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Interim Report of the Working Group on Crangon Fisheries and Life History (WGCRAN)

7-9 November 2017

Hamburg, Germany

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

The 2018 meeting of the Working Group on Crangon Fisheries and Life History (WGCRAN) was held in Hamburg, Germany, November 2017. The meeting was chaired by Josien Steenbergen (the Netherlands) and attended by 12 participants representing 4 countries.

The members of WGCRAN see the priority of this expert group in understanding the interactions between: i) the brown shrimp population (structure and abundance) and human activities (mainly fishing effort); ii) the shrimps and the environment (temperature, currents); and iii) the role of brown shrimps in the ecosystem (trophic interactions). Stock status indicators like biomass estimates, interannual and seasonal changes in landings per unit effort, total mortality and shares of large shrimp in the surveys were discussed. During this years' meeting on Wednesday special attention was given to the MSC process of the Dutch, German and Danish industry. On invitation of the chair representatives of Dutch and German industry joined this session, a representative of the Danish fishermen was delegated to join the whole meeting. During the session state of the art of the process and research needed where identified.

Available stock parameters indicated that in 2016, a total of 25 907 tonnes Crangon was landed in the North Sea, a rather low amount when compared with the landing figures in the years before. Especially in Germany landings where much lower than the years before which remarkable low landings & LPUE's in spring and autumn when compared to the years before. Dutch landings where a little lower than the year before. Landings and effort data showed however the same pattern as the years before with a peak in landings and LPUE in autumn. The Danish total catch was also less than the years before where the catches in UK, Belgium and France where higher than in 2015. Looking at the survey data from autumn 2016, there seems to be a relation with a high abundance of whiting in 2016 in the German areas and the very low shrimp abundance in the same area. In all other areas the whiting invasion was not noticed.

The mean annual mortality was slightly lower in 2016 (5.1) as compared to 2015 (5.8). The share of >60 mm shrimps does not show a clear trend in recent decades but varies from 10 to 25%. The swept area estimate for the last three years shows a decline compared to 2013.

1 Administrative details

Working Group name

Working Group on Crangon Fisheries and Life History (WGCRAN)

Year of Appointment within current cycle

2016

Reporting year within current cycle (1, 2 or 3)

2

Chair(s)

Josien Steenbergen, the Netherlands

Meeting dates

7–9 November 2018

Meeting venue

Hamburg, Germany

2 Terms of Reference

a) 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 of higher accuracy for the Netherlands with horse power days calculated based on hours at sea. Investigate methods to gain a better understanding of the recruitment processes and density dependence. (Lead persons: all group members)
b) Combine VMS, landings and effort data to gain a population distribution indicator and to monitor regional distribution and regional shifts in fishing effort. Evaluate the variability of the results by comparing different VMS data interpolation methods. (Lead persons: Katharina Schulte, Torsten Schulze)
c) Develop brown shrimp specific management decision support tools to evaluate strategies on how to sustainable and efficiently harvest the brown shrimp stock (Lead persons: Marc Hufnagl, Tobias van Kooten, Karen van de Wolfshaar)
d) Analyze and enumerate 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 efficiency and the possible lpue based management strategies (Lead persons: Bart Verschueren, Josien Steenbergen)

e) Analyze and evaluate possible methods to assess and manage the brown shrimp fisheries in the ICES region. Gather, compile and evaluate information on the onboard and ashore sieving fractions and processes and new national by-catch/discards data from e.g. DCF (Lead persons: Josien Steenbergen, Axel Temming)
f) Analyzing infection levels with bacilliform viruses and/or the occurrence of other diseases and determining the potential effects they might have on the population (Lead persons: Benigna van Eynde)
g) Determining the potential on using brown shrimp as a species for use in aquaculture system. Improvement on how to rear and grow shrimps in the lab and to obtain "in-situ", real field growth rates for comparison (Benigna van Eynde, Marc Hufnagl, Axel Temming)
h) Optimize and harmonize German and Dutch surveys to improve comparability, to analyze spatio-temproal trends of stock indicators (biomass, distribution, mortality, etc.) and to ground-truth VMS derived lpue estimates. (Lead persons: Holger Haslob, Ingrid Tulp)
i) Exchange of information on national legislation, laws (e.g. concerning Natura 2000) and developments (MSC process) concerning the brown shrimp fisheries in the whole North Sea for an improved cooperation and coordination of research and advice efforts. Presentations on developments and ongoing brown shrimp research in the ICES area. (Lead persons: all members)

3 Summary of Work plan

Year 1	Stock status indicators (ToR a) shall be udated and harmonized between countries. Data for Manuscripts related to ToR b-d and f-g shall be available New hauls to be included in the analysis under ToR h shall be available New information from ToR I shall be reported
Year 2	Stock status indicators (ToR a) shall be udated and harmonized between countries. Data for Manuscripts related to ToR b-d and f-g shall be analyzed New hauls to be included in the analysis under ToR h shall be available New information from ToR I shall be reported
Year 3	Stock status indicators (ToR a) shall be udated and harmonized between countries. Manuscripts related to ToR b-d and f-g shall be submitted New hauls to be included in the analysis under ToR h shall be available New information from ToR I shall be reported

4 List of Outcomes and Achievements of the WG in this delivery period

a) Stock status indicators

I. Indicators updated (see section 5)

b) VMS , landings and Effort data

I. ***Dissertation:*** *The monitoring of the spatiotemporal distribution and movement of brown shrimp (Crangon crangon L.) using commercial and scientific research data*

II. ***Manuscript***: Not Easy To Catch: New insights into factors affecting catch rates of partly pelagic brown shrimps (*Crangon crangon L.*). Schulte, K.F., Temming, A., Hufnagl, M., Dänhardt A., Siegel, V., Neudecker, T., Wosniok, W. (in press)

c) Brown shrimp specific management decision support tools

I. No updates this year

d) Effects of new gears

I. New research project in the Netherlands was presented.

e) Possible methods to assess and manage the brown shrimp fisheries

I. Update of the evaluation of HCR

II. Update of mesh size evaluation

f) Infection levels with bacilliform viruses and/or the occurrence of other diseases

I. ***No new update:*** Persons involved in the research did not join the meeting

g) Potential on using brown shrimp as a species for use in aquaculture system

I. Update of new growth experiments was provided

h) Optimize and harmonize German and Dutch surveys

I. Abundance indices of two overlapping sampling areas (405 and 406) were compared

i) Exchange of information

I. Danish research project presented

5 Progress report on ToRs and workplan

5.1 ToR a) Stock status indicators

Stock status indicator figures are given in Annex 2.

Progress

Landing statistics

For the first time this year the Netherlands is also able to provide the effort in das corrected for actual hrs at sea (DAS is hrs@sea/24). This effort data is now available from 2010 onward.

In 2016, a total of 25 907 tonnes brown shrimp (*Crangon crangon*) was landed in the North Sea, a rather low amount when compared with the landing figures in the years before. The last time less than 30 000 tonnes was landed was 2002 (Figure 7). Especially in Germany landings where much lower than the years before and share of German landings in relation to total landings was only around 25% where this is normally between 35 and 45% (Figure 1). Looking at the monthly landings especially spring and in autumn deviate; where there is normally a peak in landings, this time there is none. Effort is even higher in spring than the year before and a little lower in autumn. As one can expect the LPUE's where much lower in 2016 when compared to 2015 and the average of the 5 years before (Figure 11). Clearly, there was a low shrimp abundance in 2016 in the German coastal waters. Dutch landings where a little lower than the year before, and the total share of Dutch landings compared to the total landings went up to 60% in 2016 (Figure 2). Landings and effort data showed the same pattern as the years before with a peak in landings and LPUE in autumn (Figure 9; Figure 11). The Danish total catch was also less than the years before (Figure 3), which probably has to do with low landing figures in autumn and an overall lower LPUE throughout the year (Figure 9, Figure 11). Remarkable enough the catches in UK, Belgium and France where higher than in 2015 (Figure 4, Figure 5, Figure 6). However, as the share total catches of these countries are between 0–4% these higher figures did not affect the total catches.

Fraction of large shrimps

The fraction of shrimps > 60 caught in the different surveys conducted during autumn decreased over time (Figure 12). However this decrease is predominantly caused by the contrast in the bycatch time-series and the two surveys. Both bycatch series the decline from the start of the series in 1955 until the eighties, whereafter the percentage large shrimp stabilises. The share of >60 mm shrimps does not show a clear trend in recent decades but varies from 10 to 25%. (Figure 12). In the DFS the fractions in 2015 and 2016 were exceptionally low. The fractions of shrimp >70mm show an even more pronounced decline.

Mortality

The mean annual mortality was slightly lower in 2016 (5.1) as compared to 2015 (5.8) (**Figure 13**; methods see Hufnagl *et al.* 2010). The trend since 1995 shows strong annual variations, after a continuous increase in the period 1955–1995.

Biomass production/swept area estimate

In (Tulp *et al.* 2016) total biomass production was calculated based on a swept area estimate of brown shrimp. In this report we only update the swept area estimate (Figure 14), not the full biomass production estimate (that takes P/B ratio into account based on the mortality estimate). The value for the last three years shows a decline compared to 2013.

Area specific trend in brown shrimp and whiting

The area specific trends of brown shrimp was compared to those in whiting for all ICES areas (Figure 15, Figure 16). The high abundance of whiting in 2016 was only apparent in the German areas 410, 411 and 412 and coincided with very low shrimp abundance. In all other areas the whiting invasion was not noticed.

Cooperation with other WGs

- WGBEAM

Cooperation with Advisory structures

- Crangon Advice, WKCCM, ADCRAN

Science Highlights

The extremely low LPUE's in autumn in German indicate weak year class of the 2016 cohort in that area. When looking at the data of the autumn Surveys (DFS and DYFS), there seems to be a relation with a high abundance of whiting in 2016 in the German areas and the very low shrimp abundance. In all other areas the whiting invasion was not noticed.

5.2 ToR b) VMS, landings and effort data

Progress

Combine VMS, landings and effort data to gain a population distribution

This task was dealt with by Katharina Schulte (Schulte 2015; http://ediss.sub.uni-hamburg.de/volltexte/2016/7938/pdf/Dissertation.pdf). For the years 2007–2013 data of the German fleet were used to analyse the logbook, landings and VMS information of 226 vessels. By using all vessels recorded in the data base a "mean vessel" was defined, and all LPUEs were standardised to the LPUEs this "mean vessel" would have reached. In a next step the expected ln(LPUE) for the mean vessel were calculated. This expected ln(LPUE) is attained by a mean vessel under mean conditions of year, month, depth and other vessel- independent factors (Figure 17, Figure 18).

Other publication: Not Easy To Catch: New insights into factors affecting catch rates of partly pelagic brown shrimps (*Crangon crangon L.*). Schulte, K.F., Temming, A., Hufnagl, M., Dänhardt A., Siegel, V., Neudecker, T., Wosniok, W. (in press).

Thünen-SF (Torsten Schulze) aims to update the abundance index during for the years 2014 to 2017 using the German fleet data. Idealy an approach is developed so that using data of Belgium, the Netherlands and Denmark can also be used.

Combine VMS, landings and effort data to monitor regional distribution and regional shifts in fishing effort

A straightforward approach to calculate the distribution of fishing effort is to use the ICES database gained from the OSPAR-HELCOM VMS data call. In the set of data all effort is document by own c-square level and by metier level 6 (TBB_16–31_CRU identifies the beam trawlers targeting brown shrimp). It needs to be solved with ICES if the dataset can be used to produce maps and other output. It might be necessary to ask the data delivering states if the data can be used for this purpose.

Changes/ Edits/ Additions to ToR

The part "compare different VMS data interpolation methods" is also dealt with by Katharina Schulte (Schulte 2015; http://ediss.sub.uni-hamburg.de/volltexte/2016/7938/pdf/Dissertation.pdf). However, this analyses does not seems to be addressing the overall focus of WGCRAN but might be useful for WGSFD. It will not be reviewed in the WGCRAN report.

Cooperation with other WG

WGSFD – see above need to check with chair if the dataset from the OSPAR-HELCOM VMS data call can be used to produce maps and other output.

Cooperation with Advisory structures

Non

Science Highlights

Significant steps are made on how to use the LPUE's as an indicator for the population distribution. This in the end can be used for management purposes.

5.3 ToR c) Brown shrimp specific management decision support tools

No updates this year.

Cooperation with Advisory structures

Crangon Advice, WKCCM, ADCRAN

Science Highlights

Brown shrimp specific management decision support tools can be used to evaluate strategies on how to sustainable and efficiently harvest the brown shrimp stock.

5.4 ToR d) Effects of new gears

No updates this year work is in progress. In 2018 a Dutch research project into the effects of pulse fisheries on bycatch will start. In September 2017, a new gear design with rigid grids was tested on the Solea in a joined German, Dutch research effort. Results are not yet publised.

Science Highlights

The shrimp industry has an important task to reduce their impact on the ecosystem. One of the tools to reduce this impact on for example the shrimp stock and the bycatch of other (fish) species is develop new/other innovative gears. The research that is designed around these innovations provide insight in how effective these new gears are in relation to the traditional methods.

5.5 ToR e) Possible methods to assess and manage the brown shrimp fisheries

Progress

Harvest control rule

Due to the MSC process, an industrial management plan came into operation on 1 January 2016, which includes a harvest control rule (HCR) to regulate fishing intensity. The HCR follows the design proposed by Temming *et al.* (2013), with exception of the actual reference or trigger values.

In action, a fleet wide LPUE-value (landings divided by hours at sea) is calculated at the end of every calendar month, and compared to a set of monthly specific trigger values. If the fleet wide LPUE falls below the first of these trigger values, fishing effort is limited to 72 hours at sea per week. If the following trigger values are undershoot in the same month, fishing effort is further reduced.

The year 2016 was a year with overall poor landings and generally low LPUEs. The HCR kicked in two times, in April and May (Figure 19). LPUEs in the first half of 2016 were the continuation of the overall low LPUEs in autumn 2015. Those low LPUEs (autumn 2015 and spring 2016) suggest a weak year class in 2015. In the second half the year, the mean LPUE over all nations is well above the trigger value, however there are large differences in LPUEs between nations: Dutch LPUEs are more than two times higher than monthly trigger values, while Danish and German LPUEs are lower. Nevertheless, in the second half of 2016 the HCR did not kick in.

In 2014, German landings were high in comparison to 2016 (Figure 20). The difference in the amount of landings is most pronounced in autumn. LPUEs in May, September and November 2016 are the lowest compared with the foregoing years 2014 and 2015. Despite the kicking in of the HCR in April and May 2016, overall effort in 2016 is higher and very high in some rectangles compared with previous years. In September and November 2016, overall LPUEs slightly increased but stayed far below values of previous years. At the end of the season (November), a part of the German fleet switched to fishing grounds further west reaching the Dutch coast.

Varying fleet behaviour like the change of fishing grounds of some of the German cutters in 2016 (example of a year with low landings) can bias the HCR in its present form: Without taking into account any spatial effect, fleet-wide LPUEs may always be higher than the reference values.

In next report, the survey LPUE's of the combined DFS and DYFS data for the years before 2016 and the year 2016 should be compared. As it is suspected that a much stronger decline in survey LPUE is observed than is indicated in the LPUE data from the self-management. If this is the case, than this clearly highlights the problem of the current approach.

Mesh size evaluation

The industrial management plan schedules a stepwise increase in cod-end mesh size starting with 20 mm in 2016 and ending with 26 mm in 2020. Up to now, the MSC brown shrimp fishers apply a mesh size of 22 mm.

The aim of this mesh-size increase is the reduction of growth overfishing (Temming & Hufnagl 2015) and to contribute to minimizing the risk of recruitment overfishing. However, a necessary precondition is, for instance, that the effort is restricted to a certain level allowing for growth compensation effects.

While it is obvious that the larger mesh sizes save large amounts of undersized shrimp, especially in the months preceding the main season in autumn the model, this comes at the price of a certain loss of commercial sized shrimp. The reason being the relatively large selection ranges of the cod ends. Whether the loss is actually overcompensated by the growth of the saved fraction of shrimp is so far only a model prediction. However, the model is based on the best available evidence. The unknown part is the degree of density dependence that may reduce the weight gains. While the fishing industry wishes a test of this effect – such a test cannot be performed in the real world where many uncontrolled factors - such as variable recruitment, predation, lack of food and the competition with other species affect the result.

It had been suggested that a pre-season survey with smaller meshes may be a way to monitor differences in the recruitment signal and hence make results of the subsequent fishing season more comparable. However, even if this would work (e.g., the other three factors would stay constant), the test could only be done based on a number of years with contrasting mesh sizes.

During a postulated ongoing self-sampling, MSC fishermen were requested to demonstrate the increased mesh sizes do actually reduce the amount of undersized shrimp. For this purpose samples were from parallel hauls with the old (20 mm) and the new (22 mm) cod-end. The test essentially failed due to a very small number of samples, which furthermore showed contradicting results. However, if it cannot be demonstrated that the larger meshed cod ends actually operate as on the scientifically controlled cruises, than any test of compensatory effects in the later season due to growth of the survivors is superfluous.

Growth overfishing can likewise be countered with effort reductions, e.g. by means of closed seasons or generally limited effort. This and other alternative scenarios, such as theuse of large meshes only in some critical months, were also discussed during the meeting.

Evaluation bycatch

In order to maintain the MSC certificate the following recommendation is given to the industry with regard to the registration of bycatch: *The design and collection of improved catch composition data across all three countries is encouraged, so that bycatch data can be com-*

pared and trends noted; ie harmonized Dutch and German (and Danish) sampling programmes and methods (MSC certificate report[1]).

Catch composition data is available from observer programmes of the DCF regulation. How ever the coverage is low and in Germany and the Netherlands the monitoring effort represents less than 1% of days-at-sea sampled. Observer programmes are cost consuming and thus a self-sampling programme could be an alternative. However, depending on the method chosen risks with self-sampling are that some of the fish species of the catches are under represented. If there is a representative (self) sampling programme in place next important question is; what does it say? Of many (non-commercial) species in the by-catch the population size is not known. There for the bycatch data of these species cannot be put in perspective.

Another important parameter to put the bycatch data into perspective is the discards survival. A series of discard survival experiments have been conducted on board of two commercial vessels. One aim was to test to what extent the earlier results of about 90% discard survival rates (Lancaster & Frid) are applicable to the German fishery using mostly rotary sieves and larger vessels. The second aim was to observe the discard survivors longer than the 24 h applied in Lancaster & Frid and to also register if the survivors can successfully moult. Two cutters were chosen, a small one with a riddle sieve which was comparable to the one used in the earlier study and a larger vessel with a rotary sieve. Haul duration was varied between 5 min and 120 min with the 5 min hauls serving as baseline. Shrimp were sampled from the holding device and after passing the sieves and transported to a aquarium facility for further observation. One of the most striking results was a very high immediate mortality even in the 5 min hauls during the May campaign with mortality rates between 7 and 34% which increase subsequently to between 32 and 66%. One hypothesis to explain this unexpected result was an effect of intense fishing in the days prior to the experiment in the same region, which may have led to a large number of shrimps having undergone the discard procedure repeatedly. In the other months mortality rates within 24 h were below 10% as described by Lancaster & Frid but increased up to 29% for the 120 min hauls after 21 days of observation.

Science Highlights

The poor performance of the HCR in a year with very low landings like 2016 and the huge differences in LPUEs between nations in autumn raise the question of the reliability of the HCR as an effort regulation tool in its present form.

Possible improvements of the HCR follow in general four directions:

(1) the increase of reference values to increase the precautionary nature of the HCR as an effort regulation tool. For instance, trigger values proposed by Temming *et al.* (2013) are higher than the ones which are in action so that the HCR would have kicked in more often in 2016 (Figure 19).

(2) a stronger reduction of effort when the HCR kicks in. In the actual management plan, effort is reduced to 72h at sea per week and vessel when the LPUE falls below the #1 trig-

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[1] https://www.msc.org/docs/librariesprovider8/de/zertifizierung-nordseekrabben/20171103-nsbs-pcr-final.pdf

ger value. However, in the case of the German fishery, only few cutters would be restricted with this effort value while the bulk of vessels do not exceed 72h under normal conditions (Temming *et al.* 2013). Thus, real effort could probably still increase, even if the HCR kicked in, which is what happened in May 2016 (Figure 20).

(3) The development of an international and mandatory protocol on how to calculate the monthly LPUEs. Here, it should be checked if all nations include the same period/amount of days. Furthermore, the whole fleet should be included in th estimation of revised reference values to account for the large variability in LPUEs between vessels. Overall transparency and data availability is needed, especially since the Dutch data are only based on small reference fleet of 25 vessels with unknown characteristics.

(4) The integration of spatial effects. Up to now, spatial effort allocation for 2016 was performed with logbook data of the German fishery (Figure 21); this analysis should be expanded for the whole fleet, and if possible, based on logbook and VMS data. The method of calculating the mean has also to be reconsidered to take spatial patterns of effort into account.

Data on catch rates of bycatch in the Shrimp fisheries should be put into perspective in terms of the total population of the species caugth and also discards survivability should be taken into account.

5.6 ToR f) Infection levels with bacilliform viruses and/or the occurrence of other diseases

Progress

This ToR is very specific and has little to do with the overall aim of the WG. The phd working on this topic was not present at the meeting. The WG decided this ToR will not be discussed in the WG.

Changes/ Edits/ Additions to ToR

This ToR will not be further discussed in the WGCRAN.

5.7 ToR g) Potential on using brown shrimp as a species for use in aquaculture system

Progress

At IHF a series of new growth experiments was conducted to investigate to what extent reproducible high growth rates can be induced with optimal diets and ad libitum feeding. Once successful, such feeding tests could be used to detect growth limitation in the field by transferring shrimp to the lab and contrasting the initial increments with subsequent increments realized under optimal diets. Currently tested diets include acartia tonsa copepods reared on a rhodomonas diet, which have proven successful in preliminary trials (Hufnagl & Temming 2011)

Other part of ToR, focus aquaculture not relevant for this group.

5.8 ToR h) Optimize and harmonize German and Dutch surveys

Progress

Kim Hünerlage presented the results on the abundance and length distribution of adult *Crangon crangon* during autumn 2016. The data were collected during the German Demersal Young Fish Survey (DYFS), which is annually performed every autumn by the Thünen Institute of Sea Fisheries since 1974.

In 2016, more than 260 stations were sampled. The results showed a 5 times reduced *Crangon crangon* abundance compared to 2015. *Crangon* biomass (kg per 15 min haul) varied from 0 to 12 (Figure 21). The low biomass is believed as a result from high predator pressure, i.e. particularly the abundance index of whiting was clearly above the 10 years average.

The DYFS survey uses a 3-m beam trawl without a tickler chain (stretched mesh size of 20 mm). In comparison, the Dutch Demersal Fish Survey (DFS) uses a 6-m and a 3-m beam trawl with tickler chains and a 20 mm mesh in the codend.

During this year`s meeting, it was stated that there would be no spatial overlapping hauls between den German and Dutch surveys anymore. This could not be confirmed by the chair of WGBEAM. Hence, the harmonization and optimization of both surveys is still under discussion.

To estimate the survey comparability of DYFS and DFS, *Crangon crangon* abundance indices of two overlapping sampling areas (405 and 406) were compared over a period from 1997 to 2016. The results highlight the still existing need for performing parallel hauls in the future (Figure 22).

Cooperation with other WG

WGBEAM

Science Highlights

The harmonization and optimization of the German and Dutch survey is still under discussion. There is still a need for performing parallel hauls in the future.

5.9 ToR i) Exchange of information

Progress

Update of Danish research project was provided during the meeting. Details will follow in the next report.

6 Next meetings

The 2018 meeting is scheduled on 9–11 October at ICES Headquarters, Copenhagen, Denmark.

Annex 1: List of participants

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Annex 2: Statistics (figures)

Total landings time-series and percentages landed per country

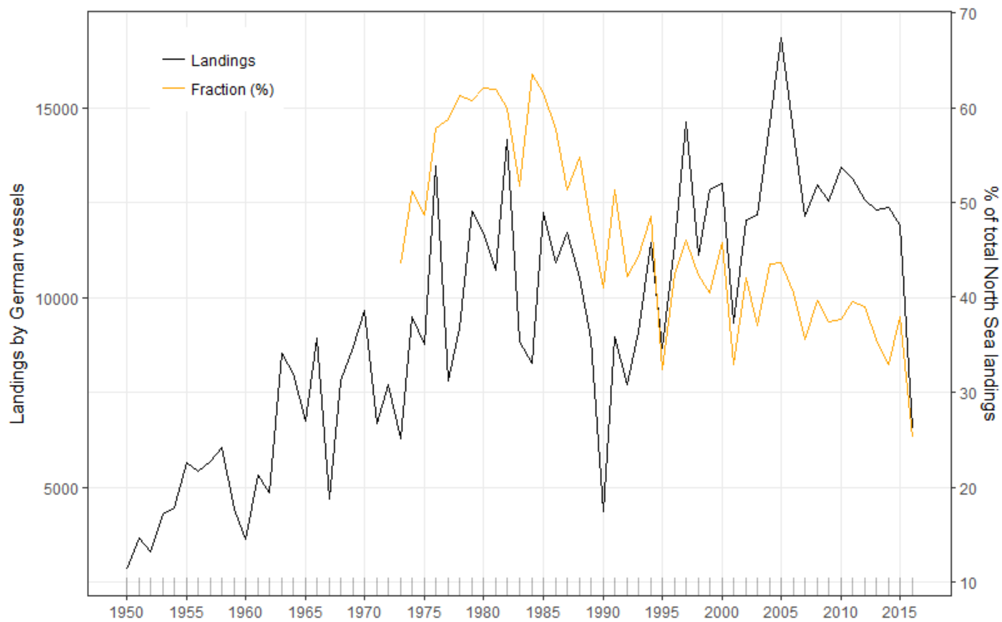


Figure 1. Consumption shrimps landed by German vessels over the period 1950 to 2016 in t (primary y-axis) in European harbours. Yellow line and sec y-axis: Percentage of German landings in relation to total landings (whole North Sea, all nations).

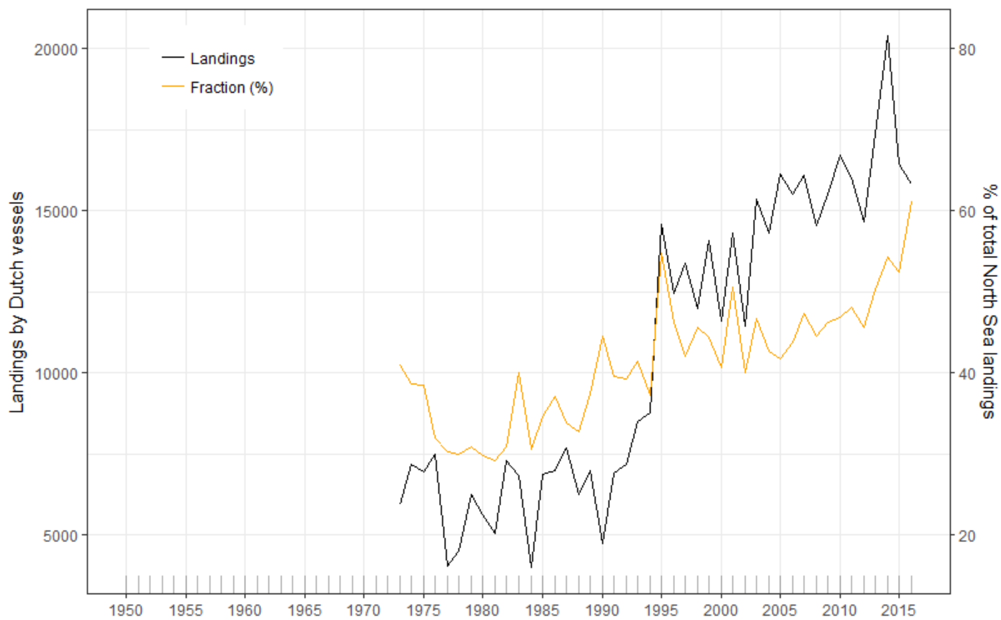


Figure 2. Consumption shrimps landed by Dutch vessels over the period 1973 to 2016 in t (primary y-axis) in European harbours (Data source before 1995; from Producer organisations (inclusion of foreign landings unclear), 1995 onwards; VIRIS log book data including landings in foreign harbours). Yellow line and sec y-axis: Percentage of Dutch landings in relation to total landings (whole North Sea, all nations).

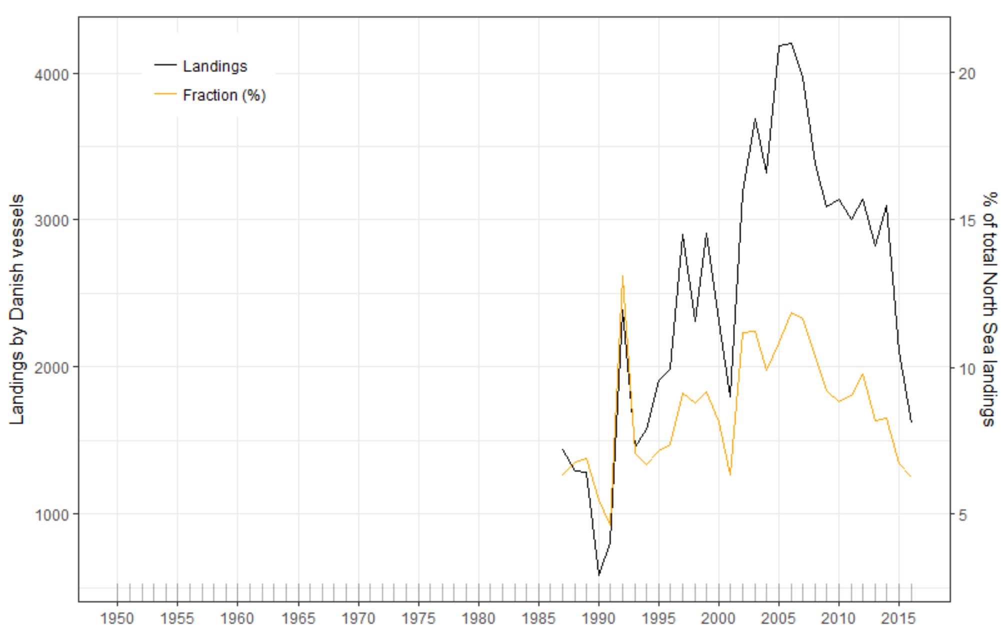


Figure 3. Consumption shrimps landed by Danish vessels over the period 1987 to 2016 in t (primary y-axis) in European harbours. Yellow line and sec y-axis: Percentage of Danish landings in relation to total landings (whole North Sea, all nations).

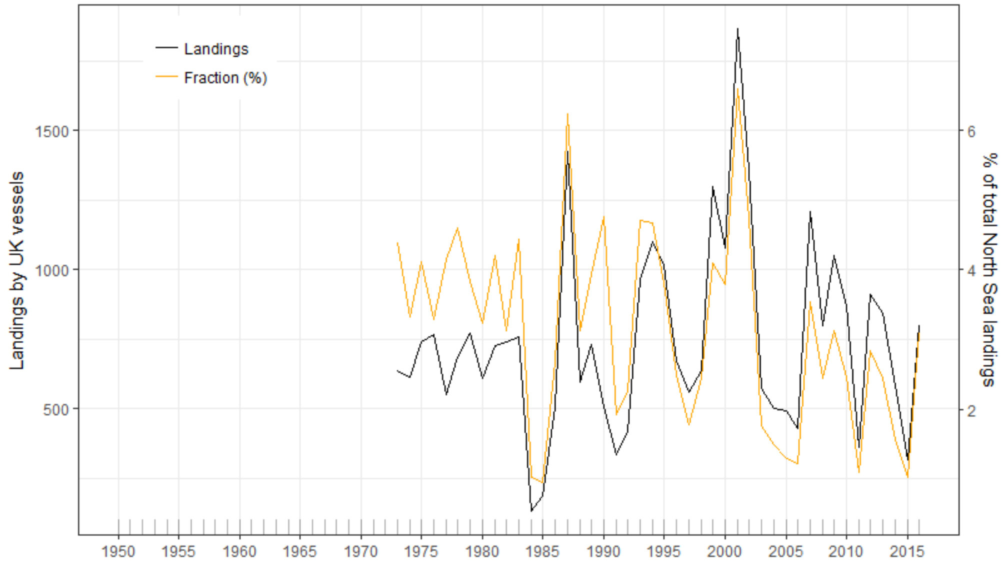


Figure 4. Consumption shrimps landed by UK vessels over the period 1973 to 2016 in t (primary y-axis) in European harbours. Yellow line and sec y-axis: Percentage of UK landings in relation to total landings (whole North Sea, all nations).

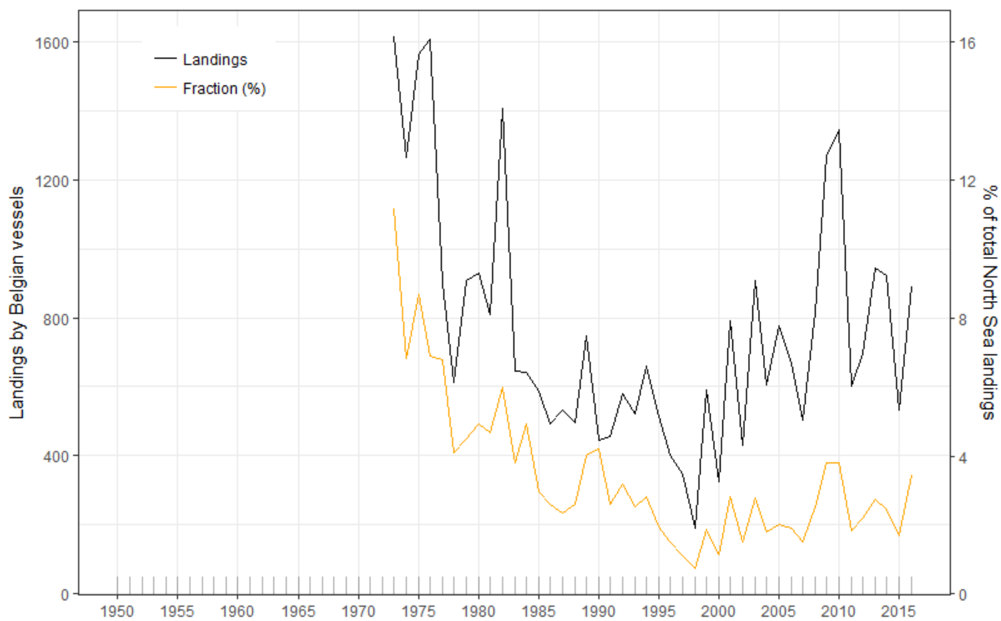


Figure 5. Consumption shrimps landed by Belgian vessels over the period 1973 to 2016 in t (primary y-axis) in European harbours. Yellow line and sec y-axis: Percentage of Belgian landings in relation to total landings (whole North Sea, all nations).

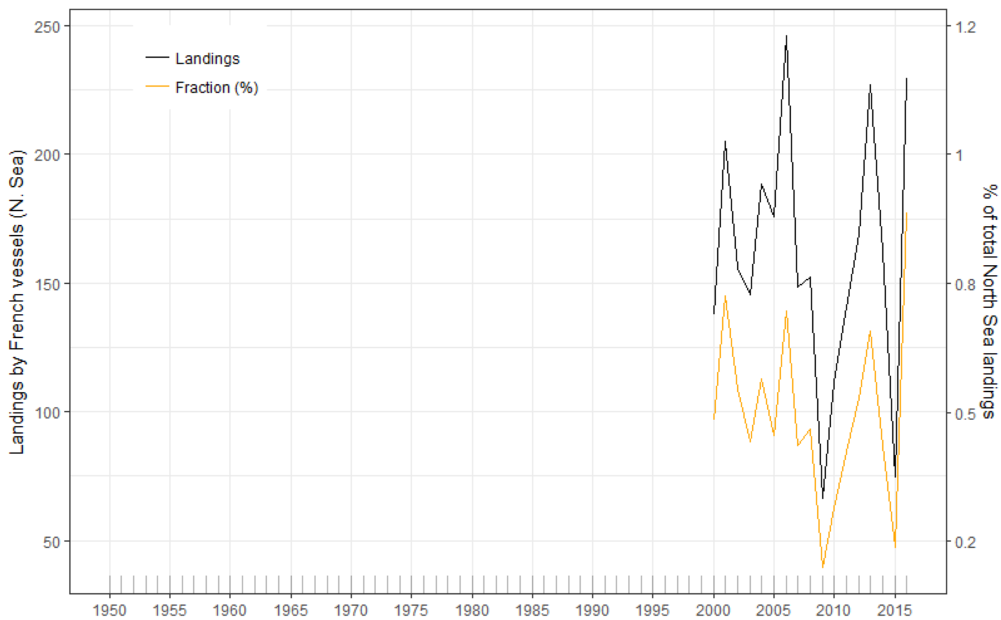


Figure 6. Consumption shrimps landed by French vessels over the period 2000 to 2016 in t (primary y-axis) in European harbours (North Sea, ICES area IV and VIId only). Yellow line and sec y-axis: Percentage of French landings in relation to total landings (whole North Sea, all nations).

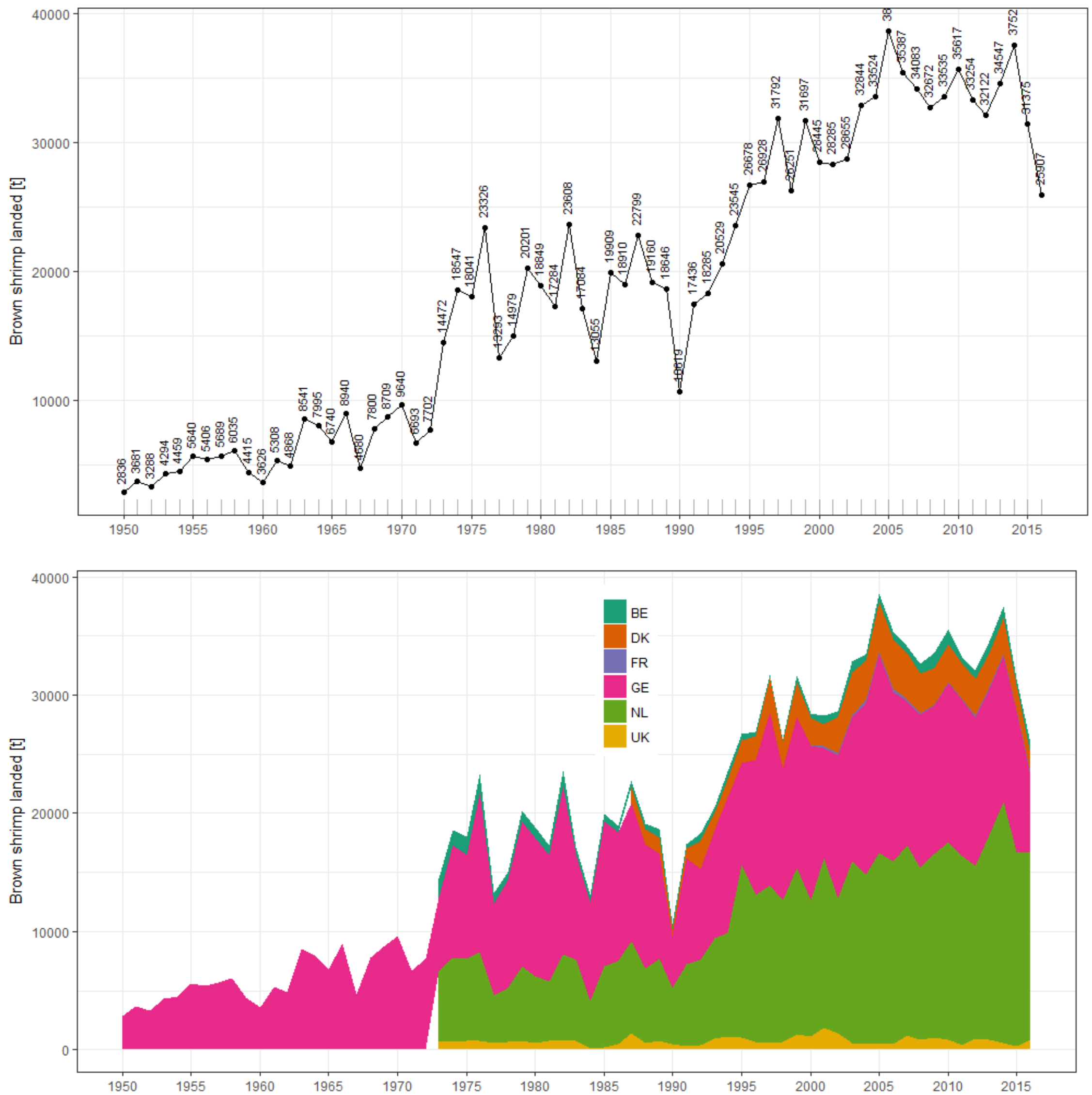


Figure 7. Upper panel: Total landings of Crangon crangon from the North Sea [t]. Lower panel: Total landings of Crangon crangon from the North Sea [t] by country.

Seasonal (monthly) statistics by country

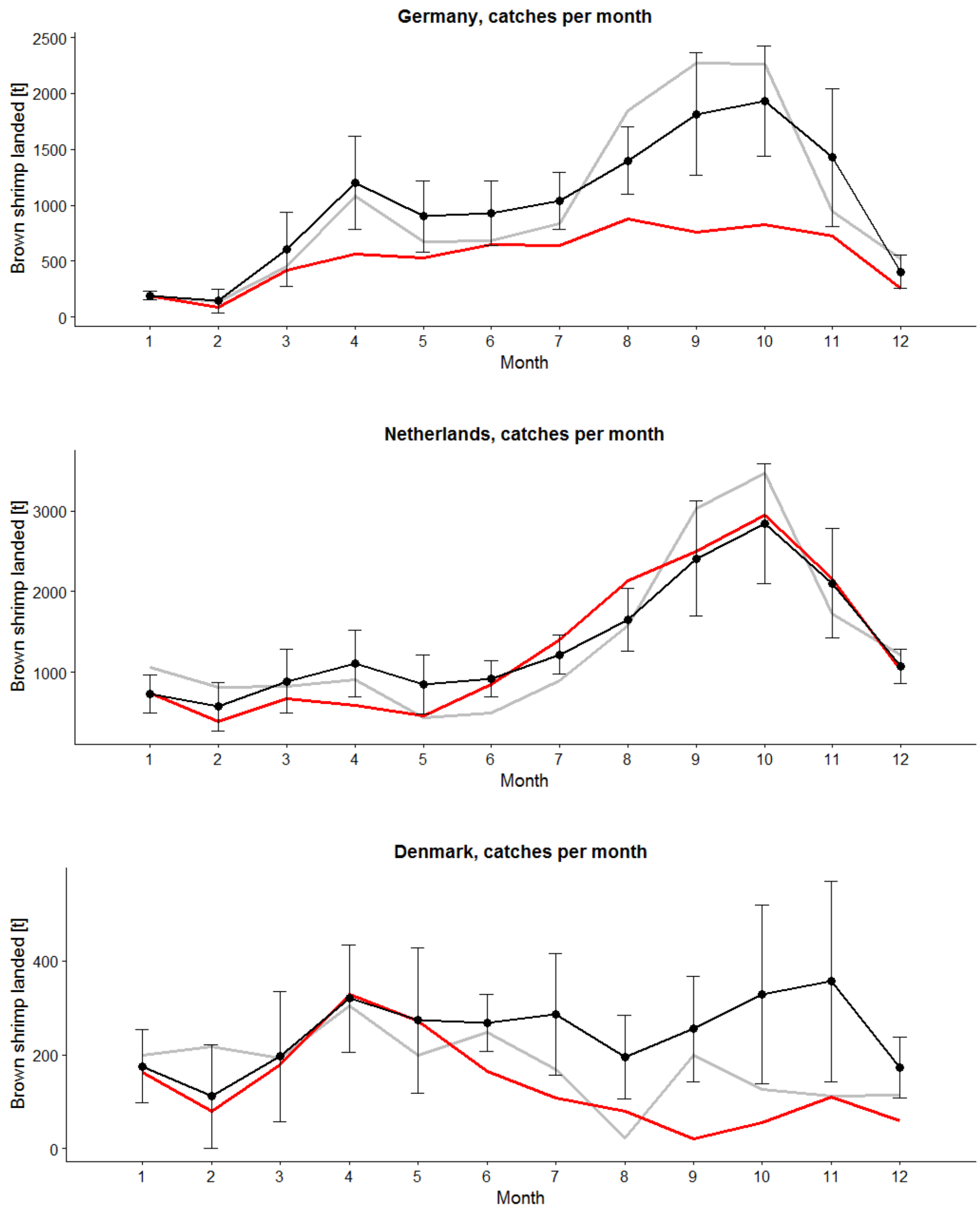


Figure 8a. Consumption shrimps landed per month and country (Germany, Netherlands and Denmark). Black line: 10 year average and standard deviation (whiskers). Grey line: total landings per month for the year 2015, red line: total landings per month for the year 2016.

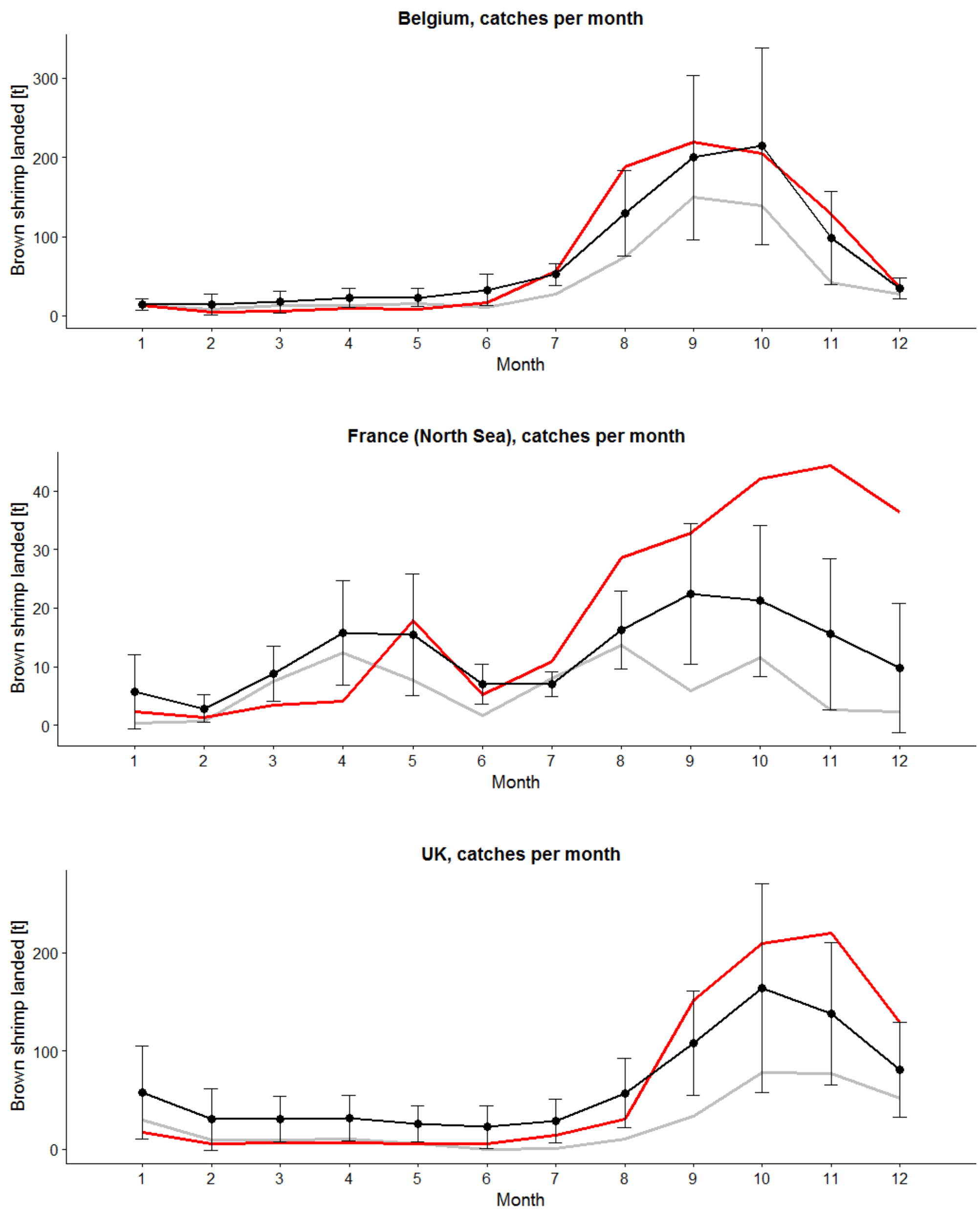


Figure 8b. Consumption shrimps landed per month and country (Belgium, France, UK). Black line: 10 year average and standard deviation (whiskers). Grey line: total landings per month for the year 2015, red line: total landings per month for the year 2016.

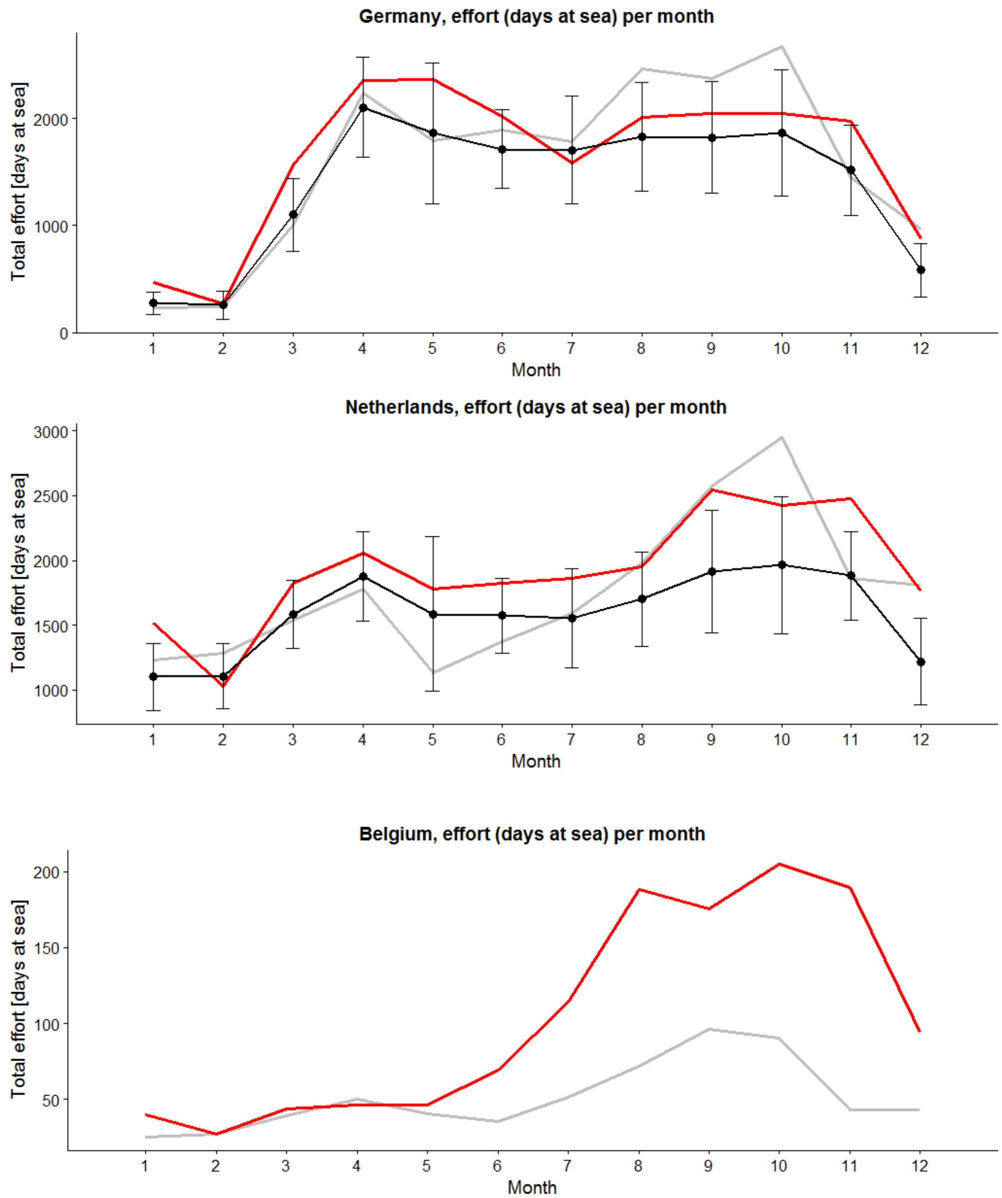


Figure 9. Monthly effort in days at sea (leaving to returning to harbour) per country (Germany, Netherlands and Belgium). Black lines and whiskers indicate the 10 year means and standard deviations for the nations. Grey lines indicate the effort for 2015 the red line the effort for 2016. No recent data for Denmark, UK and France. No long term data for Belgium.

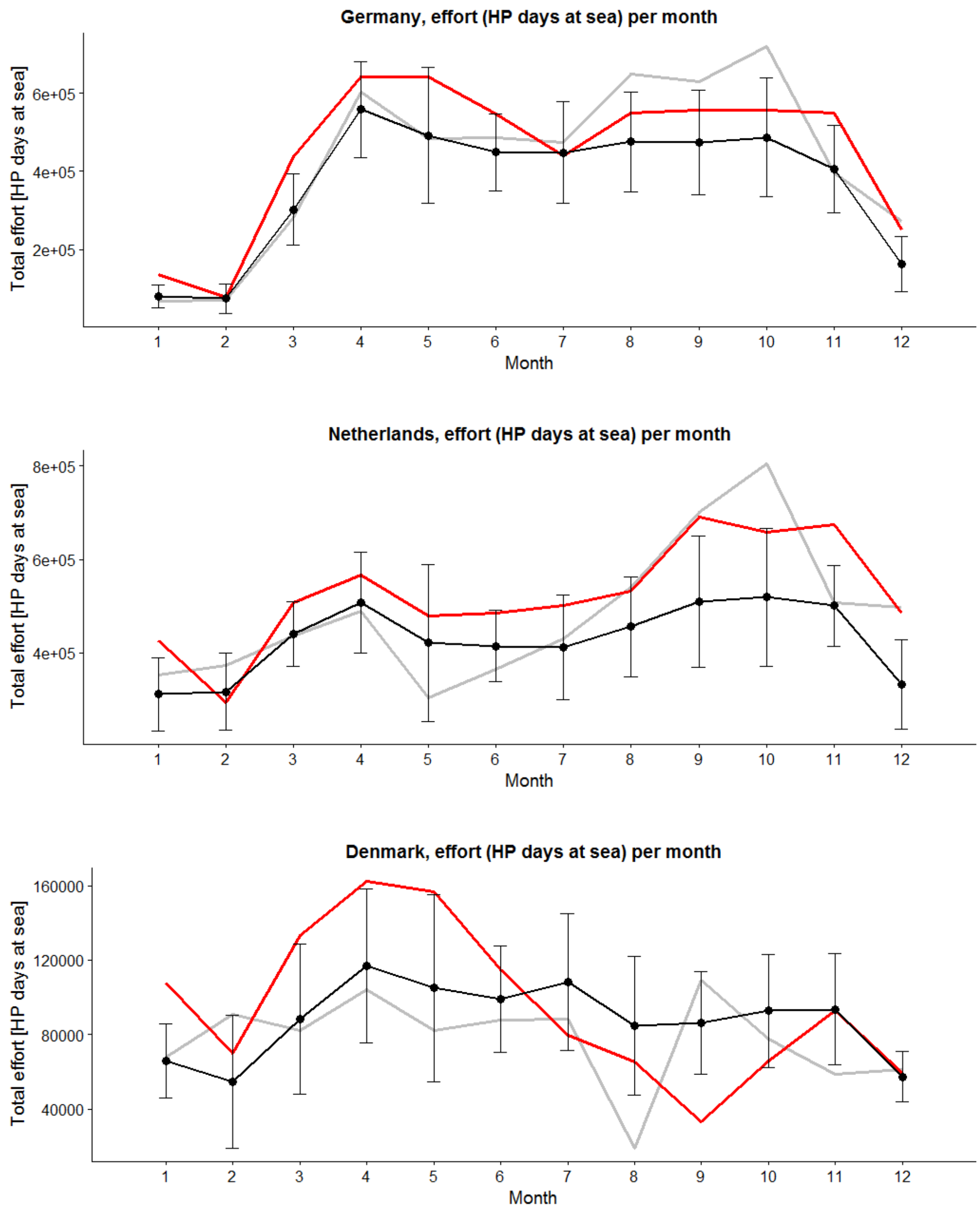


Figure 10a. Monthly effort in horse power days at sea (leaving to returning to harbour) per country (Germany, Netherlands and Denmark). Black line and whiskers indicate the 10 year average and standard deviation for each nation. Grey line indicates the effort for 2015 and the red line the effort for 2016.

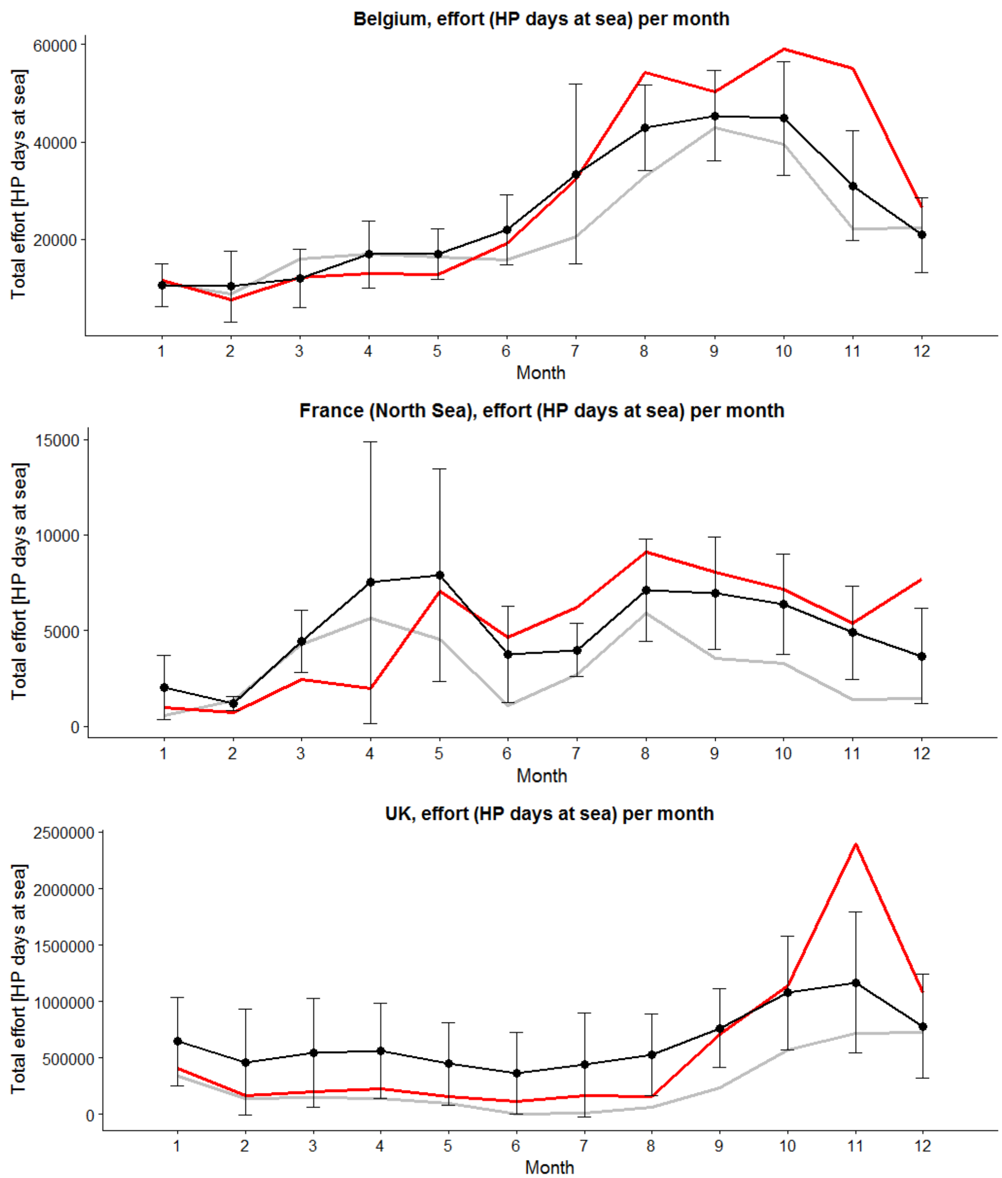


Figure 10b. Monthly effort in horse power days at sea (leaving to returning to harbour) per country (Belgium, France, UK). Black line and whiskers indicate the 10 year average and standard deviation for Belgium and UK. For France black line and whiskers indicate average of available years 2011–2016. Grey line indicates the effort for 2015 and the red line the effort for 2016.

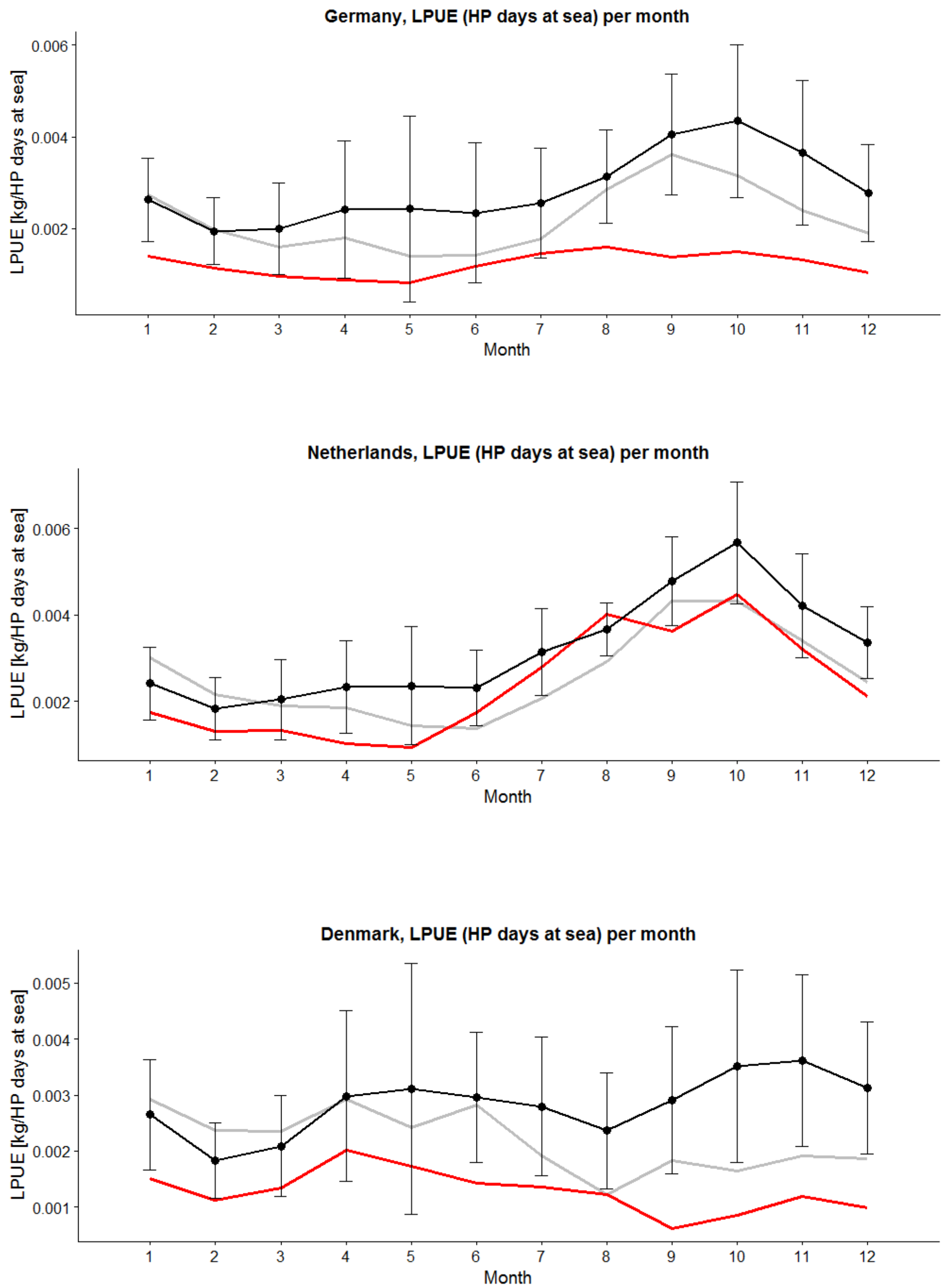


Figure 11a. Monthly landings per unit effort in kg per horsepower days at sea per country (Germany, Netherlands and Denmark). Black line and whiskers indicate the 10 year average and standard deviation for each nation. Grey line indicates the effort for 2015 and the red line the effort for 2016.

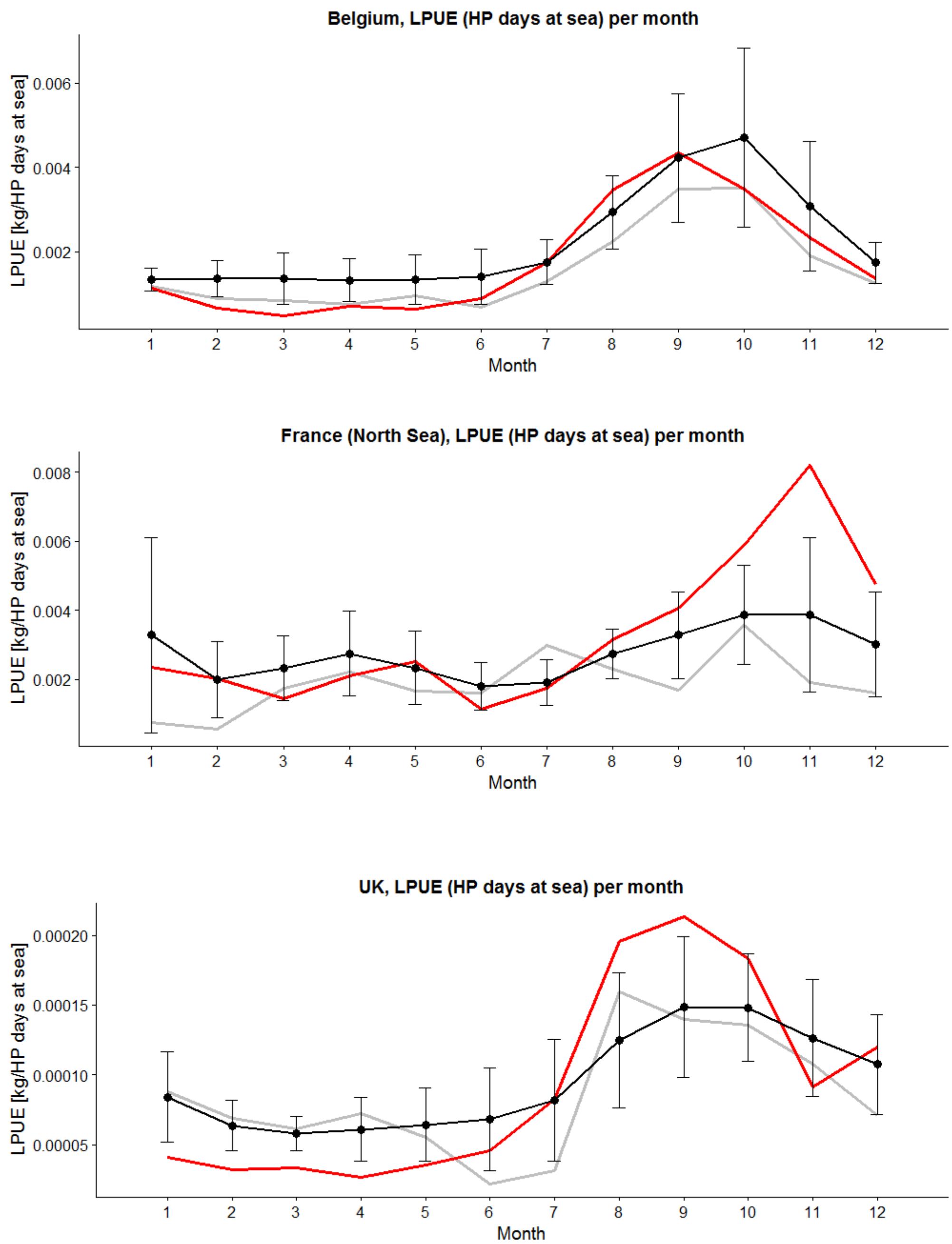
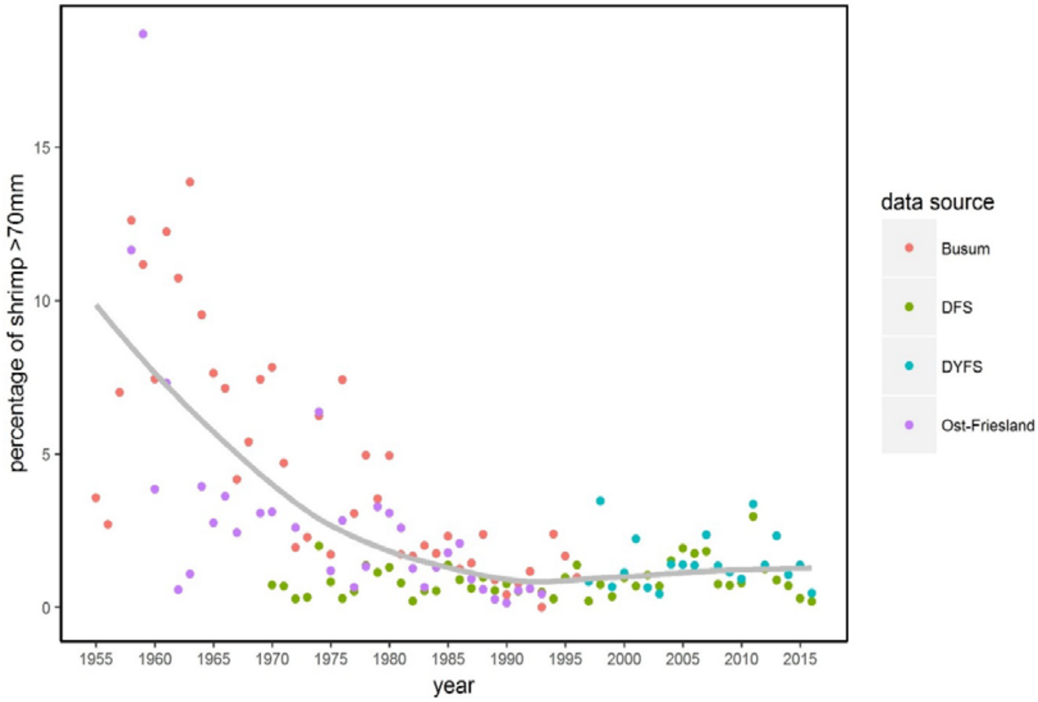


Figure 11b. Monthly landings per unit effort in kg per horsepower days at sea per country (Belgium, France, UK). Black line and whiskers indicate the 10 year average and standard deviation for Belgium and UK. For France black line and whiskers indicate average of available years 2011–2016. Grey line indicates the effort for 2015 and the red line the effort for 2016.



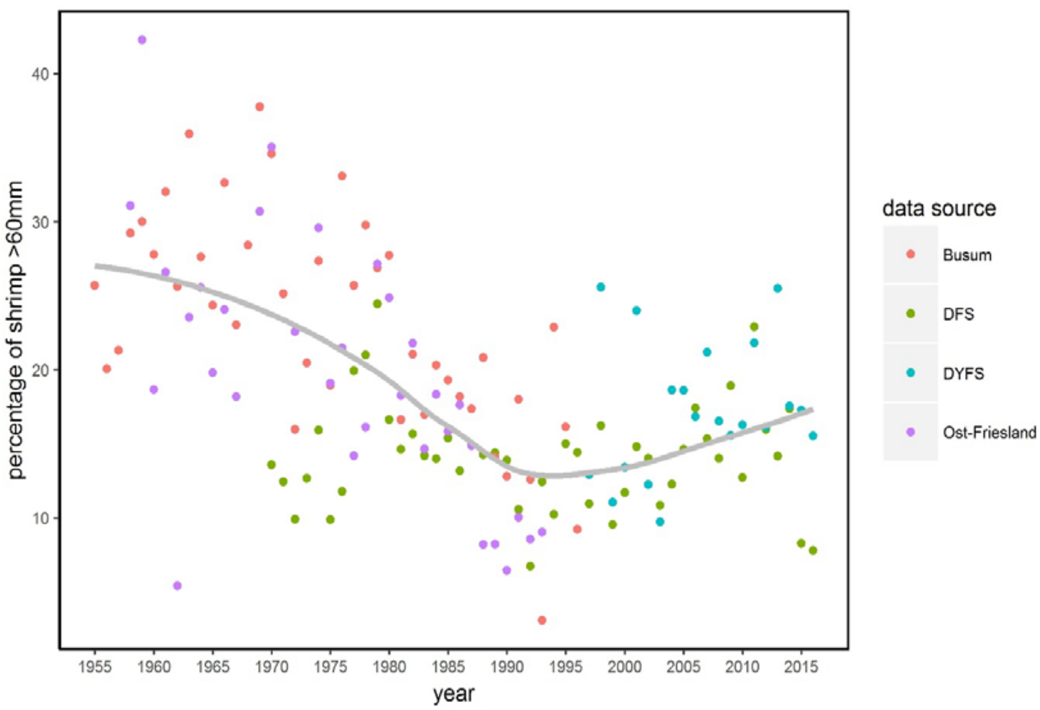


Figure 12. Time-series of proportion of large shrimp (>60mm and >70 mm) in four different survey programs. The line is a Loess smoother. Busum and Ostfriesland are German bycatch series. The fraction is expressed as the fraction of all shrimp>45mm.

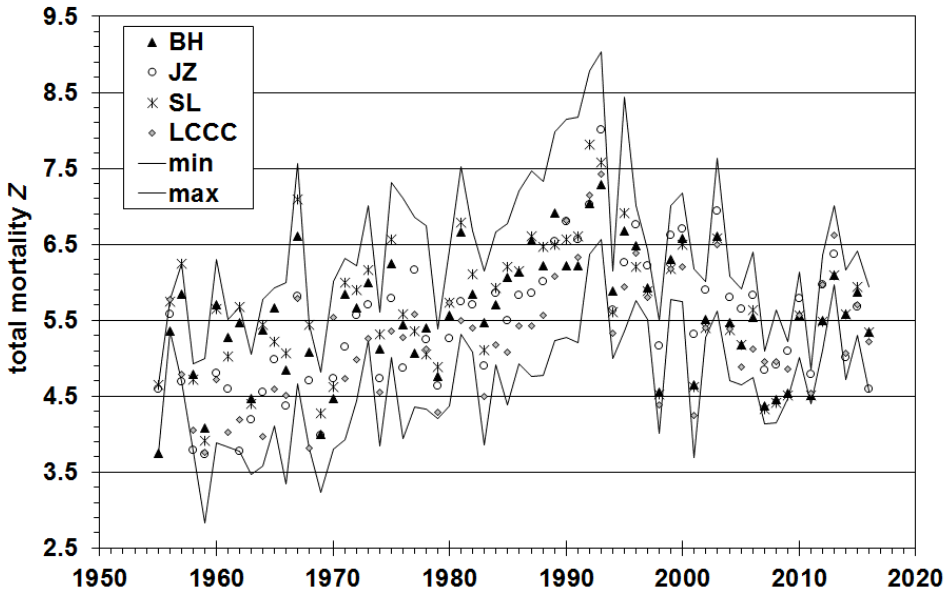


Figure 13. Total annual exponential mortality rate Z [a-1] estimated using length-based methods. Four different methods were used (represented by the different symbols): Beverton & Holt (BH), Jones and van Zalinge (JZ), Ssentongo & Larkin and Length Converted Catch Curve (LCCC). The methods and as well as the validation of the methods are presented in Hufnagl et al (2010).

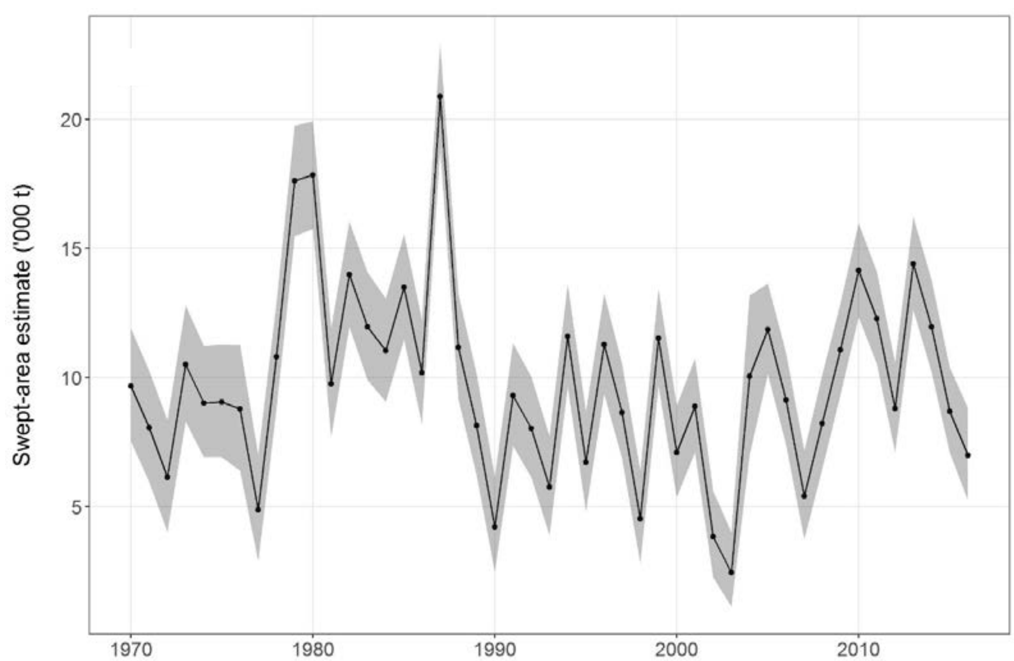


Figure 14. Time-series of the swept area estimate as calculated according to (Tulp *et al.* 2016).

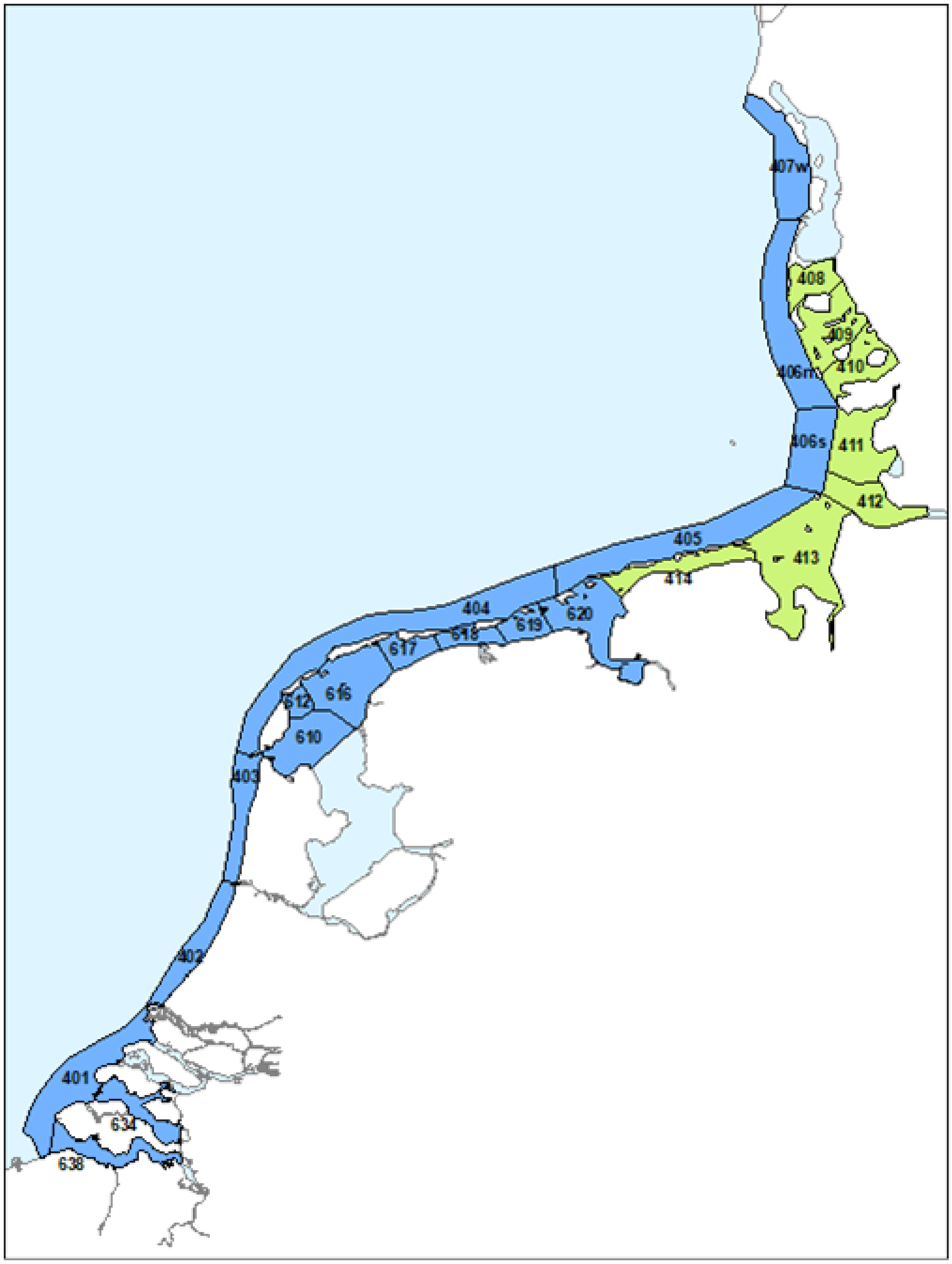


Figure 15. Map with all ICES areas used in this section. The blue areas are covered by the Dutch DFS, the green area by the German DYFS. Areas 405 and 406 are covered by both surveys.

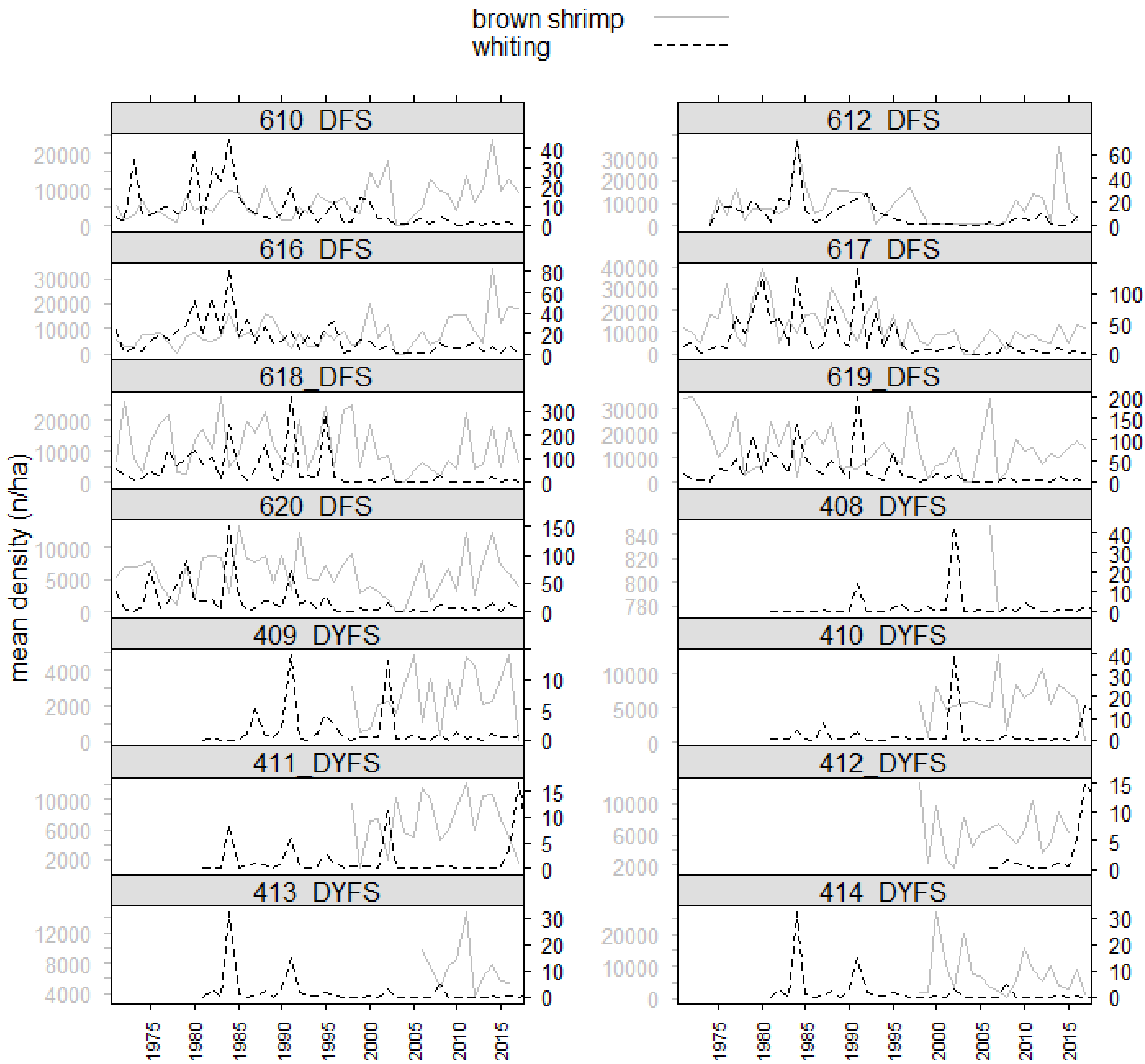


Figure 16. Time-series of brown shrimp and whiting in all DFS and DYSF Wadden Sea areas. See for area locations Figure 15.

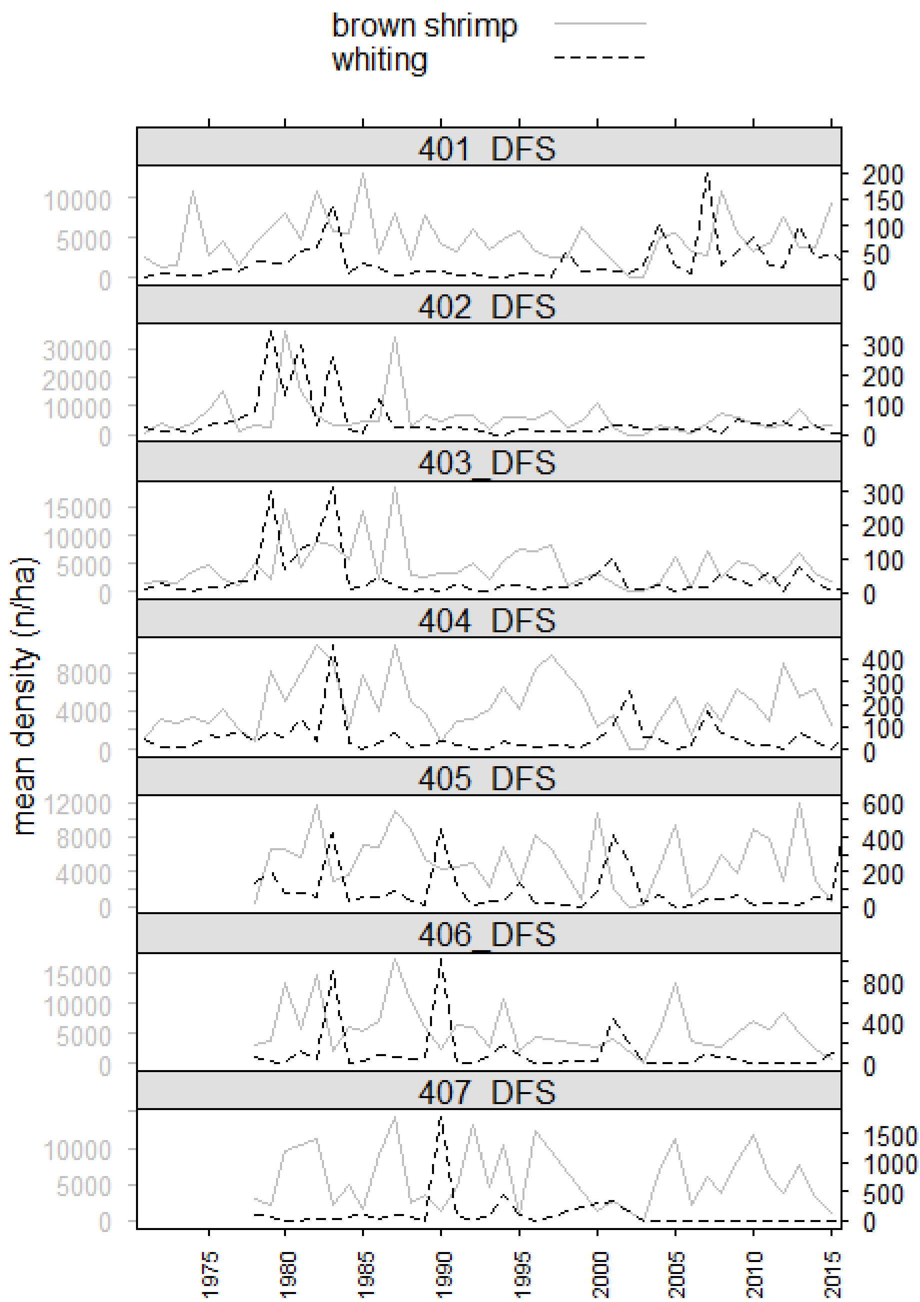


Figure 16 continued. Time-series of brown shrimp and whiting in all DFS coastal areas. See for area locations Figure 15.

Other figures

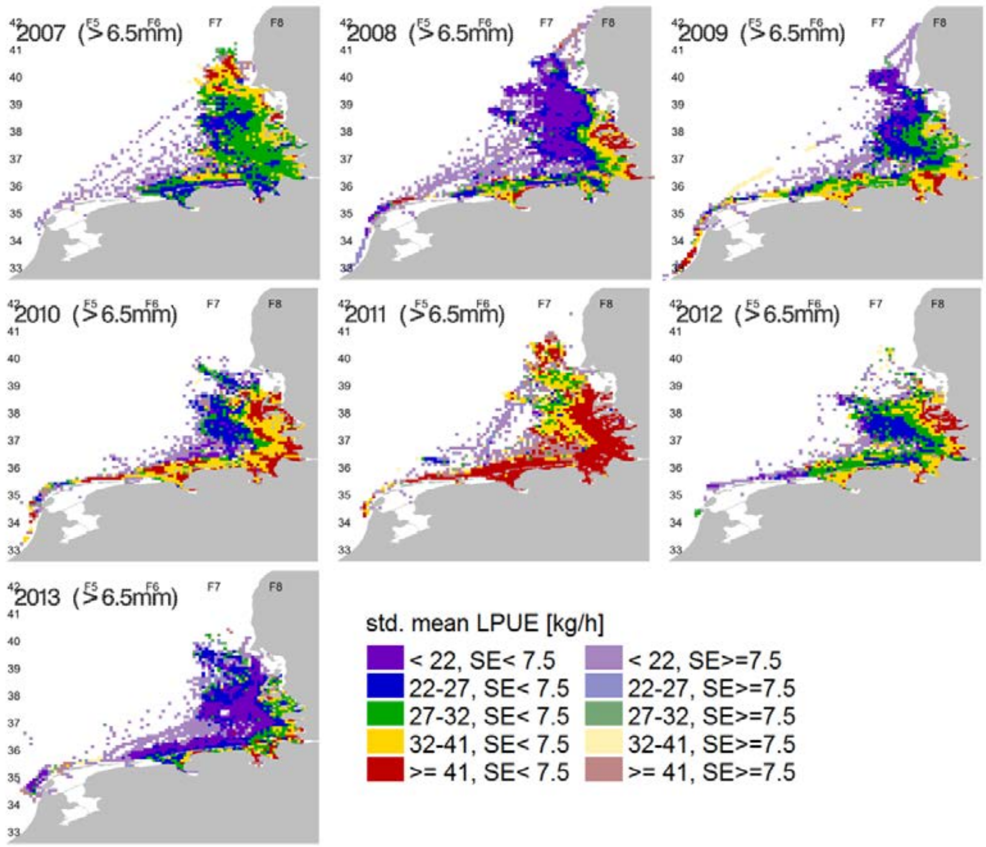


Figure 17. Spatial distribution of standardised mean LPUEs of commercial brown shrimps for human consumption (carapace width > 6.5 mm ≙ total length of ca. >50 mm) in different years.

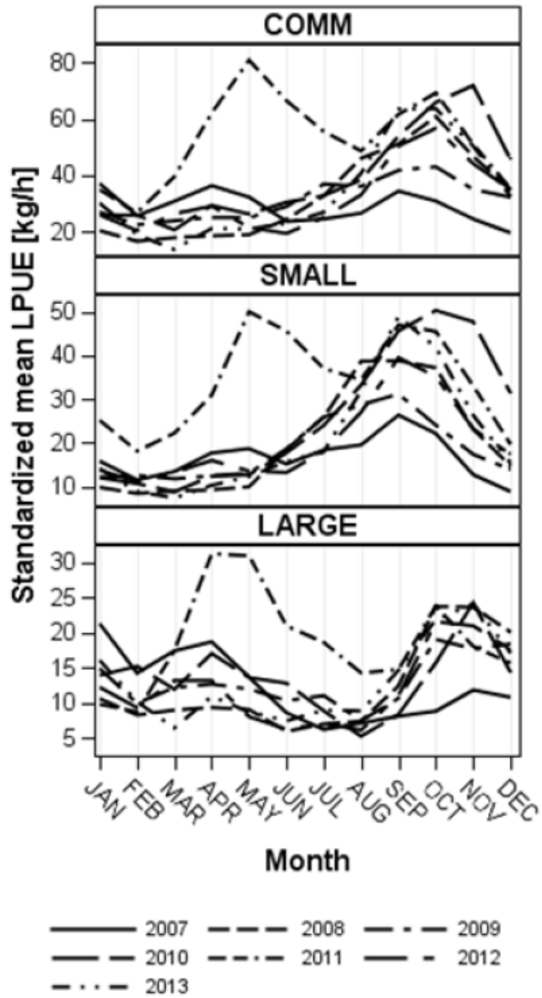


Figure 18. Course of the different years of the standardised mean LPUEs of commercially used brown shrimps for human consumption (COMM: all brown shrimps used for human consumption, ca. > 50 mm total length; SMALL: small fraction of brown shrimps for human consumption total length: ca. 50 mm – 73 mm; LARGE: large fraction used for human consumption. Total length: ca. > 73mm). Note, that the y-axis is differently scaled.

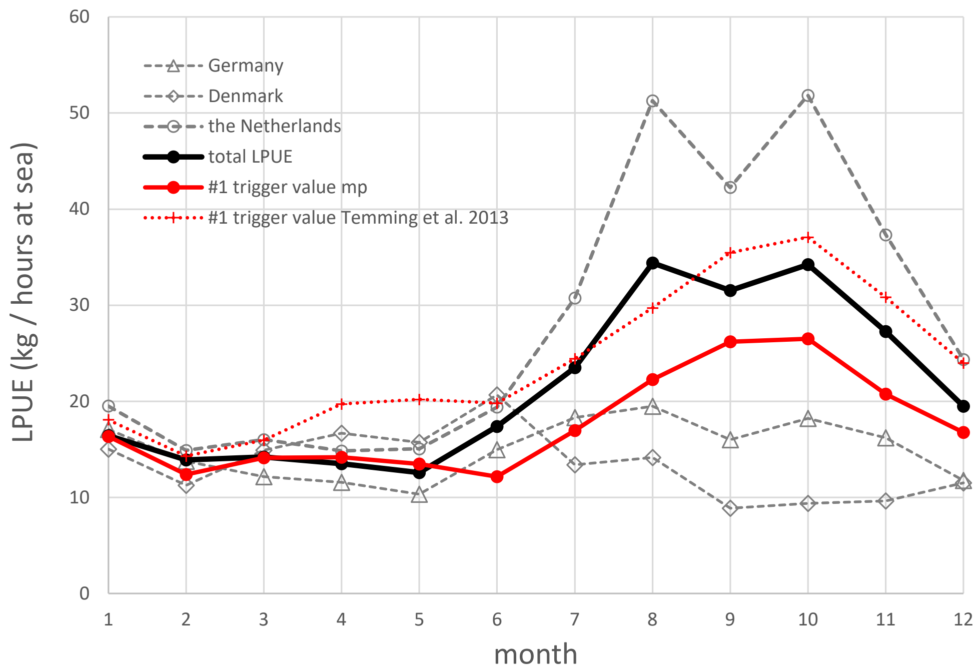


Figure 19. Solid lines: monthly landings per unit effort and #1 trigger values of the industrial management plan (mp); dashed lines (not used to trigger the HCR): national landings per unit effort (grey) and the #1 trigger values suggested by Temming *et al.* (2013) (red).

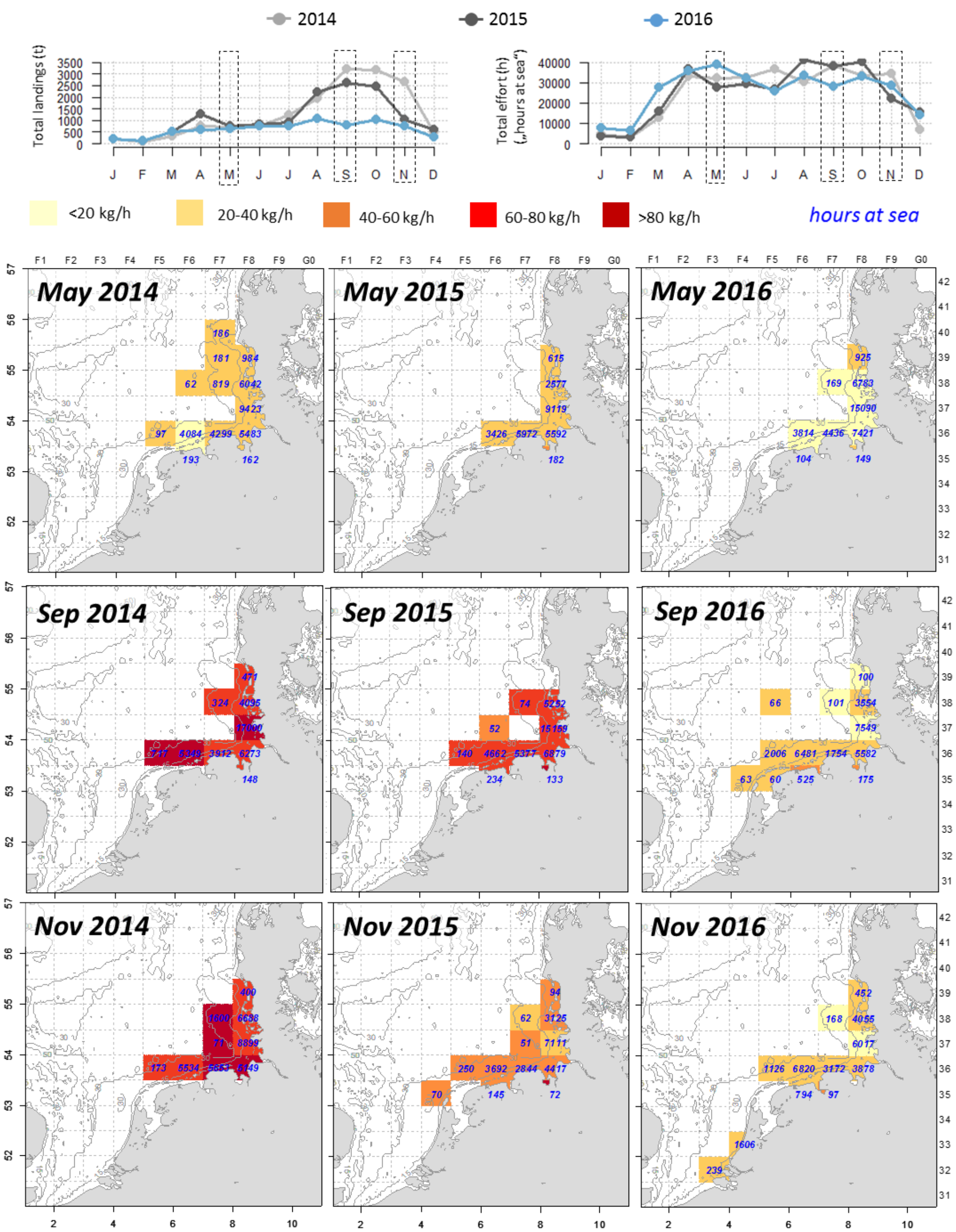


Figure 20. German LPUEs (landings per hours at sea) from logbook data (2014–2016). The xy-plots in the top shows the monthly total logbook catches (left) and the total effort. LPUEs of highlighted month are illustrated in the spatial panels below on ICES-rectangle basis. Blue numbers in the rectangles indicate hours at sea. Note that the HCR kicked in during May 2016, but the effort was higher compared to previous years.

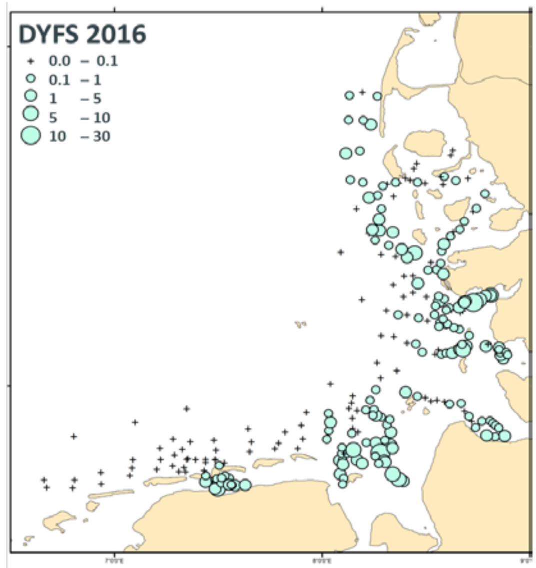
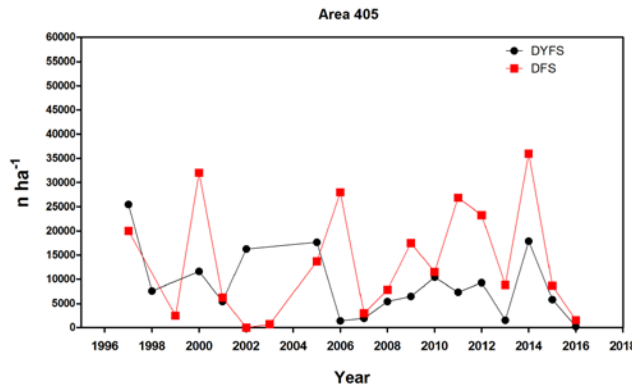


Figure 21. Stations and associated biomass of *Crangon crangon* sampled during the German Demersal Young Fish Survey (DYFS) in autumn 2016. Values represent kg *Crangon* haul^{-1} (15 min).



Values are given as means; SD not shown (n varies from 1 to 57)

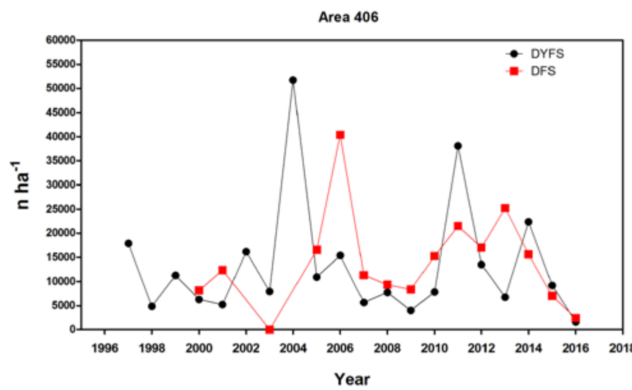


Figure 22. Crangon crangon abundance indices of two overlapping sampling areas (405 and 406) were compared over a period from 1997 to 2016. For the DYFS (black) and DFS (red).