Building Knowledge on Squids: A Developing Resource for Dutch Fisheries

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Summary

The Dutch squid fishery has grown rapidly since 2019, making the Netherlands the second-largest EU contributor to squid landings. Historically absent from these fisheries, the Dutch fleet, initially the flyshooters and, more recently, the otter trawlers and beam trawlers, has increasingly targeting squid during winter. This shift is likely driven by the high profitability of this new fishery, the need for the fleets to diversify their activity, and the absence of quota restrictions of squid, coupled with a rising squid abundance in the North Sea.

Given the increasing importance of this fishery in the Netherlands, there is a need to develop a good knowledge basis on these species and the fishery they sustain. This study examines the recent development and current state of Dutch squid fisheries, characterising the shift of the part of the demersal fleet to squid fishing. Catch rates, bycatch species composition, and the importance of squid as bycatch in other fisheries are also quantified. The study also explores changes in squid distribution using scientific survey data and examines market dynamics, as two potential factors influencing the developments in the fishery. A literature review synthesizes the available knowledge on squid biology, ecology, and their role in the food chain. Finally, this work reviews the regulations in place in the EU and the UK that apply to squid fisheries and provides an overview of global strategies for managing squid stocks.

The literature review gathered useful information on the unique biology and ecology for these species. Both the veined squid (*Loligo forbesii)* and the European squid (*Loligo vulgaris*) have a widespread distribution over the European waters. They are highly mobile and undertake migrations from offshore foraging grounds to inshore spawning habitats. Spawning and nursery grounds of the *L. forbesii* are located primarily in the northern areas (from West Ireland, Scotland and northern North sea) while, for *L. vulgaris* , they are mainly located between the Celtic Sea, English Channel, and southern North Sea.
The literature review also confirmed that both species have extended their distribution range into the North Sea: southwards into the southern North Sea for *L. forbesii,* which was historically only abundant in the northern and central North Sea, and northwards, towards the central North Sea for *L. vulgaris,* which is typically more abundant in the Celtic Sea and English Channel. These changes presumably occurred as winter water temperatures increased in the southern North Sea. The analysis of scientific survey data conducted in this study confirm this, indicating an overall increase of *L. forbesii* in the central and southern North Sea, and an increase of *L. vulgaris* in the southern North Sea.

Both species have a short life-cycle, with a longevity just over one year, and are characterized by an extremely fast growth and semelparity (death of all individuals after reproduction). This implies that the fishery exploits each year a single year-class, and the yields are strongly driven by recruitment strength. Biological processes such as recruitment are strongly linked to the environmental conditions, and are therefore very variable. It is believed that each species have one main recruitment event per year, although other *Loligo* species are known to have successive recruitment “waves” or even two separate recruitment seasons in a year (e.g. *Doryteuthis gahi* in the Falklands). The review of management approaches implemented worldwide showed that the traditional fisheries management approach (steering the fisheries so the stock remains close to target biomass levels compatible with MSY) does not work for such short-lived stocks for which escapement strategies are generally used (to ensure that enough individuals are left alive at the end of each fishing season). Such management approaches require regular in-year monitoring to the stock, with biomass assessed using depletion model based on near real-time catch information.

Analyses of the fisheries logbook confirmed the rapid development in the fishery. Targeting of squid in the winter months (November to March) by the flyshooters appears to have been stable over the period studied (2018 to 2024). Mainly conducted in the eastern English Channel, this fishery increased slightly in the southern North Sea. The targeting of squid with bottom otter trawl has strongly increased since 2018, and the landings from this gear now represent half of the yields of the flyshoot fishery. The vessels fishing squids with bottom otter trawl mainly operate in the southern North Sea, where their fishing grounds overlap with those of the

flyshooters. Different types of vessels target squid with bottom otter trawl : pure bottom trawlers that increasingly target squid, and beam trawlers that have installed net rolls to be able to also operate bottom otter trawl in alternance with their traditional beam trawl. This adaptation of beam trawlers to be able to operate bottom otter trawl might have been encouraged by the boom of the squid fishery, as several beam trawlers were found in this study to have done this transition at once in 2023 to immediately start targeting squid. This illustrates the interest for squid as a new target species for the beam trawler fleet, as it faces many challenges with its traditional fishing practices.

The fishing activity targeting squids generates a significant amount of by-catch, especially for the flyshooters fleet. Next to squid, these vessels also have significant landings of striped red mullet and cuttlefish (two non-quota species with high commercial value), mackerel and horse mackerel (both valuable pelagic species), and the less valuable gurnard and whiting. The squid typically represents one third of the catches. For the bottom otter trawl, the proportion of squid is higher (around 50%) and the less abundant bycatch is mainly composed of pelagics (mackerel and horse mackerel) and whiting, representing a less valuable complement to the squid landings than for the flyshooters. Smaller quantities of squid are also caught as by-catch in the beam trawl fishery, while targeting flatfish in the southern North Sea, and by the pelagic freezer trawlers during their blue whiting and North Sea herring fisheries. The discards from the squid fisheries are not yet fully quantified, but the first observations indicated that discarding of whiting, herring, striped red mullet and flatfish occur in these fisheries.

The increasing focus on squid was also made possible by the well-organized post-harvest chain in the Netherlands. As the fishery developed, Dutch fish processors and seafood wholesalers have taken the initiative to promote this fish product. It was successfully presented as a new Dutch seafood product, next to the traditional flatfish, to the Italian, Spanish and French markets, creating an immediate demand for this product. An important part of the landings occur in foreign harbors (mainly Boulogne-sur-Mer and Ostend) but the squid is transported to the Netherlands to be sold, either in the auction or by contract, to Dutch fish processors and seafood wholesales. Half of the Dutch production is then sold as fresh product to the hospitality industry in Belgium and France. The second half of the production is sold frozen, to southern Europe countries. While the volume exported increased strongly (almost 6-fold since 2016), the price also raised, indicating a steady demand for this product.

The Dutch squid fishery operates under unique regulatory conditions, having to do with the definition of directed fishing, mandatory minimum mesh sizes and applicable authorisation schemes. Which regulations apply to certain fisheries mainly depends on their target species, fishing area and vessel type, but also bycatch species. Squid is not regulated by quota, meaning that EU catch quota, the landing obligation (LO), or national quota ("*contingenten*"), are not applicable to these species. There are also no minimum reference conservation size (MRCS) nor marketing standards in place. Furthermore, squid is not part of the multiannual plan for the North Sea demersal fisheries (MAP). Currently, no authorisations are granted specifically for the directed fishery for squid in the Netherlands. Caution should however be given to which regulations apply to squid or to the Dutch squid fisheries (e.g. via vessel type used, target area, bycatch species). An authorization requirement under the MAP (Vismachtiging meerjarenplan Noordzee , VMN) is not solely determined by its target species but also by its bycatch composition. Moreover, the most important bycatch species in squid fisheries are subject to regulations, including the LO. A common thread is therefore the consideration that a clear definition for 'targeted' or 'directed' fishing ('gerichte visserij') lacks in legislation and regulations. This report has shown that several complex jurisdictional areas of discussion remain, given the regulatory nuances and interpretations underlying them. At this moment, directed fishing for squid is in principle allowed with a mesh size of at least 40mm, but in practice, a minimum mesh size of 80 mm is most commonly applied in the Dutch squid fishery. Recently both national and international requests have been submitted to increase the minimum mesh size of directed squid fisheries to 80 mm to enable more sustainable fishing practices. The amendment will likely be integrated in regulations in 2025. Similar developments are seen in UK regulation, where option for directed squid fishing with a minimum mesh size of 40 mm was removed for all towed gears leading to an increase of minimum mesh size to 80 mm. Recently, it was again increased to 100m for demersal; seine.

The present study also conducted an overview of potential selectivity devices to reduce the by-catch of whiting in trawl fisheries. The most promising device is a square mesh panel positioned on the top part of the net.

However, the efficiency of such a device for the squid fishery (i.e. reducing whiting by-catch without reducing the squid catches) remains to be tested.

1 Introduction

Squid, together with cuttlefish or octopuses, belong to the phylogenetic class of the Cephalopods. In the North Sea and English Channel, several squid species are documented, predominantly from the families Ommastrephidae (short-finned squids) and Loliginidae (long-finned squids). Ommastrephid squids are typically oceanic and pelagic, making them less susceptible to demersal fishing gears commonly used in North Sea fisheries. Conversely, loliginid squids are more demersal, inhabit relatively shallow waters, and are more likely to be caught as bycatch or in targeted demersal fisheries (van der Kooij, Engelhard & Righton, 2016). The region marks the distributional boundary for several loliginid species, including the commercially important veined squid (*Loligo forbesii*). While *L. forbesii* has an extensive range across the eastern Atlantic from 20° to 60° N, it reaches its northern limit in Irish and British waters (van der Kooij et al., 2016). The European squid (*Loligo vulgaris*) is also present in the English Channel and southern North Sea. The European common squid (*Alloteuthis subulata*)—though abundant—is less commercially valuable due to its smaller size (van der Kooij et al., 2016). The landings in the demersal fisheries conducted in the North Sea and English Channel are dominated by the two main *Loligo* species, *L. forbesii* and *L. vulgaris* (ICES, 2023). Therefore, this report focusses only on these two species.

Significant squid fisheries have been conducted in the English Channel and the North Sea for many years, primarily by the UK and France. Although the Dutch fleet was historically not involved in these fisheries, it has increasingly targeted squid in recent years, with landings showing a marked increase since 2019. The Netherlands has now become the second largest contributor to squid landings among EU member states (ICES, 2024). An increasing number of demersal fishing vessels from the Netherlands are switching periodically from traditional target species (flat fish, shrimps or *Nephrops*) to actively targeting squid in winter. Vessels targeting squids are primarily flyshooters and bottom otter trawlers, but also more recently beam trawlers.

The main reasons for the development of the Dutch squid fishery still need to be clarified, but they are likely linked to the current profitability of the fishery on squid, combined with the need for part of the Dutch demersal fleet (the beam trawlers) to diversify their list of target species. In addition, apart from some restrictions on access, the fishery is currently not limited by quota restrictions and therefore vessels can join the fishery even though they have no historical rights. Changes in the squid distribution and increasing abundances in the North Sea have also been suggested as potential factors driving this development.

Squid fisheries in the English Channel and Southern North Sea are conducted both in the European Union and in the United Kingdom Exclusive Economic Zones (EEZs), and the management of these fisheries falls under the authority of these two parties. Although vessels fishing for squid are subject to a number of technical measures and restrictions on access, there is currently no specific management measure implemented by the EU and UK to explicitly limit the impact of the exploitation on squid. However, if the political context changes, there might be a will from one or both of these parties to start imposing more limitations to these fisheries. Even though, due to the annual life cycle of squid, these fisheries are primarily recruitment driven, defining management measures may also be a necessity to ensure the biological and economic sustainability of the fishery. Squids are known to show quick fluctuations in abundances, which means that not having mechanisms to adjust effort or catches may lead to risk of overexploitation , especially in the current context of growing fishing effort.

Given the increasing importance of this fishery in the Netherlands, and the possible future development of management measures, there is a need to develop a good knowledge basis on these species and the fishery they sustain. While squids are included in the Dutch market sampling program only since 2024 (under Statutory Research Tasks), there is ample information on squid landings in the past years in the logbook data. This data needs to be analyzed to provide a first overview of the Dutch squid fisheries, describing the recent changes in the fleet targeting squid (number of vessels, types of gear used), and the spatial and seasonal dynamics of the fishery. Likewise, although these species have not been the focus of many scientific research projects in the Netherlands, there is a rich scientific literature on squids both in European waters and worldwide. There is therefore a need to gather this existing knowledge and build an expertise on squid. Developing this knowledge base is a first necessary step for the Netherlands to be able to effectively participate in future work on squid, both on the scientific and management side.

This study describes, based on sources of information and data readily available, the recent development and current state of the Dutch squid fisheries. It first analyses which segments of the Dutch demersal fleet have been switching to squid fishing (number and types of vessels), and what is the associated fishing strategy (type of targeting behavior, seasonality of this new activity). The interannual trends, seasonality and spatial distribution in the effort and landings are presented, and the dynamics of the catch rates (in landing per unit efforts) are shown. A first exploration of the suitability of this data for stock assessment is also presented. The species composition and proportion of bycatch species in the squid fisheries are also described for the different fishing techniques, and the importance of squid as bycatch in other Dutch fisheries is also quantified. Scientific survey data is analyzed to explore possible recent changes in the squid spatial distribution. An analysis of market dynamics is also conducted to understand any recent changes with regard to squid that may have been an explanation of the trend in the fishery. A literature review is also conducted to synthesize the existing knowledge on squid biology (species composition, growth, reproduction, demographic traits) and ecology (role in the food chain, sensitivity to environmental drivers). Finally, current regulations applied in the EU and neighboring countries are listed and an overview of the different management strategies applied worldwide to manage squid stocks is presented.

2 Stock structure, life cycle, ecology and environmental drivers of squid in the North Sea and adjacent areas

2.1 Distribution

The two *Loligo* species have similar distribution ranges, stretching from Northwest Africa to the Northern Shelf of the European continent (Laptikhovsky et al., 2022). *L. vulgaris* extends its range northward to the areas north of Ireland and Scotland, the Kattegat, and possibly southern Norway, while *L. forbesii* reaches slightly farther north, extending to the Orkney Islands and central Norway (Laptikhovsky et al., 2022).
The distribution of the two *Loligo* species in the North Sea and adjacent areas has expanded significantly over recent decades (van der Kooij, Engelhard & Righton, 2016). In the early 1980s, they were primarily recorded in the northwestern (*L. forbesii*) and southernmost (*L. vulgaris*) regions of the North Sea. However, they are now almost ubiquitously present throughout the North Sea.

2.2 Population structure

Knowledge on population structure for the two *Loligo* species remains limited, making it a critical area for research in the management of commercial fisheries (Royer et al., 2002). There are currently no stocks defined by ICES (ICES, 2023).
For *L. forbesii,* genetic studies showed a high genetic homogeneity across the northeast Atlantic, with only the samples from the Rockall bank being found genetically different from the rest (Sheerin et al, 2022). Statolith[1] shape analyses indicate that clusters can be identified, possibility indicating that individuals originating from a particular nursery ground tend to remain together as a separate ecological group over the first part of their life cycle (Sheerin et al, 2022). *L. forbesii* has variable spawning seasons throughout the Northeast Atlantic, including in Scottish waters, the Celtic Sea, the English Channel, the Faroe Bank, and the North Sea. Bobowski et al. (2024) noted that while statolith shapes differed significantly among most areas, there was a relatively high misclassification rate for samples from the Celtic Sea. Moreover, statolith shapes did not differ significantly between samples from the Celtic Sea and the North Sea, suggesting a connectivity between these two regions likely facilitated by migration. The existence of multiple groups of *L. forbesii* within the North Sea is further supported by differences in size classes and breeding populations. Previous research identified two distinct breeding populations in the North Sea (Pierce et al., 2005) and noted two size-groups that suggested separate spawning areas—one associated with the English Channel and another in the northern regions. However, recent findings by Laptikhovsky et al. (2022) did not find evidence of spawning activity of *L. forbesii* in the English Channel, implying that the southern spawning area is more likely the Celtic Sea. In summary, evidence points to the seasonal presence of *L. forbesii* from two distinct sub-populations in the North Sea: individuals originating from the Celtic Sea and native North Sea spawners (with a potential contribution from the West of Scotland spawners, Bobowski et al., 2024). The slightly higher misclassification rates within the North Sea during the first quarter of the year suggest a greater mixture of stocks during this period compared to the third quarter. While it is currently challenging to quantify the exact composition of these clusters, the findings underscore the complexity of *L. forbesii* population dynamics in the region.

No pan-Europan study of population structure of *L. vulgaris* could be found in this literature review.

[1] Statoliths are hard calcareous structures in cephalopods, part of the organ responsible for detection of linear and angular acceleration. Like otoliths in fish, they can provide information on the age of the individual, and their shape is influenced by the conditions in which the individuals growth and therefore often varies among different stocks

2.3 Spawning, egg distribution, recruitment and growth

Spawning behavior and egg distribution

Both *L. forbesii* and *L. vulgaris* are annual, semelparous species, meaning they spawn only once in their lifetime. They migrate from offshore feeding grounds to inshore spawning habitats, depositing eggs on various types of substrates in relatively shallow waters where fishing activities like dredging and beam trawling can occur (Laptikhovsky et al., 2021). Due to their mobility, identifying spawning areas based solely on the presence of mature females can be misleading; therefore, the presence of egg masses provides a more accurate indication of spawning locations, although species-level identification of these egg masses remains challenging (Laptikhovsky et al., 2022).

Spawning of *L. forbesii* and *L. vulgaris* mainly occurs in two main areas in the northwestern European waters - a northern area for *L. forbesii* and southern area for *L. vulgaris* – although egg distribution also overlap to some extend for the two species. The northern grounds encompass waters around Ireland, northern England, Scotland, and western Norway, predominantly utilized by *L. forbesii*. Spawning season for this species covers the months December to June with peak spawning occurring in the winter months, although mature individuals are sometimes observed year-round. *L. forbesii* generally spawns in deeper waters ranging from 10 to 150 meters, occasionally reaching depths up to 700 meters in warmer regions. The spawning and nursery grounds are likely influenced by the Shelf Edge Current, which flows along the shelf edge from Brittany to northern Scotland and continues toward the North Sea (Laptikhovsky et al., 2022).
The southern spawning grounds extend from the eastern shallow regions of the Celtic Sea and the Bristol Channel to the waters off the Netherlands and Germany. These areas are mainly utilized by *L. vulgaris*, although *L. forbesii* reproduction is also possible in certain locations (Laptikhovsky et al., 2022). *L. vulgaris* typically reproduces between November and April in the English Channel, peaking in February and March. In the southern North Sea, spawning occurs later, from April to August. This species lays eggs at depths between 2 and 120 meters, predominantly in waters shallower than 50 meters.

Egg characteristics and development

Females of both species exhibit extended spawning periods, intermittently laying several egg batches. Their egg masses consist of numerous finger-like capsules or "strings," which are individually attached to substrates. Females often add eggs to existing masses, resulting in capsules at different embryonic stages due to staggered deposition times (Laptikhovsky et al., 2021). Large egg masses of *L. vulgaris* in the English Channel can contain up to approximately 42 000 eggs.
Recent studies have confirmed that the eggs and embryos of *L. vulgaris* are smaller than those of *L. forbesii*, allowing for species identification once the developmental stage is known (Laptikhovsky et al., 2021). In the western English Channel, spawning of *L. vulgaris* occurs in late winter and concludes by April, as mature females are no longer observed afterward. Conversely, recent evidence of *L. forbesii* spawning in this area is limited, suggesting possible shifts in spawning locations due to environmental changes.

Recruitment patterns and growth

The nursery grounds of both species generally coincide with their spawning areas, with no evidence of early juveniles outside regions where egg masses are observed (Laptikhovsky et al., 2022). These areas are influenced by oceanic currents and water temperature, facilitating the eastward and northward expansion of spawning activities following the coldest part of the year.
Recruitment patterns differ between the two species. Sampling of squid landings from the English channel indicates that *L. forbesii* recruits appear in June and peak in July, while *L. vulgaris* begins to appear from September onward, with recruits comprising over 80% of sampled individuals by November (Marcout et al., 2024). Spawning occurs approximately seven months before the recruitment of a new cohort, aligning with the time when individuals reach their largest sizes, suggesting that females are ready to lay eggs shortly before dying.
Growth studies have utilized methods such as statolith increment analysis to estimate age and growth rates. In *L. vulgaris*, individuals with mantle[2] lengths ranging from 59 to 520 millimeters corresponded to ages

[2] The mantel is the muscular part of the body that protects internal organs

between 51 and 543 days, with males estimated to have a lifespan of up to 17 months and females up to 14 months (Lishchenko et al., 2021). For *L. forbesii*, similar analyses suggested lifespans of up to 18 months for males and 16.5 months for females (Lishchenko et al., 2021). These estimates are somewhat higher than those based solely on statolith readings, indicating potential variations in growth rates.

Further studies by Challier, Pierce, and Robin (2006) aimed to deepen the understanding of *L. forbesii*'s life cycle in the English Channel and Scottish waters, focusing on age at recruitment and individual growth variability. Their findings revealed that although recruitment in the English Channel begins when squids are about 6–7 months old, the majority (95%) were actually between 8 and 10 months old. In Scottish waters, recruits were slightly older, with smaller individuals aged 7–8 months and others between 8 and 11 months. This suggests that *L. forbesii* may have a one-year life cycle with rapid growth during the adult phase or that its maximum lifespan exceeds one year.

High interannual fluctuations in *L. forbesii* recruitment have been observed, with strong recruitment in 1993–1994 and poor recruitment in 1998 (Challier et al., 2006). This variability may partly reflect density-dependent mechanisms affecting early life stages: when egg and juvenile abundance is high, competition can slow growth and potentially increase mortality, thereby limiting how large final recruitment can become. Conversely, lower densities may allow faster individual growth and higher survival among juveniles, which can help buffer against low recruitment. However, if fishing pressure excessively reduces the overall stock, the diminished spawning population may undermine future recruitment despite faster growth of the remaining individuals. In addition, environmental factors (e.g., temperature, prey availability) appear to play a strong role in shaping local population dynamics—*L. forbesii* in the English Channel and Scottish waters show marked differences in growth and morphology, despite little to no genetic differentiation (Challier et al., 2006).

2.4 Ecology

Squids are a vital component of marine ecosystems, serving both as predators and prey. As short-lived and fast-growing cephalopods, they feed on a variety of pelagic and demersal fishes, other cephalopods, and crustaceans, while also being a key food source for many apex predators (van der Kooij, Engelhard & Righton, 2016).

L. forbesii exhibits a diverse diet that evolves with age. Younger individuals primarily consume crustaceans, while larger squids shift their preference towards fish, including species from the *Ammodytidae* (sandeel), *Clupeidae*, *Gadidae*, and *Gobiidae* families (Oesterwind & Piatkowski, 2023). Additionally, larger individuals exhibit cannibalistic behavior more frequently, which may be linked to food scarcity or high population densities (Wangvoralak, Hastie & Pierce, 2011). Given their relatively high numbers, *L. forbesii* has the potential to exert considerable predation pressure on various fish species, some of which are commercially valuable (Oesterwind & Piatkowski, 2023).

L. vulgaris has a diet comparable to *L. forbesii*. In both the North Sea and Spanish waters, smaller *L. vulgaris* feed more on crustaceans, whereas larger individuals consume more fish. Notably, sprat (*Sprattus sprattus*) appears most frequently in their stomachs. Although *L. vulgaris* is less abundant in the North Sea, its local impact on commercially important fish species could become significant if its population increases (Oesterwind & Piatkowski, 2023).

The increasing biomass of various cephalopod species in the North Sea suggests that their ecological impact is growing (van der Kooij, Engelhard & Righton, 2016). Larger squids have become more prominent predators of fish, potentially influencing the dynamics of commercially targeted populations. Continued monitoring and research into the trophic ecology of North Sea cephalopods are essential for assessing their role in the ecosystem. Such knowledge is crucial for implementing ecosystem-based fisheries management strategies in the future (Oesterwind & Piatkowski, 2023).

2.5 Environmental Impacts and Climate Change

Squid populations in the North Sea and adjacent areas are highly sensitive to environmental conditions due to their short lifespans and rapid growth rates (van der Kooij, Engelhard & Righton, 2016). Traditional methods of population estimation are often unsuitable for managing these species, as their annual stock sizes depend almost entirely on recruitment success, which is strongly influenced by environmental factors. Consequently, squid abundance can fluctuate significantly from year to year, emphasizing the need for a deeper understanding of how environmental variables affect their populations to ensure sustainable fishery management (Marcout et al., 2024).

Environmental factors play a crucial role during the pre-recruitment period, impacting adult fecundity, egg quality, hatching success, and the growth and mortality rates of paralarvae and juveniles (Marcout et al., 2024). Among these factors, bottom temperature has been identified as the most significant influence on the recruitment of both *L. vulgaris* and *L. forbesii*, explaining 20% and 9.62% of the variance in recruitment, respectively (Marcout et al., 2024). Warmer bottom temperatures positively affect *L. vulgaris* recruitment by accelerating the development of paralarvae and juveniles, effectively shortening the duration of the egg phase. In contrast, increased bottom temperatures negatively impact *L. forbesii* recruitment, likely because this species spawns in deeper, cooler waters — often under 150 meters but sometimes reaching depths of 300–700 meters (Marcout et al., 2024). This negative effect aligns with findings that *L. forbesii* hatching size decreases as temperatures rise (Gowland et al., 2002).

Salinity during the pre-recruitment period also influences recruitment, contributing 7.68% for *L. forbesii* and 3.5% for *L. vulgaris* (Marcout et al., 2024). High salinity levels exceeding 34 PSU negatively affect *L. forbesii* recruitment but have a positive effect on *L. vulgaris*. Laboratory studies have shown that salinity below 34 PSU can lead to embryonic mortality in *L. vulgaris* at early developmental stages, indicating a preference for higher salinity conditions for successful reproduction (Marcout et al., 2024).

Additionally, primary production appears to have a negative effect on recruitment for both species during the pre-recruitment period, explaining 6.3% for *L. forbesii* and 5.1% for *L. vulgaris* to the variance in recruitment (Marcout et al., 2024). The reasons behind this negative relationship are not fully understood and warrant further investigation.

Under the scenario of global warming, these environmental influences suggest differing futures for the two species. *L. vulgaris* may experience increased recruitment due to rising temperatures and salinity levels, leading to shorter paralarvae stages and faster growth and maturity at smaller sizes and younger ages (Marcout et al., 2024; Oesterwind et al., 2022). This could favor rapid population turnover and expansion for *L. vulgaris*. Conversely, *L. forbesii* is likely to be negatively impacted by climate change, with rising temperatures and salinity contributing to decreased recruitment. This is consistent with observations of declining proportions of *L. forbesii* in fishery landings at the Port-en-Bessin market and a reduction in its distribution range within the English Channel (Marcout et al., 2024; Oesterwind et al., 2022).

Squid populations have exhibited significant changes in distribution and abundance, likely influenced by climate change. *L. forbesii*, the most widely distributed species in the northeast Atlantic, has expanded from the northwestern and southern parts of the North Sea to occupy nearly the entire North Sea over recent decades (van der Kooij et al., 2016). This expansion correlates strongly with climatic variables, particularly the Atlantic Multidecadal Oscillation[3] (AMO) and annual sea surface temperatures (SSTs) in the North Sea. Interestingly, *L. forbesii* has exhibited a predominantly southward expansion into the North Sea, from northern parts of the North Sea. While this may seem counterintuitive given its preference for warmer temperatures, it aligns with the winter temperature gradient in the North Sea, where shallow southern areas become colder than the deeper northern regions. Severe winter conditions may have previously made southern areas unsuitable for this species, but warming temperatures have facilitated its spread. Similar patterns have been observed in other warm-water-associated fish species in the North Sea. *L. vulgaris*, although less abundant is found exclusively in the southern part of the North Sea (van der Kooij et al., 2016).

[3] natural climate cycle of sea surface temperature fluctuations in the North Atlantic Ocean, occurring over periods of about 30–80 years

2.6 Conclusion

Squids in the North Sea and adjacent waters have become increasingly important both ecologically and commercially. Their unique life history traits—short lifespans, semelparity, and rapid growth—result in highly variable population dynamics, posing challenges for traditional management approaches (Marcout et al., 2024). Literature indicates that population structure of key species such as *L. forbesii* is more complex than previously understood, with evidence suggesting distinct stocks and potential connectivity between regions (Bobowski et al., 2024).
Despite significant advancements in our understanding of squid biology and ecology, notable knowledge gaps persist. For *L. vulgaris*, there is limited recent information on trophic relationships outside the Mediterranean, and a better understanding of their migration routes and seasonality is needed, particularly in the context of global warming. Similarly, for *L. forbesii*, gaps in knowledge of distribution and abundance remain, especially in areas and times not covered by scientific surveys (Lishchenko et al., 2021). Furthermore, little is known about their migration patterns.

Climate change impacts on squid species require further investigation. Detailed distribution data, including depth preferences, are necessary to understand potential shifts due to global warming, which could have significant ecosystem-level consequences, particularly on trophic interactions. Ongoing monitoring of reproductive status at the species level in overlapping regions is essential, as shifting distributions may lead to competitive interactions among species (Marcout et al., 2024).

3 Squid distribution in the North Sea and eastern English channel; an exploration of available data from scientific surveys

3.1 Introduction

This section analyses the information available on both *L. forbesii* and *L. vulgaris* from scientific surveys conducted in the North Sea and eastern English Channel. Abundance indices are calculated for each survey to look at the change in abundance over time. Synthetic indicators of the distribution of the species in each survey (e.g. centre of gravity) are calculated to describe the changes in distribution.

3.2 Methods

3.2.1 Survey data

The data for the relevant surveys was extracted from the ICES Database of Trawl Surveys (DATRAS) over the period from 1985 to 2023.
The surveys that have been used are listed in table 3.1. The Dutch Sole Net Survey (SNS) and the Demersal Young Fish Survey (DYFS) are both inshore beam trawl surveys, conducted along the Dutch and German coats, and targeting primarily young flatfish. The offshore Beam Trawl Surveys (BTS), also mainly targets flatfish species and covers the entire North Sea. The North Sea International Bottom Trawl Survey (NS-IBTS) and the French Channel Groundfish Survey (FR-CGFS) use a bottom trawl with larger vertical opening and target demersal fish species in general.

Table 3.1: Species or species groups and associated surveys (1985 – 2023).

English name	Scientific name	Survey (Quarter)
Veined squid	*Loligo forbesii*	BTS (Q3); SNS (Q3); DYFS (Q3); FR-CGFS (Q4); NS-IBTS (Q1 & Q3)
European squid	*Loligo vulgaris*	BTS (Q3); SNS (Q3); DYFS (Q3 & Q4); FR-CGFS (Q4); NS-IBTS (Q1 & Q3)

3.2.2 Catch data and abundance estimation

The DATRAS database provides survey catches per trawling station per species or at higher taxonomic level when individuals are not identified at the species level. For stations with positive catches, information on the total number of individuals caught per haul is available. For many commercial fish species, the number of individuals caught per length group is available. This allows for the transformation of numbers at length to biomass at length using empirical length-weight relationships based on the available data. An aggregation across lengths would consequently allow for an estimate of the biomass caught per haul. However, this approach was not suitable here as information about the length composition for squid was often missing. Instead subsequent calculations are based on the number of individuals caught per haul.

3.2.3 Analysis of survey abundance distribution

To visualize the spatial distribution of the population based on estimated numbers per haul, the occurrence and magnitude of catches are mapped for each species, survey, and year. These visualizations display catch locations along with a calculated centre of gravity (CoG) to represent the central tendency of the catch spatial

distribution. The CoG is determined by computing, separately for the latitude and longitude, the mean of the coordinates of each station weighted by the corresponding catches of *L. forbesii* or *L. vulgaris*.
Additionally, ellipses based on the spatial variance of the data are overlaid to indicate a 95% confidence around the CoG.

To arrive at these ellipses, a parametric approach is taken. First the variance for each principal axis is calculated as follows:

$$Var_{lat} = \frac{\sum((latitude_i - CoG_{lat})^2 * catch_i)}{\sum catch_i} \quad (3)$$

$$Var_{lon} = \frac{\sum((longitude_i - CoG_{lon})^2 * catch_i)}{\sum catch_i} \quad (4)$$

Secondly the covariance between the two axes is calculated (equation 5), to arrive at a covariance matrix M (equation 6).

$$COV_{lat,lon} = \frac{\sum((latitude_i - CoG_{lat}) * (longitude_i - CoG_{lon}) * catch_i)}{\sum catch_i} \quad (5)$$

$$M = \begin{bmatrix} Var_{lat} & COV_{lat,lon} \\ COV_{lat,lon} & Var_{lon} \end{bmatrix} \quad (6)$$

Through eigen decomposition this covariance matrix, eigenvalues and eigenvectors are obtained. The eigenvalues represent the magnitude of variance along each axis in 2D space, and the eigenvectors describe the direction of that variance.

To reflect the 95% confidence region around the CoG, these eigenvalues are scaled by the critical value informed by the chi-squared distribution with two degrees of freedom (for latitude and longitude).

$$S\_Eig\_Val_{major} = \left(Eig\_Val_{major} * \chi_{95}\right)^{0.5} \quad (7)$$

$$S\_Eig\_Val_{minor} = (Eig\_Val_{minor} * \chi_{95})^{0.5} \quad (8)$$

The last step is to calculate the ellipse representing the 95% confidence region around the CoG.
Since the eigenvectors provide the direction of variability, they need to be aligned with the geographic axes If the greatest variability (major axis) is found along the latitude direction, the parametric equations for longitude and latitude at angle θ (ranging from 0 to 2п) are:

$$lon_i = CoG_{lon} + S\_Eig\_Val_{maj} * \cos(\theta) * Eig\_Vec_{lon} + S\_Eig\_Val_{min} * \sin(\theta) * Eig\_Vec_{lat} \quad (9)$$

$$lat_i = CoG_{lat} + S\_Eig\_Val_{maj} * \cos(\theta) * Eig\_Vec_{lat} + S\_Eig\_Val_{min} * \sin(\theta) * Eig\_Vec_{lat} \quad (10)$$

3.2.4 Analysis of survey catches per unit effort (CPUE)

To investigate the temporal dynamics of survey catches two approaches can be considered.
The simpler of the two approaches calculates the annual mean of the catch per unit of effort (CPUE) over all stations for each survey and species. This method is similar to what is implemented by the ICES WGCEPH (ICES, 2023).
The more sophisticated approach involves applying a statistical model. The advantage of this approach is that it can include covariates related to survey operations (such as vessel and gear) and geographical position and bathymetry. This allows for a standardisation of the CPUE and processes abundance indices which are not biased by the small variations that can occur in the survey design. Modelling approaches also allow to combine the information from different surveys in a single index. Trials were conducted to test the implementation of a delta-lognormal GAM model (Berg et al., 2014), the most common approach currently used within ICES. However, no acceptable fit of the model to the data could be achieved, likely due to the high patchiness in the catches of the two *Loligo* species in the surveys. Consequently, the model-based approach was not pursued further, and the simpler averaging method, similar to WGCEPH, was used for the analysis.

3.3 Results

3.3.1 *L. forbesii*

Coastal surveys (DYFS, SNS)

L. forbesii occurred rarely in the catches of the two coastal surveys, DYFS and SNS (it was caught only in three hauls since 1985). A single individual was caught in 2012 and in 2013 in division 4b and an 83 individuals were caught in one haul in 2020 in 4c. These catches all occurred during the DYFS, and no individuals were ever caught in the SNS.

Offshore surveys (BTS, NS-IBTS, FR-CGFS)

For the offshore surveys, the frequency of occurrence and the mean catch per hour of *L. forbesii* have increased over the last decade (figure 3.1). This increase is particularly clear in the NS-IBTS-Q3 in the southern and central North Sea (divisions IVb and IVc, figure 3.1) and in the Skagerrak (IIIa20). During that same time of the year, the occurrence of *L. forbesii* also increased in the beam trawl survey (BTS) in the northern North Sea (division Iva), but with lower catches than in the bottom trawl survey. Abundance of *L. forbesii* also increased in the first quarter of the year (NS-IBTS Q1), mainly in the northern North Sea. The abundance also increased in the eastern English channel in quarter 4.

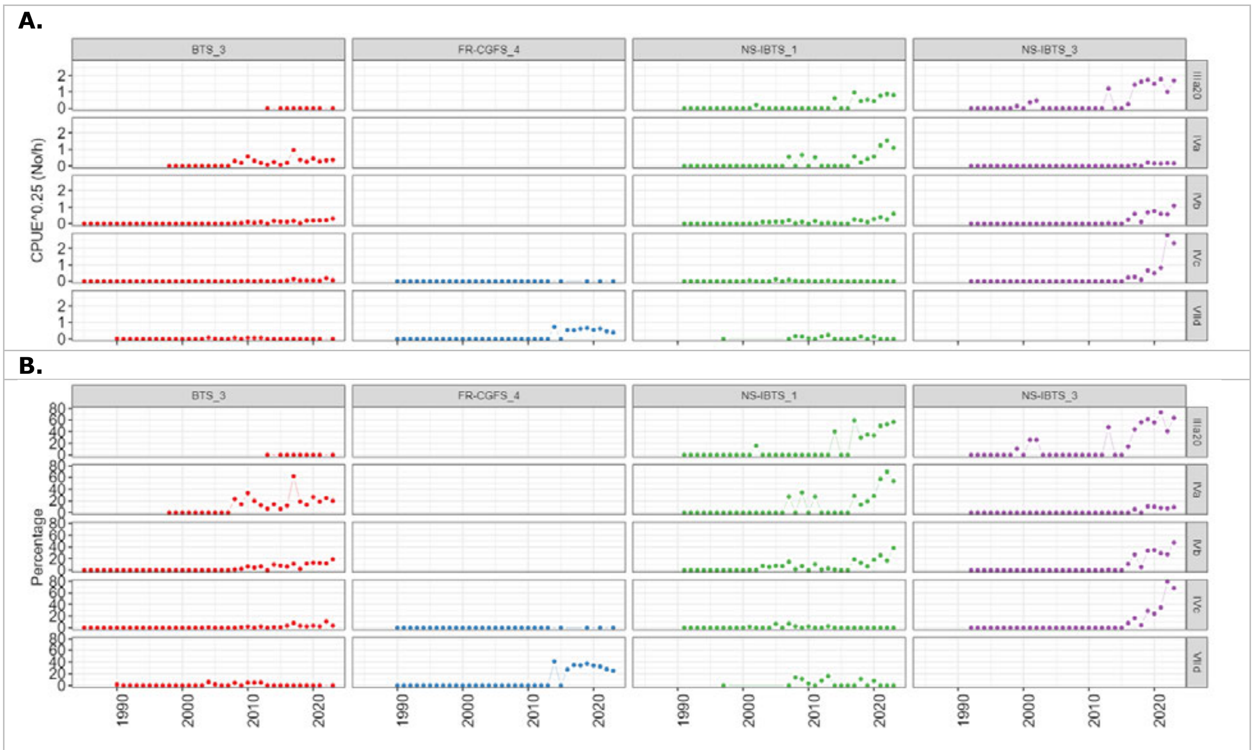


Figure 3.1: *L. forbesii* in offshore surveys : (A) average catch per hours of per survey and ICES division (forth root transformed to improve comparability) and (B) percentage hauls with presence. BTS : beam trawl survey ; FR-CGFS : French Channel groundfish survey ; NS-IBTS : North Sea internation bottom trawl survey. The number in the survey name refers to the quarter in which the survey is carried out.

NS-IBTS Q1

During the NS-IBTS-Q1 survey in the early 2000's, *L. forbesii* was sporadically reported and therefore the position of the centre of gravity was very variable (figure 3.2). Catches of *L. forbesii* during those years occurred primarily in the central North Sea and in the Skagerrak. In 2007, the species was caught in greater numbers along the northernmost parts of the North Sea. This happened again along that same area during the surveys of 2009 and 2011. Between 2012 and 2014, there were lower catches and during 2015 and 2016 no catches are reported for this species in the NS-IBTS Q1. Between 2017 and 2019, larger amounts of *L. forbesii* were caught in a wider area, including the northern central North Sea. Since 2020, high quantities are caught in the northern North Sea and catches have increased in the central North Sea.

During the first quarter of the year, *L. forbesii* seems to have the CoG of the stock primarily in the northern North sea (division 4a). It has occasionally occurred more southernly, spanning parts of the central North Sea, especially in recent years. Data suggest also that *L. forbesii* sporadically occurred in the English channel, but never in considerable quantities.

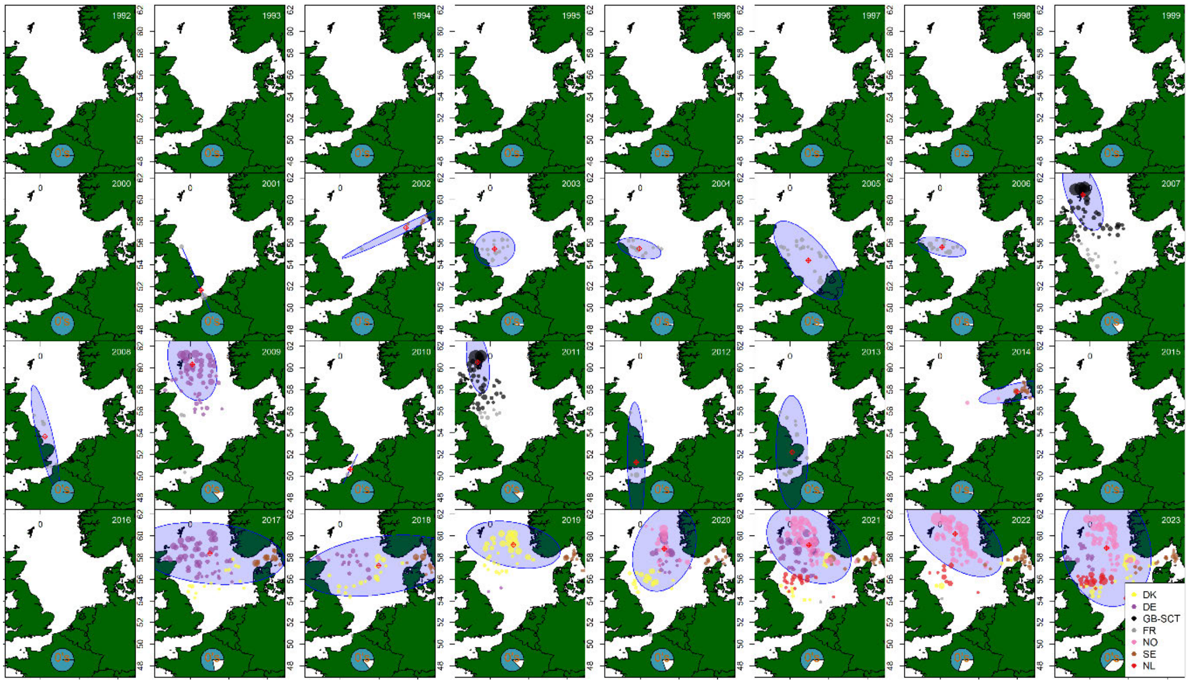


Figure 3.2: Distribution of catches of *L. forbesii* in the NS-IBTS Q1 (1982-2023). The red crosshair depicts the Centre of gravity (CoG) of the catches, and the encircling blue ellipses reflect the 95% uncertainty boundary of the CoG. Catch locations are visible as tiny dots and the radius of these dots reflects the magnitude of the catch number at that location. The colors of the dots refer to the country that made the observations. The pie-diagram in each facet presents the percentage of zero hauls.

NS-IBTS Q3

During the NS-IBTS Q3 survey, catches of *L. forbesii* were first reported in 1999, in the Skagerrak. Similar catches were reported again in 2001 and 2002. After a period without any reported catches in the NS-IBTS-Q3 survey, new catches occurred again in 2013 also in the Skagerrak. In 2016, catches of *L. forbesii* occurred along the northeastern British coast and in subsequent years, catches were reported throughout the North Sea. Catches in the Skagerrak peaked in 2018, with 2964 individuals caught across 14 hauls. In 2019, catches in the northern North Sea reached 3151 individuals across 13 hauls, while catches in central North Sea peaked at 3457 individuals across 50 hauls. Additionally, from 2016 to 2023, there was a marked increase in the number of positive hauls and CPUE in southern North Sea.

The CoG of the *L. forbesii* catches in the NS-IBTS-Q3 primarily lies in the central North Sea (figure 3.3). However, in the last five years, the CoG has shifted southwards toward the southern North Sea, reflecting a broader distribution. This shift is further supported by trends observed in the survey catches in weight (Annex 1).

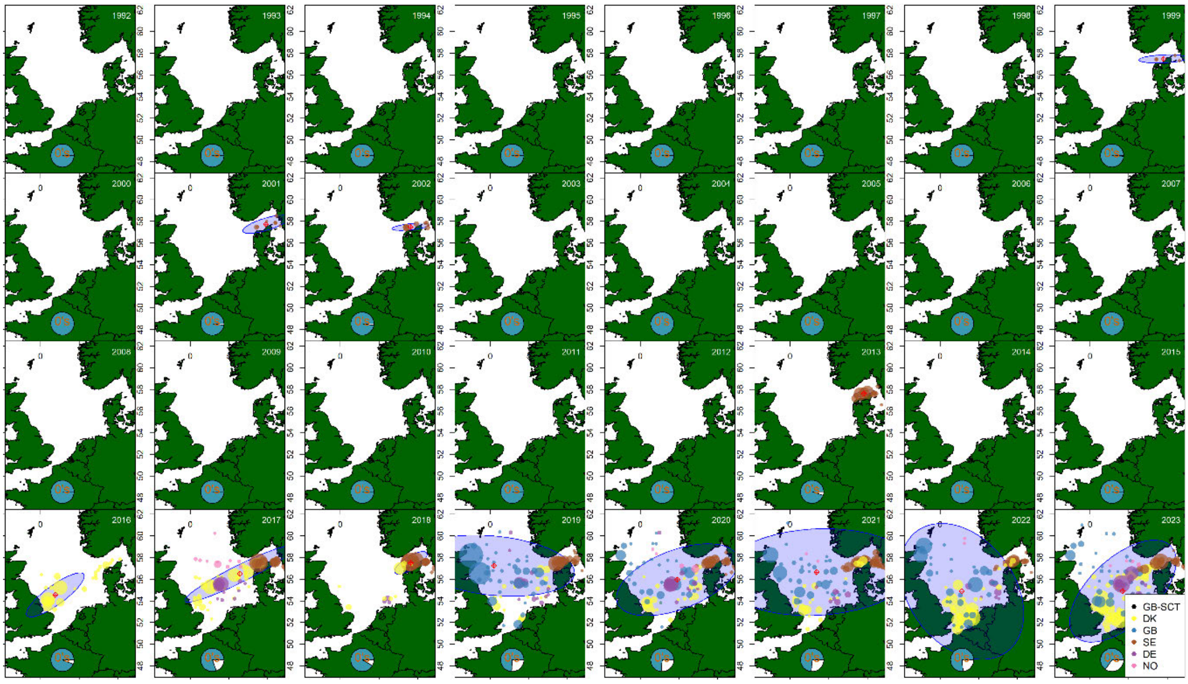


Figure 3.3: Distribution of catches of *L. forbesii* in the NS-IBTS Q3 (1982-2023). The red crosshair depicts the Centre of gravity (CoG) of the catches, and the encircling blue ellipses reflect the 95% uncertainty boundary of the CoG. Catch locations are visible as tiny dots and the radius of these dots reflects the magnitude of the catch number at that location. The colors of the dots refer to the country that made the observations. The pie-diagram in each facet presents the percentage of zero hauls.

BTS surveys in Q3

L. forbesii has consistently been caught in the BTS surveys since the second half of the 2000's. It was first reported in 1990 when 2 individuals were caught in a single haul in the eastern English Channel. The next catches happened in 2004 and 2005 with low quantities caught in the eastern English Channel and the southern North Sea. Since 2008, *L. forbesii* is caught over a wider distribution. Catch numbers have been mostly low but consistent, with slightly higher catches since 2019 in the southern and central North Sea.
The distribution of catches in the BTS surveys do not display a particular trend in the CoG and the uncertainty around it is wide, stretching from the Dutch coast to the eastern Scotland (figure 3.4).

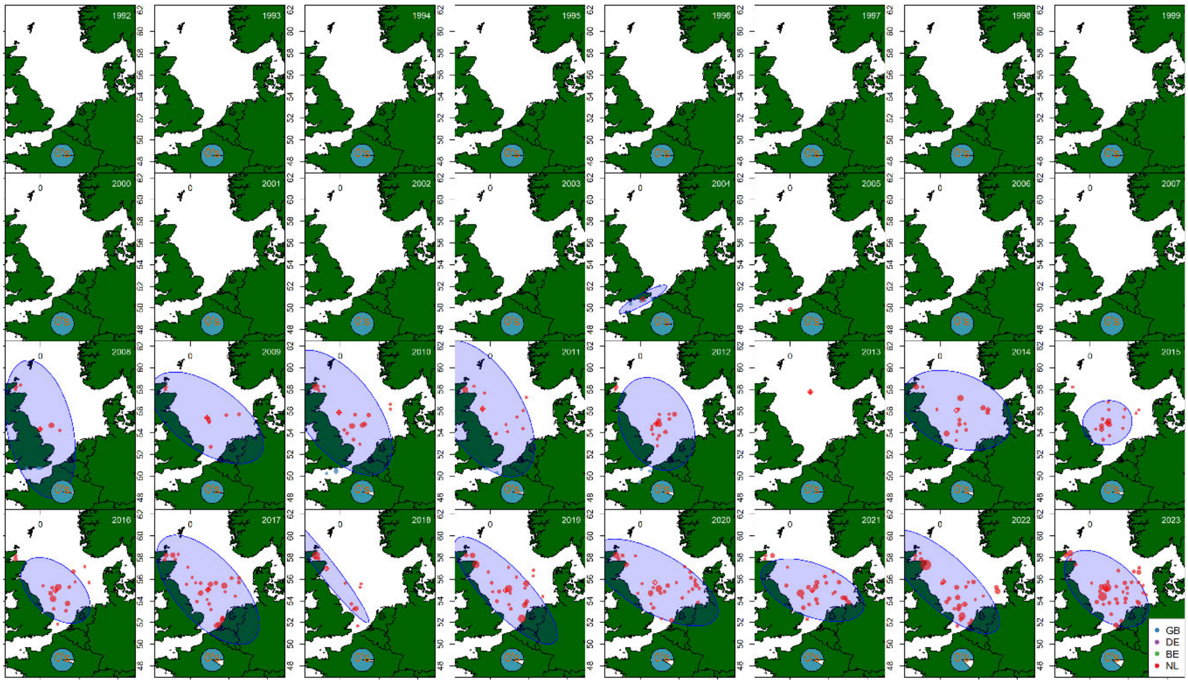


Figure 3.4: Distribution of catches of *L. forbesii* in the BTS Q3 surveys (1982-2023). The red crosshair depicts the Centre of gravity (CoG) of the catches, and the encircling blue ellipses reflect the 95% uncertainty boundary of the CoG. Catch locations are visible as tiny dots and the radius of these dots reflects the magnitude of the catch number at that location. The colors of the dots refer to the country that made the observations. The pie-diagram in each facet presents the percentage of zero hauls.

FR-CGFS Q4

The first record of *L. forbesii* in the FR-CGFS in Q4 survey in DATRAS occurred in 2014. The FR-CGFS has almost exclusively stations in the eastern channel and occasionally fishes in the southern North Sea. Catches for this species have solely occurred in division 7d. Since 2014 the number of positive hauls and overall catch numbers in the survey area has remained stable.

Since this survey solely covers the eastern English channel area a figure displaying the distribution is not insightful and is therefore not shown. The CoG has not shifted throughout the years when catches were registered.

3.3.2 *L. vulgaris*

Coastal surveys (DYFS, SNS)

Positive catches of *L. vulgaris* occurred only sporadically in the coastal surveys (figure 3.5). Small catches are registered in the DYFS survey in 2003 and in 2015 (southern North Sea division 4c) but catches become much more frequent in the southern North Sea after 2020. Similarly, *L. vulgaris* has been absent from the SNS Q3 survey until higher occurrences were recorded after 2017 (central North Sea) and 2018 (southern North Sea). There is hardly any report of *L. vulgaris* in the SNS survey.
Overall, the species has not occurred often in the data of these coastal surveys and the spatial distribution of the catches in these surveys was not investigated.

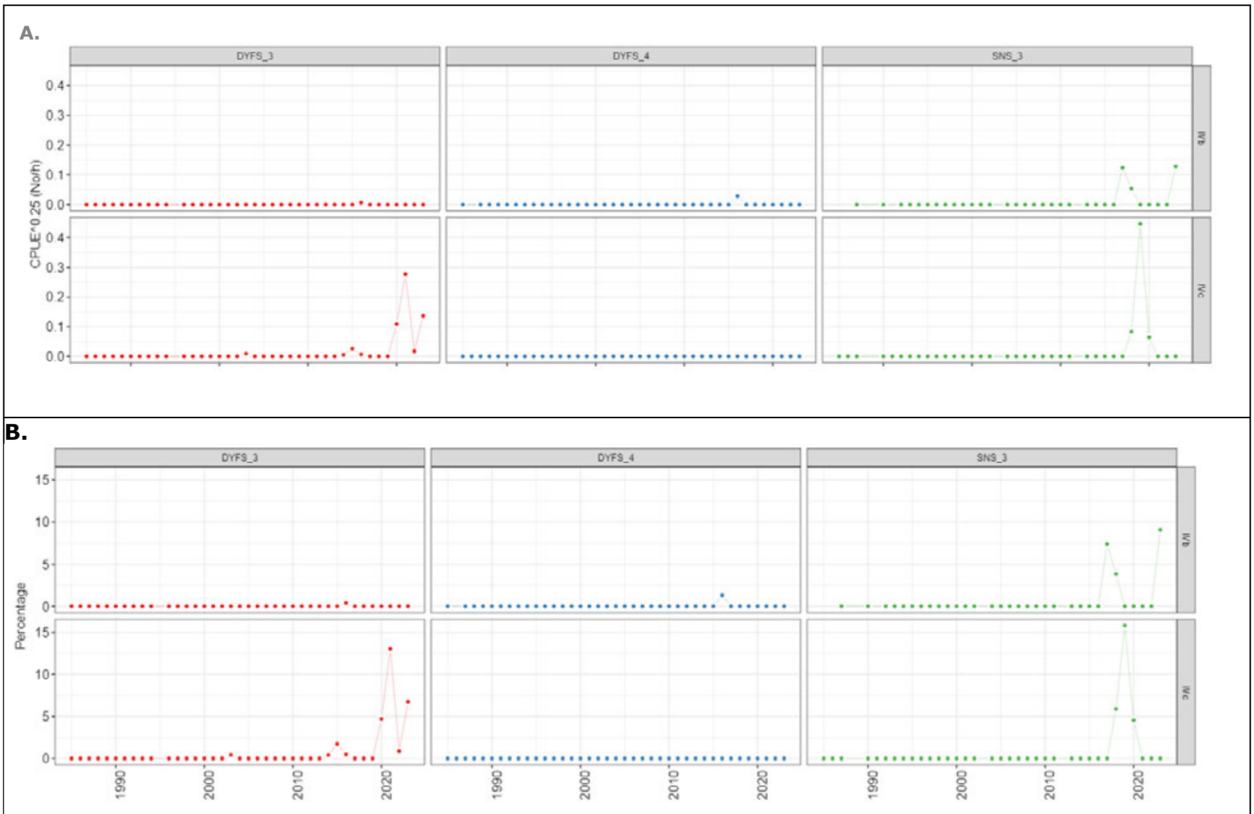


Figure 3.5: *L. vulgaris* in coastal surveys (1983-2023) : (A) average catch per hours of per survey and ICES division (forth root transformed to improve comparability) and (B) percentage hauls with presence of European squid. DYFS : demersal young fish survey ; SNS: sole net survey. The number in the survey name refers to the quarter.

Offshore surveys (BTS, NS-IBTS, FR-CGFS)

For the offshore surveys, there are very few reported catch of *L. vulgaris* before the mid 2000's. The highest occurrences are recorded in the French CGFS Q4 survey, in which the species is caught in almost all the stations after 2003 in the eastern Channel and in the most recent years in the southern North Sea. In Q1 the NS-IBTS has also reported high percentages of positive catches in division 7d, where it has been sampling stations since 2007 and consistently observes the highest CPUE in this area. Over the last decade, catches in division 4b and 4c have also shown an increase, but abundances remain lower than in the more southern areas (figure 3.6).
During Q3, the species only rarely caught, especially in the BTS surveys.

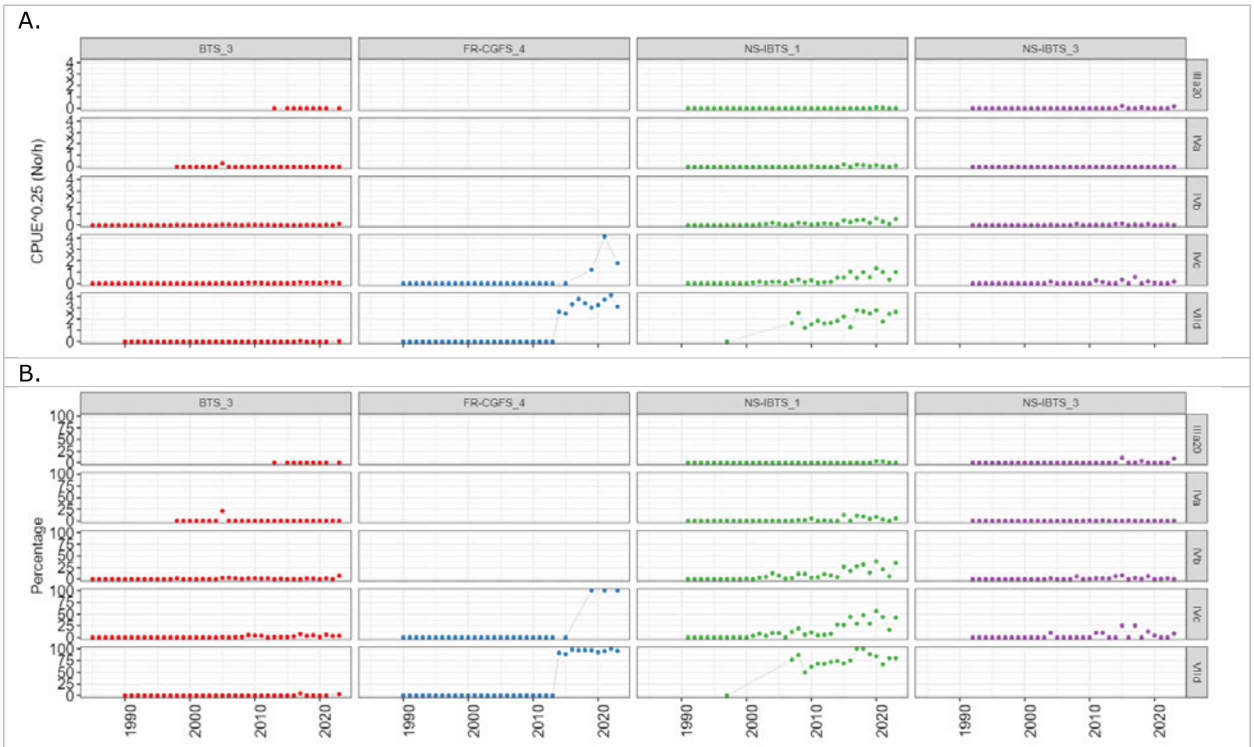


Figure 3.6: European squid (L. *vulgaris*) in offshore surveys : (A) average catch per hours of per survey and ICES area (forth-root transformed to improve comparability) and (B) percentage hauls with presence of European squid. BTS : beam trawl surveys ; FR-CGFS : French Channel groundfish survey ; NS-IBTS : North Sea internation bottom trawl survey. The number in the survey name refers to the quarter.

NS-IBTS Q1

There are few records of *L. vulgaris* in the NS-ITBS Q1 before 2002. After this date, the distribution of the species was predominantly centred on the southern North Sea, with a period between 2009 and 2014 when it moved to the eastern English Channel (figure 3.7).

NS-IBTS Q3 and BTS surveys in Q3

L. vulgaris occurs more rarely in the NS-IBTS Q3 survey and predominantly in the southern North Sea. There is no clear spatial pattern in the distribution of the catches of *L. vulgaris* in this survey and large shifts are observed in the position of the centre of gravity which reflects the scarcity of the data (not shown). The situation is similar for the BTS Q3 surveys, with an even lower occurrence of *L. vulgaris* in these surveys.

FR-CGFS Q4

Catches of *L. vulgaris* in the FR-CGFS in Q4 survey started in 2014. Since 2014, *L. vulgaris* is present in almost all stations. Catches for this survey in covering the eastern English Channel are much higher than in other quarters and other areas by other surveys. Since this survey solely covers the eastern English channel area, and catches have been fairly stable since 2014, the CoG has not shifted throughout the years when catches were reported (not shown).

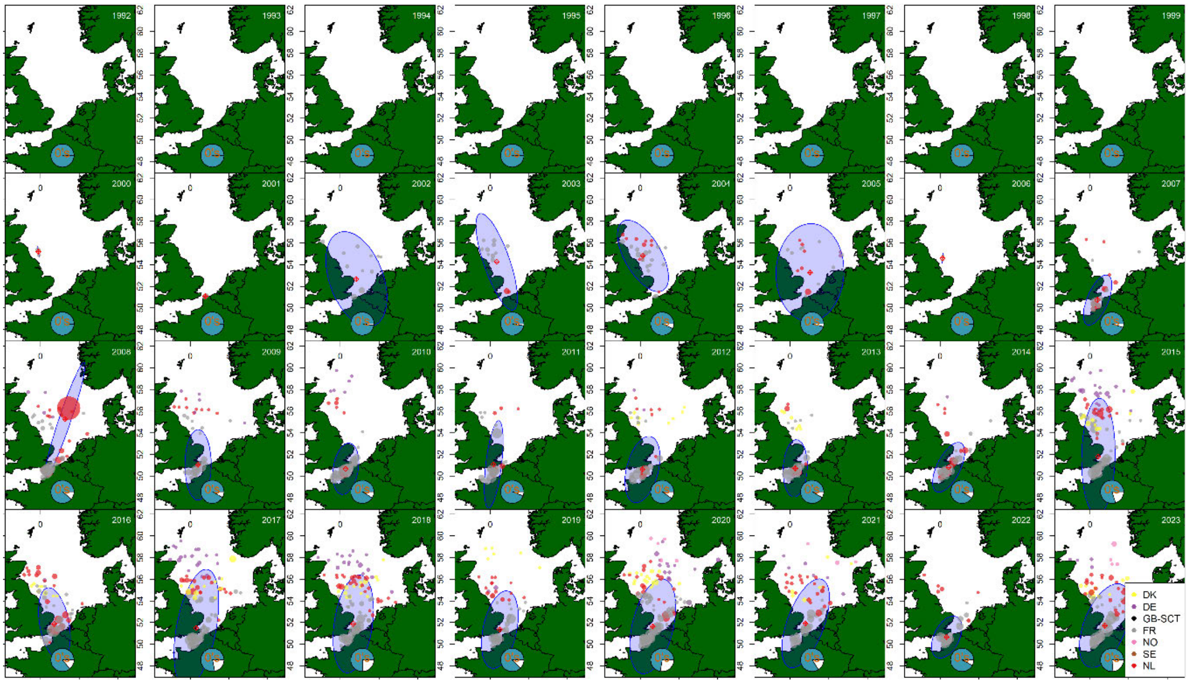


Figure 3.7: Distribution of catches of *L. vulgaris* in the NS-IBTS surveys in quarter 1 (1982-2023). The red crosshair depicts the Centre of gravity (CoG) of the catches, and the encircling blue ellipses reflect the 95% uncertainty boundary of the CoG. Catch locations are visible as tiny dots and the radius of these dots reflects the magnitude of the catch number at that location. The colors of the dots refer to the country that made the observations. The pie-diagram in each facet presents the percentage of zero hauls.

3.4 Discussion

3.4.1 Changes in distribution of *Loligo* species based on the DATRAS data

The investigation into the data from coastal and offshore surveys provides valuable insights into the seasonal dynamics and distribution of the two *Loligo* species in the eastern English Channel and the North Sea.
Surveys indicate an increase of *L. forbesii* in the North Sea since the mid-2010s. This species appears to be mainly distributed in the northern North Sea in Q1 and more abundant in the central and southern North Sea in Q3 with a strong increase in occurrence in the southern North Sea in the recent years. It is also quite frequent in the eastern Channel in Q4, in slightly lower abundances than in the North Sea.
L. vulgaris is on the other end very abundant in the eastern English Channel, both in Q4 and in Q1. Its abundance seems to have increased in the North Sea, mainly in the southern part, in Q1, but it remains rare in the northern North Sea. Its abundance is low in the Q3 surveys.

Overall these conclusions are in line with the information found in the literature review presented above that indicates that both species increased their abundance in the southern North Sea (from the Channel for *L. vulgaris*, and from the more northern parts of the North Sea for *L. forbesii*).

3.4.2 Data limitations and survey constraints

The data used extracted from the DATRAS database might have several limitations and the conclusions from these analysis should be treated with caution.

There are for instance questions about the taxonomic level at which the catches of squid in the survey are reported. Some countries do report their catches both at species level (*L. forbesiii* and *L. vulgaris*) but also at the genus level (*Loligo*). Records reported at the genus level were not used in the analyses presented here. The level at which catches are reported may also have changed over time, but it is difficult to get a clear overview of these changes in reporting practices. Likewise, although DATRAS data can be extracted as far back as the early 1990's, it is unclear if all the countries started reporting the catches of squid in their surveys from this date onwards, or if they started at a later date, and if so how this varied between countries. For example, some countries have not consistently reported catch in weight data meaning that the distribution patterns based on catch in weight represent only a partial view of the species' distribution. Similarly, there is no record of both *L. forbesii* and *L. vulgaris* in the survey covering the eastern English channel before 2014, while these two species have been commercially fished in this area for decades.

While according to the survey data, recent years have seen an increase in the occurrence of squid species in the North Sea, it remains currently unclear to what extend this increase reflects a true population expansion or is primarily an artifact of improvements in data collection and reporting.

A large international effort would be required to harmonise the data. This would require to contact the national data submitters to ask them how squids survey data has been submitted over time, which is a far too large undertaking for the present project. This should be undertaken in a larger project.

WGCEPH (ICES, 2024) has established protocols for data collection, and currently only reports on the responses to their data call. This allows for cautious inferences about trends, but it limits the broader insights that can be drawn from the available data.

3.4.3 Future directions

The bottom trawl surveys (NS-IBTS and FR-CGFS) appear to have a good catchability for the two *Loligo* species, and although questions on the historical data available in DATRAS need to be addressed first, they can provide suitable information on the changes in abundance of *L. forbesii* and *L. vulgaris* in the English Channel and in the North Sea.
The CGFS is conducted in October, which broadly corresponds to the start of the fishing season in the English channel. This survey can therefore provide a quantification of the abundance of squid at the start of the fishing season, which can be a useful information for stock assessment tools, and can also be used to set catch limits. The timing of the NS-IBTS surveys is either too early (summer) or to too late (first quarter), to give early indication on the initial squid abundance. Early information on the size of the recruitment in the North Sea could be derived from the catch rate in the commercial fleet at the start of the season, or, more ambitiously, by developing an industry survey to measure the incoming recruitment (as it is done in the Falklands, see chapter 7).

4 Recent trends and current state of the Dutch squid fisheries

4.1 Methods

4.1.1 Fleet Composition

To describe the Dutch fleet segments involved in squid landings, logbook data from the Dutch fleet spanning January 2018 to July 2024 was analyzed. Logbooks provide daily records of landings composition, gear type, vessel characteristics (e.g., dimensions, engine power, mesh size), and fishing locations in ICES quadrants. Data cleaning was performed by removing duplicate entries, invalid trips (e.g., overlapping trips, arrival before departure), and trips commencing before January of the recorded year. For most years, this lead to the removal of less than 1% of the trips.

The main squid species of commercial interest to the Dutch fleet are *L. vulgaris* (European squid, 3-alpha code SQR) and *L. forbesii* (veined squid, 3-alpha code SQF). However, fishers have historically been using the code "SQS" for "squids" (while it in reality corresponds to the sevenstar flying squid, *Martialia hyadesi*, a non-native species). More recently, under the instruction of the Rijksdienst voor Ondernemend Nederland (RVO), most landings have been ascribed to *L. vulgaris* (SQR), while part of the catch is *L. forbesii*. Fishers however not do sort the catch of the two species or don't even distinguish them, and which in principles corresponds to the code "SQZ" (*Loliginidae*).

Consequently, the analyses reported species codes as recorded in logbooks, with caution advised in interpretation. Table 4.1 details the 3-alpha codes, corresponding species, and usage observations.

Table 4.1 : 3-alpha code used for the main squid species or species groups in the Dutch fisheries

3-Alpha code	English name	Scientific name	Comment
SQF	Veined squid	*Loligo forbesii*	Commonly landed, but not distinguished from *L. vulgaris*, code not used
SQR	European squid	*Loligo vulgaris*	
SQC	Common squids nei*	*Loligo spp*	Not used
SQE	European flying squid	*Todarodes sagittatus*	
SQI	Northern shortfin squid	*Illex illecebrosus*	
SQM	Broadtail shortfin squid	*Illex coindetii*	
SQS			Code used historically by fishers for "squids", although this code formally corresponds to the Sevenstar flying squid, a nonnative species.
SQU	Various squids nei	*Loliginidae, Ommastrephidae*	
SQZ	Inshore squids nei	*Loliginidae*	Not used

*nei = not elsewhere identified

4.1.2 Temporal and Spatial Patterns of Landings

To investigate annual, monthly, and spatial patterns of squid landings, reported landings for each fishing gear type were aggregated by year, month, and 3-alpha code. Spatial patterns were analyzed using ICES divisions, derived from logbook-recorded ICES rectangles. For rectangles spanning over two divisions, landings were assigned to the division containing the majority of recorded catches (e.g., 7.d-e assigned to 7.d). The number of vessels per gear reporting squid landings exceeding 100 kg was calculated to understand fleet engagement in squid fisheries.

4.1.3 Spatial Distribution Analysis

Spatial data from Vessel Monitoring System (VMS) records were combined with logbook data to study the geographic distribution of squid fisheries. Since 2012, all Dutch vessels longer than 12 meters are required to carry VMS, which records vessel ID, geographic coordinates, speed, and heading at 30–120-minute intervals. VMS data were cleaned following Hintzen et al. (2013), removing invalid coordinates, pings in harbor, pings on land, duplicates, and speeds exceeding 20 knots. Fishing activity was identified based on vessel speed and behavior.
Logbook landings were linked to fishing activity inferred from VMS, enabling the analysis of fishing intensity on finer spatial scales. Details on VMS-logbook linkage methodology are available in Hintzen et al. (2013).

4.1.4 Identifying Target Species and Fishing Effort

To identify fishing trips targeting squid, trips where squid (all 3-alpha codes combined) accounted for the largest share of landing value (in euros) were classified as squid-targeting. Landings composition for squid-targeting trips was derived from logbook records, with landed species grouped into categories (e.g. flatfish, mullets, gurnards, clupeids). Landings-per-unit-effort (LPUE) was calculated by dividing squid landings by fishing effort (in days), which was derived from the sum of time intervals between fishing pings in VMS data.

4.1.5 Seasonal Trends in Landings per unit effort

Seasonal trends in landings-per-unit-effort (LPUE) were analyzed for trips identified as targeting squid to understand the temporal dynamics of squid fisheries during the peak fishing season (November to March). These trends provide insights into the exploitation patterns of the two main fleet segments targeting squid: vessels equipped with bottom otter trawls (OTB) and flyshoot nets (or demersal seine, SSC). LPUE was calculated as the weight of squid landed per unit of fishing effort, with effort derived from the sum of intervals between VMS pings identified as fishing activity.
To evaluate how LPUEs develop over the season, depletion models were applied. Depletion models are used to determine how the removal of individuals from a population affects the relative abundance of fish remaining in the population, which can be used to estimate the size of the initial ('virgin') population (Hilborn & Walters, 1992). Here, we used the Leslie method of depletion modelling (Leslie & Davis, 1939). This approach examines the relationship between LPUE and cumulative catch, estimating two key parameters: the catchability coefficient (q) and the initial population size (N_0). The catchability coefficient reflects the efficiency of the fishing process, while N_0 provides an estimate of the abundance of the exploitable population at the start of the season. The LPUE information that can currently be derived from the logbooks is in kg per hour, and is therefore indicative of the exploitable biomass of the stock. Deriving LPUE in number of squids per hour is currently not possible, for lack of individual length or weight measurements taken on the landings. Therefore, the regression was performed between the LPUE in weight, and the cumulated catch in weight. Although this does not fully adhere to the formalism of a depletion model, this gives a first idea of the applicability of such models in the case of squid in the eastern Channel and southern North Sea. Also, given the open population structure of squid and evidence of recruitment occurring throughout the season rather than at a single time, depletion modeling serves as an exploratory tool. The assumptions underlying depletion models—closed populations with no immigration, emigration, natural mortality, or recruitment—may not fully align with the biology of *L. vulgaris* and *L. forbesii*. However, these models offer valuable preliminary insights into population dynamics.

Analyses were conducted separately for each gear type and ICES division to explore spatial and temporal variations in catch trends, using the FSA package (version 0.9.5.) in R (Ogle, 2016).

4.2 Results

4.2.1 Fleet Composition

Monthly squid landings by the Dutch fleet segments exhibited clear patterns from 2018 to 2024. Flyshoot vessels (SSC) consistently reported the highest landings between November and February, with peaks exceeding 300 tonnes per month (Figure 4.1). These landings displayed strong seasonal trends, nearly disappearing in summer. Landings by SSC were primarily recorded under the code SQR (*L. vulgaris*), with minimal use of SQS (generic code used for squids) until 2024.
Bottom otter trawl (OTB) showed a pronounced increase in squid landings over time. From negligible landings in 2018–2019, landings from this gear reached a peak of over 175 tonnes per month in January 2024, reflecting their growing focus on squid fisheries. OTB's squid fishing season was shorter than SSC's, generally ending by February or March. SQS landings are reported in smaller amounts, but the bulk of landings is reported as SQR.
Beam trawlers (TBB) reported lower landings, with a peak at approximately 35 tonnes per month in January 2024, again mostly reported as SQR but with some SQS occurring throughout the studied period, and landings of SQE (European flying squid) being reported in 2019-2020.
Squid landings by pelagic trawlers (OTM) were sporadic, primarily occurring in spring (April–May), with notable contributions in 2022 (roughly 30 tonnes per month). Squid landings were mainly reported as SQR, with more landings of SQU (Various squids nei) and SQM (Broadtail shortfin squid) since 2021.
Minor landings by other gears, such as quadrig trawlers (QUA) and paired bottom otter trawls (OTT), were also recorded.

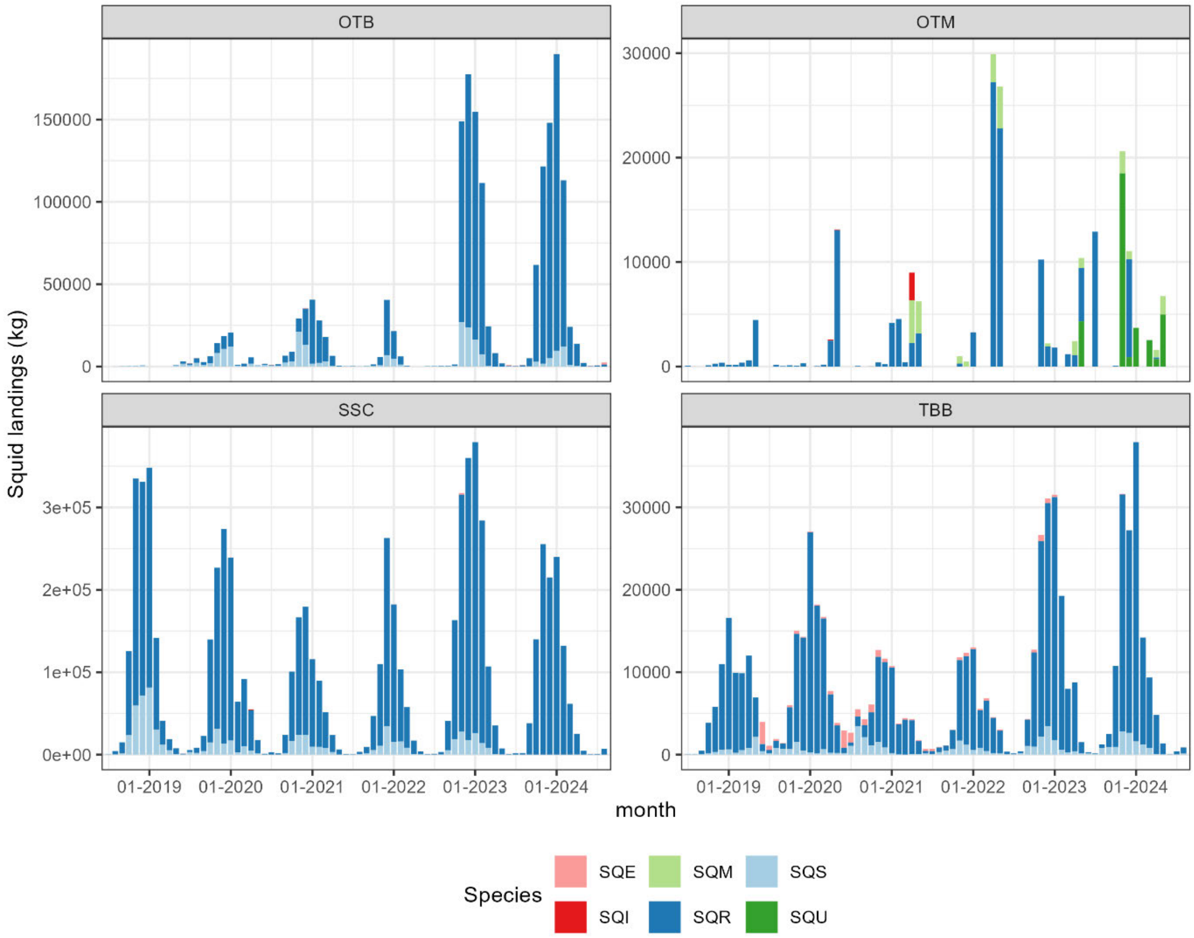


Figure 4.1. Monthly landings of squids per species and fishing gear in the Dutch fleet between the second half of 2018 and the first half of 2024. Note the different y-axis scales.

4.2.2 Temporal and Spatial Patterns of Landings

Temporal patterns of squid landings were consistent across gear types, with clear peaks in winter months (November–February, Figure 4.2). Flyshoot vessels recorded the longest squid-targeting seasons, beginning in October–November and ending in March–April. OTB seasons generally began later and ended earlier, reflecting shorter targeting windows (Figure 4.2). Seasonal patterns for TBB and OTM were less pronounced, with squid landings spread over several months.

Spatially, SSC vessels predominantly targeted squid in the eastern English Channel (7.d) but showed increasing landings in the southern North Sea (4.c) in recent years (Figure 4.2). OTB landings were concentrated in the southern North Sea, with occasional catches in the central North Sea (4.b) and minimal activity in the eastern Channel (7.d). Bycatch by the TBB mainly occurs in the southern North Sea, with limited landings in the central North Sea during summer and fall of 2019–2021. Pelagic trawlers (OTM) operated in more distant waters, with landings west of Scotland (6.a) and near the Faroe Islands (5.b).

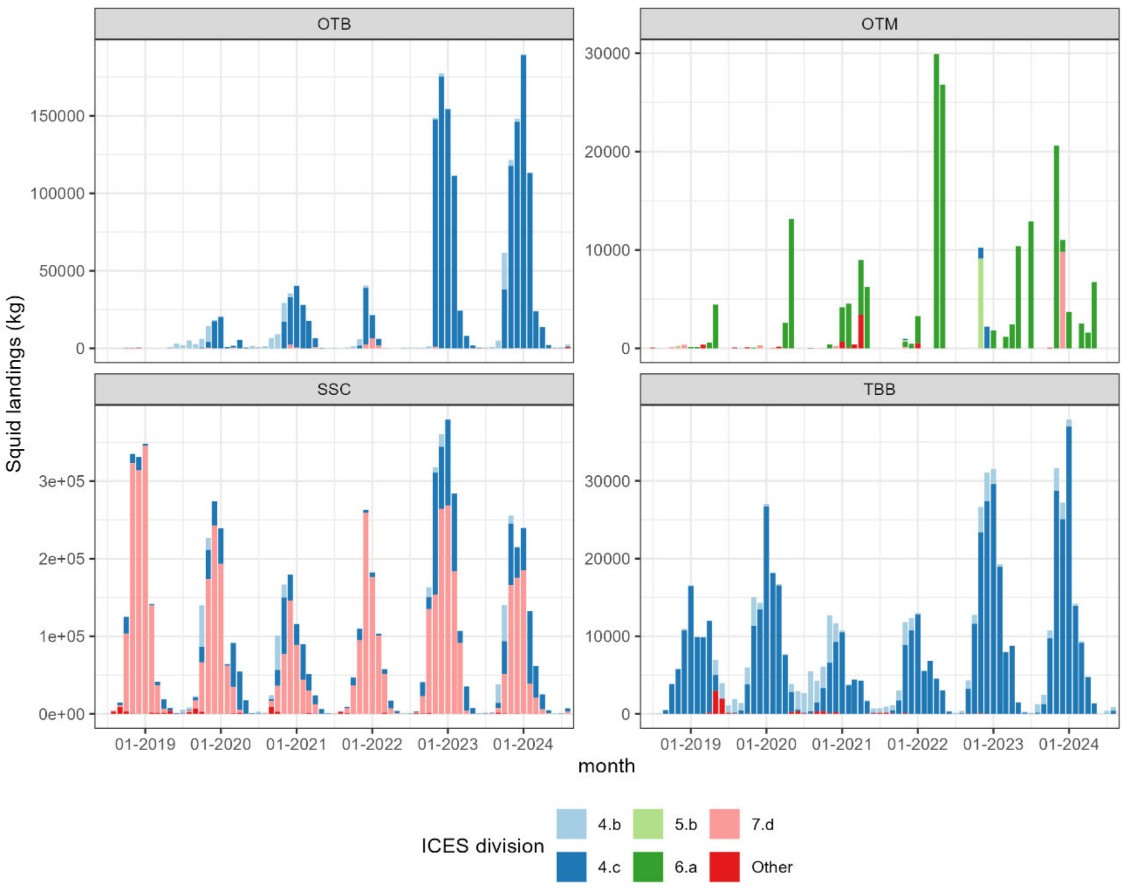


Figure 4.2: Monthly landings of squids per ICES division and fishing gear in the Dutch fleet between the second half of 2018 and the first half of 2024. Note the different y-axis scales.

Number of vessels reporting squid landings

The number of vessels landing squid (with a threshold of minimum 100kg/month) per month exhibited strong seasonal fluctuations for SSC and a steady increase for OTB (Figure 4.3). For SSC, nearly all vessels (approximately 20) reported squid landings during winter months, but just 1 to 2 vessels report of squid in summer. The number of vessels using OTB reporting squid landings (same threshold of minimum 100kg/month) increased significantly, from around 5 vessels in 2020 to 19 out of 21 active vessels by January 2024. Almost all vessels using OTB in the winter 2023-2024 reported squid.

A low percentage of the beam trawlers had landings of squid higher than 100kg/month, however given the large total number of the TBB fleet, this represented up to 20 vessels in certain months. Pelagic trawlers sporadically landed squid over 100kg per month. However, given the very large tonnages landed by the large pelagic freezer trawlers, this represents a negligeable part of their catch compared to the pelagic fish species they target.

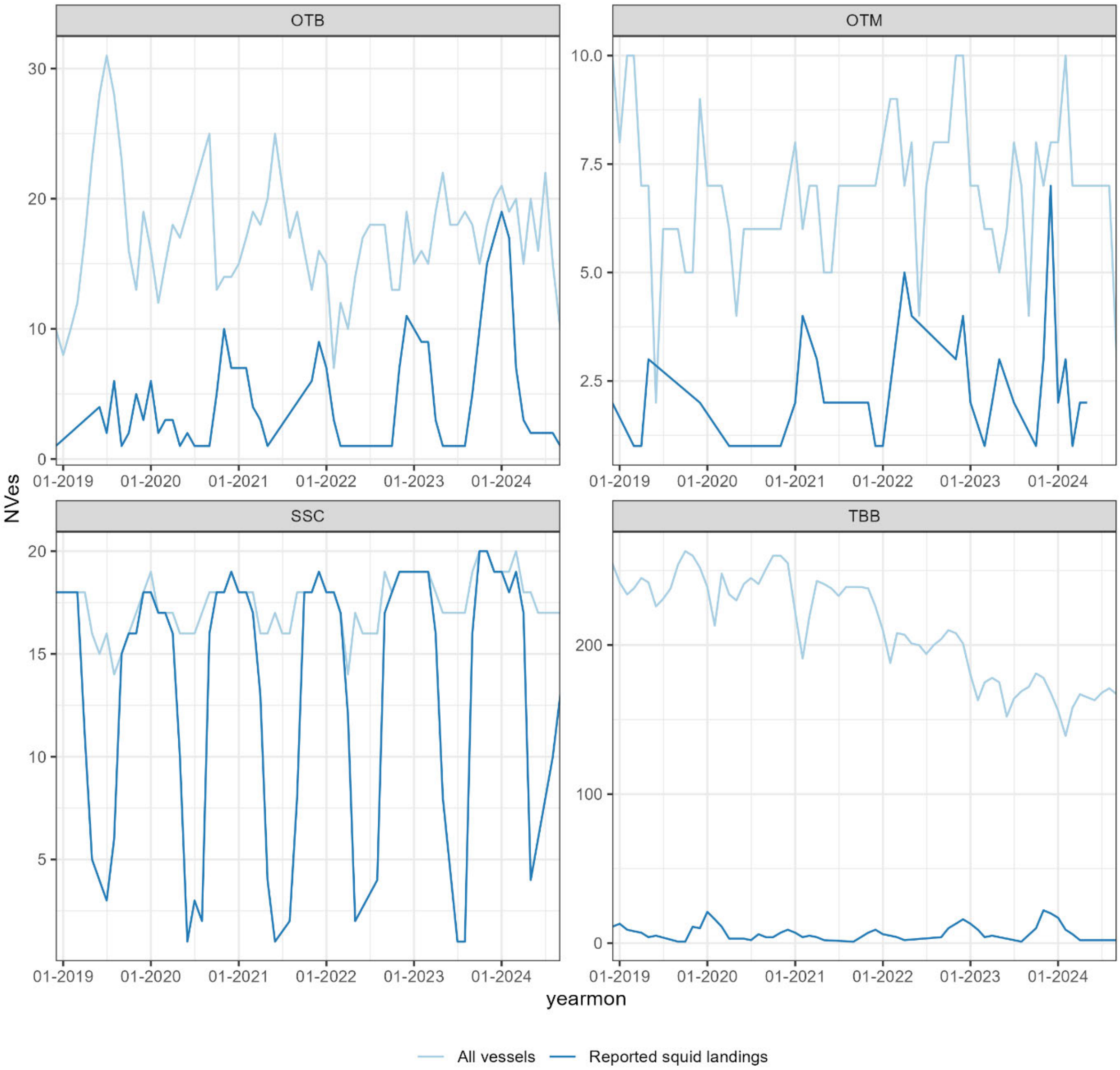


Figure 4.3: Total number of active vessels and number of vessels reporting >100kg of squid landings per month, divided by fishing gear.

4.2.3 Spatial Distribution

The spatial distribution of squid landings revealed distinct hotspots for the different gears. SSC landings were concentrated in the eastern English Channel, though recent years showed increasing activity in the southern North Sea, in front of the Belgian coast, and a third minor hotspot in the central North Sea. OTB landings were primarily in the hotspot in southern North Sea, but also the secondary hotspot exploited by the SSC fishery in front of the Dutch coast (Figure 4.4). TBB landed squid almost exclusively from the southern North Sea, while OTM operated in offshore areas west of Scotland and the Faroe Islands, with minor landings from the English Channel and southern North Sea.

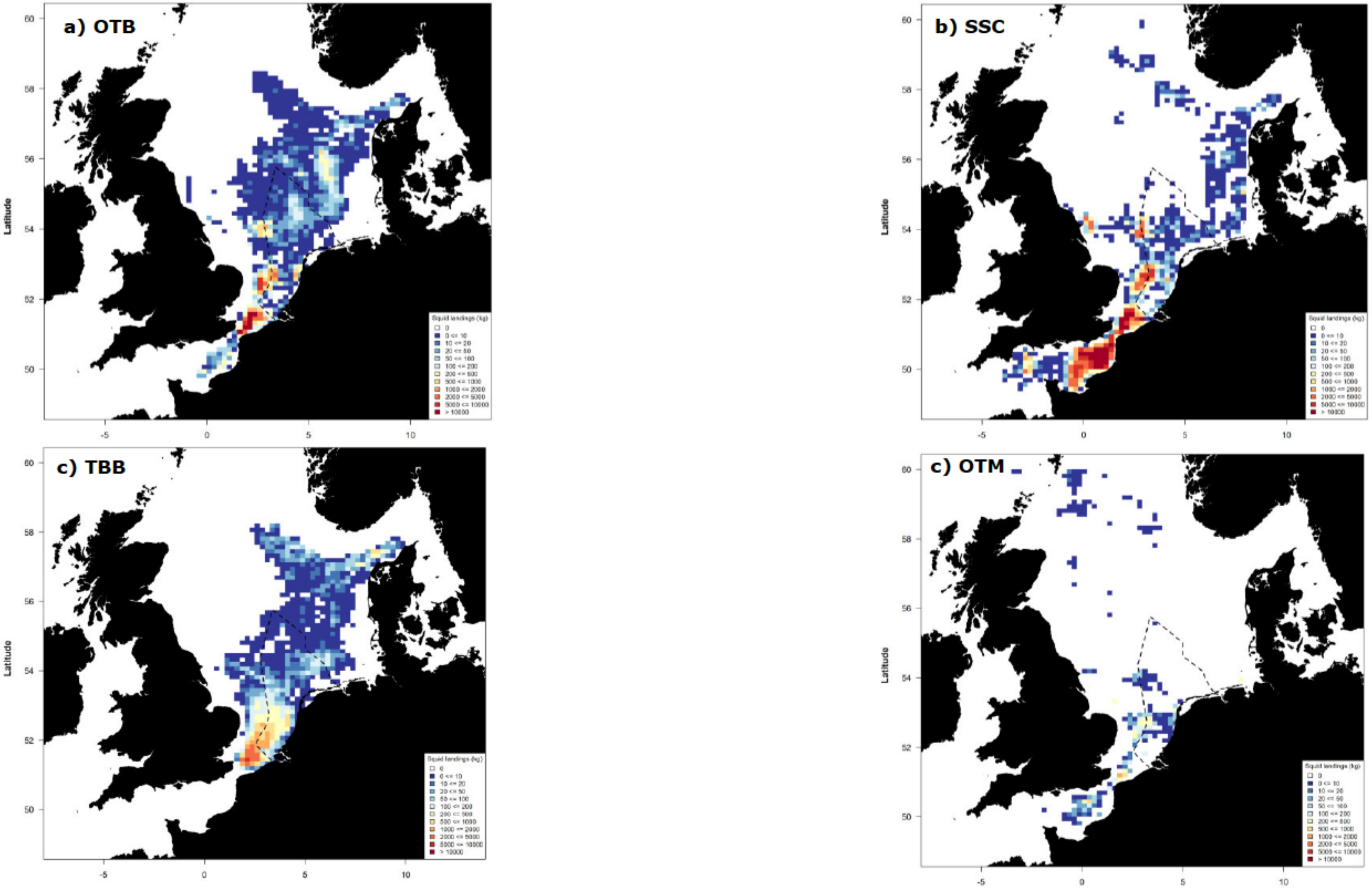


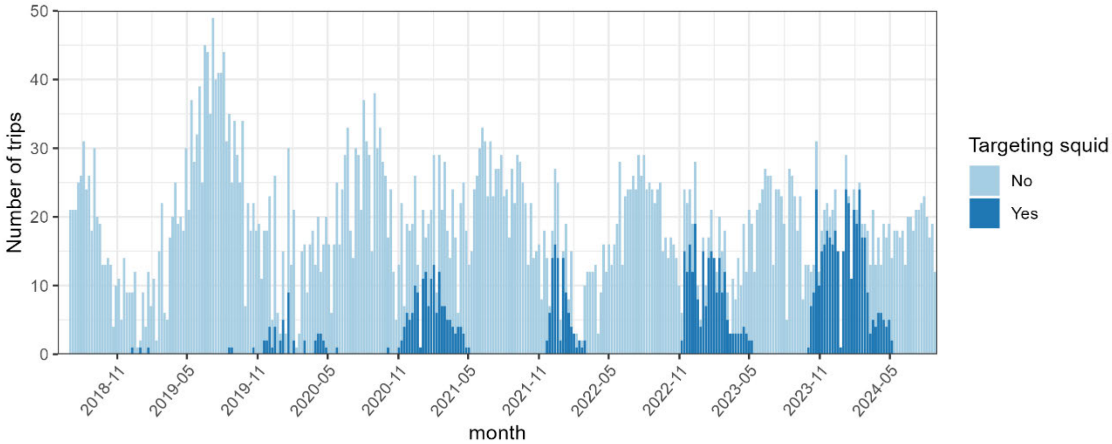
Figure 4.4: Spatial distribution of average yearly squid landings in the period 2018-2024 by a) bottom otter trawl, b) demersal seine (flyshoot) , c) beam trawls and d) pelagic trawls. The dashed line shows the Dutch EEZ.

4.2.4 Identifying Target Species and Fishing Effort

Trips identified as targeting squid (with squids being the highest landings in value in the trip) highlighted contrasting behaviors between SSC and OTB. SSC vessels consistently targeted squid during winter, with the season beginning in October–November and concluding in March–April (Figure 5.5). By contrast, OTB targeting of squid increased significantly after 2021, with nearly the entire fleet engaging in squid fisheries during winter months by 2023-2024 (figure 4.5).
Other gears, such as TBB and OTM, did not exhibit squid-targeting behavior on a trip level based on the criteria used to define targeting. Gear-switching analyses revealed that several vessels alternated between SSC and OTB, with SSC gear predominantly used during winter for squid and OTB gear during summer for other target species (Figure 4.5).

The characteristics of the vessels targeting squid with OTB evolved significantly from the 2018–2019 season to 2023–2024 (Table 4.2). The number of vessels engaging in squid-targeting increased from 7 in 2019–2020 to 23 in 2023–2024. Correspondingly, the average length of the squid-targeting season grew from 6 weeks in 2019–2020 to 12 weeks in 2022–2023 and 2023–2024. The season typically starts in late November or early December and ends by February or March.
Total squid landings by vessels targeting squid with OTB increased markedly, from 80 tonnes in 2019–2020 to a peak of 652 tonnes in 2023–2024. This growth in landings was mirrored by an increase in fishing effort, with total fishing days rising from 142 in 2019–2020 to 1 098 in 2023–2024. However, LPUE values fluctuated, peaking at 1 010 kg/day in 2022–2023 and declining to 624 kg/day in 2023–2024, reflecting increased fishing effort without a proportional rise in landings.
The fleet targeting squid with OTB gear was composed of vessels with engine power ranging from 353 to 557 kW and average lengths of 25 to 27 meters. Mesh sizes varied from 40 to 120 mm, with 80 mm being the most frequently used. Some logbook entries provided additional gear specifications, revealing that OTB fishers often employed two nets measuring 9–15 meters in width or a single larger net.

a) **OTB**



b) SSC

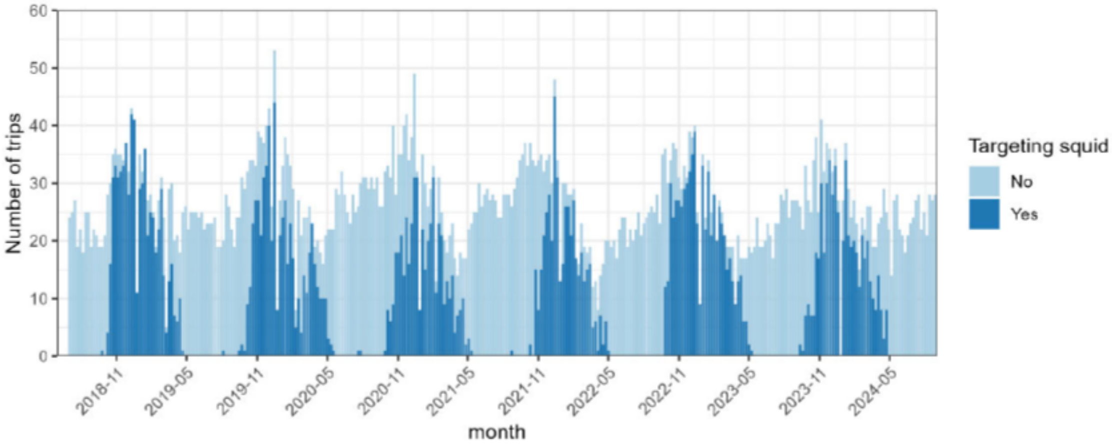


Figure 4.5 : Weekly number of trips conducted using a) OTB and b) SSC (light blue bars) and number of those trips that were identified as targeting squid (dark blue bards).

Table 4.2: Description of the squid targeting fishery with bottom otter trawl (OTB) per season, from 2018-2019 until 2023-2024. Information was obtained from fishery logbooks.

	18-19	19-20	20-21	21-22	22-23	23-24
Number of vessels	-	7	11	12	12	23
Av. season length	-	06-12 – 08-03 (6 weeks)	10-12 – 19-02 (9 weeks)	04-12 – 11-01 (6 weeks)	07-12 – 10-03 (12 weeks)	17-11 – 24-02 (13 weeks)
Total tonnes	-	80	176	77	630	686
Total fishing days	-	142	367	239	624	1,098
LPUE (kg/day)	-	563	480	322	1,010	624
Av. kW	-	454	557	353	490	430
Av. vessel length (m)	-	26	27	25	27	26
Mesh size range and mode (mm)	-	80 (80)	60-120 (80)	45-95 (80)	40-80 (80)	40-120 (80)

The SSC fleet targeting squid showed consistent engagement throughout the study period, with 18 to 20 vessels participating each season (Table 4.3). The average squid-targeting season ranged from 17 to 24 weeks, typically beginning in October and lasting through March or April. The longest season occurred in 2022–2023, lasting 24 weeks.

Annual squid landings by SSC vessels ranged from 764 tonnes in 2020–2021 to a peak of 1,700 tonnes in 2022–2023. Total fishing effort, measured in days, followed a similar trend, peaking at 1,693 days in 2022–2023. LPUE values fluctuated across seasons, reaching a low of 642 kg/day in 2020–2021 and a high of 1,004 kg/day in 2022–2023. The decline in LPUE in 2023–2024 (877 kg/day) coincided with reduced total landings. SSC vessels targeting squid had engine power ranging from 619 to 662 kW and average lengths of 29 to 30 meters. Mesh sizes varied between 40 and 120 mm, with 80 mm being the most common. Detailed gear descriptions in logbooks indicated that flyshoot nets were typically 35 meters wide, with some vessels using nets up to 60 meters wide. One vessel reported using a rope length of 3 km, demonstrating the scale of gear employed in SSC fisheries.

Table 4.3: Description of the squid targeting fishery with flyshoot (SSC) per season, from 2018-2019 until 2023-2024. Information was obtained from fishery logbooks.

	18-19	19-20	20-21	21-22	22-23	23-24
NUMBER OF VESSELS	18	20	19	19	19	20
AV. SEASON LENGTH	17-10 – 31-3 (21 weeks)	30-10 – 08-04 (18 weeks)	11-10 – 28-03 (17 weeks)	28-10 – 28-03 (17 weeks)	05-10 – 11-04 (24 weeks)	11-10 – 27-03 (18 weeks)
TOTAL TONNES	1,370	1,146	764	798	1,700	1,138
TOTAL FISHING DAYS	1,495	1,315	1,189	1,171	1,693	1,298
LPUE (KG/DAY)	917	872	642	682	1,004	877
AV. KW	627	662	622	619	620	628
AV. VESSEL LENGTH (M)	30	30	30	30	30	29
MESH SIZE RANGE AND MODE (MM)	80-100 (80)	50-120 (80)	70-120 (80)	40-120 (80)	60-120 (80)	60-120 (80)

4.2.5 Gear use

An analysis of the gear use over time for the vessels that have targeted squid at least once over the period 2018-2024 was carried out. The analysis was done separately for the vessels that used demersal seine and bottom otter trawl. The analysis looked at which gear was used by those vessels at the trip-by-trip level, and distinguished trips where squids were targeted from trips where they were not. For confidentiality reasons, the information cannot be presented here at the vessel level and the results are reported here in an aggregated form. Groups of vessels with similar patterns in gear changes and squid targeting behavior over time were identified and are shown and discussed in this section.

Demersal seine

Flyshoot vessels targeting squid demonstrated consistent gear use patterns throughout the study period. Most vessels remained dedicated to flyshoot (SSC) gear year-round, with squid targeting concentrated in winter months (October–March) (group 1 on Figure 4.6). For these vessels, squid-targeting trips typically occurred during the colder months, aligning with seasonal peaks in squid availability.

A smaller number of vessels displayed gear flexibility, switching between SSC and other gear types, such as bottom otter trawl (OTB). These switches were most common during summer, when squid landings were minimal (group 2). Some vessels used SSC gear exclusively during winter to target squid and switched to OTB gear in summer to target species such as *Nephrops* (group 3). Instances of vessels using beam trawl (TBB) gear were also noted, but these periods were short and typically preceded a switch to OTB.

Overall, SSC vessels maintained a specialized focus on squid fisheries, with only minor deviations to other gears or target species.

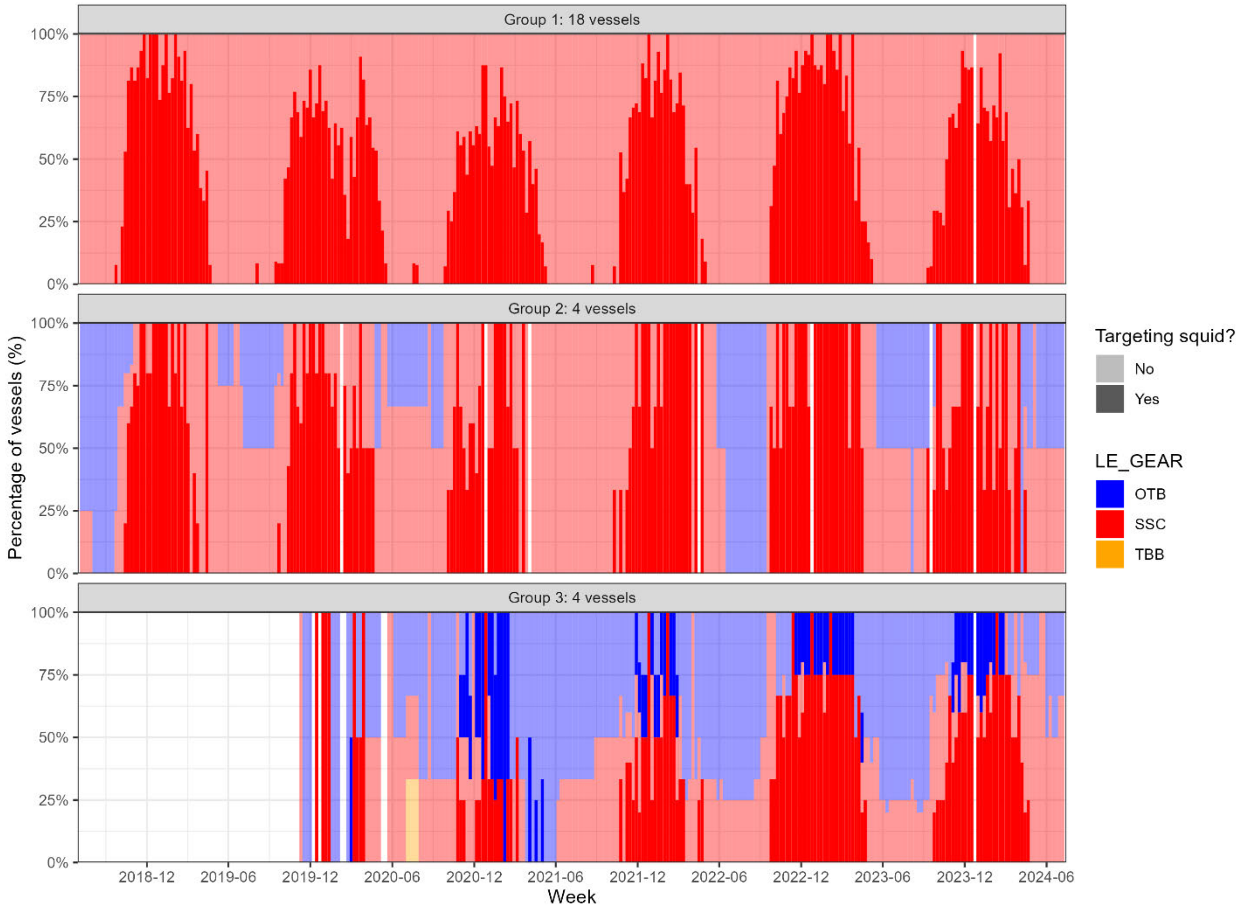


Figure 4.6: Gear use changes and squid targeting for vessels using flyshoot (SSC) gear. Darker shades indicate period of the year when squid targeting occurs, lighter shades indicates trips where squid was not targeted. A distinction is made between three groups: vessels that exclusively use SSC gear throughout the studied period (top), vessels that use both SSC and OTB gear but only target squid using SSC gear (middle), and vessels that use both SSC and OTB gear to target squid (bottom).

Bottom otter trawl

Gear usage among OTB vessels targeting squid exhibited greater variability compared to SSC vessels. Some vessels in the OTB fleet used OTB gear consistently, with an increase importance of squid as target species in winter for the last 3 to 4 years (group 1 on Figure 4.7).

Other vessels regularly switch between beam trawl (TBB) and OTB (group 2, Figure 4.7). This change of main gear often coincided with the onset of the squid season in late autumn or early winter. Vessels switching between TBB and OTB frequently installed net rolls to enable this shift. This modification provided greater flexibility in targeting multiple species, particularly squid and *Nephrops*. Despite this, most OTB vessels specializing in squid retained their primary gear configuration throughout the season.

There are also a number of vessels (5) that appear to be mainly using TBB but that have switched to OTB to target squids specifically for the winter 2023-2024 indicating an increasing interest in the fleet for this target species.

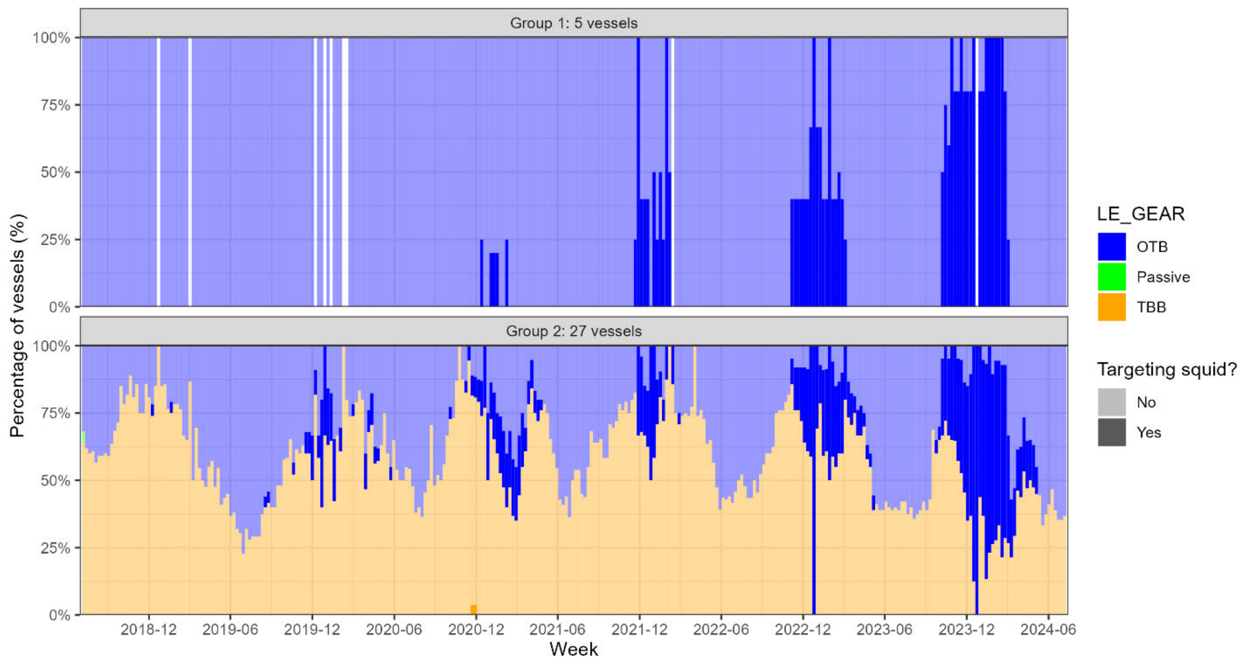


Figure 4.7: Gear use changes and squid targeting for vessels using the bottom otter trawl (OTB) gear. Darker shades indicate period of the year when squid targeting occurs, lighter shades indicates trips where squid was not targeted. A distinction is made between two groups: vessels that exclusively use OTB gear throughout the studied period (top) and vessels that switch between TBB gear and OTB gear (bottom). Vessels that used both SSC and OTB gear are included in Figure 4.6 and therefore not shown here. .

4.2.6 LPUE

Trends in landing-per-unit-effort (LPUE) were analyzed for both bottom otter trawl (OTB) and flyshoot (SSC) trips to examine how squid catch rates varied over the course of the fishing season (November to April) and across different years. LPUE was calculated as the total weight of squid landed per unit of fishing effort, with effort derived from Vessel Monitoring System (VMS) data.

For OTB vessels in the North Sea (ICES sub area 4), LPUE values showed a typical seasonal pattern, with catch rates increasing early in the season and reaching a peak in November or December before gradually decreasing through January and February. The highest LPUE value was observed in November 2022, which was notably higher than in previous years. A clear decline in LPUE was seen from January onwards, with a steep drop after March (Figure 4.8).

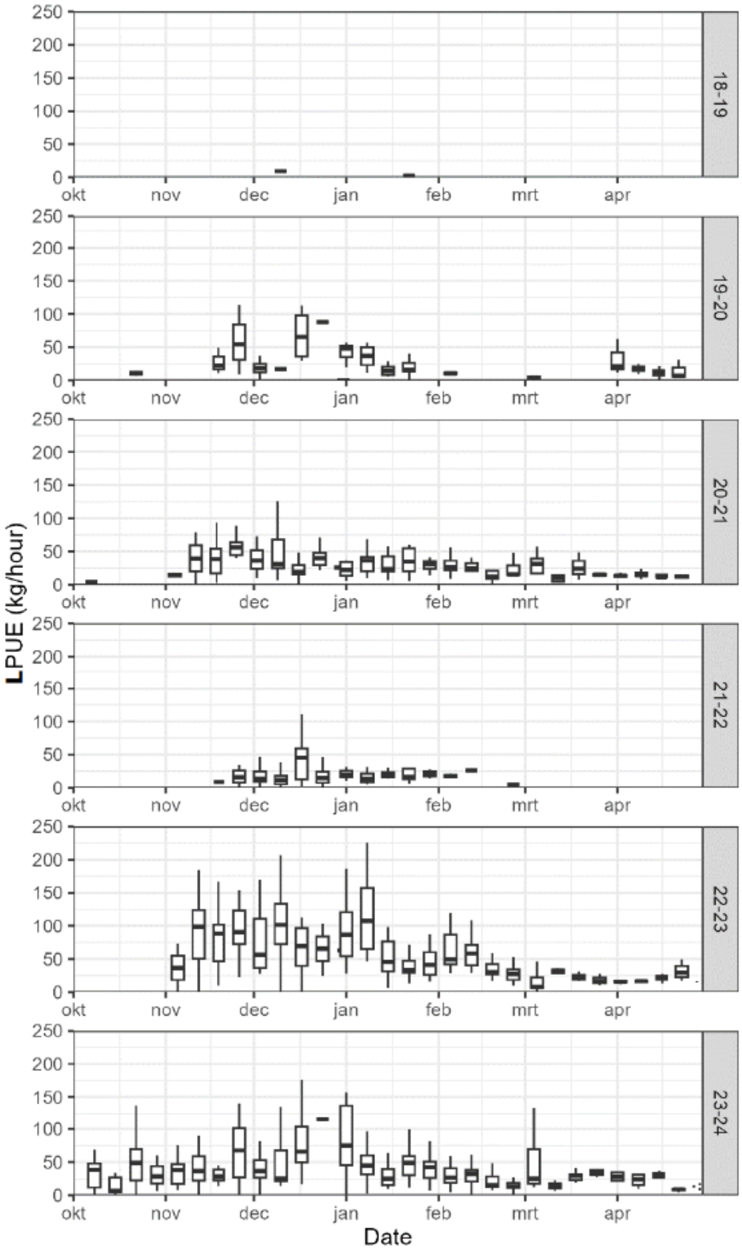


Figure 4.8. Time series of landing rates (landing per unit effort in kg/hour) for OTB vessels targeting squid in the North Sea. The box shows the median and 1st and 3rd quartiles, and the whiskers show minima and maxima (calculated as Q1-1.5*interquartile range and Q3 + 1.5*interquartile range). Outliers are not shown.

For SSC vessels, LPUE in the North Sea displayed a similar seasonal trend, with a sharp increase in catch rates during the start of the season in October–November, followed by a peak in December or January (figure 4.9).
In the English Channel (ICES divisions 7de) SSC squid fishery, LPUE also exhibited a rise at the beginning of the season, with the highest catch rates observed from November to January. LPUE values then declined in the spring months, particularly in March and April, as the season drew to a close.

Overall, the LPUE trends for both OTB and SSC vessels show a clear seasonal cycle of rising catch rates early in the squid season followed by a gradual decrease as the season progresses. These seasonal fluctuations in LPUE are likely influenced by several factors, including the availability of squid, fishing effort, and potential seasonal changes in distribution of the squid population. Lower LPUE values at the start of the season could be due to the need for fishers to 'readjust' to the fishery. It is also possible that additional recruitment to the exploitable biomass occurs later on in the season, leading to increased catch rates. In general, the observed pattern of high initial LPUE followed by a decline suggests a dynamic relationship between fishing effort and squid abundance.

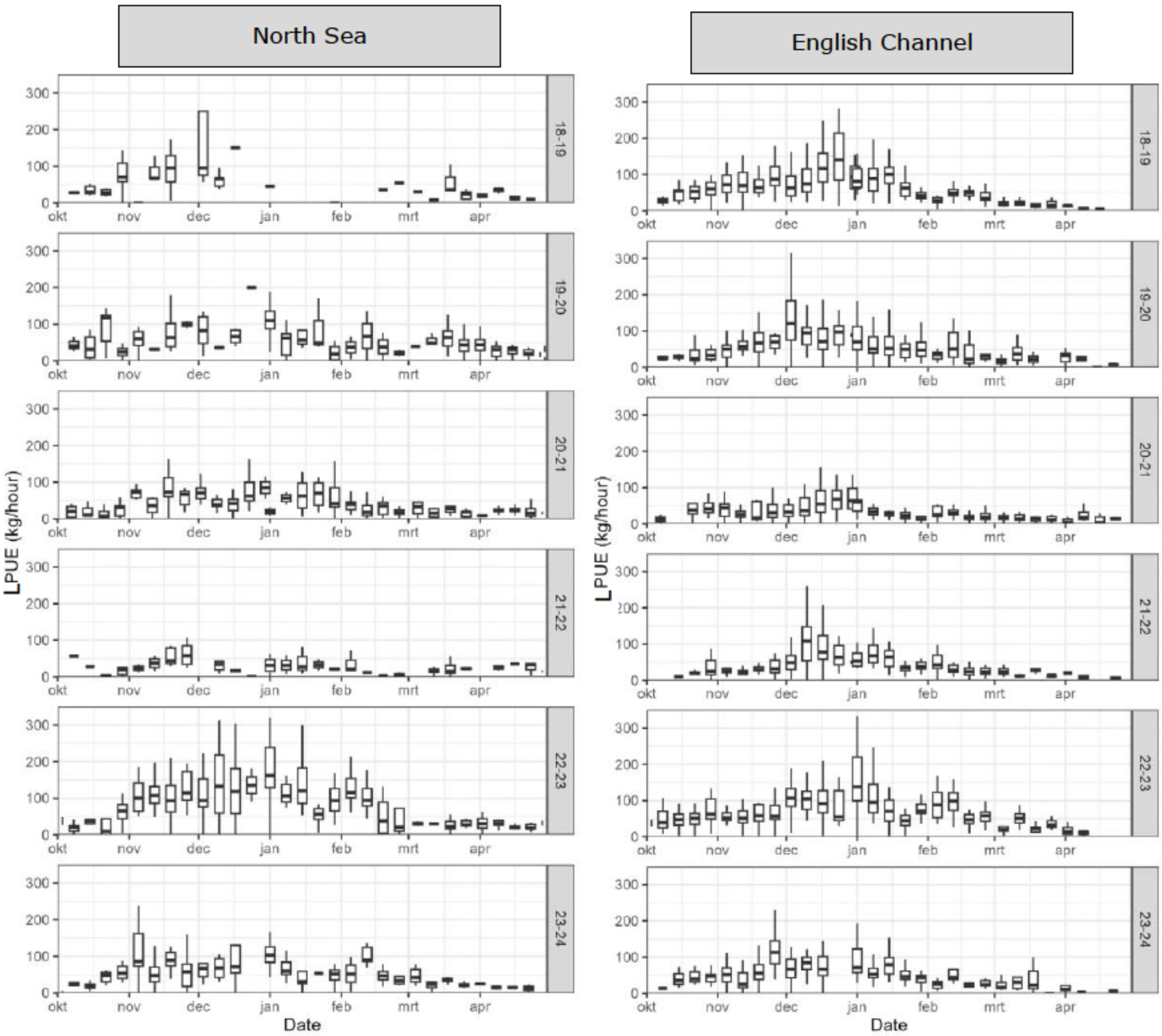


Figure 4.9. Time series of catch rates (catch per unit effort in kg/hour) for SSC vessels targeting squid in the North Sea and English Channel. The box shows the median and 1st and 3rd quartiles, and the whiskers show minima and maxima (calculated as Q1-1.5*interquartile range and Q3 + 1.5*interquartile range). Outliers are not shown.

4.2.7 Depletion models

Depletion models were used to examine the relationship between landings-per-unit-effort (LPUE) and cumulative catch for squid-targeting vessels, with the goal of estimating initial population biomass (B_0) and catchability coefficients (q) (table 4.4). The models were applied separately for both OTB and SSC fleets in the North Sea (ICES area 4) and the English Channel (ICES area 7), using data for each fishing season (2018–2024).

For OTB vessels targeting squid in the North Sea, depletion models showed significant depletion curves for most seasons, except for 2018–2019 and 2021–2022, where the models did not produce significant results. In the years where the depletion models were significant, initial population biomass estimates (B_0) were calculated, and catchability coefficients (q) were derived from the negative slope of the regression lines between cumulative catch and LPUE.

The estimated B_0 values for OTB vessels in the North Sea varied by year, with some years showing higher initial population estimates than others. For example, the B_0 estimate was relatively low in the 2019–2020 season when squid targeting was still developing within the OTB fleet, while in 2022–2023, B_0 was estimated to be much higher, reflecting the increased effort and catch rates seen in that season (Figure 4.10). The variability in B₀ values across years likely reflects differences in recruitment patterns, fishing pressure, and environmental factors influencing squid distribution.

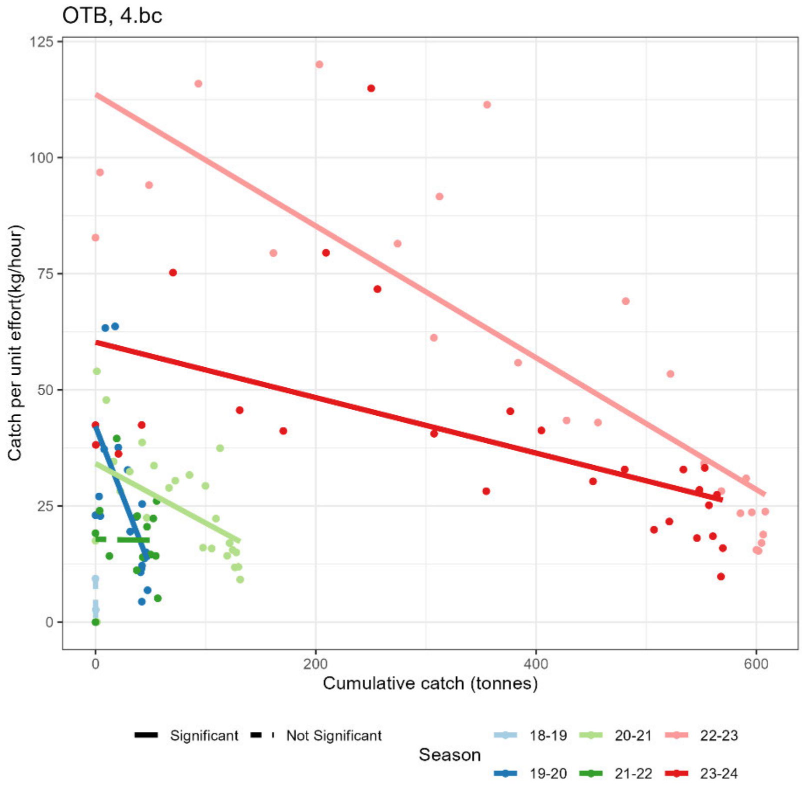


Figure 4.10 : Depletion models for OTB in 4.c, showing the relationship between cumulative catch (in kg) and catch per unit effort (LPUE, in kg/hour). Each season has a separate model. The lines represent the outcome of the regression analysis and the points the observed values. Non-significant outcomes (slopes) are represented by dashed lines, significant outcomes by solid lines.

Depletion models for flyshoot vessels in the North Sea (Figure 4.11) and the English Channel (Figure 4.12) produced similar patterns, with significant depletion curves observed in several years, particularly in 2022–2023 and 2023–2024. In these years, the models estimated relatively high B_0 values, suggesting that large populations of squid were available at the start of the fishing season. These estimates were consistent with the increased effort and catch rates observed during these years. However, in earlier seasons, such as 2019–2020, B_0 estimates were lower, indicating smaller initial population sizes. This could possibly also be attributed to a less efficient and targeted fishery in those years.

As with the OTB models, the catchability coefficient (q) for SSC vessels varied between years. The models in 2020–2021 and 2021–2022 yielded lower catchability estimates, which may be attributed to different operational conditions during those years. In contrast, higher q values in later years suggest that fishing efficiency may have increased as the fleet adapted to targeting squid more intensively.

Overall, the depletion models for both OTB and SSC vessels provided useful insights into the potential population dynamics of squid, though results varied between years. The models suggest that squid populations may not be fully closed (i.e. no immigration, emigration, natural mortality, or recruitment), as evidenced by fluctuations in B_0 and q values. These variations highlight the need for careful consideration of recruitment patterns, environmental factors, and fishing practices when interpreting the results. The depletion models presented here serve as a starting point for understanding the squid fishery and should be further refined with more data, including length-frequency distributions and additional information on recruitment waves.

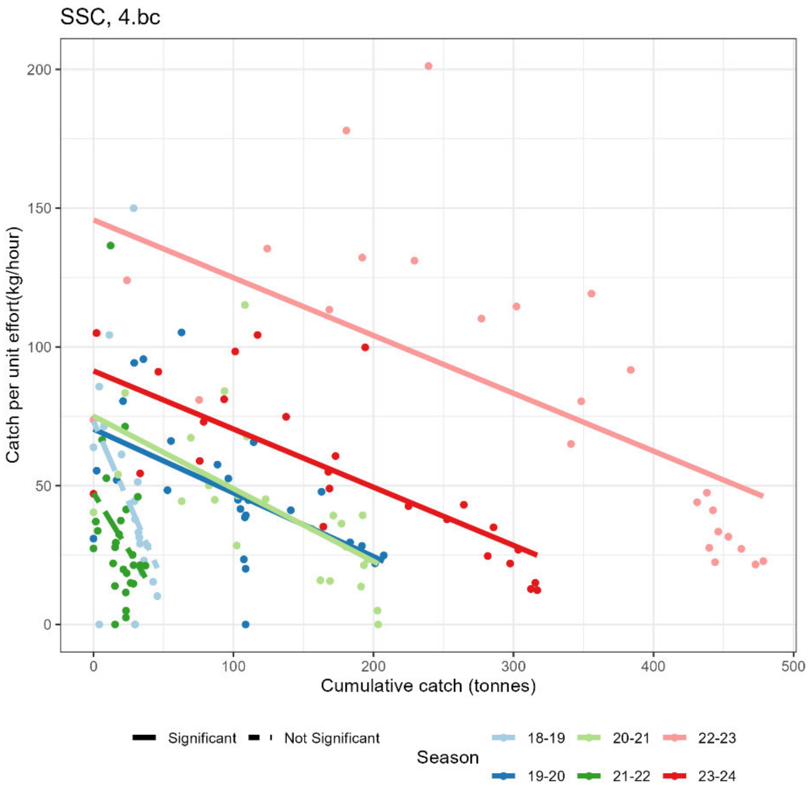


Figure 4.11: depletion models for SSC in 4.c, showing the relationship between cumulative catch (in kg) and catch per unit effort (LPUE, in kg/hour). Each season has a separate model. The lines represent the outcome of the regression analysis and the points the observed values. Non-significant outcomes (slopes) are represented by dashed lines, significant outcomes by solid lines.

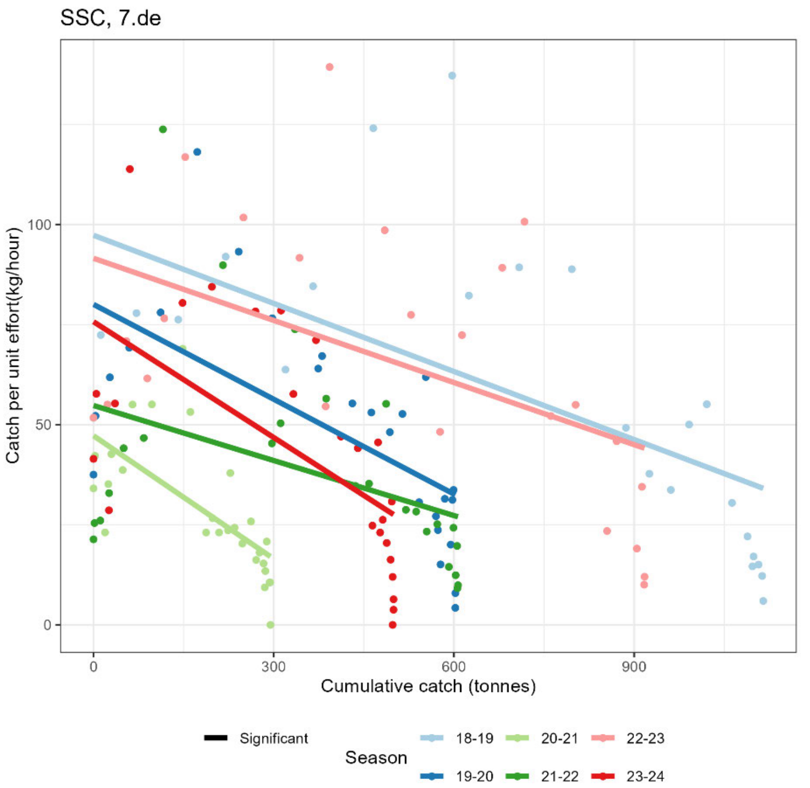


Figure 4.12: depletion models for SSC in 7.d, showing the relationship between cumulative catch (in kg) and catch per unit effort (LPUE, in kg/hour). Each season has a separate model. The lines represent the outcome of the regression analysis and the points the observed values. Non-significant outcomes (slopes) are represented by dashed lines, significant outcomes by solid lines.

Table 4.4 : estimates of initial population biomass and catchability based on the depletion models.

	4.bc				7.de	
	SSC		OTB		SSC	
SEASON	B_o (kg)	q	B_0 (kg)	q	B_0 (kg)	q
18-19	-	-	-	-	1,433,401 – 1,999,143	4.20e-05 - 7.14e-05
19-20	239,280 – 373,374	1.59e-04 - 3.01e-04	54,758 – 83,488	4.11e-04 - 8.08e-04	846,589 – 1,180,740	5.87e-05 - 9.92e-05
20-21	245,653 – 328,332	2.00e-04 - 3.23e-04	191,135 – 341,781	7.94e-05 - 1.77e-04	394,025 – 527,685	7.94e-05 - 1.26e-04
21-22	-	-	-	-	780,999 – 1,610,341	2.39e-05 - 6.78e-05
22-23	598,451 – 801,600	1.59e-04 - 2.57e-04	745,168 – 857,012	1.24e-04 - 1.59e-04	1,296,478 – 2,243,441	3.28e-05 - 7.07e-05
23-24	382,018 – 486,109	1.71e-04 - 2.49e-04	797,846 – 1,229,489	4.09e-05 - 7.81e-05	650,052 – 917,849	7.01e-05 - 1.23e-04

4.3 Discussion

The results of this study provide valuable insights into the seasonal dynamics of the Dutch squid fisheries, particularly focusing on the landings-per-unit-effort (LPUE) trends and the application of depletion models to estimate squid population dynamics. However, several factors remain to be fully understood and integrated into future analyses. Below, we discuss key considerations and recommendations for refining our understanding of the squid fishery and improving the methodologies for future studies.

4.3.1 LPUE Analysis: Species Ratio and Recruitment Waves

A critical limitation in the current LPUE analysis is the lack of detailed species-level data for *L. vulgaris* and *L. forbesii*. Although the LPUE trends provide a general view of squid landings over time, they do not account for the potential differences in catch rates between species, which may exhibit different distribution patterns and ecological behaviors. The ratio between these species is crucial, as variations in their relative abundance could significantly influence LPUE patterns. To improve the analysis, future studies should focus on species-specific data, possibly by enhancing species identification accuracy in logbooks or through market sampling for more reliable species differentiation. This would help ensure that LPUE trends reflect the actual species composition and allow for more accurate predictions of fishing effort and catch rates.

Furthermore, to refine the LPUE analysis and subsequent depletion models, it is necessary to split the catch weights into numbers of individuals based on market sampling outcomes. Depletion models, which rely on estimates of population size, are intended to work with numbers of individuals, not the total weight of landings. Converting catch data from weight to numbers per species and per recruitment group would allow for more precise modeling of squid population dynamics. Market sampling data, which often includes length-frequency distributions, can be used to estimate the number of individuals in different size classes, thereby allowing for a more accurate estimation of the number of squid caught. This approach would also facilitate the application of separate depletion models for different cohorts, improving the accuracy of population size estimates and the catchability coefficient (q).

In addition to the need for more accurate species and cohort data, incorporating information on new recruitment waves entering the exploitable population is critical. Squid populations exhibit significant recruitment variability, with different cohorts of squid entering the fishery at different times. Length-frequency distributions could provide insights into the timing and magnitude of these recruitment events, enabling a better understanding of how these cohorts contribute to total catch. By accounting for these recruitment pulses, we could refine the LPUE estimates and improve the precision of the depletion models. This would ultimately lead to more reliable assessments of squid population dynamics and more informed management decisions.

4.3.2 Start Time and Fishery Efficiency

One of the most significant factors affecting the LPUE trends is the start time of the fishing season. As observed, LPUE typically rises sharply in the early months of the fishing season (November to December) and then declines throughout the remainder of the season. This increase at the start of the season could partly be attributed to the recruitment of new squid into the exploitable population, but it could also reflect the inefficiency of the fishery at the start of the season. Fishers may require time to adapt to the spatial and temporal distribution of squid populations, which could result in relatively lower LPUE during the early months, even if the population is abundant.

Understanding the relationship between recruitment dynamics and fishery efficiency is crucial. Recruitment into the exploitable population is likely to be influenced by both biological (e.g., spawning and growth rates) and environmental (e.g., temperature, salinity) factors. Further research on the timing of squid recruitment and how it overlaps with fishing effort will be essential to disentangle these effects and improve our predictions of LPUE trends. This research should also focus on the effect of fishers' adaptation to the fishery over time and how this influences their ability to efficiently target squid.

4.3.3 Life History of Squid and the Effect of Semelparity on LPUE Trends

A key consideration in the interpretation of LPUE trends is the life history of the squid species involved. Squids, particularly *L. vulgaris* and *L. forbesii*, are semelparous, meaning they die after spawning. This life history trait is likely to have a strong impact on LPUE trends, particularly as squid populations experience natural mortality after spawning. The semelparous nature of squid suggests that LPUE may decline toward the end of the fishing season not only because of stock depletion due to fishing pressure but also because of natural mortality linked to spawning.

To better understand the influence of semelparity on LPUE, it will be essential to investigate the timing of spawning events for each species and how this relates to changes in catch rates. For example, if spawning peaks occur toward the end of the fishing season (as is typical for many squid species), this could explain the observed drop in LPUE later in the season. Incorporating data on squid reproductive timing and mortality rates would allow for a more nuanced interpretation of the LPUE trends and better predictions of squid abundance throughout the season.

4.3.4 Environmental Factors and Their Influence on Squid Recruitment

Squid populations are known to be highly sensitive to environmental conditions, which can influence their distribution, growth rates, and recruitment (Gowland et al., 2002; Van der Kooij, Engelhard & Righton, 2016; Marcout et al., 2024). Environmental factors such as temperature, ocean currents, and the availability of prey species have been shown to impact squid populations, with warmer water temperatures often leading to increased recruitment in certain regions. Understanding the environmental drivers that influence squid recruitment is critical for improving the predictability of the fishery and optimizing management strategies.

The development of models that incorporate environmental variables, such as sea surface temperature, chlorophyll concentrations, and current patterns, could provide valuable insights into the drivers of squid population dynamics. Incorporating such environmental data into depletion models could help refine estimates of squid stock size and improve predictions of catch rates under different environmental conditions.

4.3.5 Refining the Method for Identifying Squid-Targeting Trips

Another important aspect of improving the analysis is refining the method for identifying squid-targeting trips. In the current study, trips were classified as targeting squid if squid represented the largest share of the total landing value. While this approach provides a useful baseline, it may not fully capture the complexity of fishing behavior, particularly for vessels that switch between target species throughout the season. Vessels targeting squid could have landings of other species exceeding squid landings for various reasons. In this case, trips targeting squid would not be identified as such.

A more detailed classification system could involve integrating information on fishing location, gear type, and the temporal dynamics of catch composition. For instance, if a vessel is consistently landing squid during a specific period in a known squid habitat, it could be classified as targeting squid, even if the proportion of squid in the landings is not the largest share of landings value. Similarly, refining the criteria for identifying multi-species fisheries would allow for a more accurate assessment of squid-targeting efforts across the fleet.

5 Bycatch and discards

5.1 Landings of bycatch species in the squid fisheries

The landings species composition of trips targeting squid varied between gear types and ICES divisions, reflecting differences in fishing practices, target species, and bycatch species distribution. Squid was consistently the dominant species for both bottom otter trawl (OTB) and flyshoot (SSC) trips, though the proportion of squid in total landings differed.

For OTB trips targeting squid in the North Sea (ICES Division 4), squid frequently accounted for over 50% of the total weight of the landings (Figure 5.1). Significant bycatch species included whiting (*Merlangius merlangus*), particularly during the second quarter (April–June), and horse mackerel (*Trachurus trachurus*), which featured prominently in summer and fall. Seasonal changes in bycatch composition likely reflect annual variations in species availability related to migration patterns and possibly influenced by environmental factors such as temperature. It is important to note that squid targeting mainly occurs in the first and third quarters, so the importance of the other quarters is limited.
In the English Channel (ICES Division 7), mackerel (*Scomber scombrus*) and cuttlefish (*Sepia officinalis*) were notable bycatch species during squid-targeting trips using OTB, particularly in the first quarter (January–March). This highlights the region's ecological richness and the potential for multi-species interactions in OTB fisheries.

SSC trips exhibited a slightly lower proportion of squid in landings weight compared to OTB vessels, with squid typically contributing between 25% and 50% of the total (Figure 8). This may reflect differences in fishing methods, with SSC nets capturing a broader range of species due to their design and operation.
In the North Sea, key bycatch species for SSC vessels included whiting, mackerel and horse mackerel, striped red mullet (*Mullus surmuletus*), and gurnards (*Triglidae*), especially during the third and fourth quarters (July–December). Whiting remained a consistent bycatch species year-round, indicating its wide distribution and overlap with squid habitats. Mullets and gurnards were more prevalent in the second half of the year, suggesting seasonal fluctuations in their abundance.
In the English Channel, SSC fisheries targeting squid also landed significant quantities of flatfish (e.g. plaice, *Pleuronectes platessa*), gadoids, and cuttlefish. Seasonal differences were evident, with mullets and gurnards dominating bycatch in winter (October–March) and mackerel and horse mackerel becoming more prominent in spring and summer.

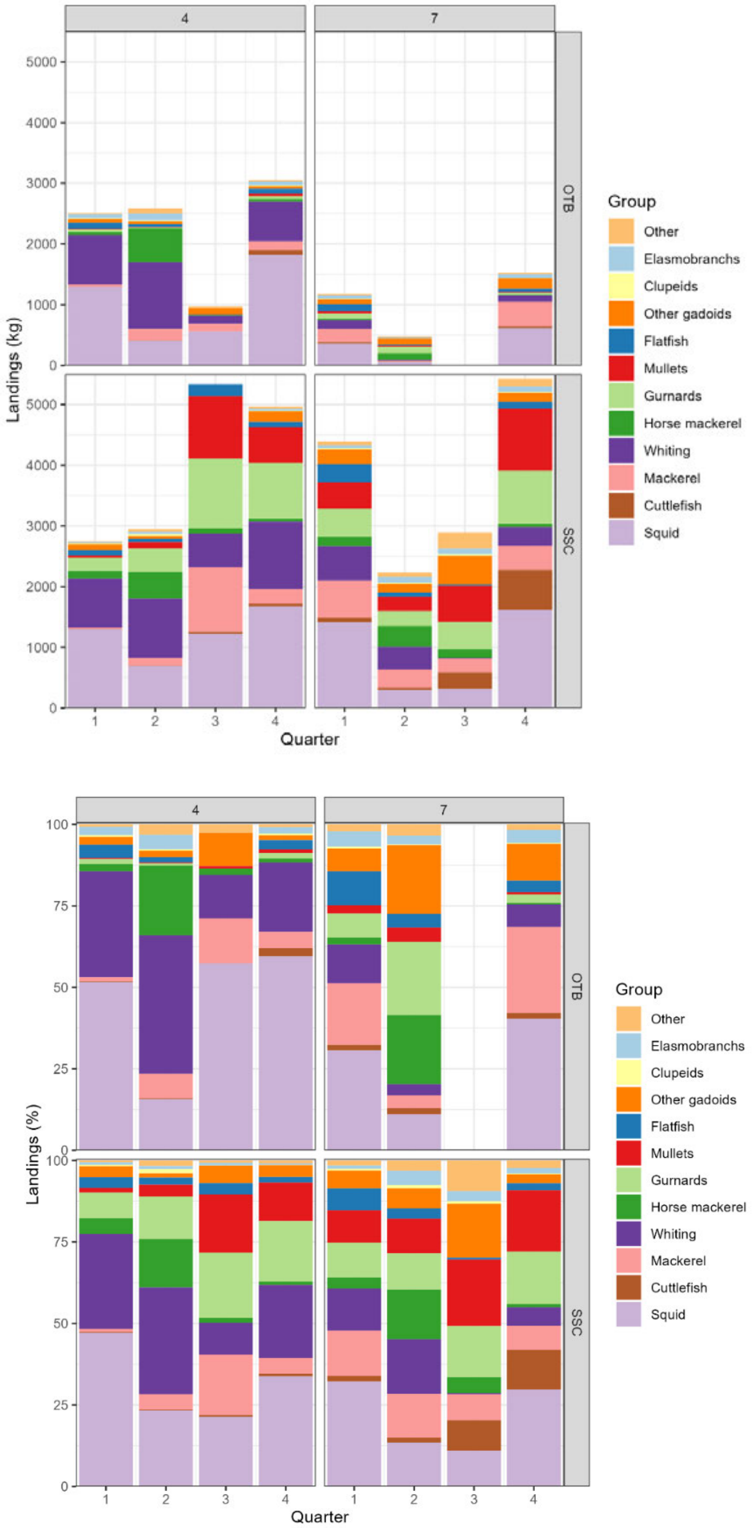


Figure 5.1: Average landings compositions for squid-targeting fishing trips for flyshoot (SSC) and bottom otter trawl (OTB) in the English Channel (Divisions 7de) and North Sea (Area 4) over the years 2018 to 2024. a) averages per species (group) in kilograms, b) averages per species (group) in percentage of total landings weight.

5.2 Squid as bycatch species

For trips where squids were landed but were not identified as the target species based on the criterium described in Section 4.1.4, we identified the main landed species. This was done for OTM and TBB gears, where squid was found to be regularly landed but never as the target species, and for each ICES division separately.

Figure 5.2 gives the average landings composition per ICES division of trips where squid is a bycatch species, for OTM and TBB separately. It becomes clear that for OTM, squid is mainly a bycatch during trips targeting herring in ICES areas 2 and 4 and division 7.d, and blue whiting in ICES areas 5, 6 and 8 and divisions 7.b. Squid is also caught in trips targeting horse mackerel in divisions 7.b, 7.e, 7.g and 7.j, and mackerel in divisions 4.a, 7.k and 8.a. Compared to total trip landings of these species, squid landings are very limited.

For TBB, flatfish are the main target species when squid is caught as bycatch. During these trips, squid landings are also negligible compared to the landings of target species, such as plaice and sole. Catch composition changes slightly between ICES divisions with an increasing proportion of the "other" species category in the southern North Sea, and even more in the division 7d.

Figure 5.2: Average composition per trip for trips where squid was landed (but not targeted), for OTM and TBB gear, separated by ICES division.

5.3 Discards in Dutch squid Fisheries

5.3.1 Introduction

Squid fisheries in the Netherlands, employing bottom otter trawl (OTB) and flyshoot (SSC), face challenges with discards, particularly of herring (*Clupea harengus*) and whiting. This section investigates, through literature study and interviews with fishers and fishery observers, the selective fishing technologies available to minimize discards while maintaining efficient squid catches. Additionally, it explores potential trial setups for the different gear types, as comparative trials with OTB and SSC gear can be complex.

Recent real-time closures due to high discard rates, such as RTC_NL_5_2024[4] triggered by high discard rates of juvenile whiting, underscore the urgent need to address discards issues. Although potential discard reduction devices exist, they are often not well understood, inadequately researched, and species-specific. For example, fishers are hesitant to adopt certain selective gear technologies, such as square mesh panels (SMPs), fearing a reduced squid catch efficiency. Furthermore, little is known about squid behavior in fishing gear, knowledge that would be beneficial for gear design.

This section aims to identify discards and develop strategies and gear modifications to reduce them.

5.3.2 Bottom Otter Trawl Fisheries

According to Afranewaa et al. (2022), OTB squid fisheries are concentrated in the southern North Sea, peaking in the fourth quarter. Of the 1.2% sampled effort of the OTB fleet targeting squid, the dominant species in the discards was herring with smaller quantities of striped red mullet and horse mackerel.
From interviews with fishers and fisheries observers, whiting also emerged as a frequently discarded species and a major concern, which has triggered real-time closures (such as the RTC mentioned above). Hence, herring and whiting should be prioritized for discards reduction gear technology research in the OTB gear.

5.3.3 Flyshoot (SSC) Fisheries

Van de Pol et al. (2023) conducted 15 observer trips on flyshoot vessels, of which 8 were targeting squid. They identified the primary discard species during squid fishing as being whiting, herring, gurnards, plaice, and dab (*Limanda limanda*) figure 5.3). Discard composition was also quite variable between trips.
From observations and interviews, occasional catches of sharks, skates and rays, and seabass (*Dicentrarchus labrax*)—particularly concerning during spawning season—were also reported. These species could also be of interest when researching discard reduction techniques.

[4] https://www.rvo.nl/sites/default/files/2024-11/Notification%20letter%20RTC%20of%20November%201%202024.pdf

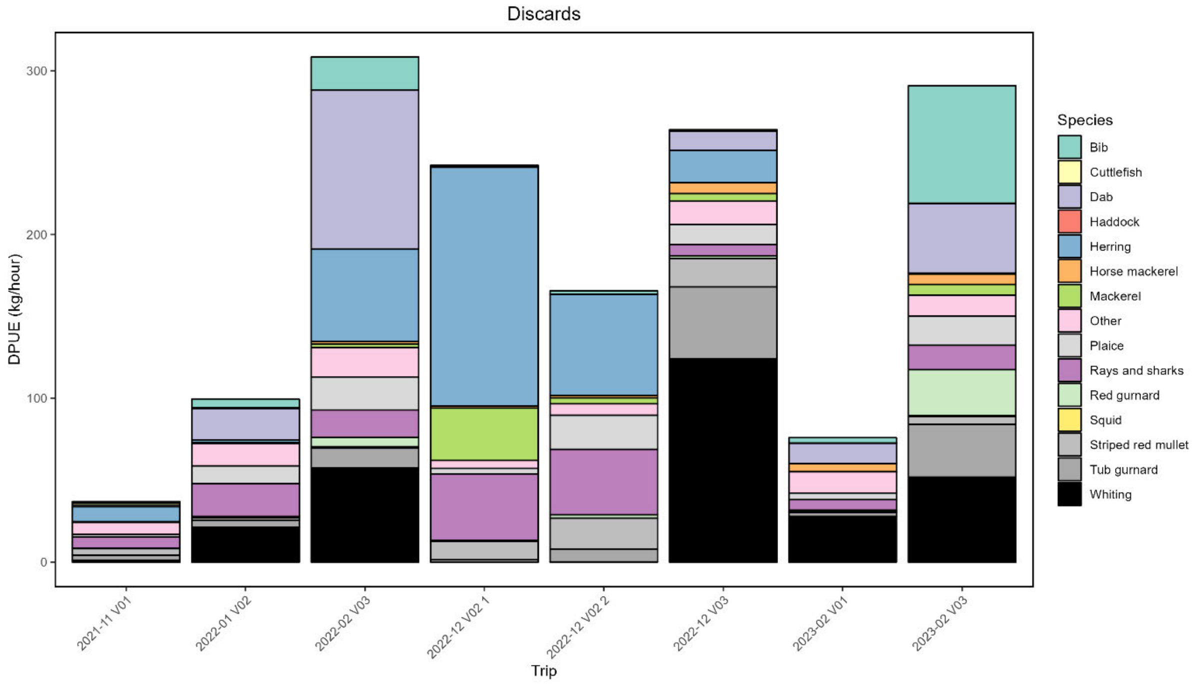


Figure 5.3 : Discard per unit effort during squid fishing activities aboard Flyshoot fishing vessels between 2021 and 2023.

5.4 Identifying selectivity devices: Whiting case study

Due to limited knowledge of squid behavior in bottom otter trawl and demersal seine, predicting the effects of selective gear on fish escapement through selectivity devices is challenging. However, a literature review has identified potential discard reduction devices tested in fisheries with high whiting discards, which could be adapted for squid fisheries. Whiting was selected as a case study species because it has been extensively researched and is recognized as a species of concern in SSC and OTB squid fisheries.

A technical note on whiting reduction devices in *Nephrops* fisheries in the Irish Sea (Cuende et al., 2024) highlights square mesh panels positioned on the upper side of the net as the most extensively studied method for reducing whiting bycatch. These panels rely on whiting's upwards escape response, making this gear modification a promising candidate for application in OTB and SSC squid fisheries.

A review of scientific and grey literature compiled additional potential gear adaptations for reducing whiting discards, summarized in Annex 2. These devices have been tested in various fisheries (not targeting squid), complicating definitive conclusions about their applicability in squid fisheries. Nonetheless, they should be considered when selecting gear for future selectivity studies. Section 5.5 outlines a proposed research plan to evaluate the optimal gear bycatch reduction devices for squid fisheries.

Further literature reviews are recommended for other species, such as herring and dab, which have also been identified as high-discard species on figure 5.3.

5.5 Proposal on comparative research trials

Behavioral Analysis of Squid in fishing nets

A lack of knowledge about squid behavior in relation to fishing nets complicates the selection of effective selectivity measures. We propose establishing an expert group consisting of scientists, fishers, and technological experts to gather behavioral insights. This research could be supported by the use of cameras in nets to observe squid behavior.

Development of Selective Fishing Nets

In SSC and OTB fisheries, squid fishing typically uses a single codend, which makes comparative selectivity trials challenging. To address this, a prototype "twin trawl net" with two codends would need to be developed to enable direct comparisons and testing of different selectivity techniques.
The planned techniques include:

- **Gear Technological adaptations**: Derived from literature (Annex 2 and Cuende et al. 2024) and expert consultations. Probably some form of square mesh panels.
- **Towing speeds**: Towing speed significantly affects the ability of fish to exhibit natural escape behavior. Exploring the reduction of towing speed or introducing pauses during hauling could be an innovative research option to enhance the release of undersized fish, such as whiting. Gaining a better understanding of this behavior could lead to improved selectivity. However, enforcing such a measure, if proven effective, may present challenges.

Testing and Evaluation

Field trials using twin codends in SSC and OTB operations will test selectivity and catch efficiency. Camera observations will provide behavioral data, essential for understanding squid behavior in nets and further refining selectivity measures.
The expected outcomes of this research would be a set of recommendations on technological adaptations, towing speeds, and net designs. For increased selectivity on desired bycaught species. A better understanding of squid behaviour in fishing nets would also be gained.

6 Market dynamics

6.1 Introduction

In recent years, squid has become an increasingly important target species in Dutch flyshoot and bottom otter trawl fisheries, particularly during the winter months. The European market has shown a strong demand for fresh, high-quality squid, making it a valuable addition to list of target species for the Dutch demersal fleet. This chapter outlines the successful introduction of Dutch fresh-landed squid to the market, detailing key characteristics such as main export destinations, average export prices, and the overall value chain.

6.2 Methodology

Trade statistics
To collect trade figures (exports and imports in value and volume), Eurostat (2024) was consulted. An annual update of the trade in fish products by the Netherlands is given during the Visserij in Cijfers publication (Agrimatie, 2024). Fish landed by foreign-flagged vessels in Dutch ports are registered as imports in the trade statistics. When collecting and analyzing trade data, fish products are recorded as six- or eight-digit codes with a label/description. These eight-digit codes are also known as Combined Nomenclature (CN) codes (Jukema et al., 2020). These codes indicate which fish species is involved (often with Latin species or genus name), preservation (fresh, live, frozen, smoked, dried, etc.) and presentation form (whole fish, fillet, with or without shell, etc.). For export data of squid there were six eight-digit codes (CN) used to specifically select *Loligo* species:

- 03074192 - SQUID "LOLIGO SPP.", LIVE, FRESH OR CHILLED
- 03074220 - SQUID "LOLIGO SPP.", LIVE, FRESH OR CHILLED
- 03074331 - SQUID "LOLIGO VULGARIS", FROZEN
- 03074931 - SQUID "LOLIGO VULGARIS", FROZEN
- 03074940 - SQUID "LOLIGO SPP.", SMOKED, DRIED, SALTED OR IN BRINE
- 03074992 - SQUID "LOLIGO SPP.", SMOKED, DRIED, SALTED OR IN BRINE

First sale data from Dutch fish auctions
First sales data (in volume) for Dutch fish auctions is approximated by dead weight (NOVA visafslagen, 2024). Catch volumes are provided as live weight (Agrimatie, 2024).

Limitations
The different data sources used give volumes in live and dead weight. It requires conversion factors to convert dead weight into live or vice versa. For the trade statistics (export and import), whole fish equivalent are provided in this report to make comparison possible from dead weight with live weight. However, there is always a range of uncertainty in the weight calculated by using conversion factors.
Another limitation is that several CN codes within trade statistics do not correspond to species level (e.g. *L. vulgaris*) but to genus level (*Loligo* species). For import this clarifies why Morocco and Spain were in the top 5 for imports by the Netherlands of the selected CN codes for *Loligo* products (see below).
Finally, trade statistics are corrected continuously. Therefore it could never be presented as an absolute value. For this reason volumes and values of landings and trade are presented rounded by 1 000 euro or tonnes.

6.3 Successful market introduction

The Dutch demersal fishing fleet and the fish processing industry have been for many years centred on flatfish species. Since 2017, landings of flatfish, in particular plaice, have decreased substantially, due a combination factors (more northern distribution of the large plaice, structural problems in the beam trawlers fleet, and the energy crisis affecting all components of the demersal fleet). These factors prompted the fleet to look for new, complementary, target species.
The development of the flyshoot fishery, mainly non-quoted species with good price, has led to an increasing volume of squids that the Dutch fish processors and seafood wholesalers had to put on the market. These fish processing and export companies, traditionally specialised in flatfish, have taken initiative to actively promote this 'new' species to the Italian, Spanish and French markets as high quality fresh species. This introduction of squid was successful and there was an immediate demand for the Dutch squid products, either frozen or fresh chilled, to supply European hotels, restaurants and caterers (HoReCa). As all steps in the value chain add value to the squid products, there are financial revenues for the entire supply chain. This successful start led to an increasing demand for squid from these clients. High first sales prices for fishers demonstrated the high quality of the fresh landed squid and increasing demand from the market by more recognition and familiarity with the squid as seasonal product. Instead of a bycatch, the squid has therefore become a target species in the winter season.
The increased fresh landed volume of squid contributes to compensate for the revenue loss due to lower plaice landings. Squid is highly valued by the EU market, with average prices ranging between around €7 and €9 per kilogram sold as whole fresh at the Dutch fish auctions Ijmuiden, Urk, Scheveningen, Vlissingen and Lauwersoog.

6.4 Value chain of squid from catch to consumption

The squid is landed fresh as a whole in French, Belgian or Dutch harbours by the flyshoot and bottom otter trawl (twin rig mainly) fisheries. Often the squid is transported by lorry from French and Belgian harbours (mainly Boulogne sur Mer and Ostend) to Dutch fish auctions to be sold. The main reason to transport the landed squid together with other fish species from these foreign harbours to Dutch fish auctions is higher first sales prices offered in the Netherlands. Most of the fish processors and seafood wholesales (exporters) purchasing fresh squid are located nearby the Dutch fish auctions of IJmuiden, Scheveningen and Urk.

At the Dutch fish auctions, the squid is sold in different qualities and landed size classes. Quality scores E (=highest score), A, B, C (=lowest and inappropriate for human consumption) are the European Communities (EC) scoring criteria (EC, No 2406/96)[5]. Since 2018, the Cooperative Fisheries Organization (CVO) has assigned private inspection agencies to execute the inspection at Dutch fish auction according Common Market Standards of the European Commission (No 2406/96)[6]. In the past (before 2018), the Dutch governmental food inspection authority (NVWA) was executing this inspection at Dutch fish auctions. Fish auctions employees are often in charge of determining the quality score for each bucket or tub of the fish to be sold. As squid is a non-quoted species, there are no minimum landing sizes prescribed. Some Dutch fish auctions determine landed squid into five size classes from 1 (=largest) to 5 (smallest size).

First sales prices for fresh landed fish species sold at Dutch fish auctions are primarily determined the law of supply and demand and factors such as quality (appearance like no damages, colour of skin, eyes, organs etc.; freshness as corpse rigidity; smell; fishing area), season, yield (has fish a high meat weight or not due to spawn disease for instance?). The squid taken as bycatch by the beam trawlers has a lower sale price than in targeted fisheries, as it remains longer in the fishing nets and is often damaged by the tickler chains and by sand erosion of the beam trawling technique. With the flyshoot and bottom otter trawl, squids are caught just before getting the fishing nets onboard and is usually of higher quality.

[5] Council Regulation (EC) No 2406/96 of 26 November 1996 laying down common marketing standards for certain fishery products: https://eur-lex.europa.eu/eli/reg/1996/2406/oj/eng.
[6] Council Regulation (EC) No 2406/96 of 26 November 1996 laying down common marketing standards for certain fishery products: https://eur-lex.europa.eu/eli/reg/1996/2406/oj/eng.

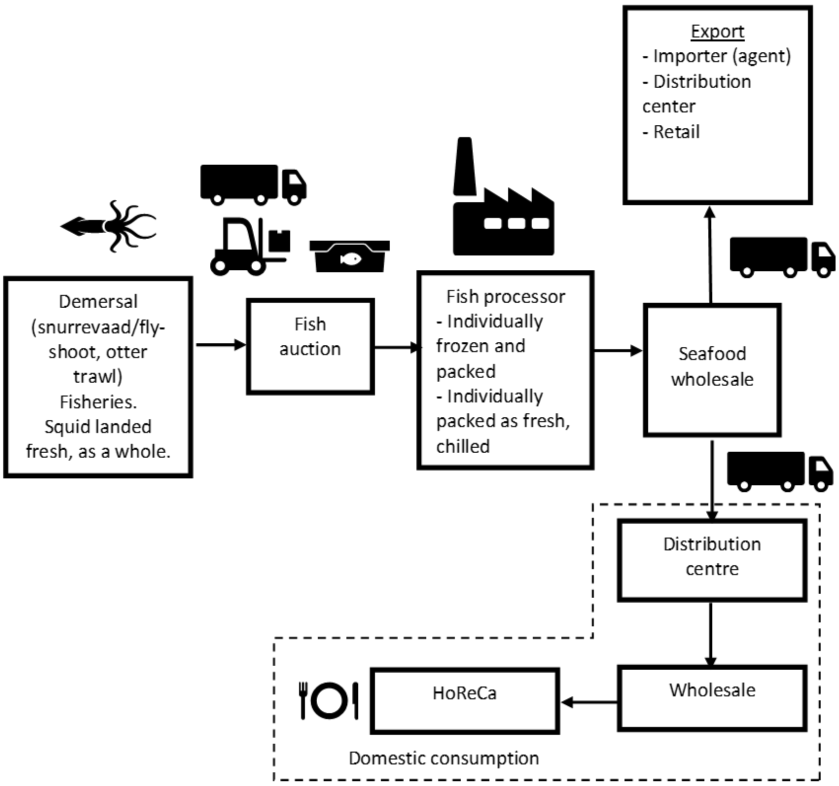


Figure 6.1 Visualization of value chain for fresh squid landed as a whole from a post-harvest perspective.

The volume and value of squid sold at the Dutch auctions has increased strongly over the period from 2019 to 2023. In 2020, the total landed volume of squid was around 2 300 tonnes with a value of € 18 million. In 2023 total landed volume was around 3 700 tonnes with a value of €32 million. Averages prices per kilogram of squid was between €7 (2020) and €9 (2021). These average prices per kilogram differ strongly per Dutch fish auction with variation between €4 per kilogram at Stellendam and €8-9 per kilogram at Ijmuiden, Urk and Scheveningen (average over the years 2019-2023). In 2023, 43% of the squid landed in the Netherlands were sold in IJmuiden, followed by Urk (38%), Scheveningen (15%), Vlissingen (2%), Stellendam (1%) and Lauwersoog (1%). This does not necessarily reflect the ranking of the auctions in terms of landed volumes, as these auctions also sell the squid that was landed in French or Belgian harbours and transported by truck to the Netherlands.

Two main product categories are delivered by Dutch fish processors and traders: fresh squid packed as a whole (with the head on) and squids frozen individually and packed, representing respectively 47% and 40% of the exported value in 2023. The remaining 13% are sold as smoked, dried or in brined product.

The squid is processed in Dutch fisheries communities with production capacity for both frozen products and fresh product such as Urk or Ijmuiden and to a lesser extent Scheveningen and in Zeeland. In terms of product differentiation, Urk is a large processor for frozen squid while IJmuiden is specialized into fresh packaging of squid. There is currently no estimation available of the proportion of the squid first sold via contract compared to the sales in publicly open auction. With the development of new communication technologies (WiFi onboard giving access to instant messaging applications, video calls and e-mail), fishers and fish processors have more frequent contact during the fishing trip about the volumes of squid caught. This influences price dynamics as fish processors and traders could already promote squid products multiple days before the squid is landed on shore and transported to the fish auctions. It is also a trend that fresh landed fish is increasingly sold by contracts driven by a higher demand than supply for North Sea fish species.

Squid popularity is mainly due to cultural heritage and traditions by religion. In southern European coastal areas it is cultural heritage to consume squid prepared as fried in olive oil as rings or as a whole squid. Another favourite recipe is the fried squid rings known as 'calamari' or 'calamares'. Another reason that clarifies the popularity of the squid is prompted by religious preferences. From orthodox Christianity and Roman Catholic it is forbidden to consume animal protein except fish products by spice laws during fasting in advance of Pentecost. Squid is an animal product that is allowed by the spices laws and therefore highly valued within the fasting period but also during the winter season when squid is caught.

6.5 Dutch production and imports of squid

Squid that is landed in Dutch harbours by foreign flagged fisheries vessels is registered as import according to trade statistics. With regard to imported squid, around 90% of the volume (kilogram) was fresh squid (CN code 03074220 - SQUID "LOLIGO SPP.", LIVE, FRESH OR CHILLED) in 2023. The Remaining 10% was frozen squid (CN code 03074331 - SQUID "LOLIGO VULGARIS", FROZEN). Most of the imported volume by the Netherlands came from the United Kingdom (UK) in 2023 based on trade statistics (Eurostat, 2024) (figure 6.2). Multiple UK flagged flyshoot and bottom otter trawl fishing vessels are owned by Dutch fishers which often land their squid catches in Dutch harbors like Vlissingen and IJmuiden. In 2024, the main countries of origin for imported squid were the UK, France and Belgium. Harbors as Boulogne-sur-Mer (France) and Ostend (Belgian) are important harbors to land squid by the Dutch fleet. Among Dutch harbors important harbors to land squid are Vlissingen, IJmuiden, Scheveningen and Harlingen. As Urk has no own sea based harbor all squid transported by truck to this fish auction.

Of the largest Dutch auctions for squid (IJmuiden, Urk and Scheveningen) most of landed fish originates from Dutch flagged vessels. For IJmuiden on average 71% originated from Dutch flagged vessels, 19% from UK flagged vessels and 10% from other flagged countries than Dutch and UK in the last five years (2019-2023). For Urk, this was 48%, 27% and 25% respectively. For Scheveningen it was 88%, 7% and 5% respectively.

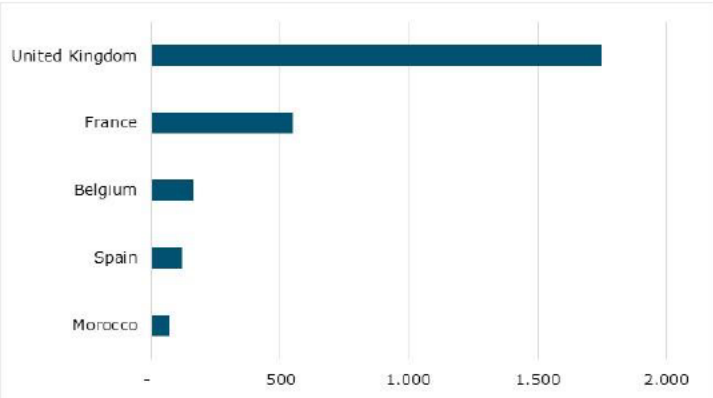


Figure 6.2 Top 5 countries of origin for imported squid (in tonnes) by the Netherlands in 2023 (Eurostat, 2024).

Increased imported volumes from 2022 and 2023 could be explained by more foreign-flagged vessels targeting squid in winter (table 6.2). As in the trade statistics multiple *Loligo* species are included, this can explain that Spain and Morocco are in the top 5 of import countries (in tonnes) for the Netherlands for squid.

Table 6.2 Imported squid (in tonnes, whole fish equivalent*) by the Netherlands from 2016-2023 (Eurostat, 2024).

Year	2016	2017	2018	2019	2020	2021	2022	2023
Imported volume (in tonnes)	107	474	542	788	367	934	2.202	2.723

*Whole Fish Equivalent is the calculated actual weight of fish by applying conversion rates to its unprocessed (raw material) state. In this case it is close to the live weight in order to enable comparison with landed volume (in live weight) from table 6.3.

Since 2021, the quantities imported are larger than the quantities landed by the Dutch flagged vessels (table 6.3). This can be potentially explained by an increase in the number of British, French and Belgian flagged vessels that decided to target squid with flyshoot or bottom otter trawl in the winter season. Flyshoot fishing in the English channel is subject to a license system, imposing a maximum number of licenses per country. For the Netherlands, the limitation of maximum 24 licenced vessels using flyshoot in the English Channel has been reached for many years. Other coastal countries that use this fishing technique in the English Channel are France, Belgium and the UK (with a maximum of 28, 6 and 17 licenses respectively). The number of British and French flagged vessels that have applied for this license to fish with the flyshoot technique in the English Channel has strongly increased since 2020. This can explain the increase for the volume imported in the Netherlands since 2021 (table 6.2).

Table 6.3 Landed volume (in tonnes, live weight) by Dutch flagged cutters from 2016-2023 (Agrimatie, 2024).

Year	2016	2017	2018	2019	2020	2021	2022	2023
landings by Dutch flagged cutters (in tonnes)	1 147	1 605	1 490	1 169	1 388	927	1 731	2 218

6.6 Most important export markets for squid from the Netherlands

The exported value of squid by the Netherlands has increased by a factor eight between 2016 and 2023, with the largest increase (+67%) occurring between 2022 and 2023 (table 6.4). In 2023, the total export value was almost 35 million euro, compared to just above 4 million euro in 2016. This corresponds to an increase from 602 tonnes (dead weight) in 2016 to 3 741 tonnes in 2023. Converted into whole fish equivalent to compare it with the sum of the volumes imported (table 6.2) and landed (table 6.3), these volumes were almost similar.

Table 6.4 Exported value (x 1 000 euro) for squid by the Netherlands in 2016-2023 (Eurostat, 2024).

Year	2016	2017	2018	2019	2020	2021	2022	2023
Exported value (x 1 000 euro)	4 234	8 970	11 077	12 449	12 386	12 641	20 760	34 654

The average export price per kilogram (dead weight) increased almost constantly from € 7.04 in 2016 to € 9.32 (2022) (figure 6.4). There was, however, a small drop in the price in 2020, due to a decrease in the activity of restaurants and in tourism in southern European coastal regions related to the COVID-19 pandemic.

Most important countries for the export of squid by the Netherlands in 2023 were Italy (€ 15 million which represented 44% of total exported value of squid), Spain (€ 10 million, 28% of total export value of squid), Croatia (2.5 million, 7%), Greece (2.2 million, 6%), France (€ 2 million, 6%) and Greece (1.5 million) (figure 6.5). In terms of exported volume similar top 5 countries from highest to lower ranked are presented as exported value (both dead weight).

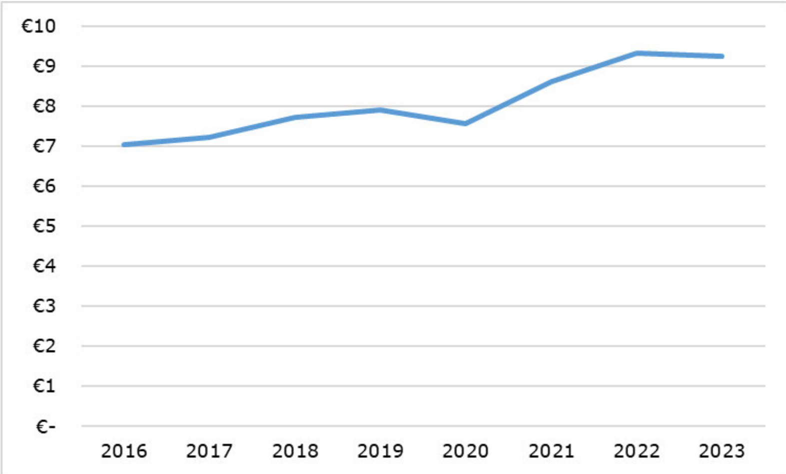


Figure 6.4 Average export price (in euro) per kilogram squid by the Netherlands 2016-2023 (Eurostat, 2024, dead weight).

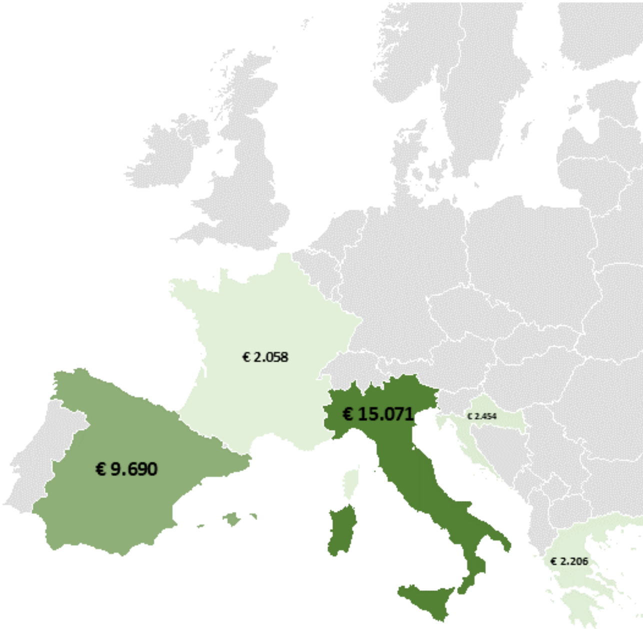


Figure 6.5 Top 5 export countries (x € 1 000) of squid for the Netherlands in 2016-2023 (Eurostat, 2024, dead weight).

6.7 Main squid producing countries in Europe (including UK)

The production of squid in Europe comes only from catches of wild stock by the fishery and there is no production from aquaculture. Landing statistics by ICES show that fisheries landed between 7 000 and 12 000 tonnes of loliginid squid for all six main fishing areas between 2000 and 2021 (figure 6.6). The French and UK fleet landed most of the volume followed by the Netherlands (figure 6.7). Catches of loliginid squid may include *L. forbesii*, *L. vulgaris*, *Alloteuthis media* and *Alloteuthis subulata*, with the latter two species being of lower commercial interest (ICES, 2023).

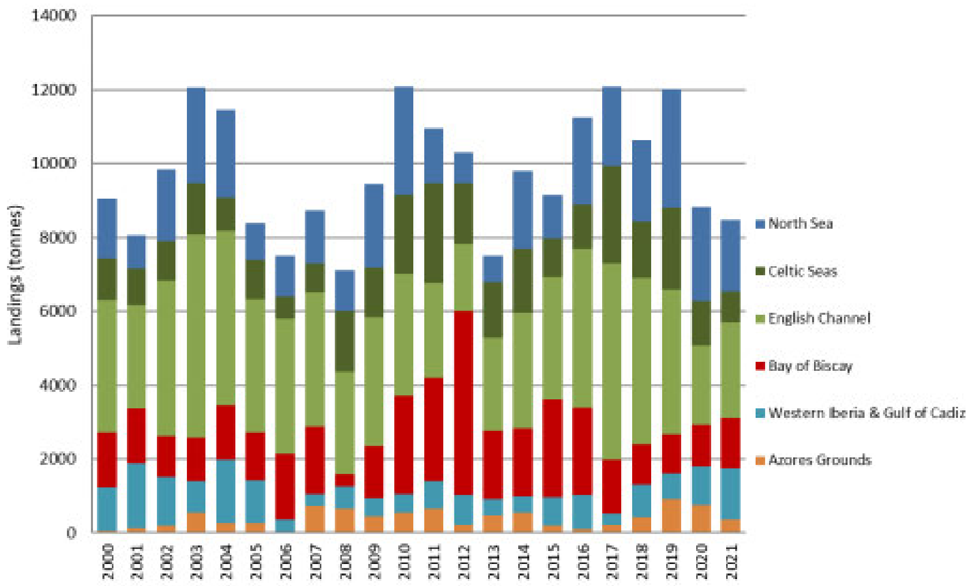


Figure 6.6 Change in the landings of loliginids in the six main fishing regions between 2000 and 2021 (ICES, 2023).

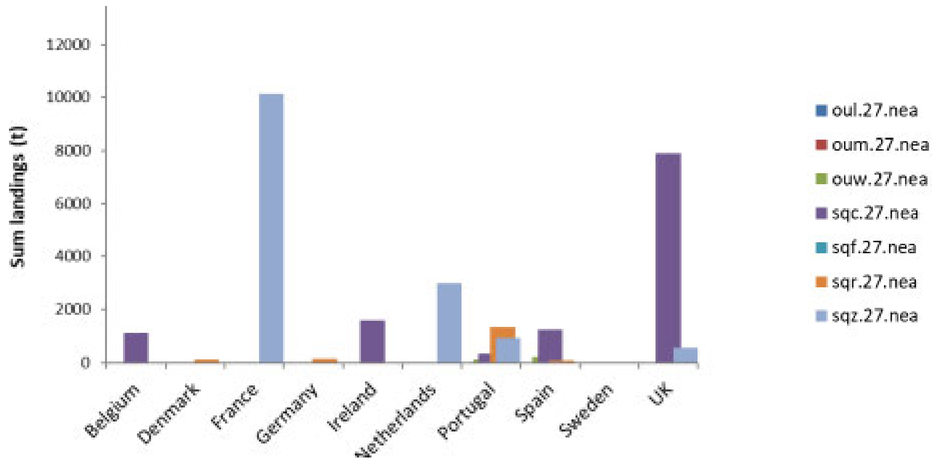


Figure 6.7 Sum of landings (tonnes) of loliginid by country in 2019–2021 (ICES, 2023).
sqr = *L. vulgaris*, sqf = *L. forbesii*, sqc = *Loligo* spp., sqz = *Loliginidae*, oum = *Alloteuthis media*, oul = *A. subu-lata*, ouw = *Alloteuthis* spp

7 Regulations and management

7.1 Regulations and legislation relevant to squid and the Dutch squid fishery

7.1.1 Introduction

This chapter elaborates on the regulations that are relevant to the Dutch directed fishery on squid. Which regulations apply to certain fisheries mainly depends on their target species, fishing area and vessel type, but also bycatch species.

As described in Chapter 4, the vessels that target commercially interesting squid species (*L. forbesii* and *vulgaris*[7]) are bottom otter trawls (OTB, 353-557 kW, average 25-27 m length) and flyshoot (SSC, 619-662 kW, average 29-30 m length). The Dutch squid fishery mainly targets two ICES divisions: Southern North Sea (ICES division 4c) and Eastern English Channel (ICES division 7d). To a lesser extent, the Dutch squid fishery directs its attention to the central North Sea (ICES division 4b) and the western English Channel (ICES division 7e). Whereas previously fishing mainly occurred in ICES division 4c, OTB vessels seem to be shifting northwards to ICES division 4b. This was verified by the Nederlandse Vissersbond (NVB). As Chapter 4 has shown, SSC also fish in division 4b early in the season and target squid in the western English Channel (ICES division 7e). Although both of these regions (ICES division 4b and 7e) currently account for only a small proportion of landings, applicable legislation are taken into account in this chapter.

Furthermore, relevant for this section are the bycatch species in the Dutch squid fisheries. As discussed in Section 5, for a limited number of OTB trips targeting squid with scientific observers onboard, this is herring, red mullet and horse mackerel (Afranewaa et al. 2022). Whiting also emerged as a frequently observed bycatch species and responsible for real time closures (RTCs). For SSC, most common bycatch species were whiting, herring, plaice and dab.

7.1.2 Regulatory framework

Firstly, the most relevant regulatory and legislative frameworks referred to in this chapter are briefly mentioned. These are either related to the directed squid fishery through the target species, vessel type, bycatch species or target area.

The EU's Common Fisheries Policy[8] (CFP) provides the basis for regulations and legislation for sustainable management of European fisheries and aquaculture and the conservation of fish stocks. Several components under/related to the CFP are most relevant for this chapter:

1. In the latest reform of the CFP, the Landing Obligation (LO, Art. 15 of CFP) was introduced to 'eliminate discards by encouraging fishers to fish more selectively and to avoid unwanted catches'[9]. The LO obliges fishers, among others, to land all species that are regulated through catch limits, and must be counted as part of the quota. Exemptions to the LO exist, including high survivability and de minimis exemptions.

2. Art. 9 and 10 of the CFP lay the basis for adoption of multiannual plans (MAPs), which contain measures to conserve and restore fish stocks. The 'Multi-Annual Plan for demersal fish stocks in

[7] As aforementioned in this report, main squid species of commercial interest to the Dutch fleet are *Loligo vulgaris* (European squid, 3-alpha code SQR) and *Loligo forbesii* (veined squid, 3-alpha code SQF). However, fishers have historically been using the code "SQS" for "squids". Fishers however not distinguish the species in sorting out of the catch. Under the instruction of the RVO, most landings have been ascribed to *L. vulgaris* (SQR).

[8] Regulation 1380/2013: https://eur-lex.europa.eu/eli/reg/2013/1380/oj

[9] Information on the LO: https://oceans-and-fisheries.ec.europa.eu/fisheries/rules/discarding-fisheries_en

the North Sea[10] (MAP North Sea)' aims to ensure the sustainable exploitation of certain demersal (defined as species that live and feed near the bottom of seas) fish stocks (covering approx. 90% of landing in area and at risk of over-exploitation, as well as their bycatches). The MAP North Sea applies to the entire North Sea and adjacent waters as far as fish stocks extend to those waters, e.g. Area 7d.

3. Technical Measures Regulation (2019/1241)[11] contains rules that govern how, where and when fishers may fish. It aims to reach the CFPs objectives, as well as good environmental status as set in the Marine Strategy Framework Directive (MSFD) and Birds & Habitat Directive (BHD). The Regulation provides definitions of allowed (directed) fisheries in both the North Sea (Annex V) and the North Western Waters (NWW) (Annex VI).

4. Control Regulation (1224/2009)[12] was initiated as part of the CFP development and lays out rules for controlling fisheries in EU-waters, Member States' territories, and of EU-vessels globally. It contains conditions for access to waters and resources, control rules for fisheries management measures, including fleet capacity. It obliges all fishing vessels to hold a valid fishing licence (Art. 6). For specific conditions, EU-vessels must also hold a specific fishing authorisation (Art. 7).

Furthermore, in the Marine Strategy Framework Directive (MSFD, in Dutch Kaderrichtlijn Marien[13] (KRM), the Netherlands like other European member states have defined their marine strategy, also includes cephalopods. Despite squid being specifically mentioned as one of the species to define descriptors for (D1C1, D1C2, D1C3), this specification has not yet occurred. Both Part 2 and Part 3 of the KRM mention that limited knowledge in (by)catches of these species prevents this specification from taking place. Squid are, however, part of the KRM monitoring program and (by)catch registration in line with the CFP obligation. Furthermore, EU member states are obligated to set mortality thresholds for species of fish and squid[14], which are not commercially exploited and whose survival is threatened by incidental bycatch in the region or sub-region.

7.1.3 Discussion and developments

The Dutch squid fishery operates under unique regulatory conditions. Table 7.1 provides a detailed overview of the most relevant regulations per ICES-region applying to the Dutch vessels targeting squid. Almost all Dutch squid fishery takes place outside territorial waters (i.e. outside of the 12 nautical miles zone). As the fishery takes place both in EU and UK waters (see Section 4), the table further makes a distinction between EU-waters and UK-waters legislation where relevant.

Several developments relating to these measures will be elaborated, each reflecting a certain complexity surrounding the question on what regulations apply to the 'Dutch squid fishery'. As mentioned earlier, it is thereby important to remain aware that which regulations account to the Dutch squid fishery is not dependent on the target species only, but also the bycatch species, vessel type and targeted areas, among others.

Target and bycatch species

Squid (*L. forbesii* and *L. vulgaris*) is not regulated by quota (i.e. non-quota species, NQS). This means EU catch quota, the LO, or national quota (*contingenten*), are not applicable to these species. There is also no minimum reference conservation size (MRCS) in place. There are currently also no national Producer Organisation (PO) measures in place regarding minimum size nor weight limits for squid.

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[10] Regulation 2018/973: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018R0973
[11] Regulation 2019/1241: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02019R1241-20241011
[12] Regulation 1224/2009: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02009R1224-20241011 with recent amendments in Regulation 2023/2842: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202302842
[13] Kaderrichtlijn Marien (KRM): https://www.noordzeeloket.nl/beleid/mariene-strategie-krm/
[14] Decision 2017/848: https://eur-lex.europa.eu/eli/dec/2017/848/oj/eng

The main bycatch species in squid fisheries are commonly subject to aforementioned regulations and legislations, including the LO. Caution should therefore be given to which regulations apply to squid *as a species* or to the *Dutch squid fisheries* (e.g. via used vessel type, target area, bycatch species). A common thread is therefore the consideration that a clear definition for '*targeted'* or '*directed'* fishing ('*gerichte visserij'*) lacks in legislation and regulations, complicating the discussion around technical measures obligations, especially regarding bycatch.

Minimum mesh size requirements

According to the Technical Measurements Regulations, in ICES areas 4 and 7, *directed fishing* for squid is in principle allowed with a mesh size of at least 40mm (Technical Measures Regulation, Annex V and Annex VI). Currently, in practice, a minimum mesh size of 80 mm is most commonly applied in the Dutch squid fishery (please also refer to Chapter 4). A motivation for fishers to use this minimum mesh size, is that exemptions to the landing obligation only applies when fishing with a mesh size larger than 70 mm (North Sea) or smaller than 80 mm (North Western Waters)[15] (pers. comm. NVB). All catches of species for which catch limits apply must be landed in this fishery. According to logbook data, however, sometimes smaller mesh sizes are also used (personal communication RVO and NVB).

Key bycatch species in the Dutch squid fisheries, are subject to other minimum mesh sizes for OTB and SSC[16], in case these species would be targeted. A minimum mesh size of 80 mm applies to directed fishing for whiting (ICES areas 4 and 7) and 100 mm for directed fishing for plaice (ICES area 4). For directed fishing on red mullet and dab, a minimum mesh size of 80 mm applies. For herring and horse mackerel only an exception is in place for pelagic fisheries (not OTB and SSC), for which the minimum mesh size is 16 mm. The absence of a clear definition of 'directed' fisheries might raise a discussion point in this sense.

MAP North Sea authorizations

A MAP lays the basis for conservation targets and obligations around authorizations, control rules and technical measures for certain stocks and fisheries exploiting these stocks. To be able to target[17] the species as listed in the MAP North Sea (e.g. whiting), an authorization (*Vismachtiging meerjarenplan Noordzee*[18]*,* VMN) is required, and the gear and mesh size restrictions listed in Article 12 of the MAP and Annex V of the Technical Measures Regulation do apply. Though squid as a species is not part of the MAP North Sea, the interpretation of how the rules under the MAP relate to the 'Dutch squid fishery' appears less clear (pers. comm. RVO and LVVN). Further consultation between government entities on these matters is required to conclude on these complexities (pers. comm. LVVN, RVO). Therefore, in consultation with LVVN, it was decided that these discussions will not be resolved in this scientific report. The following sections will, nonetheless, provide a brief overview of these complexities and related developments.

In the Netherlands, no specific authorizations currently exist for directed squid fisheries. In accordance with Article 27(5) of the Technical Measures Regulation, a fishing authorisation may be required for fisheries that deviate from the minimum mesh size of 120 mm (both for ICES Subareas 4 and 7). The Netherlands does in practice not issue fishing authorisations under this Article. For all relevant fisheries listed in Annex V of the Technical Measures regulation, authorisations are issued based on either Article 7 of the Regulation (EU) No 1224/2009 or national legislation the '*Uitvoeringsregeling visserij*'[19] (e.g. for shrimp). Currently, no authorisations as meant in Art. 7 of the Control Regulation are granted specifically

[15] Vrijstellingen op aanlandplicht op Noordzee en NWW: https://www.rvo.nl/onderwerpen/aanlandplicht
[16] Annex V of Technical Measures Regulation
[17] Regarding '*target'* in this regard, according to RVO, the current enforcement regime does not accommodate a definition for this. A fisher who lists a gear covered by the MAP as first or second gear on his fishing licence, must apply for a VMN and thus comply with mesh size regulations (pers. comm. RVO).
[18] Art. 7 of Control Regulation 1224/2009: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02009R1224-20241011
[19] Uitvoeringsregeling zeevisserij: https://wetten.overheid.nl/BWBR0030288/2024-11-26

for the *directed* fishery for squid (personal comm. RVO). National documents, similar to shrimp, do not exist for squid fishery. According to RVO, how this translates to enforcement regarding the Dutch squid fisheries appears an issue in the Netherlands (personal comm. RVO). A second discussion considering authorization covers Article 12 of the MAP, which currently states that for OTB and SSC, a VMN is issued for listed mesh sizes (100+, 70-100, or 16-32 mm). For intermediate mesh sizes, the MAP does not provide authorization specificity. As the *directed* squid fisheries are in principle allowed to use a minimum mesh size of at least 40 mm, it introduces further discussion around what authorization obligation applies to these fisheries.

However, a fishery's authorization requirement under the MAP is not solely determined by its target species but also by its bycatch composition. According to RVO, the Dutch squid fishery could, given its bycatch of MAP-listed species (e.g., whiting) in practice have to comply with VMN authorization and respecting minimum mesh size related to these species (in line with the Technical Measures Regulation Annex V[20]). To illustrate the issue: if there are high catch percentages of species Y in fisheries for target species X, and species Y is subject to a protection measure based on the MAP, i.e. the obligation to have a VMN (restricted by track records) before being allowed to catch Y, it can be argued that a VMN is needed because of species Y in fisheries for target species X. The minimum mesh sizes set by the VMN then applies to fisheries for target species X.

Current regulatory developments appear likely to (indirectly) resolve these issues in the near future. Recently both national (PO, pers. comm. NVB) and international (regional Scheveningen Group and regional North Western Waters Group[21]) requests have been submitted to increase the minimum mesh size of *directed* squid fisheries to 80 mm (with the exception of beam trawl and seine fisheries in ICES division 7j and for pelagic fisheries (OTM) in the 12 mile zone of division 7e, pers. comm. LVVN) to enable more sustainable fishing practices. A Gentlemen's Agreement was already in place between French, Dutch and Belgian SSC vessels on this (pers. comm. NVB). The amendment to the Technical Measures Regulation would solve the aforementioned ambiguity in relation to the VMN for a mesh size smaller than 70 mm, as it will inhibit the adoption of smaller mesh sizes in the Dutch squid fishery (pers. comm. RVO and LVVN). The amendment will likely be integrated in regulations in 2025 (pers. comm. NVB and LVVN). Similar developments are seen in UK regulation (paragraph below).

Mesh size in UK-waters

On 14 December 2023, the UK fisheries management plan (FMP) for demersal non-quota species in the Channel[22] was published. During the drafting process, specific sustainability concerns were highlighted for the SSC fishery for non-quota species, including squid, leading to calls for precautionary management. Following stakeholder consultation on this issue, the option for directed squid fishing with a minimum mesh size of 40 mm was removed for all towed gears (including areas 4 and divisions 7d and 7e) in UK waters, with effect from 24 October 2023[23]. This led to an increase of minimum mesh size to 80 mm. Recently, it was again increased to 100m for SSC (in effect since 16th of December, 2024[24]). A similar plan to this FMP is currently being discussed for the southern North Sea[25], which states that further research into squid and fisheries thereof in this region is required.

SSC access to territorial waters

[20] Annex V of Regulation 2019/1241: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02019R1241-20240409
[21] News article on squid mesh sizes: https://thefishingdaily.com/latest-news/nsac-recommends-increase-in-minimum-mesh-size-for-squid-fishery/
[22] UK FMP for NQS in the Channel https://www.gov.uk/government/publications/channel-demersal-non-quota-species-fisheries-management-plan-fmp/fisheries-management-plan-for-channel-demersal-non-quota-species--3
[23] Legislation change regarding 40 mm mesh size option: https://www.legislation.gov.uk/uksi/2023/1054/made
[24] The Sea Fisheries (Amendment) (No. 2) Regulations 2024: https://www.legislation.gov.uk/uksi/2024/1028/contents/made
[25] Update on FMP in Southern North Sea acknowledged in: https://consult.defra.gov.uk/fisheries-management-plans-1/southern-north-sea-demersal-nqs-fmp/supporting_documents/Proposed%20SNS%20NQS%20FMP.pdf

SSC cannot enter territorial zones (<12 mile zone) of both EU and UK waters, and therefore no directed squid fisheries is possible in those regions. There are several exceptions. In principle, SSC is still allowed in territorial waters in certain parts of the eastern Channel between 6 and 12 miles. The CFP regulates access of Dutch fishing vessels in French waters. The Dutch fleet is entitled to fish in certain French waters under Article 5 of Regulation (EU) No 1380/2013. In addition, however, French, Dutch and Belgian voluntary private agreements (referred to as a Gentlemen's Agreement, GA) on SSC in the eastern Channel (effective from 18 November 2024) have been made. This GA contains agreements on, among other things, technical specifications of the fishing gear (minimum mesh size […] is 80mm), fishing area (seine fishing prohibited within nine miles in ICES Area 7d in Hauts-de-France region, with an exception for vessels <25m and <250 UMS, and seine fishing ban for all sizes of vessel and all flags concerned by the GA in the area from Cherbourg to Le Tréport within 12 nautical miles) and fishing intensity (3+1 vessels for Belgium, 21 for France and 24 for the Netherlands" and "8 calendar days of seine fishing per 14-day period) (pers. comm. NVB).

Real time closures

Real time closures (RTC) are fisheries management measures commissioned by an European control agency, in which specific areas are closed for 21 days for certain fisheries. An RTC is put in place when too many juvenile fish of a certain species (cod, haddock, saithe and whiting) have been caught[26]. Especially whiting, indicated as key bycatch species in the Dutch squid fisheries, is of importance. Recently, a RTC due to overfishing on juvenile whiting was implemented, which involved a target area for Dutch squid fisheries[27].

7.1.4 Conclusion

This chapter has demonstrated the complexity of the regulation of squid and the Dutch squid fishery. Issues discussed included the definition of directed fishing, mandatory minimum mesh sizes and applicable authorisation schemes. It also addressed these in relation to the main bycatch species. The chapter has shown that several complex jurisdictional areas of discussion remain, given the regulatory nuances and interpretations underlying them. Concluding on these debates goes beyond the mandate of this scientific report. Nonetheless, the chapter also clarified that new developments are taking place in the regulations (i.e. increasing the minimum mesh size) that will (indirectly) mitigate some of these complexities.

[26] More information on RTCs can be found here: https://english.rvo.nl/topics/real-time-closures-north-sea, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02010R0724-20110813

[27] Notification of RTC can be found here: https://english.rvo.nl/sites/default/files/2024-11/Notification%20letter%20RTC%20of%20November%201%202024.pdf

Table 7.1. Overview per ICES-region of the legislation and regulation applying to the vessels during the squid fishery

<table>
<tr><th></th><th>Central North Sea (4b)</th><th>Southern North Sea (4c)</th><th>Eastern Channel (7d)</th><th>Western Channel (7e)</th></tr>
<tr><td>General obligations EU & UK waters (sources: PO factsheet[28], RVO)</td><td colspan="4">Fishing licence (visvergunning)
EU fishing vessels, including those using bottom otter trawl and seines (mono, twin and quadrig and flyshoot), must have a valid EU fishing licence in EU waters (under the CFP). If fishing in UK waters, also a valid licence to fish in UK waters is needed[29]. On top of the fishing licence, additional authorizations may be required. See below.

EU quota system
Squid (Loligo forbesii and Loligo vulgaris) are non-quota species (NQS). Quota may however apply to bycatch species.

National quota system
A limited number of EU-quotas are in the Netherlands through a national system (contigentenstelsel) divided over individual quota (contigent). For squid this does not apply as they are NQS. It may however apply to bycatch species.

Landing Obligation (LO)
LO applies to species subject to catch limits. Squid are not subject to compulsory landing, as they are NQS. However, LO may apply to bycatch species of squid fisheries. This means that all bycatches of species subject to catch limits must be landed.

Minimum size and weight
Squid are not subject to minimum conservation reference size (MCRS) under the Technical Measures Regulation. Regulation (EG) no. 2406/96 contains no marketing standards for squids, other than Sepia officinalis. Nonetheless, minimum sizes (both MCRS and marketing standards) do apply to certain bycatch species in squid fisheries, for example whiting (27 cm[30]).

Track records
Track records refer to the vessel’s performance during a reference period (2006-2008) with certain fishing gears (OTB, OTT, PTB, SDN, SSC,SPR,TBB,GNx,GTx,LLx) (RVO, 2025). For fishery with these gears, such track records are required to obtain a Fishing authorization MAP North Sea (VMN), based on Art. 7 of Control Regulation 1224/2009. This track record regime and related authorization practice aims to regulate the exploitation of the species listed in the MAP. However, squid is not one of the species included in the MAP North Sea. Yet important bycatch species in squid fisheries may be, which still obliges these vessels to obtain the VMN, and thus require track records (Art. 86a of the Uitvoeringsregeling Zeevisserij).

Other
Furthermore, the usual rules around vessel monitoring system (VMS), catch registration (logbook), weighing and storage apply. Crew matters, such as qualifications, medical examinations, monster-protocols, rest periods, et cetera, are also applicable.</td></tr>
</table>

[28] Informatieblad wet- en regelgeving Nederlandse Vissersbond: https://vissersbond.nl/wp-content/uploads/2024/07/Informatieblad-wet-en-regelgeving-demersale-bordentrawlvisserij-template-versie-8.pdf

[29] Licence to fish in United Kingdom waters - EU vessel: https://assets.publishing.service.gov.uk/media/6634bcf94d8bb7378fb6c204/UK_Vessel_Licence_-_External_Waters__EU__Var_1_20240506_Conditions.pdf

[30] Annex V of the Technical Measures Regulation. Table shows MCRS for North Sea and Skagerrak. The first entry is North Sea (27 cm), the second concerns Skagerrak (23 cm).

Fishing authorization: EU waters (sources: PO factsheet, RVO, EU MAP North Sea)	In all EU waters, Dutch OTB and SSC vessels may be obligated to have certain fishing *authorization,* additional to above stated fishing license, depending on the gear and fishing area[31].	
	Authorization MAP North Sea (*Vismachtiging meerjarenplan Noordzee*, VMN): Gives the right to carry out fishing activities on demersal stocks with specific fishing gear in EU waters of the North Sea. A VMN is issued in a fisherman's name and applies to the fishing vessel listed on it. A VMN is issued for specific gear categories. A VMN with gear category TR allows fishery with demersal trawls and seines (incl. OTB, SSC). It involves specific mesh size restrictions. Article 12(2) of the MAP North Sea, also involves fishing effort measures related to the Channel (see column on the right). For OTB and SSC, a VMN is in principle only required if obliged and can only be obtained for fisheries with mesh sizes is between 16-32 mm, and fisheries with mesh size or greater than 70 mm. However, according to RVO, given the type and amount of bycatch species in the Dutch squid fisheries, it can be argued that obtaining a VMN is expected for Dutch squid fishing vessels (see information in row below). To what extend fisheries with mesh sizes 32-69 mm can take place without a VMN is unclear. Unlike the Channel (see right), fishing effort in Area 4 is regulated by track records. There is no absolute maximum number of permits.	**Authorization MAP North Sea (*Vismachtiging meerjarenplan Noordzee,* VMN):** Article 12(2) of the MAP North Sea states that Member States may also limit the total capacity expressed in kW of vessels fishing with specific gear. While it does not specify these capacities, it does lay the basis for implementation of measures of fishing effort related to the Channel (see below: Authorization Demersal Species ICES Area 7). **Authorization Demersal Species ICES Area 7 (*Kanaalvergunning*/WWD7):** Gives the right to fish for demersal species in ICES areas 7d and 7e. The Netherlands' fishing effort for these areas is limited. As a result of Article 12(2) of the North Sea multi-annual plan, the Netherlands grants a maximum of 24 WWD7 permits. Furthermore, as mentioned in above section (Authorization MAP North Sea), it sets boundaries to the fishing effort: 1. the engine power is maximum 770 kW 2. the tonnage is maximum 340 GT Authorization multi-annual plan Western Waters (VMWW) does not apply to demersal fisheries.
Technical measures EU-waters (EU Verordening 2019/1241, Uitvoeringsregeling zeevisserij Art. 86, PO factsheet)	**Mesh size** Fishing vessels are subject to minimum mesh sizes, with specific conditions and exceptions to *directed fisheries*. A standard minimum mesh size of at least 120 mm applies to the entire North Sea (ICES area 4). However, for the North Sea (ICES area 4), the following exceptions to the standard mesh size apply provided that bycatch of cod, haddock and saithe are no more than 20% of total catch in living weight (which does not seem to be case for the Dutch squid fisheries): Entire North Sea (ICES Area 4):	**Mesh size** Fishing vessels are subject to minimum mesh sizes, with specific conditions and exceptions to directed fisheries. A standard minimum mesh size of at least 120 mm applies to the Channel (ICES Area 7d+e). **Exceptions to mesh size:** For the northwestern Waters (including ICES area 7d+e/the Channel) the following exceptions apply provided that bycatch of cod, haddock and saithe are no more than 20% of total catch in live weight (which does not seem to be case for the Dutch squid fisheries):

[31] More information on fisheries authorizations applicable to the Dutch fleet: https://www.rvo.nl/onderwerpen/vismachtigingen-zeevisserij

	- For ICES-regions 4b and 4c, for bottom trawls[32] (incl. OTB, SSC) applies the obligation to use at least 80 mm mesh size (including panel of 80 mm) for directed fisheries for whiting, mackerel and NQS, and at least 40 mm for directed fishing of (squid) (*Loliginidae, Omastrephidae*). **Note that this is expected to be adjusted for the directed squid fishery to 80mm (except 12-mile zone in division 7e and division 7j).** Central and southern North Sea (ICES division 4b + 4c): - Towed nets: Mesh size range 70 millimetres to 100 millimetres and are provided with a square-meshed panel of mesh size equal to or greater than 120 millimetres with a minimum length of 3 metres or with a square-meshed panel of mesh size 130 millimetres in the tunnel with the rearmost row of meshes no more than 12 metres from the codline. - Trawl nets: Mesh size range 70 millimetres to 100 millimetres and have at least 15 large meshes of 150 millimetres or more in the upper panel and are fitted with a square-meshed panel of mesh size 90 millimetres, provided that no more than 20% of the weight of the total catch is comprised of cod. - Scottish seine/Flyshoot (SSC): mesh size range 70 millimetres to 100 millimetres and have at least 15 large meshes of 150 millimetres or more in the upper half and are fitted with a square-meshed panel of mesh size 80 millimetres, provided that no more than 5% of the weight of the total catch is comprised of cod. North Sea south of 57º30' N (ICES Area 4): - At least 100 mm (TR1) for directed fishing for plaice and sole with bottom otter trawls and seines (including OTB, SSC) Southern North Sea (ICES Area 4c): - At least 80 mm (TR2): Directed bottom otter trawl fishery for sole. Square mesh panel of at least 80 mm.	- For bottom trawls (incl. OTB, SSC) applies the obligation to use at least 80 mm mesh size for directed fisheries for whiting, mackerel and NQS but at least 40 mm for directed fishing of (squid) (*Loliginidae, Omastrephidae*). No panel restrictions in the Channel (7d+e). **Note that this is expected to be adjusted for the directed squid fishery to 80mm (except 12-mile zone in division 7e and division 7j).** - By-catches of sole and plaice in squid fisheries are so small that mesh size regulations for directed fisheries for these species have been ignored in this report.

[32] See definition of 'bottom trawl' in Verordening 2019/1241, Art. 6.13: https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=CELEX%3A32019R1241

Technical measures UK-waters (source: PO factsheet, UK fishing gear requirements for North Sea[33] and Channel[34])	UK waters are mostly subject to the same technical measures as EU waters (both for minimum size and gear regulations), with a few exceptions (see below). Also allowed components regarding trawls are identical to those for EU waters. As of 24 October 2023, the option for directed fishing with OTB for (squid) with minimum mesh size of 40 mm had been removed (incl. for ICES Areas 4 and 7d+e) in UK-waters[35]. This led to a minimum mesh size of 80 mm. As of 16 December 2024[36], for SSC, it was increased to 100m. For OTB it remains 80 mm.			
	Mesh size In the UK-waters of central North Sea (4b) the baseline mesh size in this area is now a 120mm cod-end and this must be used where catches exceed 20% of cod haddock and saithe combined. If you have landed less, then you may use a different mesh size: - Plaice and Sole and non-TAC species: 100 mm cod-end and 90 mm square mesh panel - Squid: at least 100mm OR larger mesh sizes as required under existing regional technical measures.	**Mesh size** In the UK-waters of southern North Sea (IVc) the baseline mesh size is now a 120mm cod-end and this must be used where catches exceed 20% of cod haddock and saithe combined. If you have landed less, then you may use a different mesh size: - a minimum size of at least 80 mm cod-end and 90 mm square mesh panel is required for mixed demersal fishery and non-TAC species (also directed squid fishery from 24 October 2023 OR larger mesh size under existing regional	**Mesh size** In the UK-waters of eastern Channel (ICES Area 7d) the baseline mesh size is now a 100mm cod-end and this must be used where catches exceed 20% of cod haddock and saithe combined. If you have landed less, then you may use a mesh size: - A minimum mesh size of 80 mm (no panel restrictions) - Sole and non-TAC Species: 80mm cod end and 80mm square mesh panel - Whiting, Mackerel and non-TAC species:	**Mesh size** In the UK-waters of western Channel (ICES Area 7d) the baseline mesh size is now a 100mm cod-end and this must be used where catches exceed 20% of cod haddock and saithe combined. If you have landed less, you may use a mesh size: - Sole and non-TAC Species: 80mm cod end and 80mm square mesh panel - Whiting, Mackerel and non-TAC species: 80mm cod end (no panel restrictions) and 100 mm for SSC

33 UK regulations regarding the North Sea demersal towed gear fisheries: https://assets.publishing.service.gov.uk/media/66a39c76fc8e12ac3edb055b/03_-_2023_GN_-_North_Sea_-_Demersal_towed_gears_v2.pdf
34 UK regulations regarding the Channel towed gear demersal fisheries https://assets.publishing.service.gov.uk/media/61c0a7538fa8f5037ac7452f/13_-_2022_GN_-_English_Channel_-_Demersal_towed_gears_v1.pdf
35 Update on removal of 40 mm option for squid in UK waters: https://www.legislation.gov.uk/uksi/2023/1054/pdfs/uksiem_20231054_en_001.pdf
36 The Sea Fisheries (Amendment) (No. 2) Regulations 2024: https://www.legislation.gov.uk/uksi/2024/1028/contents/made

		measures) for all demersal trawls - Sole: 80mm cod-end and 80mm square mesh panel for all demersal trawls	80mm cod end (no panel restrictions) and 100 mm for SSC (since December 16th, 2024)	(since December 16th, 2024)
Closed areas EU-waters (source: PO factsheet, Technical measures regulations Annex V, part C)	Dutch fishing vessels, incl. OBT and SSC, are allowed to fish in EU-waters (>12 nautical miles) and have limited access to the coastal waters of other EU Member States. **SSC is prohibited in territorial waters** (<12 nautical miles) of the entire North Sea area (ICES Area 4). In the Channel, in French territorial waters between 6-12 nautical miles, fishing with SSC is allowed (under agreements of the GA, 2024). Allowed access vessels (**excluding SSC**) to foreign territorial waters: - Belgian and German waters of 3-12 nautical miles - Danish waters of 6-12 nautical miles between Danish/German border-Blavands huk, between Blavands Huk-Bovbjerg, and between Thyboron-Hantsholm - Danish waters of 3-12 nautical miles between Hanstholm-Skagerrak - French waters of 6-12 nautical miles from the Belgian/French border (estuary La Vire-Grandcamp-les-Bains 49º23'30‘ N-1º2’W) delimited as far as the North Sea region (ICES Area 4) In the context of nature conservation (e.g. Natura 2000) and offshore wind farms, several areas have been designated in EU-waters that are totally or partially closed to fisheries, incl. OBT and SSC.			
Closed areas UK-waters (source: PO factsheet)	Both permanently closed areas and temporarily closed areas are in force in UK waters. In the UK, OTB and SSC do not have access to 0-12 nautical miles. Passage is permitted provided a restricted speed and secured gear. In the context of nature conservation (N2000) and wind farms, several areas have been designated in UK waters that are wholly or partially closed.			

7.2 Some examples of management strategies applied to squid fisheries around the world

There are numerous squids stocks in the world, but information on management is fragmented and often difficult to access (e.g, in Japanese or Chinese). In this section, we take four examples that are illustrative of different degrees of data richness, leading to different level of precision and reactiveness of the management rules.

A Common challenge for managing squid is that they have a very short life cycle, in which birth, recruitment to the fishery, reproduction and death all occur within one year, and often at even shorter time scale. As such, the exploitable stock at a given time is entirely composed of one cohort, or several seasonal cohorts, and therefore the stock size entirely relies on the strength of the annual recruitment, which is in turn often depends on environmental conditions and is therefore very variable. Traditional fisheries management approaches, which are designed to manage stocks with biomasses composed of the accumulation of successive year-classes, cannot be applied. Likewise, traditional stock assessment methods, which follow the survival of age-groups, or the evolution of a biomass, over the years, are not applicable in this case.

In this review, the first example, the Falklands islands, represents one of only cases in which the management strategy combines a recruitment survey to determine the size of the incoming cohort and an in-year assessment, regularly updated and conducted in nearly real time. Stock projections, based on the assessment, can lead to immediate fisheries closure if the stock is forecasted to fall below a reference escapement biomass. This management system is based on an intensive data collection program, and requires a good collaboration between science, management and industry.

In two other case studies (west and east coast of the USA), the fishery is managed based on fixed catch and effort limits. This type of management is clearly not optimal as the catch limits are set and are independent of stock size. This can result in exploitation levels that are too high or too low. In both cases, assessments are conducted, but they are not used to set catch or effort limit, only to monitor the state of the stock and its exploitation.

The last case is based on a trigger levels approach in which each time the total catch or effort since the start of the fishing season reaches a given trigger, an assessment has to be carried out to ensure that the exploitation remains sustainable.

7.2.1 Management of squid fisheries in the Falkland Islands

The Falkland Islands has one of the most intensively managed squid fisheries in the world. The two commercially targeted species are Argentine shortfin squid (*Ilex argentinus*) and Patagonian squid, also called loligo (*Doryteuthis gahi*).

Loligo squid is managed as a single stock that recruits to the fishery as two cohorts, one in the summer, and one in the autumn-winter. While this stock undertakes ontogenetic migrations, it distribution remains confined to the Falklands EEZ, and management is the sole responsibility of the Falkland Islands Fisheries Department.

The shortfin squid, however, is a straddling stock fished across multiple EEZs (mainly the Falklands and Argentina). In 1990, the United Kingdom and Argentina created a regional fisheries management organization (RFMO) called the South Atlantic Fisheries Commission (SAFC) to ensure an effective co-management of the fisheries resources for the region. However, Argentina decided not to continue with the cooperative process and suspended joint scientific activities in 2005 and management measures are imposed separately by each country.

In the Falklands, the two squid stocks are managed using a combination of license system and total allowable catches distributed in ITQs. As part of the license system, the vessels (the fleet is composed of foreign vessels from South Korea and Taiwan, as well as national vessels) have to provide daily fishing information (caches, duration of trawling and position). An observer program monitors the catch composition and biological parameters (e.g. maturity stage).

For both species, management of the fishery is based on the following steps :

- Before the start of the fishing season, scientists conduct a recruitment survey in collaboration with the industry. This data is used to estimate total biomass across the fishing zone, which is used as an indicator of expected harvest outcomes.

- Once the fishing season begins, logbook information is transmitted daily to the Falkland Islands Fisheries Department. Fishery observers will join one or two vessels at a time during the season to collect additional data on size distributions.
- Scientists use these data in a depletion time-series model to estimate stock size throughout the fishing season and assess status against biological reference points set in terms of minimum spawning stock biomass. The minimum stock biomass, or escapement biomass is based on the breakpoint in a hockey-stick stock recruitment relationship
- The model also carries out projections of biomass at the end of the season. Throughout the fishing season, these projections are scrutinized to make sure that the predicted biomass at the end of the fishing season remains above the escapement biomass. If the biomass at the end of the year is projected to drop below these threshold levels, the fishery will be closed early.
- In any cases, the season is always scheduled to close before the squid in the targeted cohort are ready to spawn (Arkhipkin et al., 2013).
- Loligo squid undergo a more comprehensive re-assessment at the end of the season.

This is a unique example of a squid management strategy in which in-year assessments are fed by real-time information and can lead to in-year adjustment of the length of the fishing season. This management cycle is based on strong connection between science, commercial fisheries and management (figure 7.1). This collaboration is key to be able to conduct surveys on the initial biomass, and for the provision of real-time catch statistics and collection of data by the observers. More details on these harvest strategy can be found in Arkhipkin et al. 2013

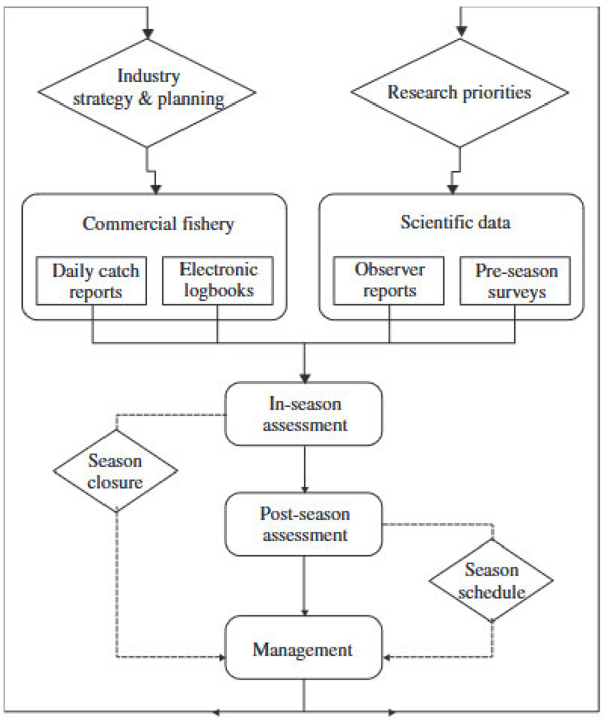

Figure 7.1: connection between science, management and industry for squid management in the Falklands from Arkhipkin et al. 2013

7.2.2 Market squid (*Doryteuthis opalescens*) in California

Market squid are a short-lived, semelparous species with a distribution from Mexico to Canada off the Pacific coast of North America. They have a lifespan of about six months and mostly recruit to the fishery in spring-summer in northern California and autumn-winter in southern California.

Since the 1990s, the fishery has been managed via harvest control rules that include an annual catch limit and specific spatial and temporal fishing constraints. In 2005, a fishery management plan was adopted, that set the annual catch limit at 107 048 tonnes, includes fisheries closure during weekends, restrictions on usage of attraction lights, and limited access to the fishery through a permitting program. This catch limit is not based on a biological model; rather, it is based on the 3-year average catch from the 1999-2000 to 2001-2002 fishing seasons, when abundance did not appear to be declining. Setting limits using historical catch data from such periods of non-declining abundance may be justifiable in data-poor situations. There is no limit reference point, such as a minimum biomass below which fishing should not occur. The catch limit has been exceeded twice since 2005, in 2010 and 2011, suggesting that enforcement is rather effective.

Fishery mortality reference points do exist, using egg escapement as a proxy for fishery exploitation rate that on average will achieve MSY, i.e. F_{MSY}. Scientists developed an eggs per recruit model to evaluate population dynamics and set an egg escapement for in-season management (Dorval et al. 2024). In this type of model, fishing mortality (F) is directly inferred from fecundity of harvested females, allowing for development of proxies for biological reference points based on F. This model is used to assess retrospectively the status of the stock and its exploitation. However, it is too costly and time-consuming to apply for real-time, for in-season management.

7.2.3 Management of squid fisheries in the Northwest Atlantic (US)

Longfin squid (*Doryteuthis (Loligo) pealeii*) is one of the two species of squid that are commercially harvested in the Northwest Atlantic region off the eastern coasts of Canada and the United States of America. The longfin squid are comprised of two seasonal cohorts each with an average lifespan of six months. Squid caught in the offshore winter fishery (October to March) mostly hatched about six months prior during the summer, while squid caught in the inshore summer fishery hatched 6 months prior during the winter.

The Northwest Atlantic longfin squid stock is currently assessed based on scientific survey indices (catchability-adjusted swept-area estimates, Hendrickson 2017) from bottom trawl surveys conducted in spring and fall that provides absolute biomass estimates. The spring and fall biomass estimates are used to represent the seasonal cohorts available to the January-June and July-December fisheries, respectively. Seasonal and annual relative exploitation rates are computed as catch divided by survey biomass, to give an indication of the fishing pressure (Hendrickson 2017).

Biomass reference points are defined for this stock. A proxy for B_{MSY} is defined as 50% of the stock's carrying capacity. The estimation of the carrying capacity is based on the average of biomass observed over a period when longfin exploitation was very light, where this average biomass was considered to represent 90% of carrying capacity. The limit reference point is then set at 50% of B_{MSY}. There are, however, no reference points defined for fishing mortality.

The squid fishery is managed using harvest control rules based on acceptable biological catch (ABC) that are common to a list of species falling under the same management body. First they set a maximum optimum yield (OY). Then the ABC can be set to a lower level, if assessments indicate that potential yield is less than OY. Depending on data richness, the availability of quantitative estimates of stock size and fishing mortality and the possibility to define reference points (similar to stock categories in ICES), the ABC is calculated based on MSY and biological risk criteria. The squids, however, fall under the lower stock assessment category due to the lack of fishing mortality reference points. For this category, the management plan recommends an annual ABC equal to the catch in the year of the highest exploitation rate (catch divided by biomass). For longfin squid this is 23 400 tonnes, the catch in 1993. Although the framework allows for a dynamic management for higher assessment categories, in the case of the longfin squid, management is in practice based on a fixed TAC. Such a management strategy, using a fixed TAC, is likely to result in lost yield when the squid population is highly productive, and may not adequately protect the resource when productivity is low (Hendrickson 2017).

The management authorities use in-season harvest quotas so that catches do not exceed the ABC. The fishery is closed when quotas are attained, based on in-season monitoring. The fishery may also be closed if vessels attain quotas set for bycatch species such as butterfish. In terms of input controls, there are requirements on minimum mesh sizes.

7.2.4 Southern Gould's Squid (*Nototodarus gouldi*) Jig Fishery Harvest Strategy in Australia

The Australian Fisheries Management Authority (AFMA) is responsible for efficient management and sustainable use of the jigging fishery on Gould's squid in southern Australia. Management arrangements are implemented to manage effort, including restricting the number of boats and regulating gear type.
Prior to the start of each fishing year, an annual Total Allowable Effort (TAE) is set. The TAE determines the total number of standard jigging machines that can be used in during the fishing year.
In the absence of biomass estimates from surveys or stock assessment, and in place of target and limit reference points, a range of triggers have been established:

- The first trigger to be considered refers to the previous fishing season. If catches or effort at the end of the previous year have been above specific trigger values, last year's catch per unit effort (both considered annually or per month) should be compared to the nine previous years to identify if there are any concern with the sustainability of the fishery (e.g. declining trends). If that's the case, the initial catch and effort limits for the new fishing season should be adjusted accordingly.

The following triggers are monitored throughout the fishing season. They correspond to different level of catch or effort being reached within the fishing year:

- When the lower triggers (3000t or 30 boats) are reached, an assessment of the state of the fisheries and the stock should be conducted, in a process that also involves the industry. This assessment involves conducting a depletion analysis (similar to the Falklands case study), and obtaining biological information to describe the stock's cohorts composition. If there are no evidence of impact (depletion), the fishery can continue, otherwise, the suitability of the next trigger values should be reviewed and those values possibly revised downwards.
- The same check is repeated when intermediate trigger is reached (4000t), where the following trigger can be lowered if any sign of depletion is observed.
- Finally, if the limit catch trigger is reached, the fishery must stop until a full spatial (specific areas of localized fishing) and non-spatial (whole fishery) depletion analysis has been carried out and the fishery may continue only if it is demonstrated that it remains sustainable.

In addition to these set triggers, if exceptional circumstances are detected, limit triggers can be modified. This is the case for example if a boom is detected by the early analysis, in which case the catch limits can be increased, or if the first analysis detect a low availability situation, in which case the catch limits can be lowered.
Recent evaluation of this management strategy (Noriega et al., 2024) showed since the adoption of management strategy, the lower triggers have never been reached. The analysis, however, further shows that there are current too many data deficiencies for the scientists to be able to conduct accurate depletion analyses, should the trigger be reached.

8 Synthesis and discussion

A unique biology, many challenges for management

Both *Loligo* species have a widespread distribution, that covers most of north European waters. They are highly mobile and undertake migrations from offshore foraging grounds to inshore spawning habitats. Spawning and nursery grounds of the veined squid (*L. forbesii*) are located primarily in the norther areas (from West Ireland, Scotland and northern North sea) while for the European squid (*L. vulgaris*) they are mainly located between the Celtic Sea, English Channel, and southern North Sea.
Focusing on the North Sea, squids were historically primarily recorded in the northwestern (*L. forbesii*) and southernmost (*L. vulgaris*) regions of the North Sea. However, both species have extended their ranges (southwards towards the southern North Sea for *L. forbesii* and northwards, towards the central North Sea for *L. vulgaris*) and they are now almost ubiquitously present throughout the area. The southern North Sea is markedly colder than adjacent areas in winter, and the increasing winter water temperatures has made it more suitable for both *Loligo* species.
The delineation of stocks is not clearly established for *Loligo* species in northern Europe. The literature review showed that clusters can be identified in *L. forbesii* (based on the shape of calcified structures), possibly indicating that individuals originating from a particular nursery ground tend to remain together as a separate ecological population over the first part of their life cycle. However there is little genetic structure in *L. forbesii*, which indicates little breeding separation. This is explained by the fact that those animals undertake long-range movements between their breeding and feeding grounds and there is a strong mixing in the population.
Loligo squids have a short life cycle, with a longevity just over one year, and are characterized by an extremely fast growth, and semelparity (death of all individuals after reproduction). This implies that the fishery exploits each year a single year class, and the yields are strongly driven by recruitment strength. Biological processes such are recruitment are strongly linked to the environment (with temperature and salinity playing an important role), and are therefore very variable.
The literature indicates that there is one main recruitment event per year, in July and in November of the *L. forbesii* and *L. vulgaris* respectively. This is consistent with the strong seasonality found in the Dutch fishery. However it is not uncommon for squids to have several recruitment waves (as it has been observed on Rockall bank for *L. forbesii*). In other part of the world, there can even be two main recruitment events, in different seasons, supporting two distinct fishing campaigns. Analysis of landings length composition could potentially provide some insight into the existence of such sub-cohorts within a given year. There is however currently too little length composition information to conduct such an analysis. The squids are usually not part of the market sampling program and sample collection is very scarce.

Short-lived species typically display very variable stock sizes. As their stock are composed of very few age groups, their size is highly sensitive to variations in recruitment. Due to this high variability, the traditional management approach, based on biomass targets (i.e. applying F_{MSY} to aim for a stock fluctuating around B_{MSY}) is not suitable for these stocks. Instead, short-lived stocks are often managed using escapement strategies, aiming to ensure that enough individuals are left alive at the end of each fishing season to ensure a normal recruitment for the following year. Such escapement strategies are also used for squids stocks, for example in the Falkland Islands.
The cornerstone for a successful management is an accurate stock assessment, providing indications on the development of the stock, and on its status. Most of the usual stock assessment methods are not suited for squids, given the very short longevity of the species. Most assessment tools rely on population dynamics models which represent how population size or biomass evolves from year to year due to fishing, natural mortality, growth and recruitment. The life cycle of the squid, for which all individuals die in just over a year, leaving room to an entirely new generation, does not comply this these assumptions. Furthermore, biomass models, the most natural approach given the data available for squids, assume stability in processes such as recruitment and growth, which is unlikely to match the reality of these species.
The alternative approaches used worldwide, based on simpler depletion models, or using abundance indices derived from scientific surveys, still remain to be developed, and tested for squids in European waters.

To implement such an approach, data requirements are high. In the Falklands, an initial indication on the fishing opportunities is given to the industry based on a recruitment survey conducted together by the industry and the scientists. During the fishing season, a large wealth of data is collected in near real-time (both logbook declaration from the industry and biological sampling onboard by scientists) to monitor the stocks with depletion models (a simple stock assessment tool), which are regularly updated. If these models predict that the biomass after the fishing season might fall under the escapement level, the fishing season will be shortened.

In this report, a first exploration of the applicability of such depletion methods was conducted, showing promising results. There are, however, still strong limitations to the applicability of these methods. The main one being, as stated above, the lack of reliable landings data at the species level. This type of model is also supposed to be applied on numbers of squids landed, which are currently not available. For this reason landings in weight were used instead. While LPUE based on numbers are expected to show the depletion of the population over the fishing season, the LPUE in weight also reflect individual growth, and therefore, LPUE in weight may not show at first, the declining trend expected in depletion models, as the individual growth will counterbalance the decreasing in numbers. This method also assumes a single recruitment event, and it is unclear whether this is fully consistent with the biology of the squids. Biological sampling of the Dutch landings will provide data on the species and length composition of the landings, which is a necessary information for a better specification of the data to be used in depletion model.

To implement such models operationally, to give real time advice, data needs to be collected on a short and regular time scale (e.g. by fortnight). Data quality also needs to be improved, as it is, for instance, essential to have species specific data. This can only be done through a strong collaboration with the industry and the development of a real biological sampling program.

Recent developments in the Dutch fisheries

Over the recent years (the period 2018 to 2024 was considered here), there was a steady number of trips conducted by the flyshoot fishery, with squid being recurrently the main species in values for most of the trips conducted between November and March. This fishery is mainly conducted in the eastern English Channel, but has also increased in the southern North Sea (ICES Division 4c) over this period. Next to this stable fishery, targeted squid fishing with bottom otter trawl has strongly increased since 2018, and the landings from this gear now represent half of the yields of the flyshoot fishery. The vessels fishing squid with bottom otter trawls mainly operate in the southern North Sea, where their fishing ground overlap with those of the flyshooters.

Unlike the flyshooters, which are for most of them purely dedicated to the flyshoot fishery, the vessels targeting squid with bottom otter trawl are both pure bottom otter trawlers that increasingly target squid, and beam trawlers that have installed net rolls to be able to also operate bottom otter trawls. Amongst those, some have been alternating for years between beam trawl and bottom otter trawl , and are increasingly using the bottom otter trawl to target squid. There are also several beam trawlers that have done this transition at the same time, over the last winter (2023-2024), and have immediately started targeting squid. This illustrates the interest for squids as a new target species for the beam trawler fleet, as it faces many challenges with its traditional fishing practices.

The fishing activity targeting squid generates a significant amount of bycatch, especially for the flyshooters fleet. Next to squid, these vessels also have significant landings of striped red mullet and cuttlefish (two non-quota species with high commercial value), mackerel and horse mackerel (both valuable pelagic species), and the less valuable gurnard and whiting. Squid typically represents a third of the catches. For the bottom otter trawls, the proportion of squids are higher (around 50%) and the less abundant bycatch is mainly composed of pelagics (mackerel and horse mackerel) and whiting, representing a less valuable complement to the squid landings than for the flyshooters.

Smaller quantities of squid are also caught as bycatch in other fisheries (around 12% of the total landings). The beam trawl fishery, targeting flatfish, also has landings of squids during the winter months in the southern North Sea. These landings have increased slightly since 2018, which might reflect the increase in the squid abundances (the fleet has not started to actively target these species with beam trawls, as they damage the squids too much). The pelagic freezer trawlers also catch significant amounts (in some years comparable to the beam trawlers) during their blue whiting and North Sea herring fisheries.

There are inconsistencies in the official fisheries statistics with regards to landing declaration at species level. Fishers have mainly used the code "SQS", wrongly interpreted as corresponding to "squids" (while in fact it corresponds to a non-native squid species). Squids have been increasingly reported as SQR (*L. vulgaris*). However, the fishers do not distinguish the species and reports of SQR are particularly due to corrections applied by the RVO (especially in 2024). Market sampling for the Dutch squid landings has only started in 2024, with a pilot study, and will be part of the standard sampling program in 2025. No information was available yet during this project, and the actual species composition of the Dutch landings could not be fully ascertained.

Reasons for this transition

The occurrence of squids in scientific surveys appears not to have been reported consistently through the years. It is doubtful that the quasi absence of squids from the DATRAS data used in this work for the earlier years (before the mid-2000s) really reflects an absence of these species in the North Sea and English channel. The fact that important fisheries have been conducted both in the North Sea (by Scotland) and the English channel (by France and UK) since 2000 (ICES, 2024) indicates that squids have been abundant in these areas before any record is available in the DATRAS database. The analyses presented have also strong limitations due to the inconsistencies (over time, and between countries) in how squid catches in the surveys are reported at species, or genus, level.
Some trends, however, emerged from the analyses presented in this report, that are in agreement with information found in the literature, and likely reflect a biological reality. In particular, trends are observed in the recent years (over the last 10 years) for which the inconsistencies in reporting in the DATRAS database are likely to be less of an issue. Surveys indicate an increase of *L. forbesii* in the North Sea since the mid-2010s. This species appears to be mainly distributed in the northern North Sea in Q1 (ICES divisions 4a and 3a) and more abundant in the central and southern North Sea in Q3 with a strong increase in occurrence in the southern North Sea in the recent years. It is now also quite frequent in the eastern Channel in Q4, however in lower abundances than in the North Sea. *L.vulgaris* is, on the other hand, very abundant in the eastern English Channel, both in Q4 and in Q1. Its abundance seems to have increased in the North Sea, mainly in the southern part, in Q1, but it remains rare in the northern North Sea. Its abundance in the North Sea is low in the Q3 surveys.
These changes in the local abundance of both squids species, may have favored the development of a targeted fishery with bottom otter trawl in the southern North Sea, the increase in the landings of the flyshoot fishery from this area, and encouraged the increasing transition of beam trawlers to seasonal bottom otter trawling in the last years.

The increasing focus on squid was also made possible by the well-organized post-harvest chain in the Netherlands. As squid emerged as an important part of the landings in the developing flyshoot fishery, some Dutch fish processors and seafood wholesalers have taken initiative to promote this fish product. It was successfully presented as a new Dutch seafood product, next to the traditional flatfish, to the Italian, Spanish and French markets, creating an immediate demand for this product. In 2024, half of the Dutch production is sold as fresh product to the HoReCA in Belgium and France, and the second half frozen to countries in southern Europe. While the volume exported increased dramatically (10-fold since 2016), the price also raised, indicating a steady demand for this product.
The Dutch production is sold both through the auction and via contracts, but no information could be found on the proportion of each. An important part of the landings occur in foreign harbors but the squid is transported to the Netherlands to be sold to Dutch fish processors and seafood wholesales. There is also an increase of the quantities landed in the Netherlands by foreign vessels (mainly UK), which are considered as importation.

Regulation and gear selectivity

The Dutch squid fishery operates under unique regulatory conditions, having to do with the definition of directed fishing, mandatory minimum mesh sizes and applicable authorisation schemes. Which regulations apply to certain fisheries mainly depends on their target species, fishing area and vessel type, but also bycatch species. Squid is not regulated by quota, meaning that EU catch quota, the LO, or national quota (contingenten), are not applicable to these species. There are also no minimum reference conservation size

(MRCS) nor marketing standards in place. Furthermore, squid as a species is not part of the multiannual plan North Sea. Currently, no specific authorisations are granted specifically for the directed fishery for squid in the Netherlands. Caution should however be given to which regulations apply to squid as a species or to the Dutch squid fisheries (e.g. via used vessel type, target area, bycatch species). An authorization requirement under the MAP (Vismachtiging meerjarenplan Noordzee , VMN) is not solely determined by its target species but also by its bycatch composition. Moreover, most important bycatch species in squid fisheries subject to regulations, including the LO. A common thread is therefore the consideration that a clear definition for 'targeted' or 'directed' fishing ('gerichte visserij') lacks in legislation and regulations. This report has shown that several complex jurisdictional areas of discussion remain, given the regulatory nuances and interpretations underlying them. Concluding on these debates goes beyond the mandate of this scientific report and therefore it was agreed with LVVN not to resolve it.

At this moment, directed fishing for squid is in principle allowed with a mesh size of at least 40mm, but in practice, a minimum mesh size of 80 mm is most commonly applied in the Dutch squid fishery. Recently both national and international requests have been submitted to increase the minimum mesh size of directed squid fisheries to 80 mm to enable more sustainable fishing practices. The amendment will likely be integrated in regulations in 2025. Similar developments are seen in UK regulation, where option for directed squid fishing with a minimum mesh size of 40 mm was removed for all towed gears leading to an increase of minimum mesh size to 80 mm. Recently, it was again increased to 100m for SSC.

Temporal closures, or RCTs, can happen when the proportion of juveniles of certain species reach a given threshold in the catches. Information on discards in squid fisheries remains limited; however, whiting appears to be one of the primary species discarded. Excessive catches of juveniles of this species have led to real-time closures. Square mesh panels positioned on the upper side of the net were found to be an efficient selectivity device to reduce whiting bycatches in other fisheries. It can be combined with other techniques, such as lowering the towing speed. However, the possibility to adapt this device to the bottom otter trawl and demersal seine used for the squid fisheries and its performance remain to be tested. Very little is known on the behavior of squids in the net, and field trials are required to observe whether this target species would also escape through the square mesh panels or be retained in the codend.

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Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

Justification

Report C021/25
Project Number: 4318100489

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Katinka Bleeker
Researcher

Signature: [redacted]

Date: April 2025

Approved: Tammo Bult
Director

Signature: [redacted]

Date: April 2025

Annex 1 maps of the survey catches in weight for squids

The analysis of trends in abundance and in distribution presented in the report used the raw information collected at each survey station : the number of squids caught. However, from a fisheries point of view, the biomass is also important. Catches in biomass are calculated for each survey by multiplying the catches at length, with the average weight at length, and summing over all length categories.
This information is however not reported consistently, and is often missing, which is why the analysis were done on the numbers of squid caught
In this annex, for the purpose of exhaustivity, the available information on catches in weight for the different surveys is reported.

Veined squid (*Loligo forbesii*)

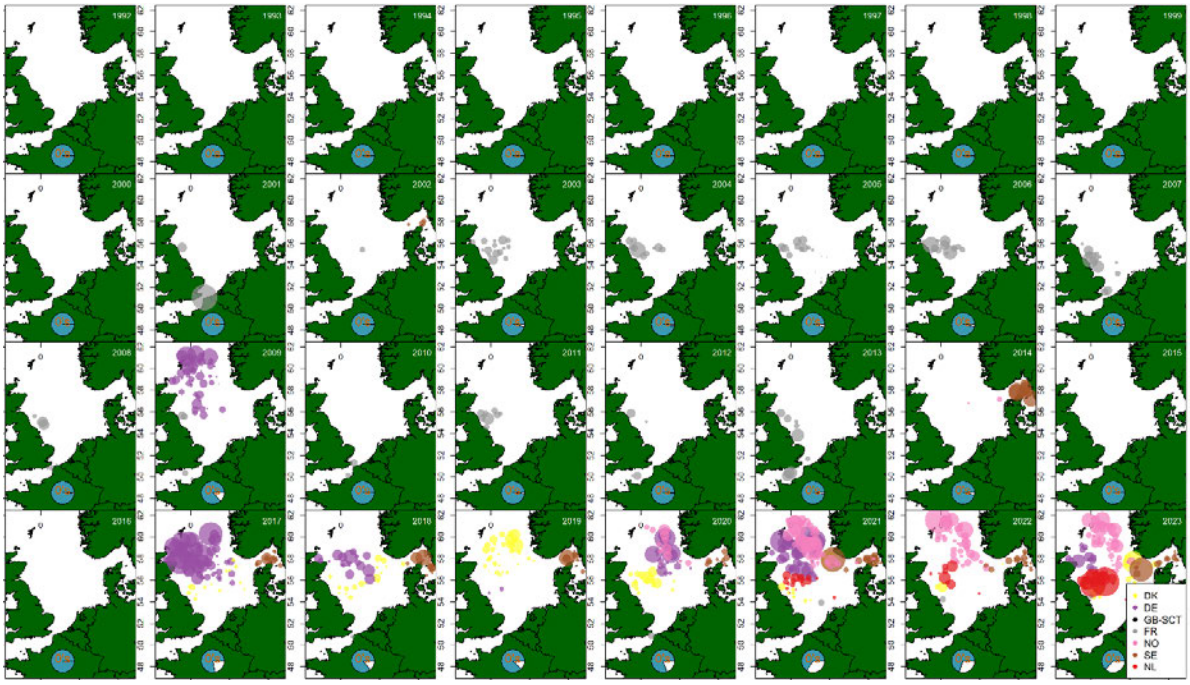

Figure A1-1: Distribution of catches of Loligo forbesii in the NS-IBTS Q1. The colors refer to the country that made the observations, The circle radius reflects the magnitude of the catch weights. The pie-diagram in each facet presents the percentage of zero hauls.

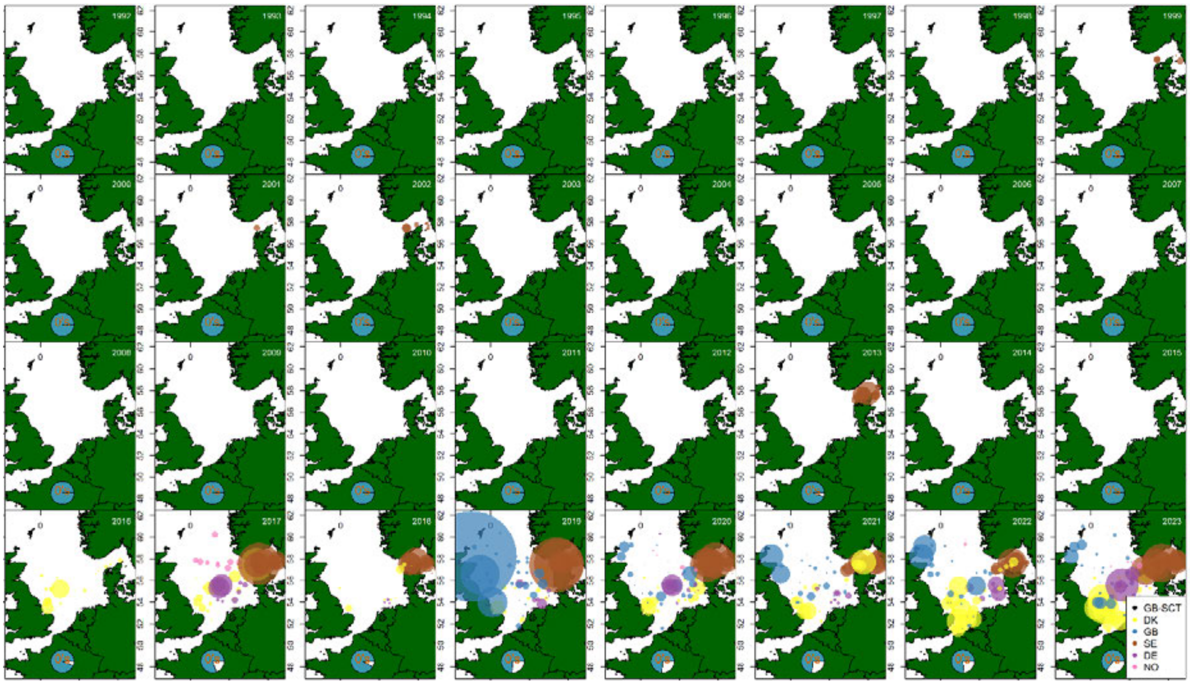

Figure A1-2: Distribution of catches of Loligo forbesii in the NS-IBTS Q3.

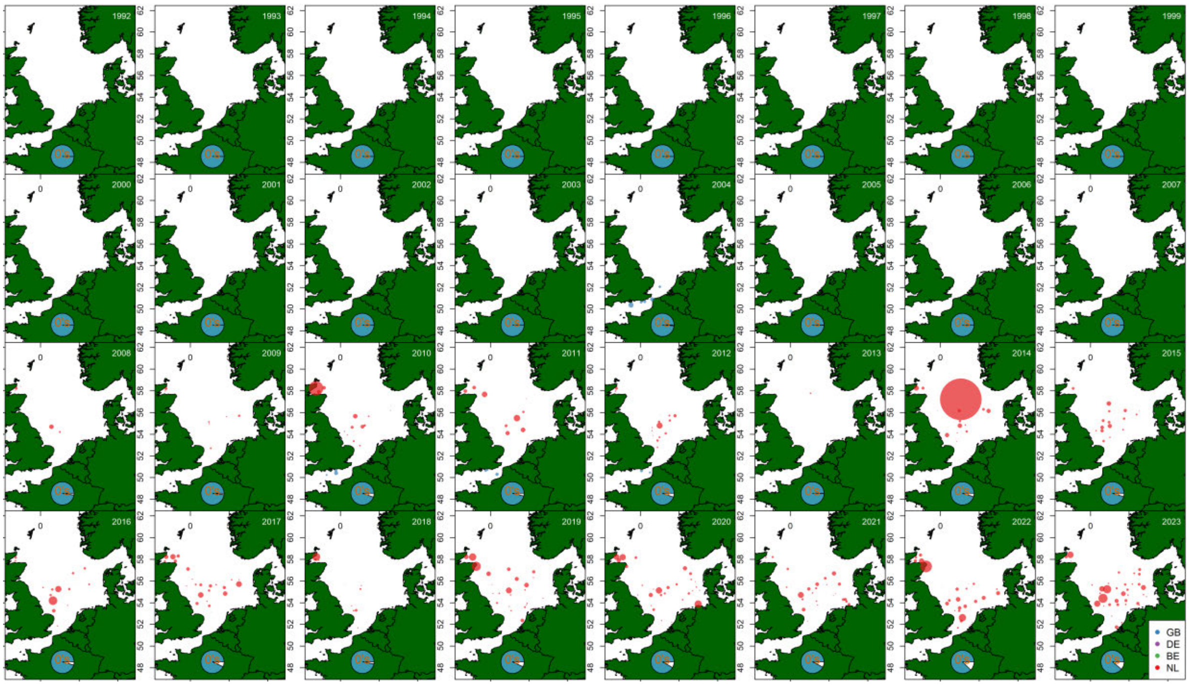

Figure A1-3: Distribution of catches of Loligo forbesii in the BTS Q3.

European squid (*Loligo vulgaris*)

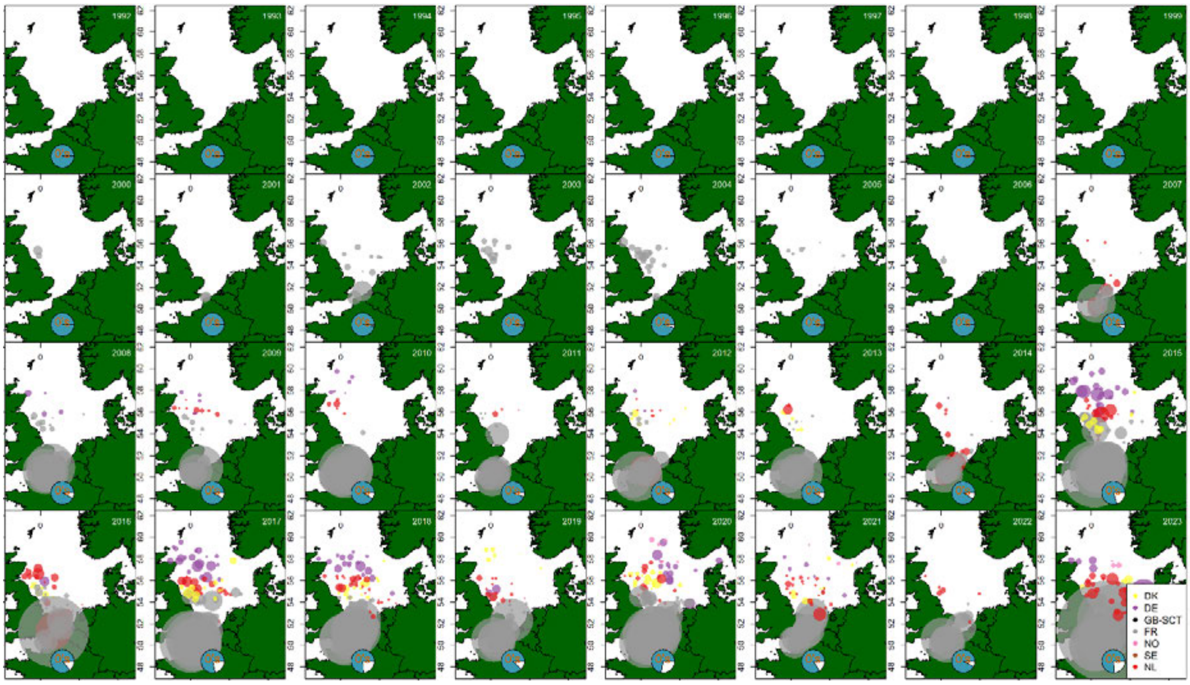

Figure A1-4: Distribution of catches of Loligo vulgaris in the NS-IBTS Q1

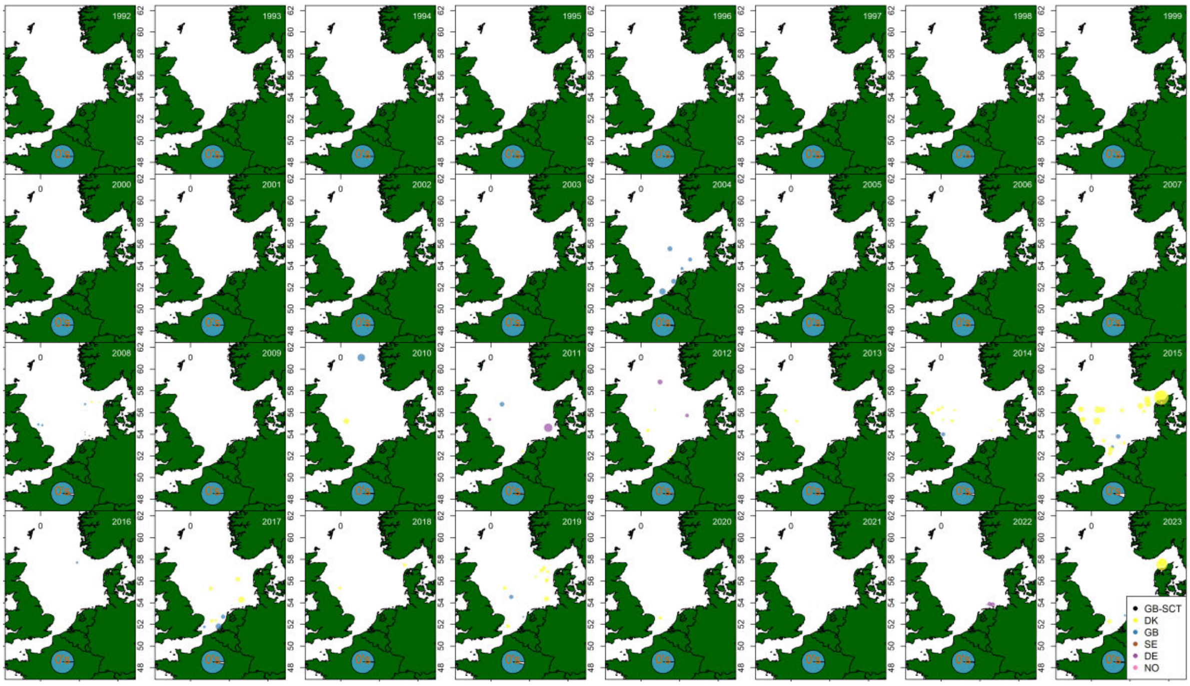

Figure A1-5: Distribution of catches of Loligo vulgaris in the NS-Q3.

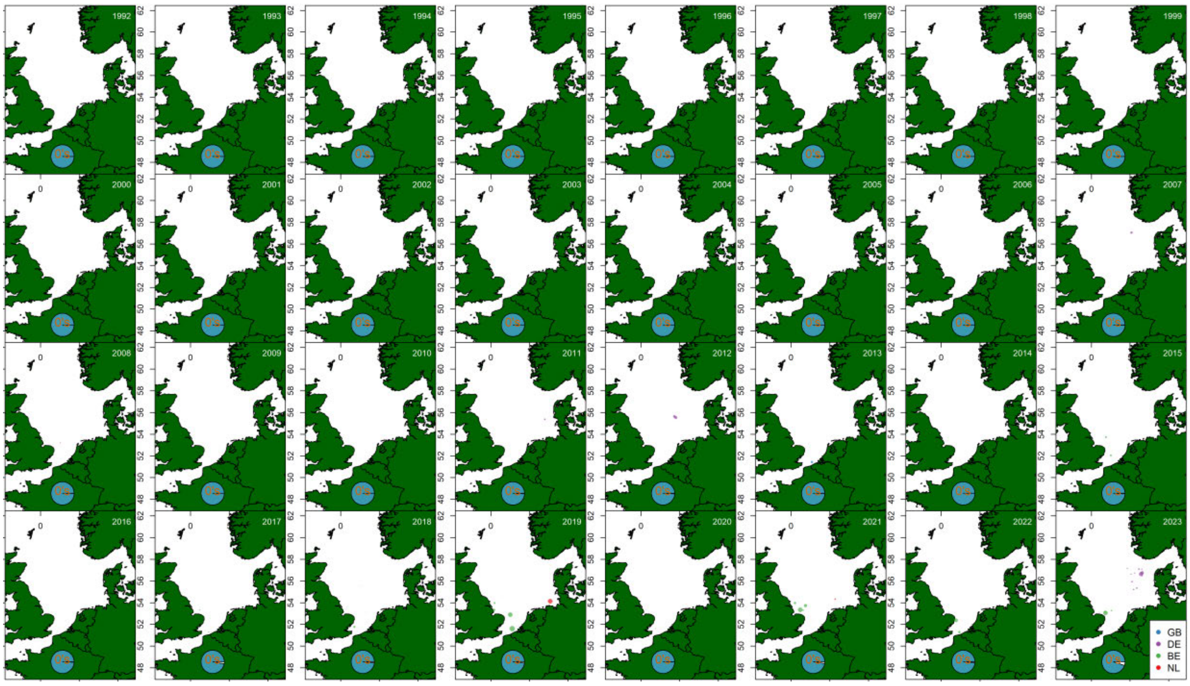

Figure A1-6: Distribution of catches of Loligo vulgaris in the BTS Q3.

Annex 2 overview of potential whiting reduction devices that could be applied to OTB and SSC squid targeting fisheries, according to expert judgment.

Gear type	Year	Target	Name	Short description and main findings	Link
TBB	2018	Flatfish mixed demersal	T-90 Extention	In the Bay of Biscay, the use of a T90 cylinder made of 100-mm diamond meshes in the extension piece of bottom trawls demonstrated effective selectivity by allowing the escape of undersized sole, horse mackerel, and seabream, with no commercial losses of cuttlefish. However, further research is needed to assess its impact on seabass and red mullet due to limited size ranges in the study.	https://link.springer.com/article/10.1007/s12562-018-1203-8
TBB	2012	Flatfish mixed demersal	Diamondmesh top panels	With a V-shaped ground rope, this panel achieved an escape rate of 30-40% for cod and whiting. However, the design was less effective with a round ground rope equipped with a chain mat. These designs were not commercially implemented due to concerns about the loss of sole and plaice. The design could be improved by adding internal stimuli to guide roundfish upwards toward the large mesh panel, such as guiding ropes or a slanted panel.	https://www.sciencedirect.com/science/article/abs/pii/S0165783603000754

TBB	2014	Flatfish mixed demersal	VIP- square mesh panels	Several positions for square-mesh panels were tested aboard the research vessel *Tridens*. Two versions were trialed on the fishing vessels *UK45* and *TX68*. Both vessels included separating panels in the codend, creating divided sections. The square panels, with a mesh size of 200 mm, measured 23x10 meshes and were positioned at the top of the codend (*UK45*), or 10x20 meshes and placed in front of the codend (*TX68*). Both innovations resulted in bycatch reductions of 15-26% without affecting the catch of marketable species.	https://research.wur.nl/en/publications/vermindering-discards-door-technische-aanpassingen-in-de-netten-v
OTB	2014	Cod	Bacoma-codend	Researchers studied the efficiency of releasing cod using various square-mesh panels placed at the top of the codend (BACOMA codend) during experimental trawl fishing. They collected data on over 25,000 cod and found that the BACOMA codend, which can be used in cod-targeted trawl fisheries in the Baltic Sea, is more efficient at releasing young cod compared to other panel designs. The study showed that the overlap between the square-mesh panel and the catch accumulation zone in the codend plays a crucial role in release efficiency. The researchers also discovered that reducing the panel size by 50% did not significantly affect the release efficiency when the panel overlapped with the catch accumulation zone. All tests were conducted on a research vessel.	https://academic.oup.com/icesjms/article/72/2/686/2801328
TBB and SSC	2023	Mixed flatfish and squid fishery	LED there be light	This project aimed to reduce bycatch and optimize catches to help the beamtrawl sector comply with the landing obligation. Trials were being conducted with LED lights at the net opening: 1) in the flyshoot fishery to improve squid catches and reduce bycatch of whiting, and 2) in the beam trawl fishery to improve catches of sole and reduce bycatch of plaice.	https://pure.ilvo.be/ws/portalfiles/portal/44877894/LED_there_be_light_21UP109DIV_-eindrapport.pdf
OTB	2012	Mixed flatfish	Scottish Eliminator trawl	The Scottish Eliminator trawl features larger mesh sizes (2400 mm) at the front and wings of the net, which reduces bycatch of cod. However, it is not suitable for catching target species (marketable cod, sole, whiting, haddock) because these are almost entirely lost in the catch, and the catches of flatfish are reduced by 80%.	https://edepot.wur.nl/245263

OTB	2012	Cod	Orkney/Shetland avoidance trawl	The Orkney/Shetland cod avoidance trawl is a type of trawl that uses larger mesh sizes in the front parts of the net (300 mm instead of 160 mm) to release cod, but it also causes significant losses of plaice and hake. Further research is needed to develop gear that reduces cod catches while retaining economically important species such as anglerfish, ray, ling, coalfish, and hake.	https://edepot.wur.nl/245263
OTB	2012	Cod	Belly panel	The 'belly panel' gear features larger mesh sizes in the lower panel, ranging from 300, 600, and 800 mm. It is effective in releasing cod, especially with larger mesh sizes. The 300 mm mesh releases about 33%, the 600 mm mesh releases 33-57%, and the 800 mm mesh releases 53-76%. Smaller mesh sizes catch more smaller haddock, while larger mesh sizes catch fewer large haddock. There was no significant difference in haddock catches between the 300 mm and 600 mm test gears and the control, but the 800 mm gear caught fewer large haddock. For coalfish, there were no significant differences between any of the test gears and the control.	https://edepot.wur.nl/245263
OTB	2014	Mixed demersal	Twin-panel	Onboard the OD6, fishing was conducted with a square-mesh panel in the upper side of the codend, with a mesh size of 120 mm. The total catch was approximately 5% (s) lower for the modified gear, with no loss of marketable fish. There is an indication of a reduction in fish discards of around 33.5%, but this was not statistically significant.	https://library.wur.nl/WebQuery/wurpubs/fulltext/387860
OTB	2022	N.A.	Piscesgate	Project exploring how innovative passive LED technology can reduce discards. Lights in various colors—deep blue, blue, cyan, green, and white—were systematically deployed. These lights were placed in different locations within the fishing gear, including on the main cable to potentially deter non-target species, and on the escape hatch to facilitate the escape of undersized fish.	https://catchcam.tech/blog/safetynet-technologies-to-undertake-selectivity-trial-in-nephrops-fisheries/

OTB	2007	Nephrops fishery	Scotnet Internal Cod Flap (SCIF)	The Scotnet Internal Cod Flap (SCIF) is a square mesh panel with a mesh size of 200 mm, positioned 20 meters from the end of a cod panel. It features a 2-meter long lead line at the bottom to keep it in place, and it is secured at the top. Below it is an outlet for fish to escape. The SCIF reduces bycatch of cod by 66% (by weight), haddock by 51% (by weight), and whiting by 58% (by weight) without any loss of target species. The SCIF is suitable for smaller vessels and allows Nephrops to pass through without issue.	https://edepot.wur.nl/245263
OTB	2007	Nephrops fishery	Seltra	The Seltra sorting box is a Danish design featuring a rectangular sorting compartment with four panels, where the top panel has a mesh size of 300 mm. It is highly effective at releasing cod (-92%), haddock (-80%), and whiting (-90%), but also results in the release of a significant number of flatfish species (plaice: -84%, monkfish: -75%, and sole: -100%). Additionally, around 30% of Nephrops were lost.	https://edepot.wur.nl/245263
Pelagic	2008	Horse mackrel	Plegic hexago-mesh	Between 2003 and 2008, several tunnels with hexagonal mesh were tested aboard pelagic trawlers with the aim of reducing the catch of undersized horse mackerel. The hexagonal meshes were 25 mm at the corners, with a 100 mm extension in the middle section. Other mesh sizes were also tested but were less successful. The meshes were kept open by 'flyers'. Additionally, efforts were made to keep the tunnel open by connecting it to a wider part of the forward net. Videos showed fish escaping. No further analysis was conducted due to the commercial setting of the experiment.	WUR Report C002/09 (confidential report)

OTB	2006	Roundfish	Top Square Mesh Panel	Between 1999 and 2000, a square mesh panel was tested for one year, each month, aboard a commercial otter trawler in the Shetlands to investigate whether it could improve the selectivity of the fishery for roundfish. The tested panel was 3 meters long with a mesh size of 90 mm (23 meshes wide), and it was placed on the top panel between 6.3 m and 9.3 m from the opening of the net. Catch analysis showed that the panel reduced the catch of undersized whiting by 34%. There was no significant reduction in the catch of monkfish, haddock, or cod.	https://doi.org/10.1016/j.fishres.2006.09.008
OTB	2016	Shrimp	Kon’s Covered Fisheye	In 2016, tests were conducted on commercial trawlers using the 'Kon's Covered Fisheyes' bycatch release panel in the Gulf of Carpentaria to determine its effectiveness in reducing small bycatch in shrimp fisheries. The innovation consists of a rigid structure placed inside the trawl's tunnel, creating a zone with reduced water flow. This allows small fish to swim out through an opening. The innovation was found to significantly reduce small bycatch species by approximately 36.7%, while the commercial shrimp catch increased by an average of 0.5%. Additionally, the gear was easy and safe for the crew to use.	KCF 2016 Scientific Trial Final Report Apr17 1.pdf (bycatch.org)
Pelagic	2020	Hake, Whiting	LED-SMP	In this study, various combinations of panels with square mesh of different sizes and positions, along with the use of LED lights, were tested to improve the selectivity for hake and blue whiting. Placing LED lights near the square mesh had no effect on selectivity. Using a larger panel increased the selectivity for blue whiting. Positioning the panel in the lower part of the net enhanced the selectivity for hake.	10.3989/scimar.04975.17A

OTB	2021	Flatfish mixed demersal	Roofless	RoofLess is a species-selective concept developed and tested by the Thünen Institute during sea trials in 2019 and 2020. It is implemented by removing a rectangular section of netting from the upper panel of the trawl extension, aiming to create a zone with heightened sensory stimuli that trigger escape responses in fish. Results obtained with the RoofLess device showed a promising and consistent reduction in cod bycatch by approximately 75%, while catch losses of flatfish species were limited to less than 15%.	factsheet_ROOFLESS_175 (thuenen.de)

With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.

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