Sussex IFCA
Inshore Fisheries and Conservation Authority

Supporting Sustainable Sepia Stocks

Report 2: The English Channel fishery for common cuttlefish (*Sepia officinalis*)

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Summary

Historically, the common cuttlefish (*Sepia officinalis*) had little fishing effort expressed on the English Channel population. In recent years, this has changed dramatically and now cuttlefish represent one of the most commercially important cephalopod fisheries in European waters. Cuttlefish are targeted throughout their natural range by a number of different nations. The UK cuttlefish fishery is of significant importance to the UK fishing industry both in terms of economic value and yield.

The UK cuttlefish fishery can be separated into two distinct fisheries. The offshore fishery, which is predominately formed of vessels using towed fishing gears that target cuttlefish in their overwintering grounds and the inshore fishery that utilises static gears such as nets and traps during the spring/summer to catch cuttlefish once they return to their breeding grounds.

A recent rise in the UK market value of cuttlefish has led to increasing rates of exploitation. In 2017, the total landings of cuttlefish to UK ports was 7182 tonnes and represented an increase of 98% over the last decade. The total revenue generated by the first sales of these cuttlefish was £25.69 million, this is an increase of 383% on the total revenue generated in 2008.

The UK cuttlefish fishery is dominated by the activities of the offshore fleet. These vessels account for over 94% of all cuttlefish landings to UK ports. In contrast, the landings Sussex cuttlefish fishery is predominately from the cuttlefish trap sector. The exploitation rate of the offshore cuttlefish fisheries is increasing, while the exploitation of cuttlefish by the inshore fleet is decreasing. This is unsurprising as the inshore fishery is entirely dependent on the number of individuals that escape exploitation by the offshore beam and otter trawlers that target cuttlefish at their over wintering grounds.

Due to the low effort that was historically applied to the catching of cuttlefish by the UK and European fishing industries, very little management has been applied to the cuttlefish fisheries that operate in the English Channel and around the coast of the UK. There is at present, no total allowable catch (TAC) quota or minimum conservation reference size (MRCS) applied to the landings of the common cuttlefish. Although some technical measures and effort control is applied to the activities of the inshore fleet, this is not mirrored in the management of the offshore fleet.

This report describes the fishing pressure on the English Channel stock. This report was written as part of the Fisheries Local Action Group (FLAG) funded project; Supporting Sustainable Sepia Stocks. The other outputs from this project are:

- The biology and ecology of the common cuttlefish (report).
- Assessing the efficacy of egg receptors within fishing traps used to target common cuttlefish (report).
- Egg survival and maternal investment (report).
- Mitigating cuttlefish egg mortality post fishing activity (poster).
- Supporting sustainable sepia stocks (presentation).

Acknowledgements

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Introduction

Despite being one of the most important cephalopod fisheries in Europe, both in terms of landings and economic value, cuttlefish fisheries remain relatively unregulated with no Total Allowable Catch (TAC) quota or Minimum Conservation Reference Size (MRCS) attached to the species (Bloor, 2012; Bloor, *et al,* 2013; Keller, *et al*, 2014). The English Channel cuttlefish population is indirectly protected by a range of measures, designed to stop the over exploitation of the marine environment. In the UK, some of the inshore cuttlefish fisheries are governed by technical measures and effort restrictions. These measures are applied by the respective regional Inshore Fisheries and Conservation Authorities (IFCAs). However, no such directed management currently exists for the offshore fisheries.

Cuttlefish have a short lifespan of between 18 and 24 months which is terminated by a reproduction event followed by mass mortality of the adult stock (Bloor *et al,* 2013; Guerra*,* 2006). The semelparous or intermittent terminal spawning nature of cuttlefish reproduction results in much of the exploitation of this species occurring before the opportunity to contribute toward the recruitment of future generations.

The English Channel cuttlefish population undertake seasonal migrations, the resulting aggregations are driven by both the temperature tolerance of cuttlefish and their breeding strategy. Unfortunately,

these aggregates are formed of different age classes and allow for high levels of exploitation with relatively low levels of effort (Bloor, 2012; Bloor *et al*, 2013; Wang *et al,* 2003).

Throughout their short life cycle, cuttlefish are exploited by a number of different fisheries using a range of different fishing gears and techniques. The multifaceted exploitation, targeting large aggregates combined with the semelparous or intermittent spawning nature of their reproduction, places them at risk of over exploitation (Richardson *et al*, 2018).

A large variation in cuttlefish development is seen across the population with individuals and different cohorts of the same year class, growing and maturing at different rates. This ontogenic irregularity, often driven by variance in environmental parameters, can generate high annual variation in recruitment. This inherent variation can create difficulties in accurately estimating the population size and structure. The variation in recruitment combined with the multifaceted exploitation creates complexity in the management of the English Channel cuttlefish fishery (Gras *et al,* 2014; Royer *et al,* 2006; Richardson, *et al,* 2018).

Importance of fishery

The cuttlefish fishery is the most important cephalopod fishery in the North East Atlantic region, both in terms of yield and economic value (ICES 2017). Other cephalopod fisheries within the region include long and short fin squid and octopuses. The English Channel represents one of the most important fishing grounds of *S. officinalis* in European waters, with 60% of all catches in ICES waters between 1993 and 2003 occurring in ICES areas VIId and VIIe (Royer *et al,* 2006).

A drop in demersal finfish stocks in the region, combined with an increase in the economic value of *S. officinalis,* has led to an increase in the exploitation of this species (MMO Landings Data 2008-2017; Molfese *et al,* 2014; Payne, *et al,* 2006).

Market value

The market value of cuttlefish in the UK across all gears and ports has increased by over £2.00 Kg^{-1} from £1.47 Kg^{-1} to £3.58 Kg^{-1} between 2008 and 2017, with some variation across those years (Figure 1). This figure is a gross calculation and doesn't account for variation in value across different gears or ports of landing.

Although the market value of cuttlefish landed to Sussex ports is lower than the market value across the entire UK, it closely follows the trend. Sussex cuttlefish fishers have seen an increase in the value

of their catch of £1.64 Kg^{-1} over ten years, rising from £1.36 Kg^{-1} in 2008 to £3.00 Kg^{-1} in 2017 (Figure 1).

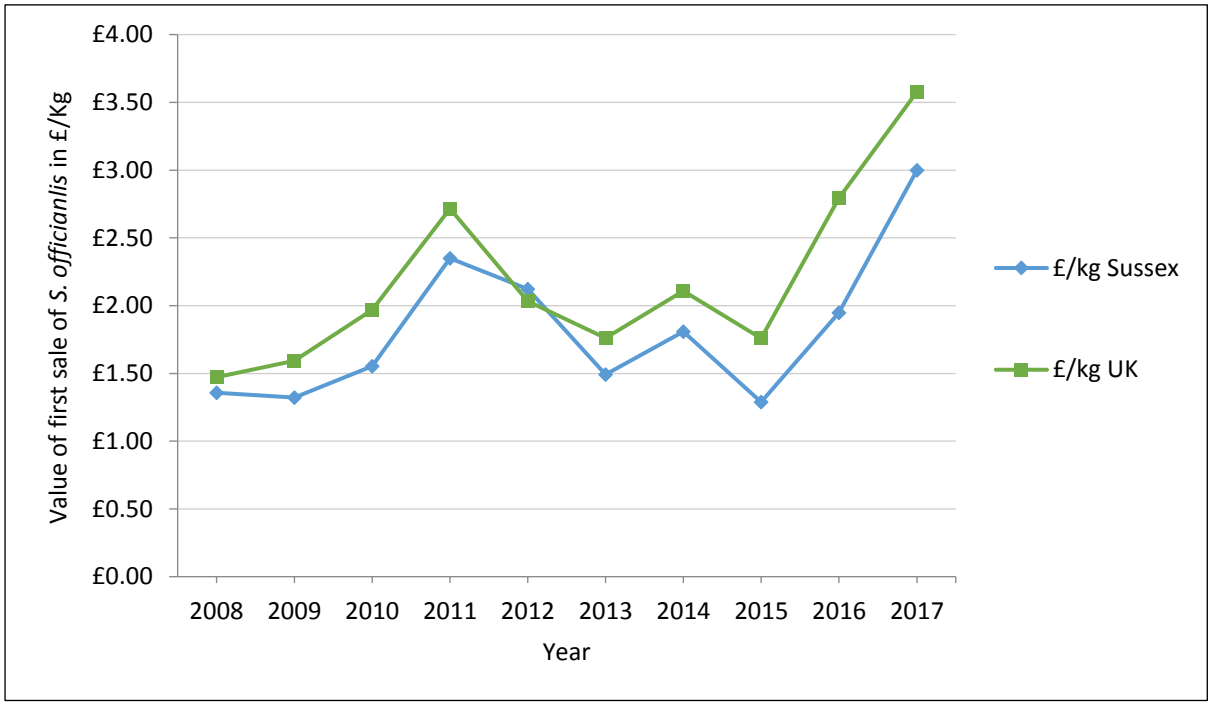

Figure 1. The market value of *S. officinalis* across all UK and Sussex ports between 2008 and 2017 (MMO landings data 2008-2017).

The increasing value of *S. officinalis* seen over the last ten years continued an increase in market value during the late 1980s and early 1990s. Between 1980 and 1987, the cost of cuttlefish was approximately £0.40 Kg^{-1}. This rose to £1.10 Kg^{-1} between 1989 and 1994, and to £1.45 Kg^{-1-} during 1995 and 1996 (Dunn, 1999). Before this increase in market value, cuttlefish was considered a nuisance species by fishers as their defensive ink would often foul other components of the catch (Joy *pers comm*, 2018).

One reason behind the rising market value of the UK cuttlefish fishery might be the result of a rising global demand that is being driven by the underperformance of existing cuttlefish fisheries in the Indian Ocean (Richardson *et al,* 2018). Karnataka is the eighth biggest state in India and has large cuttlefish fisheries within its regional waters. These fisheries target the Pharaoh cuttlefish (*Sepia pharaonic*) and these fisheries have been showing a downward trend in their landings over recent years. The total yield of the Karnataka cuttlefish fishery fell by over 57% from 17,278 tonnes in 2008-09 to just 7,409 tonnes by 2011-12 (Sasikumara *et al,* 2015).

Changes in fishing practice

Depletion of traditionally targeted finfish stocks such as gadoids and elasmobranchs has led to a change in fisher behaviour. Many fishers are shifting their efforts from the species they usually target onto other species including many invertebrate species. Many studies have been conducted on this fisher behavioural pattern and it is often referred to as 'fishing down the food web'. This occurs as the numbers of large predatory species with high tropic values and dominant positions within their respective food web become reduced and the fishers begin targeting species of a lower trophic position (Essington *et al,* 2006; Pauly, *et al,* 1998; Pauly and Palomares, 2005). This was evidenced in a recent study by Molfese, *et al*, (2014) which showed that over recent years, the proportion of catch within the English Channel represented as finfish fell. This occurred in tandem with an increase in the proportion of catch represented by invertebrates, with increases shown in decapod crustaceans, bivalve molluscs and cephalopods (Molfese, *et al,* 2014).

UK cuttlefish fishery

Weight landed

During the last ten years the landings of cuttlefish to UK ports have nearly doubled, with an increase of over 98% (Figure 2). A number of studies reported a consensus of opinion, that the English Channel cuttlefish population is either fully or over exploited. Therefore, the current growth of the cuttlefish fishery is likely to prove unsustainable (Denis and Robin, 2001; Royer *et al,* 2006; Gras *et al,* 2014; Gras *et al,* 2016).

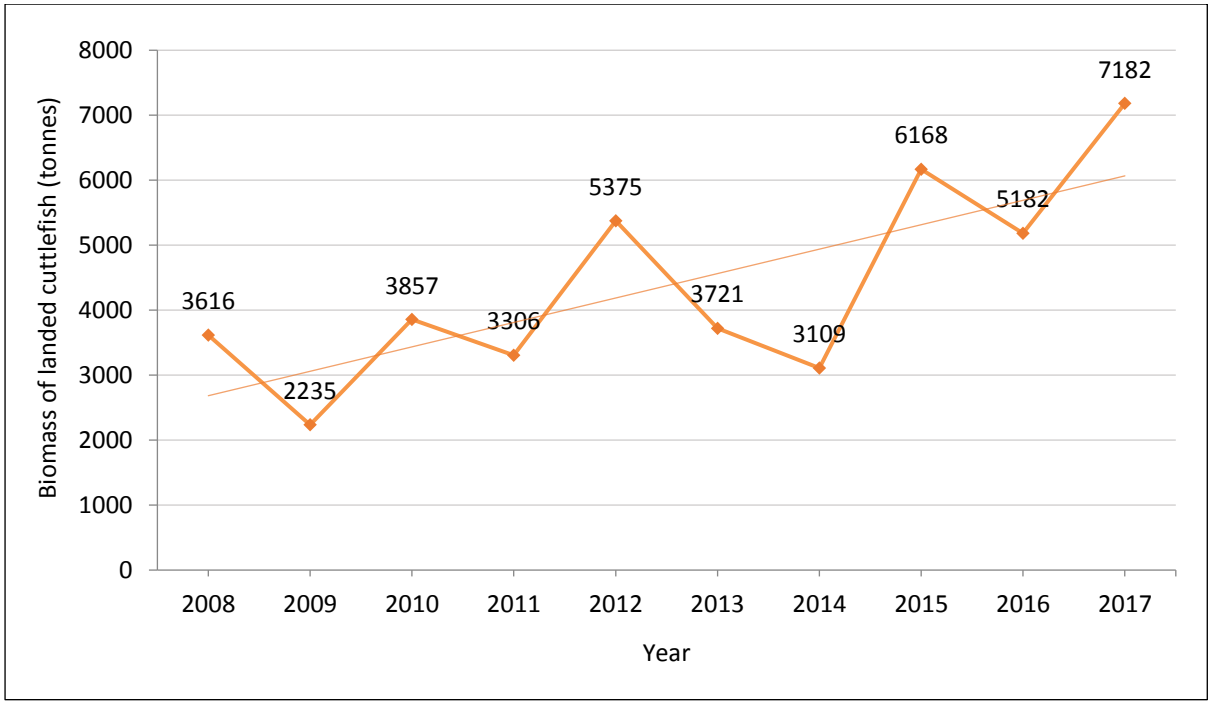

Figure 2. Total landings in tonnes of cuttlefish across all UK ports between 2008 and 2017 (MMO landings data 2008-2017).

The growing rate of exploitation is almost entirely driven by increases in the landings of the offshore fleet that target cuttlefish during the winter months and almost exclusively use towed fishing gear such as beam and otter trawls. Despite a 17% fall in the number of vessels targeting cuttlefish with beam trawls over the last ten years, the landings from this sector have increased significantly. The beam trawl sector recorded landings of 2253 tonnes of cuttlefish in 2008 (Figure 3). This figure rose to 3948 tonnes in 2017 and represents 55% of all cuttlefish landings to the UK for that year (Figure 4). On average over the ten year period the beam trawler sector landed a total of 2725 ±SE 267 tonnes per year.

Otter trawlers are the other main gear type within the offshore cuttlefish fishery and were responsible for the second highest weight of landed cuttlefish in 2017. The otter trawl sector experienced a growth in their landings over the ten year period of 279% (Figure 3). The total UK landings for 2008 of this sector were 747 tonnes. By 2017, this had grown to 2835 tonnes (Figure 4). The average landings per year for this sector were 1061 ±SE 243 tonnes per year (Figure 3).

The two main cuttlefish fisheries that operate within the inshore region (within six nautical miles of coastline) are the trap and net fisheries. Both of these fisheries have seen a dramatic drop in their landings between 2008 and 2017. Fishers operating traps to target cuttlefish have seen a drop of 26% with total landings from this sector falling over the ten year period from 361 tonnes in 2008 down to 268 tonnes in 2017. On average, this sector lands 425 ±SE 51 tonnes per year (Figure 3). The cuttlefish net fisheries have experienced the largest drop in total landings per year during the same ten year period. This sector has seen its total landings fall by over 76%, with inshore cuttlefish net fishers initially recording 242 tonnes of cuttlefish landings in 2008. By 2017, landings attributed to this sector had fallen to just 56 tonnes. Over the same ten year period the average annual landings for this sector were 119 ±SE 23 tonnes per year (Figure 3).

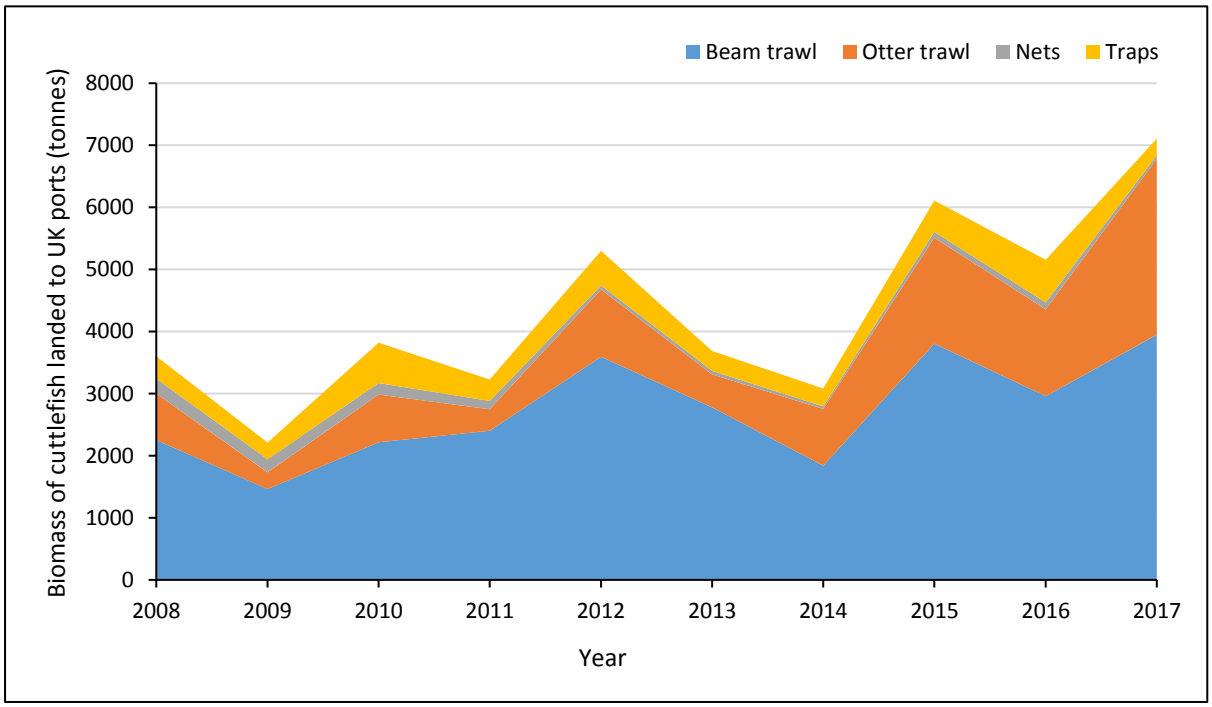

Figure 3. The biomass of cuttlefish landed to UK ports by different fishing methods between 2008 and 2017 (MMO landings data 2008-2017).

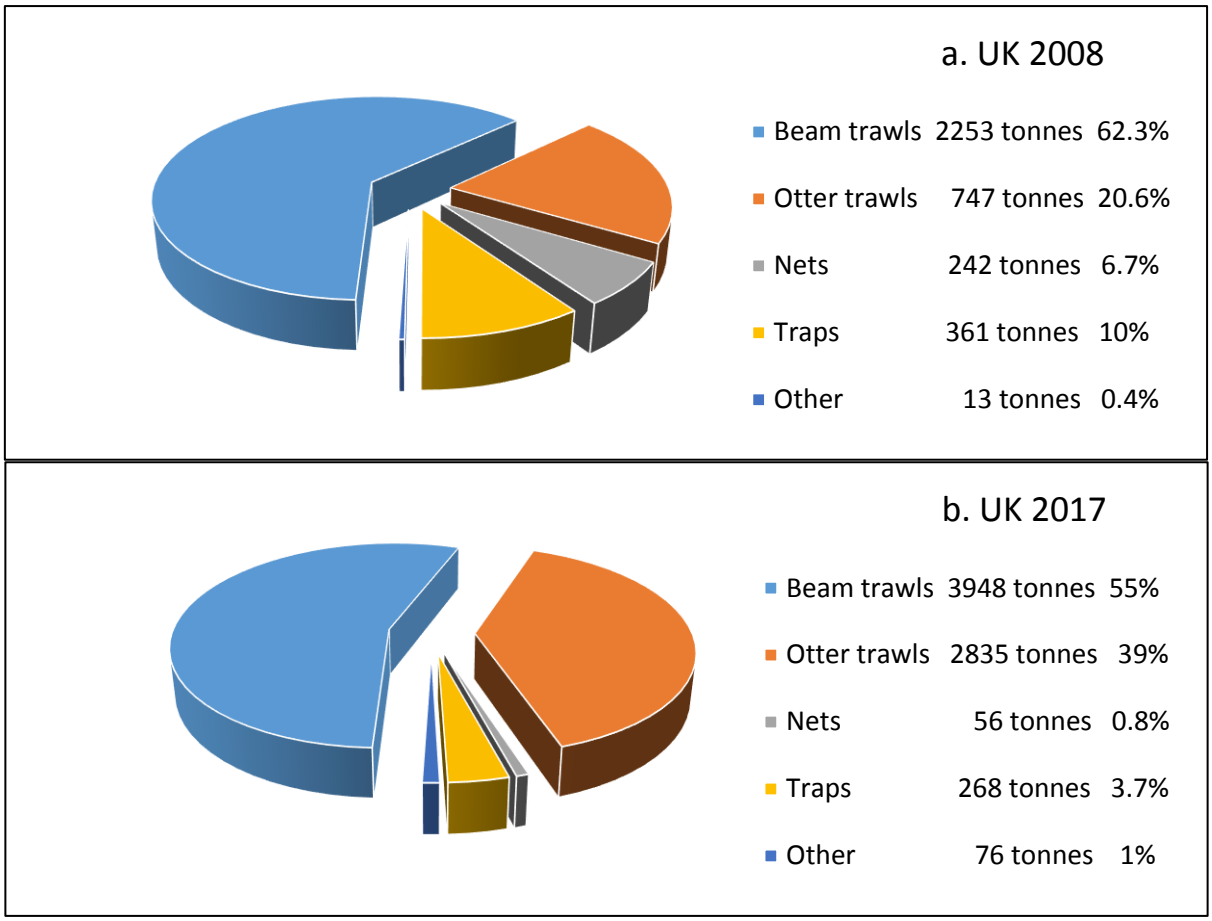

Figure 4. The distribution of cuttlefish landings by vessels operating different fishing gears, landing to UK ports in years a. 2008 and b. 2017. The legend shows each sector's landed biomass in tonnes, alongside its percentage of the year's total landings to UK ports (MMO landings data 2008-2017).

Economy

The rise in market value of cuttlefish combined with the increase in exploitation rate has resulted in a significant growth in the economic value of the cuttlefish fishery to the UK economy. In 2008, the cost of first sale for all cuttlefish landings totalled £5.32million; by 2017, this had risen to over £25.69million (Figure 5). Across the different sectors, the beam trawl fishery has seen the largest increase in income rising from £3.37million in 2008, to £14.13million in 2017 (Figure 5). When that income is spread across the 93 beam trawling vessels reporting cuttlefish landings in 2017, this equates to an average earning of £151,935 per vessel.

Otter trawlers have also seen an increase in their cuttlefish derived income, with their share of the market rising from just over £1million in 2008 to £6.7million in 2017 (Figure 5). It is worth noting that the offshore fleet operates for a larger proportion of the year and records more days at sea when compared to the inshore fleet and as such incurs higher costs.

The inshore fleets have seen a much more moderate increase in their earnings over the same ten year period, with the trap fisheries growing from £135,000 in 2008 to £174,000 by 2017 (Figure 5). However, the increase in the number of vessels targeting cuttlefish within these fisheries reduces the increase in earnings per vessel. The only metier that has seen a drop in earnings related to cuttlefish landings is the net fishery. The market share of this fishery has fallen from £340k in 2008 to £196k in 2017 (Figure 5).

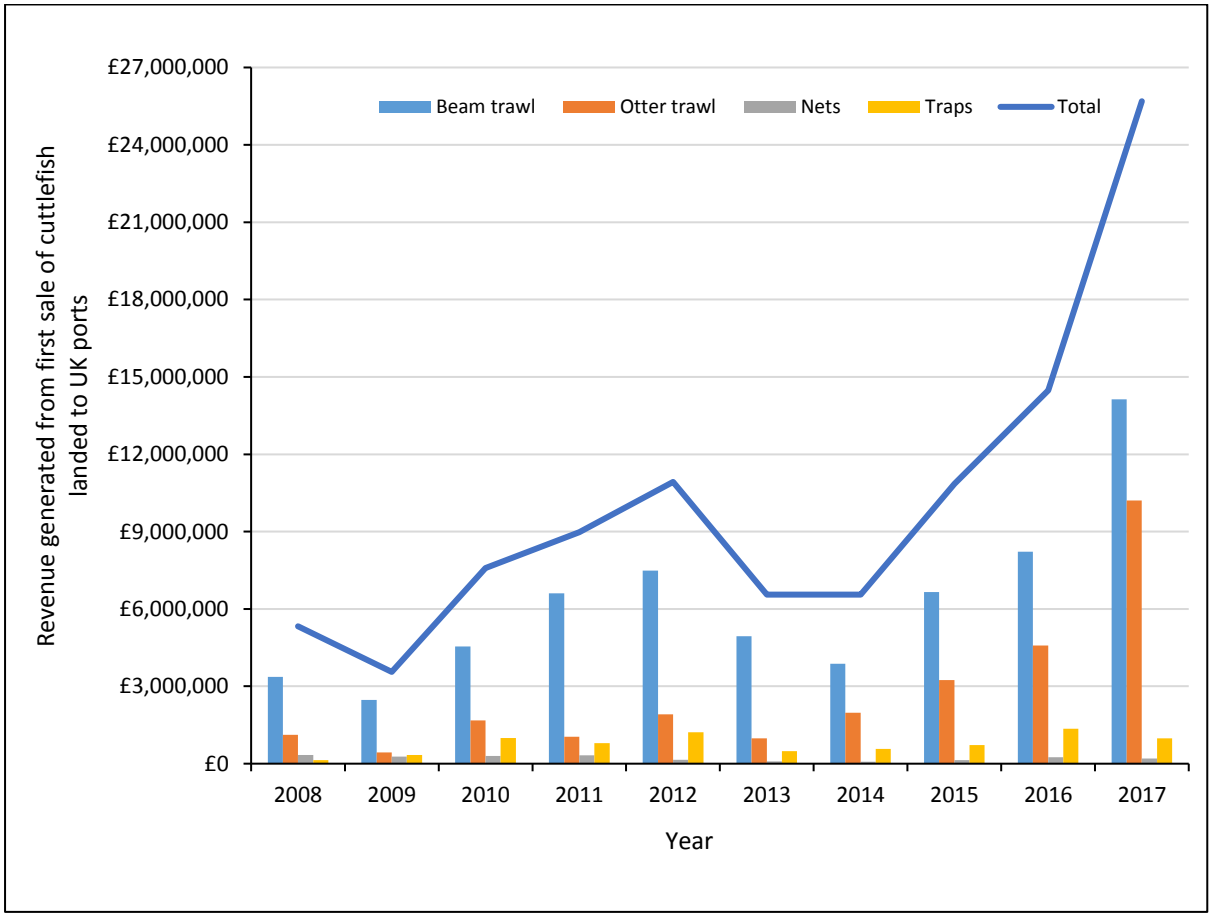

Figure 5. The revenue generated from first sales of cuttlefish landed to UK ports. The clustered columns describe the revenue for each of the main fishing techniques used to target cuttlefish. The line represents the total revenue generated (MMO landings data 2008-2017).

Number of vessels landing cuttlefish

The number of vessels landing cuttlefish to UK ports has increased over the last ten years from 654 vessels in 2008, to 759 in 2017. This represents an increase of 16%.

A review of the offshore fishery activity indicates that the number of beam trawlers targeting cuttlefish has decreased by over 17% over the same ten year period from 109 vessels in 2008, down to 93 vessels in 2017. The drop in the number of vessels using beam trawls is not mirrored in the number of vessels

operating otter trawls, this sector has grown by 28% between 2008 and 2017 from 252 vessels in 2008 up to 323 by 2017 (Figure 6).

The largest increase in the number of vessels targeting cuttlefish was seen in the inshore fisheries and is reported to have occurred with vessels operating cuttlefish traps, this has risen by 63% from 151 in 2008, to 246 in 2017. The number of vessels landing *S. officinalis* from netting has increased by 24% in the ten year period from 295 vessels in 2008 to 366 vessels in 2017 (Figure 6).

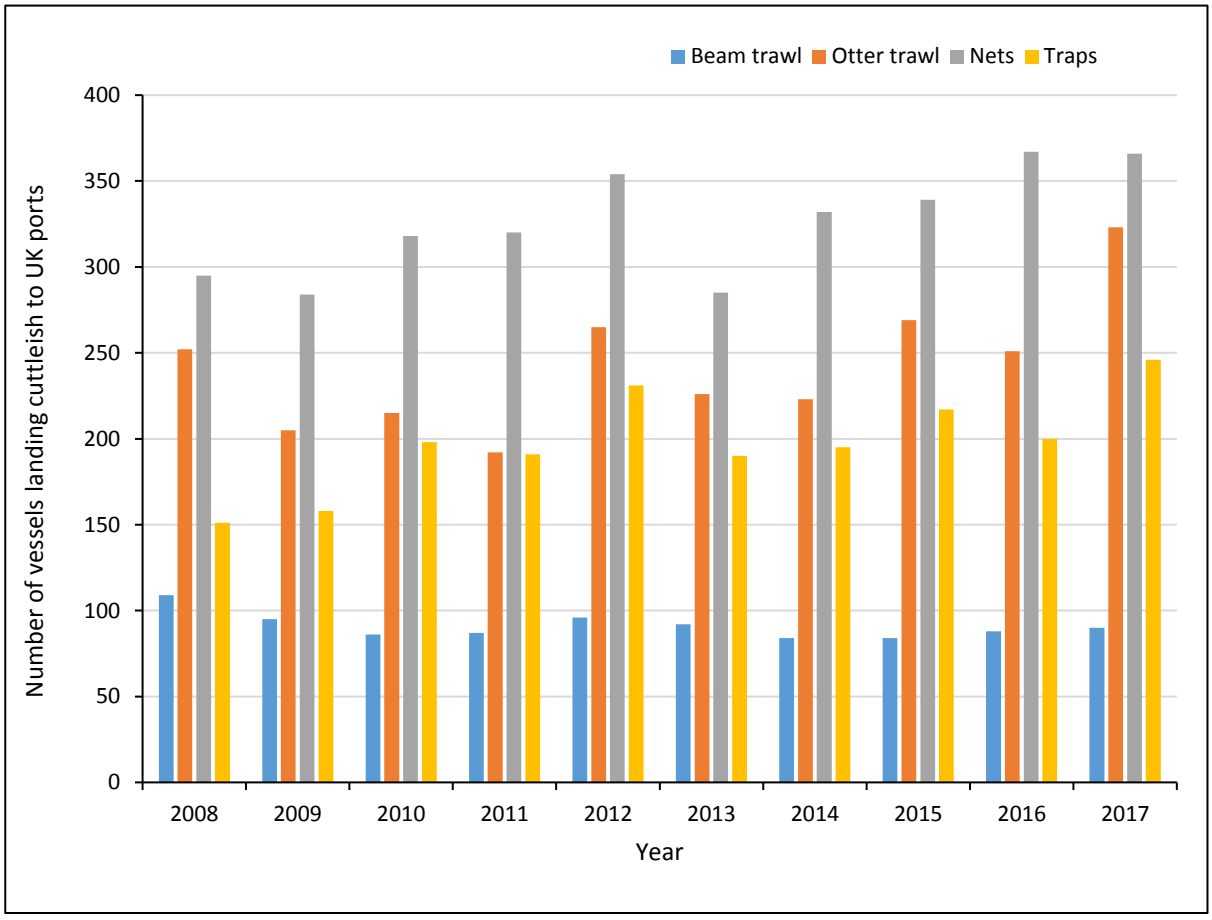

Figure 6. The number of vessels operating different gears which landed cuttlefish to UK ports between 2008 and 2017 (MMO landings data 2008-2017).

Catches per vessel

A clear divide can be seen in the average landed catch per vessel between the fishers operating in the offshore cuttlefish fishery and the fishers operating within the inshore cuttlefish fishery. Both the beam and otter trawl fisheries have experienced large increases to the amount of cuttlefish landed per vessel between 2008 and 2017.

Beam trawl fishers have seen their average catch per vessel increase by over 112% between 2008 and 2017. In 2008 beam trawl vessels were landing on average 20.6 tonnes per vessel, by 2017 this had

risen to 43.9 tonnes per vessel (Figure 7). The rise in catch per vessel in beam trawlers, is driven by both a growing exploitation rate within the sector and a reduction in the number of vessels operating beam trawls. On average over the same ten year period, beam trawlers landed 30.7 tonnes per vessel per year. Vessels operating otter trawls have experienced an increase in their landings of cuttlefish per vessel of 196% over the same ten year period. In 2008, the otter trawl fisheries recorded 2.9 tonnes per vessel, by 2017 this had risen to 8.8 tonnes per vessel (Figure 7).

While the landings of offshore cuttlefish fisheries have been growing both as a function of total landings per year and catches per vessel, the inshore cuttlefish fisheries are experiencing large reductions in their catch rates and total catches. Fishers operating nets to target cuttlefish have seen a drop of 81% in the average catch per vessel, with netting vessels recording 0.8 tonnes per vessel in 2008, by 2017 this figure had fallen to just 0.2 tonnes per vessel (Figure 7). A reduction in the annual cuttlefish landings for inshore cuttlefish trap fishers, combined with an increasing number of fishers entering the fishery has resulted in a reduction of 55% in the catch per vessel for inshore cuttlefish trap fishers. The catch per vessel for this sector has fallen from 2.4 tonnes per vessel in 2008 to 1.1 tonnes per vessel in 2017 (Figure 7).

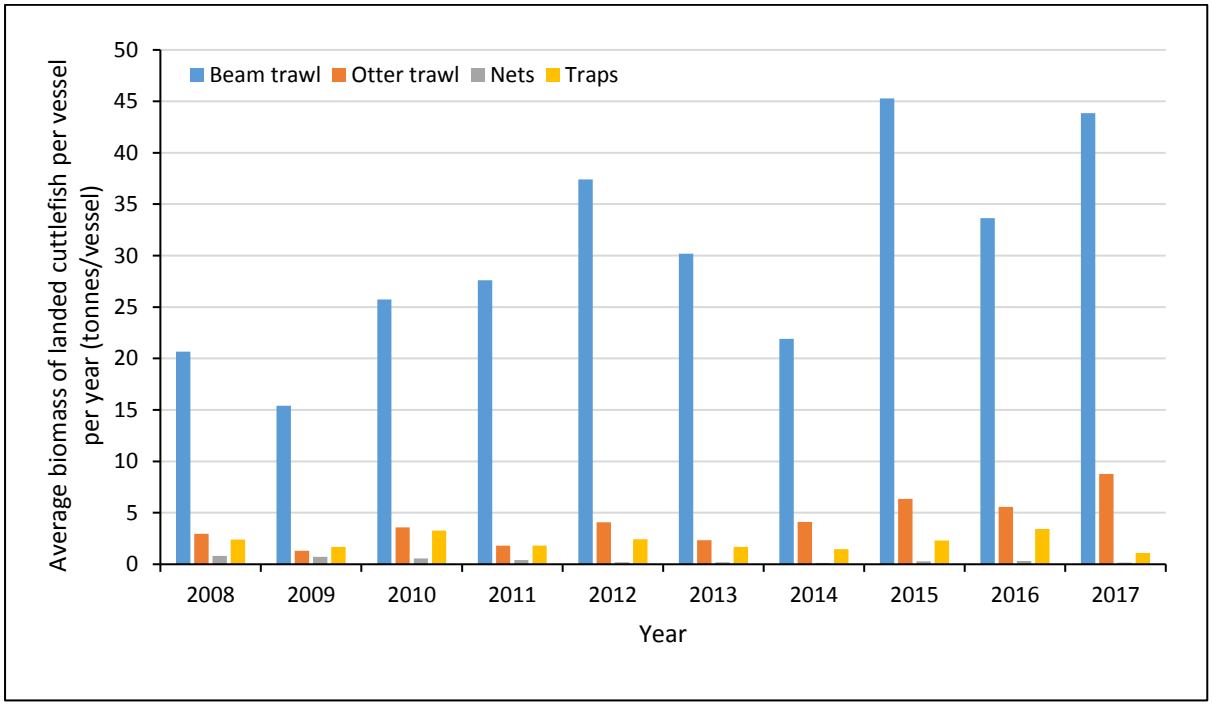

Figure 7. The catch per vessel for different gears landing cuttlefish to UK ports between 2008 and 2017 (MMO landings data 2008-2017).

Sussex cuttlefish fishery

Weight landed

In contrast to the increasing national cuttlefish fishery, the Sussex cuttlefish fishery has shown a marked decline over the last ten years. Total landings of cuttlefish to Sussex ports have fallen from 344 tonnes in 2008 to 157 tonnes in 2017, a reduction over the ten years of 54% (Figure 8). Until recently, the trends observed in the UK fishery of cuttlefish was mirrored in the Sussex fishery, with years of high catches across the nation correlating with high catches in Sussex. In 2017, that changed dramatically; at the same time the UK fishery recorded a ten year high in landings, the Sussex fishery recorded a ten year low (Figure 8).

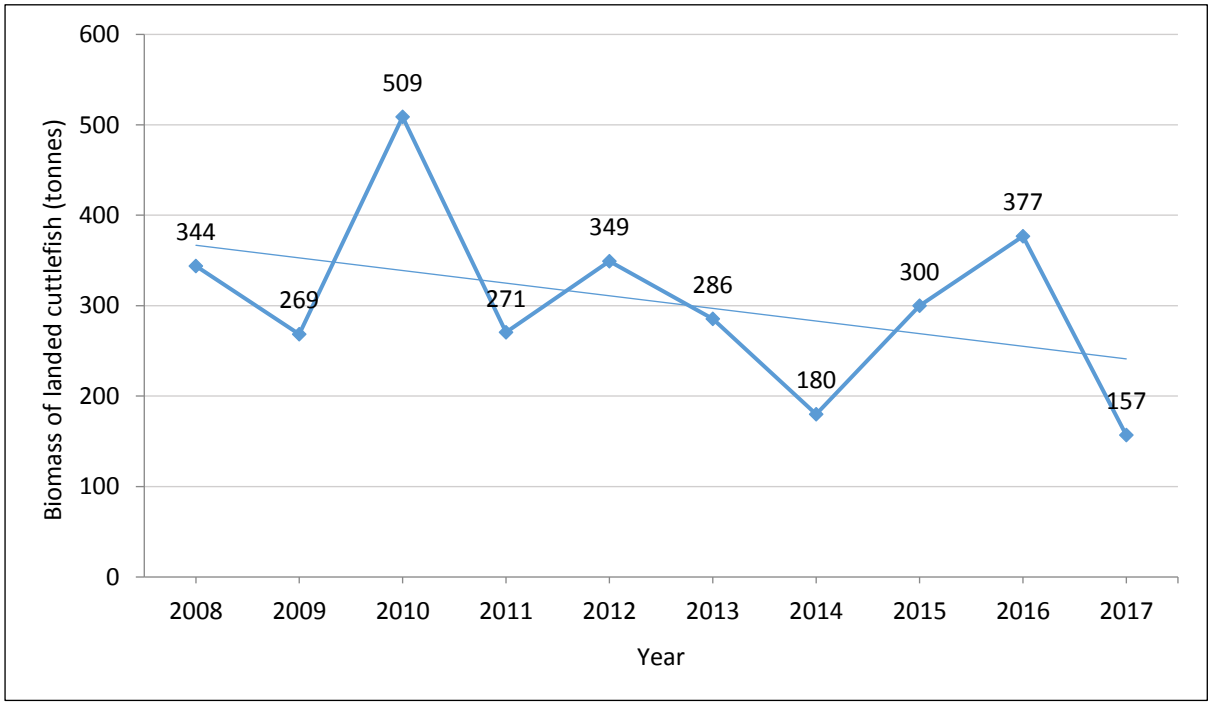

Figure 8. Total landings in tonnes of cuttlefish across all Sussex ports between 2008 and 2017 (MMO landings data 2008-2017).

The beam trawlers landing to Sussex ports have seen a drop in cuttlefish landings of 56% during the last ten years, from 46.4 tonnes to 20.3 tonnes between 2008 and 2017 (Figure 9). Despite the drop in annual landings by this sector over the ten year period, the beam trawlers have maintained a similar proportion of the total landings of cuttlefish in Sussex (Figure 10).

The Sussex otter trawler sector has experienced a slight increase in its total landings of cuttlefish over the same ten year period from, 22.8 to 26.1 tonnes per year (Figure 9). Due to the drop in total landings of cuttlefish to Sussex ports, this slight increase in catch equates to a much larger increase in their share of the total cuttlefish landings recorded across all Sussex ports (Figure 10).

In 2008, the Sussex net fishery recorded 89% of all cuttlefish landings by this sector across the entire UK and 62% of all landings of cuttlefish to Sussex ports (Figure 10). Over the last ten years this fishery has declined, with the annual landings falling from 214 tonnes in 2008 to just 29 tonnes in 2017 (Figure 9). This fishery experienced a significant drop in landings in 2012, with the annual catch in Sussex attributed to net fishers falling from 102.3 tonnes in 2011 to 9.7 tonnes in 2012, just 9.5% of the previous year's landings (Figure 9).

Since the decline in the Sussex cuttlefish net fishery, the trap fishery has been the most influential sector in Sussex. Since 2012, the cuttlefish trap fishery has routinely recorded significantly higher landings than the other sectors targeting cuttlefish. Often this sector lands more cuttlefish than all the other sectors combined. The years in which this sector recorded its highest landings correlates with the years of high catch rates across the nation, suggesting peaks in the abundance of cuttlefish. However in 2017, while the UK landings of cuttlefish grew relative to 2016, the landings of cuttlefish attributed to Sussex trap fishers fell to 61 tonnes representing a reduction of 74% on the previous year's catch (Figure 10). Whether the dramatic drop in landing seen in 2017 is a result of the increasing exploitation of cuttlefish at their overwintering grounds or some other factor is yet to be determined.

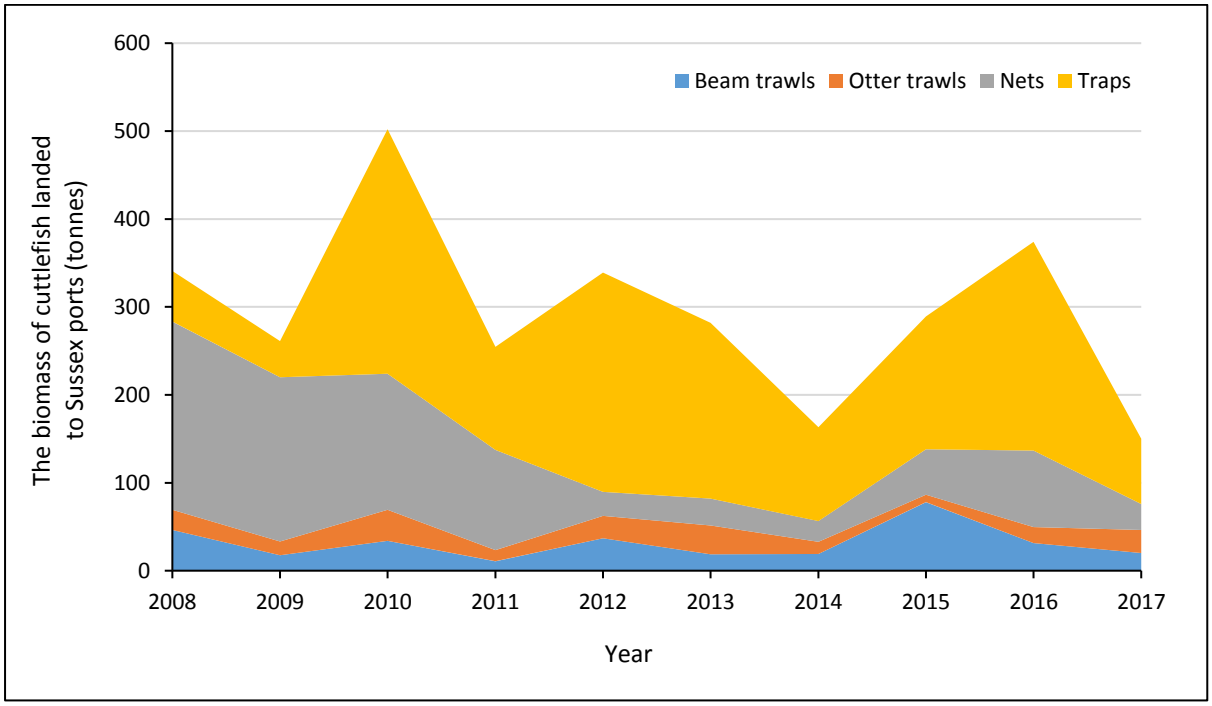

Figure 9. The biomass of cuttlefish landed to Sussex ports by different fishing methods between 2008 and 2017 (MMO landings data 2008-2017).

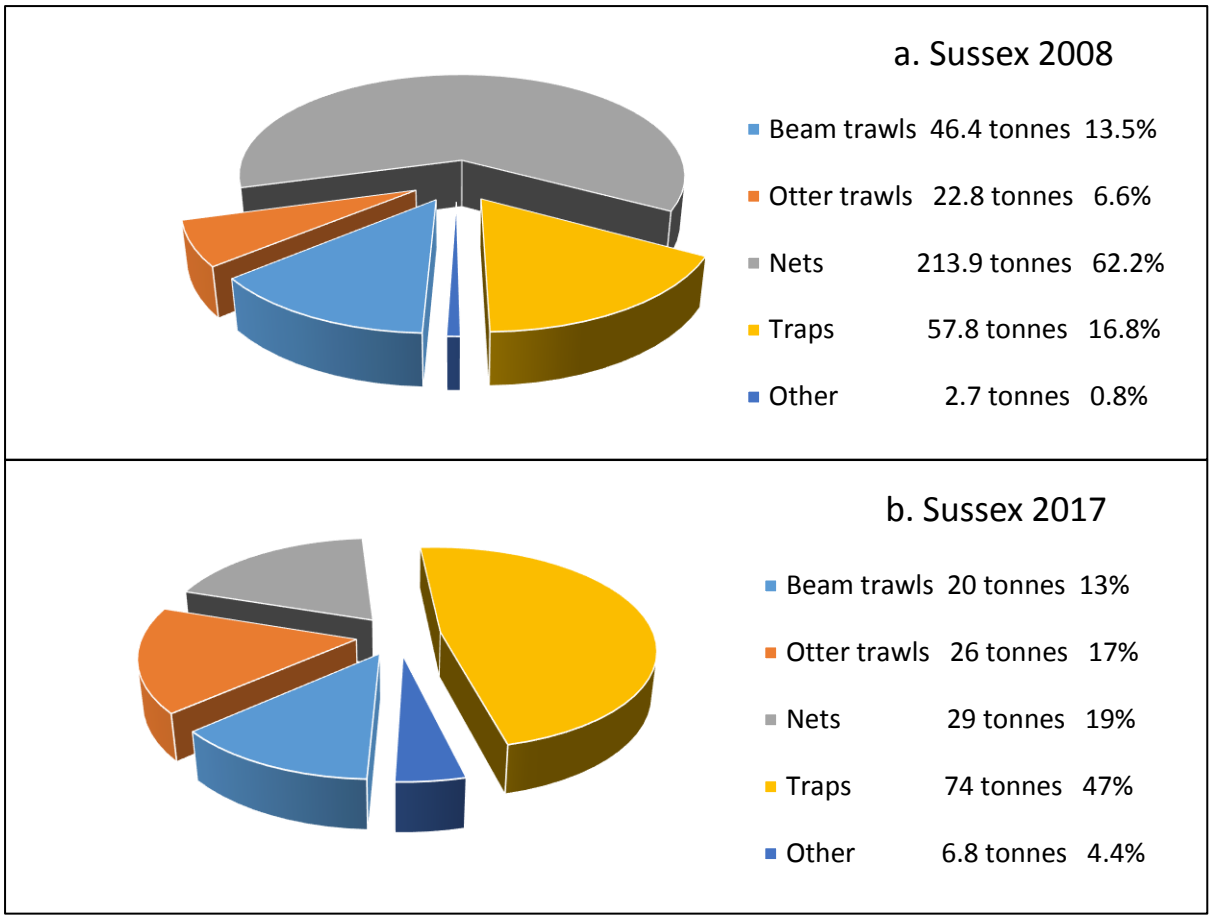

Figure 10. The distribution of cuttlefish landings by vessels operating different fishing gears, landing to Sussex ports in years a. 2008 and b. 2017. The legend shows each sector's landed biomass in tonnes, alongside its percentage of the year's total landings to Sussex ports. (MMO landings data 2008-2017).

Number of vessels landing cuttlefish

The number of vessels landing cuttlefish to Sussex ports has increased over the last ten years from 297 vessels in 2008, to 336 in 2017. This represents an increase of 13%. A small number of these vessels operate within the offshore fishery, but the majority of them are under ten metre vessels that operate within the inshore fishery.

The number of beam trawlers operating out of Sussex that target cuttlefish has fallen over the last ten years. In 2008, 26 beam trawlers were recording landings of cuttlefish, by 2017 this number had fallen to 11 vessels (Figure 11). During the same time frame, many fishers have diversified into the otter trawl fishery to target cuttlefish. This sector has seen a growth of over 61% in the number of vessels recording landings of cuttlefish to Sussex ports. The number of vessels using otter trawls to target cuttlefish has risen from 34 vessels in 2008, to 55 vessels in 2017 (Figure 11).

The number of vessels using nets to target cuttlefish within the Sussex IFCA district has remained relatively constant over recent years. From year to year some variation in the number of vessels using nets to target cuttlefish is evident. However, over the analysed ten year period of 2008 to 2017, the Sussex cuttlefish net fishery has experienced a gain of just 5 new vessels to the sector (Figure 11). The inshore cuttlefish trap fishery of Sussex has experienced a greater variation in the number of operational vessels within the fishery from one year to the next. This fishery has an average of 79 ± 6.5 vessels per year (range = 41-110). Between 2008 and 2017, the number of vessels targeting cuttlefish with traps in Sussex rose from 54 to 80 (Figure 11).

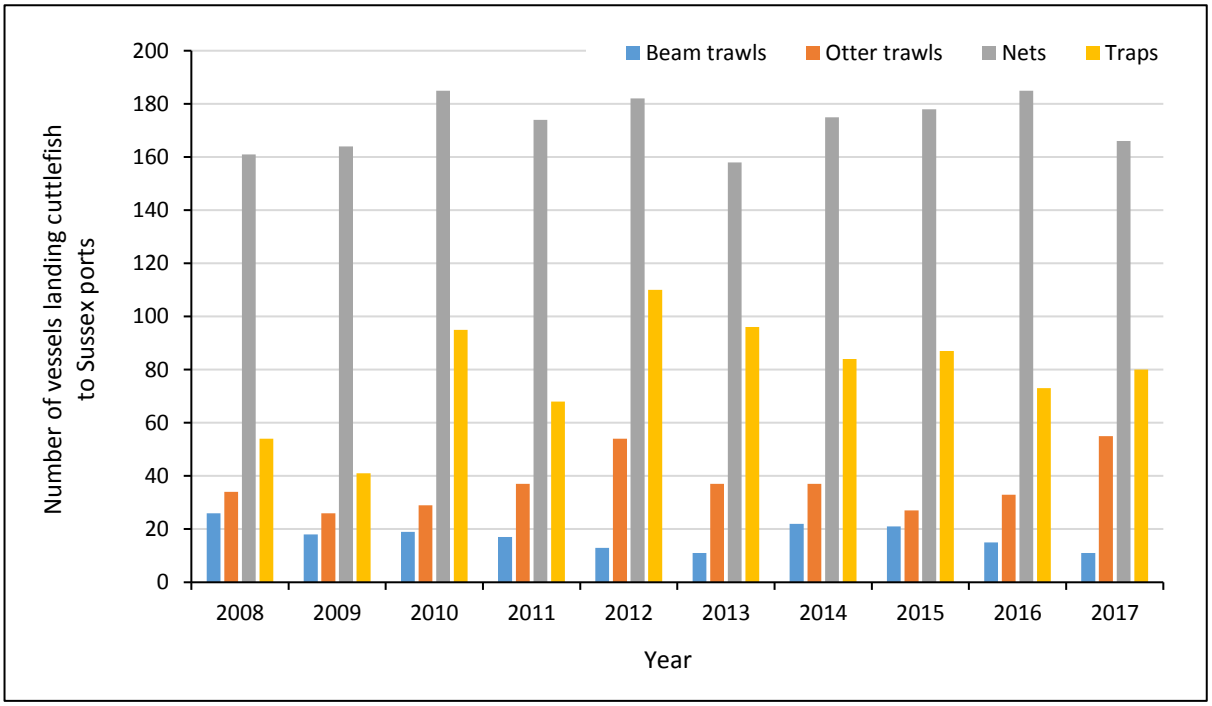

Figure 11. The number of vessels operating different gears which landed cuttlefish to Sussex ports between 2008 and 2017 (MMO landings data 2008-2017).

Catches per vessel

Generally, the average catch per vessel across the four main fisheries in Sussex has remained relatively constant. Although some variation is seen between years, this inter-annual variability can be attributed to years of peak abundance in the English Channel population of cuttlefish (Figure 12).

The Sussex beam trawl fishers have seen an increase of just 50 kg per vessel in 2017 in comparison to the average catch per vessel in 2008. The average catch per vessel per year for beam trawlers was 1.82 ±SE 0.3 tonnes per vessel per year (range= 0.64-3.71) (Figure 12). The Sussex otter trawlers also experienced a marginal variation in their catch per vessel. Landings per vessel for this sector were 670 kg per vessel in 2008, by 2017 this had fallen to just 470 kg per vessel. The average catch per vessel

per year for Sussex otter trawlers targeting cuttlefish was 0.59 ±SE 0.1 tonnes per vessel per year (Figure 12).

Fishers operating nets to target cuttlefish recorded a massive reduction in the catch per vessel of 86% between 2008 and 2017. In 2008, the netters of Sussex recorded 1.3 tonnes per vessel which had fallen to just 180 kg per vessel by 2017. This drop in catch per vessel is due to a large reduction in the amount of cuttlefish caught by this form of fishing while the numbers of fishing vessels that are recording cuttlefish landings has remained relatively constant. This suggests that many of the landings of cuttlefish by Sussex net fishers during recent years form part of a mixed species fishery and that the cuttlefish are targeted alongside other species. The behaviour of targeting multiple species allows fishers to maximise their profits.

Fishers using traps to target cuttlefish were recording 1.1 tonnes per vessel in 2008. By 2017, this figure had dropped slightly to 0.9 tonnes per vessel (Figure 12). The Sussex cuttlefish trap fishers have seen a greater degree of inter-annual variability within their catch per vessel between 2008 and 2017. This increased variability is a result of both the variation seen in the abundance of the population combined with a reliance on cuttlefish escaping the increasing rate of exploitation occurring at the over wintering grounds in the western approaches of the English Channel.

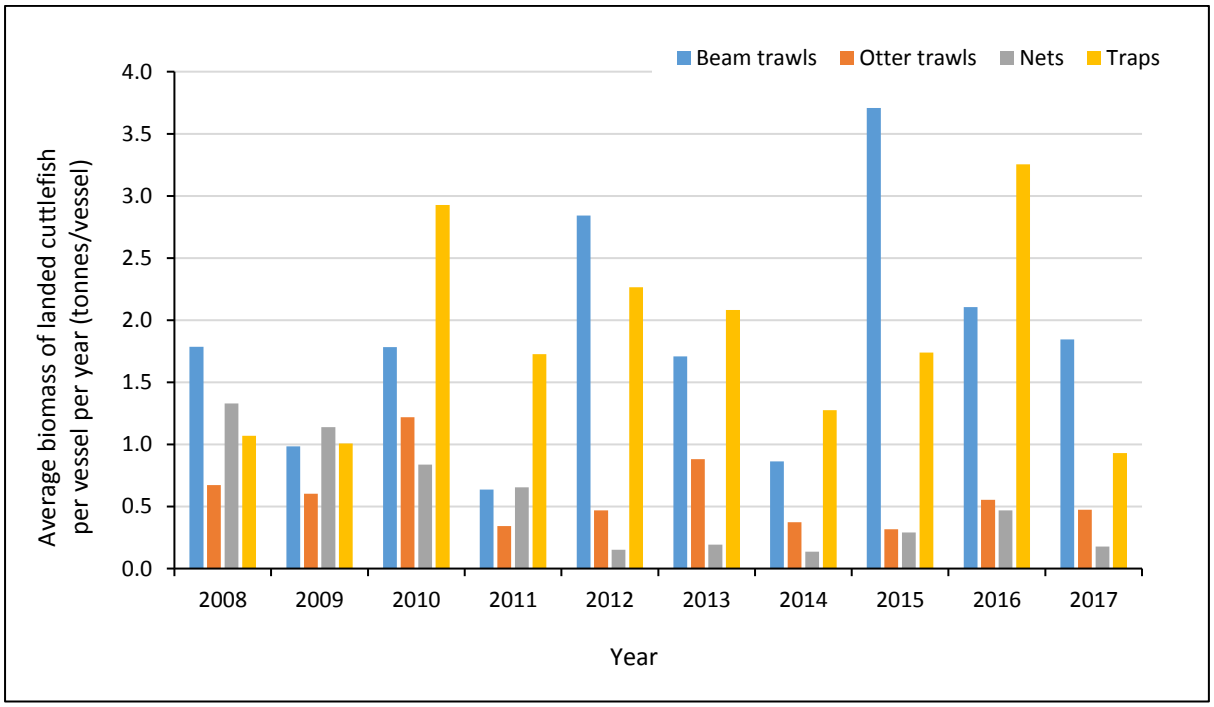

Figure 12. The catch per vessel for different gears landing cuttlefish to Sussex ports between 2008 and 2017 (MMO landings data 2008-2017).

Inshore/offshore fisheries comparison

Inshore fisheries

The fishing gears traditionally used to target cuttlefish by the inshore fisheries are deployed during the late spring and summer months (April – July) and target the spawning cuttlefish as they reach their breeding grounds (Bloor, 2012; Gras *et al,* 2014; Royer *et al,* 2006; MMO landings data 2008-2017). These gears typically include static fishing equipment such as gill and trammel nets, traps and pots (Figure 13).

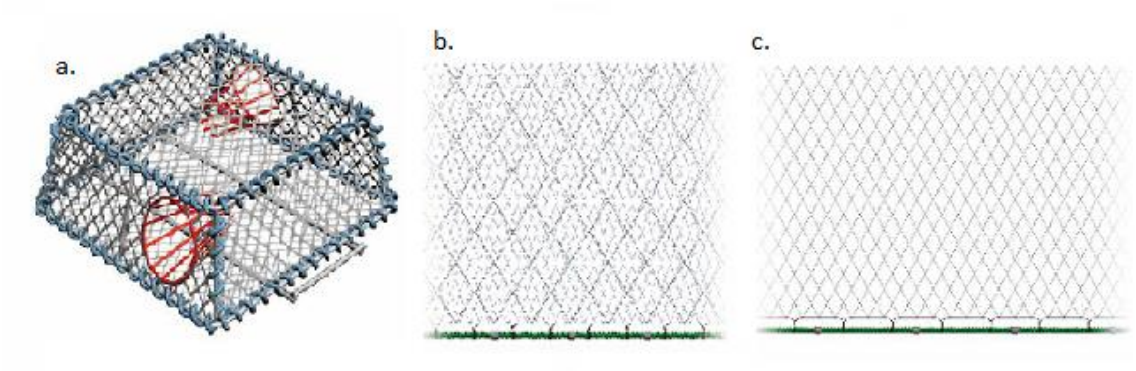

Figure 13. The three main fishing gears utilised by fishers to target cuttlefish within the inshore fisheries, a. Cuttlefish trap, b. Trammel net, c. Gill net. Image adapted from Montgomerie, 2015.

These fisheries are considered highly sustainable. The intermittent terminal spawning employed by *S. officinalis,* means that the fishers target fully grown cuttlefish at or near the end of their lives and as such, the fishing mortality of these inshore fisheries is close to natural mortality (Bloor 2012). The use of these static gears has a greatly reduced impact on the seabed habitat compared to demersal towed fishing gears (Eno *et al,* 2013; Eno *et al,* 2001; Foden *et al,* 2010; O'Neill and Ivanovic, 2016). Furthermore, the inshore trap and pot fisheries are also highly selective for the target species with very low rates of bycatch (Dunn, 1999).

However, during their use, the pots and traps used by fishers to target *S. officinalis* often become egg laying sites for the breeding adults. Although many fishers try to remove and return these eggs to sea, it is not always possible to remove all eggs (Joy *pers comm,* 2017). The subsequent loss of these eggs from the environment may have deleterious impacts on future recruitment (Barile *et al* 2013; Belcari *et al,* 2002; Blanc and Daguzan, 1998; Bloor, 2012; Bloor *et al,* 2013; Dunn, 1999; Melli *et al,* 2014; Watanuki and Kawamura, 1999). Improvement in the sustainability of the inshore cuttlefish trap fishery may be achieved by determining an efficient technique that will facilitate fishers in the removal of a higher proportion of the eggs deposited on the traps in a way that will allow them to survive.

A number of studies have been conducted into different mitigation strategies to reduce the mortality of cuttlefish eggs post trap fishing effort, mainly by adding egg laying substrates to the trap from which the eggs can be easily removed. Maternal cuttlefish have a strong oviposition (egg laying) preference for ropes of 8 mm in diameter and 50 cm in length, although lengths of between 30 and 90 cm were also used for oviposition. Although eggs were laid on the 90 cm ropes, as they became laden, the additional weight resulted in the ropes lying on the seabed and none of the eggs hatching due to smothering (Blanc and Daguzan, 1998). The use of ropes in traps could allow over 20% of eggs deposited on the traps to be easily removed, while having no impact on the efficacy of the traps (Melli *et al,* 2014).

For further information on cuttlefish biology and a trial of egg receptors in traps, see the other reports of the Supporting Sustainable Sepia Stocks project.

Offshore fishery

In contrast, the offshore cuttlefish fishery operates during the winter between September and April. When targeting cuttlefish offshore, fishers predominantly utilise towed fishing gears such as beam and otter trawls (Figure 14) (Belcari *et al,* 2002; Bloor *et al,* 2013; Dunn, 1999; Gras *et al,* 2014; Gras *et al,* 2016; Melli *et al,* 2014). As well as causing a greater amount of damage to the seabed, these fishing gears are generally less selective than the static gears employed by the inshore fishers.

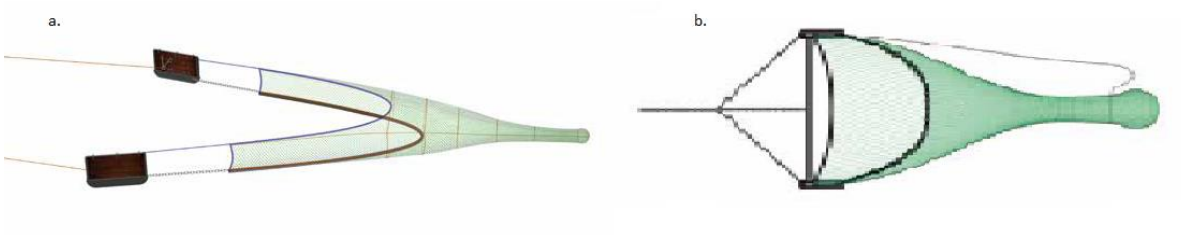

Figure 14. The two main fishing gears utilised by fishers to target cuttlefish within the offshore fisheries, a. Otter trawl, b. Beam trawl. Image adapted from Montgomerie, 2015.

The predominant fishing grounds of the offshore English Channel cuttlefish fishery occur in the western regions of the English Channel (ICES rectangles 29E6, 28E6 and 29E7) (MMO landings data 2008-2017). Fishing in these areas coincides with the seasonal migration undertaken by *S. officinalis* to the region. Due to the minimum temperature tolerance of *S. officinalis,* much of the English Channel is uninhabitable during the winter months as the shallow water depth means that the seabed temperatures fall below 10°C for protracted periods of time. This causes the English Channel *S.*

officinalis population to aggregate in the deeper waters found in the western regions of the English Channel where the temperature is more stable and rarely drops below 10°C (Bloor *et al,* 2013; Boucaud-Camou and Boismery, 1991; Gras *et al,* 2014; Wang *et al,* 2003).

Interactions

The temporal and spatial distribution of *S. officinalis* within the English Channel reduces the chance of competition over fishing grounds between the different fishing activities. The majority of beam and otter trawlers target *S. officinalis* offshore during the winter months, while the vessels utilising nets, traps and pots operate during the summer months in the inshore region (Bloor, 2012; Dunn, 1999; Gras *et al,* 2014; Royer *et al,* 2006; MMO landings data 2008-2017).

However, different fisheries are targeting the same population of individuals and as such, some technical interactions must occur between the different fishing fleets. A study by Royer *et al*, which modelled the interactions between the differing fleets showed that the beam and otter trawls have a low sensitivity to the impacts on the cuttlefish population generated by the other fishing types. The opposite of this was shown for the inshore fisheries, which are highly sensitive to the exploitation of the population by the offshore fleet. This is due to the inshore fleet being dependent on the proportion of cohorts that evade offshore exploitation and return to the inshore breeding grounds (Royer *et al,* 2006). The same study showed that the inshore artisanal fisheries had a low impact on the catch rates of different offshore fishing metiers. However, the continued removal of fertilised eggs from the environment may begin to negatively impact recruitment into the offshore fisheries (Belcari *et al,* 2002; Bloor, 2012; Bloor *et al,* 2013; Dunn, 1999; Melli *et al,* 2014).

Size at landing

In 2002, a study reviewed the exploitation of cuttlefish at three locations within the Mediterranean Sea. This work showed that similar to the exploitation patterns of the English Channel population; the majority of catches occurred in the beam and otter trawl fleets. During the study period (July 1998-June1999), the mantle length was measured for a representative proportion of the catches from each fishing metier. This data showed that an important proportion of the landings recorded by the beam and otter trawls consisted of immature specimens, and that the mode mantle length for the annual trawl catches was 8 - 12 cm (Belcari *et al,* 2002).

In a similar study, data was collected on the mantle length of cuttlefish landed at Brixham, Devon, during 2011 and 2012. The mean mantle length was 16.4 cm (range = 5-33 cm). The data showed two

clear peaks in the length of landed *S. officinalis* during the study. This represents the two age classes that are captured by the towed gears; the first peak was of immature individuals with a length of approximately 10 cm, while the second peak was of mature individuals with a length of approximately 20 cm (Bloor, 2012).

Discard rates

A study conducted by Enevera *et al* 2007, reviewed the discard rates of different fishing gears used in ICES area VII (English Channel, Celtic and Irish Seas, and west of Ireland) across a range of fisheries between 2002 and 2005. This study showed that the discard rate for UK beam and otter trawls were higher than any other fishing gear and these two fishing metiers discarded 93% of all recorded discards and accounted for approximately 21,500 tonnes of biomass. The mean discard rate for beam trawls was 71% of individuals, which represented 42% of the total catch biomass. The mean discard rate for otter trawls was 64% of individuals and accounted for 36% of the total catch biomass. The netters observed during the study had a discard rate across all species of 36% of individuals and 22% of total catch biomass. The reduced discard rate seen in the net fisheries when compared to the beam and otter trawls is indicative of the less selective nature of the beam and otter trawl metiers (Enevera *et al,* 2007).

Discard survival rates

The discarding of small immature cuttlefish (<15 cm) caught in trawls to allow them the chance of returning to their inshore breeding grounds and aiding in recruitment is unlikely to offer strong benefits to the English Channel population of *S. officinalis.* When caught in trawls, *S. officinalis* with a mantle length of less than 15cm have a low survival rate, with only 32% surviving until they are hauled onto the deck and reach the sorting process. This figure falls dramatically over the next 72 hours, with only 16% surviving beyond this time (Revill *et al,* 2015). Mortality recorded in the first 72 hours after fishing effort is referred to as acute fishing mortality. This encompasses the mortality generated by the physical damage and lethal injuries caused to each individual during the fishing process. Chronic mortality rates, those occurring over longer time frames, are often a result of reduced predator avoidance and increased susceptibility to infection in discarded individuals. These mortality risk factors are often a response to the stress and sub-lethal injuries that discarded fish are subjected to during capture, sorting and discarding and are often more difficult to assess (Uhlmann and Broadhurst, 2015).

Fishery Management

Due to the low effort that was historically applied to the catching of cuttlefish by the UK and European fishing industries, very little management has been applied to the cuttlefish fisheries that operate in the English Channel and around the coast of the UK. There is at present no total allowable catch (TAC) quota or minimum conservation reference size (MRCS) applied to the landings of the common cuttlefish. This means that fishers can land any amount of cuttlefish at any size.

Often when targeting cuttlefish, offshore fishers are using towed fishing gears such as otter or beam trawls with a mesh size of between 80-90 mm. When operating towed gear of this mesh size in European waters, the fishing activity falls under the catch composition rules of EU council regulation (EC) No 850/98 (*Article 4*). The legislation introduced technical measures for the protection of juveniles of marine organisms and governs the minimum percentage of the total catch that must be of the target species (or any other species listed in Annex 1). In the case of cuttlefish, when caught in towed gear with a mesh size of between 80-90 mm, then 70% of the catch must be comprised of cuttlefish. The same regulation (*Article 11*) also restricts the mesh size of fixed nets to ≥100 mm if 70% or more of the catch is comprised of cuttlefish. Article 34 of the same legislation also restricts the use of beam trawls within 12 nautical miles of the UK coastline (European Parliament and Council of the European Union, 1998).

The inshore fisheries (within 6 nautical miles of the coast) are managed by one of ten regional Inshore Fisheries and Conservation Authorities (IFCAs). Outside of 6nm, the fisheries are managed by the Marine Management Organisation. Six IFCAs are situated along the coastline of the English Channel; Kent and Essex, Sussex, Southern, Devon and Severn, Cornwall and the Isles of Scilly. All of these IFCAs have restriction on the maximum length of fishing vessels that are allowed to operate within their respective districts and these maximum vessel lengths range from 12 to 14 metres depending on the governing IFCA (Devon and Severn IFCA, 2018; Isles of Scilly IFCA, 2018; Kent and Essex IFCA, 2018; Southern IFCA, 2018a; Sussex IFCA, 2018).

Sussex IFCA has a shellfish permit bylaw, which allows for effort control to be applied to the inshore cuttlefish fishery. The Sussex IFCA Shellfish Permit Byelaw restricts the number of traps or pots that can be deployed by any single vessel when targeting cuttlefish to 300 within the Sussex IFCA district (Sussex IFCA, 2018).

Southern IFCA operate a voluntary code of conduct for their cuttlefish fishers. This states that it is best practice for fishers to leave their traps or pots in the sea after the fishing season has ended, allowing for any cuttlefish eggs deposited on the traps to complete gestation and hatch (Southern IFCA, 2018b).

Fisheries that operate along the coast of Normandy, France, function under a license system designed to limit fishing effort and access to the fishery. In France, inshore trawling is banned within the 3 mile limit. However, some exemptions are given in specific coastal zones during spring and late summer (International Council for the Exploration of the Seas, 2017).

Sales of cuttlefish are restricted in the Europe by common marketing standards for fishery products council regulation (EC) No 2406/96. This legislation limits the marketing of cuttlefish of ≥100g in size (European Parliament and Council of the European Union, 1996).

Conclusion

The exploitation of the English Channel cuttlefish population has nearly doubled during the last decade. The rising exploitation rate has been driven partially by a rise in the market value of cuttlefish and partially as a result of reductions in the abundance in traditionally targeted finfish (MMO landings data 2008-2017; Molfese *et al,* 2014; Payne, *et al,* 2006).

The UK cuttlefish fisheries can generally be split into two main groups, the inshore and offshore fisheries. These fisheries use different gears and target cuttlefish at different times of the year. The offshore fishery predominantly uses towed gear, operates during the winter months and targets the overwintering aggregations in the Western approaches of the English Channel. While the inshore fisheries target spawning adults in spring and early summer as they aggregate in their breeding grounds along the coastlines of the UK and France (Bloor *et al,* 2013; Royer *et al,* 2006; Wang *et al,* 2003).

The offshore fishery is responsible for the vast majority of cuttlefish landings to UK ports, with over 94% of all cuttlefish landings to UK ports in 2017 being attributed to them. This fishery is primarily formed of two towed gear fishing techniques, beam and otter trawling. The beam trawling sector is by far the most influential sector and in 2017 was responsible for over 55% of all cuttlefish landings to UK ports. The otter trawl sector is responsible for the remaining 39% of cuttlefish landings attributed to the offshore fisheries.

The inshore fisheries predominantly use traps and nets to target cuttlefish. When compared with the offshore fisheries, the inshore fisheries record more moderate landings. In 2017, fishers using traps reported landings of 268 tonnes which equates to 3.7% of the total UK landings of cuttlefish for the year. While, netting fishers only recorded 56 tonnes of cuttlefish landings this represent less than 1% of the UK's total annual landings of cuttlefish.

The inshore fishery is considered more sustainable than the offshore fisheries. This is because the static fishing gear used by inshore fleets has less impact on the seabed and the associated fauna and flora. The inshore fishing methods (traps and nets) are also more selective for the target species and catch less bycatch than the towed gear employed by the offshore trawlers.

The inshore fleet operates on the breeding grounds of the cuttlefish and are targeting cuttlefish at or near the end of their lives. This practice affords individual cuttlefish some opportunity to reproduce before capture (Bloor *et al,* 2013; Dunn, 1999; Gras *et al,* 2014; Royer *et al,* 2006; Wang *et al,* 2003). In comparison, the offshore trawlers are targeting cuttlefish of all sizes including large numbers of juveniles. All exploitation of cuttlefish by the offshore fleet, reduces the recruitment opportunities for subsequent generations (Bloor, 2012; Bloor *et al,* 2013; Dunn, 1999; Royer *et al,* 2006).

One concern surrounding the activities of the inshore fleet is that the traps used to target the cuttlefish often become egg laying sites of breeding individuals. Although many fishers try to remove these eggs and return them to sea, it is not always possible to remove all the eggs. The eggs lost in this fashion represent a reduction in the recruitment for subsequent generations (Barile *et al* 2013; Belcari *et al,* 2002; Blanc and Daguzan, 1998; Bloor, 2012; Bloor *et al,* 2013; Dunn, 1999; Melli *et al,* 2014; Watanuki and Kawamura, 1999). A number of studies have been conducted into the egg laying preferences of breeding cuttlefish in an attempt to mitigate against this loss of propagules. Maternal cuttlefish have a preference for egg laying on rope approximately 8 mm in diameter and between 40 and 50cm in length (Blanc and Daguzan, 1998; Barile *et al*, 2013). For further information see the report: Supporting Sustainable Sepia Stocks: Report 3: Assessing the efficacy of egg receptors within fishing traps used to target common cuttlefish.

The Sussex cuttlefish fishery is largely driven by the landings of its inshore fleet. Recruitment into the inshore fishery, and as such the landings attributed to this sector, are strongly linked to the offshore fishery. This link is a result of the inshore fishery being dependent on the number of individuals that escape the exploitation by the offshore fleet at their overwintering ground (Royer *et al,* 2006).

During the last ten years the catches of both the inshore and offshore fleets show correlation between the years of high landings. In these years, both inshore and offshore fisheries report high landings that are probably caused by years of peak abundance in the English Channel population of cuttlefish. In 2017, this pattern of correlating high catches changed. While both the UK cuttlefish fishery and, in particular, the beam and otter trawlers, recorded their highest landings in a decade, the Sussex inshore fishery recorded its lowest landings in a decade. Whether the dramatic drop in landings seen in 2017 is a result of the increasing exploitation of cuttlefish at their overwintering grounds or some other factor is yet to be determined.

One of the key drivers behind the increasing rate of exploitation of the English Channel cuttlefish is the rising market value of cuttlefish. Between 2008 and 2017, the first sale value of cuttlefish has risen from £1.47 per kg in 2008 to £3.58 per kg in 2017 (MMO landings data 2008-2017).

Historically, the common cuttlefish was not a target species for UK fishers and as such, required little management of the fishery. However, the recent growth of the UK cuttlefish fishery both in terms of economic value and exploitation rate has outpaced the regulative bodies that govern the fisheries. This needs to be rapidly addressed as there are concerns that the English Channel cuttlefish population is currently being fished at an unsustainable level.

References

Abecasis, D., Afonso, P., O'Dor, R. and Erzini, K. (2013). Small MPAs do not protect cuttlefish (*Sepia officinalis*). *Fisheries Research,* 147, pp. 196-201.

Barile, N., Cappabianca, S., Antonetti, L., Scopa, M., Nerone, E., Mascilongo G., Recchi, S. and D'Aloise, A. (2013). New protocols to improve the deposition and hatching of *Sepia officinalis'* eggs. *Veterinaria Italian,* 49 (4), pp. 367-374.

Belcari, P., Sartor, P., Sanchez, P., Demestre, M., Tsangridis, A., Leondarakis, P., Lefkaditou, E. and Papaconstantinou, C. (2002). Explotation patterns of the cuttlefish, *Sepia officinalis* (Cephalopoda, Sepiidae), in the Meditteranean Sea, *Bulletin of Marine Science,* 71(1), pp. 187-196.

Blanc, A., and Daguzan, J. (1999). Young cuttlefish *Sepia officinalis* (Mollusca: Sepiidae) in the Morbihan Bay (south Brittany, France): accessory prey of predators. *Journal of the Marine Biological Association of the United Kingdom,* 79(6), pp. 1133-1134.

Bloor, I. (2012). The ecology, distribution and spawning behaviour of the commercially important common cuttlefish (Sepia officinalis) in the inshore waters of the English Channel. PhD Thesis, University of Plymouth.

Bloor, I., Attrill, M., and Jackson, E. (2013). A Review of the Factors Influencing Spawning, Early Life Stage Survival and Recruitment Variability in the Common Cuttlefish (*Sepia officinalis*). *Advances in Marine Biology*, 65, pp. 1-65.

Boucaud-Camou, E., Boismery, J., (1991). The migrations of the cuttlefish (Sepia officinalis L.) in the English Channel. La Seiche: actes du Premier Symposium international sur la seiche. Caen, 1–3 Juin 1989. Centre de publications de l'universite de Caen.

Devon and Seven Inshore Fisheries and Conservation Authority (2018). *Devon and Seven IFCA Enforcement-Legislation.* Available at: https://www.devonandsevernifca.gov.uk/Enforcement-Legislation (Accessed on 17/10/2018).

Denis, V. and Robin, J. (2001). Present status of the French Atlantic fishery for cuttlefish (*Sepia officinalis*). *Fisheries Research*, 52, (1-2), pp. 11-22.

Dunn, M. (1999). Aspects of the stock dynamics and exploitation of cuttlefish, *Sepia officinalis* (Linnaeus, 1758), in the English Channel. *Fisheries Research,* 40, pp. 277-293.

Enevera, R., Revill, A. and Grant, A. (2007) Discarding in the English Channel, Western approaches, Celtic and Irish seas (ICES subarea VII), *Fisheries Research* 86, pp.143-152.

Eno, C., Frid, C., Hall, K., Ramsay, K., Sharp, R., Brazier, D., Hearn, S., Dernie, K., Robinson, K., Paramor, O. and Robinson, L. (2013). Assessing the sensitivity of habitats to fishing: from seabed maps to sensitivity maps[a]. *Journal of Fish Biology,* 83, pp. 826-846.

Eno, C., MacDonald, D., Kinnear, J., Amos, C., Chapman, C., Clark, R., Bunker, F. and Munro, C. (2001). Effects of crustacean traps on benthic fauna, *International Council of the Exploration of the Seas Journal of Marine Science,* 58, (1), pp. 11-20.

Essington, T., Beaudreau, A. and Wiedenmann, J. (2006). Fishing through marine food webs. *Proceedings of the National Academy of Sciences,* 103(9), pp. 3171-3175.

European Parliament and Council of the European Union, (1996). *Regulation (EU) No 2406/1996 laying down common marketing standards for certain fishery products*. Brussels: Official Journal of the European Union.

European Parliament and Council of the European Union, (1998). *Regulation (EU) No 850/1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms*. Brussels: Official Journal of the European Union.

Foden, J., Rogers S, and Jones, A. (2010). Recovery of UK seabed habitats from benthic fishing and aggregate extraction—towards a cumulative impact assessment. *Marine Ecology Progress Series,* 411, pp. 259-270.

Gras, M., Roel, B., Coppin, F., Foucher, E. and Robin, J. (2014). A two-stage biomass model to assess the English Channel cuttlefish (*Sepia officinalis* L.) stock. *International Council for the Exploration of the Seas Journal of Marine Science*, 71 (9), pp. 2457–2468.

Gras, M., Safi, G., Lebredonchel, H., Quinquis, J., Koueta, E. and Robin, J. (2016). Stock structure of the English Channel common cuttlefish *Sepia officinalis* (Linnaeus, 1758) during the reproduction period. *Journal of the Marine Biological Association of the United Kingdom,* 96, (1), pp. 167-176.

Guerra, A. (2006) Ecology of *Sepia officinalis. Vie et Milieu,* 56(2), pp. 97-107.

International Council for the Exploration of the Seas. (2017). Report of the Working Group on Cephalopod Fisheries and Life History (WGCEPH), 14–17 June 2016, ICES Headquarters, Copenhagen, Denmark.

Isles of Scilly Inshore Fisheries and Conservation Authority (2018). *Isles of Scilly IFCA Byelaws.* Available at: https://www.scillyifca.gov.uk/byelaws (Accessed on 17/10/2018).

Keller, S., Valls, M., Hidalgo, M., and Quetglas, A. (2014). Influence of environmental parameters on the life-history and population dynamics of cuttlefish *Sepia officinalis* in the western Mediterranean. *Estuarine, Coastal and Shelf Science*, 145, pp. 31–40.

Kent and Essex Inshore Fisheries and Conservation Authority (2018). *Regulations KEIFCA Byelaws.* Available at: https://www.kentandessex-ifca.gov.uk/i-want-to-find-out-about/regulations/keifca-byelaws/ (Accessed on 17/10/2018).

Melli, V., Riginella, E., Nalon, M. and Mazzoldi, C. (2014). From trap to nursery. Mitigating the impact of an artisanal fishery on cuttlefish offspring. *Public Library of Science ONE* 9(2): e90542. doi:10.1371/journal.pone.0090542.

Molfese, C., Beare, D. and Hall-Spencer, J. (2014) 'Overfishing and the replacement of demersal finfish by shellfish: an example from the English Channel.', *Public Library of Science One*, *9*(7), doi: 10.1371/journal.pone.0101506.

Montgomerie, M. (2015). *Basic fishing methods a comprehensive guide to commercial fishing methods.* Edinburgh: Seafish.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. and Torres Jr, F. (1998). Fishing Down Marine Food Webs. *Science*, 279(5352), pp. 860-863.

Pauly, D. and Palomares, M. (2005). Fishing down marine food web: It is far more pervasive than we thought. *Bulletin of Marine Science,* 76 (2), pp. 197-212.

Payne, A., Agnew, D. and Pierce, G. (2006). Trends and assessment of cephalopod fisheries. *Fisheries Research,* 78, pp. 1-3.

O'Neill, F. and Ivanović, A. (2016) The physical impact of towed demersal fishing gears on soft sediments, *International Council of the Exploration of the Seas Journal of Marine Science*, 73, (supplement 1), pp. i5–i14.

Reid, A., Jereb, P. and Roper, C. (2005). Family Sepiidae. In: Jereb, P. and Roper, C. (eds), *Cephalopods of the World. An Annotated and Illustrated Catalogue of Cephalopod Species Known to Date. Volume 1. Chambered Nautiluses and Sepioids (Nautilidae, Sepiidae, Sepiolidae, Sepiadariidae, Idiosepiidae and Spirulidae)*. Rome: Food and Agriculture Organisation of the United Nations.

Revill, A., Bloor, I. and Jackson, E. (2015) 'The survival of discarded *Sepia officinalis* in the English Channel', *Fisheries Management and Ecology*. *22*(2), pp. 164–171.

Richardson, H., Durrance, S. and Mitchell, R. (2018). *Management recommendations for English non-quota fisheries: Common cuttlefish.* London: MRAG Ltd.

Royer, J., Pierce, G., Foucher, E., and Robin, J. (2006). The English Channel stock of Sepia officinalis: Modelling variability in abundance and impact of the fishery. *Fisheries Research*, *78* (1), pp. 96–106.

Sasikumara, G., Mohamed, K., Rohit, P. and Sampathkumar, G. (2015b). *Policy guidance on cuttlefish fishery using Fish Aggregating Devices 2015.* Kochi: Central Marine Fisheries Research Institute.

Southern Inshore Fisheries and Conservation Authority (2018a). *Southern IFCA Byelaws.* Available at: http://www.southern-ifca.gov.uk/byelaws (Assessed on 17/10/2018).

Southern Inshore Fisheries and Conservation Authority (2018b). *Southern IFCA Cuttlefish Traps Code of Practice.* Available at: https://secure.toolkitfiles.co.uk/clients/25364/sitedata/files/Cuttlefishtrapcodeofpracti.pdf (Accessed on 17/10/2018).

Sussex Inshore Fisheries and Conservation Authority (2018). *Sussex IFCA Byelaws.* Available at: https://www.sussex-ifca.gov.uk/byelaws (Accessed on 17/10/2018).

Uhlmann, S and Broadhurst, M. (2015). Mitigating unaccounted fishing mortality from gillnets and traps. *Fish and Fisheries,* 16, (2) DOI: 10.1111/faf.12049

Wang, J., Pierce, G., Boyle, P., Denis, V., Robin, J., and Bellido, J. (2003). Spatial and temporal patterns of cuttlefish (Sepia officinalis) abundance and environmental influences a case study using trawl fishery data in French Atlantic coastal, English Channel, and adjacent waters. *International Council for the Exploration of the Sea Journal of Marine Science*, (60), pp. 1149-1158.

Watanuki, N and Kawamura, G. (1999). A review of Cuttlefish basket trap fishery. *South Pacific Study*, 19 (1-2), pp. 31-48.