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

18–20 May 2015
Ijmuiden, the Netherlands
Contents

Executive summary ................................................................................................................ 2

1 Administrative details .................................................................................................. 4

2 Terms of Reference a) – z) ............................................................................................ 4

3 Summary of Work plan ................................................................................................ 5

4 Summary of Achievements of the WG during 3-year term ........................................ 6

5 Final report on ToRs, workplan and Science Implementation Plan ......................... 9

6 Cooperation .................................................................................................................. 26

7 Summary of Working Group self-evaluation and conclusions ................................ 26

Annex 1: List of participants............................................................................................... 28

Annex 2: Recommendations ............................................................................................... 29

Annex 3: WGCRAN terms of reference ............................................................................ 30

Annex 4: Copy of Working Group evaluation ................................................................ 35

Annex 5: Figures ................................................................................................................... 42
Executive summary

The Working Group on *Crangon* Fisheries and Life History (WGCRAN) 2015 meeting was successfully held at IMARES in Ijmuiden, the Netherlands, 18–20 May 2015. Members from Germany, the Netherlands and Belgium joined the meeting. Representatives from UK, Denmark and France were represented via correspondence. Members of WGCRAN see the priority of this expert group in understanding population dynamics and factors influencing the stock and the individual to improve and provide the biological basis for advice and to identify suitable ways to sustainable manage the stock.

During the last three-annual term the working group - among other activities - derived stock status indicators from surveys like swept-area biomass estimates, length-based estimates on total mortality and the large-shrimp indicator. Fisheries related indicators like seasonal and interannual variations in landings per unit effort, spatial distribution of effort and lpue - based on VMS and logbooks - were determined and have been standardized among most of the nations. Combining all the indicators with modelling efforts and information on the shrimp predator stocks indicated that the population is at the moment growth overfished and that fishing pressure $F$ is about 4 times higher than natural mortality $M$. Effort constantly increased during recent decades and in 2013 and 2014 the highest effort (in horse-power days at sea) has been reported. $F$ is on a level of about 4.5 per year while $F_{\text{max}}$ and $F_{\text{0.1}}$ were calculated to be about 2 and 1.5, respectively.

In 2013 and 2014 the effort of the Dutch fleet was 32% and 26% times higher than the average effort for the period 2000–2014, however lpue were only -15% (2013) and +5% (2014) of the long term average, respectively. These figures indicate that at the moment the fishery is at the decreasing (or flat top) end of the yield per recruit curve. Increasing effort will thus results only in a minor increase or even a decrease in landings. As so far no effective management of the shrimp stock is in place and lpue in combination with survey data are the sole monthly available and usable indicator for the stock status, more information on the unmonitored factors (deck equipment, net types etc.) are strongly required to identify and prevent from effort creep.

At the moment catches contain about 30% shrimps of commercial size, 30% fish bycatch and 30% undersized shrimps. Updated calculations indicate that the plaice bycatch of the Dutch brown shrimp fleet alone sums up to about 12–17% of the plaice SSB. Within the last three-annual term thus new methods for improving gear efficiency and reducing bycatch have been investigated. Comparative hauls using the pulstrawl in comparison to standard gears indicated that depending on season and gear type equal or sometimes higher shrimp cpue can be obtained while fish bycatch was reduced during some seasons significantly. While this is a positive signal it needs to be considered that an increase in efficiency might further increase $F$. The effects of using different mesh types and width in the cod end of conventional gears was investigated as well and it could be shown that increasing the mesh size will decrease the bycatch of undersized shrimps and will - in a situation of a high $F/M$ ratio - lead to increased catch weights and in general larger shrimps in the catch and the population.

Within the last three-annual term WGCRAN strongly focused on the question whether a management of the shrimp fishery is needed and if so what possible routes could and should be taken. During the WKCCM (workshop on the necessity of a Crangon and
Cephalopod management) all experts concluded that a management is required to guarantee long term sustainability in any regard (stock, economic, ecologic, ecosystem). Thus an advice was formulated stating these issues and a roadmap towards a management plan was provided. So far the authorities did not follow this advice and thus the fisherman themselves started to evaluate and investigate ways on how to start a self-management, which provides, due to the restrictive behaviour of the authorities, at the moment the only possible management option in the case of a recruitment failure or a low stock biomass.
1 Administrative details

<table>
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<th>Working Group name:</th>
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<td>Working Group on Crangon Fisheries and Life History (WGCRAN)</td>
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<th>Reporting year concluding the current three–year cycle</th>
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<th>Chair(s)</th>
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<tr>
<td>Marc Hufnagl, Germany</td>
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<th>Meeting venue(s) and dates</th>
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<td>3–7 June 2013, Copenhagen, Denmark (11 participants)</td>
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<td>6–9 May 2014, Hamburg, Germany (19 participants)</td>
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<tr>
<td>18–20 May 2015, Ijmuiden, the Netherlands (16 participants)</td>
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2 Terms of Reference a) – z)

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 Ipue time-series of higher accuracy for all nations with horse power days calculated based on hours at sea for the future but also for the past where possible. (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) Publish a common publication on brown shrimp biomass estimates and annual production rates. Besides the survey based swept-area estimates the publication shall also include correction factors based on new or existing information on gear selectivity, catchability and behaviour aspects. (Lead persons: Ingrid Tulp, Volker Siegel)

d) Publish predation rates of cod and whiting on brown shrimp and discuss the role of fishing in relation to natural mortality. (Lead persons: Axel Temming, Marc Hufnagl)

e) Parameterize and use a Crangon crangon population model to investigate e.g. seasonal brown shrimp biomass dynamics, the implications of fishing effort alterations (including closures), mesh size and mesh selectivity on the population structure. The model shall be further developed to act as a decision aid for management rules and aspects. (Lead persons: Marc Hufnagl, Axel Temming)

f) The ongoing introduction of the electric beam trawl will have strong implications on the relation of the nominal effort and the fishing mortality of brown shrimp. Existing
literature and new results on the ecosystem and population impact of the introduction of the electric beam trawl into the fisheries shall therefore be reviewed and compiled. (Lead persons: Bart Verschueren, Axel Temming)

g) Gain a better understanding of the life cycle dynamics and history of brown shrimps in the different ICES regions with special focus on latitudinal gradients and the comparison of the North Sea core distribution area and the Portuguese Minho estuary at the most western distribution margin. This will include the application and further development of in situ growth methods, maturity and mortality estimates as well as the analysis of starvation and condition indices. Especially in the North Sea also the maturation and spawning process of brown shrimp shall be investigated to gain a better understanding of the recruitment process. (Lead persons: Joana Campos, Axel Temming, Volker Siegel)

h) Generate a common publication on existing data and possible methods to assess and manage the brown shrimp fisheries in the ICES region. This shall include i.) A compilation of existing brown shrimp information from commercial data and scientific surveys ii.) a review of suitable management methods gained from ICES recommendations on management of data poor and lower trophic level species and iii.) an identification and evaluation (e.g. overview table) of possible management strategies. (Lead persons: Josien Steenbergen, Axel Temming)

i) Gather, compile and evaluate information on the onboard and ashore sieving fractions and processes and new national bycatch/discards data from e.g. DCF (GER and NL) and the Dutch "Effects of shrimp fisheries on the Natura 2000 sites" - Project on i.) bycatch and discards of N2000 species and juvenile flatfish. (Lead persons: Ingrid Tulp, Josien Steenbergen).

j) 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.

k) Analysing the selectivity of different mesh openings and mesh types and the impacts they have on catch composition and stock dynamics (Lead persons: Thomas Neudecker, Sebastian Schultze, Bente Limmer)

3 Summary of Work plan

<table>
<thead>
<tr>
<th>Year</th>
<th>Details</th>
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<tr>
<td>Year 1</td>
<td>For manuscript planned under ToR b, c, d and i data analysis shall be finished and a draft version shall exist. All effort time series of all countries required for ToR a shall be provided in a standardized and updated way.</td>
</tr>
<tr>
<td>Year 2</td>
<td>For manuscript planned under ToR b, c, d and i shall be in submittable to peer reviewed journals. Data and text for manuscripts under ToR e, f and h shall be available. Stock indicators shall be updated and reevaluated.</td>
</tr>
<tr>
<td>Year 3</td>
<td>Manuscripts falling under ToR e-j shall be in a submittable form. For a set of stock indicators a sound and proven time-series shall exist that can be used to evaluate the status of the brown shrimp population.</td>
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4 Summary of Achievements of the WG during 3–year term

a) **Stock-status indicators**
   i) see section 5

b) **VMS, landings and effort data**
   

c) **Brown shrimp swept area biomass estimates**
   i) *Manuscript for submission*. Title: “Estimate of total annual brown shrimp *Crangon crangon* production in NW Europe based on a swept area estimate”. Tulp I., Siegel, V., Hufnagl, M. *et al.*

d) **Predation rates of cod and whiting on brown shrimp.**

e) **Crangon crangon population model**
   
   ii) *Report*: “Investigations into the robustness of the harvest control rule (HCR) suggested by the Dutch fishing industry for the MSC process”. Temming A., Schulte K., Hufnagl M.


f) **Pulse Trawl**

   
iii) ICES Working group report. ICES SGELECTRA report 2012, ICES CM 2012/SSGESST:06

G) Research on brown shrimp and life cycle dynamics in the ICES regions


viii) PhD-Thesis “Investigations into growth and nutritional condition of Crangon crangon (L.)” by Zaki Sharawy, University of Hamburg


xi) Manuscript for submission: Season and body size affect behavioural thermoregulation of the common brown shrimp (Crangon crangon, L.). Reiser S., Temming A., Hufnagl M., Eckhardt A., Herrmann J.-P.


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

i) ICES Report of the Workshop on the Necessity of Crangon and Cephalopod Management, WKCCM. ICES CM 2013/ACOM:82

ii) Special request, Advice October 2014. Request from Germany and the Netherlands on the potential need for a management of brown shrimp (Crangon crangon) in the North Sea. ICES Advice 2014, Book 6

i) National bycatch/discards data from e.g. DCF and national projects


j) Exchange of information on national legislation, laws and developments

k) selectivity of different mesh openings and mesh types

5 Final report on ToRs, workplan and Science Implementation Plan

a) Population status indicators

General development and overview

The total fleet targeting brown shrimp in the North Sea involves about 560 vessels made up by 205 German, 200 Dutch, 27 Danish, 29 Belgian, 44 French and 54 UK shrimpers. Since 1960 total landings constantly increased peaking in 2005 with 38 613 tons. Since then landings varied between 32 122 and 37 513 tons. Total North Sea effort between 2007 and 2010 and in 2012 varied on a level of 10 000 000 horse power days at sea (hp-das). In 2010 and 2011 strong year classes entered the fishery and the high landings in combination with the market situation led to low prices and finally resulted in a strike of the fisherman. Thus in 2011 total effort was lower than the years before and amounted to 7 000 000 hp-das. However, since then effort steadily increased and has now reached the highest ever reported level of 13 000 000 hp-das in 2013 and 2014. This is an increase of 30% in relation to the period before. Besides the Netherlands all nations now report effort in hp-das based on hours at sea (time when the vessels leaves and enters the harbour). Based on these standardized and more accurate effort landings per unit effort (lpue) time-series for up to 14 years could now be calculated. The general lpue-patterns of the main fleets (NL, GER, DK) are comparable and show a peak in 2011 followed by a steady decrease thereafter. In France and the UK the lpue maximum was reported one year later in 2012.

Commercial landings and effort data are an important indicator that gives insights into the long term development, interannual variation and seasonal patterns. Especially the latter are not resolved by the scientific surveys which are mainly conducted in autumn. However the German Demersal Young Fish Survey (DYFS) and the Dutch Demersal Fish Survey (DFS) provide valuable insights into the spatial distributions of shrimps, external drivers that influence the population dynamics and insights into the size structure and the number of fecund females. The size information obtained from the surveys can be used to estimate total mortality rates and to provide indices like the fraction of large shrimps in the populations. As the sampling is highly standardized the number of shrimps caught per unit effort can further be used to determine a swept area biomass estimate (see ToR c). Methods on how to determine the indices were published in the past and the information obtained from the surveys and the landings statistics is now regularly updated within the working group meetings. Combining the information with cod and whiting stock structures obtained from WGSAM and with spatial distribution data obtained from the International Bottom Trawl Survey it was further possible to also calculate time series of F and M in addition to the total mortality (see ToR d).

Related Publication


Siegel V, Damm U, Neudecker T (2008) Sex-ratio, seasonality and long-term variation in maturation and spawning of the brown shrimp *Crangon crangon* (L.) in the German Bight (North Sea) HMR DOI 10.1007/s10152-008-0121-z

Siegel V, Gröger J, Neudecker T, Damm U, Jansen S. (2005) Long-term variation in the abundance of the brown shrimp *Crangon crangon* (L.) population of the German Bight and possible causes for its interannual variability. FO 14: 1-16

Zaki Sharawy 2010 Investigations into growth and nutritional condition of *Crangon crangon* (L). Dissertation University of Hamburg


**Landing statistics**

Over the recent years the total amount of shrimps landed by German, Dutch and Danish Fisherman constantly increased while annual landings from the UK remained on a rather constant level and Belgian landings decreased (Figures 1–6). The share of German landings constantly decreased from a maximum of 57% in 1984 to 33% in 2014 whereas the Dutch landings share increased from a minimum of 24% on 1981 to a maximum of 54% in 2014. The Danish share increased from 5% in 1991 to 12% in 2007 and now 8% in 2014. The contribution of UK vessels to the total landings varied between 2 and 7% and the Belgian share decreased from 10% in 1981 to now 2.5% (2014). The French North Sea fleet is mainly made up by few and small boats and thus the landing share has always been below 1%.

Total shrimp landings from the whole North Sea so far peaked in 2005 with 38,613 tonnes. Between 2006 and 2013 landings varied between 32,122 and 35,388 and reached the second highest ever reported value in 2014 with 37,513 tonnes (Figure 7).

Brown shrimp grow fast but also experience high mortality rates. Egg bearing females can be observed all year round with the exception of Sep-Oct. Larvae hatching over winter experience very low temperatures which delays the development. Increasing temperatures in spring lead to a rather synchronized development of all larvae that have hatched during the months before. Thus a strong increase in juvenile abundance in the shallow waters of the Wadden Sea can be observed between May and June. In August and September this new cohort reaches commercial size which increases the catches and lpue. With decreasing effort and a migration of adult shrimps to deeper waters in December and January also landings decrease. Shrimping starts again in March and targets the previous years’ cohort. Thus there is a relation between spring and previous years’ autumn catches and lpues (see WGCRAN report 2012).

Seasonality during the last 10 years was comparable among the regions with about twice as high landings in autumn in comparison to spring. However, comparing the mean decadal seasonal landings (Figure 9) it can be seen that long term changes are present in some fisheries. In the Dutch fishery landings generally increased but especially during autumn. While in the Danish fishery between 2000 and 2010 higher spring than autumn
landings were observed, the pattern has changed now. Between 2010 and 2014 autumn landings were higher than spring landings. A similar trend was observed for the Belgian fleet where especially autumn landings increased. These patterns are likely a result of increased fishing pressure. If the cohort is heavily fished already in autumn, landings will increase during that time but decrease in spring in the next year as the same cohort is still present but reduced in numbers.

Effort has now been largely standardized for all fleets. Besides for the Dutch fleet all figures, effort and lpue values are based on hours at sea divided by 24. Thus days at sea refer directly to the time spent outside the harbour. For the Dutch fleet full days are counted thus effort might be overestimated. UK days at sea have in former reports also been determined on full days at sea but are now based on hours. As not for all trips leaving and entering times were available some bias still exists in the data. For UK multi-day trips without departure or arrival times, duration was calculated as 0 + 24 hours per calendar day away from port. Overall, date of arrival / departure was reported for 77.3% of landings records; the quality of reporting fluctuated over time and was 73.9% for 2014. The updated UK data further include slight changes as recent changes to the way that port offices record vessel and gear occurred. Thus a small proportion of the catch and effort has previously not been included (representing approximately a 1.5% increase in the catch / effort).

Effort in days at sea (Figure 10) and horsepower days at sea (hp-das, Figure 11) was comparable to the previous year (2013) but higher than the long term mean for Germany, the Netherlands, Denmark and France and lower than the average for UK and Belgium. Despite the increased effort and the second highest reported total landings lpue was lower than the long term average indicating the high fishing pressure. In Germany lpue was about half to one third of the long term average and especially low between February and July while it increased thereafter when the new cohort reached fishable sizes. Comparable to that Dutch lpue were low in the first half of the year but then increased above average in the second half (Figure 12 and 13). A similar pattern was observed for the Belgian and Danish fleet.

The seasonal variation in lpue is also reflected in the total monthly landings and effort patterns (Figure 14 and 15). While total effort was rather constant between March and November landings showed a very distinct seasonal pattern with 3 to 4 times higher landings in autumn than during the rest of the year.

Between 2002 and 2010 only slight changes between total effort (hp-das) by all fleets was observed (Figure 16). However, after the strike in 2011, where total effort was about 3 000 000 hp days at sea lower than before, effort increased and remained above 12 000 000 as also observed in 2013. This trend is only partly visible in the effort in days at sea data (Figure 16) which indicates that especially the larger ships with stronger engines increased effort.

Annual lpue varied over time and values between the nations ranged from 1 to 5 kg/hp-das in single years (Figure 18). These between nation variations decreased and the range in 2013 and 2014 was about 2–3 kg/hp-das. Since 2011 lpue are decreasing only in France in 2012 high values were obtained.
Fraction of large shrimps

The fraction of shrimps > 60 and > 70 mm caught in the DYF and DF surveys conducted during autumn decreased over time. Although between 2003 and 2008 the share of >60 mm shrimps increased from 15 to 20% it starts to decrease again thereafter. For 2013 and 2014 percentages varied between 13 and 18%.

Mortality

After the highest total mortality rate of 7.6, observed in 1993, values decreased and varied between 4.6 in 2011 and 6.6 in 2003 since then. During the last three years, mean annual total mortality rates of 5.7, 6.3 and 5.3 were determined based on the corrected autumn length frequency distributions (see also Hufnagl et al. 2010). Furthermore F and M were determined which is described under ToR d).

Biomass/Production

See ToR c)

Cooperation with other WG

Cooperation with WGBEAM on improving survey designs to match with the requirements of the brown shrimp swept area biomass estimate and to derive correction factors for the use of different gears.

Cooperation with Advisory structures

Crangon Advice, WKCCM, ADRAN

Science Highlights

In 2012, 2013 and 2014 there were more active shrimpers with stronger engines especially in the Dutch fleet which is reflected in the stronger increase in hp-days at sea and in relation to days at sea. Thereby the increase in hp-das was, on a relative scale, higher than the increase in das. While between 2012 and 2013 Dutch effort (in das) increased by 12% the effort in hp-das increased by 55%. This shows that more large and more effective boats entered the fleet. For 2014 no further increase in vessel power was determined, however, despite the high effort level catches did not increase and thus lpue decreased. The increase in effort was accompanied with an increase in total mortality by 0.6 a⁻¹ between 2012 and 2013 and was followed by very low lpue in spring 2014. Despite the reduced spawning population (shown in a decrease in the fraction of large shrimps) lpue increased in autumn 2014 indicating a stronger new class. Total mortality is still below the highest observed values and there are so far no signs that incoming cohorts are predetermined by the population size (indicated as lpue, fraction of large shrimps etc.) of the previous year. Nevertheless the increase in effort that is not correlated with increased landings but rather with decreasing lpue and decreasing fractions of large shrimps are strong indications for growth overfishing.

All findings combined indicate an increase in fishing pressure on the shrimp population and growth overfishing.
b) Effort distribution based on VMS data

Progress by ToR

VMS data contain two-hourly transmitted positions (pings), providing speed, direction and coordinates of the vessel. This resolution is insufficient for several tasks, and different methods are available to estimate the spatial extension of fishing areas and the spatial distribution of effort, catch and revenue. At least five different methods (raw pings, straight line and spline interpolation, the amplification method and ellipses) are available to deal with the unknown track between two-hourly (pings). All methods are used on VMS data in parallel without any further reasoning why a certain method is used. This implies that the methods are assumed to lead to comparable estimations regarding the vessels track and the spatial distribution of effort and catch.

To check, whether the assumption of equal estimations holds, the five different methods were applied on a VMS dataset of the German brown shrimp fleet, to check, if and on which resolution the considered methods differed in their results. The study shows that the estimations of effort and catch assigned to certain areas sometimes differ considerably. Further, the study identified the most suitable method for the German brown shrimp fleet. The analysis is finished and the publication in progress.

Applying the best suitable method in combination with German logbook and landings data from 2007–2013 were used to determine spatio-temporal estimates of effort, lpue and the fraction of larger shrimps. Spatial estimates of effort, lpue, landings and the distribution of large shrimps were created. Though VMS-data are not collected for the purpose of biological research it was shown that commercial data can be used for biological research. The study further provides comprehensive information on the intra- and inter-annual spatial and temporal distribution of brown shrimp which has not been available so far. In this analysis spatial-temporal migration signals were found and it was successfully aimed to clarify different aspects of the brown shrimp’s life cycle. This analysis is also finished and the publication in progress.

Cooperation with other WG

None

Cooperation with Advisory structures

No cooperation

Science Highlights

VMS data in combination with landings can be standardized and then used for analysing population dynamics and populations shifts.

c) Swept-area biomass and production estimates

Progress by ToR

The necessity and the general procedure and methodology to estimate biomass and production of brown shrimp in the North Sea have been described in detail in the WGCran
Correction factors have now been included and verified and the latest data from the 2014 surveys were added. Problems related to the general procedure arose while analysing the data and proceeding with the writing of the manuscript which needed further clarifications. These statistical issues were discussed during the meeting. Analyses have been carried out in two ways: one based on arithmetic mean densities and one on bootstrapped means. The results of both methods were highly similar. The publication of the results is in progress and will be finished shortly.

**Changes/ Edits/ Additions to ToR**

No changes.

**Cooperation with other WG**

**Cooperation with Advisory structures**

**Science Highlights**

The autumn swept-area biomass estimate based on the Demersal Fish and the Demersal Young Fish Survey (methods see WGCRAN report 2012) has been updated and was similar to that in 2013. Average annual biomass of shrimps > 50 mm was 12 000t resulting in a total annual production of 76 000t (using $P = B \times Z$ and $Z = 6.3 \text{ a}^{-1}$). The final production estimate and the average annual standing stock biomass of shrimps > 50 mm will be published along with the time-series reaching back to 1970 shortly.

**d) Natural mortality rates vs. fishing mortality**

**Progress by ToR**

We extended the analysis made by Welleman and Daan (2001) to the years 1996–2011 using updated stock assessment and predator distribution data. Stock numbers for the predators were derived from age based assessment data (IBTS, SMS) for the total North Sea and were multiplied with the quarterly consumption rates per individual by age class and the average share of brown shrimp in the diet of the predators. Total mortality - estimated using length based methods (see ToR a) – was then split into M (natural mortality) and F (fishing mortality) using the total consumption of the predators and the North Sea wide landings. The obtained results are presented in Temming and Hufnagl (2014). For this working group report we further updated the F and M presented in Temming and Hufnagl (2014) using the new WGSAM SMS key run from 2014. Thus F and M could be estimated for 3 more years: 2011 to 2013. For simplicity we here used the approach where we did not split the data by roundfish area. This might produce a slight bias but the trends and orders are similar (see paper for the details). First we used the new key run and compared the estimated shrimp consumption rates of cod and whiting with the 2011 key run (Figure 22 upper panel). The results are comparable for the years before 2011 but consumptions are slightly smaller for the period since 1988. The newly added years 2011–2013 remain on the level determined for the years before. Due to the lower consumption rates the ratio of landings vs. consumption increases and was, after the steep increase between 2003 and 2004 always above 2.8. Splitting Z (Figure 20) into F and M using this ratios this translates into a fishing mortality F of 4.9 in 2013 in contrast to a M of 1.4 in the same year. Using the yield per recruit mode to determine F01 and Fmax
(again see Temming and Hufnagl 2014 for details) we obtain values of 1.6 and 2.2, respectively. Thus fishing mortality is 3.1 and 2.2 times higher than Fmax and F01 indicating that effort can be reduced substantially without loosing catches.

Reference

Cooperation with other WG
SMS predator abundance by age and year data were obtained from WGSAM

Cooperation with Advisory structures
None.

Science Highlights
The North Sea ecosystem has undergone pronounced changes with overfishing and climate change causing a substantial decline in predator stocks, namely cod and whiting. In addition, both predators have shifted their range of distribution causing a reduced overlap with brown shrimp. For the first time it was possible to calculate F and M for the brown shrimp population for the years 1996–2013 using updated stock assessment and predator distribution data. We demonstrated that the decline of key predators of brown shrimp in combination with a shift in the distributional range of the predators has caused a new situation, in which the fishery has become the main mortality source of adult brown shrimp (>50 mm). Average landings since 2000 have been about 40% higher than in the 1980s and 1990s, indicating that humans have at least partly taken over the share previously taken by juvenile whiting and cod. The application of a yield-per-recruit model indicates growth overfishing of brown shrimp. From the landings and predation rate data similar indications as obtained from ToR a. were obtained that show that effort can be significantly reduced without loosing catches.

e) Yield–per–recruit model

Progress by ToR
Yield-per-recruit (Y/R) models (Beverton and Holt 1957) can be used to evaluate growth overfishing and the impact of increased fishing mortality on harvestable biomass. These curves typically increase with F from zero onwards with steadily decreasing slopes and either reach a defined maximum, or depending on growth parameters and M, appear as flat top curves. If a maximum is clearly developed, F should not be increased beyond Fmax to avoid growth overfishing. For stocks with a flat top Y/R-curve an alternative F-level has been proposed as a reference level, namely the F at which the initial slope of the Y/R curve has decreased to 10% of the initial value (F0.1). F0.1 indicates a level of exploitation, where any further increase would only result in minimal further increase of the Y/R, while at higher F levels the mean spawning stock per recruit (SSB/R) would decrease dramatically.

Based on the Y/R model presented for the first time in the WGCRAN report 2003 a new version has been developed including males and females, different mortality schemes for
larvae, juveniles and adults, updated growth and mortality rates in combinations with updated fishing effort and F/M ratios and a new recruitment index. This new model is described and published in the PhD thesis of Chris Rückert (2011). A slightly modified version (mainly concerning the coding) of this model was used to calculate landings using different F and M values based on the analysis of ToR d). The results and the model description are included in the manuscript by Temming and Hufnagl (2014) described under ToR d.

References


Cooperation with other WG
None.

Cooperation with Advisory structures
WKCCM, ADCRAN, Crangon Advice

Science Highlights
see ToR d)

The model is currently extended by a economic module to evaluate the different scenarios concerning temporal closures, the implementation of a harvest control rule, the changes in costs and benefits related to applying larger mesh sizes, etc.

f) Pulse-gear

Progress by ToR
Results published (section 3)

Changes/ Edits/ Additions to ToR
No changes.

Cooperation with other WG
SGELECTRA

Cooperation with Advisory structures
None.

Science Highlights
The future of the flatfish fishery, in particular by beam trawls, is endangered as fuel costs and obligations to reduce bycatch will further increase. Pulse fishery with electrotrawls may pose a promising alternative, offering multiple improvements. Unfortunately, not all
possible negative side effects can be excluded yet. Although various studies elucidating the effects of electrical fields on fish have been performed, various major gaps of knowledge still remain and need to be investigated. – With Shrimp electric fishing we are talking about another, lower stimulus and thus this should be regarded separately.

With regard to electric fisheries on shrimp, the used gears are getting more efficient especially as it can catch shrimp during daytime and clear water. Considerations on stock effect and management consequences with such a new gear should be done as was also concluded in the WGCRAN report 2011:

The original design of the Hovercran aimed to catch shrimp with electric pulses without bottom contact. In the current practise however, the hovercran is combined with bobbin rope, resulting in a gear that is much more efficient in catching shrimp than the traditional beamtrawls.

Given the increase of efficiency this gear (hovercran in combination with the bobbin rope) should only be used under strict regulation of catches. Increased efficiency could be an advantage (in terms of less bycatch and bottom contact per kg of shrimp caught), but only when there is a limit in total catches per year (e.g. quota). Otherwise the catch is likely to increase.

In addition to this statement it should be mentioned that the effort of the fleet continuously increased during the recent years and part of this effort is not monitored (e.g. improved deck equipment etc.). Introducing a new, likely more efficient technology is very difficult to monitor and reference data do not exist. The fishing industry has proposed an lpue-based management approach (see also ToR e. and ToR h.). This management would be based on lpue reference points determined using values of previous years. Changes in catchability of the used gears will alter these patterns and will complicate or even make it impossible to determine these reference points. Furthermore there are strong indications that the shrimp population is growth overfished. Increasing the effort while not simultaneously limiting the catch will increase the pressure on the population and the impact on the system.

g) Life cycle dynamics comparison among ICES regions

Progress by ToR

Crangon eggs and larvae

Since 2012 Germany (Thünen Institut) has conducted a pre-recruit survey on Crangon crangon in the German Bight. The survey is carried out in the last week of April/ first week of May to study the distribution and abundance of shrimp larvae as well as the reproductive effort during the main part of the spawning season. Five standard station transects running from inshore to offshore waters are sampled by 1 m²IOS net (vertical profile) with a mesh size of 0.4 mm.

Preliminary analyses compared current data of shrimp egg size and abundance of egg bearing females with historic data from the 1920s published by Havinga (1930). Havinga reported on different egg sizes during winter and summer and established the term of large winter eggs and small summer eggs. He also described a drop in the proportion of egg bearing females in February and concluded that two separate spawning periods
might exist for brown shrimp. The actual survey data since 2012 were analysed in more
detail, using the egg developmental stage classification of Meredith. From the analyses it
became evident that shrimp eggs are changing their shape during their development
from round to oval with a small and large diameter.

Both lengths were measured for each developmental stage and compared with data collected on a weekly basis over a one year period from a commercial shrimp trawler. A comparison with the historic data of Havinga showed that egg size increases with developmental stages but no summer and winter difference was detected. Furthermore, the analysis of a 20 year data set (weekly samples from commercial trawlers) showed that there is no drop in the proportion of egg bearing females during February, but that from December to May the proportion of egg bearing females is constantly increasing. A gap in the reproductive output occurs between July and November, when the proportion of egg bearing females is falling below 40% (July) and increasing again in December with a minimum of less than 5% in September/ October.

The conclusion of the preliminary study would suggest that neither the hypothesis of winter and summer eggs could not be confirmed and that neither the occurrence of two main spawning seasons (decline in egg bearing females in February) can be supported. Further analyses are required to investigate the reasons for this discrepancy, whether there are spatial differences (Havinga sampled off the coast of NL) or if there are methodological caveats attached to Havinga’s data since he did not consider the different shape of eggs during their development.

First analyses on the abundance and distribution of Zoea larvae indicated that the density of larvae was generally slightly larger in East Frisia compared to North Frisia, although the density of egg bearing females shows the opposite pattern. From 2012 to 2014 larval densities across the entire area did not show substantial interannual differences, but only more data from future surveys will provide insight into the potential variability in larval densities over time. Survey data from 2015 are currently analyzed and sampling will continue in 2016.

Behaviour of Crangon

Variations in swimming activity of different sized Crangon crangon (15 to 65 mm total length) were monitored under constant laboratory conditions immediately after catch in the German Wadden Sea. Activity of shrimps of different sizes, caught at different seasons always peaked at times corresponding with ebb tide in the habitat from where they were taken. This behaviour was maintained for several days if no external stimuli were present but shifted to night activity if a light-dark cycle was provided. The observed behaviour/activity pattern was included in a coupled hydrodynamic and individual based model (IBM) and the shift in the location of a shrimp cohort was monitored over time. Performance of ebb tide activity not only allowed the shrimps to reach the preferred deeper winter and spawning areas, but also allowed them to migrate against the dominating current from eastern nurseries to more western located spawning areas. Passively drifting larvae released at these locations and later larval and juvenile stages that perform flood tide transport can reach the nurseries again. This links the nurseries and adult spawning grounds and closes the migration triangle. The results are summarized in Hufnagl & Temming 2014.
References

Cooperation with other WG
None.

Cooperation with Advisory structures
None.

Science Highlights
Crangon eggs and larvae: New analysis of brown shrimp eggs indicated that neither the hypothesis of winter and summer eggs could be confirmed and that neither the occurrence of two main spawning seasons (decline in egg bearing females in February) can be supported.

Crangon behaviour: Laboratory and model data indicate that adult shrimp migrate against the general prevailing North Sea currents towards the west by using selective tidal transport. There they spawn and the offspring is than carried with the currents to the coastal nurseries using - as postlarvae – also flood tide transport.

The combination of observations on vertical migration in combination with a hydrodynamic model indicated that a migration triangle might exist for brown shrimp. Additionally the results indicate that the Elbe estuary might form a rough separation line of the population with adults west of the estuary migrating towards west and those located north of it towards the north.

h) Brown shrimp management

Progress by ToR
During the last three years the question whether a brown shrimp management is needed and how a management could look like were one major focus of the work of WGCRAN. In 2013 the Workshop on the necessity of a Crangon and Cephalopod management (WKCCM) was held in Copenhagen. The workshop aimed to provide advice on the need for management of the currently unregulated *Crangon crangon* (brown shrimp) in the North Sea and cephalopod stocks in the North-East Atlantic. Potential steps towards a brown shrimp and/or cephalopod management, including due considerations of research needs and required stake-holder feedback have been developed. Below a part of the summary of WKCCM is added:

*The evidence found for the need of management of C. crangon was a combination of several factors. During the workshop recent studies and stock indicators were summarized and discussed leading to the conclusion that fishing has a large impact on the C. Crangon stock. The high fishing pressure likely led to growth overfishing of the population during recent years, and a reduction of effort is believed to be possible without major losses in catches. Additionally a healthier stock with larger shrimps and higher reproduction could be obtained if gears are adjusted and fishing pressure is released in general and especially on juvenile shrimps. The reduction of “unnecessary”*
effort would lead to reduced impacts on the ecosystem through reduced discards, bottom impacts, combustion and other adverse ecosystem effects. The control of effort and efficiency, a general effort reduction, which is especially needed when population size is low, and the use of better suited gears are only possible in a controlled and managed fishery. The landings of C. crangon for human consumption have constantly increased since the 1970s, most probably due to a decrease in predation pressure and an increase in effort (engine-power) and efficiency. However, the current lack of an efficient management results in situation of uncontrolled and unmonitored effort and efficiency. The development of new and more efficient devices (e.g. pulse beam trawl) increases the call for action.

To conclude: the group requests, as a next step, ACOM to give a pro bono advice in favour of a management of C. crangon fisheries. The fishing industry has taken first steps towards sustainable management of their fisheries with the aim to get a MSC label. In this light the industry has developed an Ipu-based harvest control rule. The pro’s and con’s of this rule were discussed during the workshop (and in more details elsewhere) and it was concluded that this HCR is a good starting point, as due to the short lifespan and the high seasonal dynamics of the stock a TAC rule is not applicable for C. crangon. Suitable management strategies and measures should be identified and (further) developed in a workshop early next year taking into account existing management initiatives by the industry.

Based on the outcome of WKCCM an advice was formulated:

ICES advises that the management of the Crangon crangon fishery in the North Sea would have benefits for the fishery in terms of sustainable yield and for the environment (taking ecosystem, mixed-fisheries, and multispecies considerations into account).

ICES indicates how the management of the Crangon crangon fishery might be considered. Due to the short life span of C. crangon an annual stock assessment and annual TACs are not suitable. Appropriate management would be needed to effectively limit the fishing effort, as reaching the maximum sustainable yield does not seem possible unless effort is reduced from the current level. A harvest control rule suggested by stakeholders and further refined based on science is considered to be a good starting point for management. ICES suggests a 6-step roadmap to facilitate the possible implementation of this management approach.

For further details see:

http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2014/Special%20Requests/Germany_NL_Crangon_advice.pdf.

Changes/ Edits/ Additions to ToR
No changes.

Cooperation with other WG
WKCCM in cooperation with WGCEPH. Delegates were invited from WKLIFE2, WGMG, WGMIXFISH and ACOM

Cooperation with Advisory structures
Members of ACOM were and are involved in the process.
i) Bycatch and discard fractions

Progress by ToR

In 2012 a 2 year project has started in the Netherlands to monitor discards in *Crangon* fisheries in cooperation with the fishers. A reference fleet of 24 vessels along the whole Dutch coastline once per month took a sample from their (fish and benthic) discards. These samples are picked up at the harbour and analysed at the lab. In this way we were able to get > 400 samples / year of the (composition of) discards in *Crangon* fisheries. The results are thus far only available in a Dutch report (Glorius *et al.*, 2015)

The aims of the project were to:

- quantify the bycatch of the Natura2000 species Twait shad (*Allosa fallax*), European river lamprey (*Lampetra fluviatilis*) and sea lamprey (*Petromyzon marinus*)
- quantify the bycatch of (juvenile) fish

Fisheries on brown shrimp mainly takes place in coastal areas, which are at the same time classified as important nursery areas to several marine fish species. By-catch and discarding of juvenile (flat)fish, in particular plaice (*Pleuronectes platessa*), in the brown shrimp fisheries is of reported as a problem (Revill and Holst, 2004; Catchpole *et al.*, 2008). With the stock assessment method of plaice at hand the effect of the by-catch of young plaice in the shrimp fishery on the spawning biomass of plaice has also been calculated in the project.

Due to the sampling method the abundance of some species was underestimated. Particularly the species with similar shape and size of (landing size) shrimp ended, after the normal sieving process on board of the shrimp vessel, up in the large shrimp fraction (e.g. gobies (*Gobius sp.*)), as only samples of the (fish and benthic) discards fraction where taken, these species were not sampled.

River Lamprey was found in 14% of the trips and Twait shad in 27% of the trips. Sea Lamprey was not present in any of the samples during the sampling period.

European sprat and plaice were the most frequent species found in the samples of (fish and benthic) discards. Plaice was found in 97% of all trip with highest abundances in the 2nd and 3rd quarter of the year. Lengths of plaice in the bycatch varied between 3 and 11cm (0–1 group).

Effect on spawning stock biomass of plaice

Data from this project were also used to estimate the effect of the bycatch in the shrimp fisheries on SSB of plaice. We could no use the ICES stock assessment model because the available period of 2 years was too short. Instead we used a fictive cohort using the mean number of the oldest age group in the period 2010–2013 and the mean catches in these years. Depending on the value used for natural mortality, the estimate of the effect of shrimp fisheries on the reduction in SSB arrives at 14–20% (assuming all bycatch dies). Using a survival rate of 20% (not including predation by birds) the reduction in SSB is 12-17%.
Germany and the Netherlands are running an observer-program to monitor the catch and discards in shrimp fisheries. Both countries use the same protocol on board. About 8 trips are monitored per year. During a bilateral meeting between the institutes IMARES and TI it has been agreed on summarizing the discards in the shrimp fisheries in the Netherlands and Germany. Data of 4 years of DCF-sampling will be used in this publication. The main outcomes will be included in the final WGCRAN report (2015). Below part of the summary of the report (Steenbergen et al., 2015):

Both the Netherlands and Germany use observers on board shrimp vessels to monitor the catch. Vessels are selected on ad-hoc non-random approach. The on board sampling procedure is similar in both countries: a representative catch-sample is taken from as many hauls as possible during one trip. Fish and shrimps are measured and benthos is counted, additionally in Germany benthos is also weighted. In the Netherlands all sampled components are raised in relation to the estimation of the total catch volume. This raising method differs from the German method where all sampled components are raised in relation to the total brown shrimp landings given by the skipper after each haul.

In the period of 2009 to 2012, 26 trips where conducted by the Netherlands and 24 by Germany. During these trips 167 hauls where sampled by each country in 44 and 47 days respectively. Results presented provide an indication of the catches throughout the year and throughout the German and the Dutch fishing areas. Because of low sampling coverage and large variation between hauls, discard numbers that are presented are not suitable to raise to entire fleet per year.

Overall the shrimp component of the catch, landings and discards, is larger than the fish and benthic component. In the Netherlands on average the amount of shrimp landed were about equal to the amount of shrimp discarded (55 kg/hr landed and 56 kg/hr discarded). In Germany the average amount of discarded shrimp exceeds the amount of landed shrimp (61kg/hr landed and 105kg/hr). For both countries most shrimp is caught in the fourth quarter of the year and catches are relatively low in the beginning of the fishing season (first quarter in the Netherlands and second quarter in Germany). Highest discard rates for shrimp in the Dutch sampling programme were observed in the fourth quarter of the year, whereas highest discard rates for Germany were observed in the third quarter of the year. By-catch composition was similar for both monitoring programmes. Most abundant fish species in the discard fraction is the goby which is present in 92% of the Dutch hauls and 95% of the German hauls. In following order; plaice, herring, whiting, dab and sole where among the most frequently caught commercial species. In Germany cod was also observed in 31% of the hauls while in the Netherlands cod is only observed in 4% of the hauls.

Future considerations for both monitoring programmes are:

1. We need to find profound methodologies to raise shrimp discard data to fleet level, for example by increasing the sampling coverage and/or by the introduction of a statistically sound sampling scheme.
2. Protocols on board need to be optimized. There is a need for a better estimation of different catch fractions.
3. Harmonized Dutch and German sampling programmes and methods.
In addition to this effort fish bycatch and catches of undersized shrimps were monitored during several commercial and scientific cruises within the German CRANNET project (see ToR k).

**Changes/ Edits/ Additions to ToR**

No changes.

**Cooperation with other WG**

None.

**Cooperation with Advisory structures**

None.

**Science Highlights**

None yet.

**j) Ongoing research**

**Progress by ToR**

**New fishing gears (Bart Verschueren)**

*Shrimp distribution and extension of the German Survey (Holger Haslob)*

The German Demersal Young Fish and Brown Shrimp Survey (DYFS) is conducted in the coastal areas of the German Bight and the German Wadden Sea since beginning of the 1970s. Until 2011 the survey was conducted exclusively with chartered commercial vessels. With the inclusion of the German research vessel “Clupea” into the DYFS in 2012 a better coverage of the German Bight coastal areas was achieved. In 2012 the station coverage of FRV “Clupea” was constrained to the central part of the German Bight due to restrictions in the available working time at sea (Figure 23). This problem was solved in 2013 and since then the station coverage was extended to cover the whole German coastline (24 and 25). Details about the German DYFS can be found in the reports of the ICES Working Group on Beam Trawl Surveys (ICES, 2012, 2013, 2014). The distribution pattern of brown shrimp in September 2012 shows the highest abundances in the area of the Southern coast of Schleswig-Holstein. Relatively low abundances were observed in the coastal areas of the German Bight. However, the highest observed abundance was observed on one station on the Amrum Bank (Figure 23). In 2013 higher abundances were recorded with a center of relatively high abundances in the central part of the investigation area. While the abundances along the East Frisian and the Northern part of the Schleswig Holstein coast were low, abundances in the Wadden Sea area were in general higher. A transect across the Amrum Bank during the survey in 2013 revealed only very low abundances. In 2014 the distribution was similar for all the different Wadden Sea areas (Figure 25). Again, very low abundances were observed along the East Frisian and the Northern part of the Schleswig Holstein coast.
The length distribution of brown shrimp for different areas showed in general a similar pattern with a peak between 43 and 47mm for all areas (Figure 26). In some cases a second mode was visible around 60mm.

References

Cultivation of grey shrimp (*Crangon crangon*) and the study of a *Crangon crangon* bacilliform virus (Benigna van Eydne)

The cultivation of *Crangon crangon* could form a promising alternative for the Belgian shrimp fishery, but from preliminary research it seems that the cultivation of this species is still difficult and optimization is needed. This PhD project will therefore focus on the development of an artificial diet. For the design of the diet we will focus on the attractiveness, the palatability and texture and the composition. Also the rearing conditions will be studied during this project in order to close the lifecycle of the grey shrimp in captivity.

Another part of this project will focus on the presence of a *Crangon crangon* bacilliform virus. This virus was discovered by Stentiford *et al.* in 2004 and from preliminary data it seems that this virus occurs with a prevalence of nearly 70–90%. With further research we want to record the prevalence of this virus across the North Sea, the Baltic Sea, The Mediterranean Sea, etc. In this part of the project we will also study the pathogenesis of the virus and the transmission. We will also study the potential to use RNA interference as a vaccine against the virus.

Changes/Edits/Additions to ToR
No changes.

Cooperation with other WG
None.

Cooperation with Advisory structures
None.

Science Highlights
See above.
k) Net selectivity and the influence of using different mesh width on the shrimp population

Progress by ToR

This ToR was added in 2013 and relates to the ongoing project CRANNET. Preliminary results were presented during the meeting, final results can be expected for the 2015 meeting. The general purpose of the project is to determine selectivity functions of different mesh types and mesh sizes to determine the impact on the population and to help reduce discard of undersized shrimps and unwanted bycatch.

Cooperation with other WG

None.

Cooperation with Advisory structures

None.

Science Highlights

Sebastian Schultz (Thünen-Institute of Seafisheries, Hamburg) reported on the results from the CRANNET project. During five scientific surveys in years 2013 and 2014 FRV „Solea“ completed 321 hauls. Selectivity parameters for 24 cod ends differing in mesh size and/or geometry were subsequently analysed. Furthermore, a total of ca. 760 000 Brown Shrimp were measured within the project.

Population dynamics modelling and calculated selectivity parameters revealed that three specific cod ends gave the most promising results with respect to ecological and economic sustainability. In detail, these cod ends had mesh openings of 26 mm with diamond (T0) or T90 meshes, or square meshes (T45) with 24 mm mesh openings. The three cod ends were tested on two similar, commercial shrimp trawlers during three field campaigns in June, August and September/October in 2014.

Results show that undersized Brown Shrimp (total length <50 mm) can be reduced by up to 80%, 67%, and 40% in June, August, and September/October, respectively, compared to the catches of the currently used standard cod ends with diamond meshes and 20 mm mesh openings. Marketable Brown Shrimp (total length >50 mm) were lost by 35%, 36%, and 22%, respectively, at the same time. However, the conducted field campaign represents the situation in the fishing fleet immediately after the introduction of one of the cod ends with larger and/or turned meshes. Further calculation of population dynamics clearly show, that losses in marketable Brown Shrimp shortly after the cod end’s change will come to an end 10–12 weeks later. Monthly landings then will reach the long-term average again and turn to subsequent and long-lasting surplus catches. Therefore, changing the cod end from the current standard to one of the new cod ends at end of April will result in monthly landings exceeding the annual mean already from the third quarter of the same year continuously.

Additionally, an average loss of 20% for fish by-catch (all registered species) can be observed when using one of the tested cod ends compared to today’s standard cod ends. However, losses for individual species, especially for round fish, occur by rates of up to 60% compared to the currently used standard cod ends.
Detailed results on the project CRANNET were published with the final report submitted by the end of June 2015.

6 Cooperation

- Cooperation with other WG
  - Cooperation with WGBEAM on improving survey designs to match with the requirements of the brown shrimp swept area biomass estimate and to derive correction factors for the use of different gears.
  - SMS predator abundance by age and year data were obtained from WGSAM.
  - SGELECTRA on pulse-gear developments, ongoing projects and research results.
  - Organization of the WKCCM in cooperation with WGCEPH. Delegates were invited from WKLIFE2, WGMG, WGMIXFISH and ACOM.

- Cooperation with Advisory structures
  - Crangon Advice, WKCCM, ADCRAN

- Cooperation with other IGOs

7 Summary of Working Group self-evaluation and conclusions

General recommendations and research needs

Fleet inventory

Analysis under ToR b revealed large differences in LPUE of vessels with comparable length and engine power. Furthermore the mortality increased although the number of vessels and hpdays before 2012 remained rather constant. This indicates that there is an unmonitored increase in cutter efficiency. To identify the main factors influencing landings per unit effort a fleet inventory that includes beside length, age and weight factors like deck equipment, gear type, hull design etc. is required. This is also the basis of any further effort management which cannot be done without such an inventory and an investigation how the different factors influenced efficiency (see also advice).

Standardize the on-land sieving process and reporting

So far the on-land sieving process is not standardized and different bar width are used depending on producer organization, market situation and season. Furthermore the used bar width and the fractions of the whole catch that ended in the different size categories are only partly recoded and reported. A standardization and a detailed standardized reporting of the different size fractions would greatly improve the information on growth, cohort size and seasonality of the population dynamics and could also be used in the Harvest Control Rule as stock indicator. The administrative effort is minimal as a part of these data is already recorded but not in a standardized manner.
Improving VMS monitoring

So far VMS pings are recorded every 2h despite whether the cutter is steaming or fishing. To improve data quality without increasing the ping frequency we recommend that one additional ping is sent when the fishing gear enters the water and when it leaves the water again. With these pings the spatial resolution of LPUR can be significantly increased.

Research needs

Several aspects concerning the brown shrimp population dynamics, the interaction with the fisheries, the ecosystem and the habitat and concerning technical issues remain uncertain. These include

1) The determination of survival rates of discarded shrimps and bycatch of invertebrates and vertebrates.
2) A statistical analysis of VMS and logbook derived lpue with standardized survey lpue to identify whether commercial data can be used to fill observation gaps.
3) The improvement of gear efficiency and the development of new methods to reduce bycatch of undersized shrimps and other species.
4) A detailed analysis on the factors influencing mortality of juvenile shrimps and zoea stages to determine what factors drive population size and whether habitat limitation exists.
5) The identification of the role of brown shrimps in and brown shrimp fisheries on the ecosystem including predator prey interactions, mixed fisheries aspects and multispecies interactions.
6) Ways to determine and understand the stock recruitment relation and density dependence. This includes the determination of suitable indicators to allow for short and intermediate term stock predictions.
7) Monitoring within long term studies the effects of the shrimp fisheries on benthos communities and the bottom in comparison to unfished areas.
# Annex 1: List of participants

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Annex 2: Recommendations

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<td>1. Fleet inventory</td>
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<td>2. Standardize the on-land sieving process and reporting</td>
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</table>

**Fleet inventory**

Analysis under ToR b revealed large differences in LPUE of vessels with comparable length and engine power. Furthermore the mortality increased although the number of vessels and hpdays before 2012 remained rather constant. This indicates that there is an unmonitored increase in cutter efficiency. To identify the main factors influencing landings per unit effort a fleet inventory that includes beside length, age and weight factors like deck equipment, gear type, hull design etc. is required. This is also the basis of any further effort management which cannot be done without such an inventory and an investigation how the different factors influenced efficiency (see also advice).

**Standardize the on-land sieving process and reporting**

So far the on land sieving process is not standardized and different bar width are used depending on producer organization, market situation and season. Furthermore the used bar width and the fractions of the whole catch that ended in the different size categories are only partly recoded and reported. A standardization and a detailed standardized reporting of the different size fractions would greatly improve the information on growth, cohort size and seasonality of the population dynamics and could also be used in the Harvest Control Rule as stock indicator. The administrative effort is minimal as a part of these data is already recorded but not in a standardized manner.
Annex 3: WGCRAN terms of reference

Draft Terms of Reference a) – i) for 2016 to 2018

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 bycatch/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)

Working group meeting draft resolution for multi-annual ToRs (Category 2)

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

<table>
<thead>
<tr>
<th>MEETING DATES</th>
<th>VENUE</th>
<th>REPORTING DETAILS</th>
<th>COMMENTS (CHANGE IN CHAIR, ETC.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 2016</td>
<td>June (TBA) Ijmuiden, Netherlands</td>
<td>Interim report by 1 August to SSGEPD</td>
<td></td>
</tr>
<tr>
<td>Year 2017</td>
<td>Interim report by Date Month to SSGXXX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2018</td>
<td>Final report by Date Month to SSGXXX</td>
<td></td>
<td></td>
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</tbody>
</table>

ToR descriptors

<table>
<thead>
<tr>
<th>ToR</th>
<th>Description</th>
<th>Background</th>
<th>Science Plan topics addressed</th>
<th>Duration</th>
<th>Expected Deliverables</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Evaluation of the stock status.</td>
<td>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.</td>
<td>141, 143, 131, 134, 161, 162, 212, 311, 321</td>
<td>year 1,2,3</td>
<td>A timeseries of standardize stock indicators shall be delivered by all WGCRAN members within each annual report.</td>
</tr>
<tr>
<td>b</td>
<td>VMS analysis</td>
<td>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.</td>
<td>133, 141, 143, 144, 146, 212, 311</td>
<td>year 1,2,3</td>
<td>Results shall be summarized in peer-reviewed paper.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>References</td>
<td>Year</td>
<td>Summary</td>
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<tr>
<td>c</td>
<td>Decision support tools</td>
<td>Develop brown shrimp specific management decision support tools to evaluate strategies on how to sustainable and efficiently harvest the brown shrimp stock</td>
<td>141, 145, 134, 311, 312, 334</td>
<td>1, 2, 3</td>
<td>Results shall be summarized in a peer-reviewed paper.</td>
</tr>
<tr>
<td>d</td>
<td>Effects of new gears</td>
<td>Analyze and enumerate the effects of new gears (e.g. pulsetrawl, combined pulsetrawl 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</td>
<td>141, 134, 213, 214</td>
<td>1, 2, 3</td>
<td>Results shall be summarized in a peer-reviewed paper.</td>
</tr>
<tr>
<td>e</td>
<td>Possible methods to assess and manage the brown shrimp fisheries</td>
<td>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 asheore sieving fractions and processes and new national bycatch/discards data from e.g. DCF</td>
<td>161, 162, 141, 143, 212, 214, 215, 311</td>
<td>1, 2, 3</td>
<td>Results shall be summarized in a peer-reviewed paper.</td>
</tr>
<tr>
<td>f</td>
<td>Infections and diseases</td>
<td>Analyzing infection levels with bacilliform viruses and/or the occurrence of other diseases and determining the potential effects they might have on the population.</td>
<td>141, 145, 146, 134, 131, 212, 311</td>
<td>1, 2, 3</td>
<td>Results shall be summarized in a peer-reviewed paper.</td>
</tr>
<tr>
<td>g</td>
<td>Aquaculture aspects</td>
<td>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</td>
<td></td>
<td>1, 2, 3</td>
<td>Results shall be summarized in a peer-reviewed paper.</td>
</tr>
<tr>
<td>h</td>
<td>Harmonize German and Dutch surveys</td>
<td>Optimize and harmonize German and Dutch surveys to improve comparability, to analyze spatio-temporal trends of stock indicators (biomass, distribution, mortality, etc.) and to ground-truth VMS derived</td>
<td></td>
<td>1, 2, 3</td>
<td>Results shall be summarized in a peer-reviewed paper.</td>
</tr>
</tbody>
</table>
### Summary of the Work Plan

<table>
<thead>
<tr>
<th>Year</th>
<th>Stock status indicators (ToR a) shall be updated and harmonized between countries.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>Data for Manuscripts related to ToR b-d and f-g shall be available.</td>
</tr>
<tr>
<td></td>
<td>New hauls to be included in the analysis under ToR h shall be available.</td>
</tr>
<tr>
<td></td>
<td>New information from ToR I shall be reported.</td>
</tr>
<tr>
<td>Year 2</td>
<td>Stock status indicators (ToR a) shall be updated and harmonized between countries.</td>
</tr>
<tr>
<td></td>
<td>Data for Manuscripts related to ToR b-d and f-g shall be analyzed.</td>
</tr>
<tr>
<td></td>
<td>New hauls to be included in the analysis under ToR h shall be available.</td>
</tr>
<tr>
<td></td>
<td>New information from ToR I shall be reported.</td>
</tr>
<tr>
<td>Year 3</td>
<td>Stock status indicators (ToR a) shall be updated and harmonized between countries.</td>
</tr>
<tr>
<td></td>
<td>Manuscripts related to ToR b-d and f-g shall be submitted.</td>
</tr>
<tr>
<td></td>
<td>New hauls to be included in the analysis under ToR h shall be available.</td>
</tr>
<tr>
<td></td>
<td>New information from ToR I shall be reported.</td>
</tr>
</tbody>
</table>

### 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.

**Resource requirements**

The research programmes which 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.
<table>
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<tr>
<th>Linkages to ACOM and groups under ACOM</th>
<th>WGCRAN aims at a permanent linkage with ACOM after year 2 when sound and proven stock indicators have been developed and a good management plan has been developed under ToR h.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linkages to other committees or groups</td>
<td>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.</td>
</tr>
<tr>
<td>Linkages to other organizations</td>
<td>CWSS = Common Wadden Sea Secretariat; TMAP = Trilateral Monitoring and Assessment Programme; RCM –NSEA</td>
</tr>
</tbody>
</table>
Annex 4: Copy of Working Group evaluation

1) Working Group name: Working Group on Crangon Fisheries and Life History (WGCRAN)

2) Year of appointment: 2013

3) Current Chair: Marc Hufnagl, Germany

4) Venues, dates and number of participants per meeting.
   3–7 June 2013, Copenhagen, Denmark (11 participants)
   6–9 May 2014, Hamburg, Germany (19 participants)
   18–20 May 2015, Ijmuiden, the Netherlands (16 participants)

WG Evaluation

5) If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution.

Goal 1 “Develop an integrated, interdisciplinary understanding of the structure, dynamics, and the resilience and response of marine ecosystems to change”

WGCRAN has identified key mechanisms of how brown shrimp fisherman, predators and top predators interact. The North Sea underwent changes in the past and in the Wadden Sea the number of potential shrimp predators (cod, whiting) decreased. The released predation pressure increased the shrimps available for the fisherman. Parallel to the decline in shrimp predators the number of top predators (seals and whales) increased which keeps the cod and whiting abundance in the coastal areas of the southern North Sea low. Thus the whiting and cod dominated system with low shrimp catches changed to a top predator dominated system with high landings.

Goal 2 “Understand the relationship between human activities and marine ecosystems, estimate pressures and impacts, and develop science-based, sustainable pathways” as well as goal 3 “Evaluate and advise on options for the sustainable use and protection of marine ecosystems.”

A strong focus of the group has been the development and evaluation of a management plan for a sustainable shrimp fishery. All three meetings and the WKCCM workshop finally led to a first advice including a roadmap on how to proceed to obtain a management plan to prevent from overfishing.

Bycatch data have been collected and analyzed to identify the impact of the brown shrimp fisheries on other ecosystem components. Furthermore is WGCRAN focussing on the development of new gears and strategies to reduce bycatch and bottom impact. For this purpose the pulsbeam in comparison to conventional gears and different mesh width and mesh designs have been investigated in several field campaigns.
Goal 4 “Promote the advancement of data and information services for science and advice needs”. Goal 5 Catalyse best practices in marine data management, and promote the ICES data nodes as a global resource

To be able to determine the stock status a large variety of different indices have been derived from international catch and effort data from national surveys and from combined VMS and logbook data. Efforts have been undertaken to standardize effort reporting by the different member countries and to determine correction factors for the different gears used in the different surveys. An evaluation of different VMS interpolation methods has been performed and in the future the combined VMS and lookbook data shall be compared to standardized surveys to be able to gain year round information on the spatial distribution and abundance of shrimp.

6) In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc. *

Stock-status indicators
1. see section 5

VMS, landings and effort data


Brown shrimp swept area biomass estimates
4. Manuscript for submission. Title: “Estimate of total annual brown shrimp Crangon crangon production in NW Europe based on a swept area estimate”. Tulp I., Siegel, V., Hufnagl, M. et al.

Predation rates of cod and whiting on brown shrimp.

Crangon crangon population model
7. **Report**: “Investigations into the robustness of the harvest control rule (HCR) suggested by the Dutch fishing industry for the MSC process”. Temming A., Schulte K., Hufnagl M.


**Pulse Trawl**


**Research on brown shrimp and life cycle dynamics in the ICES regions**


20. PhD-Thesis “Investigations into growth and nutritional condition of Crangon crangon (L.)” by Zaki Sharawy, University of Hamburg
23. Manuscript for submission: Season and body size affect behavioural thermoregulation of the common brown shrimp (Crangon crangon, L.). Reiser S., Temming A., Hufnagl M., Eckhardt A., Herrmann J.-P.

Possible methods to assess and manage the brown shrimp fisheries
28. Special request, Advice October 2014. Request from Germany and the Netherlands on the potential need for a management of brown shrimp (Crangon crangon) in the North Sea. ICES Advice 2014, Book 6

National bycatch/discards data from e.g. DCF and national projects

**Exchange of information on national legislation, laws and developments selectivity of different mesh openings and mesh types**


7) **Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.**

WGCRAN together with WGCEPH has initiated the WKCCM workshop to identify if a management of the brown shrimp fishery is needed and what kind of management would be suitable. The workshop was followed by and advice drafting group which formulated an advice published 30 October 2014: “ICES advises on the benefits of a potential shrimp management system”. The following was concluded:

“A decline in predators coupled with an increase in fishing effort and efficiency has meant that landings of *Crangon crangon* (brown shrimp) have increased steadily since the 1970s.

Currently, the *C. crangon* fishery in the North Sea is largely unregulated. However, Germany and the Netherlands have requested that ICES provide advice on the potential need for a management of the *C. crangon* fishery in this area. The advice delivered today by ICES advice presents the pros and cons of implementing a management system for the brown shrimp fishery. Within this advice ICES has considered the role of *C. crangon* in the ecosystem and the food web, as well as the impact of this fishery on other species and fisheries.

There are indications that the increased fishing effort has led to growth overfishing of the target species. One consequence of this is that shrimp are being harvested at a suboptimal average size. Implementing a sustainable management system should include the avoidance of this growth overfishing. Further benefits include a potential increase in the sustainable yield, a decrease in costs associated with fishing, and a reduction of the environmental impacts of the fishery.

The main drawback of any management system is the creation of additional tasks for managers, control authorities, scientists, and most likely for the fishermen and their producers organisations.

ICES has suggested a 6-step roadmap to develop a Harvest Control Rule and to facilitate its possible implementation for management.

Because of the short life span of *C. crangon*, the proposed management system operates on a shorter time scale than the common annual interval and will require more data at a higher temporal resolution than presently available.”
8) **Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6).** For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies’ activities.

The project CRANNET funded by the EFF, German federal ministries and the fishing industry has been started from members of WGCRAN in relation to issues discussed during the meetings and the need to improve the sustainability of the fishery.

The results of different model simulations, mortality estimates and survey results as well as the ideas on how to manage the population and the basics of the ICES advice were presented at the NSAC meeting in 2015.

9) **Please indicate what difficulties, if any, have been encountered in achieving the workplan.**

It was not possible to standardize all reported efforts. Due to the short trip length of shrimpers it was decided to switch from horsepower days at sea to horsepower hours at sea. For all countries besides the Netherlands this data format is now available however due to difficulties with the data format and incomplete reporting the Dutch data could not be obtained.

**Future plans**

10) Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)

WGCRAN thinks that a continuation is required as the ICES advice strongly suggest the management need. So far a Harvest Control Rule has been identified as the best option. However, due to the reluctance of the governments the fisherman themselves within an MSC process are developing this option. Several analysis as well as a continuous evaluation of this method will be required to guarantee an effective management which at the moment can only be provided in an independent manner by WGCRAN.

The shrimp fishery ranks among the top 10 (concerning value) fisheries of the North Sea with more than 500 vessels involved. The fishery is hardly regulated and the bottom impact as well as the impact on bycatch species is not finally resolved. A combined evaluation of existing data, an independent discussion of project results and a link to international authorities is, due to a lack of international funding, at the moment only possible through WGCRAN.

11) If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.

No new WG s required and WGCRAN should be extended as is. The existing ToRs have been reformulated and adjusted and were included in the WGCRAN 2015 report.

12) What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?
13) Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific)
Annex 5: Figures

Figures from the report are given below.
Total Landings time series and percentages landed per country

Figure 1 Consumption shrimps landed by German vessels over the period 1987 to 2014 in t (primary y-axis) in European harbours. Red line and sec y-axis: Percentage of Dutch landings in relation to total landings (whole North Sea, all nations).

Figure 2 Consumption shrimps landed by Dutch vessels over the period 1987 to 2014 in t (primary y-axis) in European harbours. Red 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 2014 in t (primary y-axis) in European harbours. Red 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 2014 in t (primary y-axis) in European harbours. Red 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 2014 in t (primary y-axis). Since 2001 all landings of all Belgian ships landing in all harbours are included. Before only landings by Belgian ships in Belgian harbours. Red line: 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 2014 in t (primary y-axis). Solid black line indicates shrimps landed in ICES area IV and VIIId and the grey line total amount of shrimps landed by the whole French fleet (from North Sea and Atlantic). Red line indicates the percentage of French landings (area IV+VIIId) in relation to total (whole North Sea all nations) landings.
Figure 7 Upper panel landings of Crangon crangon from the North Sea [t]. Middle panel landings of Crangon crangon from the North Sea [t] by country. Insert pie chart landings in t per country for year 2014. Lower panel: contribution of single countries to the total amount of shrimps landed by all countries (Sea all nations) landings.
Consumption shrimps landed per month and country. Black line: long term average and standard deviation (whiskers), grey line: total landings per month for the year 2013, red line: total landings per month for the year 2014. For France only: light grey line all areas and black, dark grey and red line for ICES areas IV+VIId.
Figure 9
Decadal averages of landings per country. Black thick line 1970s, grey dashed line, black line with dots, 1990s, red line 2000s, green line mean since 2010.
Figure 10  Monthly effort in days at sea (leaving to returning to harbour) per country. Black lines and whiskers indicate the long term means and standard deviations for the nations. Grey lines indicate the effort for 2013 the red line the effort for 2014.
Figure 11  Monthly effort in horse power days at sea. Black line and whiskers indicate the long term mean and standard deviation for each nation. Grey line indicates the effort for 2013 and the red line the effort for 2014.
Figure 12 Monthly landings per unit effort in t per days at sea. Black line and whiskers indicate the long term mean and standard deviation for each nation. Grey line indicates the effort for 2013 and the red line the effort for 2014. UK and Dutch data are based on days at sea all others on hours at sea / 24
Monthly landings per unit effort in kg per horsepower days at sea. Black line and whiskers indicate the long term mean and standard deviation for each nation. Grey line indicates the effort for 2013 and the red line the effort for 2014.
Figure 14
Cumulative monthly total landings per nation. Upper panel all nations, lower panel only UK, France and Belgium

Figure 15
Cumulative monthly efforts per nation and month for 2014. Upper panel days at sea, lower panel horse power days at sea.
Figure 16 Cumulative efforts in horse-power days at sea per nation and year. Besides the Dutch data all based on hours at sea.

Figure 17 Cumulative efforts in days at sea per nation and year

Figure 18 Annual landings per unit effort per nation in kg per horse power days at sea. For the NL data are based on days at sea for all remaining countries based on hours at sea divided by 24.
Figure 19 Fraction of shrimps >60 mm (upper panel) and >70 mm (lower panel) estimated using different surveys (German Demersal Young Fish Survey: DYFS, Dutch Demersal Fish Survey DFS, German Bycatch Series from East Frisia and Büsum, Hufnagl et al. 2010). Data for 2013 are indicated by red rectangles (DFS) and blue triangles (DYFS).

Figure 20 Total annual exponential mortality rate \( Z [a^{-1}] \) estimated using length-based methods. The time series indicated by the bold line was calculated using the mean of four different surveys (German Demersal Young Fish Survey: DYFS, Dutch Demersal Fish Survey DFS, German Bycatch Series from East Frisia and Büsum). Four different methods were
Figure 21  Total number of active shrimpers by nation and year. Belgian data since 2004. UK 2013 and 2014, DK, 2012, 2013 and 2014, B 2008, 2009, 2012, 2014 not available thus numbers from the year before were used. Note in the lower graph the number of Dutch and German vessels is scaled along the secondary y-axis.
Natural and fishing mortality rates determined following Temming and Hufnagl 2014 using the new 2014 ICES WGSAM SMS key run to determine predator biomass and to estimate consumption of shrimps >50 mm by predators. A: Difference in estimated consumption of shrimps using the two different key runs. B: Ratio of shrimps consumed by predators and landings. C: using the consumption to landings ratio to split Z into F and M. D: determine F in relation to Fmax and F01 obtained from a Y/R model.
Figure 23  Distribution of brown shrimp in the German Wadden Sea and the German Bight in September 2012. Light blue: FRV Clupea, dark blue: chartered commercial vessels.

Figure 24  Distribution of brown shrimp in the German Wadden Sea and the German Bight in September 2013. Light blue: FRV Clupea, dark blue: chartered commercial vessels.
Figure 25  Distribution of brown shrimp in the German Wadden Sea and the German Bight in September 2014. Light blue: FRV Clupea, dark blue: chartered commercial vessels.

Figure 26  Brown Shrimp length frequency distributions for the different statistical areas of the German DYFS, September 2012. Upper three panels display the coastal areas (405, 406S and 406N), lower six panels display the Wadden Sea areas (409 – 414). For area definition see WGBEAM report 2014 (ICES, 2014).