-80%, and predicted to continue at a rate of 0.2-0.7% per year (Lotze *et al.,* 2006; Airoldi & Beck, 2008; Mossman *et al.,* 2012). A potential mitigation action for saltmarsh habitat loss is the construction of Managed Re-alignment schemes. Managed Re-alignment is a coastal management technique whereby the sea is encouraged to flood low lying coastal land, as opposed to reinforcing the shoreline with concrete defences. This process creates new intertidal area, which develops into either saltmarsh or mudflat habitat (Mossman et al., 2012).

Figure 12- Steart Marsh (managed re-algnment scheme), Somerset (image credit - The Environment Agency)

Managed re-alignment/restored wetland sites in the USA have developed within a few years to resemble those of natural salt marsh communities, in terms of plant community structure and ecological functioning (Byers & Chmura, 2007). However, Garbutt et al. (2006) and Mossman et al. (2012) estimated it may take ≥100 years for managed re-alignment sites within northern Europe to resemble those of natural salt marsh habitat. Five years after breaching, Tollesbury managed re-alignment site in East England, was classed similar to adjacent "ancient" salt marsh in terms of the presence of floral species, although in terms of species abundance the site was not comparable (Garbutt et al., 2006). Mossman et al. (2012) compared several natural salt marsh habitat and those created by managed re-alignment, concluding that "marshes reactivated by managed re-alignment do not provide habitats and species in comparable proportions to natural marshes and do not have equivalent biological characteristics."

Colclough *et al.* (2005), Fonseca *et al.* (2011) & Nunn *et al.* (2016) studied fish utilization of managed re-alignment schemes compared to local natural habitats. The results have indicated that in general managed re-alignment schemes do provide valuable feeding habitat for some commercially important fish species. However, further survey work is required to provide additional support to these studies as well investigate broad scale patterns across the UK. Furthermore, as part of the English climate change adaptation strategy, the UK government has committed to "re-align" 10% of the UK coastline 2030 (Esteves, 2014). As a result, the construction of managed re-alignment schemes is likely to increase, and the importance of these novel habitats from a fisheries perspective is of growing interest to fisheries managers (Fonseca *et al.,* 2011).

4.1.a - Project Aims

The aim of this study is to compare fish utilization of habitats within managed re-alignment schemes (MRAS) to natural saltmarsh (NSM). The following metrics will be used to compare differences between MRAS and NSM; fish diversity, diet and feeding success.

4.1.b - Research Questions

1. Is there a significant difference in fish diversity between Managed Re-alignment Schemes (MRAS) and natural saltmarsh (NSM) sites
2. Is there a significant difference in fish feeding success between Managed Re-alignment Schemes (MRAS) and natural saltmarsh sites (NSM)?
3. Is there a significant difference in fish diet between Managed Re-alignment Schemes (MRAS) and natural saltmarsh sites (NSM)?

4.2 - Methods

4.2.a - Capture technique

Due to the variety of habitats found within managed re-alignment and natural saltmarshes, two methods were used to capture fish; fyke and seine nets (Table 5). Due to the differences in the catch efficiency, data concerning fish diversity were analysed separately for each fishing method. Fish that were used to assess diet and feeding success between MRAS and NSM were pooled across both fishing methods.

Fyke nets were deployed within representative creeks in NSM and MRAS. When each fyke net was deployed a temperature, salinity and submersion sensor was attached to the 1st door the fyke net. The sensor recorded when the net was submerged and therefore actively fishing (for effort calculations), plus temperature and salinity measurements every 10minutes.

Seine nets were deployed in open pond like habitats within NSM and MRAS. When each seine net was deployed, temperature and salinity measurements were recorded.

Each fish collected was measured (total length), and identified to as low a taxonomic resolution as possible. Fish retained for feeding success and diet analyses were euthanized via an appropriate method, and preserved within 70% industrial methylated spirit.

Table 6 - Methods used to capture fish within Managed Re-alignment survey

	Fishing Method	
	Fyke Net 6.5, 8 & 10mm Mesh – 53cm * 2.75 meters – 16ft Leaders)	Deployed in saltmarsh creeks
	Seine Net 6mm Mesh - 30 * 1.5m	Deployed in open pond like habitats

4.2.b - Sampling Locations

This study focussed on three of largest Managed Re-alignment Schemes in the UK; Steart Marsh (figure 10), Jubilee Marsh (Wallasea Island) and Medmerry Nature reserve (Figure 11 & Table 4). These MRAS are distributed throughout the UK, and therefore experience different environment conditions (e.g. tidal amplitude and local weather patterns). Furthermore construction design varied between MRAS, and the construction of each MRAS was completed at different times. As a result of these issues, the development of saltmarsh habitat varied at each MRAS.

To account for this source of variation, a nested experimental design was employed. Each MRAS included in the study is located at various locations around the UK, from herin these locations are referred to by the name of the local MRAS. When a survey was conducted at each location, the MRAS and 2 local NSM were surveyed during the same tidal cycle. The local NSM were used to compare local fish communities and feeding success to the respective local MRAS. All NSM sites have been selected based on their proximity to their respective MRAS, and where possibly equivalence in size. Please note in most locations the MRAS had a significantly larger spatial area than local NSM. This is an unavoidable component of the survey as expansive areas of saltmarsh are not a common habitat in the UK (Best *et al.,* 2007).

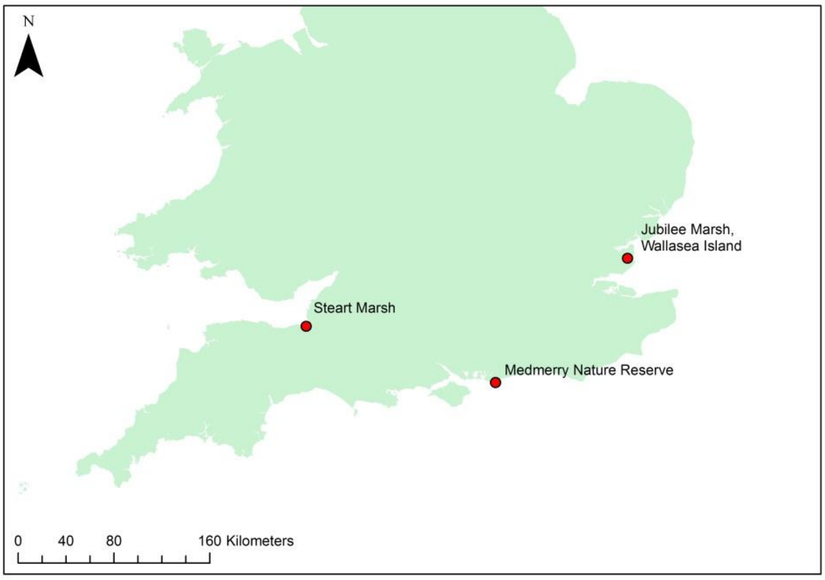


Figure 13- Proposed sampling sites for small fish surveys within managed re-alignment vs natural saltmarshes

Table 7 – Name of survey locations with managed re-alignment scheme and local natural saltmarsh. MRAS – Managed Re-alignment Scheme; NM- Natural Marsh.

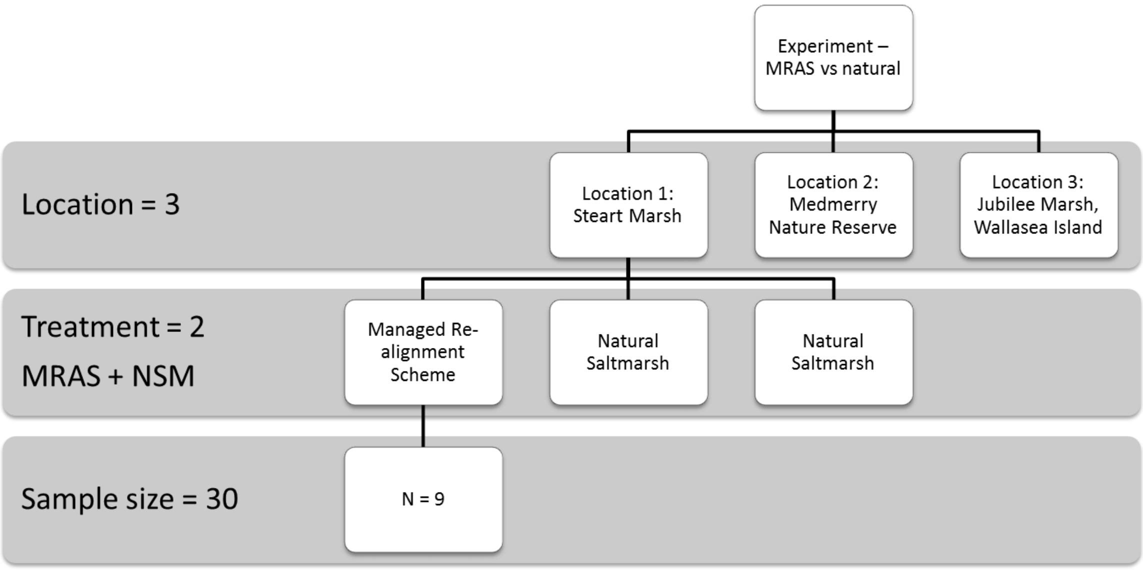
Survey Location	Site Name	Initials	MR/NM	Year construction completed
Jubilee Marsh, Wallasea Island	Jubilee Marsh	JM	MRAS	September 2015
	Paglesham Creek South	PCS	NM	N/A
	Paglesham Creek North	PCN	NM	N/A
Medmerry Nature Reserve	Medmerry Nature Reserve	MNR	MRAS	Autumn 2013
	Pagham Harbour	PH	NM	N/A
	East Head	EH	NM	N/A

	Steart Marsh	SM	MRAS	September 2014
Steart Marsh	Bridgewater Bay SSSI	BBSSSI	NM	N/A
	Huntspill Nature Reserve	HNR	NM	N/A

4.2.c - Method: Differences in fish communities between MRAS and NSM

At each of 3 locations (figure 11) one MRAS and 2 NSM were surveyed (Treatment = Managed Re-alignment (MRAS) or Natural Saltmarsh (NSM)). At each MRAS or NSM site three fyke nets were deployed in representative saltmarsh creeks, and actively fished for a period of 3 tides. Due to high variability in fish capture between nets and tides, each tide fished or net deployment is considered an independent observation of the fish community. Therefore, for each site there was a minimum sample size of 9 (3* nets *3 tides = 9 net deployments), if logistically feasible more net deployments were conducted.

Fish communities within estuaries are known to be highly seasonal (Koutsogiannopoulou & Wilson, 2007). To monitor seasonal effects on fish communities within MRAS and NSM, the fish community within Steart Marsh (plus local NSM) will be surveyed in May, August and October. All other MRAS and NSM included within this study will be surveyed once during the summer (June-August), when fish abundance is highest within saltmarsh habitats (Koutsogiannopoulou & Wilson, 2007). When comparing between locations, surveys conducted at Steart Marsh in August will be used, as this survey is most comparable to when other MRAS where surveyed (June-August).



Analysis method

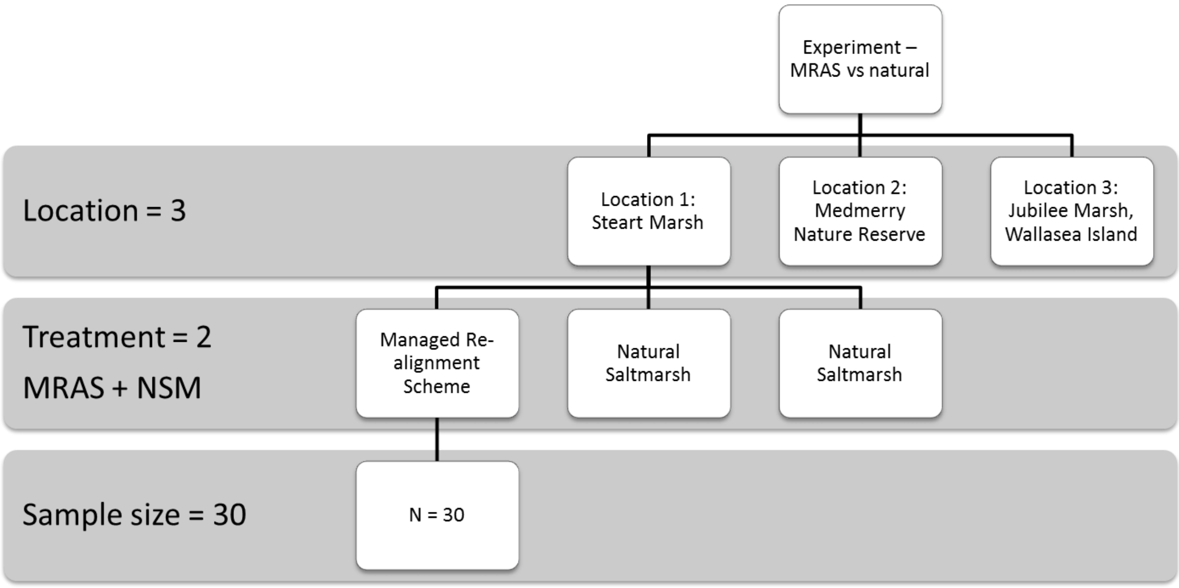
For fyke net catches, Catch Per Unit Effort (CPUE) was calculated for each net deployment by dividing the total catch with the total amount of fishing time (minutes). CPUE was then used to compare; average fish diversity (univariate) and the overall fish community (multivariate) between MRAS and NSM.

To assess differences in fish diversity, The Shannon Weiner index was calculated using CPUE instead of the actual abundance of fish. Due to high variability in fish diversity between samples, all univariate comparisons were conducted using non-parametric Kruskal Wallis test. This test was selected because it is analogous to parametric ANOVA tests, but data do not have to conform to the assumptions of normality and heteroscedasticity (Dytham, 2003).

All multivariate data analyses were conducted within Plymouth Routines in Multivariate Ecology Research (PRIMER) v6 (Clarke and Gorley, 2006). All data analysis was undertaken from a Bray-Curtis similarity matrix derived from log+1 transformed data. PERMANOVA was then used to test for statistical significance between MRAS and NSM. The following were included as fixed variables; Location, Treatment (Managed realignment vs natural). The net deployment was included as a random effect, nested within Survey and Treatment.

A Multi-Dimensional Scaling (MDS) plot was also produced to show similarity in regard to the overall fish community between net deployments.

4.2.d - Method: Differences in fish feeding success between MRAS and NSM



Laboratory methods

Fish stomach weight relative to the overall body weight was used as a proxy for feeding success, i.e. Higher stomach weight indicates a higher abundance of prey was consumed. Digestion time is unknown; however for the purposes of this study stomach weight was considered a good proxy for recent feeding history.

The overall weight of each fish was measured, then the stomach removed and weighed independently.

Analysis methods

All data analyses were conducted within the statistics package of the R project (R Core Team, 2016). Normal data distribution was assessed by visual assessment of normal QQ plot. Heterogeneity of variance was assessed by Breush Pagan Test.

An Analysis of Covariance (ANCOVA) was used to test for statistically significant differences between fish stomach weights between samples sites. Stomach and body weight were correlated, and site of capture was included as a covariate. Inspection of slope intercepts between sample sites was used to assess if stomach weight (proportional to body weight) was lower in MRAS or NSM. When this project is complete, data will be re-analysed using a mixed effect modelling approach, with location set as a “random factor”.

4.2.e - Method: Differences in fish diet between MRAS and NSM

Laboratory methods

The oesophagus and stomach were dissected from each fish. Under light microscopy, all stomach contents were identified to as a low a taxonomic resolution as possible. All prey items were counted, and weighed to 0.001g.

Analysis methods

All multivariate data analyses were conducted within Plymouth Routines in Multivariate Ecology Research (PRIMER) v6 (Clarke and Gorley, 2006). All data analysis was undertaken from a Bray-Curtis similarity matrix derived from log+1 transformed data. PERMANOVA was then used to test for statistical significance between MRAS and NSM. The following were included as fixed variables; Location and Treatment (Managed realignment vs natural).

A Multi-Dimensional Scaling (MDS) plot was also produced to show similarity in regard to diet of 0+ European Bass between individual fish.

4.3 - Results

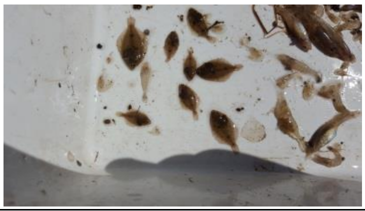
To date four surveys have been successfully completed, with a total of 103 net deployments across these surveys (Table 6). At the MRAS: Medmerry Nature Reserve the survey was not successful, therefore, no comparison in the fish community at Medmerry Nature Reserve and local natural saltmarshes was possible.

Table 8 – Total number of fyke net deployments to assess fish utilization of managed re-alignment schemes (MRAS) and natural saltmarsh (NSM)

Survey Location	Sample site name	Treatment	N
Medmerry**	East Head	NSM	12
	Medmerry	MRAS	2
	Pagham Harbour	NSM	12
Steart Aug 17	Bridgwater Bay SSSI	NSM	9
	Huntspill Nature Reserve	NSM	9
	Steart Marsh	MRAS	9
Steart May 17	Bridgwater Bay SSSI	NSM	6
	Steart Marsh	MRAS	12
Steart Oct 2016	Bridgwater Bay SSSI	NSM	2
	Steart Marsh	MRAS	8
Wallasea July 17	Jubilee Marsh	MRAS	12
	Paglesham Creek (North)	NSM	18
	Paglesham Creek (South)	NSM	18

Across all sampling locations a total of 16 fish species/taxa were captured, including European eel which is of conservation interest in Europe and 9 fish species of commercial interest (Table 7).

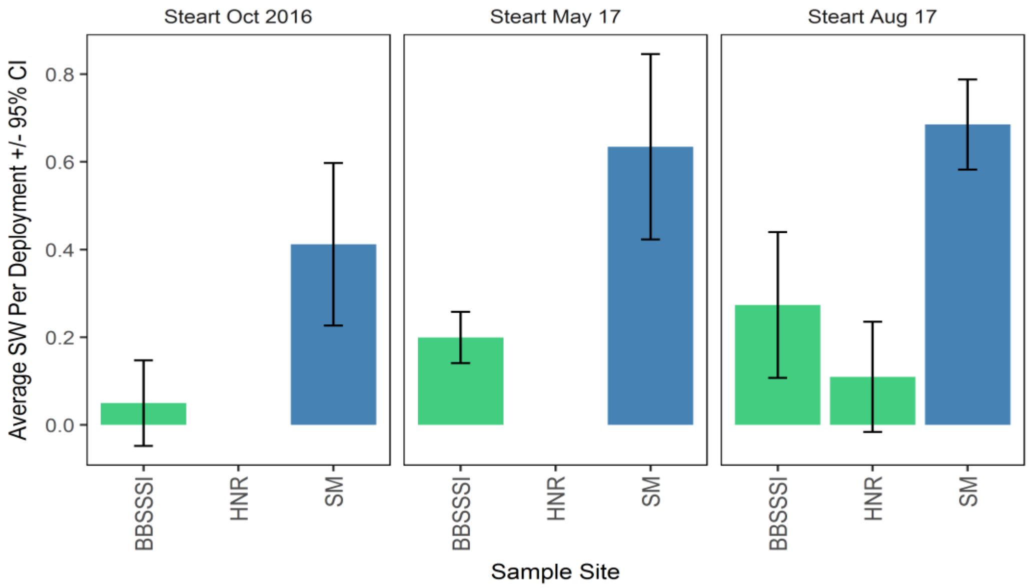
Table 9 - Fish species of commercial and conservation interest captured as part of Managed Re-alignment fish survey

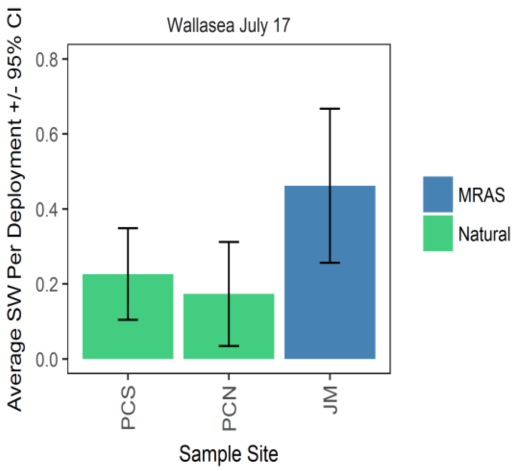
		
European bass (*Dicentrarchus labrax*)	Whiting (*Merlangius merlangus*)	Flat fish: Flounder (*Platichthys flesus*), Plaice (Pleuronectes platessa)
		
Clupieds: Herring (*Clupea harengus*); Sprat (*Sprattus sprattus*)	Grey Mullet: Thinlip (*Chelon ramada*); Thicklip (*Chelon labrosus*); Golden grey (*Chelon aurata*)	European eel (*Anguilla anguilla*)

4.3.a - Differences in fish community between Managed Re-alignment and Natural Saltmarsh

Fish diversity

At each survey, significantly higher fish diversity was recorded in MRAS when compared to local NSM. These results are highlighted within figure 12.





Survey	Chi Squared	df	P
Steart Oct 16	4.3	1	0.04
Steart May 17	5.05	1	0.02
Steart Aug 17 (Overall)	15.5	2	>0.001
SM-BBSSI	6.7	1	>0.01
SM-HNR	12.2	1	>0.001
BBSSI-HNR	4.3	1	0.04
Wallasea Island (Overall)	6.13	2	0.05
JM-PCS	3.7	1	0.05
JM-PCN	4.96	1	0.02
PCS-PCN	0.81	1	0.36

Figure 14 – Fish diversity within Managed Re-alignment (MRAS) and Natural saltmarsh (NSM), plus Kruskall-Wallis test statistics to assess differences in fish diversity between MRAS and NSM.

Overall fish community

A significant difference was found in the fish community between locations and between MRAS and NSM (Figure 13 and Table 8). At each location one to two fish species/taxa dominated the fish community. Differences in the fish community between locations were attributed to the relative abundance of these species.

As stated previously, higher fish diversity was recorded within MRAS when compared to local NSM. Differences in the fish community recorded between MRAS and NSM is attributed to the higher fish diversity within MRAS.

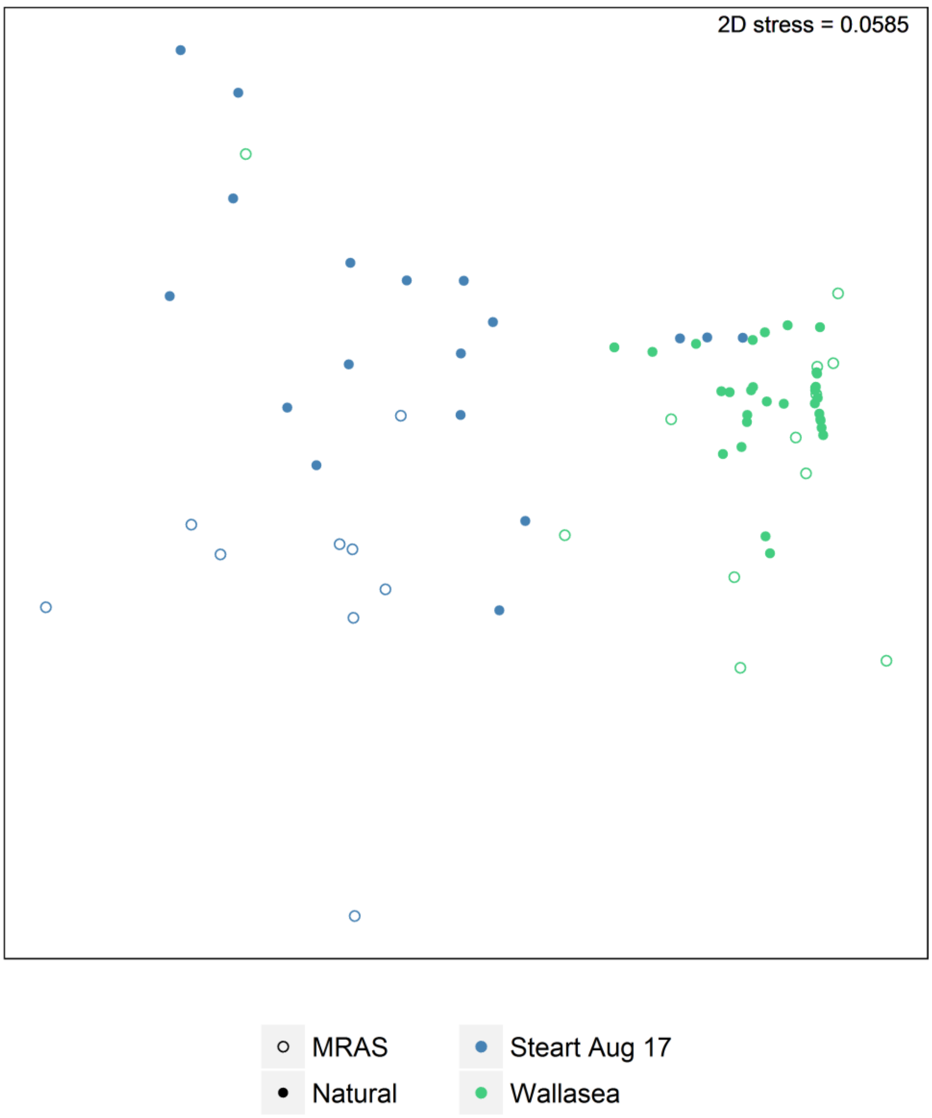


Figure 15 – MDS plot displaying the relative similarity of the fish community captured in fyke net deployments from Managed Re-alignment (MRAS) and Natural saltmarsh at locations: Steart Marsh (august survey) & Wallasea island.

Table 10 – PERMANOVA results, testing for differences in the fish community between MRAS and NSM

Source	d,f	SS	MS	Psuedo F	P(perm)	Unique perms
Location	1	13353	13353	29.335	0.0013	9909
Treatment	1	1570.4	1570.4	3.8687	0.0264	9925
Location * Treatment (interaction)	1	939.74	939.74	2.3213	0.0893	9940
Site(Net) - Nested within Location and Treatment	8	3329.8	416.23	2.2251	0.0068	9905
Residual	42	7856.7	187.06			
Total	53	27049				

4.3.b - Differences in fish feeding success and diet between MRAS and NSM

To date, only suffuicient numbers of 0+ European bass have been dissected. Sufficient numbers of Thinlip Mullet (*Chelon ramada*) and Goby Species (Pomatoschistus spp. + *Gobius niger*) have been preserved for analysis. Analysis of the feeding success and diet of fish species which occupy different feeding niches, such as Thinlip Mullet (Benthic grazer) or Gobies (Omnivorous) will provide further insight into the habitat provision of MRAS when compared to NSM.

Feeding success and diet of 0+ European bass within MRAS vs NSM

To date, 67 0+ European bass have been dissected from locations: Steart Marsh & Wallasea Island (Table 9).

Table 11 - Number of individual 0+ European bass dissected to assess differences in feeding success between Managed Re-alignment (MRAS) and Natural Saltmarsh (NSM)

Survey	Sample Site	NM/MRAS	0+ European Bass
Steart Marsh Aug 17	Bridgwater Bay SSSI	Natural	12
	Huntspill Nature Reserve	Natural	1
	Steart Marsh	MRAS	18
Wallasea Island July 17	Jubilee Marsh	MRAS	8
	Paglesham Creek North	Natural	13
	Paglesham Creek South	Natural	15
Total			67

To meet the assumptions of normality and heteroscedasticity data was log transformed. A highly significant difference was found in 0+ European bass stomach weight between sampling sites: $F_{(5,67)} = 3.9298$; $P = 0.003$. At each survey location the MRAS had the lowest slope intercepts (Table 10 & Figure 14), indicating 0+ European bass stomachs weighed less (relative to overall body weight) within MRAS when compared to local NSM.

Table 12 – Regression coefficients for 0+ European bass stomach weight (relative to body weight) within Managed Re-alignment (MRAS) and Natural Saltmarsh (NSM)

Location	Sample Site	Treatment	Intercept	Slope Coef
Steart Marsh	Bridgwater Bay SSSI	NSM	-1.719441075	0.666916851
	Huntspill Nature Reserve	NSM	-1.82110677	N/A
	Steart Marsh	MRAS	-2.297422957	0.815329366
Wallasea Island	Paglesham Creek South	NSM	-2.019493281	1.202861056
	Paglesham Creek North	NSM	-2.151651381	0.992769714
	Jubilee Marsh	MRAS	-2.422853645	0.85172343

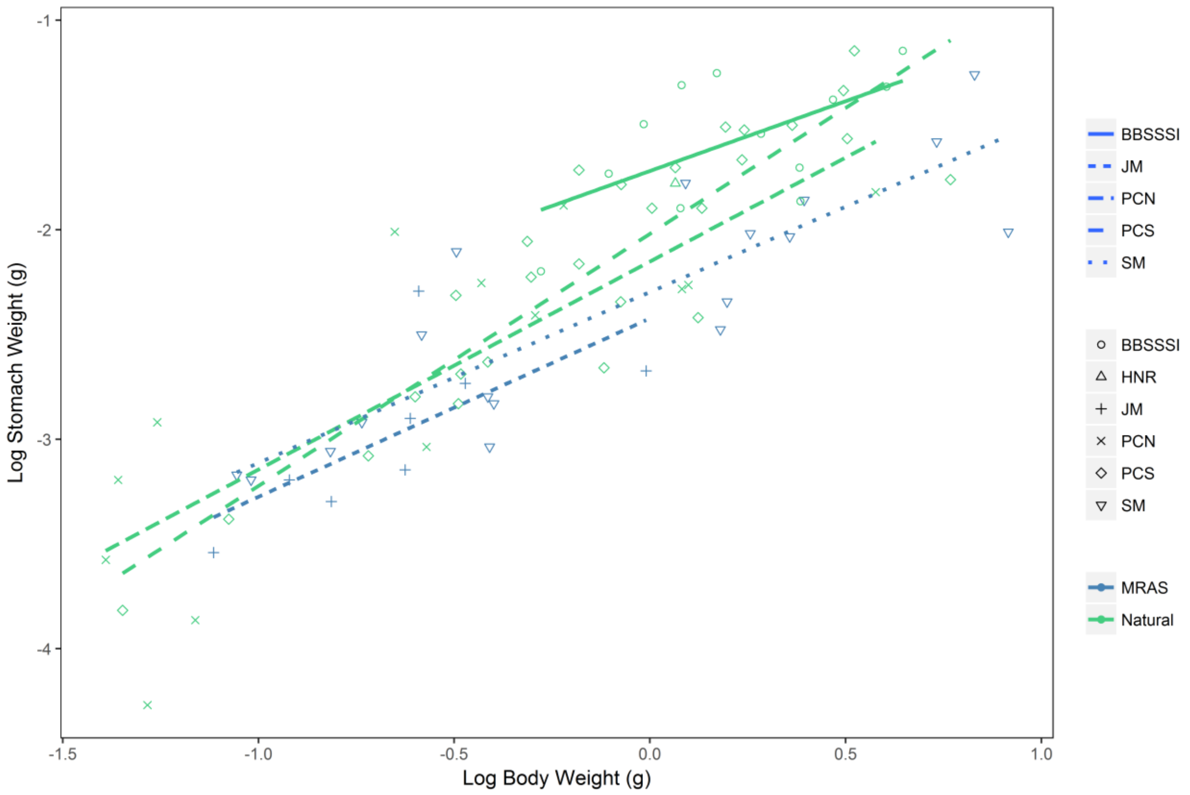


Figure 16 – Regression for 0+ European bass stomach weight (relative to body weight) within Managed Re-alignment (MRAS) and Natural Saltmarsh (NSM). Symbols represent initials of site of capture (Table 5). MRAS displayed as blue; NSM displayed as green

PERMANOVA results indicated a significant difference in 0+ European bass diet when captured within MRAS compared to NSM, as well as significant between site differences.

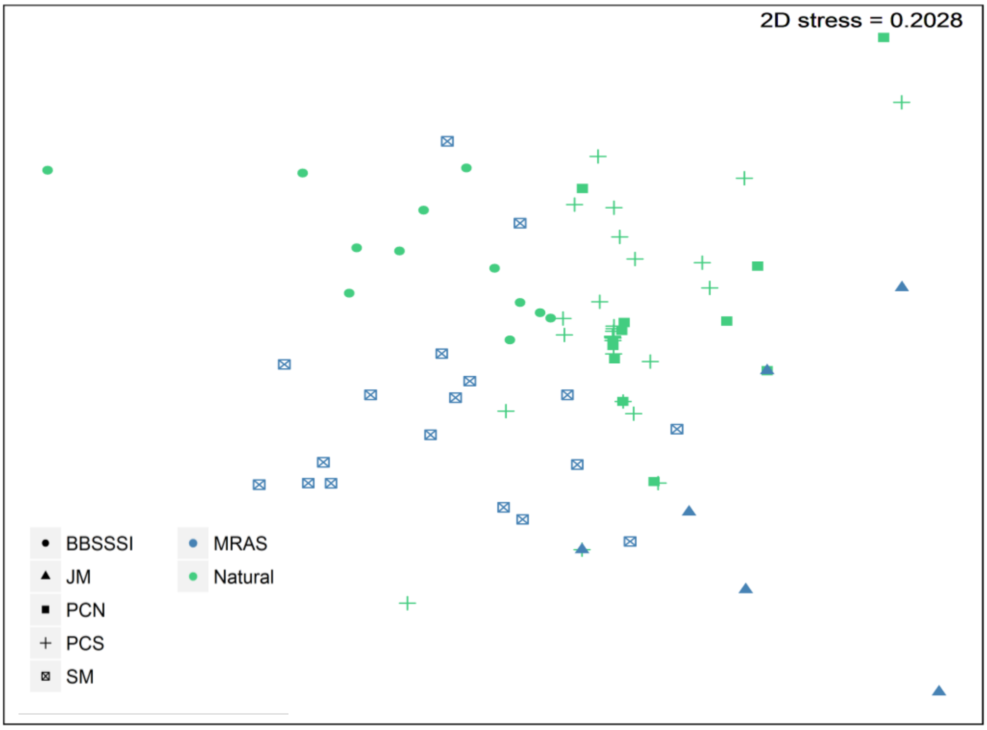


Figure 17 – MDS plot displaying relative similarity of 0+ European bass captured within Managed Re-alignment (MRAS) or Natural Saltmarsh (NSM). Symbols represent initials of site of capture (Table 5). MRAS displayed as blue; NSM displayed as green

Table 13- PERMANOVA results, testing for differences in 0+ European bass diet between MRAS and NSM

Terms added sequentially (first to last)	d,f	SS	MS	Pseudo F	R2	P
Managed Realignment vs Natural	1,68	1.8445	1.84455	8.1404	0.07304	0.001
Sample Site	5,68	9.3619	1.87239	8.2633	0.37069	0.001
Residuals	62,68	14.0486	0.22659		0.55627	

4.4 - Discussion

The results indicate that the MRAS surveyed in this study do provide habitat which is being exploited by numerous fish species of conservation and commercial interest, however the habitat within MRAS is not currently equivalent to that provided within local natural saltmarsh. This has been supported by differences in fish communities captured, as well differences in 0+ European bass diet and lower feeding success within MRAS when compared local NSM.

Higher fish diversity captured within MRAS is currently not fully understood, however further survey work will be conducted in 2018 and 2019 to monitor inter-annual differences, and potentially habitat trajectory as MRAS saltmarsh habitat becomes more established.

4.5 - References

1) Airoldi L, Balata D, Beck MW (2008) The gray zone: relationships between habitat loss and marine diversity and their applications in conservation. Journal of Experimental Marine Biology and Ecology 366:8-15
2) Best M, Massey A, Prior A (2007) Developing a saltmarsh classification tool for the European water framework directive. Marine Pollution Bulletin 55:205-214
3) Byers SE, Chmura GL (2007) Salt marsh vegetation recovery on the Bay of Fundy. Estuaries and Coasts 30:869-877
4) C D (2003) Choosing and using statistics: a biologists guide
5) Colclough S, Fonseca L, Astley T, Thomas K, Watts W (2005) Fish utilisation of managed realignments. Fisheries Management and Ecology 12:351-360
6) Fonseca L, Colclough S, Hughes RG (2011) Variations in the feeding of 0-group bass Dicentrarchus labrax (L.) in managed realignment areas and saltmarshes in SE England. Hydrobiologia 672:15-31
7) Garbutt R, Reading C, Wolters M, Gray A, Rothery P (2006) Monitoring the development of intertidal habitats on former agricultural land after the managed realignment of coastal defences at Tollesbury, Essex, UK. Marine Pollution Bulletin 53:155-164
8) K.R C, R.N G (2006) PRIMER v6: User Manual/Tutorial. PRIMER-E: Plymouth
9) Koutsogiannopoulou V, Wilson JG (2007) The fish assemblage of the intertidal salt marsh creeks in North Bull Island, Dublin Bay: seasonal and tidal changes in composition, distribution and abundance. Hydrobiologia 588:213
10) L E (2014) Managed Re-alignment: A viable long-term coastal management strategy. Faculty of Science and Technology: Bournemouth University. Bournemouth University
11) Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, Kidwell SM, Kirby MX, Peterson CH, Jackson JB (2006) Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312:1806-1809
12) Mossman HL, Davy AJ, Grant A (2012) Does managed coastal realignment create saltmarshes with 'equivalent biological characteristics' to natural reference sites? Journal of Applied Ecology 49:1446-1456
13) Nunn A, Clifton-Dey D, Cowx I (2016) Managed realignment for habitat compensation: Use of a new intertidal habitat by fishes. Ecological Engineering 87:71-79
14) Team RC (2016) A language and environment for statistical computing. In: Computing RFfS (ed)

5 - Estuarine movement and habitat use characteristics of European Bass within Designated Bass Nursery Areas

5.1 - Background Information

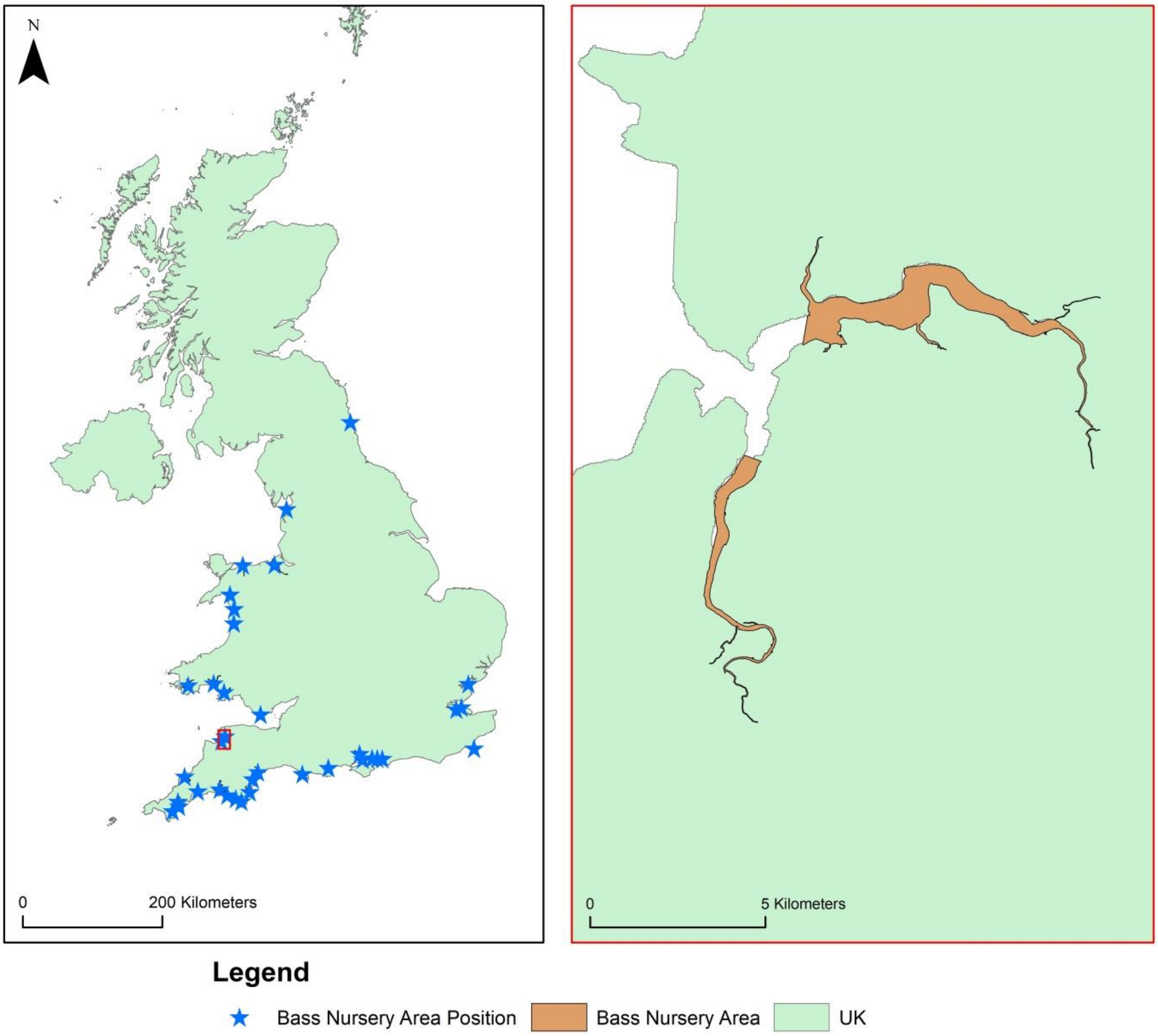


Figure 18 - Designated Bass Nursery Areas (BNAs) in England and Wales (Left). Taw & Torridge designated bass nursery area, Devon (Right)

From 2013-2016 ICES reported a dramatic decline in North Atlantic European bass (*Dicentrarchus labrax*) stocks, and recommended corresponding severe reductions in landings. The reason for declining North Atlantic seabass stock is unclear, however has been linked the high dependency of bass on coastal or estuarine nursery area which are highly impacted by human activities (Pickett & Pawson, 1994; Colclough *et al.,* 2005).

In 1990, 34 Bass Nursery Areas (BNA) - estuaries, power plants and shallow embayments where designated largely within estuaries along the south east, south and south west coast of England and Wales (Figure 16). Within BNAs targeted commercial bass fishing is prohibited for all or part of the year. However, from approximately year 2 adolescent bass may begin feeding in coastal areas outside BNA boundaries where they are vulnerable to capture within either targeted fisheries or as by-catch in non-targeted fisheries.

Very little information is known on juvenile bass movement patterns or habitat preferences. Growing human demand and threats to coastal habitats means there is an increasing need to understand the mechanisms that support juvenile bass development in BNA and surrounding coastal habitats.

To date, studies have suggested bass maintain residency to well defined feeding and spawning grounds (see: Pawson *et al.,* 1987; Pickett *et al.,* 2004; Fritsch *et al.,* 2007; Pawson *et al.,* 2007; Cambiè *et al.,* 2016). However, little information is known on juvenile bass movement within coastal areas or in association to designated Bass Nursery Areas (BNA). Pickett *et al.* (2004) tagged 6438 Bass across 11 BNAs in England and Wales. Of the undersized (defined as <32cm total length by Pickett *et al.* (2004)) bass that were re-captured 88.2% were within 50km of where they were originally tagged. Indicating that undersize/immature Bass are likely to stay regionally faithful to their BNA and/or feeding ground. However, for the purposes of management finer resolution is required.

5.1.a - Project Aims and Research Questions

The project aims are to use acoustic telemetry to record the frequency and duration of immature/undersize European Bass (*Dicentrarchus labrax*) (<42cm) habitat use within, and in coastal areas adjacent to, Bass Nursery Areas (BNA) of Devon, UK.

The proposed project will be able to provide valuable evidence which highlights the efficiency of BNA legislation at protecting immature/undersize bass, as well as provide advice on BNA boundaries or netting practices within close proximity to BNAs. The project may also increase the sustainability of regional bass fisheries within the North Atlantic, as well as help inform estuarine management from a bass conservation perspective.

5.1.b - Research Questions

1) What is the frequency and duration of undersized (<42cm total length) European Bass (*Dicentrarchus labrax*) movement in coastal habitats outside the boundaries of Bass Nursery Areas?
2) Do undersized (<42cm total length) European Bass (*Dicentrarchus labrax*) preferentially exploit specific habitats within Bass Nursery Areas?
3) Is undersized (<42cm total length) European Bass (*Dicentrarchus labrax*) movement significantly different with season, or affected by temperature and/or salinity?

5.2 - Methods

5.2.a - Acoustic Telemetry

Unlike mark recapture studies acoustic telemetry provides continues fine scale monitoring of marked individuals. Acoustic telemetry primarily relies on two parts of equipment; an acoustic tag and receiver (Table 12). An appropriately sized tag is surgically inserted within the body cavity of the host European Bass, and coded to emit a unique “ping”. Tag pings can then be recorded by strategically placed receivers.

Table 14 - Example images of acoustic telemetry equipment

Equipment Name	Example Image
Acoustic tag	
Acoustic receiver (static or mobile)	

5.2.b - Sampling Sites

Acoustic telemetry will be used to track the movement patterns of undersized European bass residing within 2 estuaries and 1 ria system of Devon (Figure 17 & Annex 1). The sampling sites are as follows:

- Taw/Torridge (Estuary),
- Salcombe Harbour (Ria),
- Dart (Estuary)

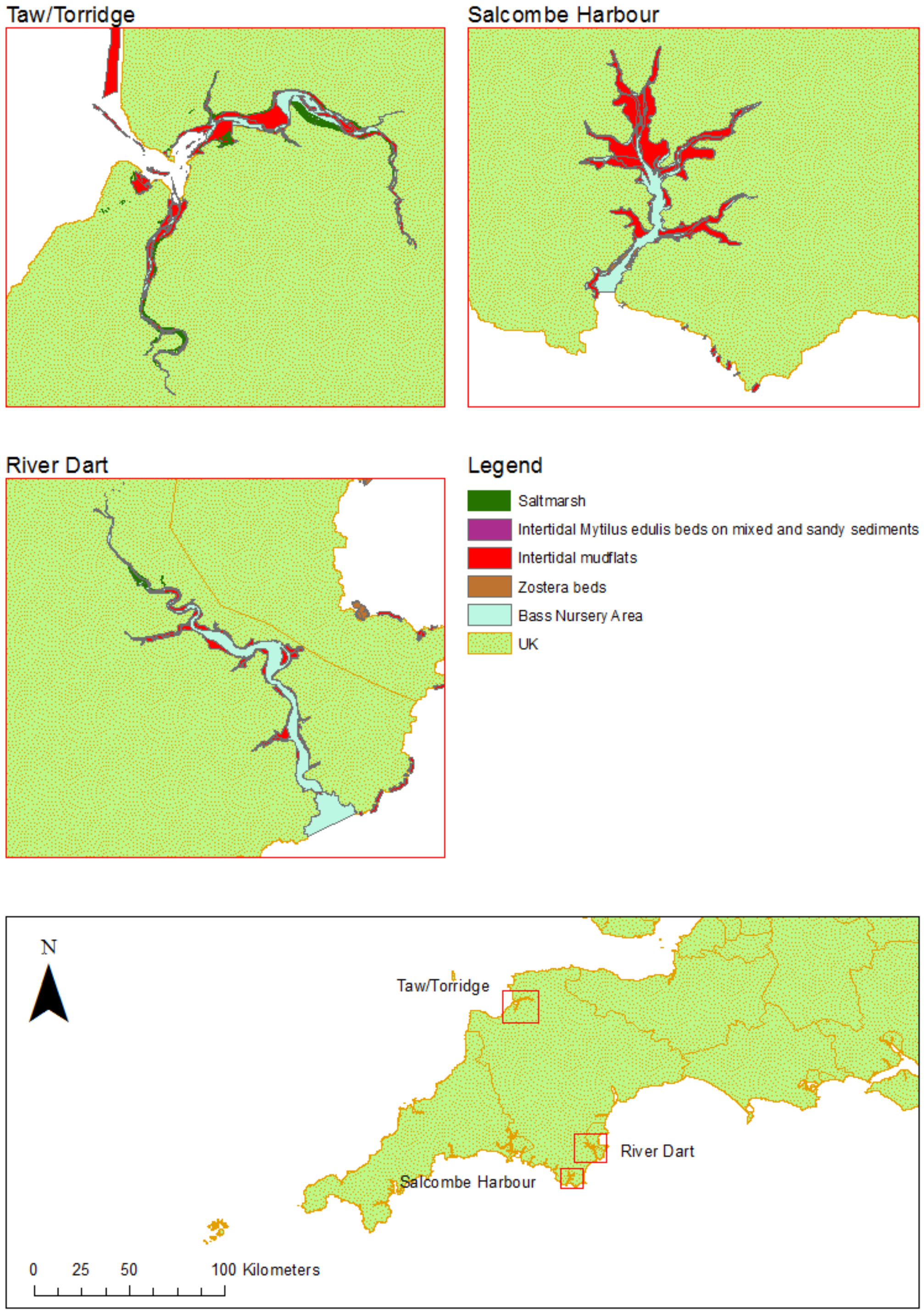
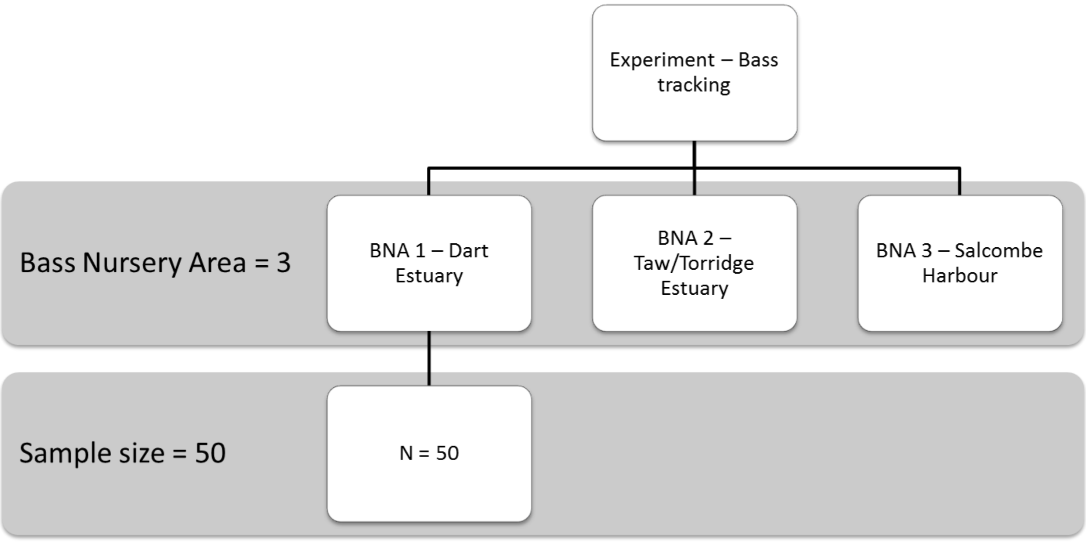


Figure 19 Proposed sampling locations for European Bass tracking project

5.2.c - Experimental design



5.3 - Progress to date

Funding has been secured from the European Maritime and Fisheries Fund (EMFF) to cover project costs. The total funding awarded to the project is £250k.

A total of 84 acoustic receivers, 1 mobile receiver and 150 transmitter tags have been purchased. For the purposes of tagging the European bass within the project, six Plymouth university staff members have been trained and received Personnel Licenses from the UK home office.

A home office project license is also required prior to any fish being tagged. This process is ongoing, however tagging is planned for spring 2018.

5.4 - References

1) Cambiè G, Kaiser MJ, Marriott AL, Fox J, Lambert G, Hiddink JG, Overy T, Bennet SA, Leng MJ, McCarthy ID (2016) Stable isotope signatures reveal small-scale spatial separation in populations of European sea bass. Marine Ecology Progress Series 546:213-223
2) Colclough S, Fonseca L, Astley T, Thomas K, Watts W (2005) Fish utilisation of managed realignments. Fisheries Management and Ecology 12:351-360
3) Fritsch M, Morizur Y, Lambert E, Bonhomme F, Guinand B (2007) Assessment of sea bass (Dicentrarchus labrax, L.) stock delimitation in the Bay of Biscay and the English Channel based on mark-recapture and genetic data. Fisheries Research 83:123-132
4) Pawson M, Pickett G, Kelley D (1987) The distribution and migrations of bass, Dicentrarchus labrax L., in waters around England and Wales as shown by tagging. Journal of the Marine Biological Association of the United Kingdom 67:183-217
5) Pawson M, Pickett G, Leballeur J, Brown M, Fritsch M (2007) Migrations, fishery interactions, and management units of sea bass (Dicentrarchus labrax) in Northwest Europe. ICES Journal of Marine Science: Journal du Conseil 64:332-345
6) Pickett G, Kelley D, Pawson M (2004) The patterns of recruitment of sea bass, Dicentrarchus labrax L. from nursery areas in England and Wales and implications for fisheries management. Fisheries Research 68:329-342
7) Pickett GD, Pawson MG (1994) Sea Bass: Biology, Exploitation and Conservation, MAFF Fisheries Laboratory Lowestoft, UK

5.5 - Annex 1: Proposed Acoustic Receiver Positions

River Dart (Estuary)

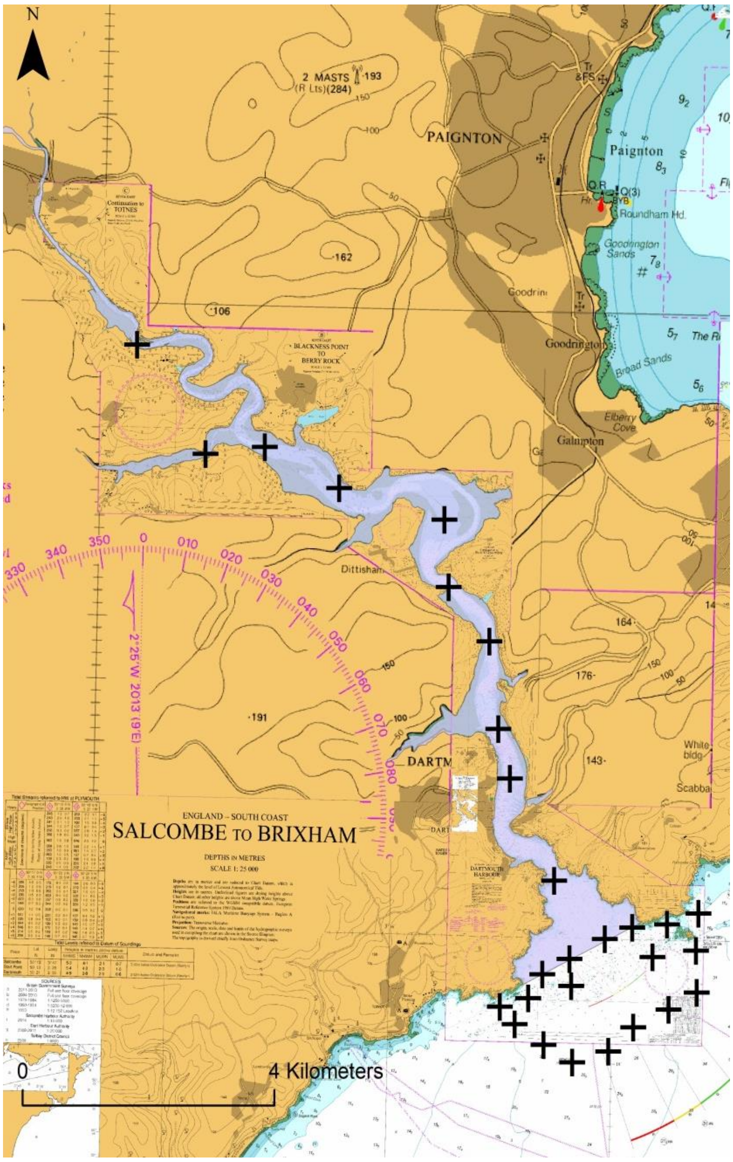


Figure 6 - Proposed Receiver Positions within River Dart Bass Nursery Area and Adjacent Coastal Areas

Salcombe Harbour (Ria)

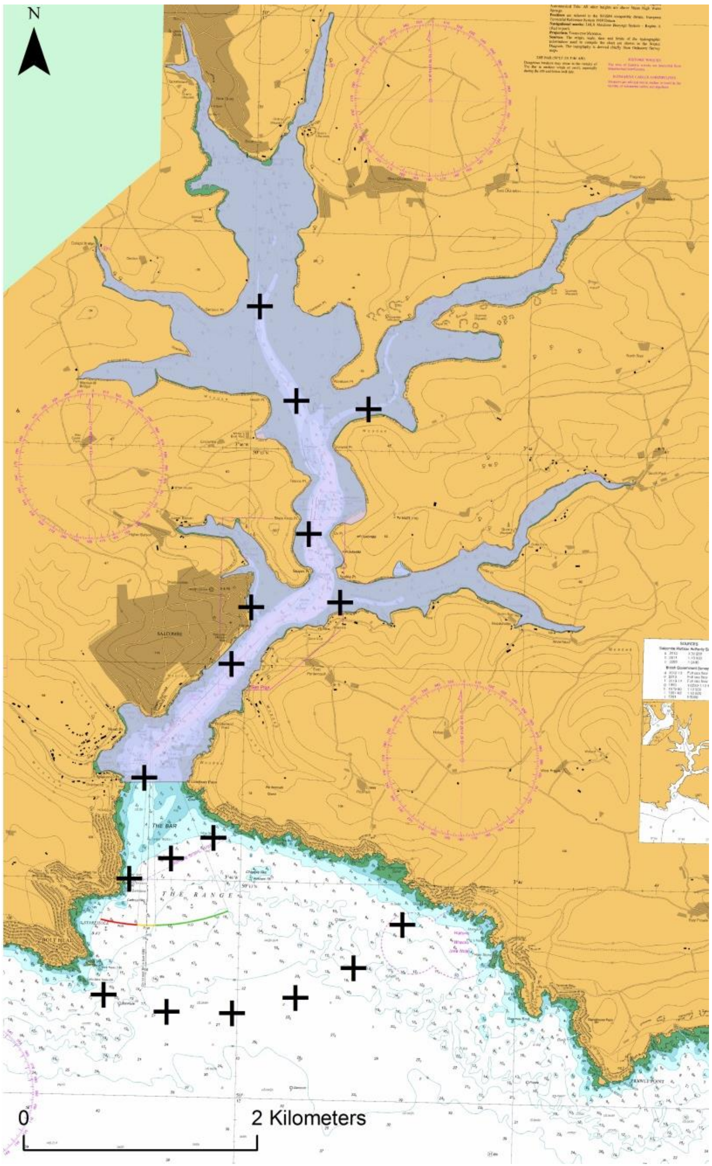


Figure 9 - Proposed Receiver Positions within Salcombe Harbour Bass Nursery Area and Adjacent Coastal Areas

Taw/Torridge (Estuary)

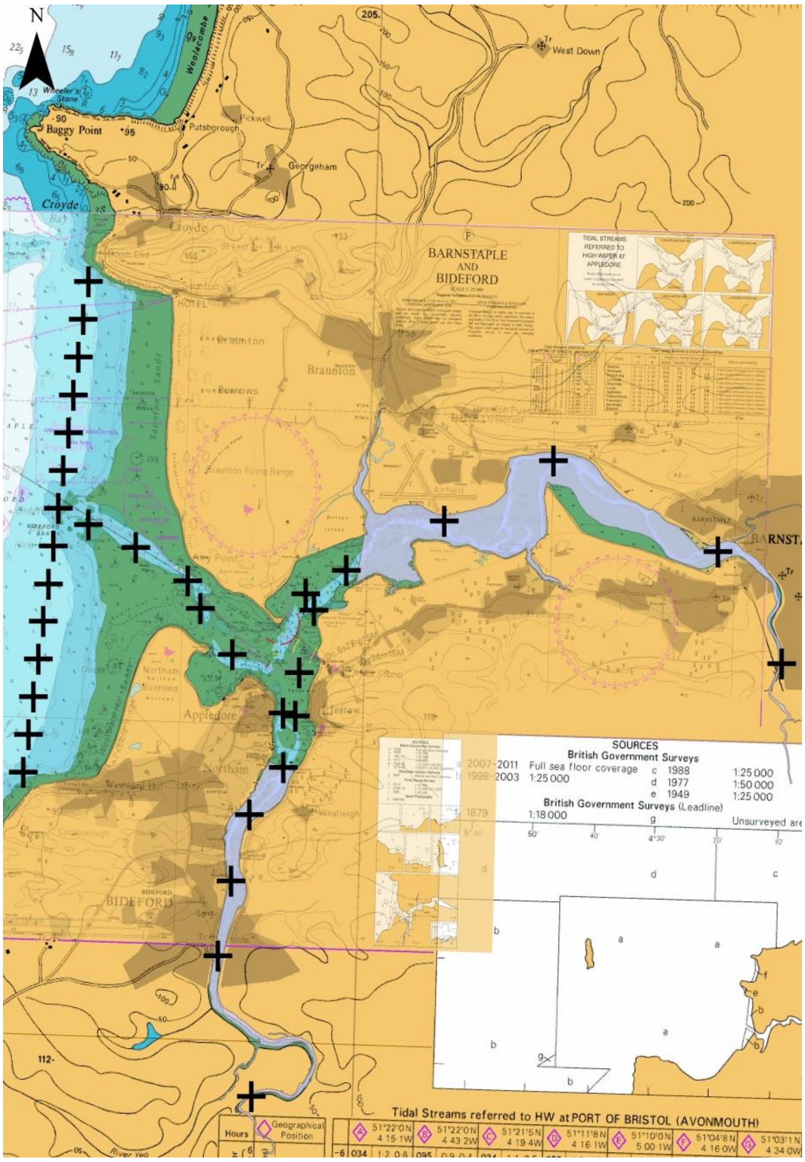


Figure 12 - Proposed Receiver Positions within River Taw & Torridge Bass Nursery Areas and Adjacent Coastal Areas

6 - Exploring alternate management options of static net fishing activities within close proximity to estuaries

6.1 - Background information

6.1.a - Netting Permit Byelaw

Coastal netting is a key fishing activity undertaken by the commercial sector and to a lesser degree by the recreational sector in inshore (<6 nautical miles) coastal areas of the UK. Specifically within the Devon and Severn Inshore Fisheries and Conservation Authority (D&S IFCA) district, Gill and Entangling nets have accounted for 5% of landings weight (Tonnes) and 7% value (£) from 2011-2015. This fishing activity is not targeted however typically captures fin fish such as; Turbot (*Scophthalmus maximus*), Brill (*Scophthalmus rhombus*), Cod (*Gadus morhua*), European Bass (*Dicentrarchus labrax*) and Mullet (*Mugilidae*). The activity takes many forms and is conducted both legitimately and illegally in estuaries and coastal areas of the D&SIFCA district. Estuarine and coastal netting is currently controlled by a range of legislation including legacy byelaws, national and EU conservation measures.

At present the D&S IFCA are reviewing local by-laws which were inherited from the Devon Sea Fisheries Committee (DSFC). Netting activity is currently managed within the D&S IFCA district via existing and inherited by-laws. In 2016 The D&S IFCA published a draft “netting permit byelaw” for public consultation. The draft “netting permit byelaw” will replace five existing byelaws with an overarching Netting Permit Byelaw. Existing byelaws include spatial restrictions such as those highlighted in Table 1, Annex 3. However, the draft netting permit byelaw will also severely limit netting activity within estuaries, to protect vulnerable fish stocks. The proposed byelaw aims to ensure a balance between the needs of the person(s) netting and the requirement to secure sustainable marine and local socio-economic environments. The byelaw operates through a permit scheme which allows the D&S IFCA to introduce flexible management measures which can control netting fisheries within their district. These permitting conditions include; catch, gear, spatial and time restrictions, which are to be reviewed periodically using the best available evidence, including data collected by; the D&S IFCA, Statutory Nature Conservation Bodies and permit holders. The D&S IFCA have spatially and temporally defined areas, each of which has specific permitting conditions (see table 1 & Figure 1). In particular, the areas defined within annex 3 otherwise known as “coastal areas”, are focused in areas influenced by freshwater input, which may act as migratory corridors for salmonids, (D&S IFCA, 2016) and extend from the lowest astronomical tide to 1 nautical mile. Within these areas the byelaw stipulates; a permit holder or named representative can only deploy a net where:

- The headline of the fixed net is set at least 3 metres below the surface of the water at any state of the tide;

A 3m headline depth on all fixed nets is presently enforced to mitigate by-catch of migratory salmonids (See-Migratory Salmonids)

- The net used is a seine net; or
- The net used is a drift net.

Table 15 -Permit conditions of D&S IFCA netting permit byelaw

Annex Name	Permitting Conditions

Annex 1 - MCZ	When fishing in the district a permit holder or named representative, is not authorised to retain on board or have in their possession any catch that does not comply with any of the catch restrictions set out in sections 1.2 – 1.5.3. Within the areas below this includes any European Spiny Lobster.
Annex 2 - Estuaries	A permit holder or named representative, is not authorised to use any nets within the area to the landward side of the lines drawn across the estuaries listed in this annex, unless the permit holder uses a seine net for the purpose of catching sand eels and: a) The net measures no longer than 20 metres in length, b) All species caught other than sand eel are returned immediately to the water, c) The size of mesh does not exceed 20mm and, d) The net being used by a Category two permit holder or named representative is tagged with a tag issued by the Authority to the permit holder.
Annex 3 - Coastal areas	A permit holder or named representative, is not authorised to use any fixed nets within the areas enclosed within the following positions within one nautical mile of the shore as defined by the lowest astronomical tide, unless the headline of the fixed net/s is set at least 3 metres below the surface of the water at any state of the tide. Where estuary boundaries exist within these coastal areas, the fixed net provisions apply seaward of the estuary boundary lines.
Annex 4 – Lundy MCZ	A permit holder or named representative is not authorised to use a net within the area of the Lundy - No Netting Area.
Annex 5 – Temporal Restrictions	A permit holder or named representative is not authorised to use any fixed nets in the areas defined in this annex unless authorised to do so under section 4.1 of the Permit Conditions.

The Environment Agency (EA) have submitted a formal response to the D&S IFCA regarding the netting permit byelaw, within which evidence was presented that a 3m headline depth was not sufficient mitigation to limit migratory salmonid by-catch in costal net fisheries and may result in a significant bycatch of Atlantic Salmon (*Salmo salmar*) and Sea trout (*Salmo trutta*). Coastal net fisheries targeting sea trout, European Bass (*Dicentrarchus labrax*) and Grey mullet (*Chelon labrossus*) (Potter & Pawson, 1991) may result in incidental capture/bycatch of adult salmon (Summer, 2015). Adult sea trout may also be incidentally captured within Atlantic Salmon, European Bass, Grey Mullet, Sole (*Solea solea*) and Plaice (*Pleuronectes platessa*) fisheries (Summer, 2015). However, the examples presented by the EA are either from estuaries, rather than coastal environments or from coasts with very few, if any, spatial netting measures such as those already in place in the D&S IFCA district. The EA have proposed a 5m headline depth in coastal static net fisheries would mitigate bycatch risks to migrating salmonids and should be included within the D&S IFCA netting permit byelaw.

6.1.b - Migratory salmonids and movement in coastal areas

Atlantic salmon is a designated Annex 2 species under the European Commission (EC) Habitats Directive, and identified as a qualifying feature of Dartmoor Special Area of Conservation (SAC) as well as occurring, but not as a qualifying feature, within both Exmoor Heaths (Somerset) and River

Axe (Devon & Dorset) SACs. Sea trout (*Salmo trutta*) is not designated under the EC habitats directive however does have significant economic value in both commercial and recreational fisheries. Summer (2015) provides a detailed account of salmonid movements within coastal waters and the potential impacts of coastal net fisheries. Various studies (e.g. Holm *et al.,* 2006; Sturlargsson *et al.,* 2009; Davidson *et al.,* 2013; Godfrey *et al.,* 2014) have indicated Atlantic salmon are highly associated with shallow water depths (<5m) whilst in coastal areas, but take irregular but frequent "deeper" dives. Godfrey *et al.* (2014) fitted 50 adult Salmon with "pop up" satellite tags which recorded depth. Of the 50 tags, 34 yielded data which suggested the tagged salmon spent 72–86% of time at 0–5 m, 79–90% at 0–10 m, and 6–9% of time at 20 m depth. Guðjónsson *et al.* (2015) retrieved 7 data storage tagged (DST) Salmon, which recorded temperature and depth for a period of approximately 1 year. Similar to Godfrey *et al.* (2014) the results indicated diving behaviour was highly varied between individual, however most tagged fish remained highly associated to shallow water depths (0-6m). Data concerning sea trout diving behaviour is less available. Rikardsen *et al.* (2007) retrieved 8 DST tagged sea trout released in a Norwegian fjord, concluding sea trout were highly associated with shallow water depths spending 97-93% of the time in water <3m over a liberty period of 1-40 days.

If incidentally captured within static nets, physical damage is likely however will vary with; gear type, retention time, species and handler (Summer, 2015). Damage from nets could result in any of the following; mucous and scale loss, net marks, abrasion, fin tear and loss, visceral damage, haemorrhaging and barotrauma (Potter & Pawson, 1991; Chopin & Arimoto, 1995; Makinen *et al.,* 2000; Vander haegen *et al.,* 2004; Baker *et al.,* 2013; Nguyen *et al.,* 2014). Upon contact with nets, salmon survival rates are thought to be highly varied, however is lower than in fish that do not encounter nets (Summer, 2015). Furthermore, evidence has shown that delayed mortality as a result of entanglement, is estimated to be 49% and 43% in Chinook Salmon (*Oncorhynchus tshawytscha*) when compared to control fish (Vander Haeger *et al.,* 2004). Similarly Baker & Schindler (2009) recorded pre-spawning mortality of gillnet injured Sockeye Salmon (*Oncorhynchus nerka*), which naturally escaped from downstream commercial fisheries, was significantly greater than that of uninjured control fish (51% compared to 6%). With the incidence of past entanglement in commercial gillnets given as 11, 18 and 28% in a three year study, this could represent a significant reduction in the reproductive capacity by the stock. See Summer (2015) for a more detailed review, however, the evidence presented above suggests the survival and reproductive fitness of salmonids which have encountered fishing nets can be significantly reduced. Therefore, the EA argue management measures which minimise the risk of incidental capture of Salmonids by non-target fisheries is an important component in their conservation effort.

6.1.c - Project Aims

Evidence submitted within Summer (2015), and references therein, suggest salmonids are highly associated with shallow water (0-5m) and that migrations and reproduction may be negatively affected by accidental contact with coastal net fisheries. However, there is no direct evidence (e.g. netting surveys) which demonstrate an increase in headline depth to 5m would significantly decrease salmonid bycatch. Furthermore, an increase in headline depth to 5m may decrease the catch efficiency of static nets on targeted species e.g. European bass and grey mullet. D&S IFCA are therefore interested in conducting a project which will directly measure the targeted catch and bycatch rates of static nets set up at different headline depths within the D&S IFCA district.

6.1.d - Research Questions

1) Does increasing the headline depth of static nets from 3m to 5m significantly decrease bycatch of Atlantic salmon and sea trout?

2) What are the economic implications, in terms of catch loss, for static net fishermen if headline depth is increased from 3 – 5m?

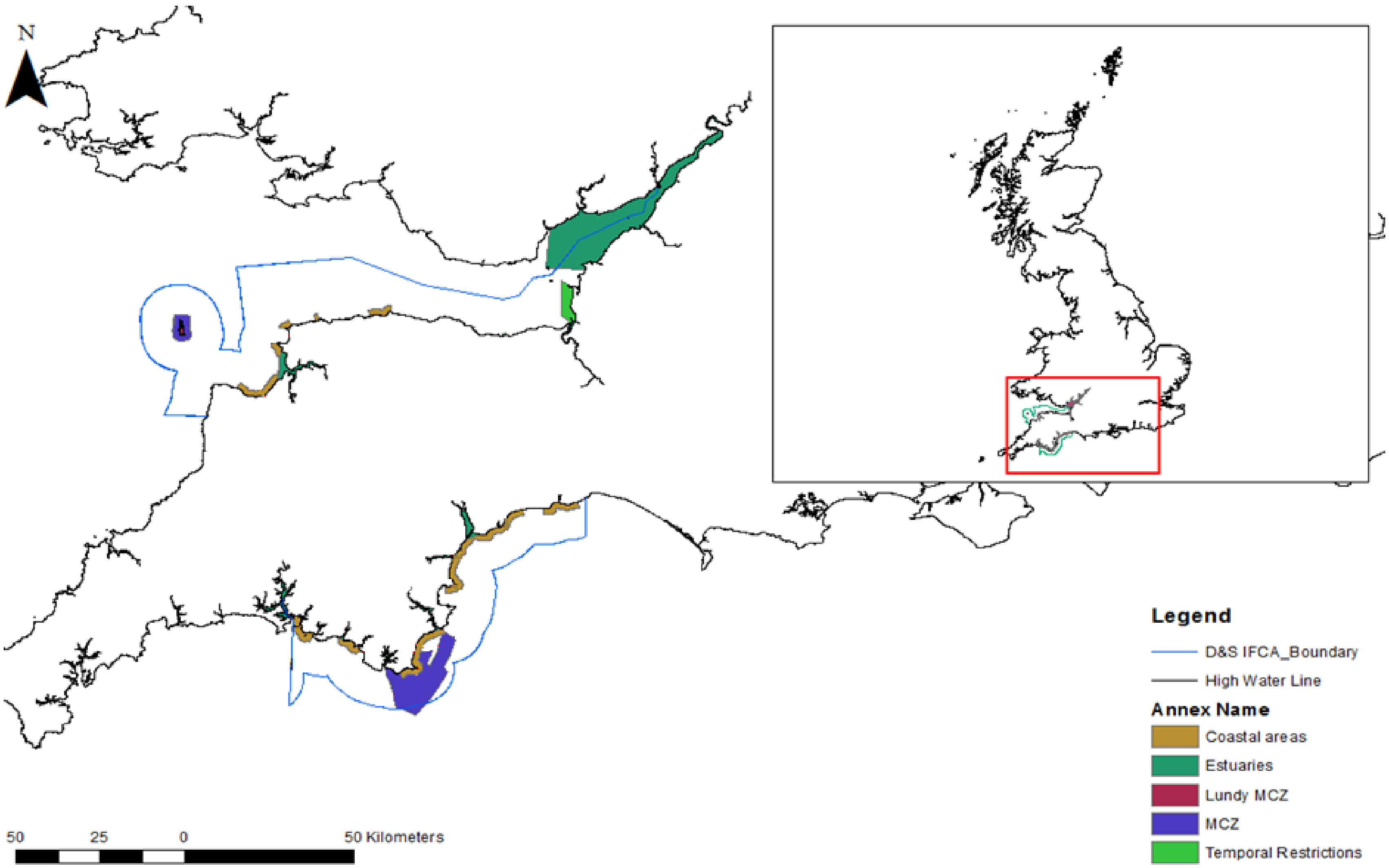


Figure 20 - Spatial areas as defined within permitting conditions of the D&S IFCA permit byelaw. Red circles indicate potential target estuaries or ria systems sampled to assess the effect of 3 and 5m headline depths on migratory salmonid bycatch and catch efficiency of net fishing

6.2 - Method

Industry relevant static gill nets of a standard dimension and mesh size, or within a standardized range, will be deployed within the D&S IFCA district.

Specific sampling locations have yet to be defined; however will be standardized for depth and surrounding habitats.

At each sampling event (see figure 2), 2 gill nets will be deployed in close proximity and left actively fishing for an industry relevant standardized soak time (e.g. 24 hours). Each net will be set at one of the following headline depths:

1) 3m (static net b, Figure 2)
2) 5m (static net c, Figure 2)

The catch from each net will be identified, enumerated and measured (total length, mm). During each sampling event the net setup (figure 2) will be deployed for a minimum of 3 successive standardized soak times.

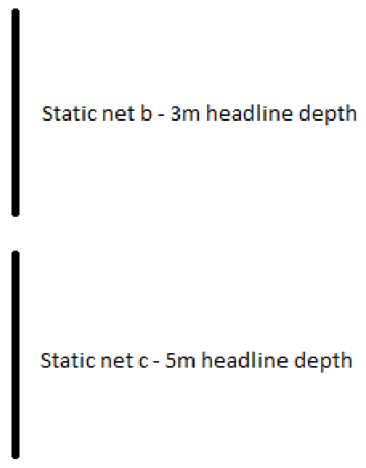
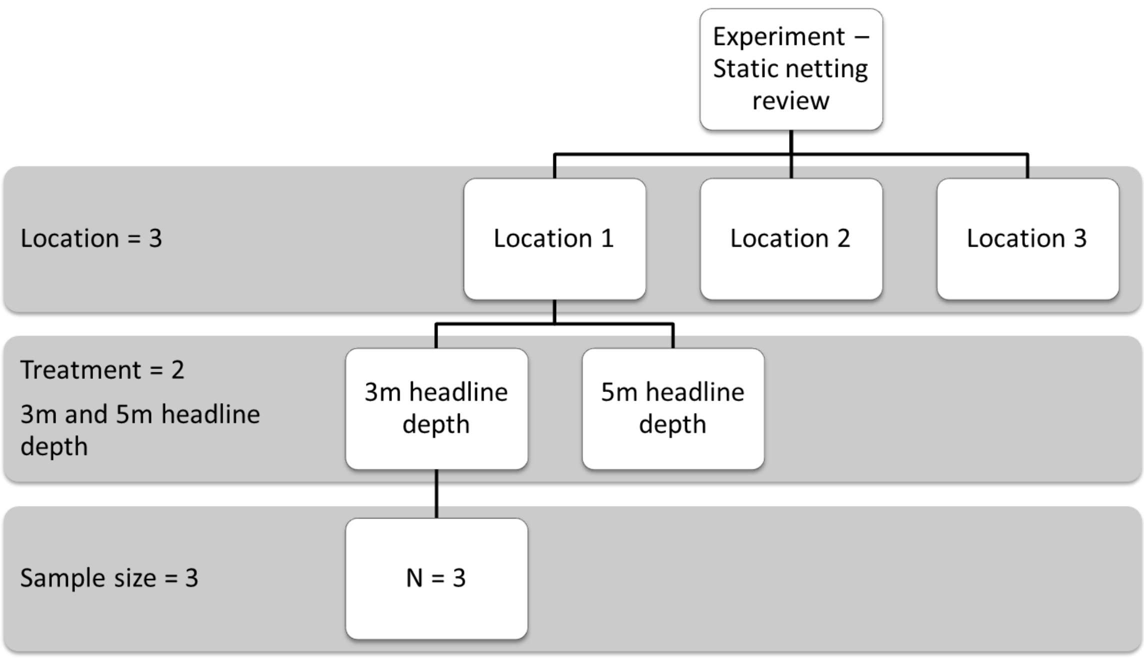


Figure 21 - proposed experimental net configuration to assess the impact of net headline depth on migratory salmonid bycatch

Sampling will specifically target both migratory salmonid spawning/return migrations. Sampling is likely to be from March-November, however the specific dates of sea trout and salmon runs within the D&S IFCA district is likely to vary between rivers and due to environmental fluctuations. Local knowledge will be sought to time sampling in conjunction with salmon and sea trout runs.

6.2.a - Experimental design



6.2.b - Data analyses

1) Does increasing the headline depth of static nets from 3m to 5m significantly decrease bycatch of Atlantic salmon and Sea trout?

Univariate statistics, such as Analysis of Variance (ANOVA), can be used to determine if the abundances of Atlantic salmon (*Salmo salmar*) and sea trout (*Salmo trutta*) are significantly lower in catches from nets set with a 3 or 5m headline depth

2) What are the economic implications, in terms of catch loss, for static net fishermen if headline depth is increased from 3 – 5m

Univariate statistics, such as Analysis of Variance (ANOVA), can be used to compare overall finfish abundance, as-well as for specific species

6.3 - Progress to date

To date, other than planning the scope of the project no progress has been made with this project.

6.4 - References

1. Devon and Severn Inshore Fisheries and Conservation Authority (2016) Netting Permit Byelaw. In: Stamp T (ed), Email communication
2. Baker MR, Kendall NW, Branch TA, Schindler DE, Quinn TP (2011) Selection due to nonretention mortality in gillnet fisheries for salmon. Evolutionary applications 4:429-443
3. Baker MR, Swanson P, Young G (2013) Injuries from non-retention in gillnet fisheries suppress reproductive maturation in escaped fish. PLoS one 8:e69615
4. Chopin FS, Arimoto T (1995) The condition of fish escaping from fishing gears—a review. Fisheries research 21:315-327
5. Davidsen JG, Rikardsen AH, Thorstad EB, Halttunen E, Mitamura H, Præbel K, Skarðhamar J, Næsje TF (2013) Homing behaviour of Atlantic salmon (S almo salar) during final phase of marine migration and river entry. Canadian Journal of Fisheries and Aquatic Sciences 70:794-802
6. Godfrey JD, Stewart DC, Middlemas SJ, Armstrong JD (2014) Depth use and migratory behaviour of homing Atlantic salmon (Salmo salar) in Scottish coastal waters. ICES Journal of Marine Science: Journal du Conseil:fsu118
7. Guðjónsson S, Einarsson SM, Jónsson IR, Guðbrandsson J (2015) Marine feeding areas and vertical movements of Atlantic salmon (Salmo salar) as inferred from recoveries of data storage tags. Canadian Journal of Fisheries and Aquatic Sciences 72:1087-1098
8. Holm M, Jacobsen JA, Sturlaugsson J, Holst JC (2006) Behaviour of Atlantic salmon (Salmo salar L.) recorded by data storage tags in the NE Atlantic–implications for interception by pelagic trawls. In: ICES (ed) ICES. ICES, ICES
9. Mäkinen TS, Niemelä E, Moen K, Lindström R (2000) Behaviour of gill-net and rod-captured Atlantic salmon (Salmo salar L.) during upstream migration and following radio tagging. Fisheries Research 45:117-127
10. Nguyen VM, Martins EG, Robichaud D, Raby GD, Donaldson MR, Lotto AG, Willmore WG, Patterson DA, Farrell AP, Hinch SG (2014) Disentangling the roles of air exposure, gill net injury, and facilitated recovery on the postcapture and release mortality and behavior of adult migratory Sockeye Salmon (Oncorhynchus nerka) in freshwater. Physiological and Biochemical Zoology 87:125-135
11. Potter E, Pawson M (1991) Gill netting. Citeseer, Ministry of Agriculture, Fisheries and Food
12. Rikardsen AH, DISERUD OH, Elliott J, Dempson JB, Sturlaugsson J, JENSEN AJ (2007) The marine temperature and depth preferences of Arctic charr (Salvelinus alpinus) and sea trout (Salmo trutta), as recorded by data storage tags. Fisheries Oceanography 16:436-447
13. Sturlaugsson J, Gudbjornsson S, Stockhausen H (2009) Orientation of homing Atlantic salmon (Salmo Salar L.) mapped in relation to geomagnetic fields. ICES CM
14. Summer (2015) Review of Protection Measures for Atlantic Salmon and Sea Trout in inshore waters. In: Agency E (ed) Environment Agency. Environment Agency, Environment Agency
15. Vander Haegen G, Ashbrook C, Yi K, Dixon J (2004) Survival of spring Chinook salmon captured and released in a selective commercial fishery using gill nets and tangle nets. Fisheries Research 68:123-133

7- Timeline of Future Planned work

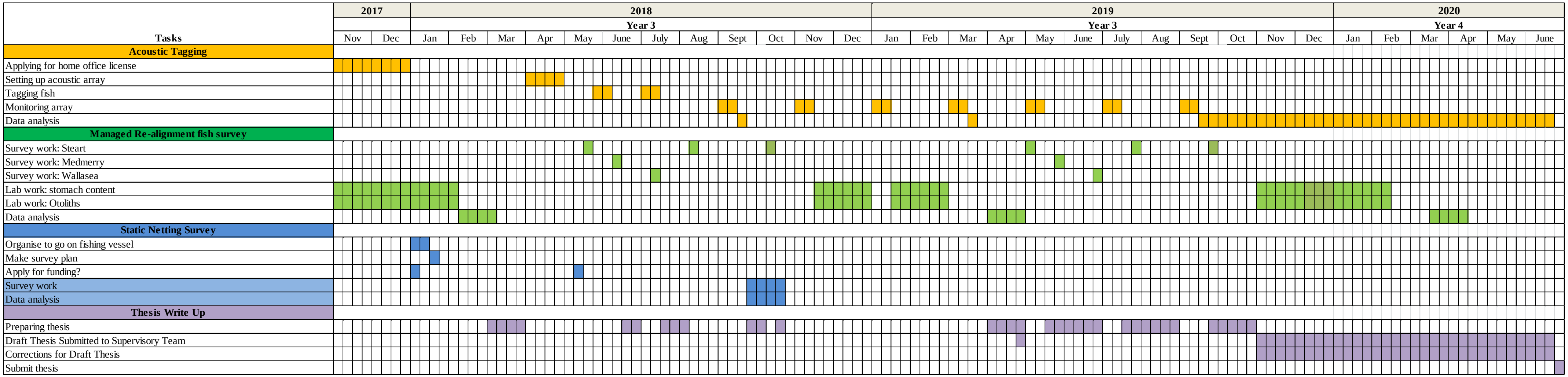


Figure 22 – GANTT chart detailing planned works associated with PhD: The Ecology and Distribution of European Bass in the southwest UK

Due to unforeseen delays in the project, the D&S IFCA have agreed to provide financial support to extend the PhD to June 2020. The GANTT chart above (Figure 20) reflects the extended duration of the PhD.