WORKING GROUP ON CRANGON FISHERIES AND LIFE HISTORY (WGCRAN)

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International Council for the Exploration of the Sea
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H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Lara Kim Hünerlage • Eva Maria Pedersen

Authors

Ulrika Beier • Lara Kim Hünerlage • Thomas Lanssens • Henrik Mosegaard • Mattias van Opstal
Eva Maria Pedersen • Torsten Schulze • Daniel Stepputtis • Juan Santos • Jasper van Vlasselaer

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Contents

i Executive summary

The Working Group on *Crangon* Fisheries and Life History (WGCRAN) works on studying the population dynamics of the brown shrimp *Crangon crangon* and factors influencing the stock as well the individual. A central goal of the group is to provide a biological basis for advice and to identify ways for sustainable management.

Next to the reporting of the international landing statistics from 2022, a main outcome of the 2023 meeting was the decision/initiative to create a common workflow for uniform data retrieval of international survey data from the ICES DATRAS database. From 2024 onwards, biological stock status indicators (swept area biomass, annual mortality, and fraction of large shrimp) shall be accessible by the use of one common R script. For transparency, all workflows of WGCRAN will be stored and made accessible at GitHub.

The meeting further aimed at discussing and reporting on different approaches of population modelling, i.e. potential improvements of data inputs, giving updates on ongoing national projects related to *Crangon* research (e.g. gear technology, national legislation) and presenting the results of the trilateral bycatch co-sampling programmes which were reported to the Scheveningen group in May 2023.

ii Expert group information

Expert group name	Working Group on *Crangon* Fisheries and Life History (WGCRAN)
Expert group cycle	Multiannual
Year cycle started	2022
Reporting year in cycle	2/3
Chair(s)	Hünerlage, Lara Kim, Germany
	Pedersen, Eva Maria Fenger, Denmark
Meeting venue and dates	21-23 June 2022, Bremerhaven, Germany
	13-15 June 2023 in Oostende, Belgium
	18-20 June 2024 in Lyngby, Denmark

1 Stock indicators (ToR a)

1.1 General development and overview

Since 1960, when commercial fishing on brown shrimp *Crangon crangon* for animal feed ceased and changed to a fishery for human consumption, total landings have consistently increased and from 2003 to 2015 total North Sea landings were steadily above 30 000 tons (Figure 1.1). In 2016, landed biomass dropped to 25 713 tons and even further in 2017 to 22 535 tons - the lowest registered amount landed since 1993 (20 529 tons). In 2018, an exceptionally high biomass was landed (46 015 tons), accounting to the highest landings of the times-series. Thereafter, landings have dropped to around 25 000 tons and in 2022, an total of 25 508 tons of brown shrimp were landed.

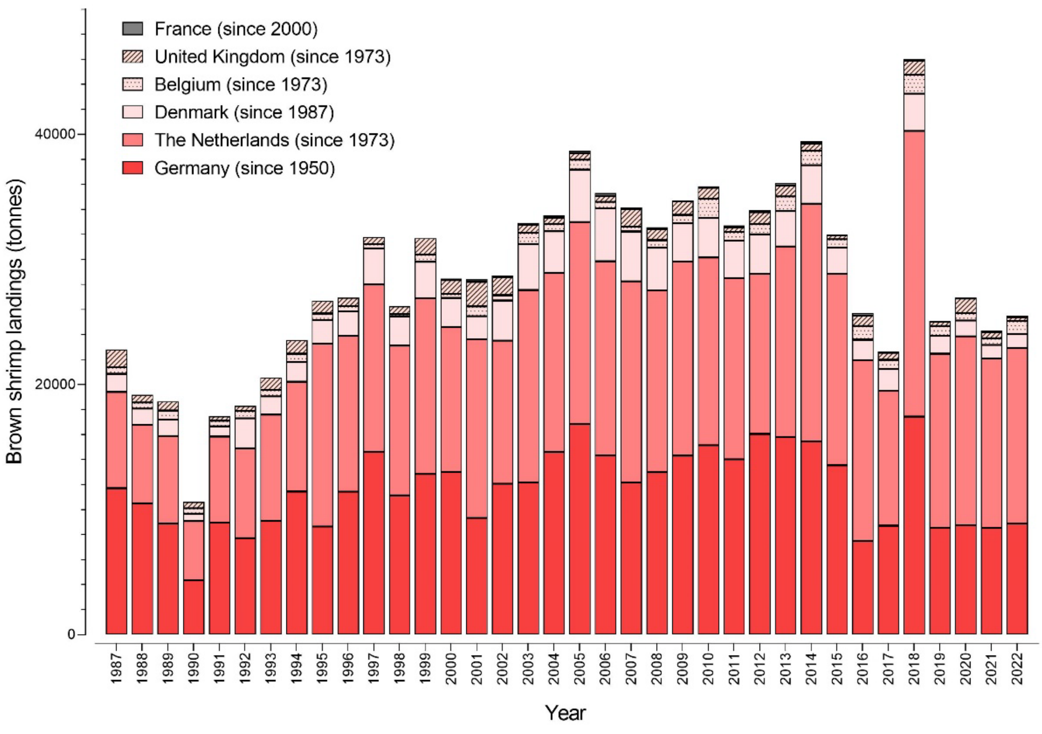

Figure 1.1. Total brown shrimp landed for human consumption (in tons) from the North Sea by country. The numbers in brackets give the year since data collection of the respective country started. For detailed countries' time series, see Figure 1.5. *Note: Since the introduction of the common workflow (WGCRAN Meeting 2022), the data are queried and updated annually retroactively back to 2009 (data from DE, DK & BE) or 2015 (data from NL) from the EFLALO database. This may result in minor deviations compared to figures/values of previous reports.

Since 2016, the annual effort in the North Sea brown shrimp fishery showed a decreasing trend (Fig. 1.2): from 13.2 million horsepower days at sea (hpDAS) (2016), over 11.7 million hpDAS (2018) to a minimum of 8.2 million hpDAS (2019). Thereafter, total annual effort remained at > 10 million hpDAS (10.1 million hpDAS in 2020 and 10.8 million hpDAS in 2021). Prominent factors influencing the effort were a fishing halt in 2019 due to storage bottlenecks in the processing industry caused by good catches in the previous year, the COVID-19 pandemic in 2020/2021 and high fuel prices resulting from the war in the Ukraine starting in 2022. In 2022, the fishery spent a total of 10.4 million hpDAS, with 3.9 million hpDAS for Germany, 4.9 million for the

Netherlands, 0.4 million for Denmark, 0.3 million for Belgium, 0.7 million for the United Kingdom and 0.1 million hpDAS for France (Figure 1.2 B).

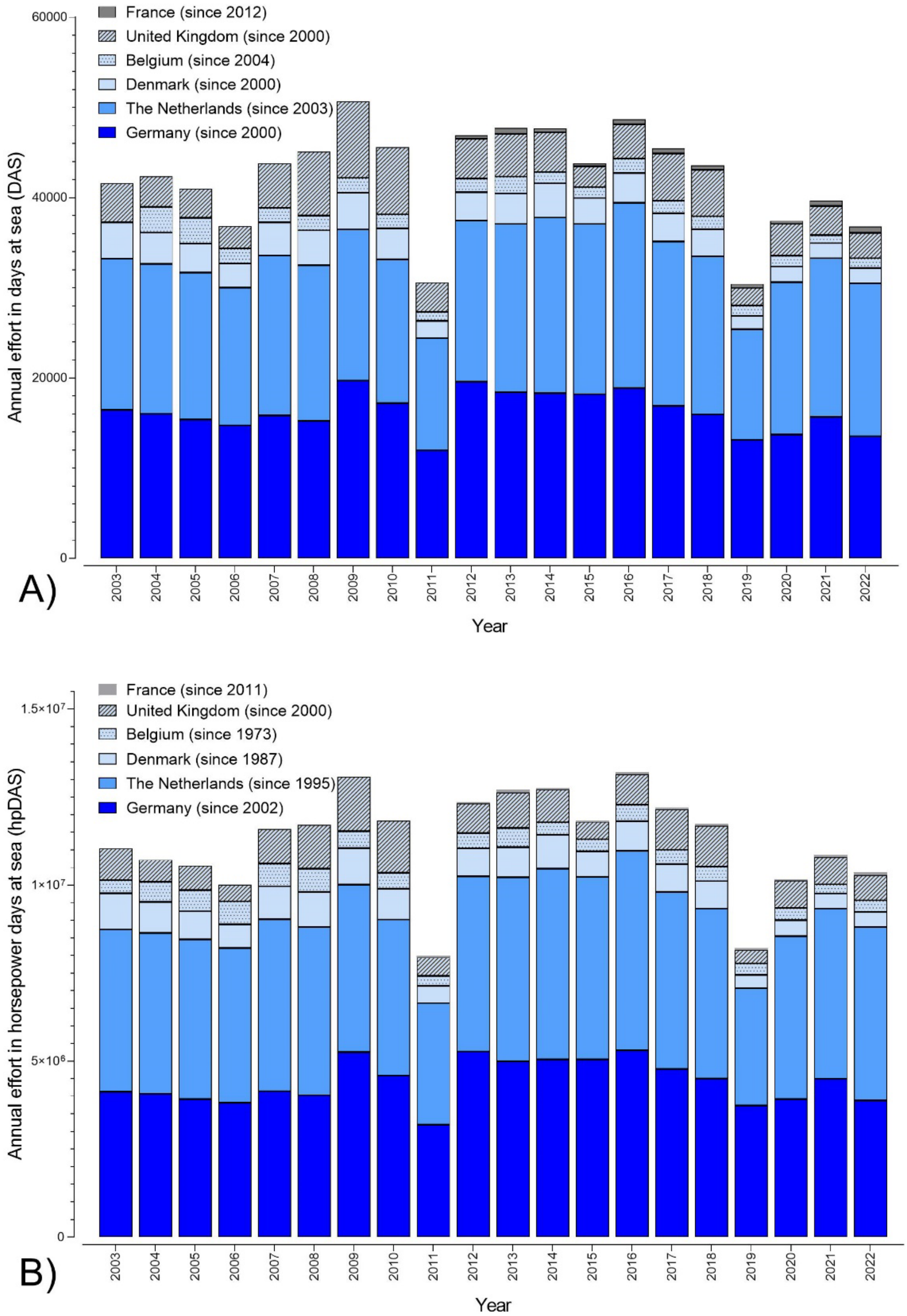

Figure 1.2. Total annual effort in A) days at sea (DAS) and B) horsepower days at sea (hpDAS) of the brown shrimp fishery by country. The numbers in brackets indicate the year since the data became available for WGCRAN. * Since the introduction of the common workflow (WGCRAN Meeting 2022), the data are queried and updated annually retroactively back to 2009 (data from DE, DK & BE) or 2015 (data from NL) from the EFLALO database. This may result in minor deviations compared to figures/values of previous reports.

For getting a more precise estimate of the active fishing effort, total annual effort of the Netherlands, Germany and Denmark was further split into VMS recorded total fishing time and steam time (= total effort – VMS recorded total fishing time). The relation between steam time and fishing time is more or less stable for all countries and all years (Figure 1.3). However, since 2017, a decrease in steam time is observed for the Netherlands. This could indicate an increased fishing effort near the Dutch own national coast resulting into reduced steam time to the fishing areas.

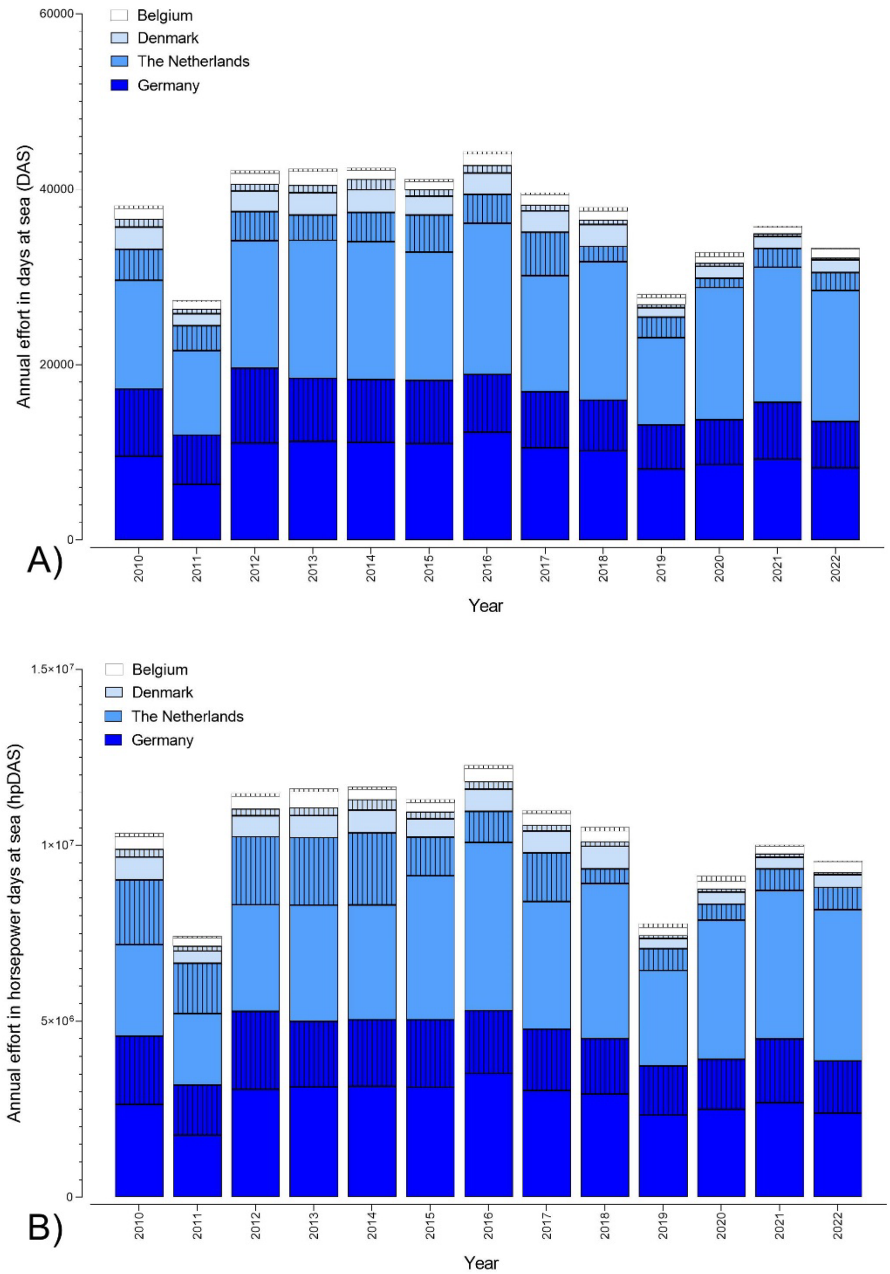

Figure 1.3. Total effort in A) days at sea (DAS) and B) horsepower days at sea (hpDAS) per country. Effort is split into fishing time and steam time (= striped). *Note: Since the introduction of the common workflow (WGCRAN Meeting 2022), the data are queried and updated annually retroactively back to 2009 (data from DE, DK & BE) or 2015 (data from NL) from the EFLALO database. This may result in minor deviations compared to figures/values of previous reports.

The landings per unit effort (LPUE) show a similartrends for most of the countries (Figure 1.4). Lowest LPUE are given by the United Kingdom and France. However, counting horse power into the calculation, France integrates to the LPUE of the other countries (NL, DE, DK and BE). Since the high values in 2018, the LPUEs decreased especially for the Dutch, German and Danish fleet and are in the lower range of the time series provided to WGCRAN. In 2022, annual LPUE (kg per hpDAS) were 2.9 for the Netherlands, 2.3 for Germany, 2.6 for Denmark, 3.1 for Belgium, 2.1 for France and 0.4 for the United Kingdom.

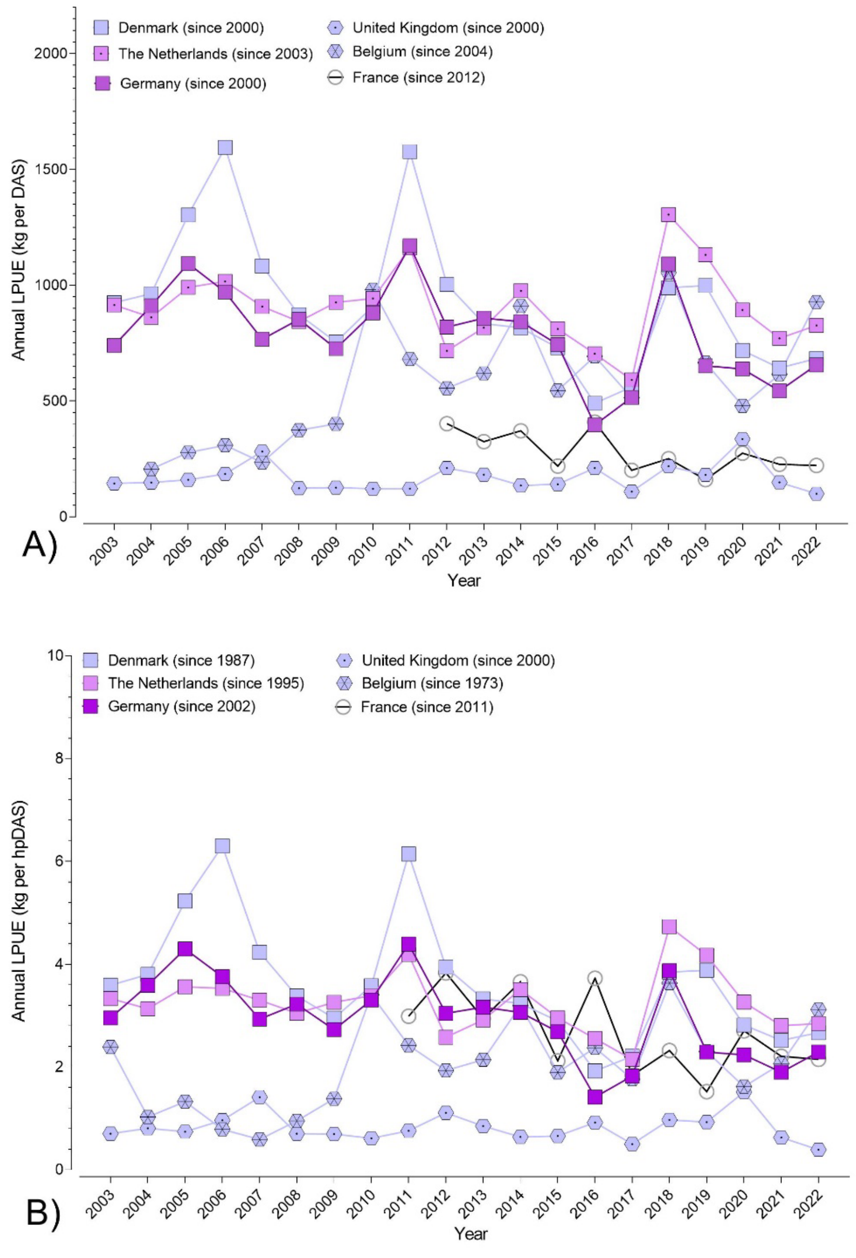

Figure 1.4. Annual landings per unit effort (LPUE) in kg per A) days at sea (DAS) and B) horsepower days at sea (hpDAS) of the brown shrimp fishery by country. The numbers in brackets indicate the year since the data became available for WGCRAN. *Note: Since the introduction of the common workflow (WGCRAN Meeting 2022), the data are queried and updated annually retroactively back to 2009 (data from DE, DK & BE) or 2015 (data from NL) from the EFLALO database. This may result in minor deviations compared to figures/values of previous reports.

1.2 Landings and effort statistics 2022

National annual landings

In 2022, the largest share of the total *Crangon crangon* landings belonged to the Netherlands (55.0%), followed by Germany (34.8%), Denmark (4.5%), Belgium (4.0%), United Kingdom (1.1%) and France (0.6%) (Figure 1.5).

With 8879 tonnes of brown shrimp, German landings in 2022 were comparable to the previous years - four consecutive years with low values (Figure 1.5).

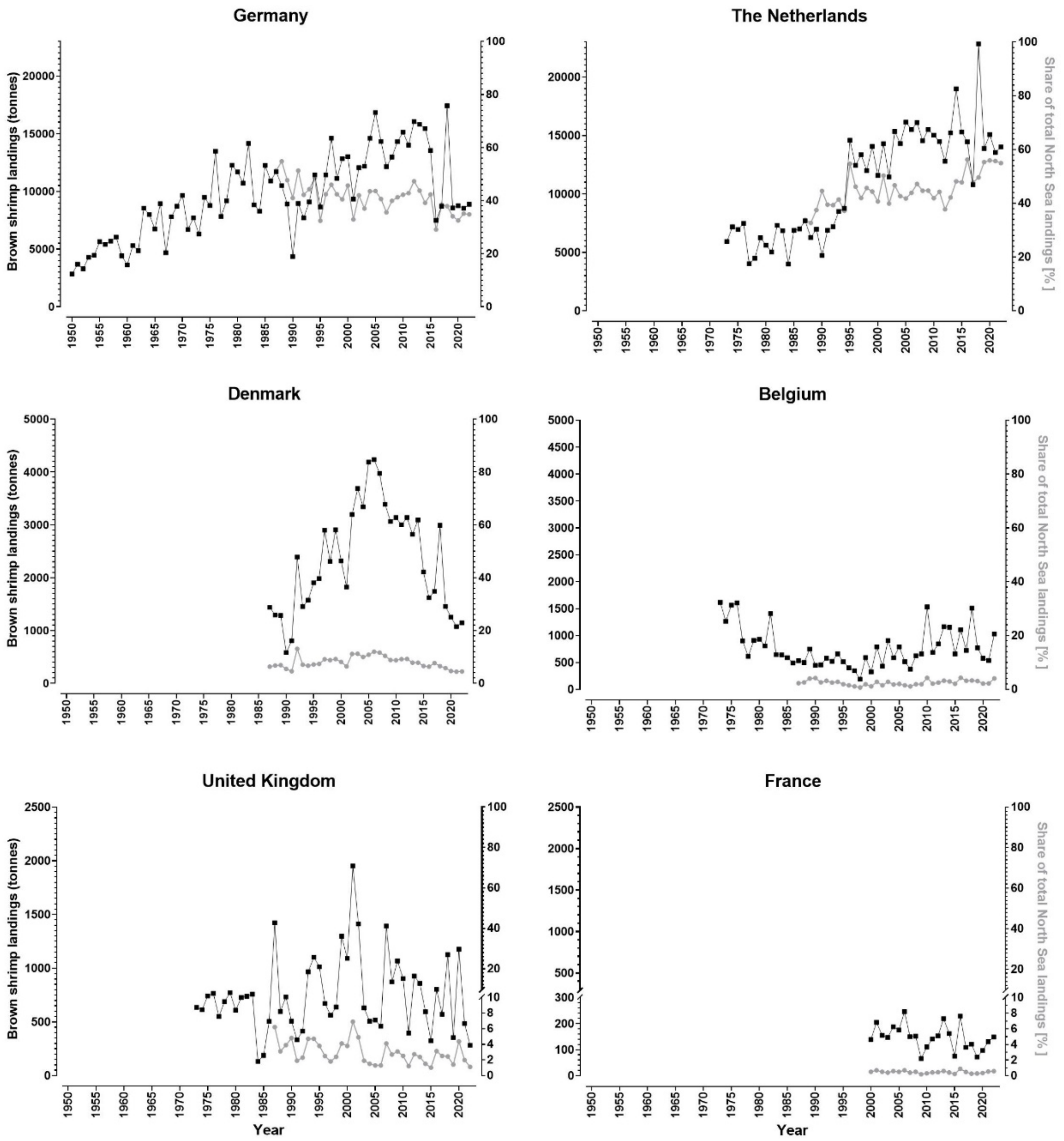

Figure 1.5. Country specific time-series of brown shrimp landed for human consumption (in tonnes). Data in grey give the percentage of landings in relation to total (whole North Sea, all nations). *Note: Since the introduction of the common workflow (WGCRAN Meeting 2022), the data are queried and updated annually retroactively back to 2009 (data from DE, DK & BE) or 2015 (data from NL) from the EFLALO database. This may result in minor deviations compared to figures/values of previous reports.

Dutch landings totalled 14,022 tonnes in 2022, an amount that has been common for this fleet since 1995 (Figure 1.5). In 2022, a total of 1145 tonnes of brown shrimp were landed by Danish shrimpers, this is similar to landings within the last four years which is the lowest registered for 25 years. In contrast, Belgian landings increased in 2022 to a value of 1,029 tonnes. (Figure 1.5).

Both the landings from the UK and France have fluctuated widely in recent decades, with no discernible trend. In 2022, 282 tonnes of *Crangon crangon* were landed by the UK and 148 tonnes by France.

National monthly landings, effort and LPUE

The national monthly patterns of landings, fishing effort and LPUE in 2020, 2021 and 2022 are discussed below and compared with the average pattern over the last ten years (2013–2022) (Figure 1.6–1.8).

Like the two previous years, the German landings in 2022 were generally below the 10-year running mean, especially in the autumn (Figure 1.6). The effort was only slightly lower than the running mean, which results in a LPUE close to the 10-year running mean (2013–2022). Generally slightly below, but in July just above (Figure 1.7 & 1.8).

The Dutch landings in 2022 (Figure 1.6) were following the trend of the 10-year running mean relatively close with the highest catch in October and the lowest in February, however all months except July and October had a slightly lower catch than the running mean (2013-2022). The effort in 2022 were fluctuating but close to the 10 year running mean (2013–2022) with a slightly higher efforts in May and October and lower efforts in April and August (Figure 1.7), resulting in a Dutch LPUE slightly below the 10-year running mean the entire season, except from July 2022, in which the LPUE was just above the mean (Figure 1.8).

When comparing the two main fleets (Germany and the Netherlands), the monthly average patterns are very similar to the same magnitude of landings, effort and LPUE from March to July 2022 (Figures 1.6-1.8). However, the peak in the Dutch landings in autumn is around 30% higher than the German, and landings and effort in winter were both about 50% higher. This corresponds to a slightly higher LPUE for the Dutch fleet compared to the German.

The Danish landings and effort correspond to a maximum of 1/10 of what is seen in the Dutch or German fishery (Figure 1.6 and 1.7). The seasonal pattern of the total landings is quite different as both a spring and an autumn peak of equal size around 200 tonnes a month is observed, which is similar to the previous two years but below the 10-year mean. The effort was in 2022 well below the 10 year mean but following the same trend, only March had a very high effort even above the 10-year mean (Figure 1.7). The Danish LPUE for 2022 generally followed the same trend as previous years with a lower winter (Jan.-March) than summer value (Figure 1.8). However, the LPUE for July and August were well above the 10-year mean, but due to a low effort especially in August this is not reflected in the total landings.

The Belgian landings in 2022 followed the general pattern of the 10-year running mean, with very few tonnes landed within the first half of the year and a peak in September and October, however the peak in October and November were higher that normally observed. Especially high were the landings in November which were close to the level for October (Figure 1.6). The effort in 2022 was slightly lower than the 10-year running mean (2013-2022), but higher than the two previous years (Figure 1.7). The patterns of effort and landings, combined for 2022, meant that the LPUE values from July and onwards were above the 10-year running mean (Figure 1.8).

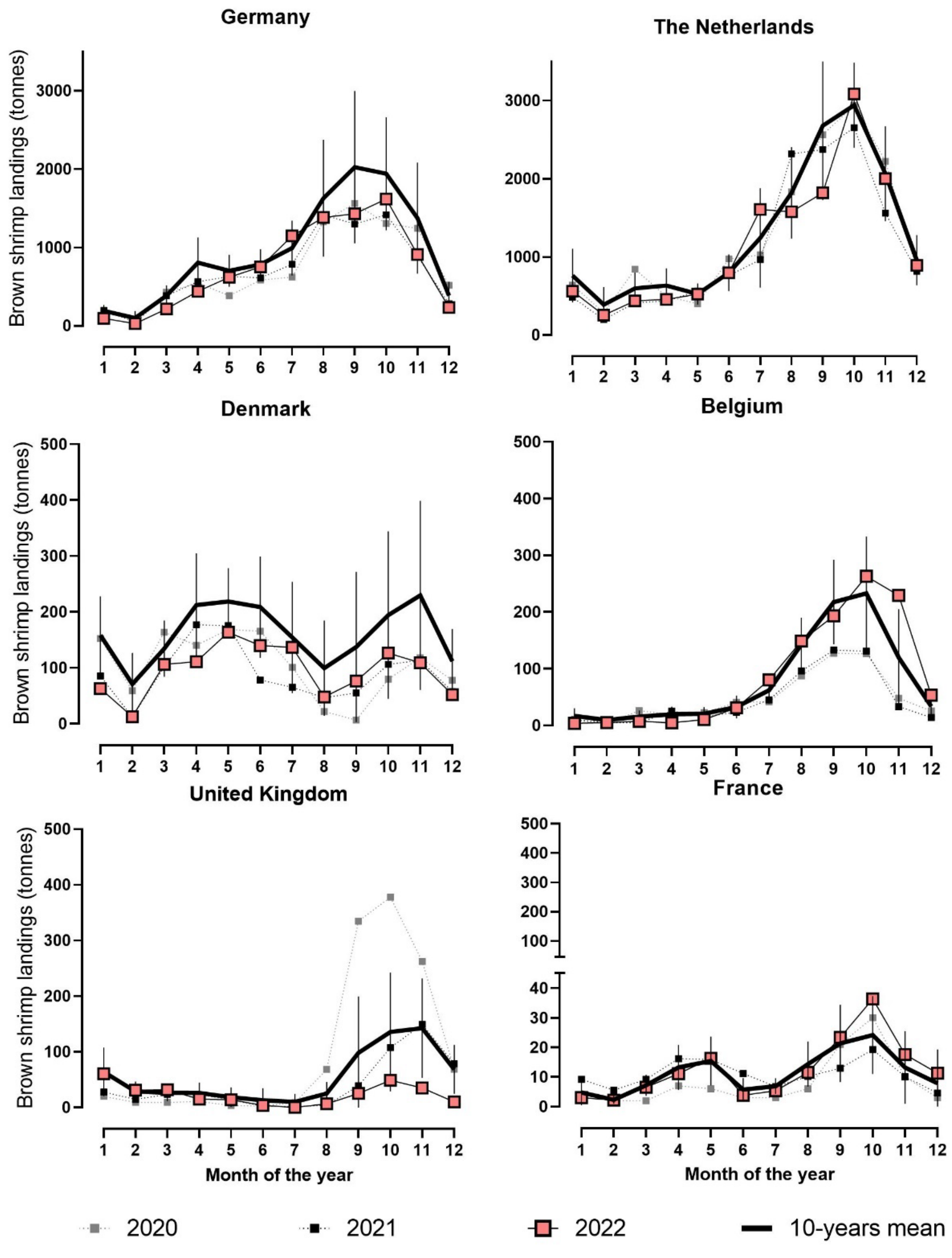

Figure 1.6. Monthly landings of commercial sized brown shrimp (in tonnes) per country in 2020, 2021, 2022 and the last 10 years 2013-2022 (10-years running mean +/- SD). *Note: Since the introduction of the common workflow (WGCRAN Meeting 2022), the data are queried and updated annually retroactively back to 2009 (data from DE, DK & BE) or 2015

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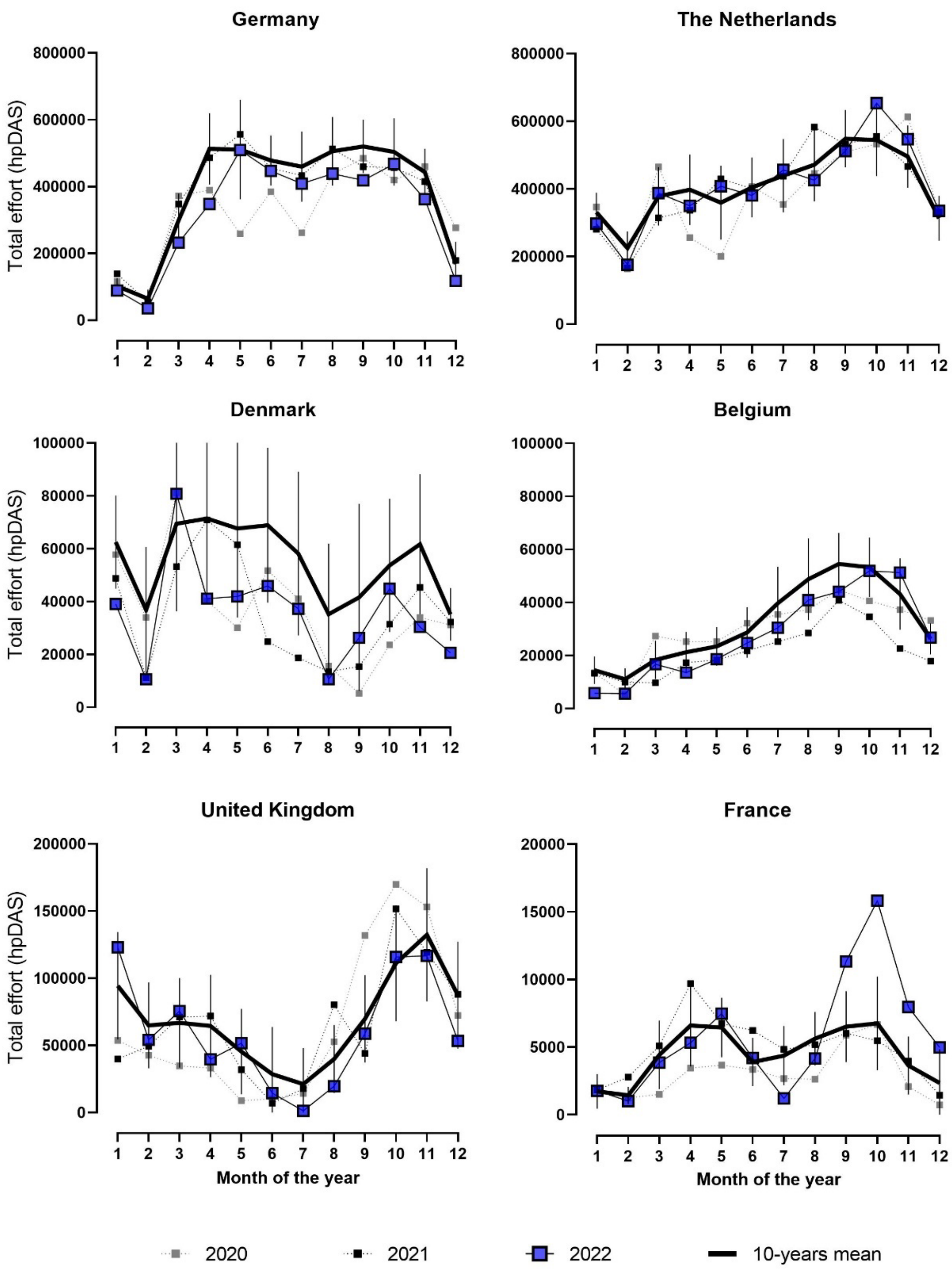

Figure 1.7. Monthly total fishing effort on commercial sized brown shrimp per country in 2020, 2021, 2022 and the last 10 years 2013-2022 (10-years running mean +/- SD). Effort is given as horsepower days at sea (hpDAS). *Note: Since the introduction of the common workflow (WGCRAN Meeting 2022), the data are queried and updated annually retroactively

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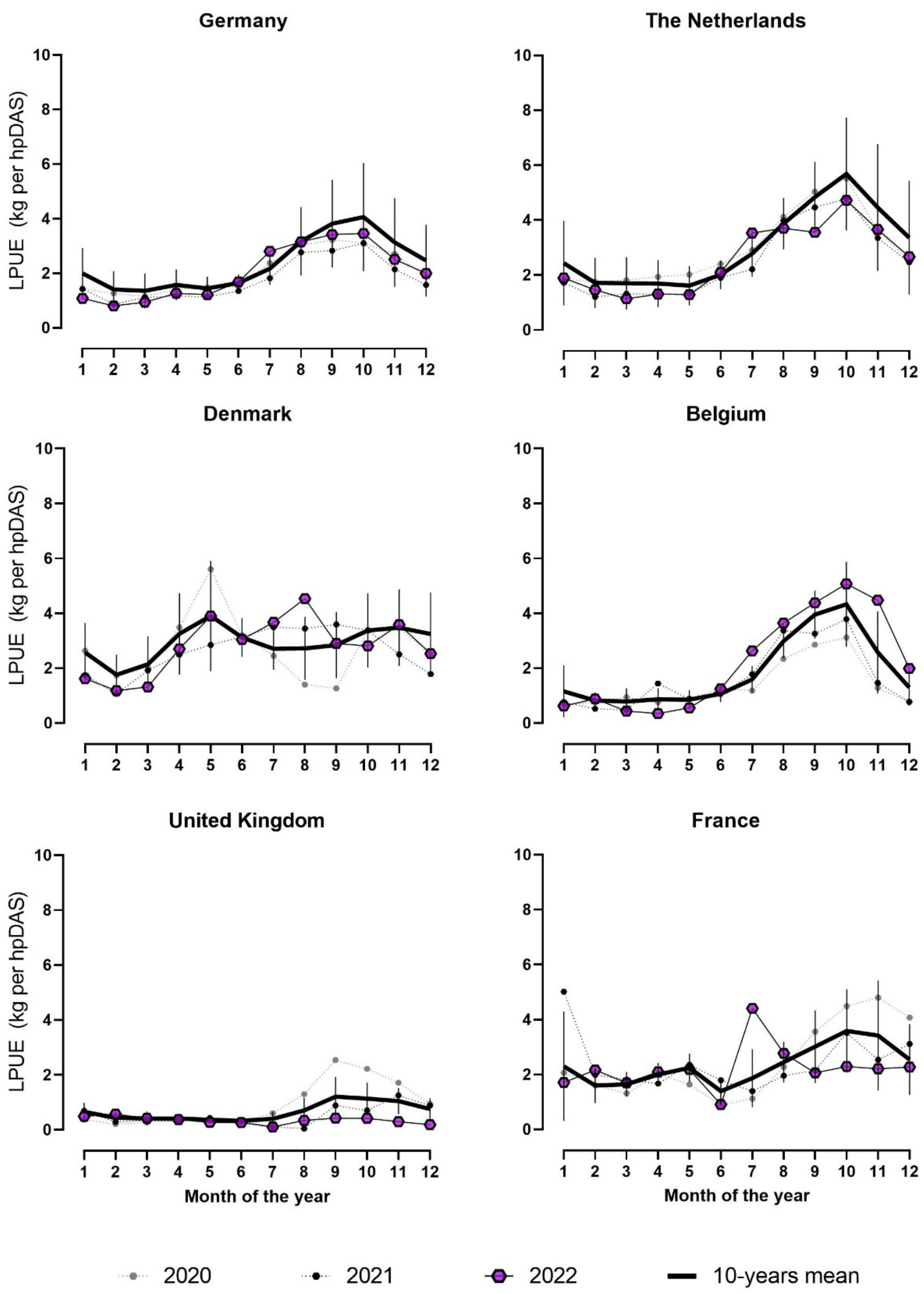


Figure 1.8. Monthly commercial sized brown shrimp landings per unit effort (LPUE) per country in 2020, 2021, 2022 and the last 10 years 2013-2022 (10-years running mean +/- SD). LPUE is given as in kg per horsepower days at sea (hpDAS). *Note: Since the introduction of the common workflow (WGCRAN Meeting 2022), the data are queried and updated annually retroactively back to 2009 (data from DE, DK & BE) or 2015 (data from NL) from the EFLALO database. This may result in minor deviations compared to figures/values of previous reports.

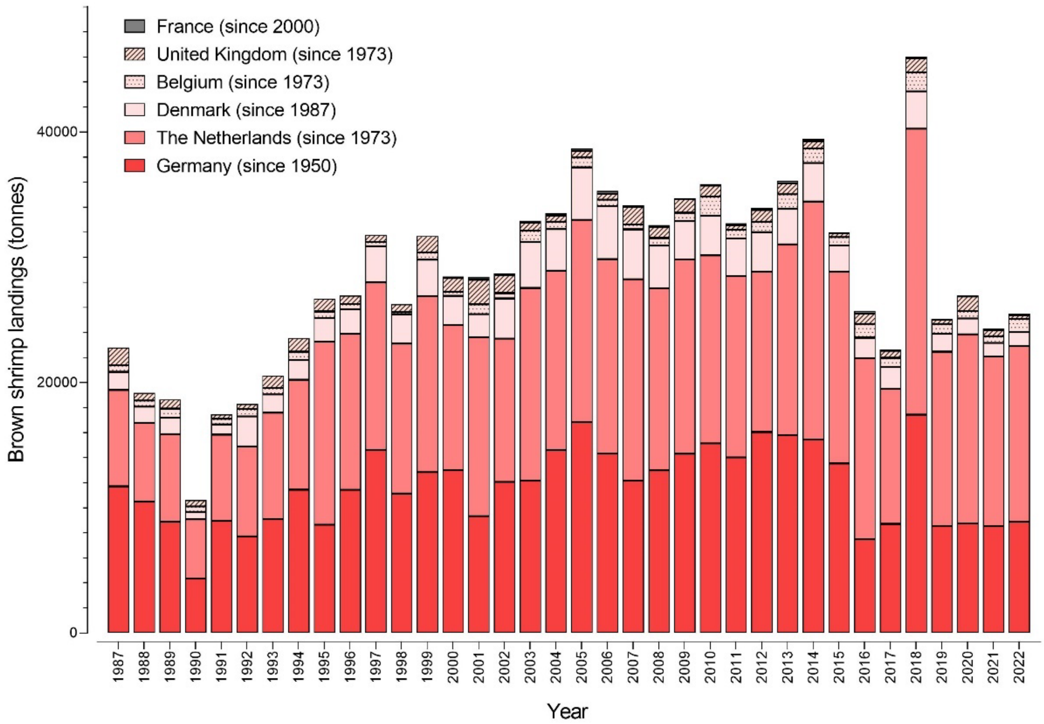
The landing pattern and magnitude in the UK fishery are usually similar to the Belgian fishery, with a pronounced peak in autumn, however in 2022 the landings were very low and only a slight increase in landings were observed October (Figure 1.6). The UK effort in 2022 have two peaks, a spring peak in March/April and an autumn peak in October/November like in the 10-year running mean, however the effort are the entire year fluctuating above and below the 10-year running mean (Figure 1.7). The LPUE values for UK in 2022 were stable on a low level during the entire year. In the first half of the year this level is very close to the 10-year running mean, however in the last part, it was below this 10-year mean (Figure 1.8).

French average landings, effort and LPUE (2013–2022) (Figure 1.6-1.8) exhibited two peaks, one in the first and one in the second half of the year. The French landings in 2022 followed roughly the level of the 10-year mean except from in October where the landings were close to the double of the 10 year average. (Figure 1.6). The effort were high in the second half of the year compared to the 10 year running mean especially during the last two years (2020 and 2021), where the effort was almost doubled in September and more than doubled in October (Figure 1.7). The French LPUE values for 2022 were for the first 6 months of the year close to the 10-year running mean, In July the LPUE value was almost doubled compared to previous years and from September and the rest of the year the LPUE were at the same level as in the spring, which is below the 10-year running mean for the last part of the year (Figure 1.8).

2 Stock status indicators (ToR a)

2.1 General development and overview

Since 1960, when commercial fishing on brown shrimp *Crangon crangon* for animal feed ceased and changed to a fishery for human consumption, total landings have consistently increased and from 2003 to 2015 total North Sea landings were steadily above 30 000 tonnes (Figure 1.1). In 2016, landed biomass dropped to 25 713 tonnes and even further in 2017 to 22 535 tonnes - the lowest registered amount landed since 1993 (20 529 tonnes). In 2018, an exceptionally high biomass was landed (46 015 tonnes), accounting to the highest landings of the times-series. Thereafter, landings have dropped to around 25 000 tonnes and in 2022, and total of 25 508 tonnes of brown shrimp were landed.



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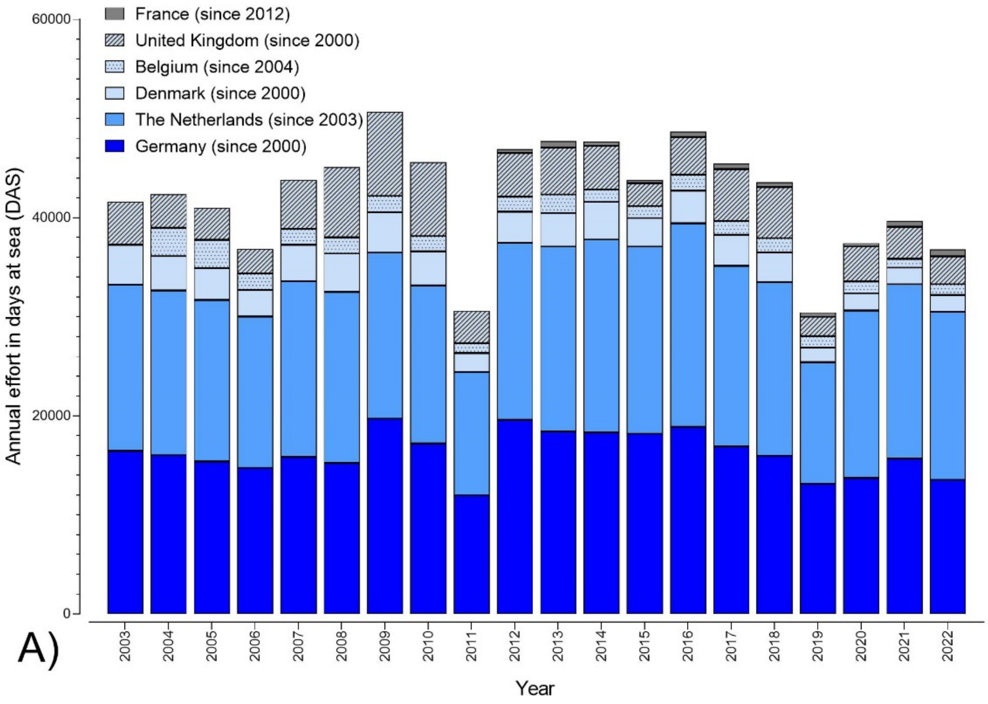

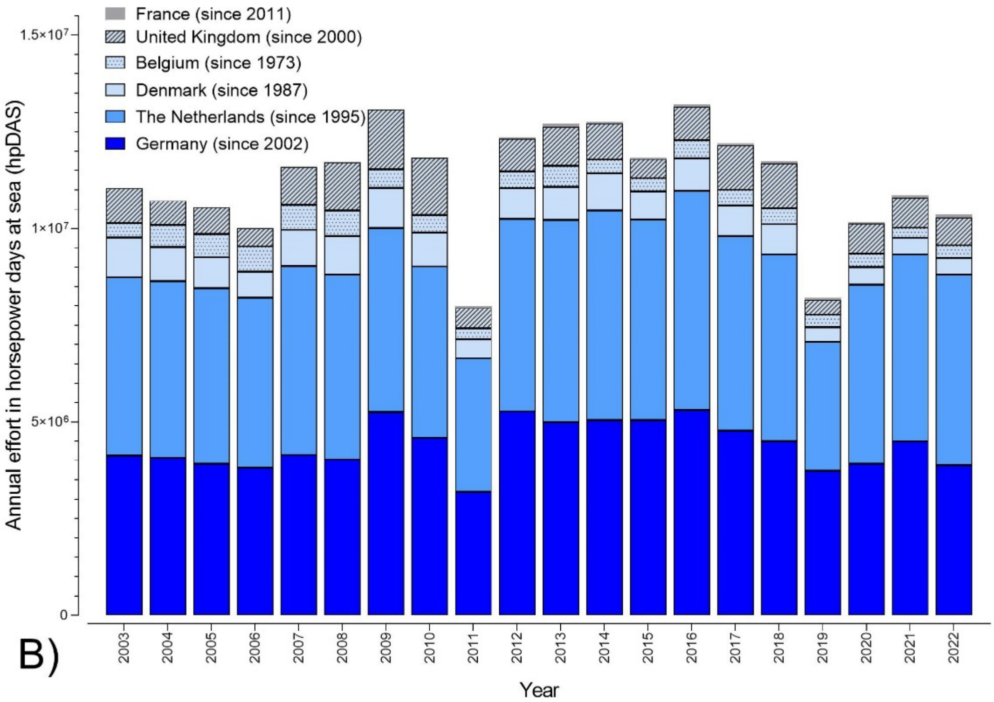

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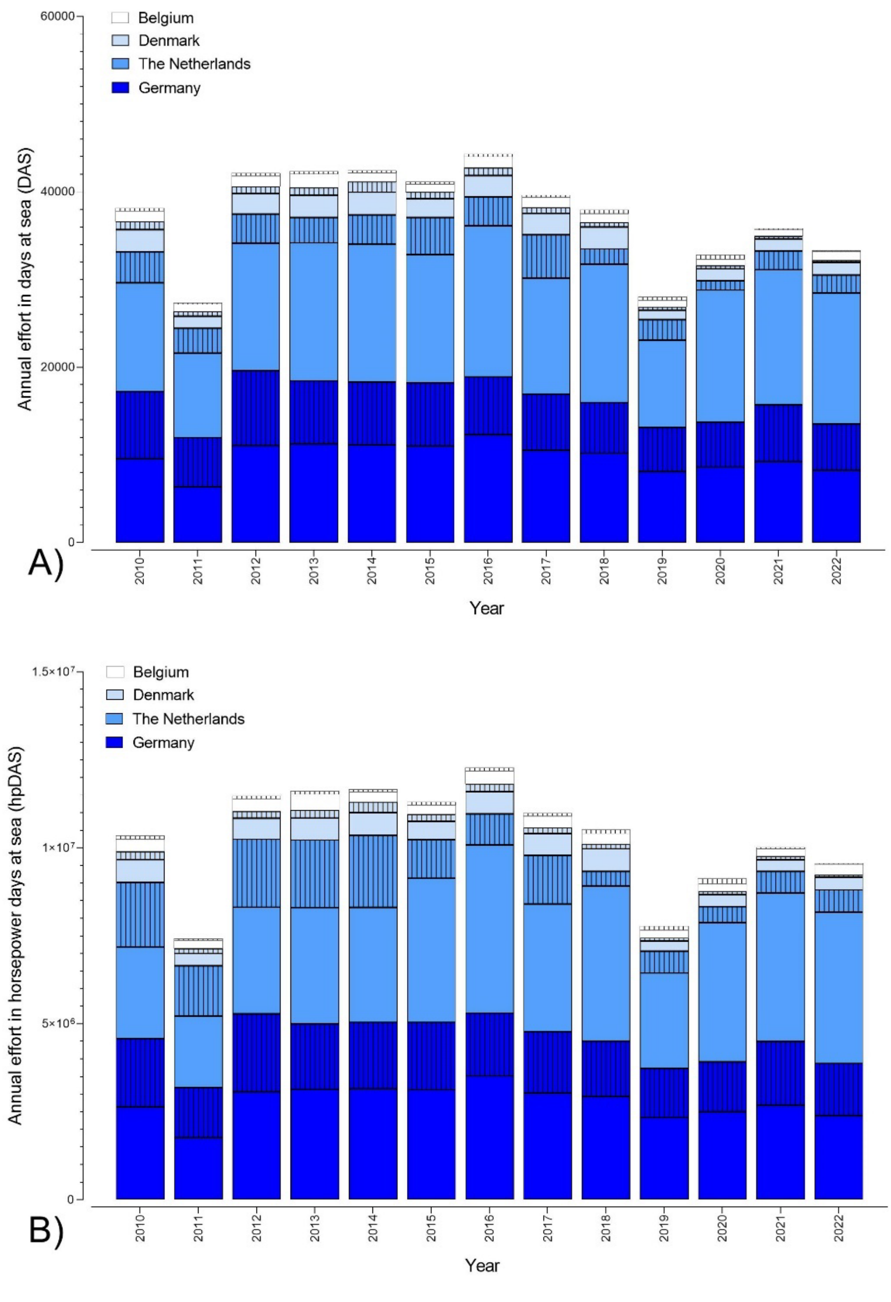

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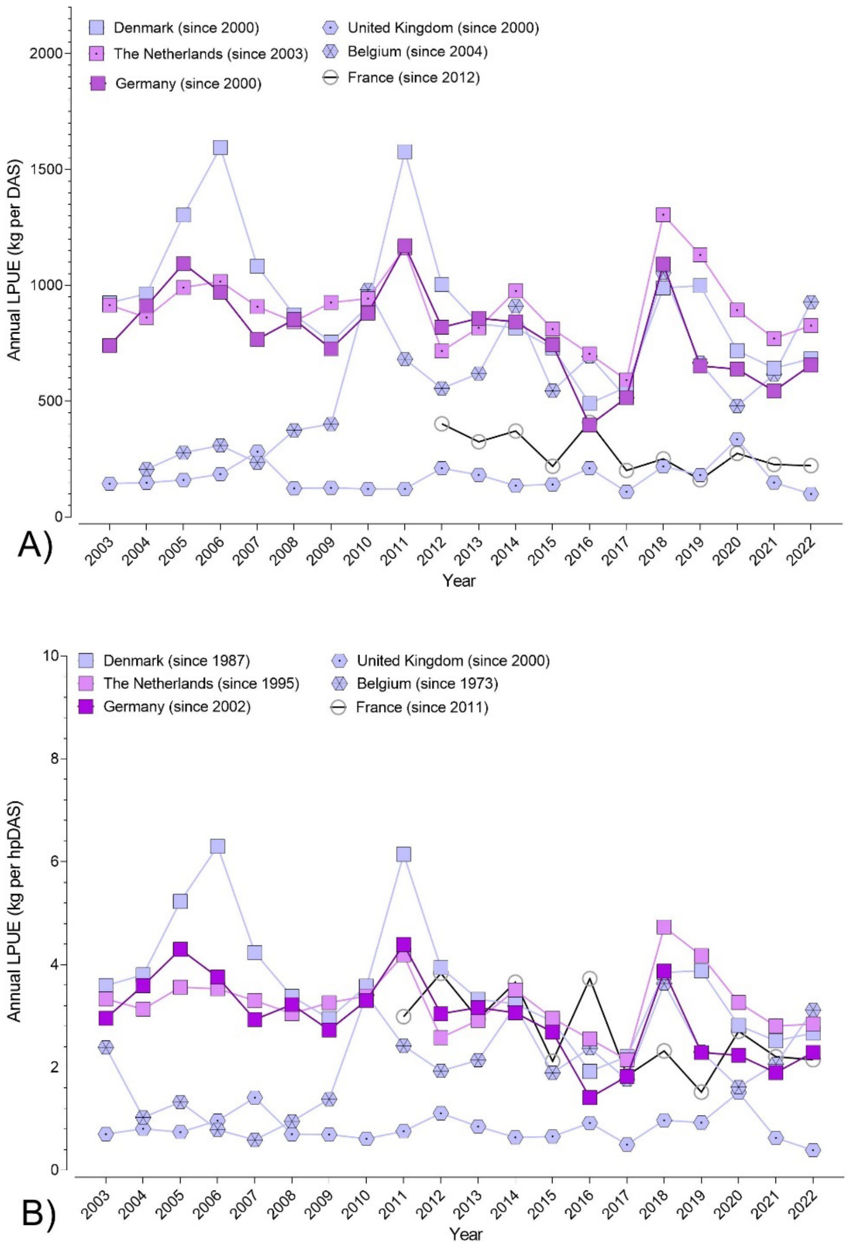

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3 Development of decision support tools (ToR c)

Progress in population models

To motivate using modelling for management advice and evaluation, it will be essential to show effects of management measures on stock recruitment. Modelling may thereby facilitate advice on how to increase the sustainability in shrimp fisheries, in connection to other goals (e.g. nature protection, socio-economy).

During a session focusing on possibilities to use modelling for assessment of the brown shrimp stock and implementing different management measures, the modelling approaches used by Hamburg University and Wageningen Marine Research were presented (see Table 2.1 for overview). Differences in the modelling approaches were discussed, knowledge gaps were pointed out and possible ways forward were outlined.

3.1 Hamburg University (UHH)

A life-stage specific yield-per-recruit-model for brown shrimp was developed at Hamburg University (Temming *et al.* 2017). Rather than to predict shrimp stock status, the model was initiated to understand the biology of the shrimp. In connection to shrimp stock dynamics the cohort structure was studied, i.e. to see if shrimp in the fishery originated from the winter or summer cohort. The model is based on fishery statistics (i.e. time-series of effort and landings), field data on shrimp length composition as well as various experimental data. This large amount of data enables simulation of population structure and size distribution of landings and catches by simulating the fate of daily starting cohorts of shrimp using estimated life-history parameters. Seasonal pattern of landings, recruits and egg production can thereby be produced with high accuracy.

The UHH model has stepwise been improved and modified since the early 2000s, and has been used for designing a Harvest Control Rule (HCR) and for investigating effects of management measures by simulating different harvest control rules, different mesh sizes etc. The present aim is to close the life cycle in the population model, i.e. to include spawner-recruit relationship. One major challenge is to include the variation in recruitment. A model with a closed life cycle would result in a modelled shrimp population which can then sustain itself.

3.2 Wageningen Marine Research (WMR)

The WMR model was initiated to understand patterns in shrimp catches and size distributions. The idea was triggered by theoretical studies on the different time trajectories of natural mortality and fishing mortality (e.g. Deroba and Schueller 2013). WMR developed a mechanistic modelling framework, incorporating both a physiological dynamic energy budget model of the shrimp population, as well as an agent based fleet dynamics model describing the behaviour of the fishing fleet (Steenbergen *et al.* 2015). By connecting the fishery operating under defined sets of rules with the shrimp stock in a system consisting of nine subareas (representing shrimp fishing areas in Denmark, Germany, and the Netherlands) effects of different management scenarios may be investigated.

The model includes density dependent growth with two yearly reproduction pulses based on body size. As females need to grow to reproduce, a stock-recruitment relationship is implicit, although it is not included per se. The shrimp population has a temperature dependent intake rate, their food source has a temperature dependent renewal rate, and these in turn both influence temperature dependent growth. Feedbacks between the shrimp stock and the fishery are included, as fishing pressure affects growth and recruitment patterns of the (local) shrimp stock. In turn the shrimp stock density and composition affect the behaviour of the fishing fleet as recent catches influence decisions to stop or to go on fishing, or move to another subarea.

Table 2.1: Overview of modelling approaches used by Hamburg University (UHH) and Wageningen Marine Research (WMR) to model the shrimp stock and fisheries.

	UHH (Temming *et al.* 2017)	**WMR (Steenbergen *et al.* 2015)**
Principle model setup	A "standard model run" defined for a shrimp fleet using average temperature-, fishing- and natural mortality patterns as well as effort and landing data from 2002 and onwards	Mechanistic model, based on processes leading to observed patterns; no complex fitting to observed data or direct calibration to studied system
Main goals	I. Estimation of landings depending on mesh sizes used and fishing pressure (varying fishing mortality) Effects of mesh size on the share of undersized shrimp in (unsieved) catches and sized shrimp in landings Influence of small changes in growth, timing of recruitment and temperature effects of effort reduction (temporal closures) of the fishery in contrast to mesh size increase (22 to 24 mm; 24 to 26 mm) **→To test management measures for increasing sustainability in shrimp fisheries**	Development of a Dynamic Energy Budget population model for shrimp Development of a fleet dynamics model to describe behaviour of the fishing fleet under various management scenarios The above models are connected to model 1) the effects on (local) shrimp stock by recent fishing pressure; 2) the response of fishing vessels to recent catch **→ To quantify (seasonal) estimated effort, landings and bycatch of undersized shrimp by applying different management measures**
Shrimp population	Yield-per-recruit approach with seasonal spawning pattern (index); temperature dependent growth and moulting; random noise; seasonal variation in natural and fishing mortality (obtained from dataseries); no density dependence	Physiological (DEB) model (Campos *et al.* 2009); 2 cohorts per year; food resources (semi-chemostat dynamics) determining size- and density dependent individual growth and reproduction; size-dependent background mortality
Fishing mortality	Selectivity curves; sieving process including some survival of sieved shrimp	Selectivity curves; assuming 100% mortality for caught shrimp
Regional variation	No regional division (Germany); noise included of (natural) temperature variation	9 areas with different temperature regimes; determined by their size individuals either occupy "deep" (fishery occurs) or "shallow" (refuge from fishery)
Fleet	Noise included of variation in fleet efficiency and effort (German fleet)	2 fleet categories in all 9 areas: local (stay in one area) and mobile (moving between areas)
Fleet behaviour	Based on time-series of effort; No specific response by fleet to catches	Agent based modelling framework; harvesting strategies differ between fleet categories; giving up densities (LPUE) based on recent catch + movement (time) costs

3.3 Knowledge gaps and possible ways forward

Growth, mortality and density dependence

Growth and mortality are sensitive parameters in model approaches of both UHH and WMR. These parameters are inter-connected and may also be more or less connected to density dependence. The UHH model does not include density dependence, following field observations of shrimp densities and size distributions which so far did not clearly support density dependent growth. Density dependence is implemented in the WMR model by a renewable food source (semi-chemostat dynamics) as well as shrimp intake rates, growth rates and mortality rates which are size-dependent. Increased fishing mortality thereby results in faster growth by releasing some of the density dependence. Other studies have concluded shrimp densities to be highly variable both spatially and temporally (Schulte *et al.* 2020), to vary substantially with seasons (Friese 2020), and to be density dependent in years with high shrimp densities resulting in limited shelter from predators (Henderson *et al.* 2006).

It can be concluded that density dependency may act in different ways. High densities may on one hand limit individual growth from competition, but on the other hand increase mortality if competition for food leads to increased starvation. Furthermore, predation mortality may increase if high shrimp densities attract predators - or increase fishing mortality for the same reason. Furthermore, cannibalism in shrimp is documented from the field (e.g. Pihl and Rosenberg 1982, del Norte-Campos and Temming 1994). At high densities, cannibalism may potentially be an important source of food as well as a significant source of mortality. Including variations in growth in the model may motivate to also include effects of cannibalism.

The WMR model assumes that shrimp in one area have identical size-dependent growth rates. However, field and experimental studies indicate a strong variation in growth. With high mortality, it can be predicted that faster growing individuals will live longer (until they are fished). One question is then why there are slow growers. To explore population effects while including variation in growth, could be done by modelling individuals having different food availability (WMR), i.e. adding a dimension to density dependence. The mean asymptotic length is concluded to depend on total mortality. Varying mean asymptotic length can be suggested as part of sensitivity analyses of the modelling approaches.

Reproduction and fecundity

In the aim to close the life cycle (UHH model), this includes adding a spawner-recruit relationship. The question was raised if this relationship is also connected to the composition of old and young females. Preliminary experimental results indicate that female size may (or may not) be related to, e.g. survival of larvae (Arlene Encendencia, pers. comm.) which calls for further study.

Factors affecting effort

In the UHH model, seasonal effort is based on time-series including noise. In the WMR model, resulting effort is in principle a result of the model. Comparisons with monthly effort in different areas show that model results resemble seasonal observed effort, although some areas and periods differ. It can be hypothesized that this is an effect of price. Price may be included as a factor influencing the fishing effort of the fleet (WMR). Fleet behaviour is also a parameter which could be adjusted according to more detailed information on what determines decisions made by fishers.

Using available data

It is suggested to use data, both from sampling from the fishery as well as scientific surveys to find supporting information for modelling. Regarding densities, data from sampling of the fishery (total biomass of shrimp) during different periods may be used. During certain periods, fishing pressure has been limited (e.g. 2011, 2019). LPUE as well as data from sieving stations or auction data (logbook related) from such periods could be compared with data from other 'normal' periods. Differences in size categories between periods could for example indicate density dependence.

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4 Research on bycatch (ToR d)

4.1 Outcome from trilateral co-sampling programme 2019–2022

In March 2023, the results of the trilateral co-sampling programme were reported to the Scheveningen Group, and included in the *Joint Recommendations on the landing obligation and on Technical Measures Regulation* and further evaluated by the Scientific, Technical and Economic Committee for Fisheries (Beier *et al.* 2023). In June 2023, the STECF commented positively on the results presented and the "*de minimis* exemption for all species subject to catch limits in the fishery for brown shrimp" was further prolonged from 2024 onwards (STECF 2023).

Background

In 2018, the brown shrimp fishery was included in COMMISSION REGULATION (EU) 2018/2035 (Article 9), which granted an exemption from the landing obligation under *de minimis* "[...] (i) in the fisheries for brown shrimp by vessels using beam trawls in Union waters of ICES Divisions 4b and 4c: a quantity of all species subject to catch limits, which shall not exceed 7% in 2019 and 2020, 6% in 2021 of the total annual catches of all species subject to catch limits [...]". The legal text was updated in 2019 ((EU) 2019/2238 Article 10) and last in 2020 ((EU) 2020/2014) to "[...] (j) in the fisheries for brown shrimp by vessels using beam trawls, in the Union waters of ICES divisions 4b and 4c: a quantity of all species subject to catch limits, which shall not exceed 7% in 2020 and 6% in 2021 and 2022, and 5% in 2023 of the total annual catches of all species subject to catch limits made in those fisheries [...]".

To obtain the *de minimis* exemption, the EU fishery on brown shrimp should demonstrate that the bycatch of TAC species remains within these limits. Based on this, Denmark, Netherlands and Germany established sampling programmes in which the fishery should deliver unsorted samples from their catches (for details on the sampling procedures see ICES 2022 and ICES 2023).

Due to different funding periods in the three countries, the sampling period varied between nations: Germany sampled from 2019 to 2022, Denmark from 2020 to 2022 and the Netherlands from 2021 to 2023. An overview of sampling periods and samples collected is listed in Table 3.1.

Table 3.1: Overview on sampling period and sampling details from Danish, German and Dutch sampling programmes.

	Denmark	Germany	The Netherlands
Sampling period	2020 - 2022	2019 - 2022	2022 - 2023
No. of vessels participating	21	24	22
∑ Quarters sampled	12	13	6
∑ Samples delivered	91	209	211
∑ ICES rectangles sampled	9	8	17

4.2 Results from trilateral co-sampling programme 2019-2022

All countries raised their samples by weight ratios between samples and total catch (first to haul level and then to trip level) - assuming that the samples are representative for the respective trip sampled. National data was then compiled into a common data sheet. A temporal-spatial statistical model was used to calculate the fleets' total bycatch of TAC species for the years 2019-2022. Only the four most common bycaught species (plaice, whiting, herring, and sprat) were estimated as a direct outcome of the model whereas the seven rarely bycaught species ("other TAC species" = brill, cod, horse mackerel, lemon sole, sandeel, sole, and turbot) were estimated as one group (Table 3.2) and later split into species by annual ratios weighted by annual brown shrimp catches (Table 3.3).

The estimated total bycatch by species and year is presented in Table 3.2. The measure of precision are the 25% and 75% percentiles of the resampled distributions. There have not been estimated confidence limits for the individual species in the combined group of other TAC species.

Table 3.2: Estimates of total bycatch (in tons) per year for plaice, herring, whiting, sprat, and a combined group of other TAC species consisting of brill, cod, horse mackerel, lemon sole, sandeel, sole and turbot. Numbers are median and in brackets percentiles of tons bycatch. DE = Germany, DK = Denmark, NL = the Netherlands.

	2019 (DE)		**2020 (DE, DK)**		**2021 (DE, DK, ½NL)**		**2022 (DE, DK, NL)**	
	tons	**(25% - 75%)**	**tons**	**(25% - 75%)**	**tons**	**(25% - 75%)**	**tons**	**(25% - 75%)**
Plaice *Pleuronectes platessa*	604	(360-1060)	488	(268-943)	985	(673-1499)	1799	(1423-2283)
Herring *Clupea harengus*	402	(183-1020)	317	(135-896)	556	(302-1156)	626	(433-975)
Whiting *Merlangius merlangus*	424	(107-2001)	255	(86-1093)	1657	(629-6251)	2793	(1346-6771)
Sprat *Sprattus sprattus*	161	(54-533)	129	(56-359)	264	(105-742)	266	(120-702)
Other TAC species	3	(1-25)	2	(0-14)	19	(7-63)	80	(36-197)

According to the regulation, bycatch should be set as a percentage of the total annual catches of all species subject to catch limits within ICES Divisions 4b and 4c. In 2020 it should not exceed 7%, in 2021 6% and in 2022 and 2023 not exceed 5 % of the total annual catches. The ICES advised TACs in tonnes for the relevant species can be found in Table 3.3.

Table 3.3: ICES advised TACs (tonnes) for North Sea fish stocks dominating and "other" TAC fish stocks (in italics) appearing in the bycatch of the brown shrimp fishery.

TAC species	2019	2020	2021	2022
Plaice (ple)	142,217	166,499	167,785	142,508
Herring (her)	311,572	431,062	365,792	532,183
Whiting (whg)	24,195	22,082	26,304	88,426
Sprat (spr)	177,545	138,726	207,807	106,715
Brill (bll)	*3,170*	*2,559*	*2,303*	*1,878*
Cod (cod)	*28,204*	*12,072*	*14,755*	*14,276*
Horse mackerel (hom)	*145,237*	*83,954*	*81,376*	*71,138*
Lemon sole (lem)	*5,484*	*4,297*	*4,011*	*3,081*
Sandeel (san)	*225,526*	*331,717*	*166,799*	*157,418*
Sole (sol)	*12,801*	*14,931*	*21,361*	*15,330*
Turbot (tur)	*4,952*	*4,538*	*3,948*	*3,609*
Sum	*425,374*	*447,212*	*294,553*	*266,730*

The model output show that, only whiting exceeded the bycatch limit by 0.3% in 2021 by having a bycatch percentage of 6.3% (Table 3.4), even with the 2023 limit of 5%, whiting in 2021 is the only exceedance. Of all the other TAC species bycaught, only plaice exceeded 1% of the quota in the year 2022. These results were reported to the ministries of the participating nations (Denmark, the Netherlands and Germany) and further on reported to the Scheveningen Group and STECF.

Table 3.4: Bycatch of dominant TAC species in the brown shrimp fishery as % to the species-specific quota for the North Sea.

	2019	2020	2021	2022
Plaice *Pleuronectes platessa*	0.4%	0.3%	0.6%	1.3%
Herring *Clupea harengus*	0.1%	0.1%	0.2%	0.1%
Whiting *Merlangius merlangus*	1.8%	1.2%	6.3%	3.2%
Sprat *Sprattus sprattus*	0.1%	0.1%	0.1%	0.2%

Table 3.5: Bycatch of less dominant TAC species in the brown shrimp fishery (in tonnes). Numbers in brackets give the % to the species-specific quota for the North Sea.

Species	2019	2020	2021	2022
Brill *Scophthalmus rhombus*	0 (0.0%)	0.2 (0.0%)	0 (0.0%)	0 (0.0%)
Cod *Gadus morhua*	0 (0.0%)	0.1 (0.0%)	3.7 (0.0%)	0 (0.0%)
Horse mackerel *Trachurus* spp.	0 (0.0%)	0 (0.0%)	0.3 (0.0%)	1.5 (0.0%)
Lemon sole *Microstomus kitt*	0.5 (0.0%)	0.8 (0.0%)	7.9 (0.2%)	2.6 (0.1%)
Sandeel *Ammodytes & Hyperoplus spp.*	2.6 (0.0%)	0.7 (0.0%)	4 (0.0%)	13.3 (0.0%)
Sole *Solea solea*	0.3 (0.0%)	0.3 (0.0%)	2.7 (0.0%)	61.2 (0.4%)
Turbot *Scophthalmus maximus*	0 (0.0%)	0.1 (0.0%)	0.2 (0.0%)	0.9 (0.0%)

4.3 Outlook

After submission of the report, a non-optimal fit to the log-normal distribution of bycatches was found in the detection limit model (DLM) used for the analysis. All data were therefore reanalysed using a zero inflated model (ZIM). This resulted in narrower confidence limits and a whiting bycatch of less than 5%. Exploration and progress on this subject will be decided on follow-up meetings during summer 2023.

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5 International survey data (ToR e)

Biological stock status indicators

The dataseries on the calculated biological stock status indicators (i.e. fraction of large shrimps, mortality, and swept-area biomass estimate) will be updated and published with the report of the next WGCRAN meeting.

The reason is that more time and expertise is needed for the merging of the different calculation modules (SAS scripts, R scripts, Excel files) into a common workflow (an R script with direct access to the ICES DATRAS database).

5.1 Sample size analysis on Belgian survey data

In 2022, the WGBEAM asked the WGCRAN following question: "What is the minimum number of shrimp measured per stratum (i.e. subarea)?" (ICES 2023a)

Next to the analyses performed by the WGCRAN in 2022 [see WGCRAN working document "Descriptive statistics of *Crangon crangon* length distributions from the DYFS survey in 2021" (Mosegaard 2022)], WGBEAM conducted a case study on the Belgian DYFS data in 2023 (ICES 2023b). The outcome if this analysis is presented in the following sections.

Background: National differences of DYFS shrimp sampling

Currently all three countries (the Netherlands, Germany & Belgium) sampling brown shrimp during DYFS, select a different number of shrimp to measure per haul. The Netherlands take 50 specimens, Germany 250 grammes (about 350 specimens) and Belgium takes on average 600, maximum 750 specimens. The haul of the Netherlands and Germany are grouped in subareas, whereas the stations of the Belgian data each are considered as a separate subarea.

Furthermore, in contrast to the other countries, the Belgian DYFS survey uses a shrimp sorting machine before taking subsamples. This results in three fractions (small, medium and large) and thus a broader length distribution and a better capture of the extreme lengths, especially the larger specimens.

Bootstrapping

The bootstrap was performed on the Belgian DYFS data from 2022. Depending on the bin size, more data could be dropped and still result in a similar length distribution. Figure 4.1 shows the different results of the bootstrapping. The columns reflect the different bin sizes (1 mm interval, 2 mm, 3 mm, 4 mm and 5 mm) and the rows show how much of the data has been selected. The grey area is the 95% confidence interval.

The original length distribution is on the bottom left of figure 4.1, with a 1mm interval and 100% of the data. If we keep a bin size of 1mm, we can drop 40% percent of the data and still have a same length distribution. If the bin size is set at 5mm (less precise length distribution), we can drop 60% or more in order to keep a similar length distribution. In numbers this means we can go from 600 specimens to 360 or even 240 specimens.

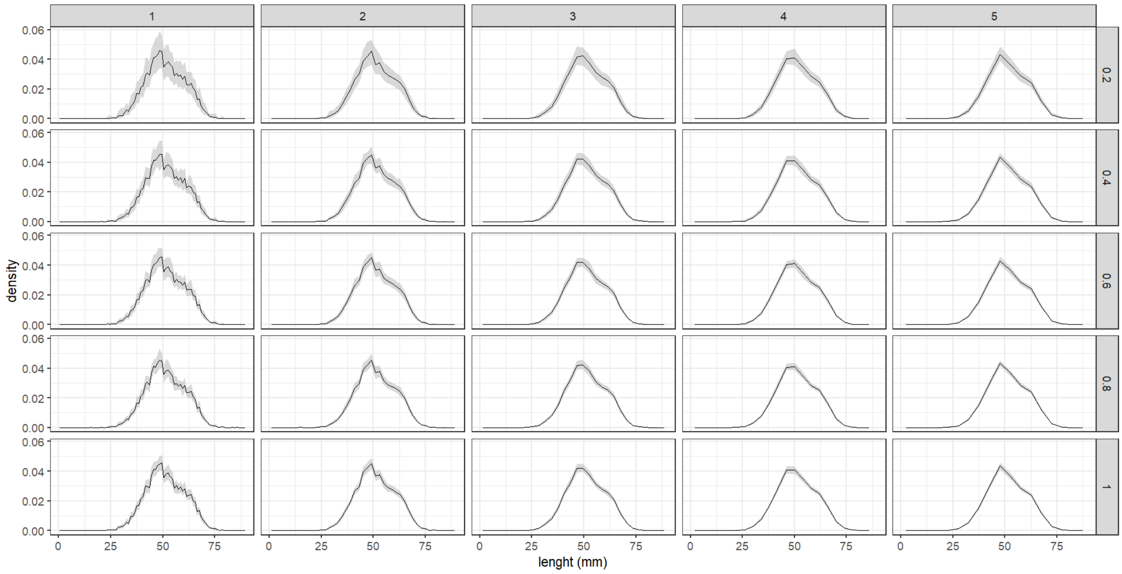

Figure 4.1. Length distributions and 95% confidence intervals (grey area) after bootstrapping results of shrimp lengths. Belgian survey data

Figure 4.2 shows the probability that the bootstrap result is not within the 95% confidence interval of the original length distribution. These reflect a similar outcome as figure 4.18. With a bin size of 1mm, a drop of 20 to 40% (subsampling size of 0.8 to 0.6) data results in a probability between 0 and 0.2. An 80% drop in data yields a probability of over 0.6. With a bin size of 5mm, the probability stays under the 0.4, even with a data drop of 80%.

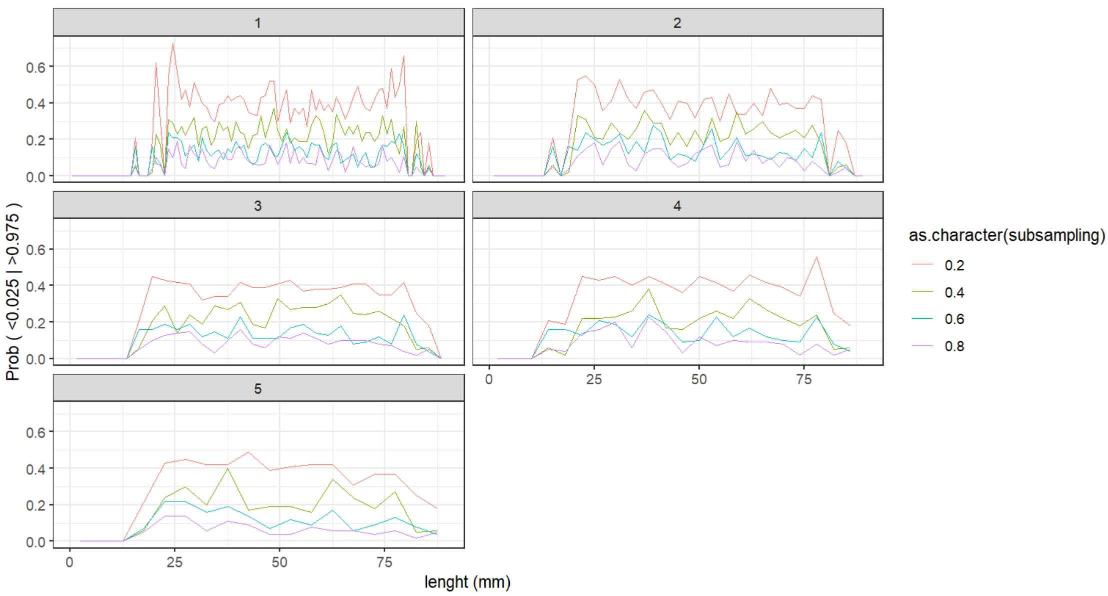

Figure 4.2. Probability that the length distribution after bootstrapping is not within the 95% confidence interval. Each graph represents the bin size, the colours reflect different subsample sizes. Belgian survey data

The biggest question that remains on this topic is how large or small the bin size has to be, because this has a huge influence on the outcome of this case study. In order to determine the bin size, we need to know what the data is used for and how a larger bin size will affect the outcome of data products. The most important data product is the shrimp mortality: the shrimp lengths are used here for a calculation of the shrimp mortality.

Next steps

A first step is to investigate how a change in length distribution will affect the mortality calculations and other data products. Only then can a correct bin size be determined and thus a minimum number of measurements.

The next step is to calculate the minimum number of shrimp for the other countries: Germany and the Netherlands.

References

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6 Legislation law and management (ToR f)

6.1 EU Action Plan

The EU Commission suggests the exclusion of all mobile bottom contacting gears from all marine protected areas (COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries. COM (2023) 102 final; Brussels, 21.2.2023). The implementation of this plan would have severe effects on the largest single species fisheries in the North Sea, the fisheries on brown shrimp (*Crangon crangon*), which is deployed by the Belgic, Dutch, German and Danish fisheries. Together with the installation of wind farm areas the cumulative impact on this fishery which operates mostly in near shore waters was analysed. As an example, the potential impact of the EU Action Plan and the offshore windfarm areas on the German shrimper fleet was investigated. We assume that the other fleets would be impacted in a similar way.

The analysis of spatially high-resolution VMS-based data shows potential revenue losses, especially of the German North Sea shrimp fishery, at over 85% (Table 5.2). The key factor here is the closure of marine protected areas in coastal waters (within the 12 nautical mile zone, Figure 5.8). Nearly 90% of enterprises (vessels) would lose fishing areas where they had generated more than 60% of their revenues in recent years, and 64% of vessels would lose fishing areas where they had generated more than 90% of their revenues in recent years (Table 5.3). For the shrimp fishery, it is highly unlikely that sufficient areas for displacement will be available for the large area losses in the main fishing areas. On the one hand, the resource *Crangon crangon* is only adequately abundant in coastal areas, on the other hand, the fleet consists mainly of rather old, small cutters that have limited ability to move, for example, to deeper waters or to more offshore areas.

If the proposals from the Action Plan were implemented, the economic viability of a large part of the German shrimper fleet would no longer exist. It is questionable whether there could be suitable alternative fishing opportunities with others than mobile bottom contacting gear for the crab fishery and thus whether this marine resource could be economically exploited at all in the future. Even a modernization of the fleet to larger vessels would probably only be able to compensate for a small part of the fishing area losses, since the few remaining deeper areas are not as productive as the areas closer to the coast in the marine protected areas. In any case, a complete transformation of this segment would be required, supported by government funding or levies on the major land users.

To estimate potential revenue losses, data from the Vessel Monitoring System (VMS, mandatory for vessels 12 m LÜA and above) are merged with data from logbooks, landings, and the vessel register. The VMS positions thus merged to, among other things, vessel characteristics, gear used, catch and revenue are overlaid with the corresponding areas and intended management (gear exclusion regime) and the affected catch and revenue per species, as well as the number of vessels affected, are estimated. Fishing with mobile bottom contacting gear by vessels under 12 m LÜA is negligible in the North Sea and is not included in the analysis. Three scenarios were examined in accordance with the request made (Table 5.1, Figure 5.1).

The following gear classes are distinguished:

Mobile bottom contacting gears	Passive and pelagic gears
TBC: Beam trawls aiming for brown shrimp, *C. crangon* (Trawl Beam Crangon, officially TBB_CRU_16-31)	**PGE**: Passive gears with bycatch of marine birds and mammals (Passive Gears Entangling)
TBB: Beam trawls not aiming for *C. crangon*, also pulse trawls (mostly TBB_DEF; Trawl Bottom Beam)	**PGO**: Other passive gears (Passive Gears Others, pots and fykenets)
DTD: towed nets (e.g. OTB, Demersal Trawls and Dredges)	**PTS**: Pelagic gears (Pelagic Trawls and Seines)
BTP: OTB and SSC > 120 mm aiming for pollack (Bottom Trawl targeting POK)	**OTH**: OTHer gears, e.g. long lines
DSN: Demersal seines (Demersal SeiNes)	

The estimated stress level profiles per gear class (Figure 5.2) show that from the Action Plan's proposed measure of complete exclusion of mobile bottom contacting gears in marine protected areas by 2030 (see scenario AP30), the shrimp fishery (TBC) would be extremely affected, losing areas that generated nearly 85% of revenues (approximately 32 million euros, Table 5.2).

Looking at the potential revenue lost by individual vessels (enterprises) and relating this to the total revenue lost by a vessel (Individual Stress Level, ISL), the median for shrimp fishers is nearly 100% (Table 5.3). Figure 5.4 shows that only about 10% of the vessels would not be affected by the measures, and the classes with high ISL values are dominated by shrimpers (TBC).

Of 160 shrimpers in the analysis in 2021, each vessel had effort in marine protected areas proposed for mobile bottom contacting exclusion (Table 5.4).

The impact for the overall German fleet, as well as the Lower Saxony and Schleswig-Holstein fleets (Figure 5.5) and the port communities of the towns on the German North Sea coast (Figure 5.6) would be obvious.

The maps showing the distribution of revenues in space (Figure 5.7) show why SL and ILS values for shrimp fisheries would be so severely impacted by the Action Plan, while demersal species fisheries (gear classes TBB, DTD, DSN) would be impacted by wind energy development. The catch by species, specifically brown shrimp, sole, plaice, and Norway lobster) affected by the proposed action and wind energy development is shown in Figure 5.9.

Table 5.1: Scenarios considered in the VMS analysis

Scenario	Scenario Code
1) Nature conservation areas (FFH and bird protection according to Action Plan 2030): shaded in black	AP30
2) Wind energy areas (planned, reserved, already built on; as of March 2023): shaded blue	Wind
3) Cumulative of 1 and 2	AP30.Wnd

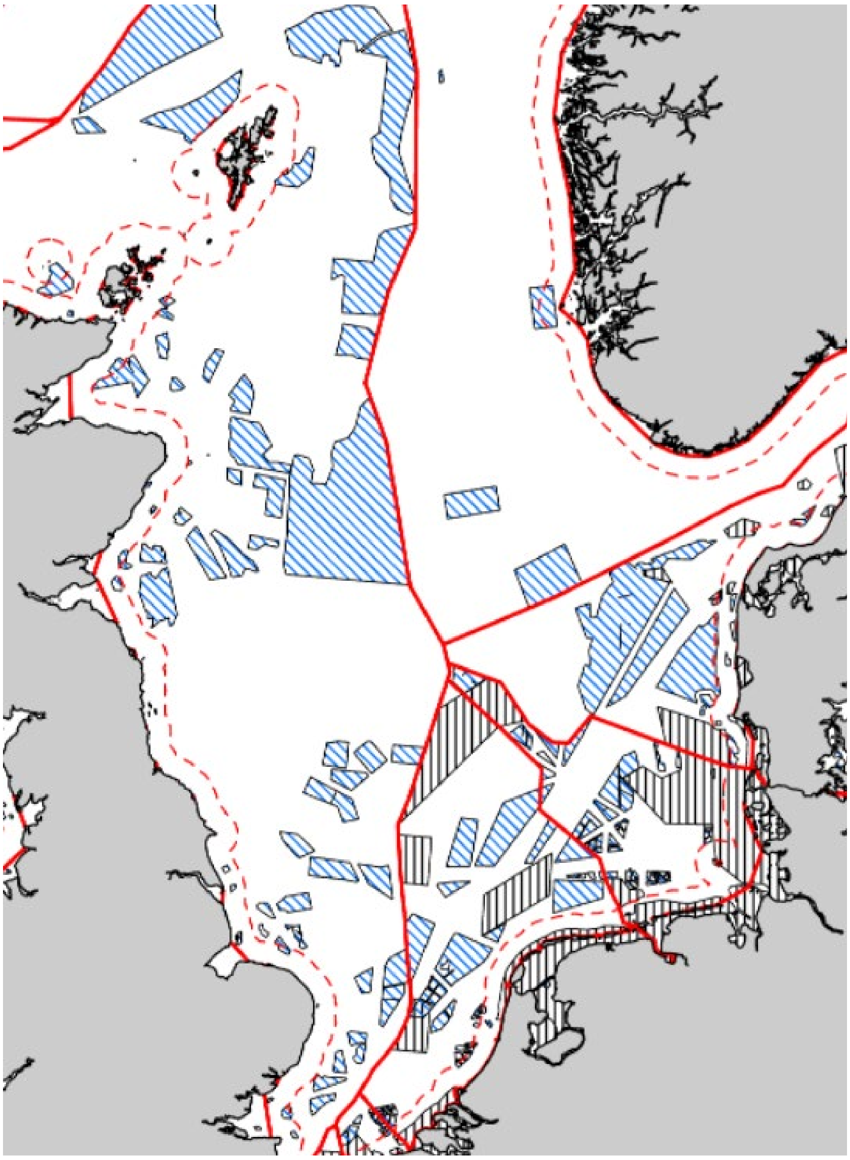

Figure 5.1: Location of potential wind energy and marine protected areas (FFH and bird protection). Red lines: EEZ borders and baseline. Red dashed lines: 12 nm. Blue hatched areas: wind energy. Black hatched areas: marine protected areas (FFH and bird protection).

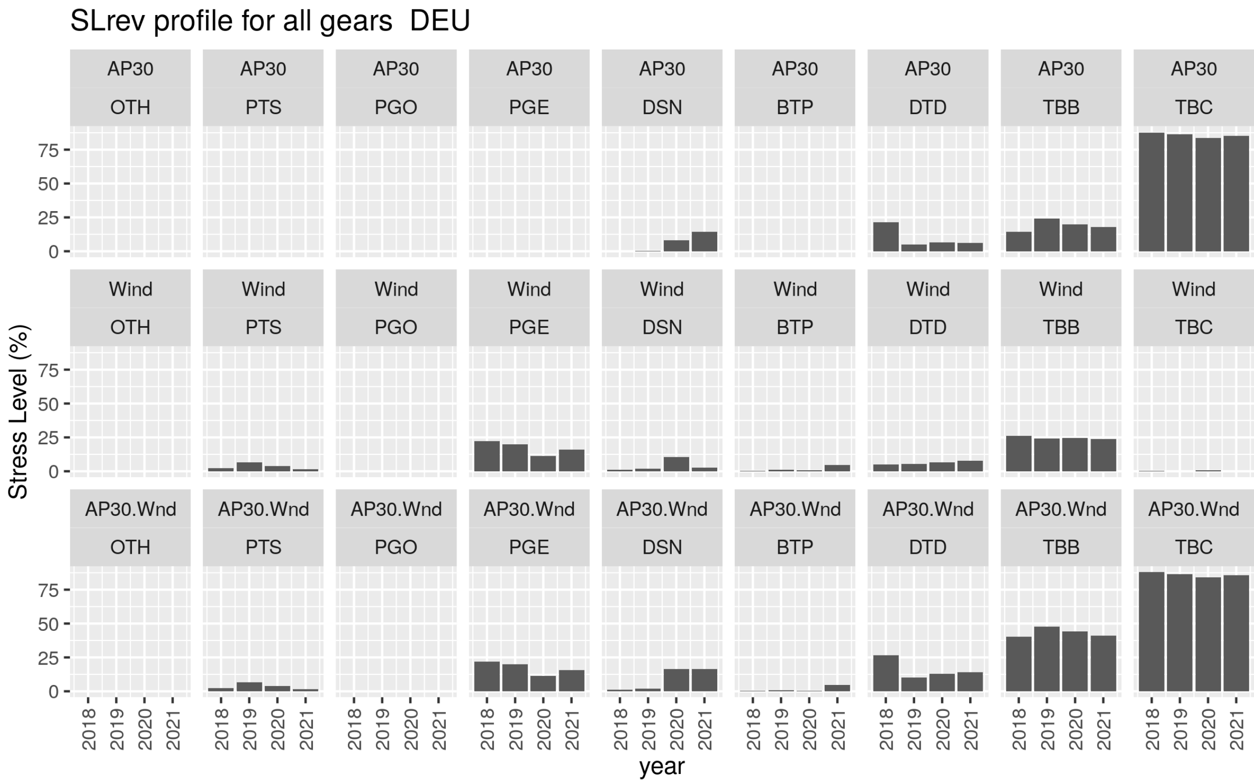

Figure 5.2: Stress Level (SL) profile per scenario and gear class of the years 2018-2021.

Table 5.2: Potential yearly loss of revenues and stress levels (revenues). Values are shown as means of the years 2018-2021.

Revenue (Euro)	TBC	TBB	DTD	BTP	DSN	PGE	PTS
AP30	31'599'590	2'304'372	4'765'484	0	34'016	0	0
Wind	107'352	3'020'588	2'467'948	381'483	21'022	509'593	2'466'874
AP30.Wnd	31'706'163	5'283'061	7'233'169	381'483	50'794	509'593	2'466'874
Stress Level (%)							
AP30	85.7	19.0	9.8	0.0	5.7	0.0	0.0
Wind	0.3	24.7	6.2	1.6	4.0	17.3	3.6
AP30.Wnd	86.0	43.3	15.9	1.6	9.0	17.3	3.6

Tabelle 5.3: Percent of vessels per ISL and device class over the years 2018-2023 for the cumulative scenario AP30.Wnd.

	ISL Klasse								
Gerät	0	>0-5	>5-10	>10-15	>15-30	>30-60	>60-90	>90	mittleres N vessels
TBC					2	10	25	64	166
TBB					15	54	4	25	12
DTD	6	13	14	9	12	33	1	12	25
BTP	28	63	3	3	3				8
DSN	0	50	25	0	0	25			1
PTS	0	48	22	13	13	4			6
PGE	18	24	6	6	35	12			4
PGO	50	0	0	0	50				1
OTH	75	25							1

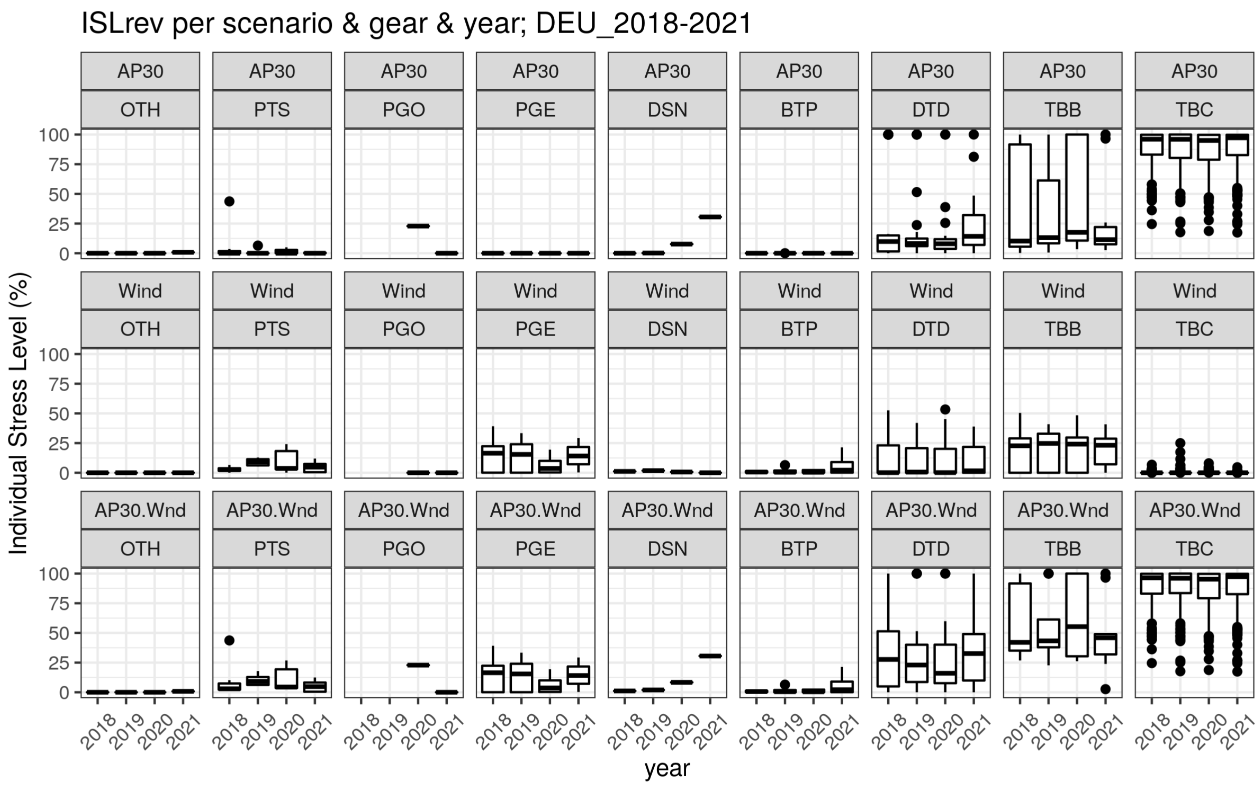

Figure 5.3: Individual Stress Level (ISL, revenues) per scenario and gear class of the years 2018-2021.

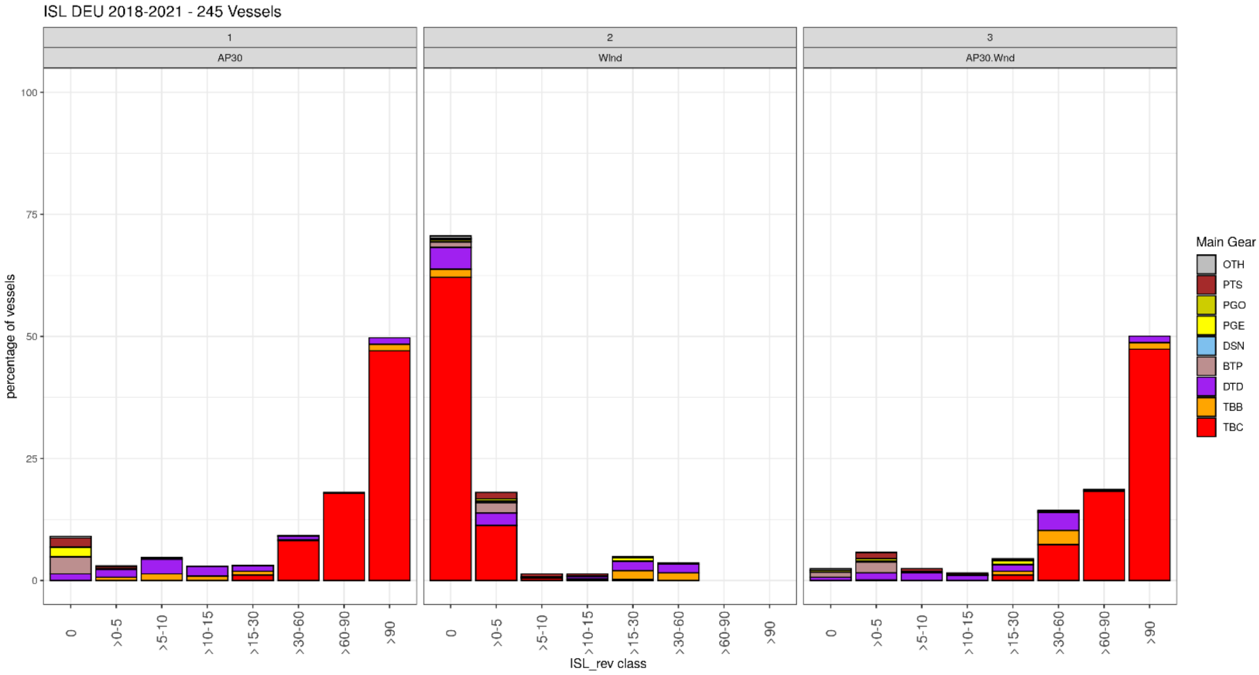

Figure 5.4: Percentage of vessels by Individual Stress Level (ISL) classes (revenue) per scenario and main gear used. Mean values for the years 2018-2021.

Table 5.4: Number of vessel by individual ISL class (revenues) of the scenario AP30WND per year and gear class.

Gerät Jahr	ISL Klasse 0	>0-5	>5-10	>10-15	>15-30	>30-60	>60-90	>90	Summe
TBC									
2018					1	17	41	115	**174**
2019					3	11	48	107	**169**
2020					2	20	41	99	**162**
2021					4	18	34	104	**160**

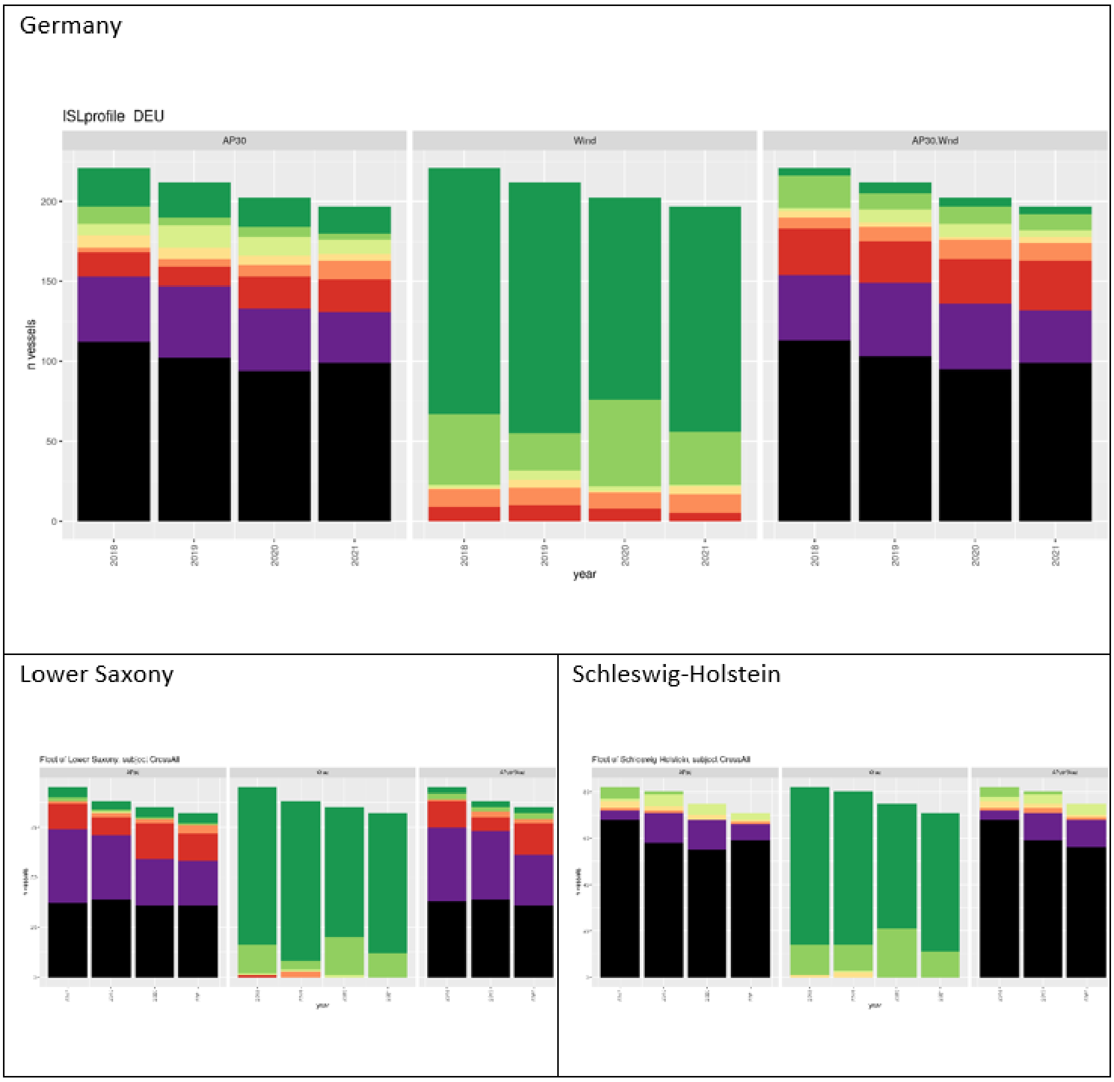

Figure 5.5: ISL-profiles (revenues) of the fleets of Germany (total), Lower Saxony and Schleswig-Hostein of the years 2018-2021.

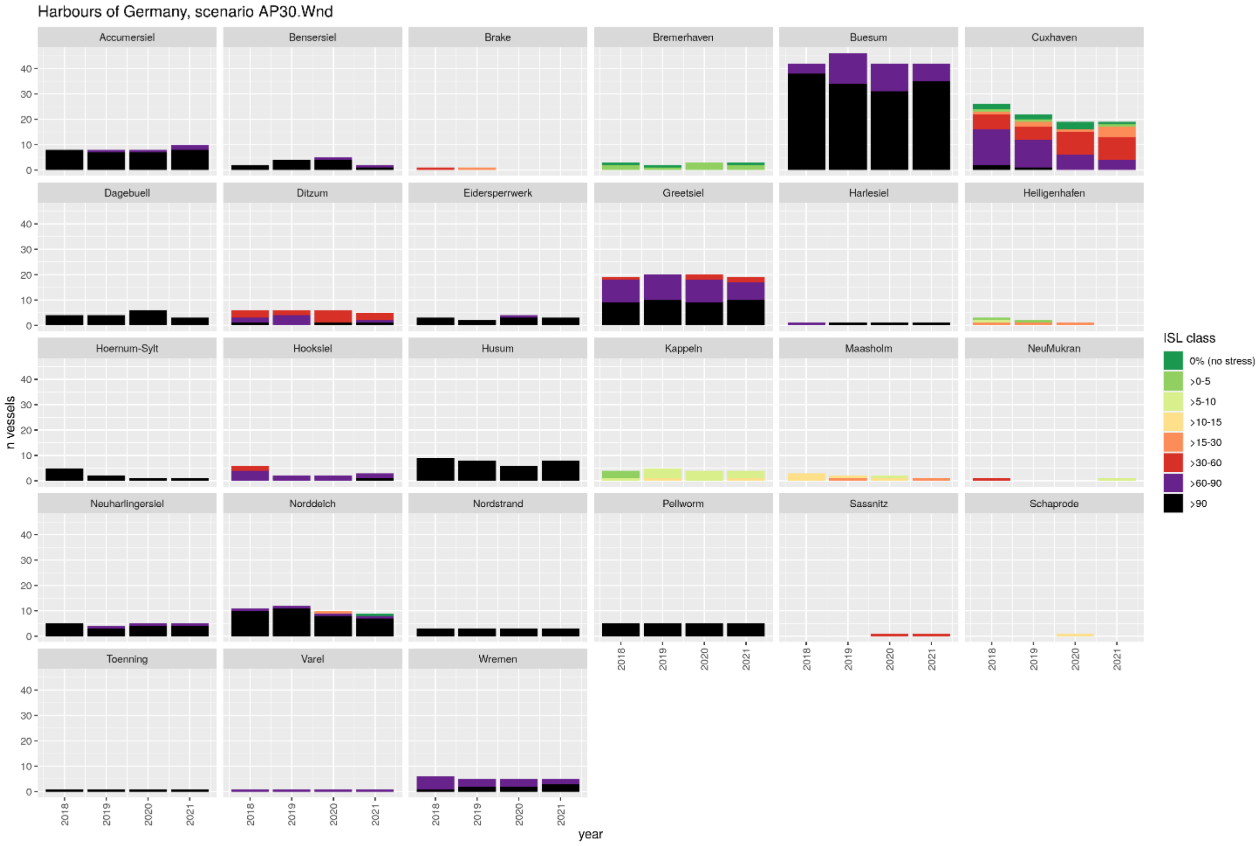

Figure 5.6: ISL-profiles for scenario AP30.Wnd of harbour communities of the years 2018-2021.

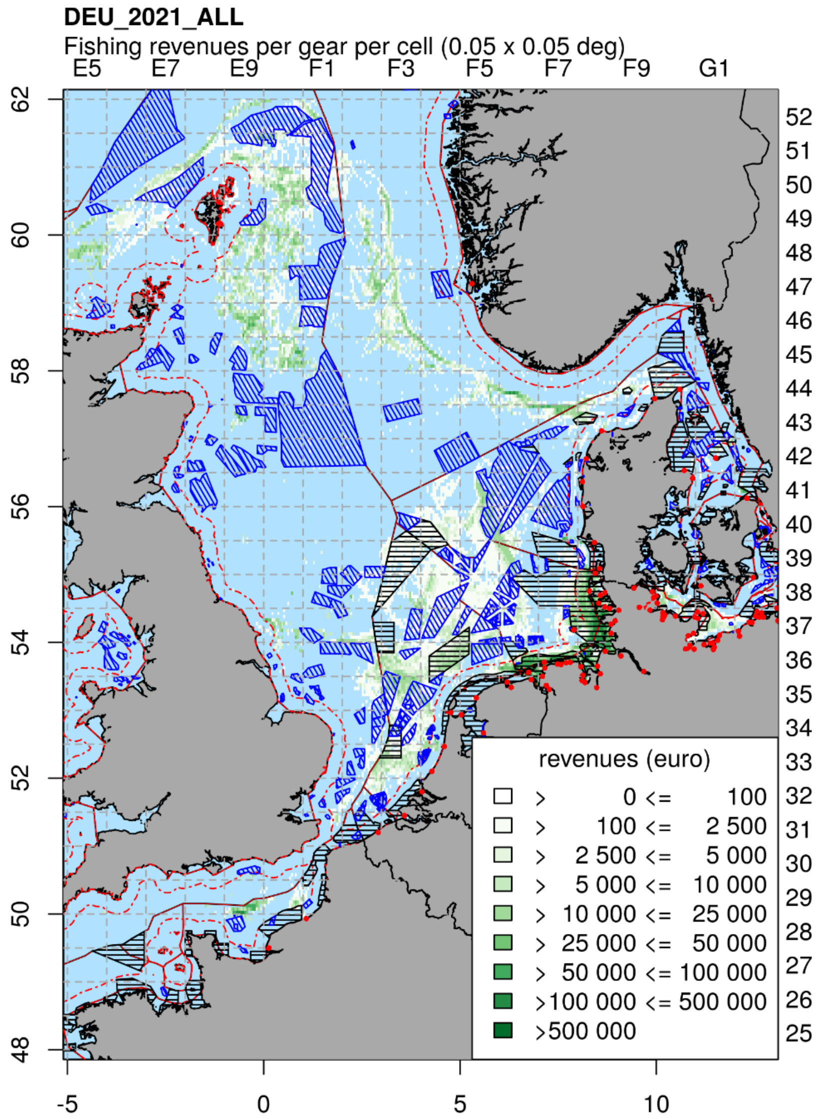

Figure 5.7: Example of the year 2021. Distribution of fishing revenues of the German fisheries (all gears) per c-square 0.05° (approx. 1.5 x 3 sm² in the North Sea). Cells with green scale: yearly revenues (scale see legend). Red and black lines: EEZ borders and baseline. Red dotted line: 12 nm. Blue hatched areas: wind energy. Black hatched areas: marine protected areas (FFH and bird protection) suggested to exclude mobile bottom contacting gears. Red dots: harbours with landings of German flag vessels.

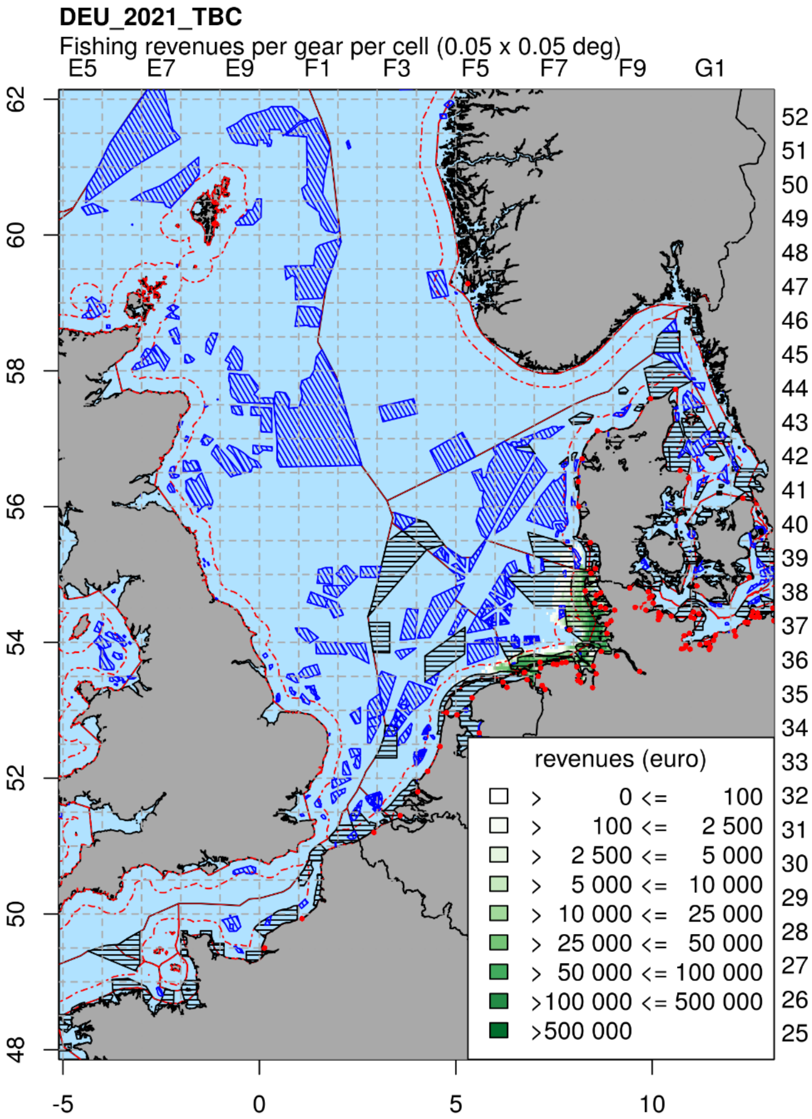

Figure 5.8: Distribution of fishing revenues of the German shrimp fisheries (TBC) per c-square 0.05° (approx. 1.5 x 3 sm² in the North Sea). Example of the year 2021. Cells with green scale: yearly revenues (scale see legend). Red and black lines: EEZ borders and baseline. Red dotted line: 12 nm. Blue hatched areas: wind energy. Black hatched areas: marine protected areas (FFH and bird protection) suggested to exclude mobile bottom contacting gears. Red dots: harbours with landings of German flag vessels.

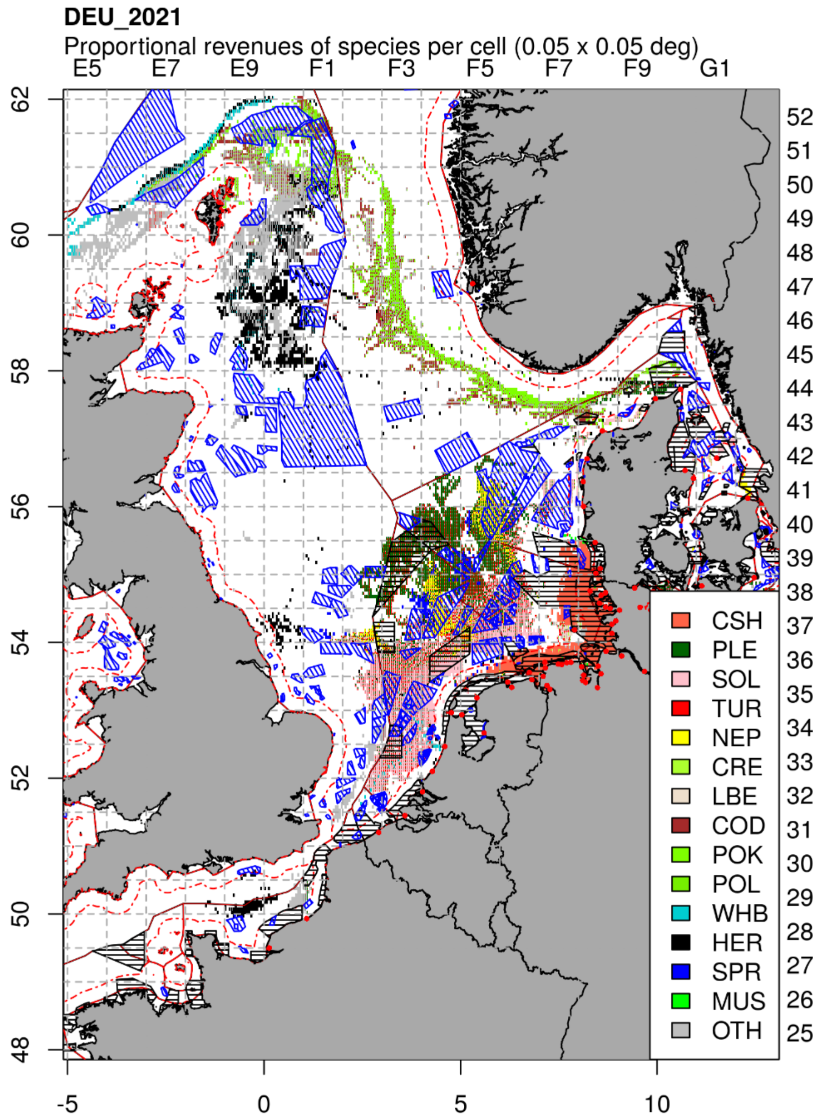

Figure 5.9: Example of the year 2021. Proportional distribution of revenues by species per c-square 0.05° (approx. 1.5 x 3 sm² in the North Sea). Coloured cells: proportional revenues per species (tree plots). Red and black lines: EEZ borders and baseline. Red dotted line: 12 nm. Blue hatched areas: wind energy. Black hatched areas: marine protected areas (FFH and bird protection) suggested to exclude mobile bottom contacting gears. Red dots: harbours with landings of German flag vessels.

6.2 Natura2000

Nature2000 fisheries measures in the Dutch and German EEZ entered in force in spring 2023. Detailed information can be found in the Delegated Regulation (EU) 2017/118 establishing fisheries conservation measures for the protection of the marine environment in the North Sea (https://eur-lex.europa.eu/eli/reg_del/2017/118/2023-03-08).

6.3 MSC certification

General development

The MSC certified Danish, German and Dutch brown shrimp fishery was audited in 2022 and an updated management plan v. 1.2 was adopted in December 2022 (CVO visserij 2023, MSC 2023).

The main change was, that "[...] from the 1st of January 2023, participating vessels that are member of CVO and MSC-GbR shall reduce their effort by at least 6.1% per year and participating vessels that are member of DFPO will reduce their effort by at least 12% per year. Effort shall be reduced according to one of the party specific reduction schemes within each measure period as described [...]" in the management plan (MSC 2023).

UK- Wash shrimp certificated

The Wash brown shrimp fishery (UK) was MSC certified in January 2020. In 2022, an onsite audit was performed. According to the surveillance report no new recommendations were raised during this surveillance audit (MSC 2022).

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MSC (2022). Wash Brown Shrimp Surveillance Report, [online] https://cert.msc.org/FileLoader/FileLinkDownload.asmx/GetFile?encryptedKey=0gSbWk5WyvrX2oScWDYhZA8fe3WSc/32S6ytAaZpZumUtmey7DwnLfISxM7e2Rxn , (accessed on 15.8.2023)

MSC (2023). North Sea Brown Shrimp 4th Surveillance Report, [online] https://cert.msc.org/FileLoader/FileLinkDownload.asmx/GetFile?encryptedKey=TtysSd2dIgtLXfcI1/K2t297U0cjSKToDKOhOEACibtdH/em+z+/gB+8ORSUPhe1 , (accessed on 15.8.2023)

7 Ongoing research projects (ToR g)

For an informative overview, all (inter-) national *Crangon* related projects known to the working group are listed in the following table (Table 6.1). Details of a Belgian fishing gear project investigating LED light as well as the OPTITOG laser beam technology in shrimp fisheries can be found in the following section (See sub-chapter 6.1).

Table 6.1 Overview of current projects related to *Crangon crangon* (fishery) research

Project name	Country	Time	Description
SepCran	BE	2018-2022	Selectivity studies to minimize bycatch in shrimp fishery (report due October 2023)
CRANIMPACT	DE	2018-2023	Impact of shrimp fishery on the seabed
LED there be light, SYMAPA, OPTITOG	BE	2018-2023	Trials using LED light and OPTITOG laser beam technology in brown shrimp fishery
Co-sampling shrimp fishery	DE	Since 2019	Estimating discard percentages of TAC species in the German shrimp fishery for a *de minimis* exemption
Bycatch reduction in the North Sea brown shrimp beam trawl fishery	DK	2019-2023	Document and reduce bycatch of fish with special emphasis on juvenile TAC species. This include the development of a BRD and a co-sampling programme for the Danish *de minimis* exemption
IRC shrimp	NL	2019-2023	International Research Cooperation Shrimp; development of an international platform for stakeholders (WP1) & data collection on bycatch in Dutch shrimp fishery (WP2).
SHRIMPBREED	BE	2020-2023	Study on the technical and economic feasibility of brown shrimp *Crangon crangon* farming for product diversification.
Co-sampling shrimp fishery	NL	2021-2023	Estimating discard percentages of quota species in the Dutch shrimp fishery for a *de minimis* exemption
iSeal	DE	2021-2024	Investigation of the effects of **climate change**, **fisheries** and **invasive species** on the Wadden Sea National Parks of Lower Saxony and Schleswig-Holstein
Structural Change Coastal Fisheries	DE	2021-2027	https://www.thuenen.de/en/cross-institutional-projects/structural-change-in-coastal-fisheries
Management scenarios of shrimp fisheries	NL	2022-2023	Investigating ecological and economic effects of three main management scenarios using modelling approaches, project for the Dutch Ministry of Agriculture, Nature and Food Quality
Passive shrimp fishing in the Wadden Sea	NL	Since 2023	Shrimp fishing using passive gear in the Dutch Wadden Sea https://research.wur.nl/en/publications/projectvoorstel-passieve-garnalenvisserij-op-de-waddenzee

7.1 Using light in fisheries: A brighter future for brown shrimp fisheries?

Brown shrimp (*Crangon crangon*) are targeted by beam trawlers throughout the North Sea. This type of fishing is infamous for its bottom contact and disturbance of the seabed, high fuel consumption due to the towing of the nets, and large amounts of bycatch. Worldwide, fishing for shrimp can reach up to 90% of bycatch.

Over the past years, the fishery techniques team at the Flanders Research Institute for Agriculture, Fisheries, and Food (ILVO) has performed a series of experiments using lights to reduce the amount of bycatch. In one of them, we used a white LED rope which was attached to the beam. This led to a significant reduction in plaice and in roundfish (mostly *Gobius* spp.) without loss of shrimp. This trial was repeated with green LED lights called Pisces from SNTech where we got a significant loss of fish, mostly gobies again, but not of flatfish as plaice were not present in sufficient numbers. Based on the OPTITOG project (Hreinsson *et al*. 2018) a virtual trawl using lasers was tested on brown shrimp. The idea was conceived for herding the prawn *Pandalus borealis* in a codend without having an actual net or ground gear, reducing bottom impact and bycatch. We performed lab trials to verify the effect of the lasers on the behaviour of *C. crangon* in our tanks. In the first trail the tank was divided in two by a laser beam, in the second, the beam was hauled through the tank. In neither of the experiments did the lasers elicit a reaction from the shrimp. *P. borealis* lives in clear waters and has keen eyesight while our brown shrimp live in turbid waters and probably do not even conceive the laser light.

On the other hand, we managed to increase catches of shrimp in pots using the Pisces lights. In pots without light, only a few shrimp were caught. In the pots with blue light, more than a hundred shrimp were caught. The answer to why they are attracted to the light is not yet known to us, but the reason why they did not react to the light in the other trials is probably due to the beam trawl moving too fast for shrimp to actually be attracted to or evade the lights. Pots allow them to elicit the reaction of being attracted to the light. Although this is far from a commercial fishery, it does allow for some opportunities.

7.2 Development of bycatch reduction devices

One of the historical problems associated with the beam trawl fisheries targeting brown shrimp in the North Sea is the bycatch of fish species and non-targeted invertebrates, which happens mostly due to the small mesh size of the codends required to catch the targeted shrimp. This issue has been intensively addressed in the past by national and international research, devoted to the development of bycatch reduction devices (BRD) able to provide escape possibilities to fish species before entering the codend. Those research efforts focused mostly on two BRD concepts, namely sieve-nets and sorting grids. These two devices are mandatory in the fishery since more than two decades and, consequently, fishers are obliged to mount one of them in their trawls. Historical trials in the frame of the EU-Study 98/012 "Reduction of discards in *Crangon* trawls (DISCRAN, 1999–2000)" revealed good sorting properties of both devices, except for age-0 fish, a major bycatch component in German fishing grounds (van Marlen *et al.* 2001).

However, the intended sorting efficiency of sieve-nets and sorting grids designed more than two decades ago might not be appropriate in the present, considering the changes occurred in the environment, exploited populations and fishing conditions over time. In this regard, there is increasing concerns in the German fishery regarding the increasing density of seagrass and bryozoans encountered by the trawl when fishing in estuarine grounds, especially during summer season. Those seagrass and unwanted invertebrates tend to clog the sieve-net meshes. Clogging events often lead to massive catch losses of marketable shrimps, hampering the economic viability of the fishery. Therefore, to address current challenges in the fishery, the selectivity technologies concepts already in place needs to be adjusted - or innovative solutions need to be found - in order to effectively mitigate the negative impact of the beam trawl fishery targeting brown shrimp (*Crangon crangon*). Accordingly, a series of two research cruises were conducted in September 2022 and April 2023 in the German Wadden Sea on-board the RV "Solea".

During the fishing trials, the sorting efficiency of the standard sieve-net was tested and compared to I) the letterbox device and II) different grid designs varying in size, construction material and bar spacing. As a result, lightweight grids made of plastic material and bar spacing between equal or below 16 mm yielded the best bycatch separation rates among the different BRD tested (Figure 6.1).

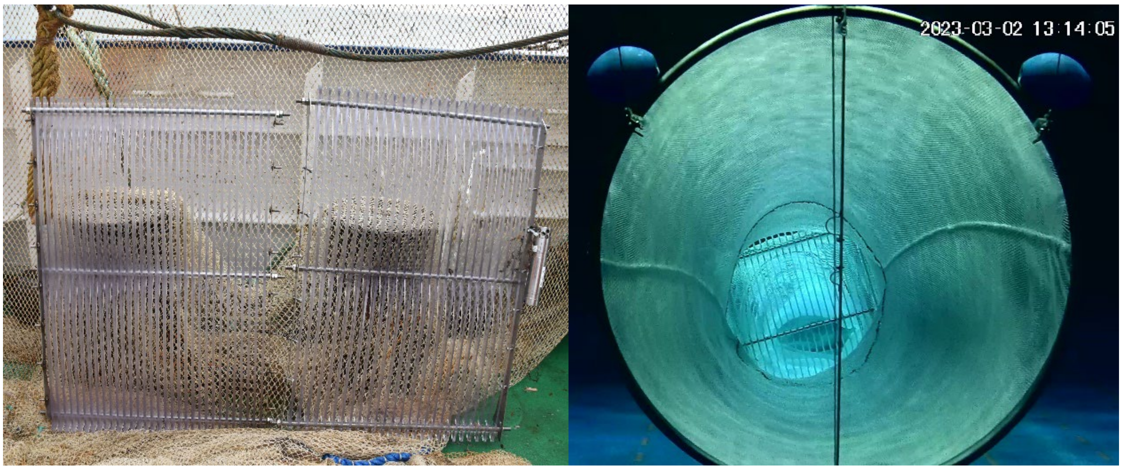

Figure 5.1: Plastic grids as bycatch reduction device. Left: Plastic grids with different bar spacing as tested in April 2023; Right: Test of plastic grid in flume tank.

Using the plastic grids, catch losses of marketable shrimp (>50 mm) were comparable to losses produced when using standard sieve-nets. Therefore, the recent sea trials revealed the potential of plastic grids as alternative to sieve-nets. Further investigations in commercial conditions and subjected to potential clogging events due to the presence of seagrass in the fishing grounds are being planned.

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Hreinsson E., Karlsson H., Gudmundsson G., Jonsdottir H., Thorhallsson T. (2018). Catching Northern Prawn without benthic contact. Symposium on the Light session and the Topic Group Lights: ICES-FAO Working Group on Fishing Technology and Fish Behaviour. June 4–8,Hirtshals, Denmark

Annex 1: List of participants 2023

Name	Institute	Country (of institute)	Email
Beier, Ulrika	Wageningen University & Research	The Netherlands	ulrika.beier@wur.nl
Encendencia, Arlene	The Flanders Research Institute for Agriculture, Fisheries and Food	Belgium	arlene.encendencia@ilvo.vlaanderen.be
Günther, Claudia	University of Kiel - Research & Technology Centre West Coast	Germany	guenther@ftz-west.uni-kiel.de
Hünerlage, Lara Kim	Thünen-Institute of Sea Fisheries	Germany	kim.huenerlage@thuenen.de
Lanssens, Thomas	The Flanders Research Institute for Agriculture, Fisheries and Food	Belgium	thomas.lanssens@ilvo.vlaanderen.be
Mosegaard, Henrik	DTU Aqua, National Institute of Aquatic Resources	Denmark	hm@aqua.dtu.dk
Örey, Serra	Thünen-Institute of Sea Fisheries	Germany	serra.oerey@thuenen.de
Pedersen, Eva Maria	DTU Aqua, National Institute of Aquatic Resources	Denmark	emp@aqua.dtu.dk
Raat, Heleen	The Flanders Research Institute for Agriculture, Fisheries and Food	Belgium	heleen.raat@ilvo.vlaanderen.be
Schulze, Torsten	Thünen-Institute of Sea Fisheries	Germany	torsten.schulze@thuenen.de
Stepputtis, Daniel	Thünen-Institute of Baltic Sea Research	Germany	daniel.stepputtis@thuenen.de
Respondek, Georg	Institute of Marine Ecosystem and Fishery Science	Germany	georg.respondek@uni-hamburg.de
van Kooten, Tobias	Wageningen University & Research	The Netherlands	tobias.vankooten@wur.nl
van Opstal, Mattias	The Flanders Research Institute for Agriculture, Fisheries and Food	Belgium	mattias.vanopstal@ilvo.vlaanderen.be
van Vlasselaer, Jasper	The Flanders Research Institute for Agriculture, Fisheries and Food	Belgium	jasper.vanvlasselaer@ilvo.vlaanderen.be

Annex 2: Resolutions

2021/FT/EPDSG05 The **Working Group on *Crangon* fisheries and life history** (WGCRAN), chaired by Lara Kim Hünerlage, Germany, and Eva Maria Pederson, Denmark will work on ToRs and generate deliverables as listed in the table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2022	21–23 June	Bremerhaven, Germany	Interim report and e-evaluation	
Year 2023	13–16 June	Oostende, Belgium	Interim report and e-evaluation	
Year 2024	18–20 June	Lyngby, Denmark	Final report by August 2024 to SCICOM	

ToR descriptors

ToR	Description	Background	Science Plan Codes	Duration	Expected Deliverables
a	Data collection of the status of the *Crangon* stock.	Report and evaluate population status indicators like recent landings and effort trends in the brown shrimp fisheries. Generate a standardized lpue time-series and provide a detailed description of the process of collecting the dataseries effort, landings & lpue for WGCRAN.	1.1; 2.1	year 1,2,3	A time-series analysis of the standardized stock indicators will be delivered by all WGCRAN members within the annual report(s)
b	Compilation of Logbook information & VMS analysis	To combine VMS, landings and effort data to develop a spatial indicator of shrimp distribution based on LPUE and to monitor regional distribution and regional shifts in fishing effort.	2.1; 2.4; 3.5; 5.4	year 1,2,3	Results will be presented in the annual report(s)
c	Development of decision-support tools for brown shrimp harvesting	To develop and evaluate brown shrimp-specific management decision-support tools to evaluate strategies on how to sustainably and efficiently harvest the brown shrimp stock.	2.1; 2.2; 5.1; 5.4 6.1	year 1,2,3	Results will be presented in technical reports, summarized in a peer-reviewed paper and included in the annual report(s)
d	Assessment of brown shrimp bycatch	Review the status and results of research on bycatch time-series and	3.1; 3.2	year 1,2,3	Results as well as updates on the development of

		consider the implications for management. Evaluate methods and procedures used on board for collecting data on bycatch. Gather, compile and evaluate information on the onboard and ashore sieving fractions and processes and new national bycatch/discards data from e.g. DCF.			sampling procedures will be presented in the annual report(s)
e	Analysis of spatio-temporal trends of survey based stock indicators	Analysis of German, Belgian and Dutch scientific survey data to assess spatio-temporal trends of survey based stock indicators (e.g. biomass, length distribution, mortality); Ground-truthing of VMS derived lpue estimates.	3.1; 3.2	year 1,2,3	Results will be presented in the annual report(s)
f	Overview of Legislation, Law and Management	Information on national legislation, laws and management concerning the brown shrimp fisheries in the whole North Sea will be synthesized (e.g. Natura 2000, MSC process, landing obligation,...).	7.1	year 1,2,3	An overview and update of relevant information on legislation, law and management will be included in the annual report(s)
g	Overview of ongoing research	Present and review ongoing brown shrimp research in the ICES Area (impact studies, development of fishing gears, life cycle studies...) aiming at supporting international collaboration as well as evaluating management implications.	6.1	year 1,2,3	The summaries of updates on ongoing research will be included in the annual report(s)

Summary of workplan

Year 1	Stock status indicators will be updated and harmonized between countries (ToR a). German and Dutch survey data will be analysed and reported, Belgian data will be included in the analyses (ToR e). Data used for the compilation of manuscripts in support of ToR b and c will be made available. Information and updates on national legislation, laws and management concerning the brown shrimp fisheries will be summarized (ToR d and f). New information generated from ToR g will be reported.

Year 2	Stock status indicators will be updated and harmonized between countries (ToR a). German, Belgian and Dutch survey data will be analysed and reported (ToR e). Data used for the compilation of manuscripts in support of ToR b and c will be made available. Information and updates on national legislation, laws and management concerning the brown shrimp fisheries will be summarized (ToR d and f). New information generated from ToR g will be reported.
Year 3	Stock status indicators will be udated and harmonized between countries (ToR a) as well as German, Belgian and Dutch survey data will be analysed and reported (ToR e). Data used for the compilation of manuscripts in support of ToR b and c will be made available. Information and updates on national legislation, laws and management concerning the brown shrimp fisheries will be summarized (ToR d and f). New information generated from ToR g will be reported.

Supporting information

Priority	*Crangon* fisheries are economically important with landings value ranking this species among the top three species caught from the North Sea. The priority of WGCRAN is to understand the interactions between the brown shrimp population (structure and abundance) and human behaviour (mainly fishing effort), the environment, and the ecosystem. One important aspect is and will be the monitoring, investigation and development of population status indices. WGCRAN is the only expert group to evaluate the Brown Shrimp Fisheries Management Plan which was developed by the industry in the course of the MSC certification.
Resource requirements	The research programmes that provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The group is normally attended by some 10 members and guests.
Secretariat facilities	Standard EG support.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	WGCRAN aims at a permanent linkage with ACOM after year 2 when sound and proven stock indicators and tools to evaluate management strategies have been developed (ToR a, b, c).
Linkages to other committees or groups	There is a linkage to WGBEAM through the international scientific surveys (DFS & DYFS). WGINOSE by providing data for the integrated assessment. WGSAM as the SMS key runs will be used to estimate natural mortality of brown shrimp. Members of WGCRAN are also members in these groups.
Linkages to other organizations	CWSS = Common Wadden Sea Secretariat; TMAP = Trilateral Monitoring and Assessment Programme; RCM – NSEA

Annex 3: Plans for WGCRAN 2024

Due to problems with timely delivery of VMS data to ICES, the associated analyses were further postponed to a working group in autumnof 2023.

A focus of the upcoming WGCRAN meeting will be the implementation of the new common workflow for processing stock biological status indicators as well as the inclusion of data on swept-area estimates collected before 2014 (ToR e). Furthermore, it is planned to reintroduce the biomass production estimation according to Tulp *et al.* (2016). To this end, an R-code will be included in the common workflow.

As part of ToR c (Development of Decision Support Tools), further discussions are planned on the incorporation of the different population model approaches.

References

Tulp I., Chen C., Haslob H., Schulte K., Siegel V., Steenbergen J., Temming A., Hufnagl M. (2016). Annual brown shrimp (*Crangon crangon*) biomass production in Northwestern Europe contrasted to annual landings. ICES Journal of Marine Science, 73(10), 2539-2551. https://doi.org/10.1093/icesjms/fsw141