WORKING GROUP ON CRANGON FISHERIES AND LIFE HISTORY (WGCRAN; outputs from 2021 meeting)

VOLUME 4 | ISSUE 14

ICES SCIENTIFIC REPORTS

RAPPORTS SCIENTIFIQUES DU CIEM

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
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ISSN number: 2618-1371

ICES Scientific Reports

Volume 4 | Issue 14

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Recommended format for purpose of citation:

ICES. 2022. Working Group on Crangon Fisheries and Life History (WGCRAN; outputs from 2021 meeting).
ICES Scientific Reports. 4:14. 77 pp. http://doi.org/10.17895/ices.pub.10056

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i Executive summary

The ICES Working Group on Crangon Fisheries and Life History (WGCRAN) examines the various interactions of the brown shrimp to better understand the species.

Stock status indicators were deduced from scientific surveys and indicated (1) a high shrimp biomass in 2018 compared to the years before and after, (2) a lower fraction of large shrimp compared to previous years, especially in 2019 and 2020, and (3) an above-average total mortality in 2019. North Sea landings were exceptionally high in 2018, but below average in 2019 and 2020 when compared to the mean of the last two decades. Total effort in 2018 was above average, but a distinct effort reduction occurred in the following years due to storage and processing bottlenecks in the industry.

Average Landing Per Unit Effort (LPUE) in 2018 was almost twice as high as in 2017, the year with the lowest value of the times-series. In the following years LPUE decreased by about 30%. The high LPUEs in 2018 were supported by a strong shrimp cohort entering the fishery in autumn 2018. LPUEs in the first half of 2019 were still generated by the overwintering 2018-cohort. These high LPUE values, were followed by moderate and below-average values in 2020, with Germany and Denmark showing the lowest values. To ensure standardized effort data and investigate spatial patterns, Vessel Monitoring System (VMS) and logbook data were analysed. Here, LPUEs showed a significant negative trend in the first quarter for all regions, with the steepest decrease in the North. Up to 86% of the variability in summer landings in German and Danish waters could be explained by the effort in the preceding winter months in two southern areas. Altogether this hints toward a possible impact on the following recruitment by excess fishing effort in winter.

Existing and planned measures of the self-management were evaluated and tested. Undersized shrimp in catches decreased after the introduction of the self-management, suggesting a positive effect of mesh size increase on the population structure. The Harvest Control Rule failed to protect the poor stock in the Northern region in 2016 and 2017, mainly because reference values are too low and because higher catches in the southern regions managed to keep the mean LPUE just above the reference values. National sampling campaigns started to quantify bycatches and test the "de minimis" exemption in the brown shrimp fishery.

ii Expert group information

Expert group name	Working Group on Crangon Fisheries and Life History (WGCRAN)
Expert group cycle	Multiannual
Year cycle started	2019
Reporting year in cycle	3/3
Chair	Claudia Günther, Germany
Meeting venue(s) and dates	8–10 October 2019, IJmuiden, the Netherlands; 11 participants
	18–20 August; 9–10 November 2020, online meeting; 12 participants
	28–29 September; 16 December 2021, online meeting; 15 participants

1 Extended summary

The Working Group on Crangon Fisheries and Life History (WGCRAN) objective is to understand population dynamics and factors influencing the stock and the individual. A central goal is to establish a biological basis for advice and to identify suitable ways for sustainable management.

Brown shrimp stock status indicators were deduced from scientific surveys (DFS, DYFS) and indicated (1) a high shrimp biomass in 2018 compared to the years before and after (swept-area estimates), (2) a lower fraction of large shrimp compared to previous years, especially in 2019 and 2020, and (3) an above-average total mortality in 2019.

Annual statistics in the North Sea area showed exceptionally high landings in 2018 (> 45 000 tons), accounting to the highest landings of the times-series. In the following years 2019 and 2020, landings were below 30 000 tons (slightly higher than 2016 and 2017) and thus again lower compared to the period from 2003 to 2015. The largest share of brown shrimp during the last three years was landed by the Netherlands (>50%), followed by Germany (> 30%), Denmark (> 5 %), United Kingdom (< 3%), Belgium (< 3%), and France (< 1%). Total fishing effort in the North Sea reached a peak in 2016 and was since than slightly decreasing: In 2018, effort was little less than in 2016, but a distinct reduction occurred in 2019 due to storage bottlenecks in the processing industry. In 2020, with the beginning of the covid-19 pandemic, effort slightly increased but was still reduced due to a shortage in shrimp processing (pealing).

Average North Sea wide Landing Per Unit Effort (LPUE) in 2018 was almost twice as high as in 2017, which was the year with the lowest value of the times-series. In the following years (2019 and 2020), LPUE decreased to about 30% of the value of 2018 in 2020. The high LPUE in 2018 was supported by a strong shrimp cohort entering the fishery in autumn 2018. LPUE in the first half of 2019 was still generated by the overwintering 2018-cohort. These high LPUE values, which were the highest in the times-series of the Netherlands, were followed by moderate and below-average values in 2020, with Germany and Denmark showing the lowest values. However, during a check of German effort data, inconsistencies in the times-series have been uncovered and this issue was added to the working group's future agenda. Thus, German effort/LPUE data should be interpreted with care.

For the first time the working group analysed Vessel Monitoring System (VMS) and logbook data from the main North Sea fishing fleet (including the Netherlands, Germany, and Denmark). Compared to the annual analysis of national landings and effort statistics, this approach ensured standardized effort data between nations and enabled a spatial examination of landings and effort data from 2009 onwards. LPUE showed a significant negative trend in the first quarter for all regions, with the steepest decrease in the northern regions. Up to 86% of the variability of the following summer landings in German and Danish waters could be explained by the effort in the preceding winter months in two southern areas (around Dutch and German East Frisian Islands). Altogether this hints toward a possible impact on the following recruitment by excess fishing effort in winter.

In the context of landings obligations, national sampling campaigns started in the Netherlands, Germany and Denmark to quantify bycatches and test the "de minimis" exemption in the brown shrimp fishery. The working group provided a platform for exchange and alignment.

Milestones of the self-management were documented and existing and planned management measures evaluated. An initially planned stepwise mesh-size increase from 20 mm (and smaller) to 26 mm to reduce growth overfishing (and catches of small/undersized shrimp) stopped at 24 mm, and due to rounding up decimals and adding of an uncertainty margin, the actual mesh size used in the fishery can be even smaller. Nevertheless, DCF data showed a decrease of undersized shrimp in catches after the introduction of the self-management, suggesting a positive effect of this measure on the population structure. New estimates of mortality of discarded shrimps were higher than previously assumed and support the management measure of mesh size increase as undersized shrimp may already escape under water. New growth data indicate a lack of density dependence in growth rates. This suggests that shrimp escaping the larger meshes early in the season may actually – as predicted by the Y/R-model - increase catches later in the season, even though stock biomass is somewhat increased as a side effect. Having similar selection characteristics like a 26 mm cod-end, a selection grid with 6 mm bar width equipped to a fishing gear with 22 mm in the cod end would be a useful alternative. As another alternative, seasonal closures were simulated and a similar effect as mesh size increase to 26 mm would be achieved with one month closure in winter (February) to protect egg-bearing females and an additional month closure in summer (July /August) when the wave of small shrimp from the new cohort enters the fishery. The Harvest Control Rule failed to protect the poor stock in the Northern region in 2016 and 2017, mainly because reference values are too low and because higher catches in the southern regions managed to keep the mean LPUE just about the reference values. A regional HCR is discussed taking into account different stock sizes in Southern and Northern areas of the North Sea.

Lists of outcomes and achievements per ToR

a) Stock Status indicators

See section 2

b) Logbook information & VMS analysis

Respondek G., Günther C., Beier U., Bleeker K., Pedersen M., Schulze T., Temming A. 2022: Connectivity of local sub-stocks of *Crangon crangon* in the North Sea and the risk of local recruitment overfishing. Journal of Sea Research 181: 102173 (https://doi.org/10.1016/j.seares.2022.102173)

c) Decision-support tools

Respondek G., Nowicki M., Günther C., Temming A. 2018. Scientific guidance and consulting for the brown shrimp management plan during the MSC-certification process – Part II. Project Report, University Hamburg

Temming A., Bönisch A., Hagen W., Brenneken C., Dänhardt A., (submitted): Unexpected high discard mortalities of juvenile brown shrimp (*Crangon crangon*) in the North Sea shrimp fishery.

d) New gears

Veiga-Malta T., Feekings J.P., Frandsen R.P., Herrmann B., Krag L.A. 2020. Testing a size sorting grid in the brown shrimp (*Crangon Crangon* Linnaeus, 1758) beam trawl fishery. Fisheries Research 231: 105716 (https://doi.org/10.1016/j.fishres.2020.105716)

Related publications:

Santos J., Herrmann B., Stepputtis D., Günther C., Limmer B., Mieske B., Schultz S., Neudecker T., Temming A., Hufnagl M., Bethke E., Kraus G. 2018. Predictive framework for codend size selection of brown shrimp (*Crangon crangon*) in the North Sea beam-trawl fishery. Plos One (https://doi.org/10.1371/journal.pone.0200464)

Günther C., Temming A., Santos J., Berkenhagen J., Stepputtis D., Schultz S., Neudecker T., Kraus G., Bethke E., Hufnagl M. 2021 Small steps high leaps: Bio-economical effects of changing codend mesh size in the North Sea Brown shrimp fishery. Fisheries Research 234: 105797 (https://doi.org/10.1016/j.fishres.2020.105797)

e) Bottom impact of the fishing practices

Quirijns, F., Beier, U., Deetman, B., Hoekstra, G., Mol, A., & Zaalmink, W. 2021. Beschrijving garnalenvisserij: Huidige situatie, knelpunten en kansen. (Wageningen Marine Research rapport; No. C049/21). Wageningen Marine Research. https://doi.org/10.18174/547410

f) Research on bycatch

See section 7

g) Life cycle dynamics of brown shrimps

Related publications

Sharawy Z. Z., Hufnagl M., Temming A. 2019. A condition index based on dry weight as a tool to estimate in-situ moult increments of decapod shrimp: Investigating the effects of sex, year and measuring methods in brown shrimp (*Crangon crangon*). Journal of Sea Research 152: 101762 (https://doi.org/10.1016/j.seares.2019.05.004)

Hünerlage K., Siegel V., Saborowski R. 2019. Reproduction and recruitment of the brown shrimp *Crangon crangon* in the inner German Bight (North Sea): An interannual study and critical reappraisal. Fisheries Oceanography 28: 708-722 (https://doi.org/10.1111/fog.12453)

h) Survey data

i) Information exchange

See section 10

j) Information on ongoing research

Related publications

Schadeberg, A., Kraan, M., & Hamon, K. G. (2021). Beyond metiers: social factors influence fisher behaviour. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsab050

Goti-Aralucea, L., Berkenhagen, J., Ralf, D., & Sulanke, E. (2021). Efficiency vs resilience : The rise and fall of the German brown shrimp fishery in times of COVID 19. 133(August). https://doi.org/10.1016/j.marpol.2021.104675

Döring, R., Berkenhagen, J., Hentsch, S., & Kraus, G. (2020). Small-Scale Fisheries in Germany: A Disappearing Profession? In J. J. Pascual-Fernández, C. Pita, & M. Bavinck (Eds.), Small-Scale Fisheries in Europe: Status, Resilience and Governance (pp. 483–502). https://doi.org/10.1007/978-3-030-37371-9_23

2 Stock status Indicators (ToR a)

2.1 General development and overview

The total actual number of vessels targeting brown shrimp in the North Sea are about 500. In the national monthly statistics, the maximal number of active vessels in 2020 contributing to landings were 181 in the Netherlands, 173 in Germany, 25 in Denmark, 15 in Belgium, 34 in France and 48 in the United Kingdom. However, there are more licences than vessels contributing in 2020 (see 10.2). According to the MSC surveillance report from 2019 (Addison *et al.* 2019), 422 vessels were listed as active in the MSC-certified part of the fishery (which should cover nearly the whole fleets of Germany, Netherlands, Belgium and Denmark).

Since 1960s total yearly landings of brown shrimp increased and annual landings were steadily above 30 000 tons from 2003 to 2015 (Figure 1). In the following two years, 2016 and 2017, they dropped to below 24 000 tons. In 2018, exceptionally high quantities were landed (45 601 tons), accounting to the highest landings of the times-series. Total landings in 2019 were again low with 26 122 tons, and only slightly higher than in the poor year of 2017. Landings in 2020 were higher than in 2019 (28 823 tons).

The main national shares of total landings have changed over time (Figure 2); until the 1990s, Germany accounted for most landings, but in subsequent decades, the Netherlands achieved the most. From 2018 to 2020, the largest share belongs to the Netherlands (56.9 %), followed by Germany (32.4 %), Denmark (5.6 %), UK (2.6 %), Belgium (2.3 %) and then France (0.3 %).

Total North Sea effort steadily increased during the last decades and reached a maximum in 2016 with 14 million horsepower days at sea. Since then, effort decreased gradually counting 12 Mio horsepower days at sea in 2018. A distinct reduction in effort occurred 2019 (to about 9 Mio. hpdays) due to storage bottlenecks in the processing industry. Effort in 2019 was the second lowest in the last twenty years (lowest effort in 2011). In 2020, with the beginning of the covid pandemic, effort slightly increased but was no longer as high as before 2018.

Average effort over the last twenty years was highest in the Netherlands and Germany, followed by Denmark, UK, Belgium, and France (Figure 3). Inconsistencies in the effort times-series have been uncovered in the German data, the origin of which has not yet been conclusively determined. However, it is becoming apparent that data prior to 2012 are subject to a different calculation routine than later data and should therefore be interpreted with caution.

The general patterns of landings per unit effort of the main fleets (NL, GER, DK) are comparable and all show a peak in 2011 (Figure 4). In the following years, a general decreasing trend can be observed for Germany and Denmark, but not for the Netherlands, where LPUEs of 2018 and 2019 were the highest of the times-series. On average, the Dutch LPUE was 80% higher than the Danish, and 45% higher than the German LPUE between 2018 and 2020. Even if not outstanding like the Dutch LPUE, the German and the Danish fishery had higher LPUEs compared to the years before due to the strong recruitment of shrimp in 2018. However, in the Danish fishery, this peak in LPUE occurred in 2019 because the Danish fleet was mainly fishing on the overwintering strong shrimp cohort from 2018 in the first half of the year. Belgium's average LPUE in the last 10 years was less than half (1.2 kg/hpdays) of the average LPUE of the Dutch, German, and Danish fleet (3.4 kg/hpdays, 2.5 kg/hpdays and 3.2 kg/hpdays). Compared to the main fleet (NL, GE, DK), the average LPUE of the UK fleet is also lower (0.7 kg/hpdays) The reasons for this difference may be multiple (e.g., longer distances to the fishing location, lower shrimp density in the Belgian fishing area, different effort calculations) and have not yet been investigated.

National landings and effort data are important indicators giving insights into the long-term development, interannual variation and seasonal patterns of the fishing fleet. However, weaknesses of this times-series were changes and differences in the reporting of effort (e.g. German times-series) and the lack of spatial resolution. Furthermore, fishing vessels often cross borders, thus impede a straightforward interpretation of national times-series. To overcome these problems analyses of logbook and VMS were performed and reported in ToR b.

2.2 Landings and effort statistics 2018–2020

National landings

Dutch landings between 2018 and 2020 exceeded 15 000 tons (Figure 5). Thereby, landings in 2019 and 2020 were again higher than in the year with the lowest landings of the last decade (2017). The share of Dutch shrimp landings in total landings has increased from about 30% in the 1980s to almost 60% (2020). In parallel, landings increased over time, but in recent years (starting with 2014) this trend is only sustained by the exceptionally strong year 2018.

German landings were over 15 000 tons in 2018, nearly double the 2019 landings (Figure 5). In 2020, German landings were slightly higher than the previous year, but still low compared to the years prior to 2015 and only slightly higher than the year with the lowest landings in the last ten years (2016). The German share of total landings has been above 30% for the last three years, continuing a declining trend that started with 50% in the early 1980s.

In Denmark, landings in the exceptional year 2018 were about 3000 tons, equivalent to the annual landings between 2009 and 2014 (Figure 5). However, landings in the subsequent years 2019 and 2020 were the lowest in the last 25 years. After peaking in 2006, Danish landings and Denmark's share of total North Sea landings began to decline. Both landings and share have more than halved since then (to less than 1500 t and 5%, respectively).

Belgian landings decreased from 2018 to 2020 and the share of total landings decreased from 3% to 2% during this period (Figure 6). However, there is no strong trend in landings or in the share of total landings over the last 20 years, if at all then a positive one.

Landings from the UK exceeded 1000 tons in 2018 and 2020, while they were below 500 tons in 2019 (Figure 6). The share of total landings has been below 4% for the last three years. Landings from the UK have fluctuated widely in recent decades, with no discernible trend.

The French Channel fishery has landed less than 150 tons since 2002 and accounted for less than 0.5% of total landings between 2018 and 2020 (Figure 6).

Seasonal national patterns of landings, effort and LPUE

The national seasonal patterns of landings, fishing effort and LPUE in 2018, 2019 and 2020 are discussed below and compared with the average pattern over the last ten years (2007–2017).

The seasonal patterns of landings and LPUE of the main fishing nations, the Netherlands (Figure 7) and Germany (Figure 8), reflect the occurrence of one main recruitment wave (e.g. Temming *et al.* 2017): the landings peak in autumn is supported by the cohort entering the fishery in summer. The overwintering shrimps of this cohort ensure landings in the first half of the next year.

The exceptionally high Dutch landings in 2018 (Figure 7) were based on catches in the second half of the year that were well above average (2007–2017). With the exception of May, June and July, fishing effort was below average, resulting in a Dutch autumn peak in LPUE that was three times higher than the average of the last ten years. The strong shrimp cohort of 2018 that supported the high autumn values of landings and LPUE also provided above-average LPUE values in the first half of the following year (2019) and disappeared thereafter. Dutch fishing effort in 2019 was well below average in the first three quarters and in February, April, May and June

2020. The LPUE values in the second half of 2019 and the entire following year were very close to the mean value of the years 2007–2017.

The seasonal average patterns in Germany (2007–2017) are similar to those in the Netherlands, with the same magnitude of landings and effort (and LPUE) from March to July (Figure 8). However, the peak in German landings in autumn is not as high as the Dutch peak (about 30% lower), and landings and effort in winter were both about 70% lower. As in the Netherlands, the strong cohort of 2018 led to above-average German landings in the second half of 2018. In contrast to the Dutch decline in fishing effort and exceptionally high LPUE in autumn 2018, German fishing effort was similar and LPUE was twice as high as the average (2007–2017). The German LPUE in the first half of 2019 was still above average carried by the overwintering 2018-cohort. LPUE in the following autumn (2019) was well below average and remained below average in 2020, with the exception of July and August, which were similar to the mean of 2007–2017.

Apart from the fact that landings and fishing effort were significantly lower, the seasonality of the Danish patterns was not as pronounced as in Germany and the Netherlands (Figure 9). Average landings were below 200 tons in winter (December-March) and August and above 300 tons in April and autumn (October-November). Like landings, mean Danish effort (2007–2017) in winter month (December to February) is lower compared to the rest of the year. Both landings and effort fluctuated around the mean in 2018, but were below average in 2019 and 2020, with the exception of the first quarter. LPUE was below average in 2018 in the first half of the year and above average in the second half of the year due to the large 2018 cohort. Danish LPUE was above average in the first half of 2019 and well below average in the second half. In 2020, the LPUE was average in the first half of the year but again well below average in the second half.

Belgian landings (2007–2017) were less extensive, but their seasonality was similar to that of the Netherlands: Landings were low in the first half of the year and peaked in the second half (Figure 10). The Belgian autumn peak in 2018 was twice as high as the mean (2007–2017) and was above average in the first half of 2019, but below average in the second half of 2019 and 2020. The average effort (2007–2017) increased in the first half of the year and peaked in the autumn. Effort was broadly above average in 2018, below average in the third quarter of 2019 and above average in the second quarter of 2020. The average Belgian LPUE (2007–2017) was almost consistently low from January to June and showed a peak in September/October. In the first half of 2018, the LPUE is below average and in the second half above average, due to the strong cohort in 2018. As in the Netherlands, the Belgian LPUE was above average in the first half of 2019 (overwintering 2018 cohort), but average in the second half. In 2020, the values were consistently below average.

The average landings pattern and magnitude in the UK (Figure 11) was similar to Belgium having a pronounced peak in autumn (Figure 10). Effort fluctuates slightly between 2007 and 2017, with a maximum in autumn more than double the minimum in June/July. This results in a constant average LPUE in the first half of the year and a peak in the second half. Peak landings in autumn were above, below and above the average in 2018, 2019 and 2020 respectively. Fishing effort was below average in 2019 and the first half of 2020. UK LPUE was above average in autumn 2018, and in the first half of the year 2019. In autumn 2019 it was far below average, but similar to the mean in the first half of 2020 followed by a peak above average in autumn.

French landings in the English Chanel were below 30 tons per month (Figure 12). Average Landings, effort and LPUE (2007–2017) exhibited two peaks, one in the first and one in the second half of the year. All values fluctuate between 2018 and 2020, but the very low landings and LPUES in the second half of 2019 are noticeable (comparable to UK).

2.3 Biological stock status indicators

Fraction of large shrimps

The fraction of shrimps > 60 mm during 1955–2020 caught in the different surveys conducted during autumn showed a decreasing trend over time until about 1990 (Figure 13). However, the decreasing overall trend may partly be explained by different data series, where bycatch data (Büsum and Ost-Friesland) were used 1955–1996 and survey (DFS and DYFS) time-series started later within the included time period. The proportion of large shrimp decreases in both bycatch times-series, with the proportion of shrimp > 70 mm stabilizing in the 1990s. The share of shrimps > 60 mm of scientific surveys (DFS and DYFS) showed a moderately increasing trend from 1990 until about 2010, during which period it varied from 10 to 25% (Figure 13). Since 2016, survey data indicate that the fraction of large shrimp is decreasing. In the DFS survey, the fraction of large shrimp was exceptionally low during 2015–2017, and in 2019 and 2020 the fraction of large shrimp was comparatively low in both surveys.

Mortality

After a continuous increase in total annual mortality (Z) during 1955–1995, there has been strong annual variation (Figure 14, methods see Hufnagl *et al.* (2010)). From 1994, there was a decreasing trend until 2008, thereafter there was no clear trend until 2019, when the estimated total mortality was similar to the previous maximum level in the early 1990s. However, in 2020 the mean estimated annual total mortality (Z) was 5.8 y^{-1}, i.e., close to the mean during the whole period (5.6 y^{-1}).

Swept-area biomass estimate

A swept-area biomass index of *Crangon crangon* combining the Dutch DFS and German DYFS was used in order to compare stock indices with annual landings data (Tulp *et al.* 2016). In Tulp *et al.* (2016) total biomass production was also calculated based on the swept-area estimate of brown shrimp biomass. In this report we include the swept-area estimate (Figure 15), not the full biomass production estimate (taking mortality estimates as well as various assumptions into account). The swept-area biomass index has since 2010 varied from approximately 7 to 14 thousand tonnes. In 2020, swept-area biomass was estimated to approximately 10 thousand tonnes, equivalent to the average during 2010–2020 (Figure 15).

2.4 Time-series of natural and fishing mortality (M:F)

The M:F times-series of Roundfish Area 6 from Temming and Hufnagl (2015) was extended till 2019. Natural mortality M refers the consumption of brown shrimps (larger 50 mm) by their most important predators cod (*Gadus morhua*) and whiting (*Merlangius merlangus*). The yearly consumption of the two predators was based (1) on the age-based stock assessment of the SMS model (WGSAM, North Sea Key Run, 2020) for total numbers of predators, (2) IBTS data for the spatial distribution of the predators, and (3) the ICES stomach sampling projects (1981, 1985, 1986, 1987, and 1991) and laboratory experiments by Temming and Herrmann (2003) for the consumption of size-specific brown shrimp per predator species, age class, and quarter (for details see Temming and Hufnagl, 2015). In the last decade, commercial sized shrimp predation has been dominated by whiting, while the influence of cod has been negligible (Figure 16). Despite strong fluctuations in recent years, the dominance of fishing mortality over natural mortality continued as described by Temming and Hufnagl (2015).

2.5 Consistency check of catch and effort times-series

Each year the Netherlands, Germany, Denmark, France, Belgium and the UK are asked to provide catch and effort data from their brown shrimp fisheries. But the delivered data formats vary among by the countries and sometimes change over the years. Catch is given in tons or kilogram. Effort is given in horsepower days at sea (HPDAYS) or in kilowatt days at sea (KWDAYS) and days at sea are given in hours at sea divided by 24 or in calendar days at sea. Furthermore, the units of the data provided by the countries for WGCRAN are not always included in the data files. Some countries, such as e.g. Denmark, report each year a whole times-series, while other countries, such as e.g. Germany, report each year only the actual data of the previous year, and some countries changed the amount of reported years over time (Table 1).

Therefore, the updated landings and effort data delivered yearly by the countries were checked during WGCRAN Meeting in 2019 for consistency with the older times-series before merging old and new data. Since 2020, this consistency check of old and new landings and effort data was implemented into the annual standard data analysis of the stock status indicators.

Minor differences of older and newer times-series of landings and effort data were assumed to be caused by supplement reports, quality checks and corrections within the different countries. The newest data updates were then used. Major differences of older and newer times-series were only observed for the UK data. While days at sea should be calculated from hours at sea divided by 24, the UK started in 2019 to report instead days at sea calculated as whole calendar days. This results in an overestimation of days at sea compared to previous years (Figure 17) and the other countries. Older data of HP days at sea (HPDAYS), used in the WGCRAN reports from 2015 to 2018, were observed to be unreliably high (Figure 17). The reported HPDAYS of the UK fleet reached in some years almost 2.5 million HPDAYS according to the older datasets, while the largest fleet, namely the Dutch fleet, reached only ca. 800 000 HPDAYS. This error was corrected in 2019 and did not occur since. The overestimation of the days at sea in the new data sets due to the new calculation method is a minor problem compared to the wrong HP days at sea in the older data sets.

A consistent times-series of monthly and yearly vessel numbers is still missing, because either monthly or yearly vessel numbers are reported. Monthly vessel numbers are available for the UK and Denmark (2000–2020), Belgium (2004–2020), Germany (2017, 2018, and 2020), and the Netherlands (only 2018 and 2019). Yearly numbers of vessels were reported by France (2000–2019) and the Netherlands (2020).

2.6 Conversion factor from boiled to fresh weight

For technical reasons, catches cannot be weighed directly at sea. Due to its fast perishability, *Crangon crangon* have to be processed as soon as possible after catch. After the first sorting, the catches are directly boiled at sea. Accordingly, landed weight of catches correspond to boiled weight of the product. For back calculation of the fresh biomass caught, different conversion factors are used by different countries (i.e. Belgium: 1.25; Denmark: 1.0; France: 1.10; Germany, Netherlands & Portugal: 1.18; FAO 2000). Accordingly, as in the Netherlands and Portugal, the conversion factor used for back calculations in the German shrimp fishery corresponded to 1.18. By subsequent measurements on board German shrimp vessels, the accuracy of the factor has been called into question. The debate was strengthened by the fact that the conditions and history of the origin of the conversion factor are largely unknown (albeit cited; e.g. in Tulp *et al.* 2016; ICES 2007). Therefore, the loss of weight of brown shrimp after boiling was estimated in the laboratory at the Thünen Institute of Sea Fisheries (Bremerhaven, Germany). The investigations were based on individual measurements (n=319) and combined with earlier studies from 1995 (n=441). In addition, data on size change (overall length and carapace width) were taken, and the results were distinguished between oviparous and non-egg-bearing specimens. The merged dataset resulted in a conversion factor of 1.07 (n=760; Figure 18).

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3 Logbook information & VMS analysis (ToR b)

3.1 Progress in 2019

For the first time, the working group had access to a full set of spatially resolved landings and effort data including the fleets of the main fishing nations Denmark, Germany, and the Netherlands. A data request to work with logbook and VMS data was send before the working group meeting to national institutions, describing the proposed workflow in detail.

Attached to the data request was a script in R to combine VMS and logbook data based on the “Eflalo” and “Tacsat” format for the years 2009–2018, which filters the data for trips with Crangon landings and then aggregates landings and effort on a c-square level. During the meeting, the datasets from the three nations were combined and maps showing monthly effort and landings were plotted. Additionally, the data were further aggregated based on 10 previously agreed on fishing areas (Figure 13). The original dataset was then deleted, and the aggregated table was kept for further analysis. The printed maps cannot be published in the report due to data privacy issues raised by one party. The aggregated data table was analyzed in detail and results were submitted for publication.

Although official landings statistics do not contain any information where the catch was taken, nationality has often been used as proxy for the location of the fishing activity. A first comparison of spatially resolved data (combined logbook and VMS) with the numbers delivered for official landing statistics (logbook data by nation, see ToR a) shows that this may lead to under- or overestimations of landings and effort (Figure 14): in the period from 2009 to 2018, 37% of landings (from NL, GE, and DK) were made by the German fleet, but 53% were made in the German EEZ. Thus, at least 15% of landings made in German waters were made by Dutch or Danish vessels. On the other hand, 54% of landings came from Dutch vessels, but just 41% stem from the Dutch EEZ. The Danish fleet fished 9% of landings and 6% stem from Danish waters.

This comparison supports previous studies reporting that at least a part of the fleet is highly mobile (e.g., Steenbergen *et al.* 2015) and fishes throughout the distribution area of *Crangon crangon*. Without spatial information on fishing effort and landings, important trends, like those in local LPUEs (Respondek *et al.* 2022) may be missed.

3.2 Progress in 2020

VMS and logbook data compilation at the 2019 meeting based on data that working group members brought from their national institutes with the permit of authorities. Because of the additional workload for the involved national institutions, it was decided to use the data gathered by ICES WGSFD through a yearly data call (ICES 2020).

This data had an additional column indicating the numbers of different vessels per c-square and month, which could be used to prevent areas with less than 3 different vessels from being shown. Based on the results of the 2019 analysis, it was decided to again produce a table with monthly landings and effort data, but this time with a higher spatial resolution including depth classes (Figure 15). Information on species landed is not available in the data gathered by WGSFD, only the total weight landed by the fishing operation. As usually the shrimp vessels fish exclusively on shrimp, it was decided to request the data filtered by the métier “TBB_CRU_16-31” for the years 2009–2020 and the Danish, German, Dutch and Belgian EEZ’s. No other fishery targeting a different species is fishing with this gear in the mentioned area. Although some shrimping vessels may target e.g., flatfish in some fishing trips, the métier of those trips should then be changed.

However, when comparing the total landings compiled from the data call of WGSFD with official total landings data, large discrepancies occurred (Table 1) for the years 2009–2012. The reasons of the differences could not be clarified by the working group, despite a survey of the national data processors (Table 2). Moreover, the most recent data (for 2019) were not available in the data call due to consistency issues with the data delivered through the data call from WGSFD in 2020. It was thus decided not to use this data for further analysis and to wait for the data call in 2021.

3.3 Progress in 2021

In 2021, the working group started another attempt to access landings and effort data collected by ICES WGSFD through the yearly data call in 2021 (ICES 2021). This time, data from 2009 to 2020 were available and delivered through ICES data center. Again, there were large discrepancies in the landings compared to the official landings of *Crangon crangon* from 2009–2012 (Table 3). The far larger landings in the earlier year of the times-series could not be explained, as the routines to compile the data were the same for the full period. When looking at the maps of fishing effort, in some quarters and years there are registered catches far offshore which do not display shrimp fishing effort (Figure 16). Anyhow, those data entries seem to be too less to explain a 50% overshoot in the reported catches. Even if all catches deeper than 25 m are taken out of the dataset, still the years 2009–2012 display catches of 36–67% above the officially reported landings. One likely explanation is a mis-labelling of the métier in the dataset of the data call or a bug in the routine merging the logbook and VMS datasets. It is highly recommended to investigate this issue, as the dataset gathered by WGSFD is basis for work of other ICES working groups. The shrimp fishery represents the by far largest fleet with mobile bottom contacting gear in the Wadden Sea and any under- or overestimation of the effort of this fleet would have major consequences for the anticipated development and state of the ecosystem.

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Science Highlight

The analysis of logbook/VMS data compiled in the meeting 2019 were the basis for a spatial analysis of shrimp landings and effort data from 2009 to 2018. This work is published in Respondek *et al.* 2022.

The Brown Shrimp, *Crangon crangon* supports the fourth most valuable European fishery in the North Sea (EUR 169 million in 2018). The fishing fleets of Germany, the Netherlands and Denmark are responsible for over 90% of the yearly landings.

A new publication stemming from a joint data analysis of the ICES Working Group on Crangon Fisheries and Life History (WGCRAN) indicates not only significantly decreasing abundances of Brown shrimp in the most important hatching months in all important fishing areas, but also hints towards possible impact on the following recruitment by excess fishing effort in Winter.

Despite the high value of the fishery, neither regular advice, EU-wide management of the target species nor regular stock assessments are carried out. Although large advances in the understanding of the life cycle have been made, in specific the assessment of the stock status of the brown shrimp (*Crangon crangon*) has been a challenge for decades. This is to a large part due to the lack of coherent effort data from the international fishery. In addition, biological traits such as the impossibility of age determination, the short life cycle and high predation mortality rates have impaired or complicated analytical assessments.

Brown shrimp females carry their fertilized eggs attached to the body until the larvae hatch. This coupling of the fate of the eggs and the adults presents a risk of recruitment overfishing especially in winter. Added relevance to the effect of the winter fishery comes from new results on the life cycle, which highlight the importance of the winter egg production for the first peak in late summer of adult shrimp. The intensification of the winter fishery due to the shift of even more large vessels from the Dutch flatfish fishery into the shrimp fishery since 1990 has provoked discussions about potential negative effects of the fishery in the Sylt area, at least for the northern regions. Since overall landings increased from an average of about 20 000 t before 1990 to about 30 000 in the subsequent decade, this discussion faded subsequently. The most recent years, however, were characterized by very large variations in the annual landings, especially in the northern regions. Both 2016 and 2017 were very poor years for northern Germany and Denmark and gave new relevance to this topic of winter fishing.

For the first time in 2019, the WGCRAN succeeded to gain access to a full set of spatially resolved landings and effort data including the fleets of the main fishing nations Denmark, Germany and the Netherlands. VMS and logbook data for the years 2009–2018 was aggregated based on 10 previously agreed on fishing areas during the yearly meeting and further analyzed. The results show a significant negative trend in LPUE in the first quarter of the year and for all regions, with the northern regions showing the steepest decrease. Up to 86% of the variability of the following summer landings in various regions could be explained by the effort in the preceding winter months in two southern areas. This is clearly more than previous attempts trying to explain variability in survey abundance of shrimp in German waters with the NAO index of the previous year, winter temperature, river run-off and a predator index leading to 57% explained variance. The strongest correlations and regressions involve the effort in January and February; hence the months before the eggs of the winter period are released. The large female shrimp are concentrated in characteristic areas in those month, showing a certain depth preference of 10–20 m. Along the Dutch and East Frisian coasts the relevant depth range is compressed into a narrow area, making potential aggregations quite vulnerable. The mechanism behind our correlation is most likely a reduced spawning stock impacting negatively the subsequent recruitment, as landings in July-August stem from eggs of the previous winter which were released as larvae in March-April. Most surprisingly, the correlations and linear regression of effort in NL-E in winter and LPUE in the following season in Northern Regions are highly significant even though three years with extreme LPUE values are included: 2011, 2016 and 2018. To prevent economic and ecological consequences for the shrimp stock and the fishery, transboundary management measures need to be considered and implemented. Further investigations of migration and drift patterns of brown shrimp are recommended and put on the working group's agenda for the next period. The current research results highlight the importance of access to spatially resolved, coherent fishing effort and landings data for the ICES working groups, a topic which should be put forward in cooperation with ICES data center for the coming years.

4 Decision-support tools (ToR c)

4.1 The Harvest Control Rule (HCR) and regional reference values

One of the existing management measures in the self-management of the shrimp fishery is the implementation of a Harvest Control Rule (HCR) to limit fishing effort in case of unusually low shrimp abundances. The HCR limits weekly fishing effort if the standardized landings per unit effort (LPUE) of the whole fleet falls below a predefined reference value.

A major weakness of the HCR reference values is that they are calculated exclusively from German landings and effort data, whereas the current LPUE values are calculated from all three fleets. As shown in 2018 (ICES WGCRAN 2018), the LPUE is subject to considerable spatial variation. In autumn 2016, this resulted in the monthly LPUE value being above the reference value only due to the high values achieved off the Dutch coast - while the LPUEs off the Danish and German coasts should actually have resulted in an effort reduction This spatial variance of the monthly LPUEs was calculated for the years 2016 (Figure 17) and 2017 (Figure 18), based on Dutch and German logbook data. Here, the monthly LPUE per ICES rectangle was calculated from the summed landings and effort data and related to the reference values of the management plan. The effect described above can be clearly seen: individual areas with high landings influence the LPUE average to such an extent that the monthly mean value (mean LPUE) is above the reference value, although the stock densities in individual ICES rectangles are significantly lower.

This could be prevented by an alternative management approach taking into account spatial variations. For instance, Dutch and German landings and effort data were divided into two regions, one "Southern and one Northern region (see “South” and “North” in Figure 17 and Figure 18, separated by a dashed line)). Separate reference values were then calculated for each region. In deviation from the management plan, the monthly reference LPUEs for each area were calculated from the summed effort and landings data for 2011–2015. For these years, reliable data from logbook entries were available. Those spatial reference values are shown inTable 4.

It is noteworthy that the reference values in the North are higher in the months of January to August than in the South; here again the reference values from September to November are higher. In general, the reference values, which are calculated as averages from 2011 to 2015, are higher than the values in the management plan. It remains to be discussed to what extent a year like 2011 with above-average abundances of *Crangon crangon* should be included in the calculation of the reference values and whether the zoning should follow the example presented here. A final recommendation of a spatial management should a) include the Danish fleet and b) be based on a detailed study of the stock structure and dynamic of the North Sea shrimp. Despite all this, it is clear that in 7 out of 24 months, only one of the two sub-areas would be affected by an effort reduction. In 17 months, the entire fishery would be affected by an effort reduction, compared to 6 months of effort reduction if the reference points from the management plan are applied. This effect was already shown in the 2018 WGCRAN report (ICES WGCRAN 2019); again, calculating the reference levels as recommended by Temming (2013) would have resulted in extensive triggering of HCR. This should be noted in particular as Figure 17 and Figure 18show that from March to May (2016) and February to May (2017) the monthly LPUE in many ICES rectangles is not only below the first (70% of mean LPUE) but already below the fourth reference value (70% of mean LPUE, see Table 4). The management measures implemented in these years were effort reductions to 72 hours at sea per vessel per week in calendar weeks 22 and 23 (2016) and 15 and 16 (2017). Strict implementation of the scientific advice would have meant much stricter effort reductions - possibly associated with a faster recovery of the stock.

4.2 Reaction and compliance to HCR in 2016 and 2017

The Harvest Control Rule has led to effort reductions by the German fleet in three cases so far in 2016 to 2018: in calendar weeks 22 and 23 in 2016, in calendar weeks 15 and 16 in 2017, and in calendar week 16 in 2018. In all three cases, effort was limited to 72 hours at sea per vessel per week. An initial analysis of the German logbook data from those weeks shows widespread compliance with the effort reduction; only a few vessels exceed the 72 hours mark with their weekly effort (Figure 19 and Figure 20). In all years, in the weeks not affected by the limitation, about half of the vessels are above 72 hours per week and about half are below. What is striking is the very sharp drop in effort in the first week of the effort reduction in 2017 (week 15, Figure 20). To a lesser extent, this also occurred in the first week of the reduction in 2016 (week 22, Figure 19). Then in the second week, the effort of most vessels increases again close to the 72 hours mark.

The investigation of fishermen's response to the entry into force of management restrictions is not yet complete; initial indications suggest, for example, that part of the effort reduction is achieved by saving steam time (which counts in the total hours at sea). This would mean that fishing pressure on the total population is reduced to a lesser extent than effort itself. This could also mean a re-distribution of effort from offshore to more coastal areas.

4.3 Potential dormant effort increase

The current MSC regulations allow for an effort increase of the brown shrimp fishing fleets, e.g. by increased numbers of licences, vessel and equipment modernization and an increased fishing duration (also called “dormant effort”). The dormant effort, based on a potential increase of fishing duration, was calculated for the brown shrimp fleets of the Netherlands, Germany, and Denmark. The number of active fishing vessels differs between years; therefore, a hypothetical scenario was calculated. In this scenario, all current MSC participants were assumed to fish actively. Numbers of current MSC participants were provided by the MSC steering committee. This data included 28 vessels in the Danish fleet, 200 vessels in the Dutch fleet and 190 vessels in the German fleet. However, it should be noted that differing numbers of fleet sizes for the German and Dutch fleet exist, e.g. 213 vessels (200 actively fishing) for the German fleet and 220 vessels (198 actively fishing, 22 inactive licenses) for the Dutch fleet (Addison *et al.* 2017). In the scenario, all vessels were assumed to spend as many hours at sea as a reference vessel, which was defined for each fleet separately. The reference vessel was defined as the vessel with the highest yearly effort (in hours at sea) within those vessels that spend less than 4800 hours at sea per year. Only data from 2012 to 2018 were included in the analyses as data for 2019 were only available for the Dutch fleet. In the German fleet this reference vessel spent 4444 hours at sea, in the Danish fleet it spent 4731 hours at sea and in the Dutch fleet 4397 hours at sea. This scenario would result in an effort increase in the German fleet by 126 %, in the Danish fleet by 60 % and in the Dutch fleet by 76 %. The overall effort of the whole MSC fleet could therefore almost double (Figure 26). Although this scenario is hypothetical, the annual changes in effort should be monitored.

4.4 Effects of the mesh size increase from 22 to 24 mm

Based on the results of the CRANNET project, a step-wise increase in mesh size from 20 mm to 26 mm was implemented in the management plan during the MSC certification in 2016. By this measure, small shrimp are spared resulting theoretically in a surplus production and increased landings of commercial-sized shrimp later in the year (Günther *et al.* 2021).

Before increasing cod end mesh sizes from 22 mm to 24 mm, the catch composition of shrimp catches from both mesh sizes were compared via a self-sampling of the fishermen in 2018. Three Dutch, one Danish and one German fisherman provided samples from paired trawls of 22mm and 24 mm in autumn 2018. The classification in commercial and undersized shrimp was achieved by sieving the cooked shrimp with a scientific laser-cut sieving machine with a sieve width of 6.8 mm.

The samples of the 24 mm mesh cod end contained on average 1.2 % (based on numbers) more commercial shrimp and respectively less undersized shrimp (Figure 27). However, this difference was not statistically significant which means that the size frequency distribution was the same for both mesh types.

Beside the mesh size, the amount of undersized shrimp could also be affected by the catch quantity and by the amount of bycatch due to net clogging. Estimated total catch weight did not differ between the 22 mm and the 24 mm cod end. However, the filling height in the pounder, which was reported in more detail but by few fishermen, tended to be lower for the 24 mm net compared to the 22 mm net. The non-shrimp bycatch composition and total amounts seemed similar between the 22 and the 24 mm mesh. However, samples with relatively low percentages of algae in the catch tended to contain lower percentages of undersized shrimps when originating from the 24 mm cod end compared to the 22 mm cod end. Fishermen reported that shrimps break more easily in the larger mesh, which might affect the sales price. One Dutch vessel had higher amounts of broken shrimps in the samples of the 24 mm cod end than in the smaller 22 mm cod end, but the other 4 vessels had less or equal amounts of broken shrimp in the samples of the 24 mm cod end.

The observed reduction in discard by increasing the mesh size by 2 mm was lower than expected by the CRANNET results (Berkenhagen *et al.* 2015). The discard fraction in the catches depends not only on the mesh size but also e.g. on the size composition of the local population, the towing speed, and the total catch volume. Therefore, the catch mass (in kg) and the fraction of discard shrimp were compared in the catches between commercial hauls (the German DCF discard sampling data, kindly provided by Kay Panten and Jens Ulleweit, Thünen Institute of Sea Fisheries, Bremerhaven, Germany) and scientific CRANNET hauls. During the same time and with the same 22mm mesh size, the CRANNET hauls were significantly lighter and contained lower amounts of undersized shrimp than data from commercial fishing trips (DCF; Figure 28) – indicating a higher selectivity of the nets caused by the lower catch volume. In commercial hauls net clogging might reduce the selectivity of the applied mesh size.

Still, the German DCF times-series showed an increase of the percentage of commercial shrimp and a decrease of undersized shrimp since 2016, when the management plan started (Figure 29). For comparability with the comparison of the 22mm vs. 24 mm mesh size cod end analyses, the length frequency distributions of the DCF data were virtually sieved with the selection curve of the laser-cut 6.8 mm sieve of the scientific sieving machine.

In conclusion, the direct comparison of the 22 mm and the 24 mm mesh revealed only a very small reduction in the share of undersized shrimp, while the DCF data show that a significant progress towards higher percentages of commercial and lower percentages of undersized shrimp has been made since 2016.

4.5 Discard mortality on commercial fishing trips

Mortality rates of bycaught juveniles have traditionally been considered negligible, but this assumption arose from studies with short haul durations and short observation times. Given its relevance for management recommendations on minimum mesh sizes, shrimp mortality due to trawling and handling was investigated under conditions typical of the commercial shrimp fishery in the German Bight. In 2016, a total of 1440 juvenile shrimps from 48 hauls with commercial beam trawls was analyzed in discard survival experiments, yielding insights into the effects of haul duration and two prevalent sieving methods (riddle and drum) on mortality rates. Shrimps were observed daily for three weeks to test for delayed mortality and moult performance as an indicator of fitness. On average, ca. 70% of the juvenile shrimps moulted successfully during the observation period, most of them (44.5%) in the first week. Mortality of juvenile shrimps transferred alive to tanks within the first 24 h after collection was zero (mean 0.3%) in 10 out of 12 trials. However, 6% of the shrimps were found dead immediately after the catch in the holding pit.

Haul durations > 90 min coincided with a significantly higher total mortality (15.3%) than shorter hauls (7.9%). In May 2016, a special situation was encountered with very high immediate (7.0–35.0%) and increased longer-term (19.4–31.9%) mortalities of juvenile shrimps regardless of treatment, indicating an unknown source of additional mortality. Very high local fishing activity prior to the experiment was a possible cause, assuming that the undersized shrimps had repeatedly passed through the nets and sorting devices. Trials on the effects of the sieving procedures indicated mortality increases in both sieve types with 67% increase in the riddle sieve and 100% increase in the drum sieve. The survival effect of the drum sieve was borderline not significant ($p=0.051$).

A strong correlation was found between the level of immediate dead shrimp (in the pit prior to the sieve passage) and the mortality that was observed subsequently during the 21-day observation period. These results stimulated new research within the CRANMAN project with a focus on the analysis of the share of immediate dead shrimp. Deviating from the earlier study, shrimp were only controlled after the passage of the drum sieve.

Within the CRANMAN project the vitality of discard shrimps in the beginning and the end of the onboard sorting process was observed in commercial fishing trips. Though this study is ongoing, preliminary results are available. Vitality was defined in three classes: (1) dead or alive (2) with or (3) without the ability to perform a tail flip, which is the escape reaction of shrimp. Vitality varied strongly among hauls (Figure 30). On average 18.9 % of the discard shrimp were immediately dead in the beginning of the onboard processing, rising up to on average 30.6 % in the end of the onboard processing with peak values of over 70% dead in individual hauls. Furthermore, laboratory experiments revealed that injuries from catch or sorting process led to an often-lethal shell disease. As larger hauls with a longer sorting duration resulted in lower survival rates indicating that a higher mesh size, and thus sorting the catch already under water would reduce discard mortality. Further analysis aims to quantify the impact of different factors, like fishing pressure in the area (a.k.a. wolf pack effect), haul duration, catch size, temperature, individual length and moulting stage.

The assumption that mortalities of bycaught juvenile shrimps are negligible is not supported by these results. The data clearly indicate that catch- and possibly recatch-induced mortality of undersized shrimps must be considered, when assessing fisheries effects on the population of the target species and on the ecosystem.

4.6 Alternative measures to a mesh size increase to 26 mm

According to their self-management plan, MSC fishermen were required to use cod-ends with a mesh size of 24 mm since 2018 instead of 22 mm. This increase in mesh size was the third of four steps (1st: 20 mm, 2nd: 22 mm, 3rd: 24 mm, 4th: 26 mm), aiming to reduce growth overfishing of the shrimp population. However, a further increase in 2020 to 26 mm was rejected by the fishery and has therefore not been implemented as planned. Alternative measures were proposed by the fishery. The Crangon-model of the University of Hamburg (Temming *et al.* 2017) was used to compare effects of alternative measures with those of a mesh size increase to 26 mm.

The model is a Yield-per-Recruit model, which is able to reproduce the seasonality of mean landings of the German fishing fleet. The absolute catches can be adjusted via the number of eggs released in the simulation. Thereby, life-history traits of brown shrimp are considered as well as ambient water temperatures and estimates of predators (whiting, cod) and their consumption of commercial shrimp. In its standard run, the model simulates the average situation in the years between 2002 and 2012 (for details see Temming *et al.* 2017).

To ensure comparability between measures, surplus landings, were used as quantity: Under the circumstances of growth overfishing of the shrimp population, an increase of selection size (via mesh size increase) or any reduction of effort will result in an increase of catches. In the standard run setting of the population model, an increase of mesh size from 24 mm to 26 mm result in surplus landings of 3.9%. In the model, the same increase would be achieved if the fleet remains at 24 mm and reduces its effort by 12% (implemented as reduction of fishing mortality from 3.8 y^{-1} to about 3.3 y^{-1}).

Proposed measures from the fishing sector include weekend closures, removing licenses, and seasonal closure.

Weekend closures

Basing on model calculations, a closure of Saturday and Sunday for the whole year would reduce German effort in sufficient way (>20%). However, it is unrealistic that the weekly distribution of the German fleet stays the same if the weekend is closed. In other words, a shift in effort from weekend to Monday to Friday is expected reducing the protection effect on the population.

Additionally, a weekend closure already exists in the Netherlands, and thus would only affect other nations.

Removing licenses

The effect of removing fishing licenses strongly depends on which vessels are selected to leave the fishery (Table 5). For instance, a 10% reduction of the national fleets would result in the removing of 19 Dutch, 19 German and 3 Danish vessels. If vessels with the lowest yearly effort are selected, total reduction is less than 2 % for the Netherlands and Germany and 5.6 % for Denmark. In contrast, if the vessels with the highest yearly effort are removed, more than 12 % of effort are reduced. Such measures are only effective, if the effort of the remaining vessels is not increased and no new vessels are allowed in the fishery.

Seasonal closures

The closure of the fishery for one month in summer, as proposed by the fishing sector, is not enough achieve a 12% reduction in effort. According to the model results, it is unimportant which month is selected for the closure. Likewise, a measure with two weeks closure in spring and two weeks closure in summer is insufficient. However, a closure in spring for one month combined with a closure in summer for one month would almost reach the 12% effort reduction (Figure 21).

In all alternative measures discussed here, it must be ensured that effort is not shifted to other periods or vessels. To be successful, any effort reduction must be combined with an effective effort cap, e.g. the 2011–2015 mean monthly effort per fleet.

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5 New gears (ToR d)

5.1 The Accurate Selection

In this ongoing project, an innovative sorting line is being developed for the on board sorting of the shrimp *Crangon crangon.* The machine, developed by *De Boer RSV,* has a camera that uses a multitude of parameters to detect what items pass underneath it on a conveyor belt. The goal of the innovation is to get a perfect separation of commercially sized shrimp and all unwanted by-catch, including undersized shrimp. The size of the shrimp is measured as a surface area in pixels that can be very finely tweaked in order to not catch undersized shrimps. The catches, identified by the camera, are then separated using air pressure, which "shoots" out the marketable shrimp while the rest passes straight into the sea. This greatly reduces the effort for the fishermen as they do not have to manually sort out after. Due to the shorter time on deck of the bycatch and not going through the sieve drum, it is expected that bycatch survival increases and, perhaps most importantly, a great deal of undersized shrimp is not cooked and taken to the shore. This will benefit the shrimp population and the fishermen in the long run. Some preliminary results already show that the system has a more accurate sorting than the auction sieves on land, where the fishermen consequently lose marketable shrimp. Further investigation of the innovative sorting device will be made regarding survival of bycatch and the fine-tuning of the machine.

5.2 CranPuls Innovations

Pulse trawling proves to be a good alternative to the traditional trawl when fishing for shrimp, with overall similar or higher catch rates, reduced bycatch rates, and a lower mechanical impact on bottom and benthic life. This project fine-tuned certain aspects of the pulse trawl gear that were later taken over by the stakeholders involved. Especially improvements were made regarding the loss of catch efficiency during the colder winter months and deeper waters, alternative adaptations were proposed and further investigated. In the end, five different experiments were carried out by three fishing vessels: the electrode setup, the EPLG pulse settings, adding discs between the bobbins of the bobbin rope, a sieve mat in the net, and discs instead of bobbins.

The experimental electrode setups, which was a reduction of the electrode length from 110 cm to 80 cm or an increase of the distance from the electrodes to the bobbins from 55 cm to 80 cm, were not better than the standard pulse gear. The same was also true for the EPLG experiment where the voltage of the pulse (the peak), the pulse duration, and the pulse frequency were altered, and for the sieve mat, which caused significant loss of catches. When replacing several bobbins by discs on the bobbin rope showed a slight increase in the catch of commercial shrimp while discard rates went down by almost 25%. A comparison was made between a traditional beam trawl and a pulse trawl where all the bobbins were replaced with discs. This showed a strong increase in the amount of shrimp caught paired with a substantial reduction in the amount of bycatch.

5.3 Sorting Grid

The selectivity of a shrimp trawl equipped with a sorting grid was investigated and compared with the selectivity of a standard gear (Veiga-Malta *et al.* 2020). The grid in the test gear (bar spacing 6 mm) allows small shrimps to escape, while large shrimps are directed to the cod-end (mesh size 22 mm).

The test gear was deployed on a commercial twin-beam trawler, as was a standard net with 22 mm and 26 mm mesh in the cod-end. Compared to the catches with a standard gear and 22 mm mesh size in the cod-end, the catches of small shrimp from the test gear were significantly lower. The overall selectivity of the test gear was similar to that of a standard gear with 26 mm in the cod-end. Thus, the test gear could be an alternative for fishermen to meet MSC requirements.

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6 Bottom impact of the fishing practices (ToR e)

The Dutch Ministry of Agriculture, Nature and Food Quality (LNV) have together with stakeholders been working on a future vision for the shrimp sector. As a basis for this, Wageningen Marine Research and Wageningen Economic Research have compiled an overview of the current situation. Apart from describing economical parameters as well as organization and management of the sector, previous studies on ecological effects of shrimp fishery were reviewed and compiled (Quirijns *et al.* 2021). Among other ecological effects (e.g., unwanted bycatch, food web effects, emission of CO_2 and NO_X), studies on impacts of the shrimp fishery on the sea bottom and benthic fauna were examined.

Bottom trawling is generally viewed as a main source of physical human disturbance of the seabed, with consequences for organisms living there (Eigaard *et al.* 2017; Hiddink *et al.* 2017; Kaiser *et al.* 2002). The trawl may cause direct or indirect death of organisms, which may lead to a decline in populations or reduced recruitment, e.g., in shellfish, but may also be beneficial for populations which can benefit from, e.g., reduction of competitors or predators (Glorius *et al.*, 2015). Reducing bottom trawling activities is therefore expected to improve conditions for benthic animals leading to an increase in benthic biomass and diversity (Hiddink *et al.*, 2006; Van Denderen *et al.*, 2014).

Shrimp trawls are lighter in weight compared to beam trawls used for flatfish fishing and instead of tickler chains, shrimp trawls have bobbins that roll over the bottom. A full shrimp net dragged over the bottom will however cause seabed disturbance, but the effects on the seabed and its fauna are less than the effects of heavier fishing gear (Rijnsdorp *et al.*, 2020). It has been concluded that wind may have a greater effect on the benthic community than shrimp fisheries (Prins *et al.* 2020). However, Pérez Rodríguez & Van Kooten (2019) found that although physical disturbance from winter storms does have a large impact on benthic animals, clear negative effects of shrimp fishing on long-lived benthic animals were found, especially in years with a lower natural impact (fewer storms).

In general, it can be stated that bottom trawling has a negative impact for long-lived species with lower productivity, but a positive impact on generalist species with high mobility (Craeymeersch *et al.* 2017; Riesen & Reise 1982; Tulp *et al.* 2019; 2020; Buhs & Reise 1997). Reduced bottom disturbance could be beneficial for long-lived species that are associated with lower productivity. In turn, a reduction in bottom disturbance may lead to lower benthic biomass levels. However, studies found unclear or insufficient evidence for this (Tulp *et al.* 2019; 2020). A reduction of bottom trawling that penetrates deeper into the bottom can be expected to be beneficial for species living deeper in the sediment (Craeymeersch *et al.*, 2017; Riesen & Reise, 1982; Tulp *et al.*, 2020). In contrast, generalist species with high mobility can instead easily benefit from the rapidly changing conditions resulting from bottom trawling, such as Ensis spp (Tulp *et al.*, 2020). Disturbance of the seabed by bottom trawling can therefore cause shifts in benthic communities (Buhs & Reise, 1997). However, to avoid confounding results, as has been the case in several previous studies, a careful study design is needed to be able to separate the effects of the shrimp fishery from other impact, as well as natural disturbance (winter storms), and also considering a high degree of natural variation as well as biotic interactions.

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7 Research on bycatch (ToR f)

Background

In the context of the landing obligation (Art. 15 Regulation (EU) 1380/2013), the Delegated Regulation (EU) 2020/2014 granted a de minimis exemption until the end of 2023 for by-catches in the beam trawl fisheries on brown shrimp (*Crangon crangon*) operating in ICES divisions 4b and 4c. The exemption implies that the discard quantity of TAC-regulated species shall not exceed 7% (in the years 2019 and 2020), 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; […]" (Delegated Regulations (EU) 2018/2035 Article 9(i), 2019/2238 Article 10(j) and 2020/2014 Article 11(7)).

The landing certificates of the brown shrimp fishery only record the quantity of marketable brown shrimp landed. Details on the total catch composition are not registered due to disproportional effort and limited time during on-board sorting required for the fast processing (immediate boiling) of the target species.

Accordingly, the brown shrimp fishery and the producer organisations committed to implement national self-sampling programmes in order to prove the required limit of catch percentages of TAC-regulated species. Sampling, sample processing and data analyses of the programmes are supervised and evaluated scientifically by support of the different nations' fishery research institutes.

The present report aims at giving an overview of the national sampling programmes in Denmark, Germany, and the Netherlands.

Methods by countries

Each nation's sampling strategy is listed in the appendix (Annex 5: Tables A&B).

Progress by country

The Netherlands

In the Netherlands, a self-sampling program was set up in 2021, and will be running until 2023. The program is financed by the Dutch Ministry, who have commissioned the sampling and analyses to Wageningen Marine Research (WMR). Sampling is organized by WMR in collaboration with sector organizations. 15 ships are currently included in the reference fleet. Each month, their fishing crew is asked to take and keep from 2 hauls, a 10 L sample each of the unsorted, total catch. For *every* haul of the trip, the crew is asked to note the total catch. Up to 15 trips (30 samples) are planned to be sampled per month according to the fleets spatial and temporal fishing activity. 100 sampled trips are planned per year. Samples are kept on ice until they are delivered to sieving stations where they are collected by WMR. In the laboratory of WMR, the samples are sorted by species and analysed for weight and length composition. Together with the total catch information collected for every trip, the sample information is used to estimate bycatch ratios of the brown shrimp fleet per month, year and area. The self-sampling has started in October and so far, 10 samples have been delivered by 3 vessels.

Besides the self-sampling programme, bycatch sampling is also carried out within the IRC shrimp project. This sampling is running from autumn 2019 until the end of 2022, when in total 32 fishing trips will be monitored (because of COVID-19 restrictions, sampling was not carried out during spring 2020 until summer 2021). The sampling is designed to monitor bycatch also focussing on ETP (endangered, threatened, protected) species in connection to the MSC certification of the shrimp fishery. During the sampling, one observer is present on shrimp vessels during the trip, and analyses samples taken during the trip. During part of the sampling period, "self-samples" have also been taken in the same way as for the self-sampling program (see above), which allows a direct comparison and validation between self-sampling and IRC shrimp observer sampling. Both the self-sampling program and the IRC shrimp monitoring program have been designed to representatively cover the Dutch shrimp fishery regarding fishing areas where shrimp fishery occurs during different parts of the year. Together with the total catch information collected for every trip, the sample information is used to estimate ratios of bycatch in the brown shrimp fleet per quarter, year and area.

Germany

Until the end of December 2020, a total of 117 samples were delivered by 16 shrimpers participating. The samples originated from seven ICES rectangles distributed along the German coast (35F6, 36F6, 36F7, 36F8, 37F8, 38F8, 39F8).

As the self-sampling started in July, quarter 1 and 2 were missing for 2019. In quarter 3 and 4, a total of 44 different species were found (including the target species). Seven species were identified as TAC-regulated species. Amongst these, highest mass were found for whiting *Merlangius merlangus*, plaice *Pleuronectes platessa* and herring *Clupea harengus* (listed in decreasing order).

In 2020, despite continuous fishing halts entailed by the COVID-19 pandemic, a total of 81 samples were delivered. 19 samples originated from the 1st quarter of the year, 27 samples from the 2nd quarter, 22 from the 3rd quarter and 13 samples from the 4th quarter. A total of 62 different species (including the target species) were found. Nine species were identified as TAC-regulated species. As in 2019, highest mass were found for whiting, plaice and herring. Whiting and plaice were most present in the 2nd quarter of the year whereas herring had its peak presence in the 4th quarter.

Denmark

The Danish self-sampling programme is part of the project "Bycatch reduction in the North Sea brown Shrimp beam trawl fishery" funded by The Danish Fisheries Agency and the EMFF programme running from June 2019 to July 2022. The Danish brown shrimp fleet consist of 25 vessels (with minor variations between years) and it was therefore agreed that all vessels should participate in the self-sampling programme each with two samples, twice a year, giving a total of 100 samples a year under ideal condition. The frozen samples are analysed at DTU Aqua in Lyngby splitting the catch into brown shrimp, fish by species, invertebrates and others (stones, shells etc.).

In 2020, a total of 42 samples was collected despite of the COVID-19 restriction, covering all quarters of the year. In 2021, the Danish brown shrimp fleet reportedly have had a reduced effort, some vessels switching to other fisheries and some stopping which has meant, that only 20 samples have been collected by mid-November covering all four quarters of the year.

8 Life cycle dynamics of brown shrimps (ToR g)

8.1 Investigations on growth and density dependence

During the CRANMAN project (Aug 2018 – May 2022) a series of growth experiments were conducted, with the aim of investigating effects of seasonality and density on growth potential of the common brown shrimp. The preliminary results confirmed the findings of previous studies that the growth of C. crangon varies greatly between both, different experimental trials and individuals. Based on the preliminary results, these fluctuations cannot be explained by the different densities in the field, but partly by the seasonal origin of the animals. This indicates the existence of a cohort effect, first mentioned by Hufnagl and Temming in 2011. Accordingly, animals hatched from winter eggs seem to be primarily responsible for the maximum growth rates reported in the literature. Further, more detailed results from the growth experiments of the CRANMAN project will be presented in the WGCRAN forum after the projects end in 2022. In addition to the growth performance investigations, general studies were carried out on the variability in the density of the animals. Especially in 2019 and 2020, extreme variability in density was observed at the coastal sampling site in Büsum. The number of animals found per square metre exceeded literature values for C. crangon by a factor of 4. By analysing length-frequency relationships established in parallel, high densities in autumn 2019 could be attributed to a strong summer recruitment. From a biological point of view, the years 2018, 2019 and 2020 were relatively atypical both in terms of the absolute number of animals in the catches and in terms of size distribution. The absence of large animals in autumn 2019, which was also increasingly reported by fishers, could also be observed in the samples from the sampling site in Büsum. A shift in recruitment waves towards a more pronounced summer recruitment could be seen as a cause for these atypical catch situations on both the scientific- and commercial side.

8.2 New estimations on fecundity

Another point of interest, which was further investigated within the CRANMAN project, was the fecundity of female common brown shrimp. For this purpose, egg-bearing females, caught at different sampling sites, were transported to the Institute of Marine Ecosystem- and Fisheries science in Hamburg for the use in either growth experiments, or to investigate the variability in the total number of eggs per female at a given length. Further, mature females (visible gonad formation) were brought to Hamburg in order to observe fertilization and subsequent egg production under laboratory conditions. The determination of the total number of eggs, as well as a review of published data on egg numbers at length, revealed a significantly greater variability than indicated in previous literature. Various methods were tested to determine the number of eggs and possible sources of error were identified. In addition to manual counting and software assisted counting with the help of a Zooscan (Hydroptic), the determination of the number of eggs via the total dry weight of the egg mass (taking into account the fluctuations in the individual egg weight between summer and winter eggs) proved to be a valid, fast method.

In addition to the questions regarding the number of eggs per female, several other factors affecting fecundity were investigated, and some of the model assumptions made for the population model were confirmed during the project period. It was possible to document the laying of eggs in two successive moults, as well as the synchronisation of the moulting interval and egg development in laboratory experiments. The absence of food, which may occur in winter, has been identified as a possible reason why in a few cases moulting would not be synchronised with egg development, since starvation delayed the following moult event significantly. Based on the findings of the studies, it can be assumed that egg production calculated based on existing literature is overestimated to a certain extent. The results have been directly incorporated into improved model runs of the life cycle model, whereby the egg overproduction, which had been too high in order to close the life cycle in the model, could be significantly reduced.

8.3 A critical reappraisal of reproduction and recruitment

The spawning season in the German Bight extends over several months comprising multiple unsynchronized spawning events. Data on weekly *Crangon crangon* larvae presence in 2012 and seasonal appearance of ovigerous females were analysed, in order to evaluate the relation between the abundance of ovigerous females and larvae in spring and the recruitment success in autumn (Hünerlage *et al.* 2019). The minimum shares of ovigerous females appeared in early autumn, and the highest shares in late winter bearing mostly early egg stages. The putative start of the reproductive cycle was defined for November when the frequency of ovigerous females started to increase. There was no distinct separation between winter and summer eggs, but a continuous transition between large eggs spawned in winter (the early spawning season) and batches of smaller eggs in spring and summer. Larval densities peaked in April/May. Consequently, regular annual larval surveys from 2013 to 2016 were scheduled for April/May and extended to six transects covering the inner German Bight. Ovigerous females were most abundant in shallow waters above the 20-m isobaths, which also explained regional differences in abundance between the regions off North Frisia and East Frisia. No relation was obvious between the number of larvae in spring and recruited stock in autumn. Due to the short lifespan of *C. crangon*, the combination of various abiotic factors and predator presence seems to be the principal parameters controlling stock size.

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9 Survey data (ToR h)

Optimize and harmonize surveys

Commercial landings and effort data give important insights into the long-term development, interannual variation and seasonal patterns of the shrimp stock and fisheries. Fishery independent data such as the German Demersal Young Fish Survey (DYFS) and the Dutch Demersal Fish Survey (DFS), both conducted mainly in the autumn, provide data on the spatial distributions of shrimps as well as population dynamics, e.g., size structure and the number of fecund females. Size distributions of shrimp from the surveys can be used to estimate total biomass, mortality rates as well as to provide size-based indices such as the fraction of large shrimp in the population. The catch per unit effort (CPUE) from surveys can be used to estimate swept area biomass. However, the gears used in the Dutch DFS and the German DYFS are not identical. The DFS uses a 3m beam trawl with one tickler chain in the inshore part of the survey and a 6m beam trawl with one tickler chain in the more offshore areas. The German DYFS uses a 3m beam trawl without tickler chain in all survey areas. Attempts to perform parallel sampling in overlapping areas (405 and 406) have been made, in order to compare gear catchability (ICES 2016a; ICES 2016b). However, the number of hauls was concluded not to be sufficient. WGCRAN has recommended a joint gear comparison project between the WMR and the Thünen Institute for harmonization and optimization of the Dutch and German surveys (ICES 2019), but so far this has not been carried out.

10 Information exchange (ToR i)

10.1 Natura 2000 in the German EEZ of the North Sea

In March 2021, the "**Joint Recommendation regarding Fisheries Management Measures under Article 11 and 18 of the Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy (CFP-Regulation) within the Natura 2000 sites Sylt Outer Reef, Borkum Reef Ground and Dogger Bank as Special Area of Conservation under the Habitats Directive 92/43/EEC of 21 May 1992, and the Natura 2000 site Eastern German Bight as Special Protection Area under the Birds Directive 2009/147/EC of 30 November 2009**" was agreed to by the member states with fishing interests in the area and officially sent to the EU commission (Figure 1). Of the seven proposed management measures, the measures 1 a (Sylt Outer Reef), 2 (Amrum Bank) and 5 (Borkum Reef Ground) are most relevant for the shrimp fisheries (Figure 2).

Measures 1a and 1b

Year-round exclusion of all mobile bottom-contacting gears (measure 1a) in the central area of the Natura 2000 site Sylt Outer Reef and year-round exclusion of mobile bottom-contacting gears with the exception of brown shrimp fisheries with beam trawls in the eastern area (measure 1b), both from two management zones – separated by a fishing corridor –to protect the habitat types 1110 'Sandbanks' and 1170 'Reefs' and seafloor areas comprising the biotope type 'Species-rich gravel, coarse sand and shell-gravel areas' (Figure 3).

Measures 2

Year-round exclusion of any kind of fisheries from 55% (in the central and northern part) of the area of the Amrum Bank (habitat type 1110 'Sandbanks' according to the Habitats Directive) in the Natura 2000 site Sylt Outer Reef. The measure 2 aims to protect the Amrum Bank and the biotope type 'Species-rich gravel, coarse sand and shell-gravel areas' according to the MSFD from any disturbance of any fishing activities (Figure 4). An evaluation of the effectiveness of this measure is planned eight years after its implementation.

Measure 5

Year-round exclusion of all mobile bottom-contacting gears from the entire Natura 2000 site Borkum Reef Ground to protect the habitat types 1110 'Sandbanks' and 1170 'Reefs' and seafloor areas comprising the biotope type 'Species-rich gravel, coarse sand and shell-gravel areas' (Figure 5).

10.2 Time table of management measures and certification steps

A timeline of events and the introduction of individual management measures in the shrimp fishery was created, to better understand the timing of the management process and the causal relationships between individual measures.

Before the "Management"

The stock is surveyed and evaluated by the ICES Working Group on Crangon fisheries since 1992.

1989: The "plaice box", a partially closed area in the North Sea, to reduce the discarding of undersized plaice (Pleuronectes platessa) in the main nursery areas, and thereby to enhance recruitment to the fishery is introduced.

2001: 221 kW (300 hp) was set as a maximum engine capacity per vessel and for coastal fishery in the Plaice Box (EU [EG] 850/1998 and VO [EG] 24/2001). Vessels with less than 221 kW and between 8 and 24 m total length should be listed in a "beam trawl list", which is not extendable, but leaves room for changes i.e. when a vessel leaves the fleet. Only "listed vessels" are allowed to fish within the plaice box.

2002: An EU-Commission regulation (EU (Com) 2371/2002) allowed foreign vessels to fish within the 12 nm boundary of North Sea littoral states, Germany, Netherlands and Denmark

2003: With regulation on the use of selective nets in shrimp fisheries in the North Sea" (EC 850/98), sievenets were officially implemented in large parts of the shrimp fleet, and replaced the self-initiated use of funnel nets (previously "Kabeljaubox") since 1993. Only certain months of the year the sieve net was compulsory

2005: An EU regulation from 2003 (2244/2003) obliges boats larger than 15 m to use the VMS

2009: Hovercran, a hovering pulse trawl for selective shrimp fishery was introduced. For research purposes of the new device, a small proportion of the beam fleet (e.g. only 5% in Germany) was initially allowed to use the new technology.

2009: Major retailers plan to delist fishery products without MSC label in short/medium term, leaving the impression that only the label will guarantee excess to the market in the near future.

2011: A comprehensive report and evaluation of the fishery was published on behalf of the European parliament. The authors see opportunities for improvement (including increasing the mesh size to more than the permitted 16 mm, and reducing fishing effort, to minimise the effects on by-catch species and increase profits in general).

2013: ICES convened a workshop in order to investigate the necessity for management of the Crangon stock. Both the impact of the brown shrimp fisheries on the Crangon stock, and the impact on other commercially exploited fish stocks were investigated. The ICES Workshop (ICES 2013) concluded that management of the shrimp stock was necessary, and the regulation of unnecessary fishing effort, to improve yield from the fishery as well as reduce the impact of the fishery on the wider ecosystem, was suggested as a possible solution.

2014: Request from Germany and the Netherlands on the potential need for a management of brown shrimp in the North Sea. The ICES suggested a regulation of fishing effort (harvest control rule), as usual management strategies are not suitable due to the short life span of the species and a constantly changing stock size with great variability. Furthermore, management was seen as beneficial, as it would stop uncontrolled effort increase, increase the overall yield of the fishery, and reduce the impact on the Wadden Sea ecosystem.

Depending on national regulations, sieve nets and larger meshes have already been used.

Beginning efforts towards certification and more intensive development of a trilateral management plan.

First self-management measures being implemented

May 2016: Aiming at the MSC Certificate, DE/DK/NL implemented first measures which were summarized in a trilateral management plan on:

- Maximal number of ships, kW and fishing hours

- Full fleet registry
  - Vessels must be members of the Producer Organizations (POs), and there is a cap on the number of vessels and combined kW power set at the level registered by the authorities in the Netherlands, Germany and Denmark on 1 January 2015. Vessels are restricted to 200 days at sea per year.

- Gear characteristics and mesh size
  - The combined beam length must be less than 20 m, the combined weight of the gear must be less than 4000 kg, and there is a minimum mesh size of 20 mm
  - To minimise the catch of bycatch species, the trawl must contain a sieve net with a maximum opening of 70 mm or a sorting grid with a maximum bar spacing of 20 mm as under EU Council Regulation 850/98.
  - Pulse fishing (fishing using trawls which emit electrical pulses) is not permitted within the Management Plan (EU Council Regulation 850/98).
  - Implementation of 22 mm cod end mesh size, with later 24 (2018)

- Sorting and sieving
  - Catches must be sorted on board with a bar spacing adjusted to commercial size shrimp and must also be sorted on land at the sieving station with a sieve with a minimum opening of 6.8 mm (45–50 mm total length) as set in EU Regulation 2406/96. The waste resulting from the sieving, termed the sievage, must not exceed 15% of the total landings from a vessel over a period of two calendar weeks.

- Scientific advice on: Aiming for MSY
  - Growth overfishing should be avoided by increasing mesh size
  - Potential recruitment overfishing should be prevented by means of HCR on LPUE reference values
  - Based on 5 LPUE thresholds (calculated from two bad crab years (2002 and 2007), the fishery must reduce effort in stages if the LPUE falls below the respective threshold (Harvest Control Rule [HCR]).

- Control and enforcement
  - Under EU Council Regulation 2847/1993, all vessels over 12 m in length must carry satellite Vessel Monitoring Systems (VMS) and all vessels over 15 m in length must carry Automatic Identification System (AIS) on board (Council Regulation 1224/1998). Under EU Council Regulation 2847/1993 all vessels ≥10 m in length must make landings declarations in log books, and all vessels of ≥12 m must make returns using electronic log books (Council Regulation 850/1998).
  - In addition, under the Brown Shrimp Management Plan, independent control agencies set up as part of the Management Plan will carry out regular inspections of vessels, sieving stations (processing plants) and the POs themselves.
  - Plans to introduce "Black box" monitoring systems on all vessels in the Netherlands from 1 January 2017, which will provide a much more detailed description of fishing activity than currently provided by VMS or AIS.

- Avoiding/reducing recruitment/growth overfishing
  - Introduction of generally larger meshes in should counteract growth overfishing, whereas the introduction of HCRs should counteract recruitment overfishing.
- Bycatch reduction

2017: The certificate is granted. However, the seal remains bound to some preconditions. The fishery must regularly demonstrate that management measures, such as closed seasons, are effective and that the size of the shrimp stock remains stable. Also, the ecosystem ecosystem impacts of the fishery will be reviewed annually, for example with regard to by catch of other fish species or the habitat impact of fishing.

May 2018: The planned cod end extension from 22 mm to 24 mm is carried out across the board.

January 2019: Landing obligations on all TAC species. Exception for shrimp fishery is the de minimis rule, under which certain percentages of discards, since it is very difficult to increase selectivity and the survival rate of certain species caught accidentally is high.

Ban on fishing with electric currents, poisons, pneumatic hammers or explosives by EU law, lawful from July 2021. Following a lost lawsuit by Dutch fishermen, the pulse beam fishery for common brown shrimp is now closed.

National regulations

Netherlands

- 215 licences in total
- 4,5 fishing days of the week
- Sieve net period from November to April
- VMS and Blackbox as Monitoring systems
- Some closed areas (either seasonally or permanently)

Germany

- Cap for Beam trawling licences only
- Shrimper licence necessary, no appropriate assessment not required
- 7 fishing days of the week
- Sieve net period from October to April
- Only VMS as Monitoring systems
- Also, some closed areas
- Fishing vessels of the Netherlands or Denmark are only allowed to fish as close as 3nm miles to the shore

Denmark

- 28 licences in total
- 7 fishing days of the week, with weekend stops in some month
- Voluntary restrictions on the number of fishing days
- Year-round Sieve net period
- No trawling within 3nM
- Only VMS as Monitoring systems
- “Code of Conduct” which seeks to reduce unwanted Bycatch and discard, minimize environmental consequences of fishing, cooperate with other stakeholders and participate fully in all data collection and monitoring programmes.

11 Information on ongoing research (ToR j)

The following projects contributed to Crangon research and the working group:

- **CRANMAN** (08/2018 - 05/2022): Research on population and fisheries dynamics of the Crangon stock and evaluation of the self-management of the fishery

- **SHRIMP-BREED** (07/2020-06/2023): Study on the technical and economic feasibility of brown shrimp *Crangon crangon* farming for product diversification

- **Bycatch reduction in the North Sea brown shrimp beam trawl fishery** (06/2019-07/2022): The aim of the project is to document and reduce bycatch of fish in the Danish shrimp fishery, with special emphasis of juvenile TAC species (plaice, whiting, sprat and herring). This will include development of by-catch reduction devices for the brown shrimp fishery and a self-sampling program. (DTU Aqua)

- **Self-sampling shrimp fishery** (2021–2023): Estimating discard percentages of quota species in the Dutch shrimp fishery for a de minimis exemption

- **IRC Shrimp** (2019–2022): Research on bycatch in shrimp fishery in support of a MSC certification

- **Future perspectives on shrimp fisheries** (start 2021): Desk study and modelling related work on current situation, management, and future perspectives for the Dutch shrimp fisheries, on commission by the Dutch ministry of environment

- **SepCran** (2018–2019): Selectivity studies to minimize bycatch in shrimp fishery (possible continuation?)

- **MuSSel** (11/2020 - 10/2023): One work package investigates fisheries, including the German brown shrimp fishery, as one of the multiple anthropogenic pressures on the seafloor.

- **CRANIMPACT** (07/2020-06/2023): Impact of shrimp fisheries on the seabed https://www.thuenen.de/de/sf/projekte/auswirkungen-der-garnelenfischerei-auf-den-meeresboden-cranimpact/

- **Structural Change Coastal Fisheries** (2021–2027): Future of Coastal Fisheries in the North and Baltic Sea https://www.thuenen.de/en/sf/projects/structural-change-in-coastal-fisheries/

Annex 1: List of participants

WGCRAN 2021 meeting

Name	Institute	Country (of institute)	Email
Claudia Günther (chair)	Institute of Marine Ecosystem and Fishery Science, University of Hamburg	Germany	claudia.guenther@uni-hamburg.de
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WGCRAN 2020 meeting

Name	Institute	Country (of institute)	Email
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Annex 2: WGCRAN resolution

The **Working Group on *Crangon* fisheries and life history** (WGCRAN), chaired by Claudia Günther, Germany, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2019	8–10 October	IJmuiden, Netherlands		
Year 2020	17–21 August	by corresp/ webex		physical meeting cancelled - remote work
Year 2021	28–30 September	Online meeting	Final report by 15 November to SCICOM	

ToR	Description	Background	Science Plan codes	Duration	Expected Deliverables
A	Data collection of the status of the Crangon stock.	To report and evaluate population status indicators like recent landings and effort trends in the brown shrimp fisheries or length based mortality estimates from Dutch and German scientific surveys. 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 shall be delivered by all WGCRAN members within each annual report.
B	Compilation of Logbook information & VMS analysis	To combine VMS, landings and effort data to gain a population distribution indicator 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 summarized in a peer-reviewed paper.
C	To develop a suite of decision-support tools	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	The results will be presented in technical reports and shall be summarized in a peer-reviewed paper.
D	To evaluate the effects of the efficiency of new gears on shrimp catches	To evaluate the effects of new gears (e.g. pulsetrawl, combined pulse-trawl and standard gears, large or new mesh types, pumpsystem, letterbox etc.) and their implications on the Crangon stock, the bycatch, the catch	2.1; 2.2; 5.4	year 1,2,3	An overview of the considerations shall be summarized in the WGCRAN reports.

		efficiency and the possible lpue based management strategies.			
E	To synthesise the status of research of bottom impact of Brown shrimp fishing practices	To review the status and results of research of bottom impact and consider the implications for management.	2.4; 3.2	year 1,2,3	This work will be compiled and the results will be summarized in a peer-reviewed paper.
F	To optimize and harmonize national by-catch sampling programs.	To review the status and results of research on bycatch times-series and 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.	3.1; 3.2	year 1,2,3	To standardize the available and agreed sampling procedures and compile results in the WGCRAN report.
G	To examine the life cycle dynamics of brown shrimps	To gain a better understanding of the life cycle dynamics and life history of brown shrimp in order to optimize models of population dynamics that are used for management purposes.	1.7; 5.2; 6.1	year 1,2,3	Results shall be summarized in a peer-reviewed paper.
H	To analyze German, Belgian and Dutch survey data	The analysis of spatio-temporal trends of survey based stock indicators (biomass, distribution, mortality, etc.) will be conducted. Additionally the ground-truth of VMS derived lpue estimates will be used as complementary information. The inclusion of Belgian survey data will help to complement this analysis.	3.1; 3.2	year 1,2,3	The results overview will be presented in each annual report.
I	To facilitate information exchange	Information on national legislation, laws (e.g concerning Natura 2000) and developments (MSC process) concerning the brown shrimp fisheries in the whole North Sea will be synthesised.	7.1	year 1	An overview of relevant legislations will be included in the report.
J	To provide supporting information on ongoing research	To present and review ongoing brown shrimp research in the ICES area, which can help to support and consider management implications.	6.1	year 1,2,3	The summaries of updates will be included in the annual report(s)

Summary of the Work Plan

Year 1	Stock status indicators (ToR a) shall be udated and harmonized between countries. German and Dutch survey data will be analysed and reported, Belgian data will be included in the analyses (ToR h) Information on national legislation, laws (e.g concerning Natura 2000) and developments (MSC process) concerning the brown shrimp fisheries in the whole North Sea will be summarized (ToR i). Data used for the compilaiton of manuscripts in support of ToR b, c, e, g will be made available. New information generated from ToRs d, f, j will be reported
Year 2	Stock status indicators (ToR a) willbe udated and harmonized between countries. German, Belgian and Dutch survey data will be analysed and reported (ToR h). Data for manuscripts related to ToR b, c, e, g will be made available. New information from ToR d, f, j will be reported.
Year 3	Stock status indicators (ToR a) will be updated and harmonized between countries. German, Belgian and Dutch survey data will be analysed and reported (ToR h). Data for Manuscripts related to ToR b, c, e, g will be made available. New information from ToR d, f, j will be presented and 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	None.
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 as similar surveys are used. WGELECTRA as the use of the pulse gear by a larger fraction of the fisherman might have implications on the stock, 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: Recommendations

The analysis of logbook data and VMS derived data products performed in this working period broadly improved the understanding of interactions between fisheries and stock dynamics (Respondek *et al.* 2022). The group highly recommends further analyses on a yearly basis to properly attend and advice the self-management of the brown shrimp fishery.

As explained in more detail in section 3, WGCRAN requested data from the ICES data call for VMS/Logbook data (**ICES 2021**) including the geographical range of Belgium, the Netherlands, Germany, and Denmark. These data were filtered by metier (TBB_CRU_16-31) in order to select shrimp fishers. Unfortunately, these data were of limited use for the purpose of the working Group because:

- There is a large mismatch of national landings from official statistics and national landings calculated from VMS/logbook data, especially in the years 2009–2012
- There is fishing activity far outside the regular fishing grounds which may yield landings of other species than *Crangon crangon*.

In order to successfully perform the analyses described above, the dataset must be filtered for species instead of metier. WGCRAN recommends extending the data call of ICES by the species information for brown shrimp (landings weight) for the abovementioned nations.

References

ICES 2021. VMS/Log book data for fishing activities in the North East Atlantic and Baltic Sea for the provision of ICES advice on the spatial distribution and impact of fisheries 2009 to 2020. Ref: H.4/NH/AB/ck Ref: H.4/NH/AB/ck

Respondek G., Günther C., Beier U., Bleeker K., Pedersen M., Schulze T., Temming A. 2022: Connectivity of local sub-stocks of *Crangon crangon* in the North Sea and the risk of local recruitment overfishing. Journal of Sea Research 181: 102173 (https://doi.org/10.1016/j.seares.2022.102173)

Annex 4: Figures and tables

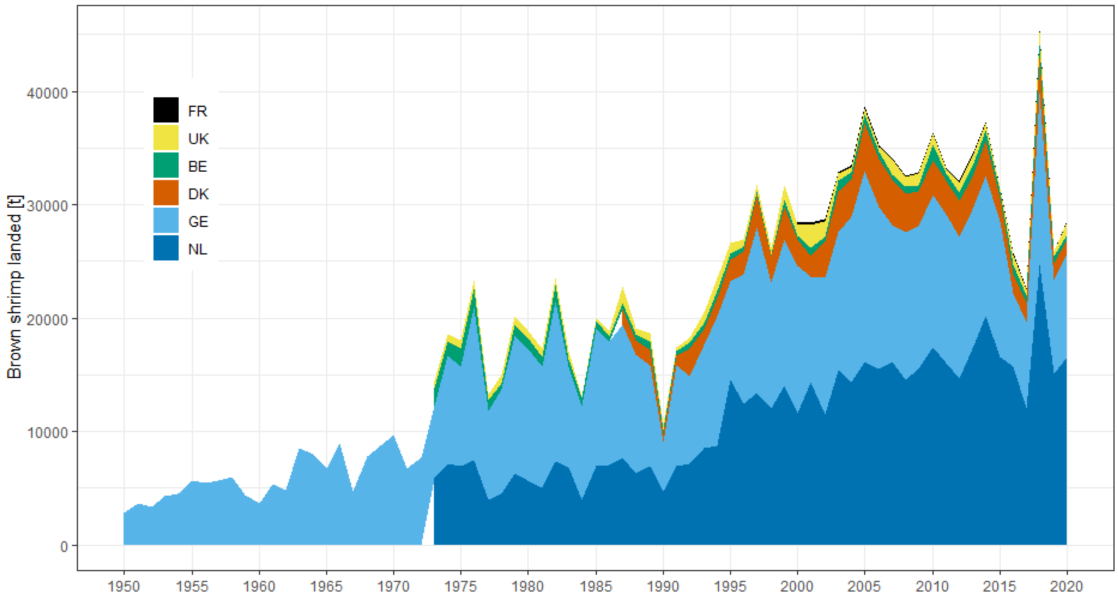


Figure 1. Total landings of brown shrimp (in tons) from the North Sea by country.

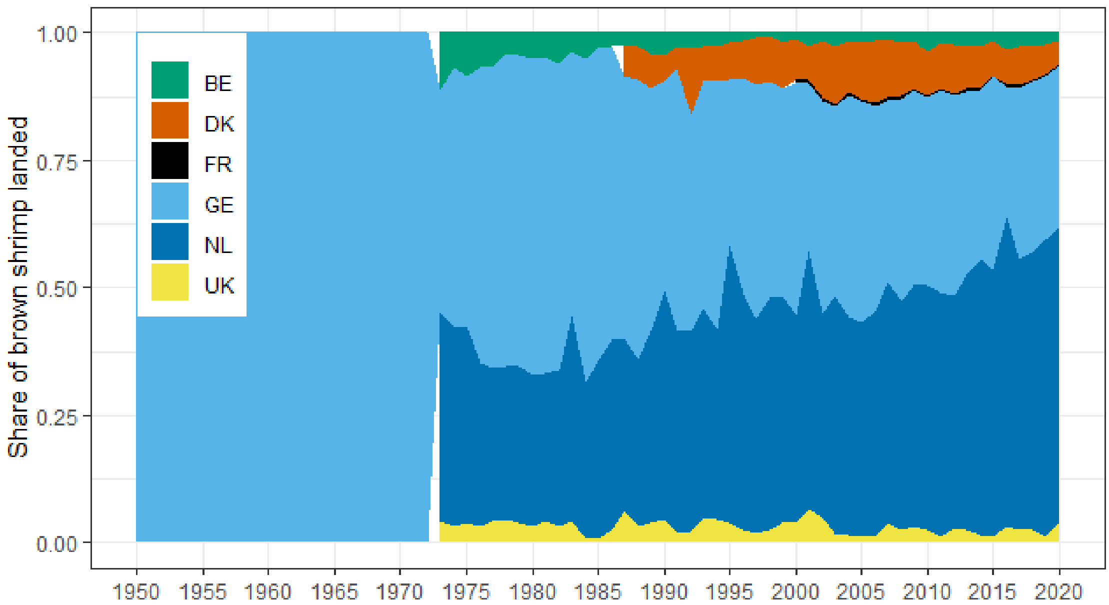


Figure 2. Share of total North Sea landings by country.

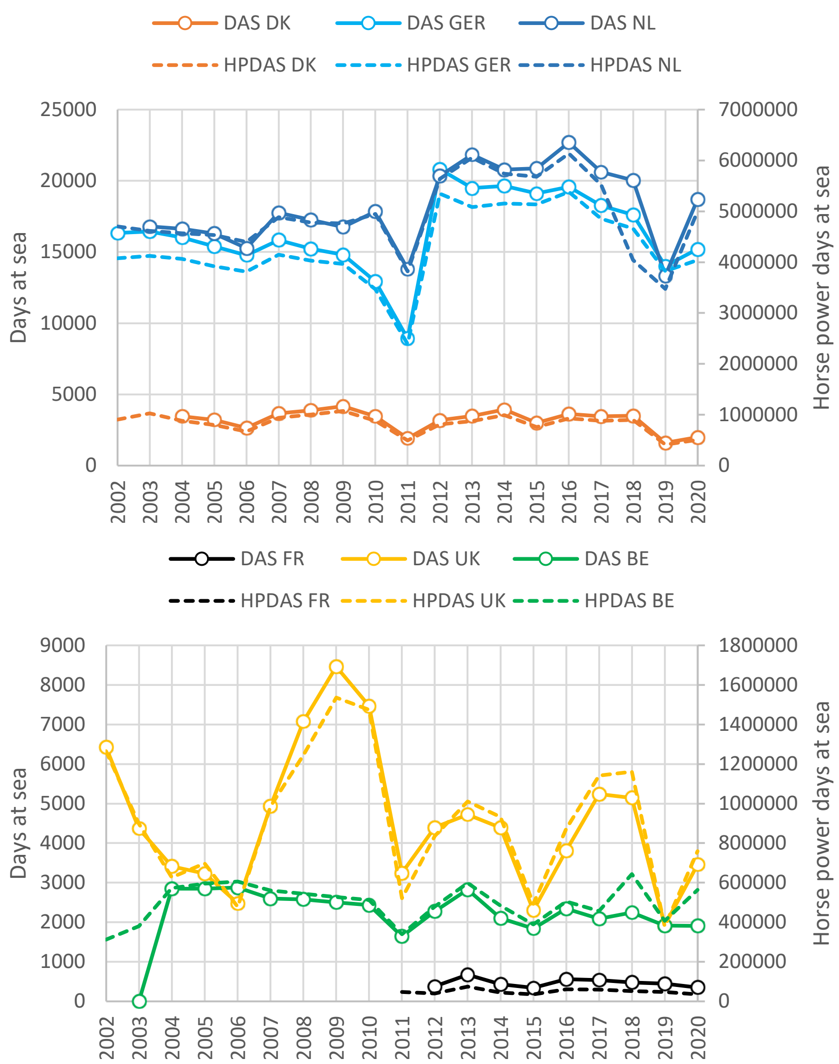


Figure 3. Effort in days at sea and horsepower days at sea of the brown shrimp fishery by country. Upper panel: Netherlands, Germany and Denmark, lower panel: Belgium, United Kingdom and France.

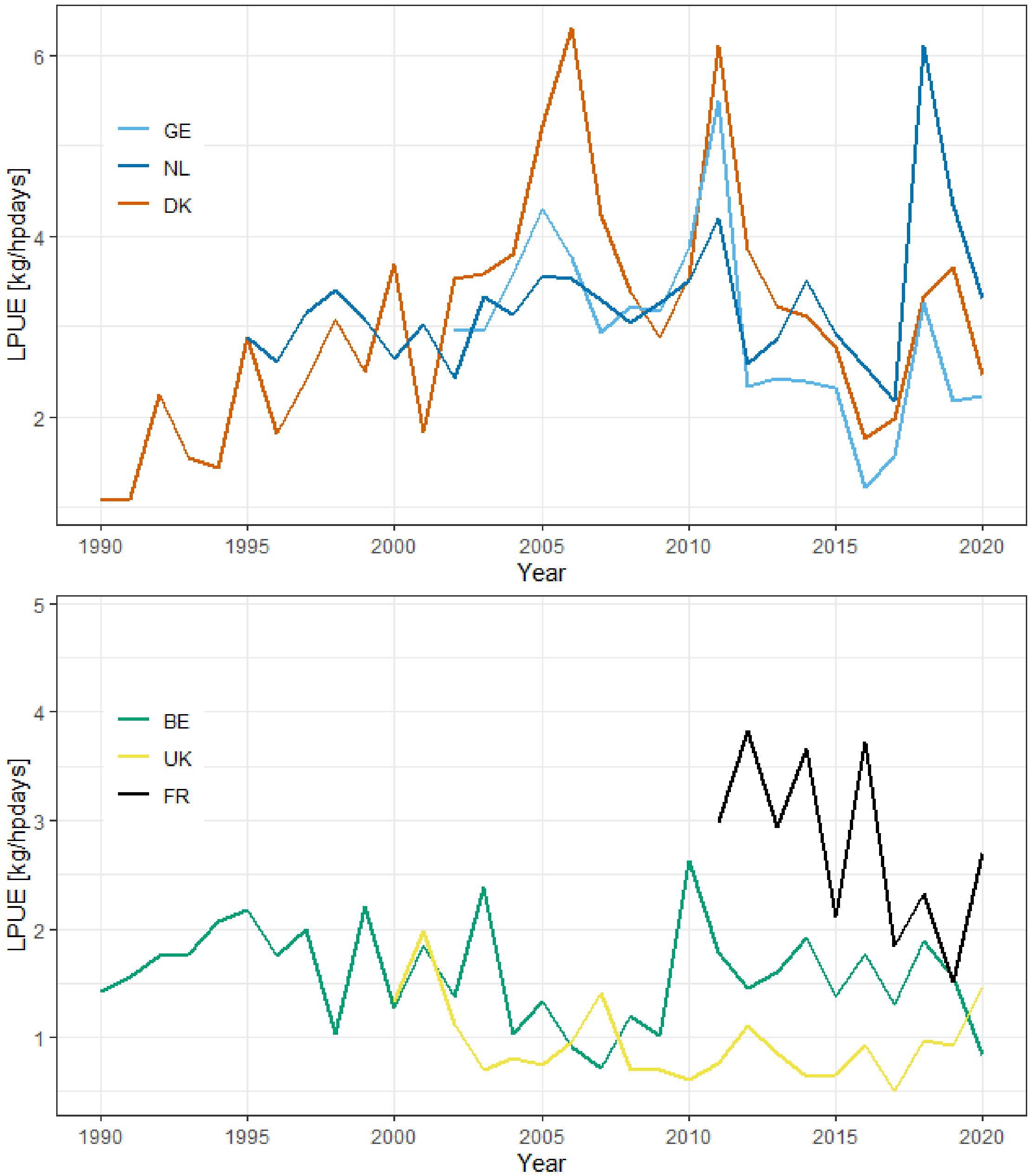


Figure 4. Landings per unit effort (LPUE) in kg per horsepower days at sea of the brown shrimp fishery by country. Upper panel: Netherlands, Germany and Denmark, lower panel: Belgium, United Kingdom and France.

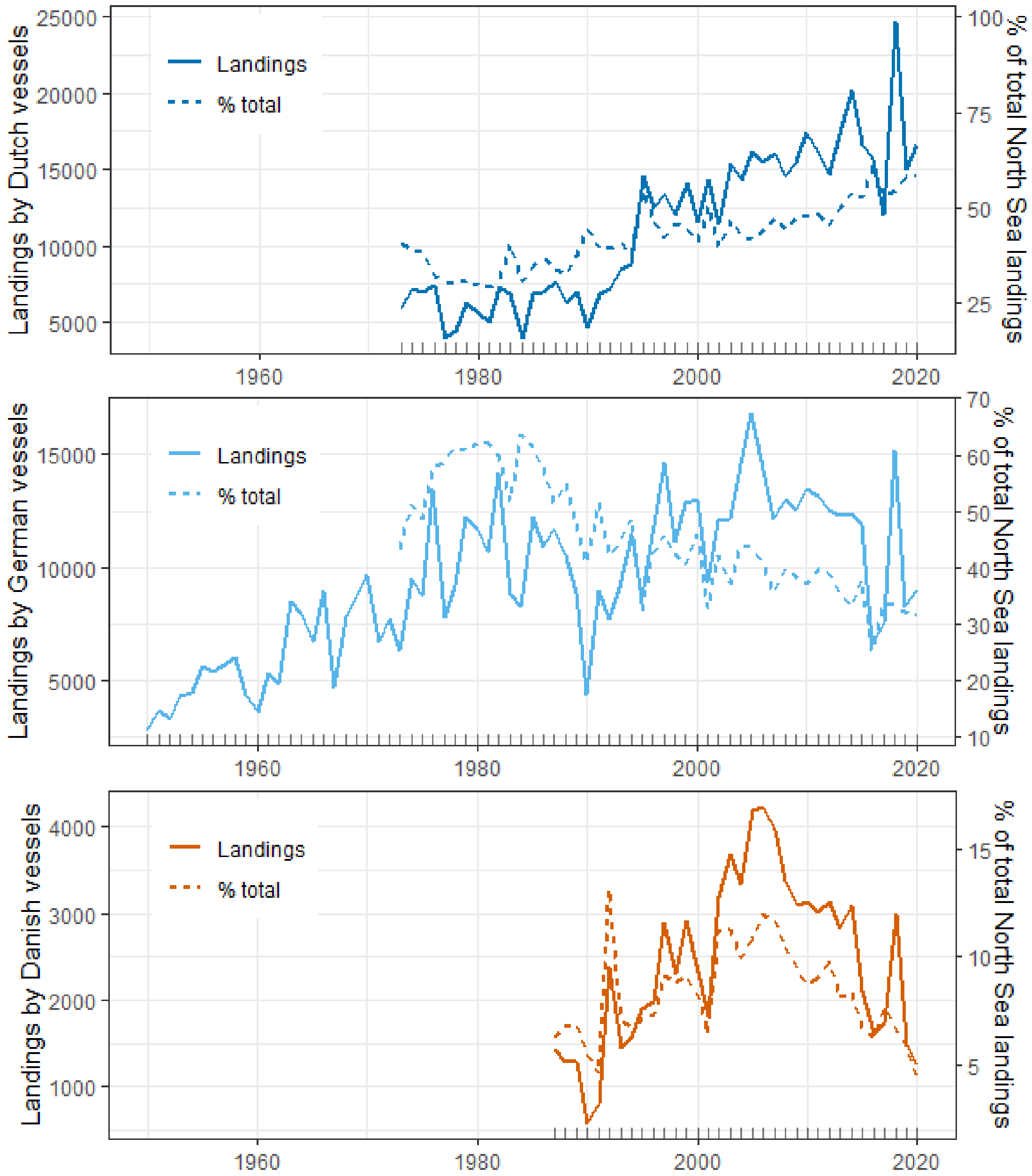


Figure 5. Brown shrimp landed by Dutch, German, and Danish vessels and corresponding percentage of national landings in relation to total (whole North Sea, all nations).

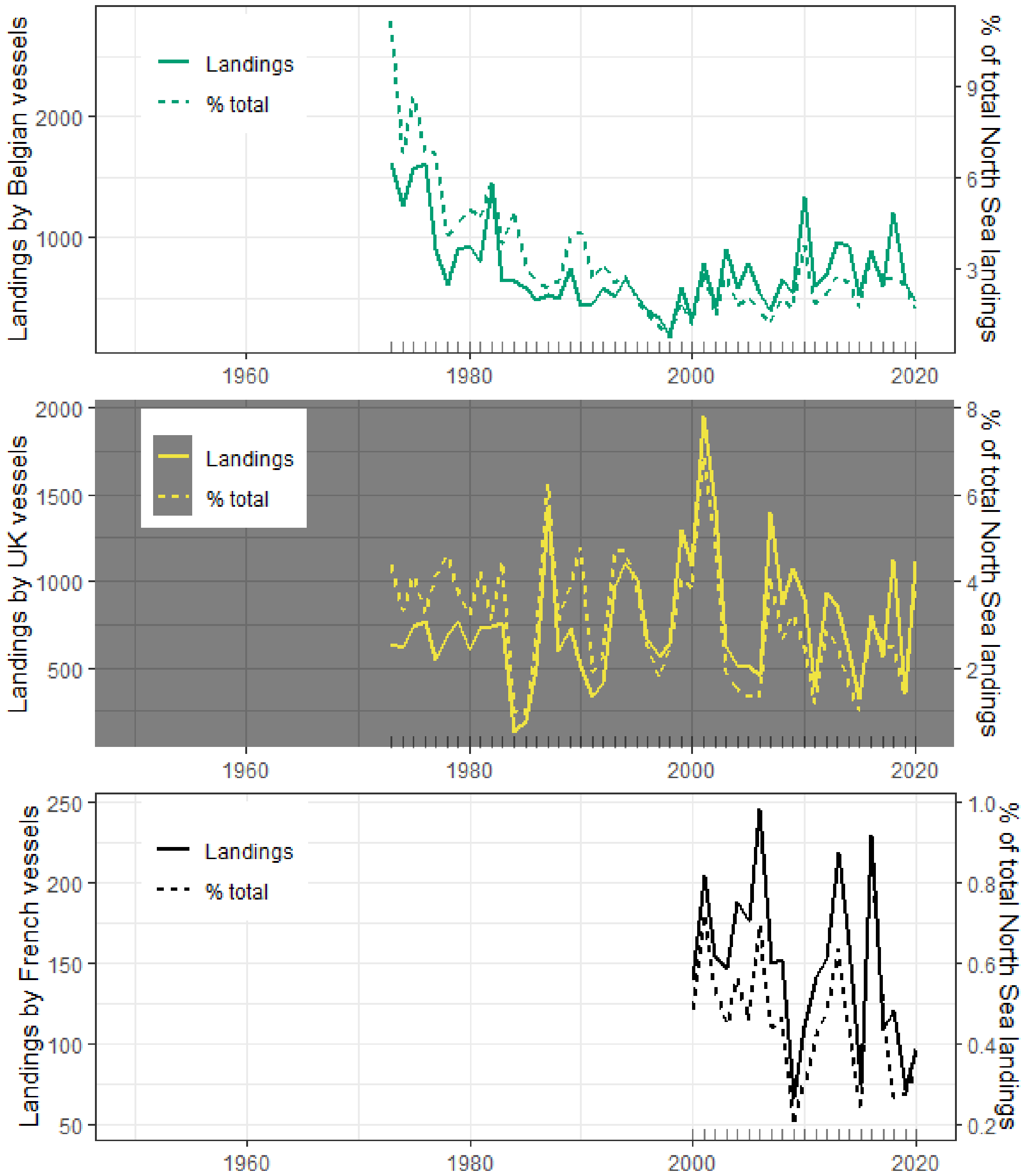


Figure 6. Brown shrimp landed by Belgian, United Kingdom, and French vessels and corresponding percentage of national landings in relation to total (whole North Sea, all nations).

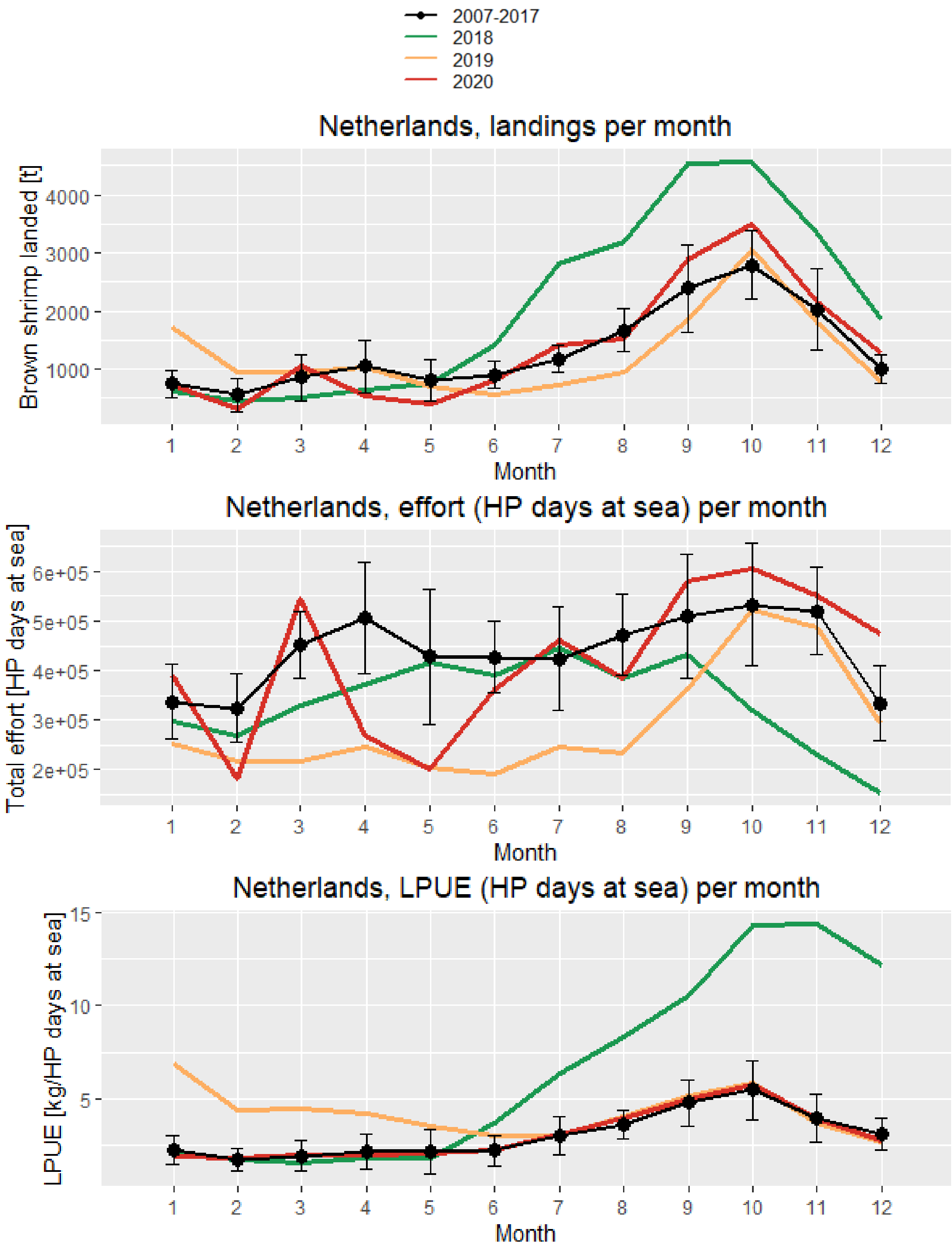


Figure 7. Seasonal patterns of the Dutch fishing fleet in 2018, 2019, 2020 and the mean of 2007–2017 (+/- SD). Upper panel: landings of commercial sized shrimps in tons; medium panel: fishing effort in horsepower days at sea; lower panel: landings per unit effort in kg per horsepower days at sea.

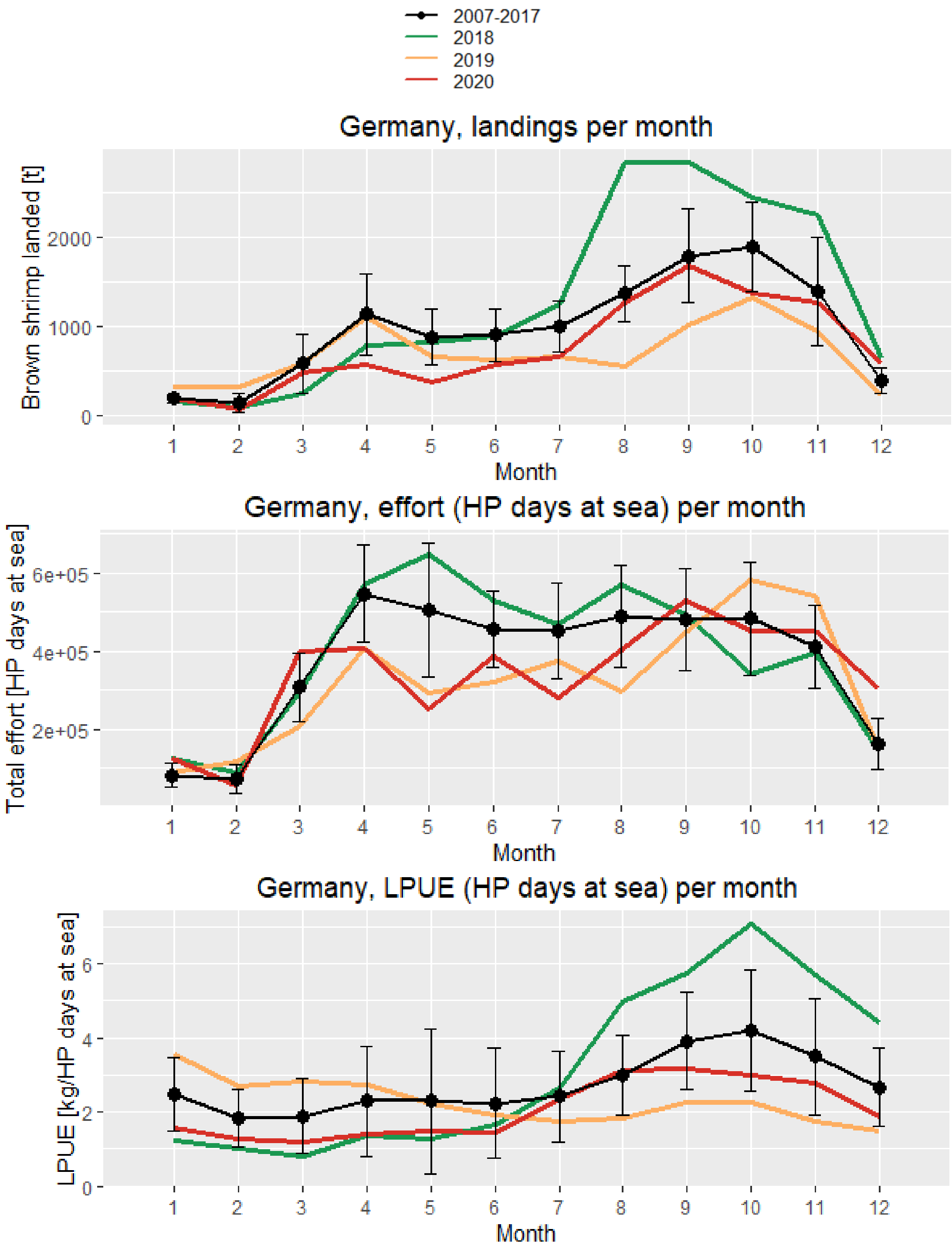


Figure 8. Seasonal patterns of the German fishing fleet in 2018, 2019, 2020 and the mean of 2007–2017 (+/- SD). Upper panel: landings of commercial sized shrimps in tons; medium panel: fishing effort in horsepower days at sea; lower panel: landings per unit effort in kg per horsepower days at sea.

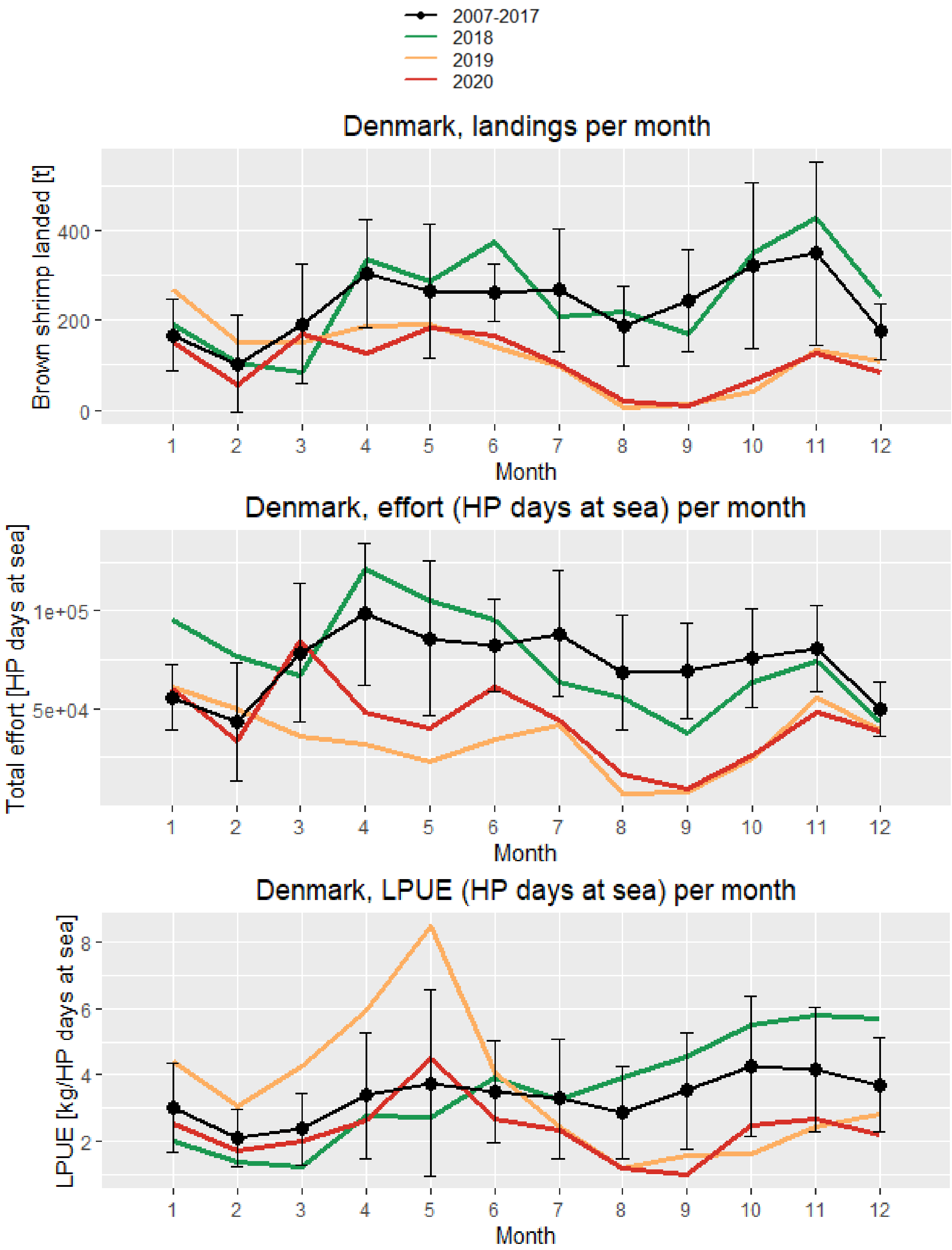


Figure 9. Seasonal patterns of the Danish fishing fleet in 2018, 2019, 2020 and the mean of 2007–2017 (+/- SD). Upper panel: landings of commercial sized shrimps in tons; medium panel: fishing effort in horsepower days at sea; lower panel: landings per unit effort in kg per horsepower days at sea.

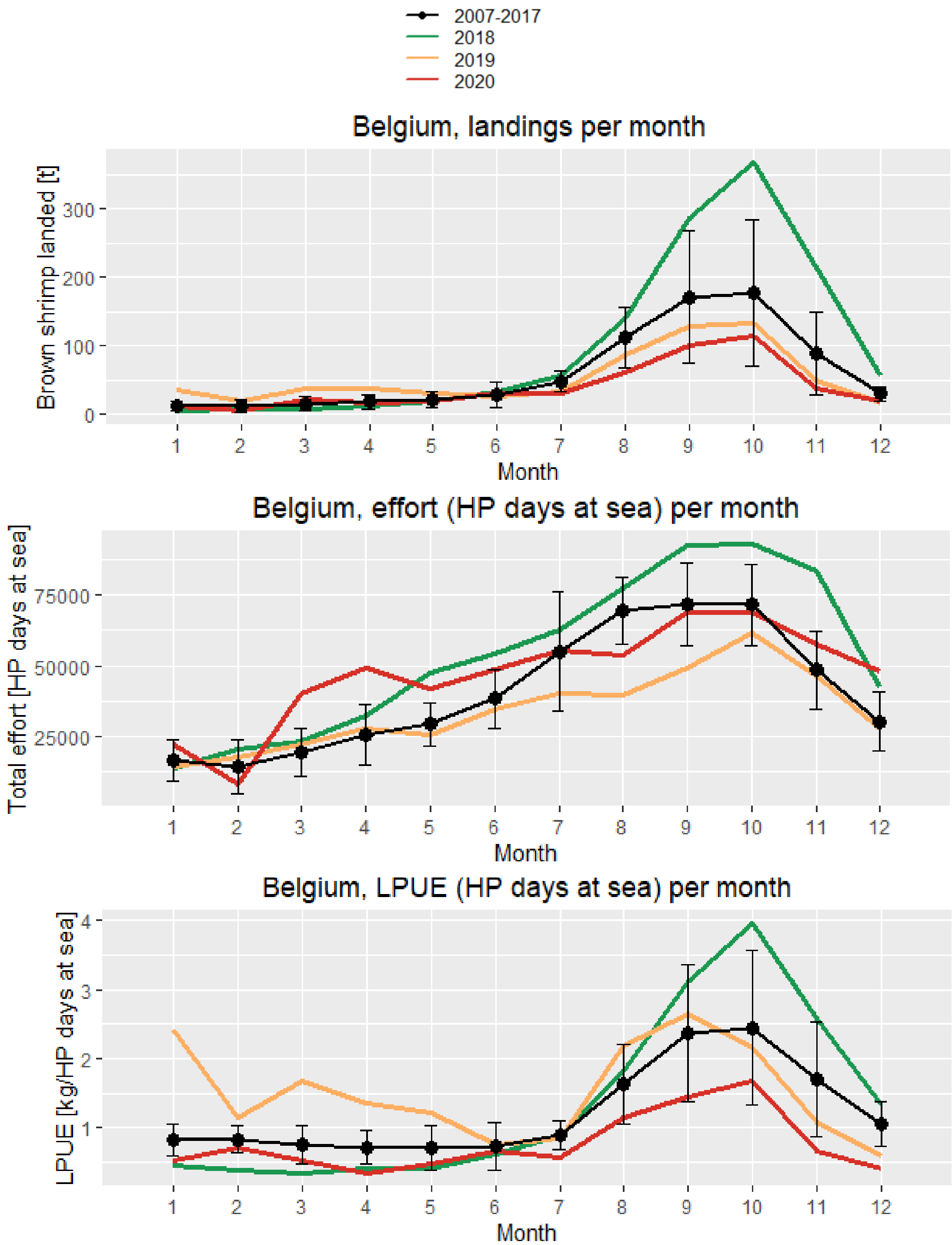


Figure 10. Seasonal patterns of the Belgian fishing fleet in 2018, 2019, 2020 and the mean of 2007–2017 (+/- SD). Upper panel: landings of commercial sized shrimps in tons; medium panel: fishing effort in horsepower days at sea; lower panel: landings per unit effort in kg per horsepower days at sea.

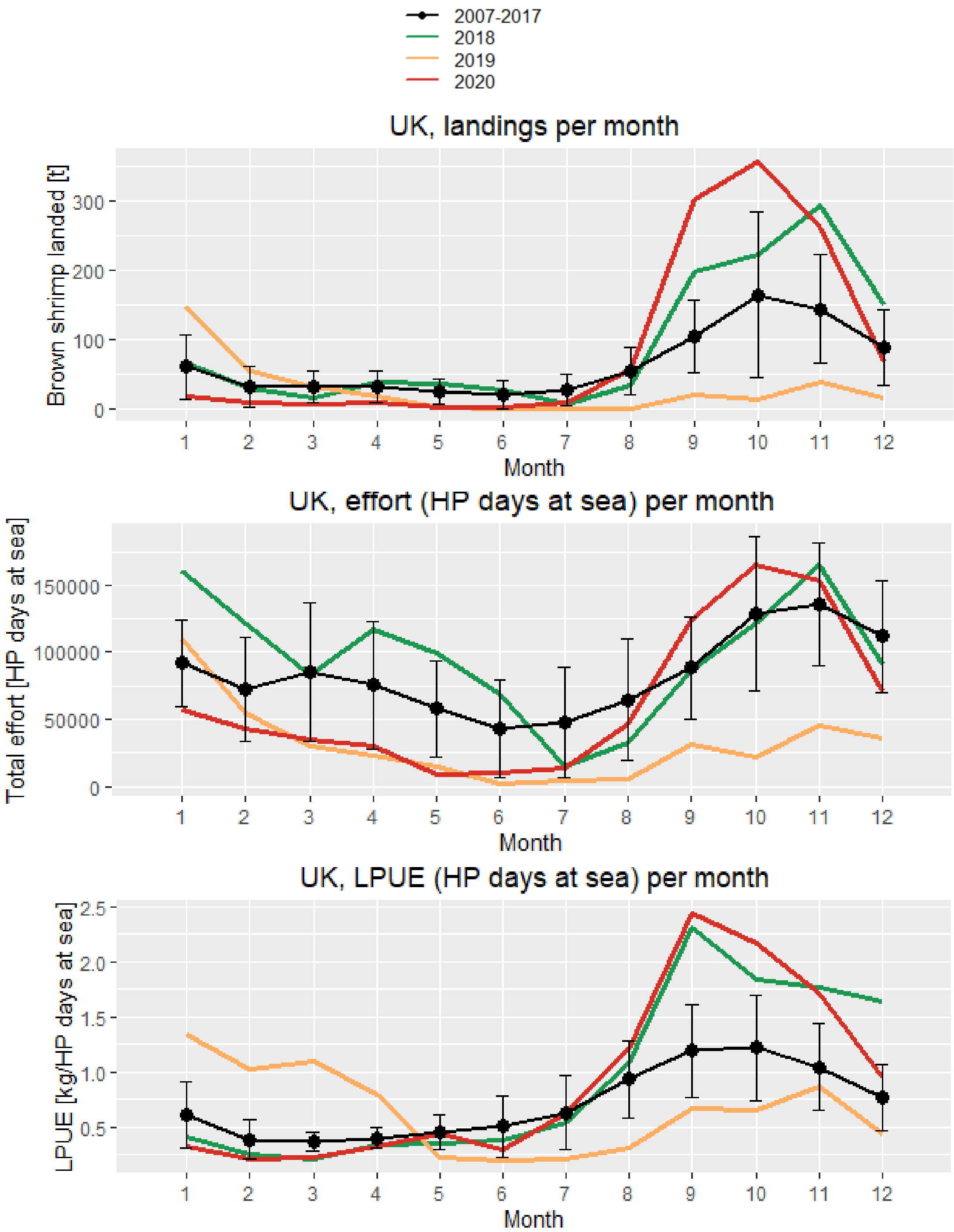


Figure 11. Seasonal patterns of the UK fishing fleet in 2018, 2019, 2020 and the mean of 2007–2017 (+/- SD). Upper panel: landings of commercial sized shrimps in tons; medium panel: fishing effort in horsepower days at sea; lower panel: landings per unit effort in kg per horsepower days at sea.

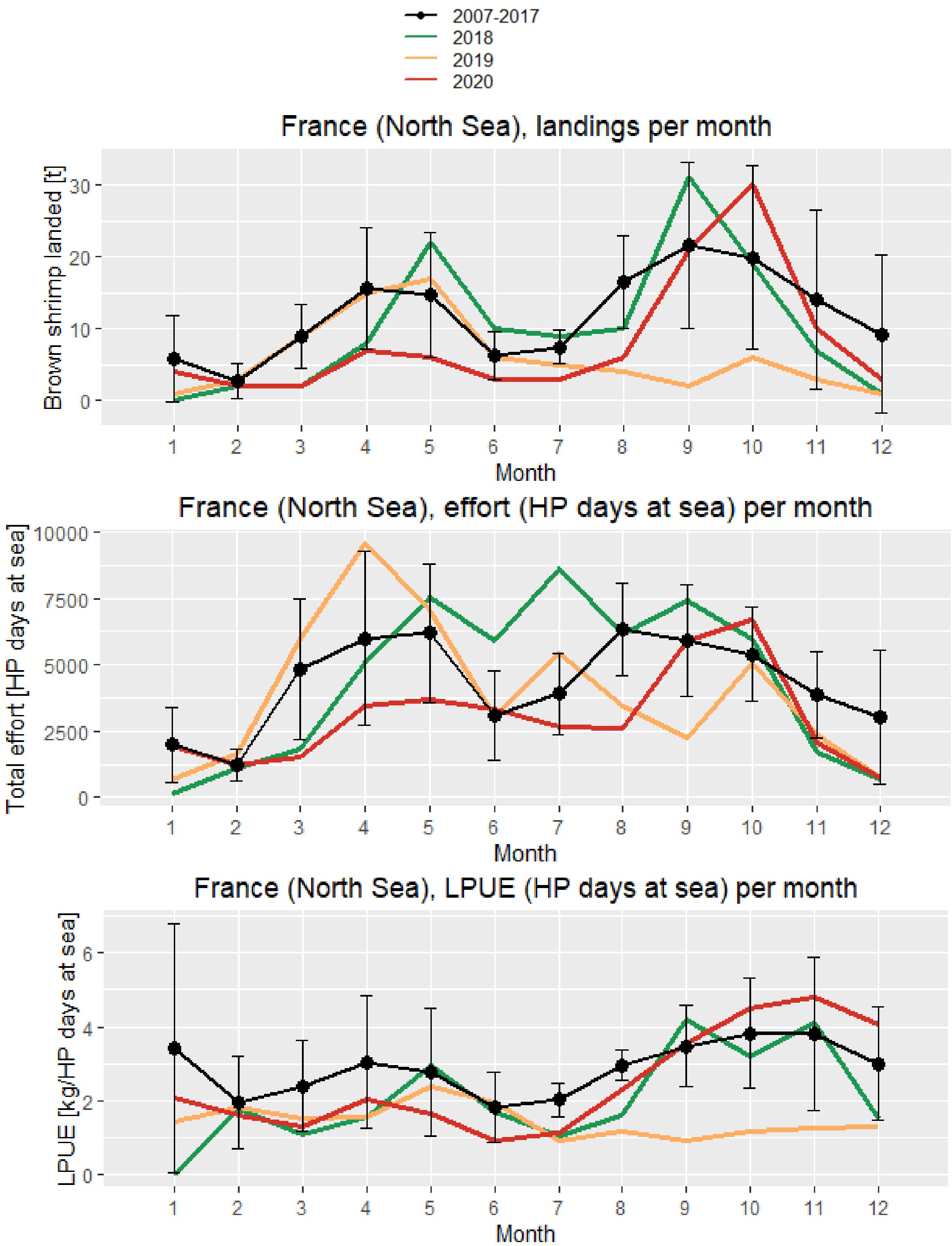


Figure 12. Seasonal patterns of the French fishing fleet in 2018, 2019, 2020 and the mean of 2007–2017 (+/- SD). Upper panel: landings of commercial sized shrimps in tons; medium panel: fishing effort in horsepower days at sea; lower panel: landings per unit effort in kg per horsepower days at sea.

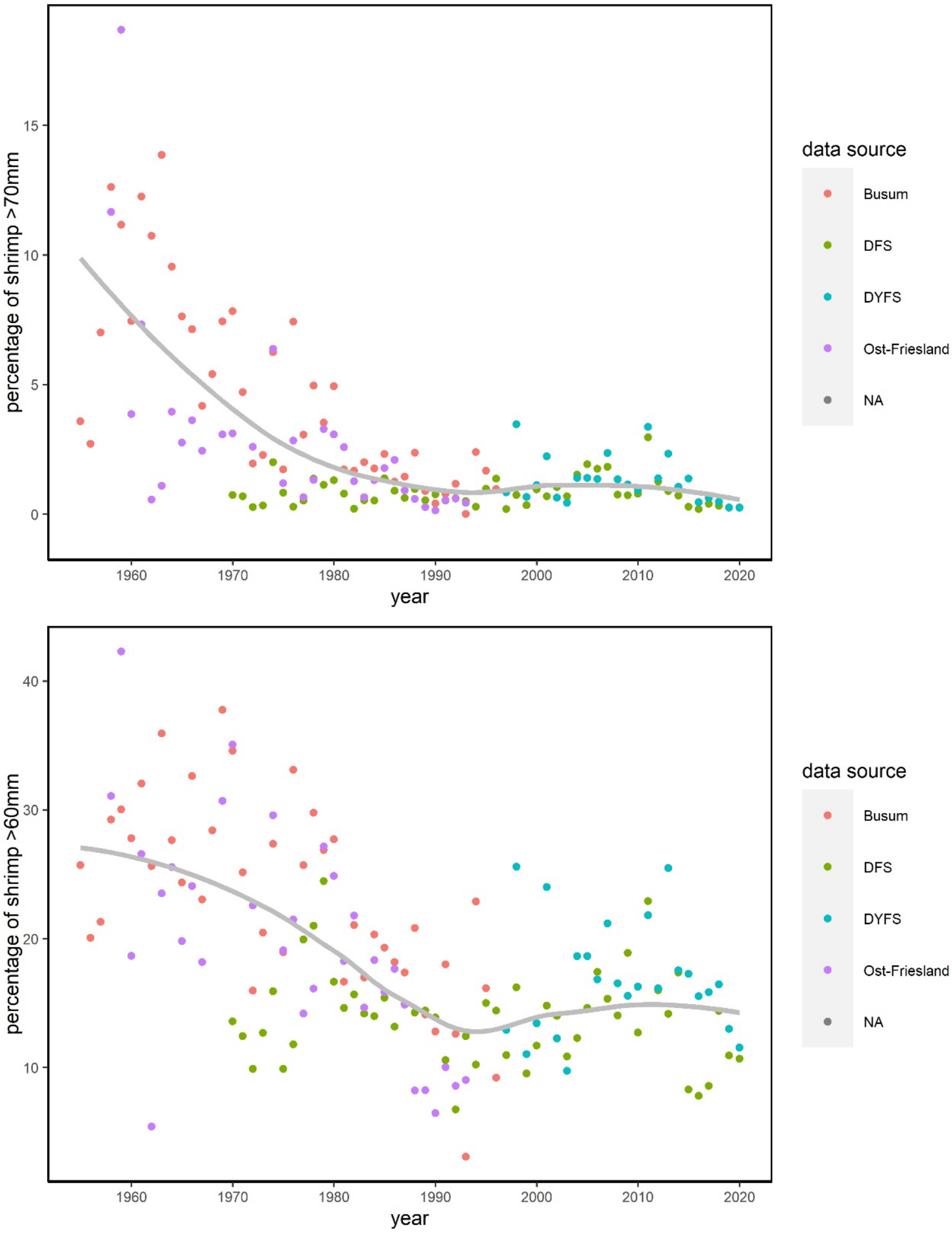


Figure 13. Time-series of proportion of large brown shrimp (>60 mm and >70 mm) in four different survey programs. DFS and DYFS are fishery-independent surveys, Busum and Ostfriesland are German bycatch series. Percentage is expressed as the fraction of all shrimp >45 mm. The grey line is a Loess smoother.

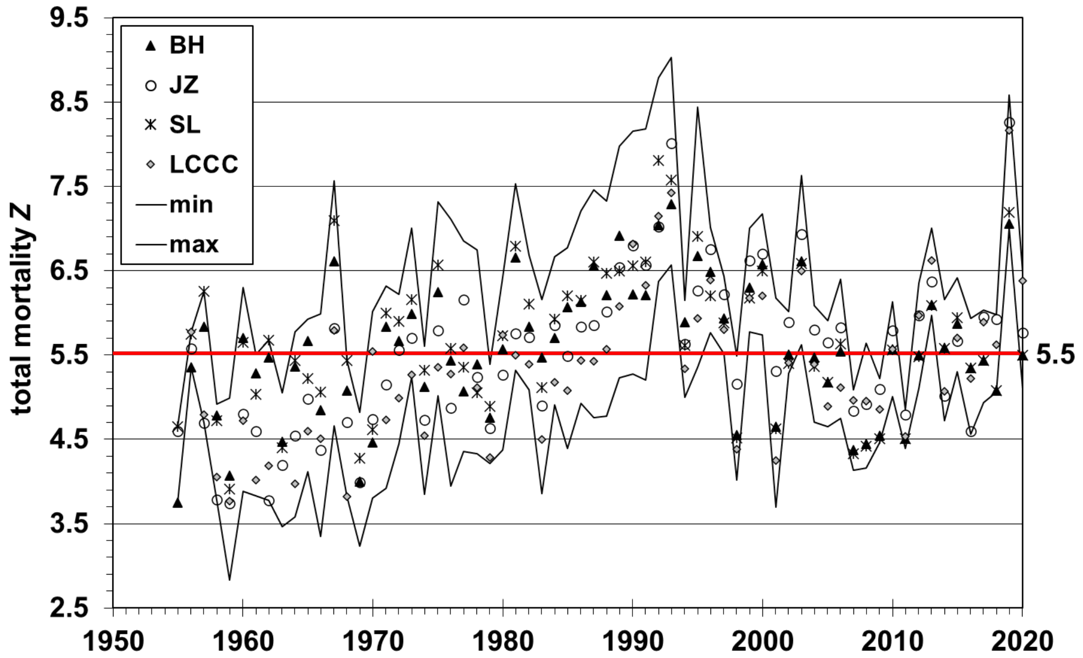


Figure 14. Total annual exponential mortality rate Z [y^{-1}] estimated for 1955–2020 using length-based methods. Four different methods were used (represented by the different symbols): Beverton & Holt (BH), Jones and van Zalinge (JZ), Ssentongo & Larkin and Length Converted Catch Curve (LCCC). Red line=mean during the whole period; methods and validations are presented in Hufnagl *et al.* (2010).

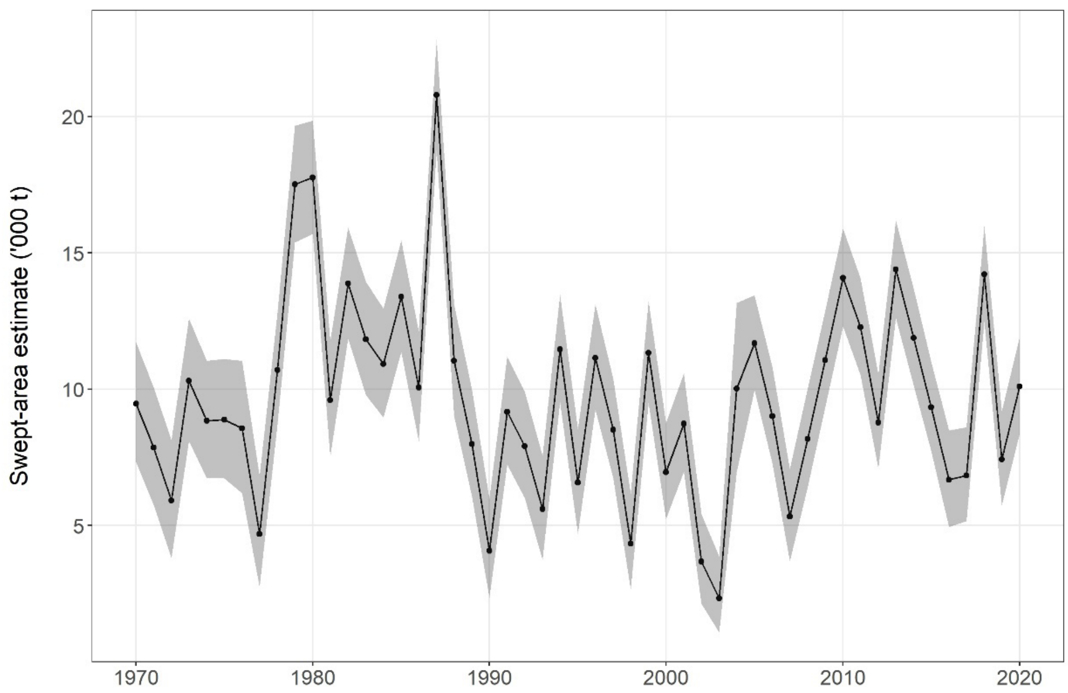


Figure 15. Time-series 1970–2020 and 95% confidence limits (grey area) of the swept area biomass estimate calculated according to Tulp *et al.* (2016).

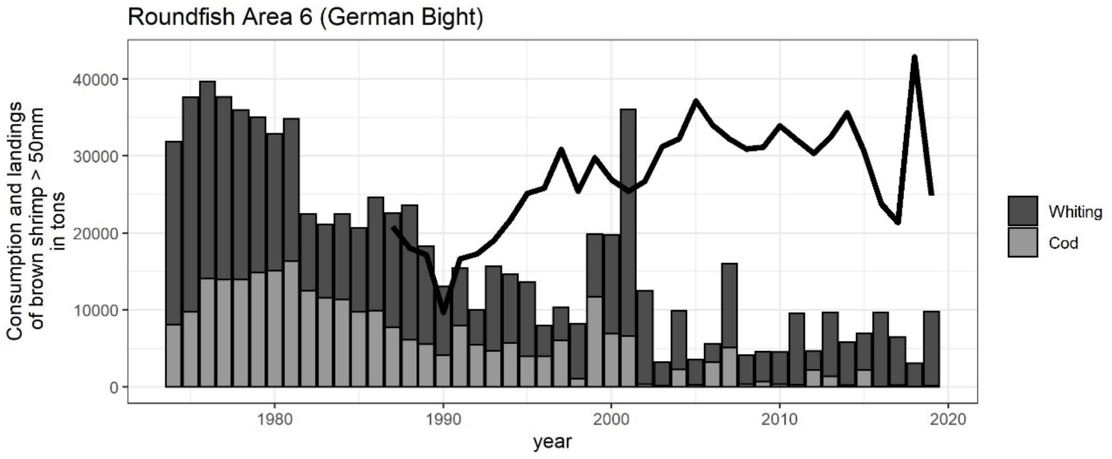
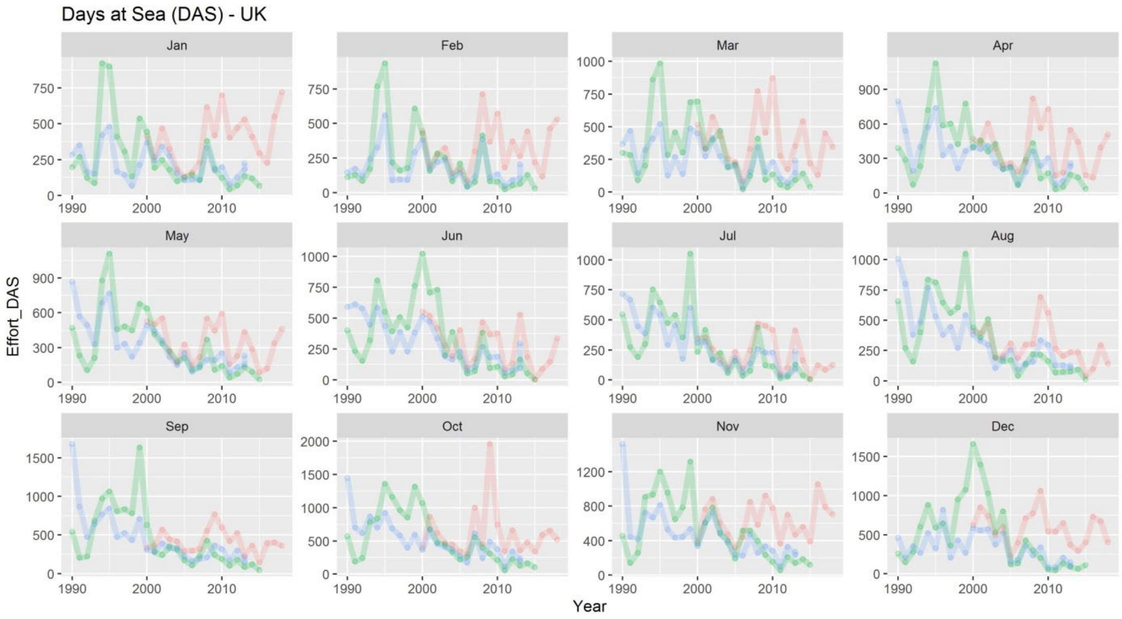


Figure 16. Biomass of brown shrimp larger 50 mm in tons (1) landed by the Dutch, German, and Danish brown shrimp fishery (black line) and (2) consumed by cod (light grey bars) and whiting (dark grey bars) in Roundfish Area 6 (German Bight).

a)



b)

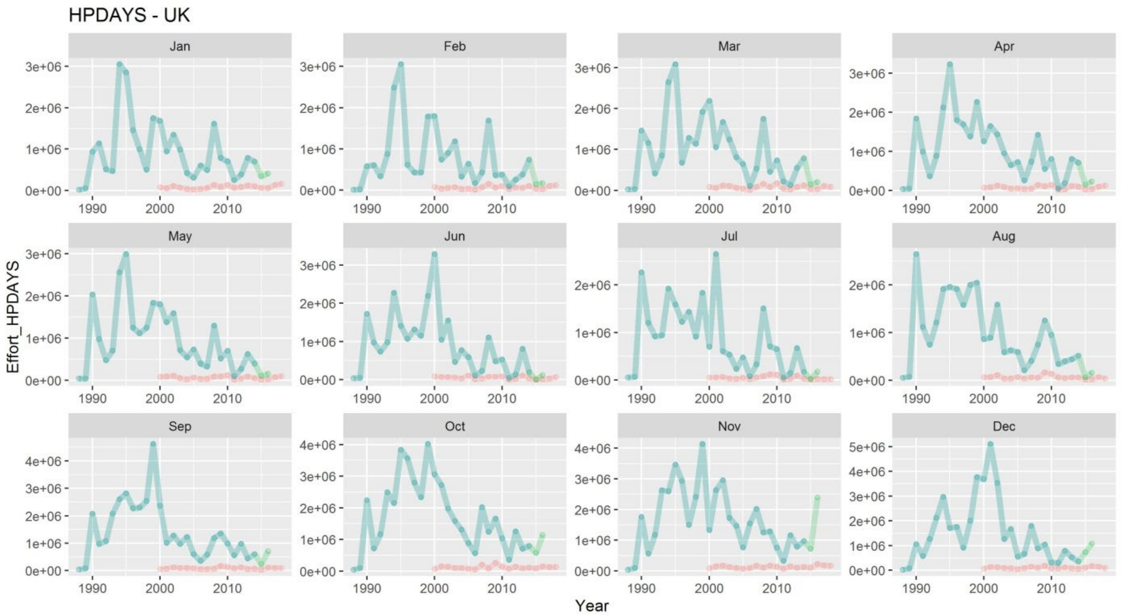


Figure 17. Inconsistencies in the UK effort data in a) days at sea and b) HP days at sea (HPDAYS). Blue: data provided for WGCRAN in 2015; green: data provided for WGCRAN in 2018, red: data provided for WGCRAN in 2019.

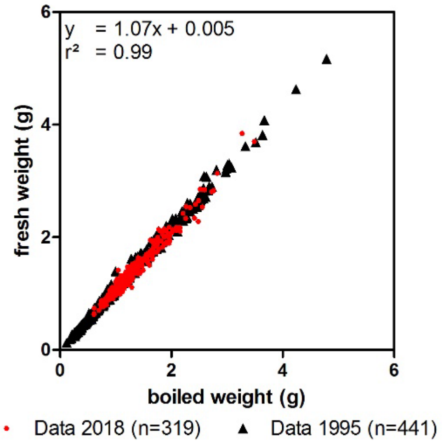


Figure 18. Weight relationship of fresh versus boiled brown shrimp *Crangon crangon* based on individual measurements. Red dots: results from individual measurements performed at the laboratories of the Thünen Institute in 2018; black triangles: individual measurements from 1995 (unpublished data from S. Riemann, Thünen Institute or formerly German Federal research institute for fisheries BFAFI). n = number of animals measured.

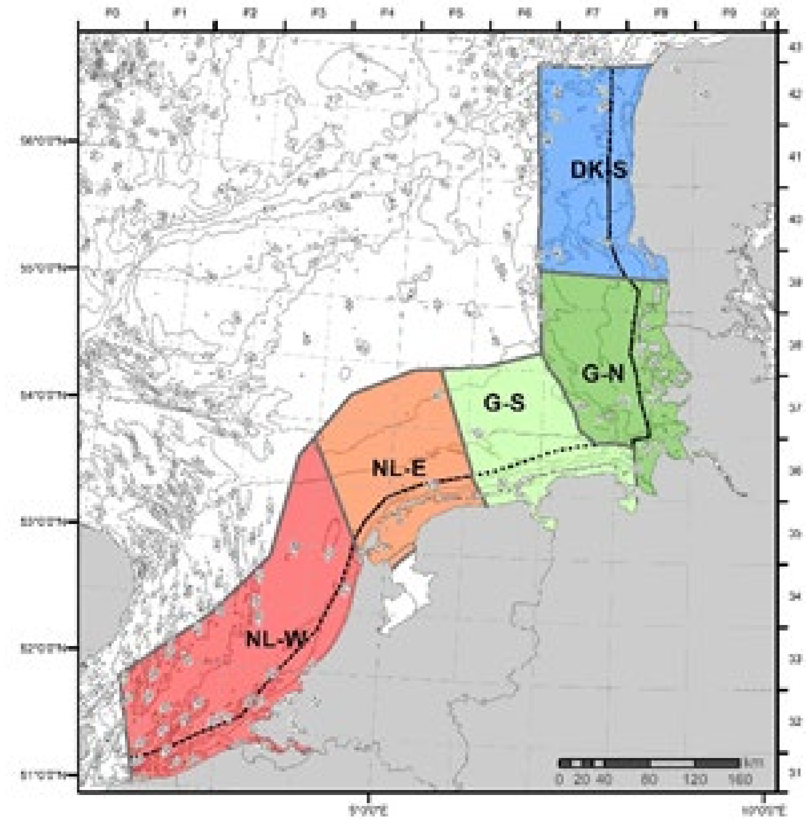


Figure 19. Fishing areas used for data aggregation in the 2019 WGCRAN-meeting. NL-W: Netherlands West; NL-E: Netherlands East; G-S: Germany South, G-N: Germany North; DK-S: Denmark South. Each area is separated in an offshore and inshore component as marked by the dashed line. X- and Y-axes show latitude and longitude. The combination of 31–42 on the right and F1 – F8 on the upper side stands for the ICES statistical rectangles 31F1 – 42F8. Thin black lines show the bathymetry in 10 meter steps.

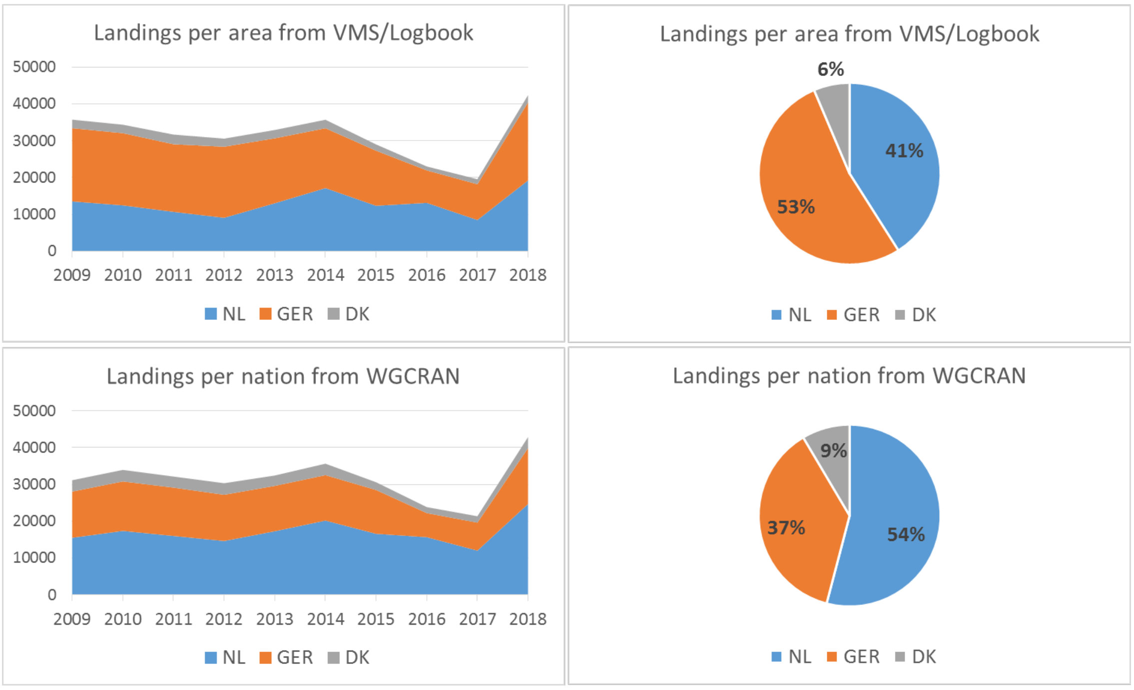


Figure 20. Landings of the main fishing nations Netherlands, Germany, and Denmark per year and share by nation. Upper panels based on data from the combined logbook and VMS analysis and lower panels based on official landings statistics from logbooks aggregated on national level (times-series discussed under ToR a). Left panels illustrate the times-series since 2009 (the beginning of the VMS times-series), right panels the mean national shares in percent.

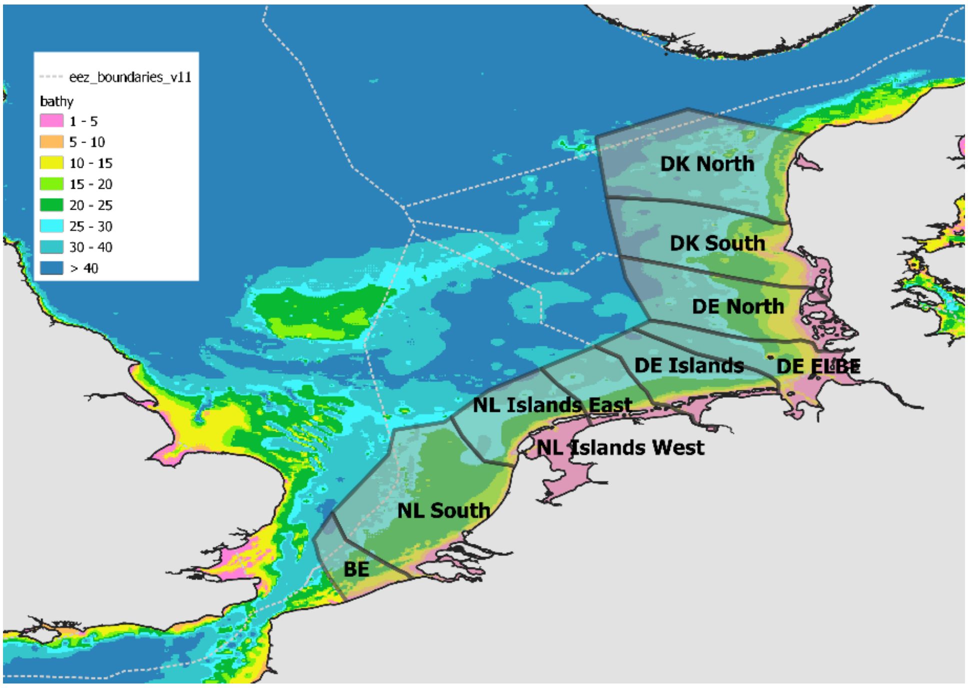


Figure 21. Fishing areas used for data aggregation in the 2020 and 2021 WGCRAN meeting. BE: Belgium; NL-South, NL-Islands West, NL- Islands East: Netherlands; DE Islands, DE Elbe, DE North: Germany; DK-South, DK-North: Denmark. Each area is separated in depth zones (see colour code).

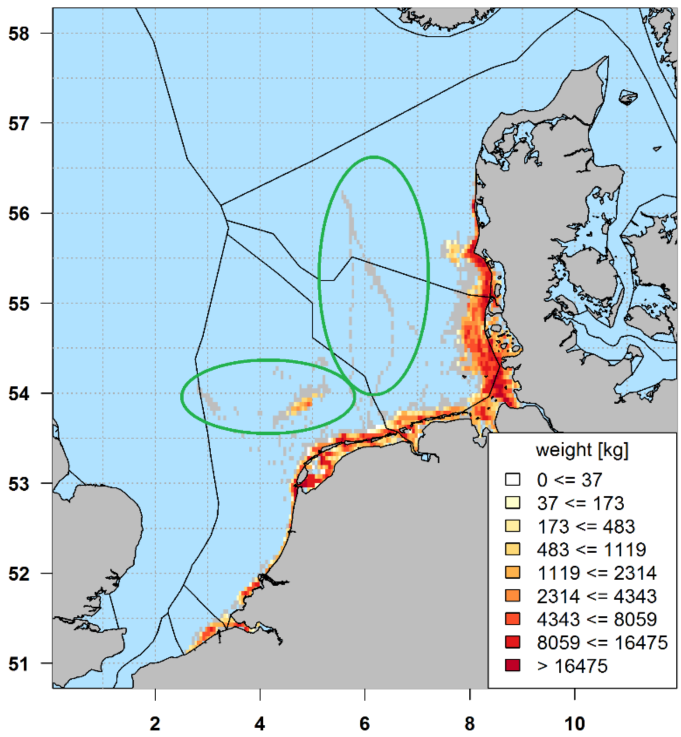


Figure 22. Landings of *Crangon crangon* per c-square for one exemplary quarter and year, based on data from the ICES data call. The green circles mark entries which are most likely not *Crangon crangon* catches. Year and quarter of the underlying data are not displayed due to privacy issues.

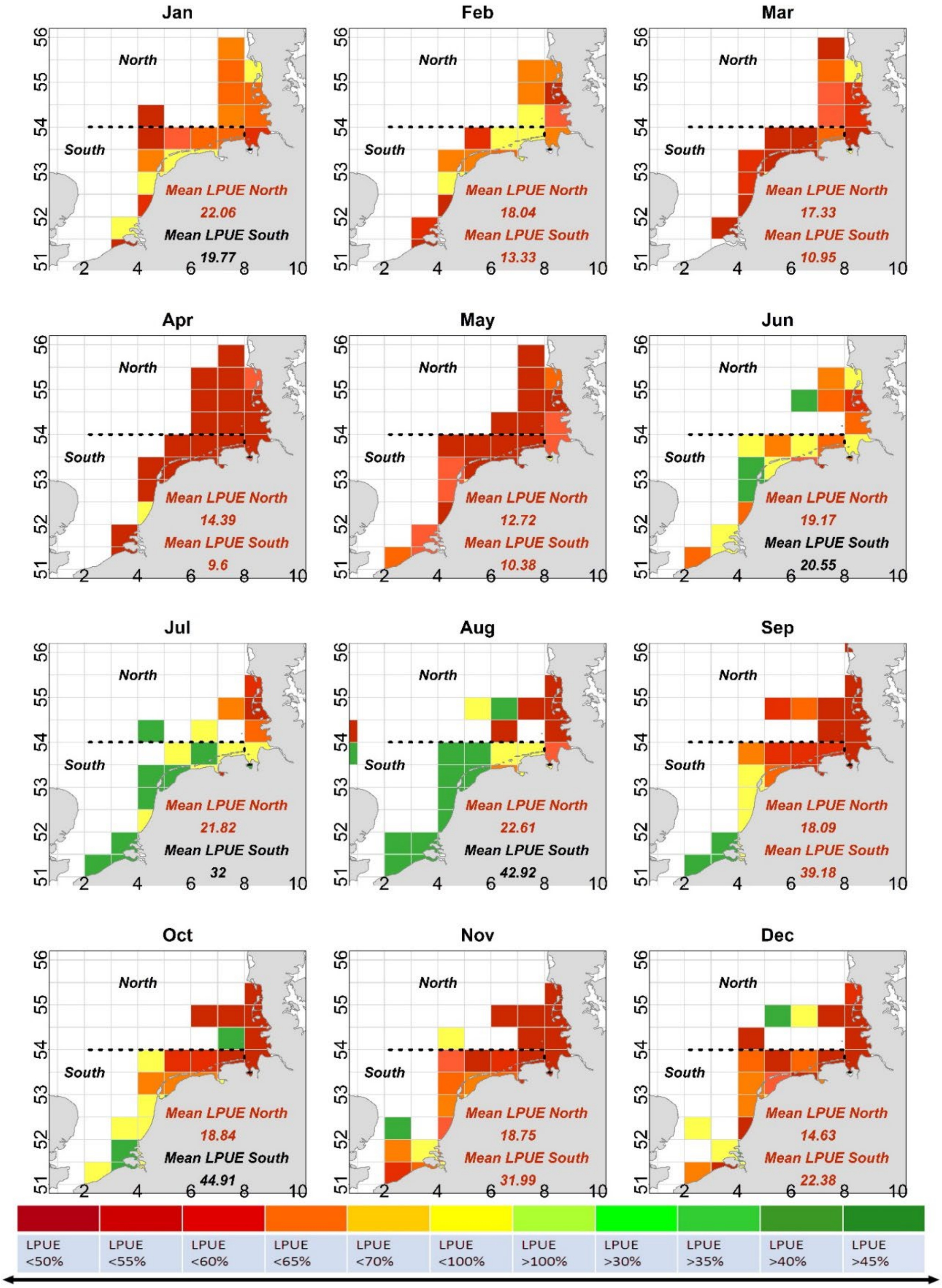


Figure 23. Monthly LPUE in kg/HS in 2016 per ICES rectangle from combined German and Dutch logbook data. The colours red to green (see legend) show the comparison of the monthly LPUE value with the monthly mean value of the management area (years 2011 to 2015, see Table 3).

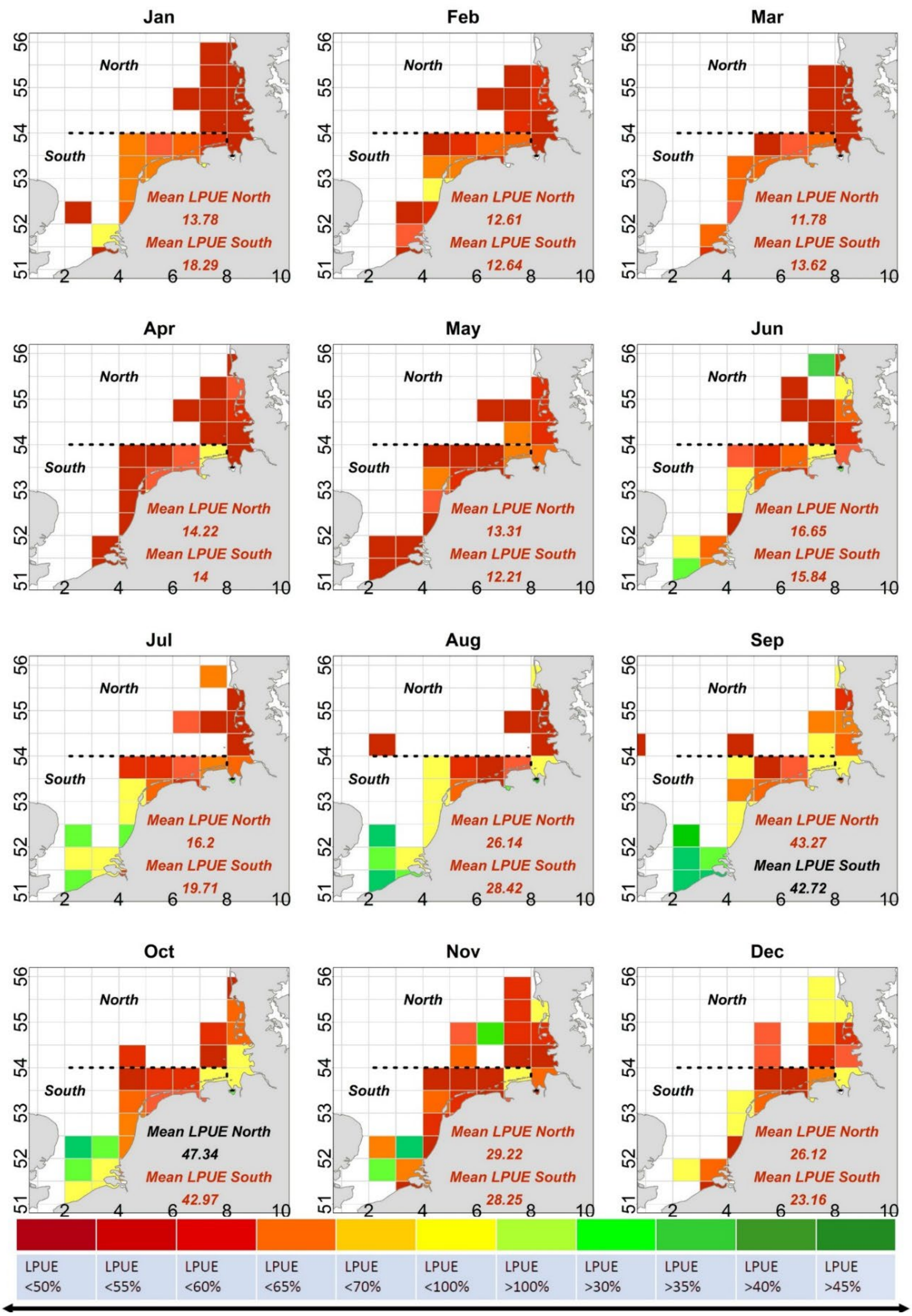


Figure 24. Monthly LPUE in kg/HS in 2017 per ICES rectangle from combined German and Dutch logbook data. The colours red to green (see legend) show the comparison of the monthly LPUE value with the monthly mean value of the management area (years 2011 to 2015, see Table 3).

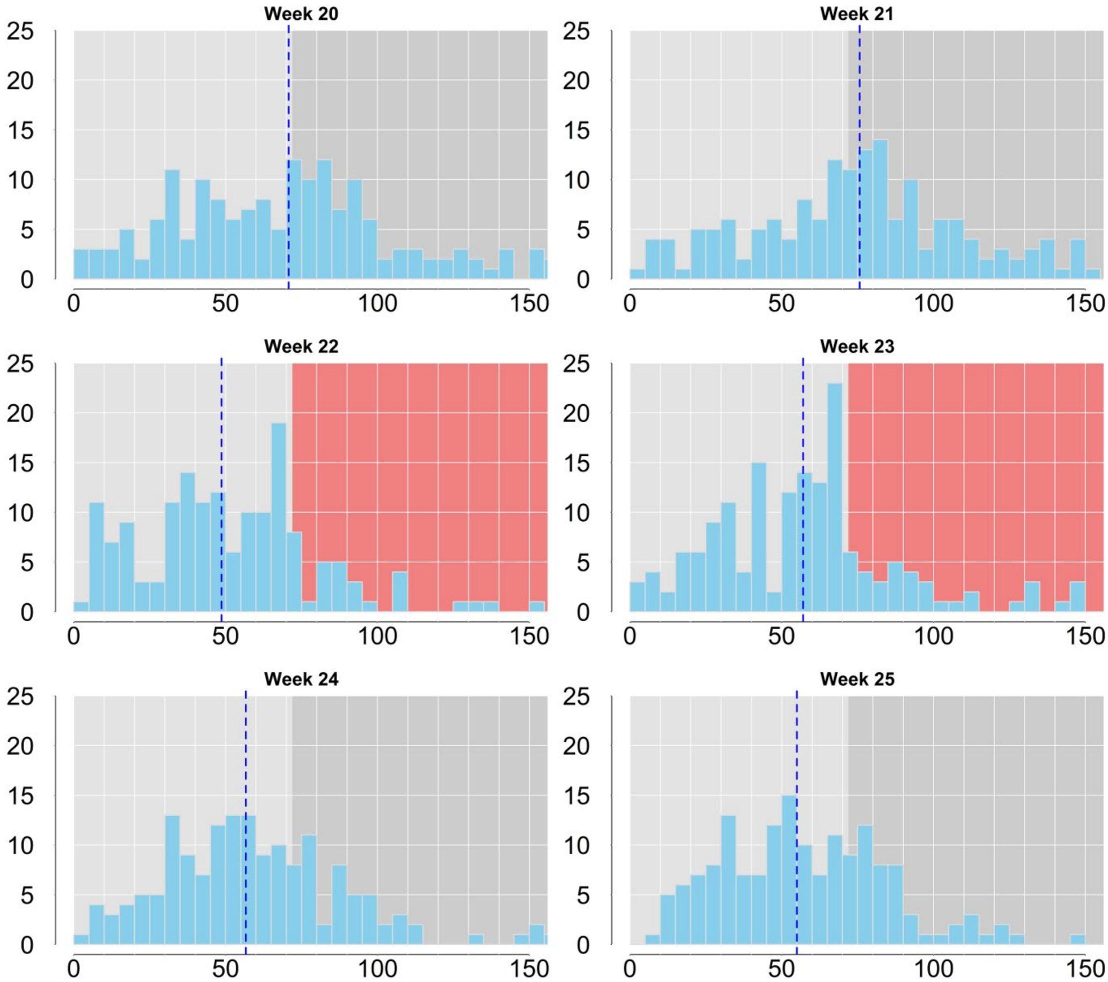


Figure 25. Weekly hours at sea per vessel in 2016, calendar weeks 20–25 (German fleet). The blue dashed line indicates the weekly mean. The dark grey (or light red for the effort limited weeks) part of the graph is over 72 hours at sea per week and vessel.

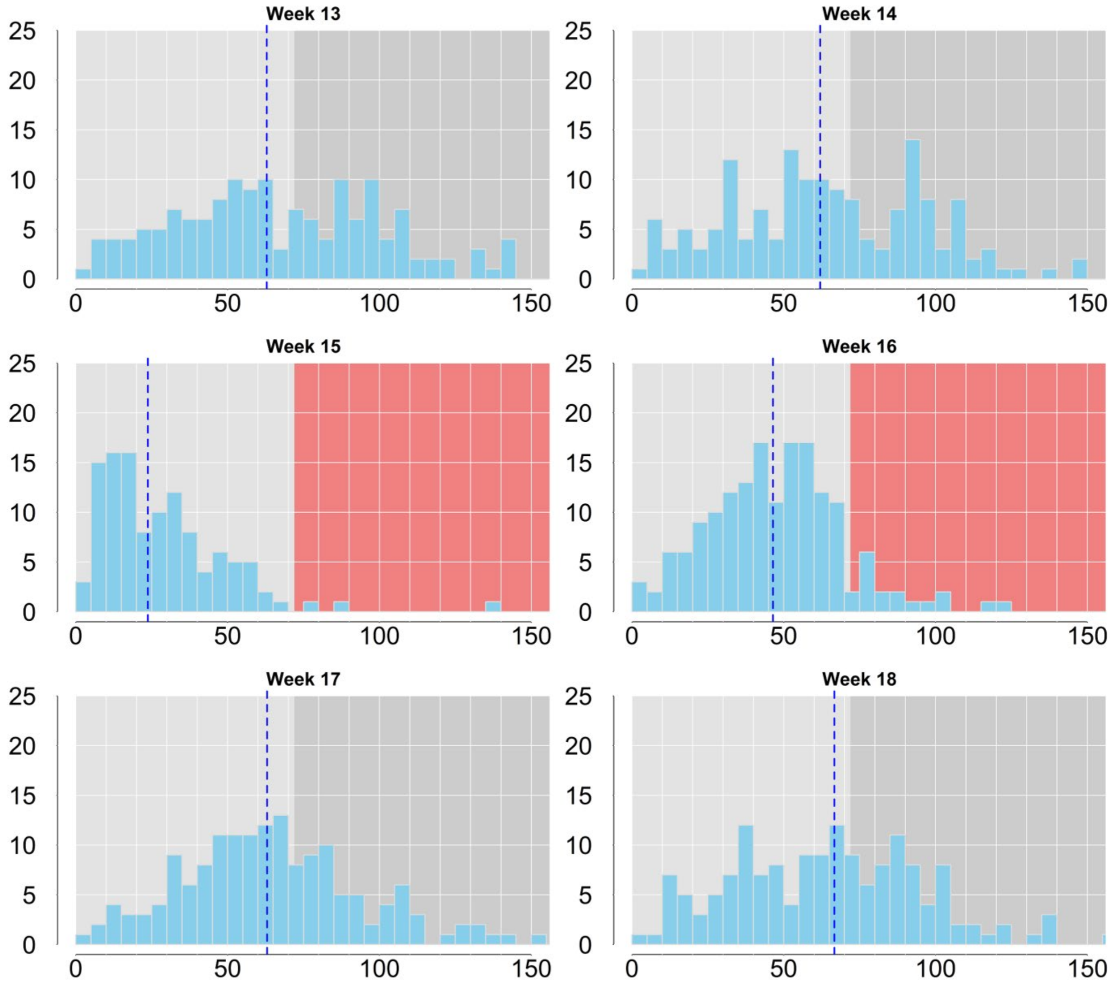


Figure 26. Weekly hours at sea per vessel in 2017, calendar weeks 13–18 (German fleet). The blue dashed line indicates the weekly mean. The dark grey (or light red for the effort limited weeks) part of the graph is over 72 hours at sea per week and vessel.

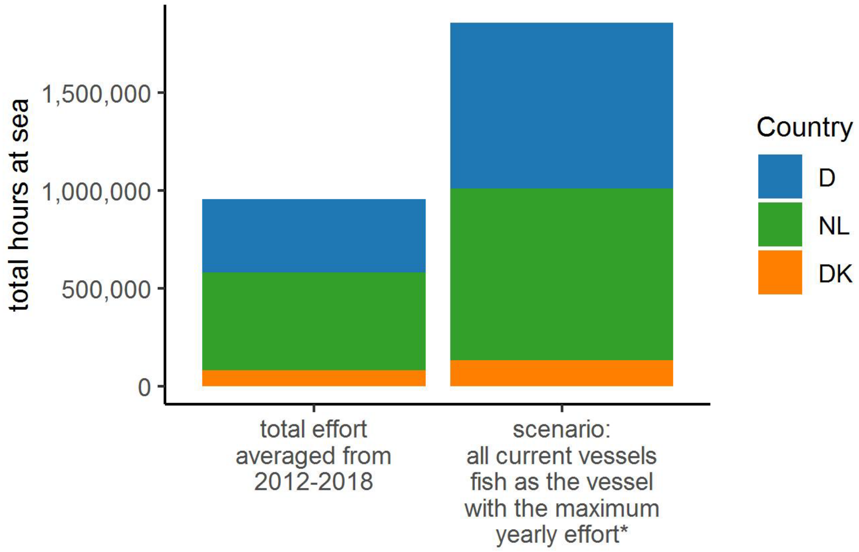


Figure 27. Fishing effort in hours at sea of the whole MSC fleet and a possible scenario of dormant effort increase

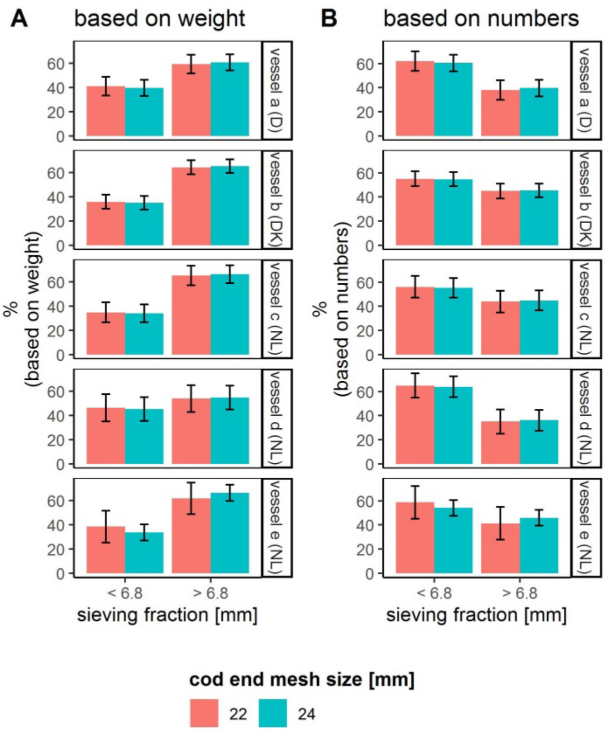


Figure 28. Comparison of the sieving fractions above and below the 6.8 mm sieve between samples of the different vessels in percent based on weights (A) and based on numbers(B) in the 22 mm cod end in red and the 24 mm cod end in blue.

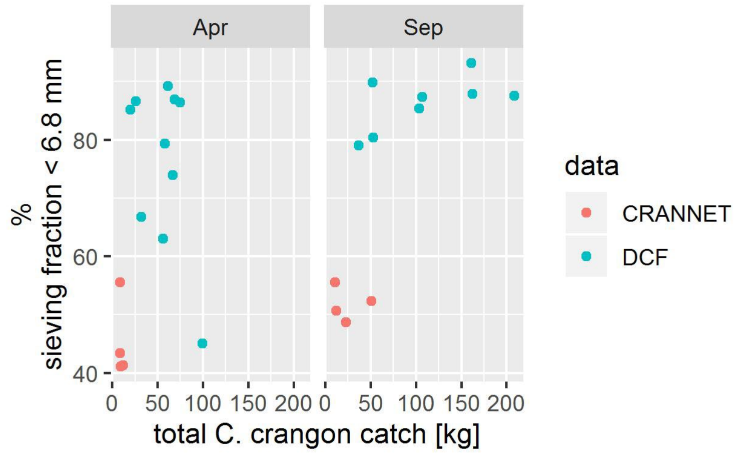


Figure 29. Total catch biomass (kg) and percentage of undersized shrimp (< 6.8 mm carapax width) in April and September 2013 and 2014 in hauls of the CRANNET project (red points) and hauls of the DCF sampling program (blue points). For comparability only hauls with a cod end mesh size of 22 mm were included.

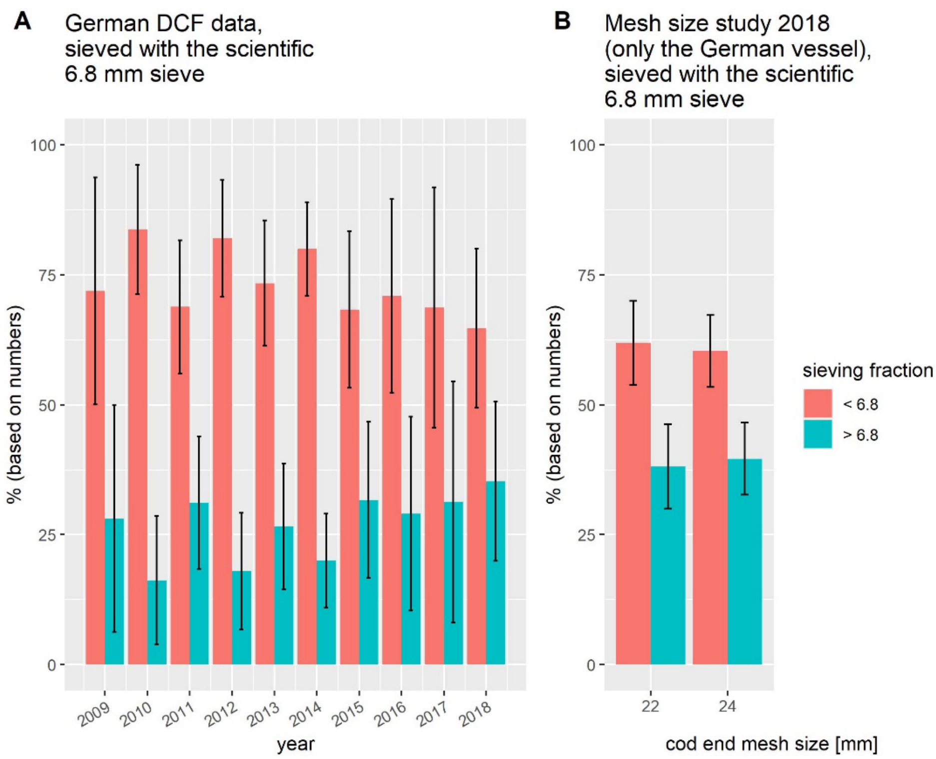


Figure 30. Comparison of the fractions of undersized shrimp (< 6.8 mm, in red, sieving done mathematically) and commercial shrimp (> 6.8 mm, in blue, sieving done mathematically) in (A) German discard sampling times-series from 2009 to 2018 (within the Data Collection Framework, DCF of the European Commission, by courtesy of Kay Panten and Jens Ulleweit, Thünen Institute of Sea Fisheries, Bremerhaven, Germany) and (B) the mesh size study comparing nets with 22 mm and 24 mm in the cod end trawled parallel. As the discard data (A) were only available for Germany, also from the mesh size study (B) only the data from the German vessel is displayed.

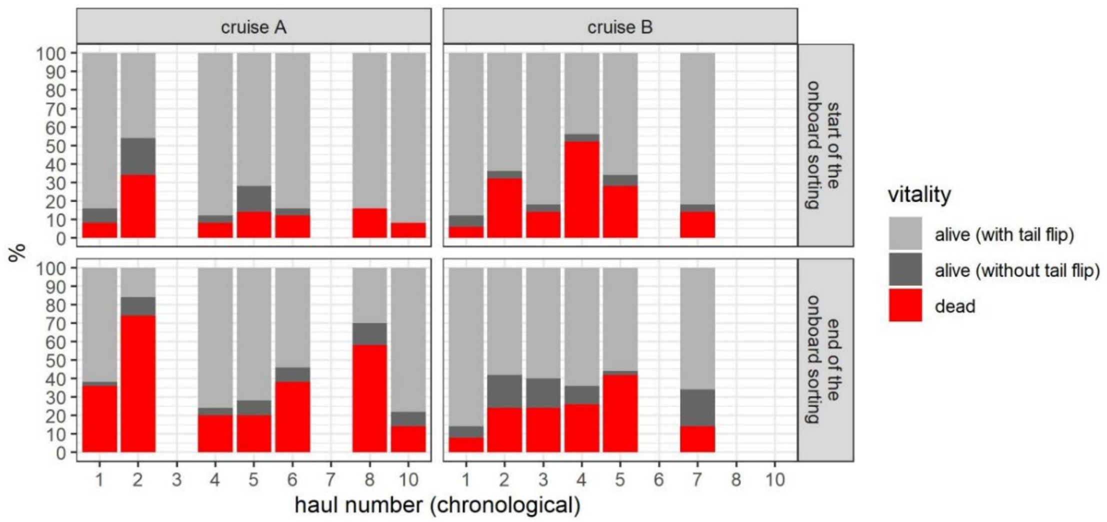


Figure 31. Frequency of occurrence of the three vitality classes (red: dead; light grey: alive with tail flip; dark grey: alive without tail flip) per haul (x-axis), cruise (columns), and processing time (rows).

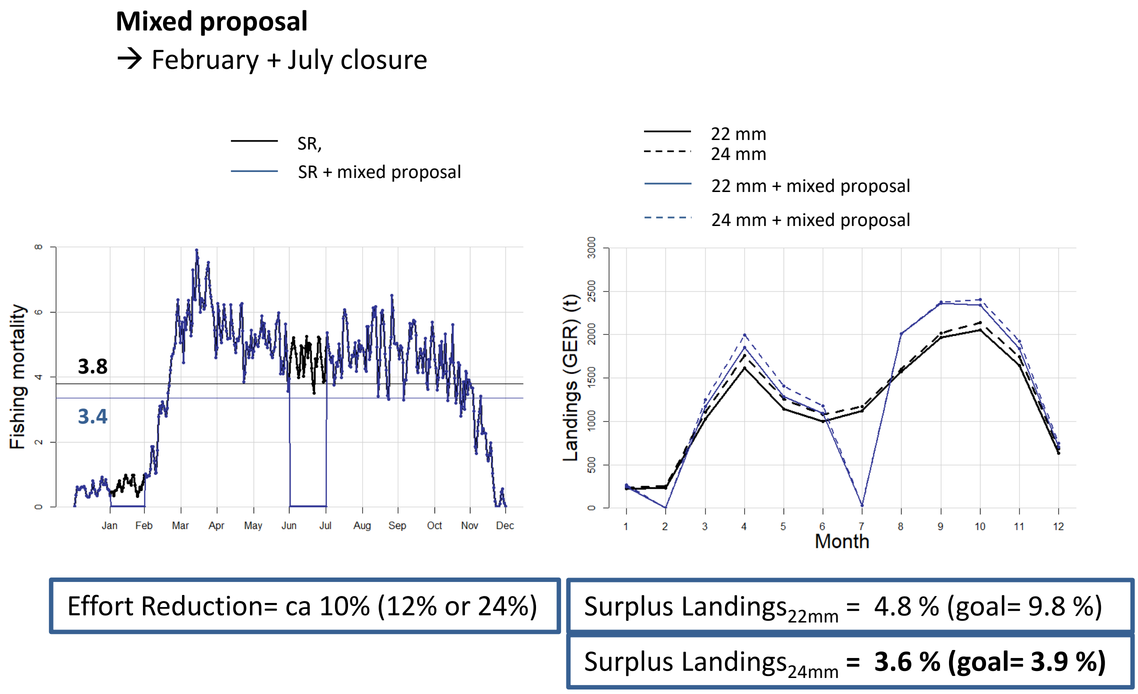


Figure 32. Scenario model run based on standard run II of the Crangon population model published by Temming *et al.* 2017. Standard run II is designed to simulate the mean German fishery in the years between 2002 and 2012. Left panel: Mean fishing mortality during the year; right panel: Mean landings during the year. Black lines: standard run fishing with 22 mm and 24 mm (dashed line) mesh size; blue lines: scenario run with a closed fishery in February and July. Total effort reduction of this scenario run is 10%; in comparison, a 12 (or 24) % reduction would be necessary to achieve the surplus landings of a mesh size increase from 24 (or 22) to 26 mm. Accordingly, 3.6 % surplus catches were generated in the scenario run with a mesh size of 24 mm, which is close to the 3.9 % target (increase to 26 mm).

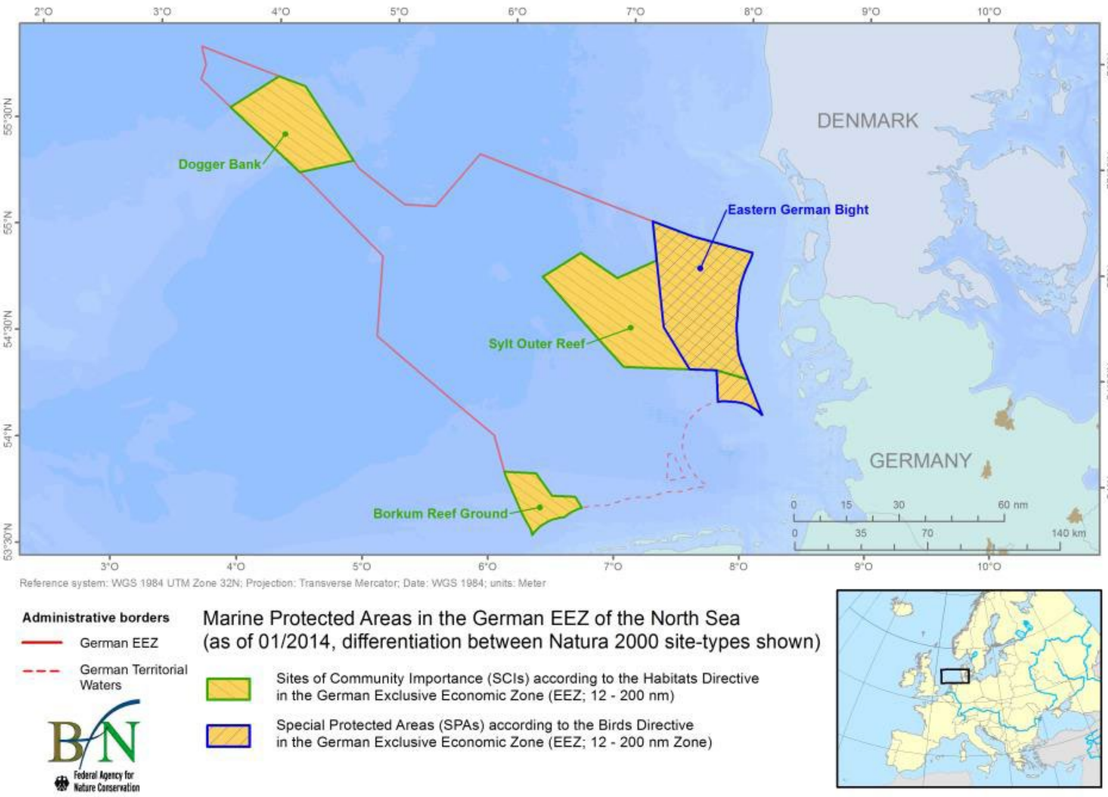


Figure 33. Natura 2000 sites in the German EEZ in the North Sea designated on the basis of the Habitats Directive and the Birds Directive.

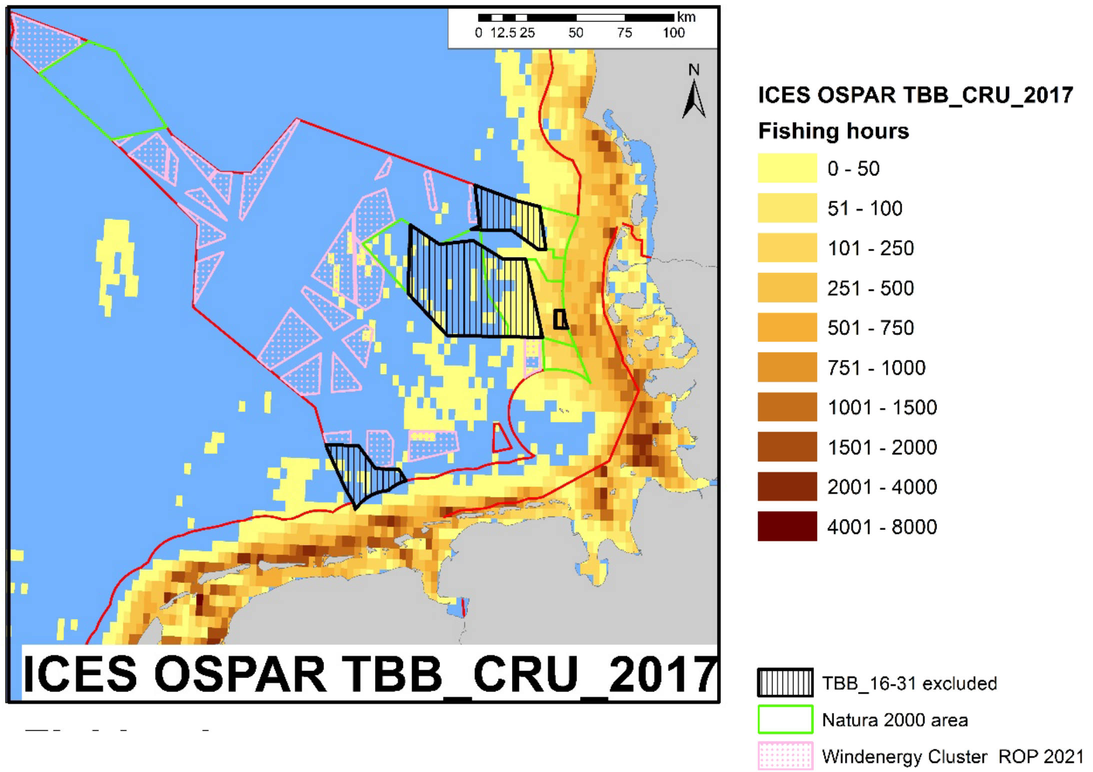


Figure 34. Fishing effort (hours) of the international shrimp fisheries in the year 2017. Source: ICES 2018.

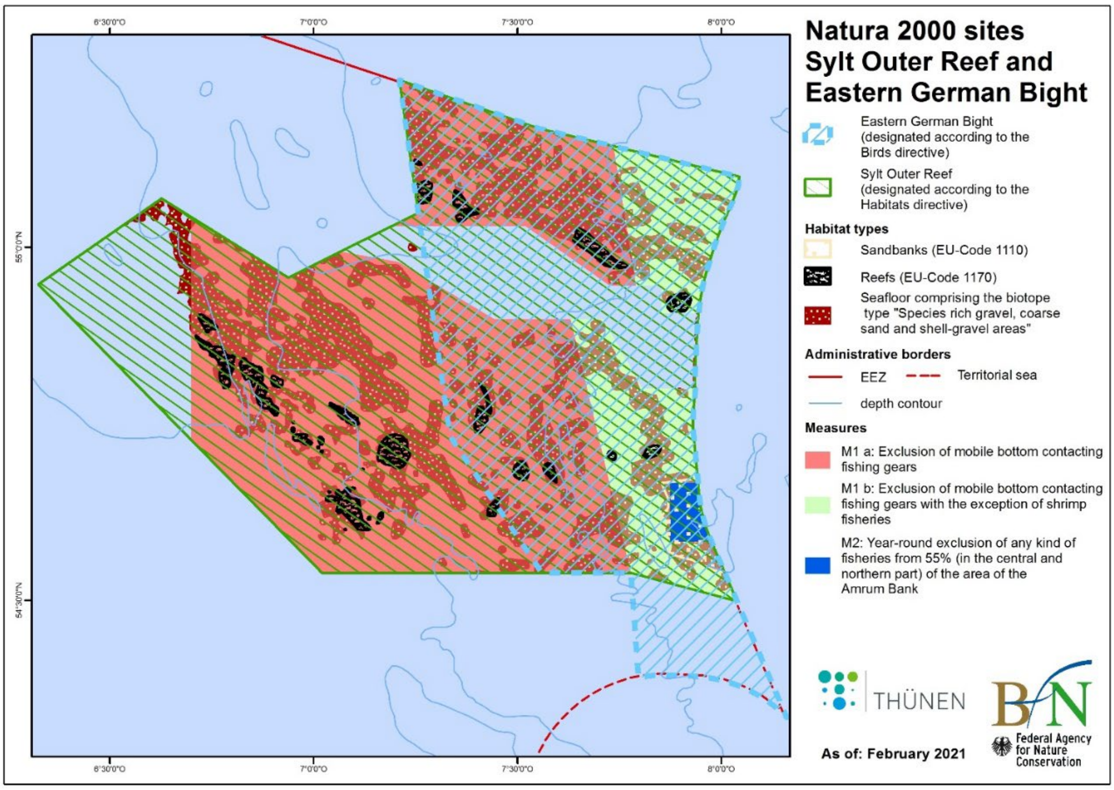


Figure 35. Measure 1a: Year-round exclusion of all mobile bottom-contacting gears in two management zones and Measure 1b: Year-round exclusion of mobile bottom-contacting gears in two management zones with the exception of brown shrimp fisheries with beam trawls within the Natura 2000 site Sylt Outer Reef.

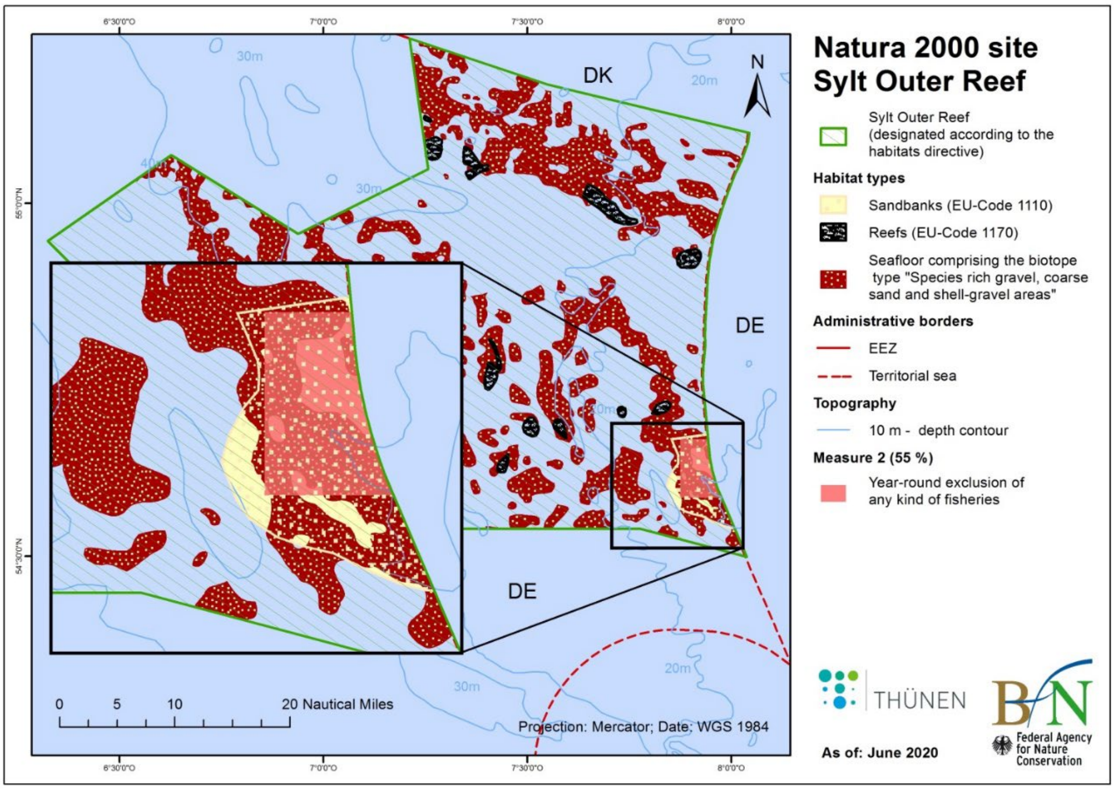


Figure 36. Measure 2: Year-round exclusion of any kind of fisheries from 55% of the area of the Sandbank “Amrum Bank” in the Natura 2000 site Sylt Outer Reef.

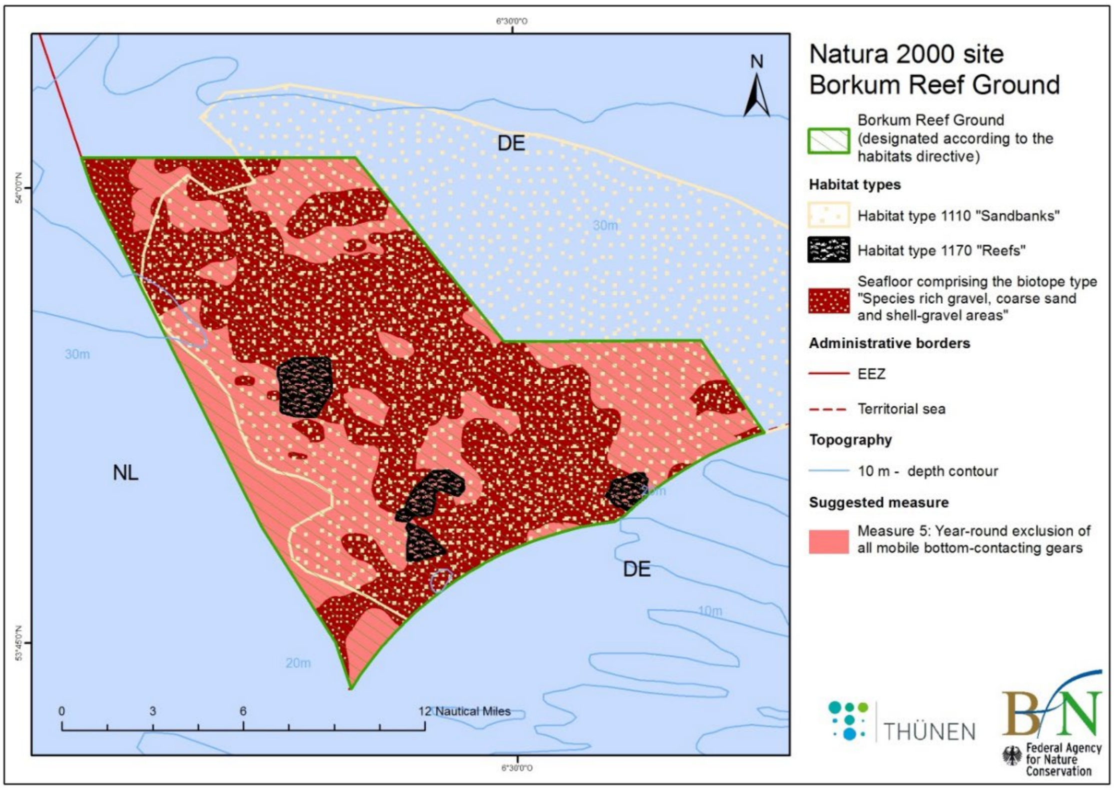


Figure 37. Measure 5: Year-round exclusion of all mobile bottom-contacting gears from the entire Natura 2000 site Borkum Reef Ground.

Table 1. Specifications of reported data per country.

Country	Landings	Days at sea	Horse-power days at sea
The Netherlands	Update 2017: Not available at SharePoint	Update 2017: Not available at SharePoint	Update 2017: Not available at SharePoint
	Update 2018: - Reported years: **2010 - 2017** - Unit: **both, kg and tons**	Update 2018: - Reported years: **2010 - 2017** - Unit: **not specified**	Update 2018: - Reported years: **2010 - 2017** - Unit: **both, kw days at sea and hp days at sea**
	Update 2019: - Reported years: **2018** - Unit: **not specified, but probably tons** - landings, effort incl. Fishing hours	Update 2019: - Reported years: **2018** - Unit: **not specified**	Update 2019: - Reported years: **2018** - Unit: **not specified**
	Update 2020: - Reported years: **2019** - Unit: **tons**	Update 2020: - Reported years: **2019** - Unit: **not specified**	Update 2020: - Reported years: **2019** - Unit: **not specified**
	Update 2021: - Reported years: **2020** - Unit: **tons**	Update 2021: - Reported years: **2020** - Unit: **not specified**	Update 2021: - Reported years: **2020** - Unit: **not specified**
Germany	Update 2017: - Reported years: **2016** - Unit: **kg**	Update 2017: - Reported years: **2016** - Unit: **hrs/24**	Update 2017: - Reported years: **2016** - Unit: **hp days at sea**
	Update 2018: - Reported years: **2017** - Unit: **not specified, but probably kg**	Update 2018: - Reported years: **2017** - Unit: **not specified**	Update 2018: - Reported years: **2017** - Unit: **not specified**
	Update 2019: - Reported years: **2018** - Unit: **not specified, but probably kg**	Update 2019: - Reported years: **2018** - Unit: **not specified**	Update 2019: - Reported years: **2018** - Unit: **not specified**
	Update 2020: - Reported years: **2019** - Unit: **tons**	Update 2020: - Reported years: **2019** - Unit: **hrs/24**	Update 2020: - Reported years: **2019** - Unit: **hp days at sea**
	Update 2021: - Reported years: 2020 - Unit: tons	Update 2021: - Reported years: 2020 - Unit: hrs/24	Update 2021: - Reported years: 2020 - Unit: hp days at sea
Denmark	Update 2017: - Reported years: **1987 - 2016** - Unit: **tons**	Update 2017: No data provided	Update 2017: - Reported years: **1987 - 2016** - Unit: **hp days at sea**
	Update 2018: - Reported years: **2000 - 2017**	Update 2018: - Reported years: **2000 – 2017**	Update 2018: - Reported years: **2000 - 2017**

continued

Country	Landings	Days at sea	Horse-power days at sea
France	Update 2017: - Reported years: **2000 - 2016** - Unit: **tons**	Update 2017: - Reported years: **2011 - 2016** - Unit: **hrs/24**	Update 2017: - Reported years: **2011 – 2016** - Unit: **hp days at sea**
	Update 2018: - Reported years: **yearly: 1970 – 2017** **monthly: 2000 - 2017** - Unit: **tons** - monthly landings of consumption shrimps from Logbook	Update 2018: - Reported years: **2012 - 2017** - Unit: **hrs/24**	Update 2018: - Reported years: **2011 – 2017** - Unit: **hp days at sea**
	Update 2019: - Reported years: **2018** - Unit: **not specified, but probably tons**	Update 2019: - Reported years: **2018** - Unit: **not specified**	Update 2019: - Reported years: **2018** - Unit: **not specified**
	Update 2020: - Reported years: **2000 - 2019** - Unit: **tons**	Update 2020: - Reported years: **2012 - 2020** - Unit: **hrs/24**	Update 2020: - Reported years: **2011 - 2019** - Unit: **Total monthy effort (days_at_sea*HP) of consumption shrimps, data from Logbook [days_at_sea = hours_at_sea / 24]**
	Update 2021: - Reported years: **2000-2020** - Unit: **tons**	Update 2021: - Reported years: **2012 - 2020** - Unit: **hrs/24**	Update 2021: - Reported years: **2011 - 2020** - Unit: **Total monthy effort (days_at_sea*HP) of consumption shrimps, data from Logbook [days_at_sea = hours_at_sea / 24]**
United Kingdom	Update 2017: - Reported years: - **1973 – 2016** - Unit: **not specified** - A small fraction (approx. 10%) of the landings originate from the Irish Sea - before 1980 and from 1997 onwards Scottish landings are believed to be near 0	Update 2017: - Reported years: - **1990 – 2016** - Unit: **not specified**	Update 2017: - Reported years: - **1988 – 2016 and Apr - Nov 1987** - Unit: **hp days at sea**
	Update 2018: Not available at SharePoint	Update 2018: Not available at SharePoint	Update 2018: Not available at SharePoint
	Update 2019: - Reported years: **2000 - 2018** - Unit: **kg** - Reported landings (so probably cooked weight)	Update 2019: - Reported years: **2000 – 2018** - Unit: **days at sea in whole days** and is an overestimate of hours at sea and hours fished	Update 2019: - Reported years: **2000 – 2018** - Unit: **computed from kW using a 1.341 raising factor**
	Update 2020:	Update 2020:	Update 2020:

continued

Country	Landings	Days at sea	Horse-power days at sea
Belgium	Update 2017: - Reported years: **2001 – 2016** - Unit: **kg**	Update 2017: - Reported years: **2013 – 2016** - Unit: **based on hours at sea**	Update 2017: - Reported years: **2001 – 2016** - Unit: **hp days at sea (based on hours at sea/24*hp)**
	Update 2018: - Reported years: **2004 - 2017** - Unit: **not specified**	Update 2018: - Reported years: **2004 - 2017** - Unit: **not specified**	Update 2018: - Reported years: **2004 - 2017** - Unit: **not specified**
	Update 2019: - Reported years: **2018** - Unit: **tons**	Update 2019: - Reported years: **2018** - Unit: **not specified**	Update 2019: - Reported years: **2018** - Unit: **kW days at sea**
	Update 2020: - Reported years: **2019** - Unit: **tons**	Update 2020: - Reported years: **2019** - Unit: **not specified**	Update 2020: - Reported years: **2019** - Unit: **not specified**
	Update 2021: - Reported years: 2020 - Unit: **tons**	Update 2021: - Reported years: 2020 - Unit: **not specified**	Update 2021: - Reported years: **2020** - Unit: **kW days at sea**

Table 2. Landings (in tons) from the VMS data call 2020, official landings (in tons) and difference in percent from the year 2009 to 2017.

Year	WGCRAN	VMS 2020	Difference
2009	31 694	23 606	-26%
2010	35 307	56 692	61%
2011	32 753	52 121	59%
2012	31 035	47 452	53%
2013	33 394	35 954	8%
2014	36 576	38 797	6%
2015	31 140	31 908	2%
2016	24 733	25 022	1%
2017	21 969	21 472	-2%

Table 3. Survey of national data processors of NL, GE and Dk to investigate the discrepancies between the dataset from the VMS data call 2020 and the official shrimp landing statistics.

Questions 1		What is in the CSH catch tones which contribute to the totweight column of the original data call: Does it contain consumption shrimps only or also industrial shrimps? Or is a special size class used here?
Answer	**NL**	All landed shrimp. NLD it's mostly for consumption, but a clear distinction is not made in the logbooks
	Dk	It contain both shrimps for consumption (in 2019 1393 ton) and industry (in 2019 105 ton). The total sum of official landings in 2019 was 1498 ton, the summed weight of landings within the metier TBB_CRU_16-31_0_0 in the ICES datacall in 2019 was 1488 ton. The difference might be caused by landings that can't be coupled to VMS data due to no positions with speeds between 2 and 4 knots within the same vessel and day.
	GE	we do not distinguish between consumption and other shrimps. Everything that is CSH is in there.
Questions 2		Is there a conversion factor used to estimate the fresh weight from the landed (cooked) weight in this column?
Answer	**NL**	This should be fresh weight in our case. We don't know if a conversion has been used as it would have been applied by the controlling agencies and not by us
	Dk	No, no conversion factor is used.
	GE	We use the estimated fresh weight (complete animal), I already sent you the conversion factors.
Questions 3		How is the shrimp fishery (targeting *Crangon crangon*, CSH) classified in the data delivery to ICES in term of metier level 6 (e.g. TBB_CRU_16-31, TBS_CRU_16-31) and on Gear level (e.g. TBS, TBB)?
Answer	**NL**	We usually report it as TBS_CRU_16-31 but there is NO other fishery in the Netherlands that is allowed to fish with 16-31 other than shrimp. So also TBB_CRU_16-31 would be shrimp for us
	Dk	It is classified as metier TBB_CRU_16-31_0_0. On gear level it is classified mainly as TBB, but the gear codes TBS, OTB and DRB occurs.
	GE	-
Questions 4		How is the threshold for fishing activity set in your workflow (e.g. per metier, per gear)? Are the shrimpers separated from other beam trawlers aiming for demersal fish?
Answer	**NL**	It's based on automatic detection of speed thresholds. We analyse the shrimp fishery in isolation of other fishing types. Thresholds are somewhere between 1.5 and 5.5 knots but they can vary a little from year to year as we run the analyses at an annual basis.
	Dk	The speed threshold is set as 2-4 knots. For beam trawlers targeting demersal fish, the speed threshold is 5-7.
	GE	I estimate the speed thresholds for fishing activity per gear, separating the shrimp cutters from the rest of the TBBs and giving them their own gear code (TBC: trawl beam crangon). For the call delivery to ICES this is again changed to the official 3-alpha code TBB.

Table 4. Landings (in tons) from the VMS data call 2020, official landings (in tons) and difference in percent from the year 2009 to 2017.

Year	WGCRAN	VMS 2021	Diff.
2009	31 694	57 507	81%
2010	35 307	54 889	55%
2011	32 753	49 839	52%
2012	31 035	47 951	55%
2013	33 394	36 878	10%
2014	36 576	39 547	8%
2015	31 140	32 148	3%
2016	24 733	25 804	4%
2017	21 969	21 927	0%
2018	44 094	46 450	5%
2019	25 492	25 405	0%
2020	27 381	26 536	-3%

Table 5. Area-specific reference values based on logbook data from German and Dutch fisheries 2011-2015 (LPUE = average value).

Month	LPUE [kg/HS]	area	Ref1 [70% LPUE]	Ref2 [65% LPUE]	Ref3 [60% LPUE]	Ref4 [55% LPUE]	Ref5 [50% LPUE]
1	35	North	24.5	22.75	21	19.25	17.5
2	26.78	North	18.75	17.41	16.07	14.73	13.39
3	31.68	North	22.18	20.59	19.01	17.42	15.84
4	31.64	North	22.15	20.57	18.98	17.4	15.82
5	24.11	North	16.88	15.67	14.47	13.26	12.05
6	29.08	North	20.36	18.9	17.45	15.99	14.54
7	32.35	North	22.64	21.03	19.41	17.79	16.18
8	47.8	North	33.46	31.07	28.68	26.29	23.9
9	65.84	North	46.09	42.8	39.5	36.21	32.92
10	66.53	North	46.57	43.24	39.92	36.59	33.27
11	54.54	North	38.18	35.45	32.72	30	27.27
12	39.96	North	27.97	25.97	23.98	21.98	19.98
1	27.93	South	19.55	18.15	16.76	15.36	13.96
2	19.46	South	13.62	12.65	11.68	10.7	9.73
3	22.2	South	15.54	14.43	13.32	12.21	11.1
4	24.42	South	17.09	15.87	14.65	13.43	12.21
5	22.75	South	15.92	14.79	13.65	12.51	11.38
6	23.76	South	16.63	15.44	14.26	13.07	11.88
7	28.7	South	20.09	18.66	17.22	15.79	14.35
8	40.97	South	28.68	26.63	24.58	22.53	20.48
9	57	South	39.9	37.05	34.2	31.35	28.5
10	62.86	South	44	40.86	37.72	34.57	31.43
11	51.46	South	36.02	33.45	30.88	28.3	25.73
12	36.63	South	25.64	23.81	21.98	20.15	18.32

Table 6. An alternative measure to a mesh size increase to 26 mm is the removing of fishing licenses. A reduction of fishing effort by 12% results in similar surplus landings as a mesh size increase to 26 mm, and are thus defined as a goal here. Calculations based on the average number of active vessels per year (2011-2018, in NL till 2019) and a 10% reduction of the fleet size is assumed.

Country	**NL**	**D**	**DK**
Number of vessels removed from the fleet (10 % of the active vessels)	19	19	3
Choosing the vessels with the **highest** yearly effort (HAS)	16.9 %	17.5 %	15.6 %
Choosing the vessels with the **lowest** yearly effort (HAS)	1.6 %	1.8 %	5.6 %

Annex 5: Tables ToR f

Table A. Self-sampling strategy by countries (NL = The Netherlands; GER = Germany; DK = Denmark).

Country	No of active vessels in the shrimp fleet (2018)	No of vessels in self-sampling fleet	Representativeness of vessels in self-sampling fleet	Number of trips sampled per vessel	Temporal spreading of trips	Number of samples per trip	Sample volume	Temporal spreading of haul samples per trip RANDOMIZATION of sampling haul	Desired total number of samples per year
NL	187	15	According to fleet category based on main harbour, motor capacity, gear, to cover spatial and seasonal pattern in fishery	2-6 (not fixed)	Sampling effort is spread over area and throughout the year according to the fleet's activity. If no fishing takes place during the assigned month, the first fishing trips thereafter will be sampled instead.	2 (from one day and one night haul)	10 L (cooled and transported on ice until analysis)	The fisher chooses the trip within the ascribed month and chooses one night and one day haul during that trip	200 (15 ships x 2 samples a trip)
GER	186	25	Elected by home port and motor capacity to cover various fishing pattern	8	Each vessel will sample twice in March, June, September and December (=2 samples per quarter)	1	10 L (frozen)	The fisher chooses the trip and the haul. For freshness of sample one of the last hauls.	200 (25 ships x 8 trips)
DK	25	25	100%	2	Each vessel will be assigned 2 given months to sample, to obtain a coverage throughout the year. If no fishing takes place during the assigned month, the next fishing trip will be sampled.	2 (from different hauls)	4 L in total, 2 L from each pounder (frozen)	The fisher chooses the haul during the first trip of the month	100 (25 ships x 2 trips x 2 samples a trip)

Table B. Progress of self-sampling since 2019 (NL = The Netherlands; GER = Germany; DK = Denmark).

	NL	GER	DK
Vessels participated	15 (in 2021)	16	25
Quarters sampled	-	4	7
# Samples delivered	10	117	62
ICES squares sampled	-	7	6
Self-Sampling Details			
Sample Volume	10L	10L	4L (2x2L)
Condition	Fresh on ice	Frozen	Frozen
Haul information	• For the entire sampled trip: Vessel`s name, date, beam length, mesh size, time of departure and arrival in harbour, number of total hauls, begin and end time of each haul, location of each haul, wind, speed, depth, temperature during each haul, total catch of each haul (height of catch in each container), total cooked shrimp (landed) per haul	• General: Vessel name, date, beam length, mesh size, consumption shrimp landed at respective trip • Haul specific: Gear at ground (longitude; latitude; time); start of heaving (longitude; latitude; time) • Catch specific: height (cm) in the container	• General: Vessel name, date, wind speed & direction, wave height & direction • Haul specific: mesh size, fishing depth, fishing time start and stop, fishing position start and stop • Catch information: height of catch (cm) in pounders (port and starboard side), estimate of total catch (kg), catch weight (kg) of brown shrimp for landing, estimate of TAC bycatch (kg)
Data collection at the institutes	Legend: ✓= yes; X = no; O = for some species		
TAC species [weight, number & mm]	[✓, ✓□✓]	[✓, ✓□✓]	[✓, ✓□✓]
Other fish [weight, number & mm]	[✓, ✓□✓]	[✓, ✓□✓]	[✓, ✓□✓]
Benthos/Invertebrates [weight, number & mm]	[✓, ✓□✓]	[✓, ✓,✓]	[✓, ✓□✓]
Brown shrimp [weight, number & mm]	[✓, X, X]	[✓, ✓□✓] Incl. separation in undersized (<50mm) and consumption shrimp (≥ 50)	[✓, X ,X]
Projection	Calculated on fleet level, per month and year with the information collected for each haul	Calculation based on the consumption shrimp landed at respective trips	

Supporting projects / funding			
	• N.A.	• EMFF 2019-2020 • Thünen-Institute internal since 2021	• .EMFF 2019- 2022 (Bycatch reduction in the North Sea brown shrimp beam trawl fishery)
Other sources/projects regarding information on by-catch in the shrimp-fishery			
	• IRC • DCF (2009-2019)	• DCF (ongoing) • Cranman (1954-1990)	• DCF (ongoing)