ICES WGCRAN REPORT 2014

SCICOM Steering Group on Ecosystem Processes and Dynamics

ICES CM 2014/SSGEF:08

Ref. SCICOM, ACOM

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

6–8 May 2014

Hamburg, Germany

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Recommended format for purposes of citation:

ICES. 2014. Report of the Working Group on Crangon Fisheries and Life History (WGCRAN), 6-8 May 2014, Hamburg, Germany. ICES CM 2014/SSGEF:08. 40 pp.
https://doi.org/10.17895/ices.pub.8856

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Executive summary

The Working Group on *Crangon* Fisheries and Life History (WGCRAN) 2014 meeting was successfully held at the Thünen Institut in Hamburg, Germany, May 2014. Members from Germany, the Netherlands and DK joined the meeting. Representatives from UK, Belgium and France could not join the meeting but were represented via correspondence. Members of WGCRAN see the priority of this expert group in understanding the interactions between the brown shrimp population (structure and abundance) and human behaviour (mainly fishing effort) and between the shrimps and the environment (temperature, currents) as well as the ecosystem (trophic interactions). Stock status indicators like biomass estimates, interannual and seasonal changes in landings per unit effort, total mortality and shares of large shrimp in the surveys were discussed. Strong emphasis during this years' meeting was set on possibilities on how to manage the population and drafting an advice. A joint session with WGBEAM was included mainly discussing how to compare the different gears used in the German and Dutch demersal fish surveys.

Available stock parameters indicated an increase in Fishing pressure in comparison to the previous two years. This was derived from the increase in total effort and total mortality while landings remained on a level comparable to 2012. Total annual landings amounted to 34 685 t where the German fleet contributed 12 316 t, the Dutch 17 393 t, the Danish 2823 t, the Belgian 945 t, the UK 844 t and the French 227 t (area IV/VIId), respectively. Total mortality of shrimps >50 mm increased compared with 2012 (5.7 a^{-1}) and was about 6.3 a^{-1}. The share of shrimps > 60 mm in autumn decreased from 16 (2012) to 14% (2013). Both factors are influenced by natural variability and fishing pressure as well. Average annual biomass of shrimps > 50 mm and based on a preliminary swept-area estimate, was 4606 t resulting in a total annual production of 57 000 t (using $P = B \cdot Z$ and $Z = 6.3\ a^{-1}$).

The review of the WKCCM report was discussed during the meeting and comments are provided in the report. Concerning suitable management approaches it was further concluded that due to the short lifespan and the high seasonal dynamic of the stock a classical age based assessment is not applicable and that, as a first step, the harvest control rule (HCR) which is already tested by the fishing industry forms an appropriate starting point. The performance, suitability and applicability of this approach will be evaluated regularly through WGCRAN.

1 Administrative details

Working Group name

WORKING GROUP ON CRANGON FISHERIES AND LIFE HISTORY (WGCRAN)

Year of Appointment

2013

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

2

Chair(s)

Marc Hufnagl, Germany

Meeting venue

Hamburg, Germany

Meeting dates

6–8 May 2014

2 Terms of Reference a) – k)

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 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 behavior 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

Work Plan year 2 according to WGCRAN report 2012:

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 re-evaluated.

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

a) Time-series of landings, effort, lpue, mortality and fraction of large shrimps have been updated and are added in the Annex 4.

Related Publication:

Hufnagl M., Huebert. K, Temming A. How does seasonal variability of growth, recruitment, and mortality affect the performance of length-based mortality estimates in fisheries science? ICES JMS (2012) DOI: 10.1093/icesjms/fss163

b) Preparation of the publication in progress

c) Preparation of the publication in progress

d) Manuscript submitted to ICES Journal of Marine Science: "Overfishing of predators, climate and marine mammals conspire to challenge the paradigm of non-management of short lived shrimps." by Axel Temming and Marc Hufnagl

e) See ToR d and extended abstract Schulte et al. ICES Annual Science Conference 2013, Reykjavik. "Introduction of a cpue-based harvest control rule in the brown shrimp fishery. Applicability and sensitivity testing. ICES CM 2013/H:13"

f) *Publication*:

Maarten Soetaert, Annemie Decostere, Hans Polet, Bart Verschueren, Koen Chiers (2013) Electrotrawling: a promising alternative fishing technique. Fish and Fisheries, DOI: 10.1111/faf.12047

Report (in Dutch): Verschueren, B., Vanelslander, B., Polet, H., 2012. Verduurzaming vande Garnalenvisserijmet de Garnalenpuls:eindrapport. ILVO MEDEDELING nr 116

http://pure.ilvo.vlaanderen.be/portal/files/1000183/20121026_Eindrapport_Waddenfonds_Final.pdf

g) *Publication:*

Hufnagl M, Temming A, Pohlmann T (2014). The missing link: tidal-influenced activity a likely candidate to close the migration triangle in brown shrimp Crangon crangon (Crustacea, Decapoda). Fisheries Oceanography doi:10.1111/fog.12059

h) Workshop on the Necessity of *Crangon* and Cephalopod Management WKCCM was held in October 2013, the results are available as an ICES report.

i) Combined Dutch German publication on the DCF data in progress.

Publication of 1st results of the N2000 project (in Dutch):

Steenbergen, J., van der Hammen, T., Rasenberg, M., Tulp, I., 2013. Tussenrapportage onderzoek "Effecten van garnalenvisserij" – onderdeel bijvangst. IMARES Rapport C047/13 (in Dutch), 39p. (http://edepot.wur.nl/258202)

j) Results of ongoing work were presented during the meeting

k) Project started and data acquisition in progress

5 Progress report on ToRs and workplan

5.1 A) Population status indicators

Progress by ToR

Landing statistics

Landings and especially efforts have in the past been reported in different ways which made a comparison of the data and especially landings per unit effort (lpue) complicated. Additionally the general definition for "days at sea" as used by other ICES groups where days are defined as calendar day led to biased results when applied to the brown shrimp fleet as the majority of the trips of the fleets are less than a day. The general definitions counts each calendar day as: any continuous period of 24 hours (or part thereof) during which a vessel is present within an area and absent from port. Several short trips especially overnight will therefore generate an artificially high effort which has not really been the case. WGCRAN therefore switched to a reporting of efforts in "real" days at sea based on hours at sea divided by 24. German data are available for the period 2002 to 2012, Dutch and UK data are not available in this format so far, Danish and Belgian data are available since 2001, French data are available for 2009 to 2012. The Belgian landings reported in 2013 and 2012 for the years 2012 and 2011 referred to fresh weight which has in this report been corrected. The whole times series for 2001 to 2013 now refers to cooked shrimps weight landed by Belgian vessels in all European harbours.

Total North Sea wide landings, as well as landings and shares by nation in 2013 were comparable to 2012 (Figures 1–7) with a continuation of the slight increase in Dutch landing shares. Total landings from all nations were 34 685 t, with 50% landed by the Netherlands, 36% by Germany, 8% by Denmark, 2% by UK, 3% by Belgium and 1% by France.

Dutch and German seasonal landing patterns were generally comparable to the long term mean but slightly higher in autumn for the Dutch fleet (Figure 8). Danish landings peaked in October. Belgian and French seasonal landing patterns were comparable to the long term average. Decadal averages (Figure 9) show a general increase in the Dutch landings especially in autumn which was also observed for the Danish data, where the spring peak that existed also during the period 2000 to 2010, decreased recently (period 2010–2013).

Effort in days at sea (Figure 10) and horsepower days at sea (hp-das, Figure 11) showed a general increase of the effort in comparison to the previous years. Especially during summer the effort of the Dutch fleet increased in comparison to 2012 and also in comparison to the long term average. German effort was higher than the average but comparable to 2012. In the Netherlands the number of shrimpers increased from 186 (2012) to 214 (2013) which is most likely an increase in the number of larger vessels switching form the plaice fishery, but needs further validation. In Germany the number of active shrimpers increased from 207 to 212.

Dutch effort was not calculated based on hours at sea but on whole days on sea. Danish effort was lowest in February and March (<22 000 hp-das) and peaked in October (134 000 hp-das). In France and Denmark effort in spring were lower than the average in the UK mainly the autumn effort was reduced.

For all fleets lpue were lower than or comparable to the average lpue and also lower than 2012 (Figure 12, 13).

Total landings of all nations peaked in October (Figure 14) lowest landings were reported for February. Seasonal effort summed by all nations was comparably high between April and November and lower between December and March. (Figure 14-15). Total effort in days at sea was comparable to previous years for the German and Dutch fleet, however effort in hp-days at sea increased especially for the Dutch fleet and was 6 250 731 in contrast to 4 045 372 hp-das in 2012 (Figure 16).

Average annual lpue of all nations either decreased (FR, NL) or remained on the previous years' level.

Mortality

Mortality increased compared with 2012 (5.7 a^{-1}) and was 6.3 a^{-1} in 2013 (Figure 19). The share of large shrimps in the catches of the scientific surveys decreased to about 14% (>60 mm) and 1% (>70 mm), respectively which was below the average of the previous years.

Biomass/Production

See ToR c)

Changes/ Edits/ Additions to ToR

No changes.

Cooperation with other WG

Cooperation with WGBEAM on improving survey design 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

None.

Science Highlights

In 2012 there were more active shrimpers in the Dutch fleet which is reflected in the increase in days at sea and hp-das. Thereby the increase in hp-das was, on a relative scale, higher than the increase in das. Where Dutch effort (in das) increased by 12% the effort in hp-das increased by 55%. This shows that larger and more effective boats entered the fleet. Despite the strong increase in effort the Dutch landings increased only by 18%. Additionally an increase in total mortality by 0.6 a^{-1} was observed in 2012 and the fraction of large shrimps decreased. These findings combined indicate an increase in fishing pressure on the shrimp population.

5.2 B) Effort distribution based on VMS data

Progress by ToR

VMS data contain two-hourly pings, transmitting 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. Five different methods (raw pings, straight line and spline interpolation, the amplification method and ellipses) 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 analysis is finished and the publication in progress.

Applying the best method in combination with logbook and landings data 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.

Changes/ Edits/ Additions to ToR

No changes.

Cooperation with other WG

None.

Cooperation with Advisory structures

No cooperation.

Science Highlights

Will be presented as soon as the publication is available (likely final report year 3).

5.3 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 report 2012. Correction factors have now been included and verified and the latest data from the 2012 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 and the publication of the results is in progress.

Changes/ Edits/ Additions to ToR

No changes

Cooperation with other WG

Cooperation with WGBEAM (joint session during this years meeting) on identifying catchability differences between the German and the Dutch demersal fish surveys.

Cooperation with Advisory structures

No cooperation

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 about twice as high compared to than 2012. Average annual biomass of shrimps > 50 mm was 4606 t resulting in a total annual production of 57 000 t (using $P = B \cdot Z$ and $Z = 6.3\ a^{-1}$).The final production estimate and the average annual standing stock biomass of shrimps > 50 mm will be provided next year along with the time-series reaching back to 1970.

5.4 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 – 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 manuscript containing the method description and the F, M and Z estimates has been submitted to the ICES Journal of Marine Science and is currently under review.

Reference

Welleman HC, Daan N (2001) the dutch shrimp fisheries sustainable? Senckenbergia maritima 31(2): 321-328

Changes/ Edits/ Additions to ToR

No changes.

Cooperation with other WG

Assessment data were obtained from WGSAM.

Cooperation with Advisory structures

None.

Science Highlights

Will be presented as soon as the publication is available (likely final report year 3)

5.5 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 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 is included in the manuscript submitted to ICES JMS mentioned under ToR d.

References

Beverton RJH, Holt SJ (1957). On the Dynamics of Exploited Fish Populations, Fishery Investigations Series II Volume XIX, Ministry of Agriculture, Fisheries and Food.

Rückert C (2011). Die Entwicklung, Parametrisierung und Anwendung eines Simulationsmodells für die Nordseegarnele (*Crangon crangon*, L.) zur Beurteilung des Befischungszustandes, PhD Thesis, Univ. of Hamburg, Germany

Changes/ Edits/ Additions to ToR

No changes.

Cooperation with other WmG

None.

Cooperation with Advisory structures

None.

Science Highlights

Work in progress, parts of the results were presented on the ASC 2013 in Reykjavik.

5.6 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 electro trawls 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:

Given the increase of efficiency this gear (hoovercran 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 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. Furhtermore 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.

5.7 G) Life cycle dynamics comparison among ICES regions

Progress by ToR

Data acquisition ongoing. In the North Sea data on the spatial abundance and the vertical distribution of shrimp larvae have been collected and will be analysed as soon as the capacity and resources are available. Meanwhile a study on the migration of brown shrimp combining field, laboratory and modelling approaches has been published (Hufnagl et al., 2014). This study indicates 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.

References

Hufnagl M, Temming A, Pohlmann T (2014). The missing link: tidal-influenced activity a likely candidate to close the migration triangle in brown shrimp *Crangon crangon* (Crustacea, Decapoda). Fisheries Oceanography doi:10.1111/fog.12059.

Changes/ Edits/ Additions to ToR

No changes.

Cooperation with other WG

None.

Cooperation with Advisory structures

None.

Science Highlights

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.

5.8 H) Brown shrimp management

Progress by ToR

During this years' meeting one day was used to discuss applicable and suitable management strategies. Additionally an advice was drafted as requested by the German and Dutch government from ICES. The discussion was based on the outcomes of the Workshop on the necessity of a Crangon and Cephalopod management (WKCCM) which was held 2013 in Copenhagen.

The draft of the advice as well detailed comments dealing with the review of the WKCCM report through ACOM members was added as Annex 3.

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.

Science Highlights

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5.9 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 take 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 hope to get > 400 samples / year of the (composition of) discards in *Crangon* fisheries.

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 5 years of DCF-sampling will be used in this publication. The main outcomes will be included in the final WGCRAN report (2015).

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.

5.10 J) Ongoing research

Progress by ToR

1) Stefan Reiser presented results obtained from his PhD dealing with temperature effects and temperature preferences of brown shrimp. These data indicate that *C. crangon* at temperatures of 0°C becomes inactive which might have implications on the catchability of winter surveys. Additionally seasonal differences in the preferred temperature of shrimps exists which is throughout the year generally higher than the field temperature.
2) The attempt to perform a life cycle assessment of the shrimp fishery was presented by Aline Hock and Biniam Samuel Fitwi.
3) Updates of the ongoing project CRANNET were presented by Sebastian Schultz, Thomas Neudecker and Claudia Günther including i.) a method to measure shrimps automatically via image analysis ii.) preliminary selectivity parameters of different cod ends (see ToR. k). iii.) the implications of

the use of different selectivity functions on the population dynamics of brown shrimps as a result of the Y/R model (ToR E).

Changes/ Edits/ Additions to ToR

No changes.

Cooperation with other WG

None.

Cooperation with Advisory structures

None.

Science Highlights

See above.

5.11 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.

Changes/ Edits/ Additions to ToR

Added as a new ToR.

Cooperation with other WG

None.

Cooperation with Advisory structures

None.

Science Highlights

None yet.

6 Revisions to the work plan and justification

Work on all ToRs have progressed following the work plan.

7 Next meeting

The next meeting will be held on 18–22 May 2015 at IMARES, Ijmuiden, Netherlands.

Annex 1: List of participants

NAME	Institute	E-MAIL
Fitwi, Biniam Samuel	GMA	biniam@gma-buesum.de
Hock, Aline	GMA	alinehock@gmail.com
Hufnagl, Marc	IHF, Hamburg	marc.hufnagl@uni-hamburg.de
Jacobsen, Jonathan		jbj@dkfisk.dk
Limmer, Bente	TI Rostock	Bente.limmer@ti.bund.de
Neudecker, Thomas	Johann Heinrich von Thünen Institute	thomas.neudecker@ti.bund.de
Oberdörfer, Phillip		p.oberdoerffer@ezdk.de
Reiser, Stefan		stefan.reiser@uni-hamburg.de
Schoute, Barbara	ICES	barbara@ices.dk
Schulte, Katharina	Johann Heinrich von Thünen Institute	katharina.schulte@ti.bund.de
Schulze, Torsten	Thünen Institute	torsten.schulze@ti.bund.de
Siegel, Volker	Johann Heinrich von Thünen Institute	volker.siegel@ti.bund.de
Steenbergen, Josien	Imares, IJmuiden	
Temming, Axel	IHF, Hamburg	atemming@uni-hamburg.de
Tulp, Ingrid	Imares, IJmuiden	
By correspondence		
Firmin, Chris	CEFAS	chris.firmin@cefas.co.uk
Håkansson, Kirsten Birch	Danish Technical University	kih@aqua.dtu.dk
Nimmegeer, Sofie	ILVO	Sofie.Nimmegeers@ilvo.vlaanderen.be
Tetard, Alain	Ifremer	Alain.tetard@ifremer.nl

Annex 2: Recommendations

None.

Annex 3: Response to the reviewer comments (WKCCM report)

Review on the Crangon part of the Report of the Workshop on the Necessity for Crangon and Cephalopod Management (WKCCM), 8–9 October 2013, Copenhagen, Denmark

Terms of reference of the review:

ICES has received this request from Germany and the Netherlands:

ICES is requested to provide advice on the potential need for a management of brown shrimp (Crangon crangon) in the North Sea considering:

i. the pros and cons of a management on the long-term sustainability and yield of the C. crangon fishery

ii. the role of C. crangon in the ecosystem and foodweb - specifically if it was considered a low trophic level species;

iii. the impact of the C. crangon fishery on other commercially exploited fish stocks in relation to multispecies and mixed fisheries considerations;

ICES is also invited to provide information on potential management approaches if the analysis has demonstrated that a management is useful, along with a roadmap for development and implementation, and to indicate research needs and required stakeholder feedback to inform the process.

The WKCCM report was reviewed on the ecological and assessment methodologies by two different reviewers in order to inform the Crangon Working Group when preparing an advice draft.

Review by Axel Rossberg (CEFAS, concentrating on Sections 3.1 – 3.3.4)

The report makes a sound and convincing argument that the brown shrimp in the area of concern is at least growth overfished, and potentially also recruitment overfished. The latter one could expect from the reduction of the number of large adult spawners in the population.

The report implies this conclusion in the passage "and with potential increase in the medium or long term." in Conclusion #1 of 3.3.4.

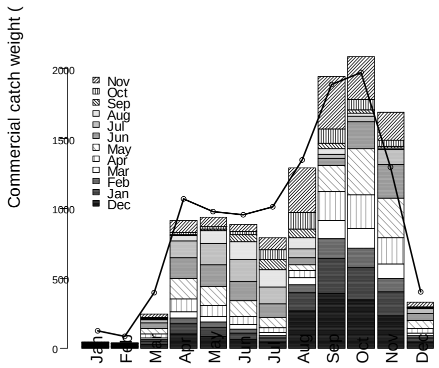
The importance of feeding interactions with other species is likely underestimated by the report. From the information provided, I would expect a notable rise in predation mortality when gadoids and other fish stocks rebuild. I also see the possibility that a drastic decline of the brown shrimp has been avoided so far only because predator abundance declined while fishing effort increased.

The report presents information on changes in fishing and predation mortality over the period 1970 – 2011. Especially Figure 7 shows the increase of F over time, which in combination with the smaller changes in total mortality (as shown in several previous reports of WGCRAN) leads to the conclusion that natural mortality (predation by cod and whiting) has gone dramatically down. The consequences of this are elaborated in Temming & Hufnagl (now submitted to ICES JMS) and have been condensed into Fig. 7 of the WKCCM report. Hence, the feeding interactions are not underestimated but rather fully taken into account. However, this could have been presented more clearly in the WKCCM report. The reviewer is correct in expecting a decrease of commercial landings in case of rebuilding stocks of cod and whiting. A rough estimate can be derived from the time series of landings, where on average 20 000t (instead of 30 000t) were landed in times of high gadoid stocks and predation. We are currently using our simulation model, to better quantify the predation impact of rebuilding predator stocks on commercial landings.

In the following, I walk through the text section by section.

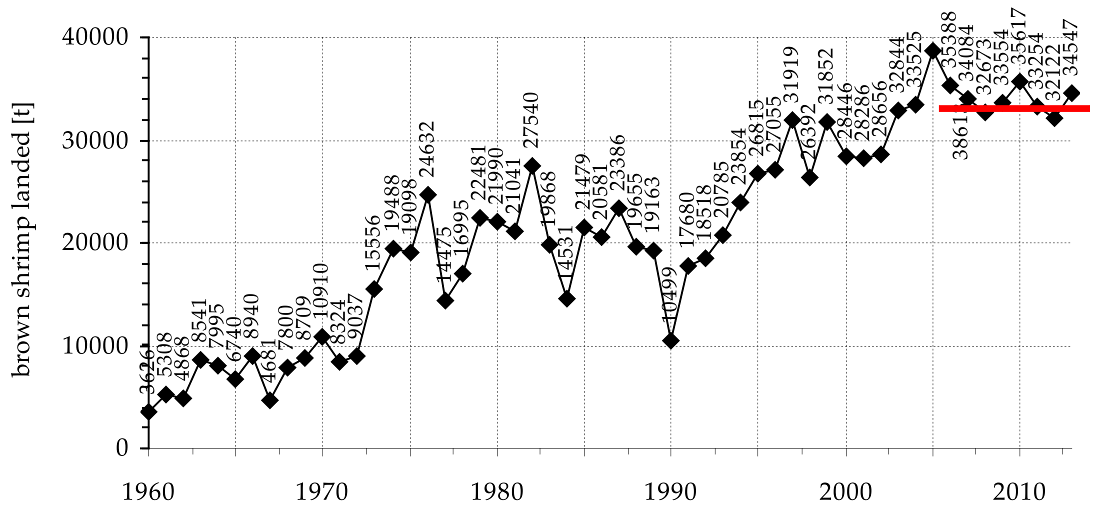
3.1.1 (summary): The unaccounted whereabouts of the summer cohort seems to be a major knowledge gap to me. If egg production in summer is of minor importance to the stock, why do the crabs then produce eggs in summer at all, rather then investing into growth? The knowledge gap could lead to biases in stock assessments if not closed.

The group agrees with the reviewer, that the whereabouts of the summer cohort are important and that there is at the moment still a knowledge gap with regard to the number of successive spawnings of female shrimp in summer and the actual seasonal differences in natural mortality of larvae and juveniles. According to the results of the simulation model the summer egg production is not responsible for the main peak of catch in autumn, but is also clearly not "wasted". It contributes to the spawning stock between late winter and spring/summer and is contributing also to landings in these months. The interlocking of the two seasonal cohorts may even be stronger, depending on the amount of variability in growth. The graph below shows the monthly contribution of each spawning month to the seasonal landings pattern as output from the yield per recruit model (Günther et al. in preparation). The black line indicates the mean monthly observed landings pattern.



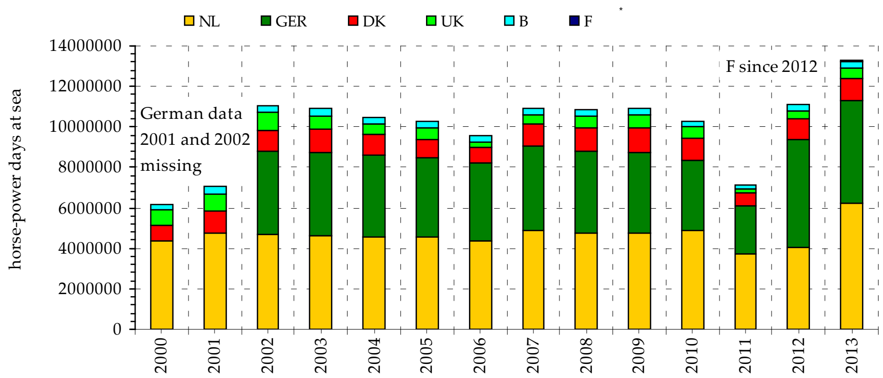
3.1.2: (Fig 1) There seems to be a gradual decline in landings since the 2005 peak, despite apparent effort creep. This could indicate that the point of recruitment overfishing has been reached. The evidence is not strong, but risk is high, which is why I would have expected more attention to this point in the report.

If the year 2005 is excluded, no such trend in landings is really visible when including latest ladings data. It rather seems that the landings have stabilized on a high level since 2002 (see figure below).

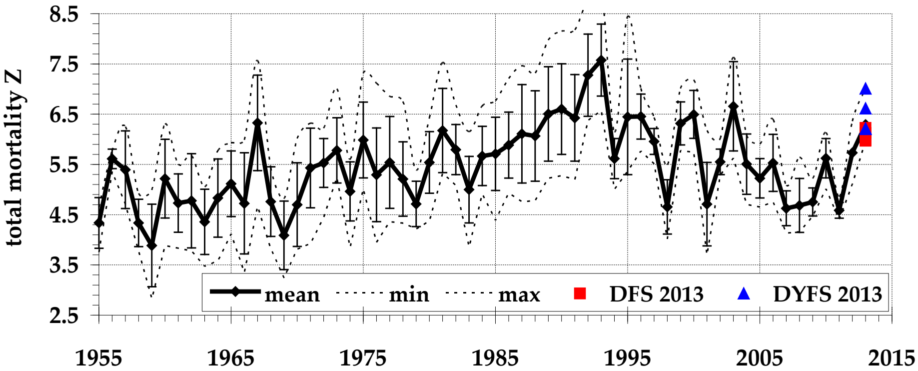


Total landings of brown shrimp from the North Sea by all nations (source WGCRAN)

However, especially since 2011 there has been an increase in the effort and in total mortality as shown below.

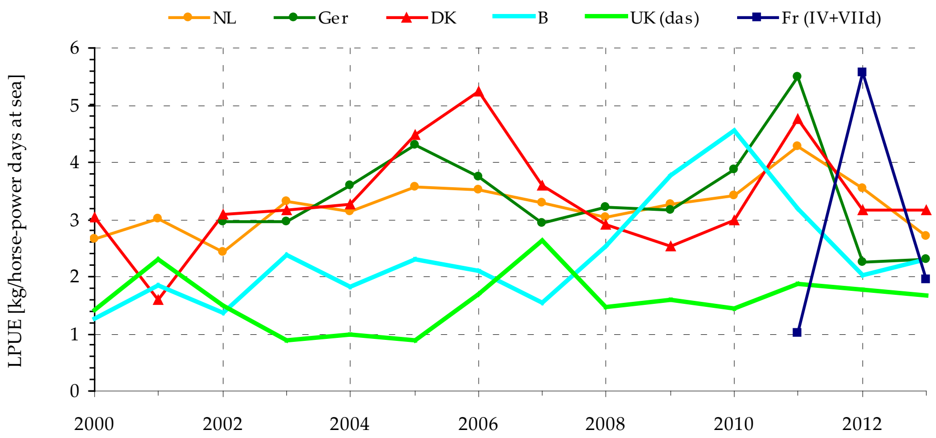


Total effort of all nations (source: WGCRAN)



Total mortality rate of brown shrimp in the North Sea based on the German demersal young fish survey (DYFS) and the Dutch Demersal Fish Survey (DFS) for the period 1997 until 2013. Years before 1997 also include the German bycatch series data. Caluclations were determined using length-based methods (see Hufnagl et al. 2010 for details)

Since this effort increase is largely referring to the Dutch fleet, some precaution must be added, since this data series suffers from internal inconsistencies with regard to the calculation of fishing time and the earlier part of the data refer to a reference fleet that was chosen on economic purposes and thus does not cover the whole fleet. The combination of both indicators resulted in an overall decline in lpue and thus indeed a sign of recruitment- or growth overfishing.



lpue by nation for the period 2000 to 2013 (source WGCRAN)

3.1.3: Evidence is presented that, at least historically, the stock size quickly rebounds from perturbations (within a year). Based on this one can conclude that the stock should withstand exploitation rates of the order of magnitude of 1 per year. (In the logistic model, the rate of rebounding to equilibrium and the exploitation rate are equal when MSY has been reached.) I do NOT see how this observation would justify the conclusion that the stock is bottom-up controlled.

We agree that the statement about bottom up control is misleading. Clearly the recruitment to the adult population (>50 mm) is largely determined by predation (hence top down), as was demonstrated by the break down of commercial catches in 1990/91, when the incoming cohort was largely absorbed by a 0-group whiting growing along with the cohort of juvenile shrimp. One might speculate, that the recruitment of the smallest juveniles is more stable and possibly habitat limited, but in the absence of a monitoring for this size class no hard conclusion is possible.

There could also be top-down control by predators of larvae, juveniles, or adults (see the fast and sensitive response to changes in fishing mortality in Fig 4).

Agreed

The statement that "the systems carrying capacity is the limiting factor" strikes me as tautological.

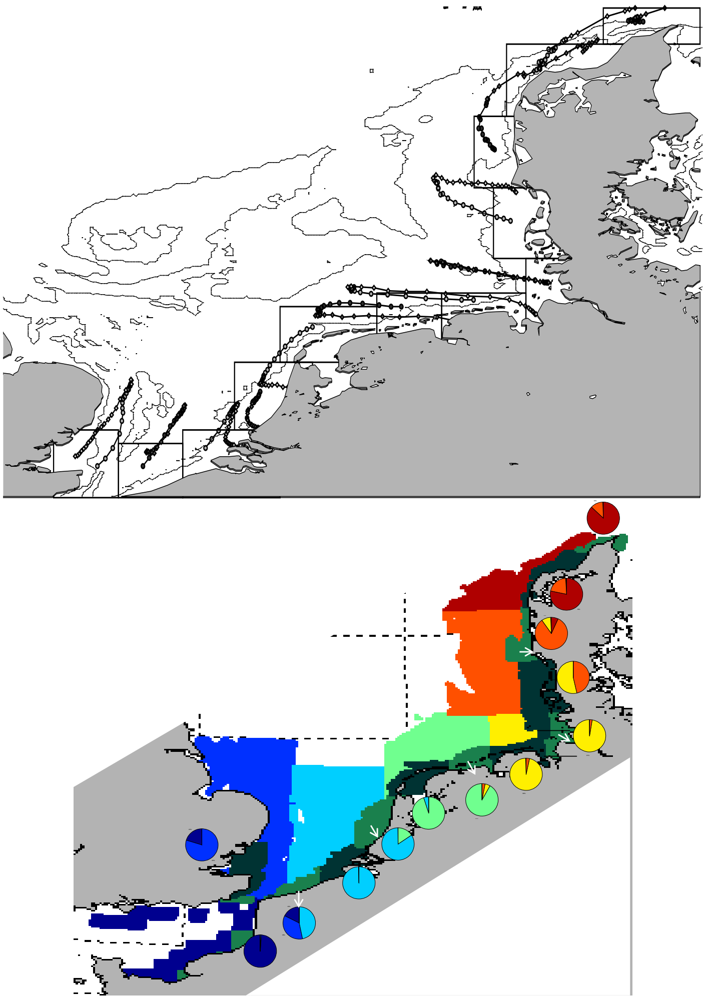
Agreed

I do not understand the entire paragraph before "In summary", except that it says that an S/R relation is difficult to identify. The reason for this might among others could be changes in the abundance of predators of early life stages.

The summary seems to confound density-independent processes that drive a population and density-dependent processes that regulate it.

In response to the comments the paragraph 3.1.3 is rewritten:

Genetic studies have not indicated genetic differentiation within the North Sea *C. crangon* population (Luttikhuizen et al., 2008) and also connectivity studies based on larval drift suggest substantial interconnections of regions although there might be a separation line between the East Frisian and the North Frisian population (see below). However, the whole North Sea population should, with respect to management, be considered as one stock.



The left graph shows the migration pattern of an adult shrimp that moves to deeper areas using ebb tide transport (circles) and the transport routes of a larval (passive) and juvenile (flood tide transport) shrimp (diamonds). Those that start west of the Elbe remain west of the Elbe, those in the north remain in the north. The left shows average positions of a multitude of drifters started within the black rectangles (see Hufnagl et al. 2014 for details). The right graph shows connectivity from the spawning areas (colored areas) to the coastal nurseries for the larval, passive drifting, shrimp stages. Mixing between areas is possible and takes place.

Habitat limitations or bottom–up factors as main population driver have been suggested in some studies (Kuipers and Dapper, 1981; Henderson et al., 2006). Evidence is presented that, at least historically, the stock size quickly rebounds from perturbations (within a year). Based on this one can conclude that the stock should withstand exploitation rates of the order of magnitude of 1 per year. The assumption that the stock is only bottom up controlled might however be questionable. As also explained in 3.3 of the report, a large variety of species feed in *C. crangon* in the North Sea and thus top down control of the species should be taken into account as well. In 1990, a mass invasion of O-group whiting (*Merlangius merlangus*) reduced *C. crangon* numbers to almost zero. Similar events were observed in 1959 (whiting), 1970 (cod, *Gadus morhua*), and 1983 (cod and whiting) (Berghahn, 1996).

This lowest observed stock in 1990 was however able to rebuild itself within less than two years. Analysis of monthly landings per unit of effort (lpue) and autumn survey data indicate only a weak and short-term relationship (ICES WGCRAN report 2012). However, a real stock recruitment relation analysis was so far not possible as a recruitment index is not available. The main scientific surveys (the Dutch Demersal Fish Survey and the German Demersal Young fish survey) are conducted in autumn during the peak in adult abundance; however, this period coincides with the lowest fraction of egg-carrying females but not with the important egg-carrying period in winter. Additionally larval abundance in spring and summer is not monitored regularly and on a large scale. Thus a sound stock-recruitment analysis needs to be performed in future using appropriate methods and surveys. In a first analysis of single years only poor stock-recruit relationships were found. If the outcome of a final analysis would underline that this is typical for *C. crangon* (no real relation and a massive surplus production of recruits), the possibility of recruitment overfishing would be reduced. However, there are indications for growth overfishing (Section 3.3.3) and a reduced stock can be expected as soon as the number of produced recruits falls below the carrying capacity of the system.

In summary: The North Sea population is well mixed and should be treated as one stock. There are indications that there is a surplus production of recruits that fuels the adult population and their survival is influenced by the carrying capacity. However, top-down control of the stock and especially of the juvenile shrimps needs to be taken into account. So far it seems that there is a weak stock-recruitment relationship, however classical stock–recruitment analysis is based on the available data not possible.

3.2:

From the report on available data, it is unclear which of these data have been used for the subsequent analyses, and which not.
Below we added the table and marked the data used so far in green and those where analysis are in progress in yellow

	CRANGON CRANGON	*Crangon crangon* IVb,c (North Sea, UK, Denmark, Germany, Netherlands, Belgium, France; inshore areas)
Current data	Captures	Monthly landings are for all nations available for more than 25 years (besides France: 12 years). Larger vessels are equipped with a vessel monitoring system (VMS) and electronic logbooks are soon mandatory for the whole fleet. So far landings and effort data are reported to WGCRAN via the delegates from the different nations, however not all data are made available or are available to the delegates.
	Effort	Monthly effort data are available for at least 10 years but not all nations report in the same format (some days at sea, some hours outside the harbour) but effort is undertaken to standardize all series to hours outside the harbour. This standardization step is an ongoing process since several years but is complicated due to problems with manpower, responsibility and data availability.
	Discards/Bycatch	Bycatch and discards mainly consist of undersized shrimps, juvenile flatfish and smaller or juvenile demersal fish. Undersized shrimps discarded after the first sieving and before the cooking have a high chance of surviving whereas fish discards are mainly dead. Bycatch is monitored regularly by observers but trips are very limited (approx .1:2000).

	Market sampling and sampling aboard	Shrimp sizes are monitored during some observer trips. Data on landings and selling price are reported. Sieving sizes and price per size fraction are not standardized and are not available. In Belgium and France, larger fractions of the catch are sold directly and are therefore not monitored and recorded during the auctions.
	Survey	Ongoing surveys are conducted in autumn and are the German Demersal Young Fish Survey (DYFS; since 1974) and the Dutch Demersal Fish Survey (DFS; 1970). In the past monthly data from commercial catches have been monitored in the German Bycatch series. Additionally a winter and a spring survey have been conducted irregularly in the past but have now been stopped.

3.3.1:

The question of resource competition with other species is touched in this section: "According to the high variety of food sources, food niche overlaps with other species are present but generally low (Feller, 2006; Pihl, 1985)" However, dietary diversity is not a good predictor of the strength of competition. With diverse diets, you can compete a bit with many species, with narrow diets you may compete a lot with one or a few other species. Absent any other evidence, I would assume that competitive interactions are, as typical for food webs, highly indirect and unpredictable, but certainly not negligible.

The analysis of the question if the brown shrimp plays an important role in the food web based on the LTL criteria (or the wasp-waist concept) strikes me as unnecessarily indirect, and so inaccurate. If there is an EwE model of the North Sea available that contains the brown shrimp (even as part of a larger compartment), analyses of the immediate response of predators of brown shrimp to changes in its abundance (and reverse) based on EwE could be more reliable, despite the known limitations of such models.

The summary of the section, however, does seem to take the limitations of the MSC method adequately into account.

The role of *C. crangon* in the foodweb from the Ecopath model has been analysed:

Mackinson & Daskalov (2007) have set up an ECOPATH model for the North Sea that considered shrimp as a functional group, consisting of a total of 30 species. Among these *Pandalus borealis* and *C. crangon* are assumed to be the most important, representing 64% of the biomass. However, in their data, the common relative *Crangon allmanni* is not mentioned at all, even though this species has a wider distribution in deep waters. According to the model output the shrimp group is responsible as food for predators with a total of 0.6 $t{\cdot}km^{-2}{\cdot}y^{-1}$. If 64% of this refers to *P. borealis* and *C. crangon* and for simplicity this is split in half between the two species, *C. crangon* accounts for approx. 0.2 $t{\cdot}km^{-2}{\cdot}y^{-1}$. Most of this consumption refers to small shrimp (see section below). This value can be compared with the following list of consumed food: small infauna (polychaetes) 122.6 $t{\cdot}km^{-2}{\cdot}y^{-1}$, small mobile epifauna 53.8 $t{\cdot}km^{-2}{\cdot}y^{-1}$, epifauna macrobenthos 13.1 $t{\cdot}km^{-2}{\cdot}y^{-1}$. Since energy is likewise channeled through small fish to higher trophic levels, for comparison a figure can be calculated of 7.8 $t{\cdot}km^{-2}{\cdot}y^{-1}$, representing the combined consumption of Sandeel, Norway Pout, Sprat, juvenile

Herring, juvenile Whiting, juvenile Haddock, other small gadoids and small demersal fish.

According to a study by Baird et al (2004) in the Sylt Rømø Bight the role of *C. crangon* in the Wadden Sea ecosystem energy flow is likewise limited. Most of the benthic production refers to macrobenthic species such as *Cerastodema edule*: 56.8 mg $C \cdot m^{-2} \cdot d^{-1}$, *Arenicola marina*: 42.3 mg $C \cdot m^{-2} \cdot d^{-1}$, *Macoma balthica*: 21.9 mg $C \cdot m^{-2} \cdot d^{-1}$, *Hydrobia ulvae*: 7.4 mg $C \cdot m^{-2} \cdot d^{-1}$ or *Nephthys spp*.: 5.3 mg $C \cdot m^{-2} \cdot d^{-1}$, compared to C. crangon with 0.3 $C \cdot m^{-2} \cdot d^{-1}$. A third of the *C. crangon* production is consumed by small fish, birds and *Carcinus maenas*, with gobies being the most important predator. This amount of consumption refers largely to the data situation of 1992 and 1993, when most fish data for this study were collected.

From these comparisons it becomes obvious that shrimp is not a wasp waist species, nor does a major flow of energy to higher trophic levels depend on this species.

3.3.2:

Citing the 1990 episode, the report argues that a recovery of the gadoids stocks could have a substantial impact on the shrimp fishery. This conclusion is convincing. The conclusion drawn in this section that the reverse effect (dependence of gadoids on the brown shrimp as food) is negligible is hard to reconcile with the conclusion draw in 3.3.1 that

This conclusion is in general based on the idea that growth overfishing of *C. crangon* will not impair the recruitment. Hence predators, which mostly rely on undersized shrimp, will be able to take their share of small shrimp not selected by the gear. If however, recruitment overfishing occurs, predators will be influenced negatively.

"Because *C. crangon* is not distributed homogeneously over the North Sea, but can occur in aggregations of high biomass (patchy distribution), it can seasonally form a substantial proportion of the diet of a wide range of predators in certain regions of the North Sea. Therefore, although on average *C. crangon* may not represent the vast majority of any predators' diet, predators may still depend seasonally and regionally on *C. crangon* for their survival."

The point here is that both key predators, cod and whiting, have a pan North Sea distribution, while *C. crangon* occurs only in a restricted part of the North Sea. Locally the effects may be more pronounced.

Besides, it is not only starvation mortality that is of concern, but also insufficient growth of predators (especially as stocks rebuild and so competition for food increases). In this context, changes in the availability of brown shrimp could make a difference, even if the contribution to the diet, at some time in the past, was only 14%.

It has been shown in food preference and growth studies, that both cod and whiting actively select gobies over brown shrimp and that their growth performance is almost twice as high on a goby diet compared to a *C. crangon* diet (Temming 1995, Jansen 2002). It is however true, that especially juvenile whiting in the SE North Sea can have very high shares of C. crangon in their diets

Mixed fisheries considerations

The argument for including *C. crangon* in mixed fishery considerations, based on plaice bycatch, is convincing.

Multispecies considerations

Here, two additional arguments are presented that the shrimp fishery has little effect on gadoid recovery.

The first argument is that gadoids are "a.) more efficient than the shrimp fisheries". The argument is not clear to me. All that matters for the gadoids is shrimp abundance. If, e.g. shrimp abundance increases as a result of stock management, then there are also more shrimps for gadoids to eat.

This conclusion is in again based on the idea that growth overfishing of C. *crangon* will not impair the recruitment. Hence predators, which mostly rely on undersized shrimp, will be able to take their share of small shrimp not selected by the gear. In this sense they are more "efficient" as they rather control what is left to recruit into the fishery than vice versa. If however, recruitment overfishing occurs, predators will be influenced negatively.

The second argument is that gadoids are considered "b.) to target to a large extend also undersized, not commercially used, juvenile shrimp."

The argument is based on a conceptual model, common in fisheries management, that recruitment is independent of SSB as long as SSB is not too low. However, one has to ask what the reason for this apparent constancy is. Usually, this is considered to be density-dependent predation of pre-recruit life stages. But this means that if there are fewer adults and so fewer eggs produced, then the number of recruits remains approximately unaffected BECAUSE fewer pre-recruits are eaten. This means that fishing of adults shrimp WILL affect availability of prey to predators of juvenile shrimp.

The point is valid, but it is not known at which life stage the regulation occurs. It is also possible that the regulation takes place in the pelagic life stage (larvae). In that case there would be no effect on the predators of juvenile shrimp. Due to a lack of diet data it is unclear, which predators might actually suffer in case of regulation at the larval stage.

3.3.3:

I can largely follow the argument and find it convincing, but asked myself the following questions:

In Fig 4, how can the reduction in effort in early April lead to a much higher lpue already in early April (without any delay!). Have alternative explanations for the outcome of the analysis been sufficiently considered? For example, as fishers reduce effort, they could spend a larger proportion of the short time on sea in richer fishing grounds, and so increase their lpue (without stock dynamics).

The criticism of the reviewer is accepted. In the period after the strike the fishermen where only allowed to fish a certain amount of shrimp and fished only 2/3 day per week. This combination of regulation of the fisheries at that time partly explains the high LPUEs after the strike. An additional effect may be a migratory pattern of high shrimp stocks back into coastal waters occurring at the same time.

The analysis based on the model in Fig 6, 7 was the stronger argument to me (for the same conclusion).

In the section with heading "Swept-area based biomass and production estimate", I was confused about the statement: "In these low production years annual catches about equal the total annual production of adult shrimp biomass." Considering that whiting was probably also eating a large part of this production, do the numbers really add up?

In most years there is plenty of production to account for predation plus landings. It should be kept in mind that the production estimates are influenced by a large number of uncertainties related with either the total mortality- or of the swept area biomass estimate. Total mortality depends on the correctness of the growth parameters, which are highly uncertain and variable, as well as on the representativeness of the length composition data, which are mostly obtained from a single season. Likewise the biomass estimate refers to a single season, does not cover all parts of the distribution area and is strongly dependent on the assumptions about catchability of the gear. Comparison of the different indices have been calculated in the past based on the assumption that Catch/Biomass equal F and consumption by predators/Biomass equals M. The sum of both values should than equal total mortality Z as Z = F + M. This Z estimate was in the same order of magnitude than the Z determined with the length based methods and showed similar trends. However, also this comparison is not completely independent as the biomass estimate is based on the same survey data which are used for the length-based estimate.

Review by Henrik Sparholt (ICES, concentrating on Sections 3.3.4 – 3.5)

Generally, the report is sound in its presentation of data and information. It also makes sound conclusions. I agree with the overall conclusion that management on long-term sustainability and yield of the *Crangon* fishery is needed, because it seems to be possible to do and because the stock (or stocks) is likely to be overexploited. Technical regulations alone, without following the stock (or stocks) development closely is too risky. An effort or TAC regulation is needed and while the WKCCM argue for an effort one I tend to think that the general experience in fisheries management in the North Atlantic area is that at least it should be combined with a TAC system.

I have in the following focused on areas where I am uncertain or disagreeing with the report.

It is stated in section 3.1.3 that: "Genetic studies have not indicated genetic differentiation within the North Sea *C. crangon* population (Luttikhuizen *et al.*, 2008) and also connectivity studies based on larval drift suggest substantial interconnections of regions although there might be a separation line between the East Frisian and the North Frisian population (Hufnagl, unpublished). However, the whole North Sea population should, with respect to management, be considered as one stock."

Maybe the conclusion should rather be two stocks then to be on the safe side.

The drift model results are in our opinion too weak to justify a stock separation. Also the drift studies indicate a constant influx of larvae from SW areas into SE and E areas. Genetic studies have given convincing evidence to consider the North Sea population as one stock for management. For management of the fisheries spatial differences could be taken into account, for example for protecting a certain type of habitat. Also Seasonal patterns in this fishery (following shrimp stocks) are more important. It should also be discussed at a later state how to react in a management plan if there are strong seasonal differences in lpue e.g. should in Denmark the fishery be closed if close to the coasts of Belgium lpue is low but in Denmark not.

It is stated in section 3.2 that: "Comparisons of the survey station grids with VMS data further indicated that the surveys do not target the whole distribution area of the shrimps. The DYFS is mainly conducted in the tidal creeks and the DFS grid is covering deeper areas but VMS data show that fishing takes place even further offshore."

Maybe survey and commercial cpue/VMS data can be combined to correct for the survey index for not covering the entire distribution area.

Agreed and will be included in the roadmap for management. At the moment the relation between VMS and surveys is still a knowledge gap. However, there is an ongoing analysis of the combined VMS and log book data by members of WGCRAN addressing these questions.

The Y/R does not take into account density dependent growth, maturation and mortality. It seems that fishery should concentrate on catching *C. crangon* late in the life cycle.

Agreed. However, there are no data on which this could be based. Currently the only approach would be to test the sensitivity of the results against the incorporation of density dependent effects in the simulation model. Late in the life cycle would roughly refer to larger shrimps. In an ongoing project the effects of using larger meshes to reduce the number of juvenile shrimps and to increase the number of "older" larger shrimps caught is in progress.

The WKCCM concludes in section 3.5.8, that: "The most suitable solution seems to be for a start an lpue based harvest control rule with regular ground-truthing through standardized survey data in combination with retrospective analysis on fishing and natural mortality, available biomass, demography and other stock status indicators."

This of course requires that the industry is cooperative, and this seems to be the case. They have suggested it and are already testing such a system. However, the general experience from ICES fisheries management is that such a system is very sensitive to political will to really reduce effort when needed. In the big picture the only area in ICES where effort is the main management tool, the Faroe Islands, it has not been able to reduce overfishing, probably because it is politically very difficult to implement the needed reduction in effort caused by the technological creeping (increase in cpue beyond what the horse power parameter explains), while fishing pressure has been reduced significantly in all other areas. Also in northeast USA an effort management system failed and they have now implemented a TAC system as the main tool.

In theory it should be possible to transfer the effort management idea in the HCR into a TAC approach. This would imply that instead of reducing the effort by, say, 30% relative to the mean effort in the same month from a reference period with no problems in the stock, one decides to limit the total catch in that month to 30% of the mean catch of that month in the reference period. Due to the high productivity of the stock, the high F/M ratio and the assumption that the population is growth overfished it could be that a reduction in effort will lead to increased landings. Vice versa, increased effort will likewise lead to ladings comparable to a lower effort situation or, if not a flat to curve is assumed, with higher effort landings could even decrease. If the TAC is about the maximum reachable and harvestable biomass in a certain year a TAC regulation would not be able to reduce F but could even increase F to an unsustainable level.

Clearly, it would not be appropriate with an annual TAC. If the current situation is that overfishing is taking place and the indications are that a reduction in effort will lead to higher catches even in the short term (due to the short life span of Crangon) one would increase the TAC - clearly a "contradiction". The point is of course that a TAC system should be by quarter (or even maybe month) and not by year, and that the main part of the catch should be taken at the end of the lifespan of *C. crangon*.

Has a quarterly VPA type approach been tested for this Crangon stock? This is not mentioned in the WKCCM report. In ICES there are several short lived stocks that are assessed by such a VPA (e.g. Norway pout in the North Sea). Quarterly VPAs are also used in multispecies VPAs e.g. for the Baltic, to take account of the rapid growth of prey items. Even though we do not have actual age determination of *C. crangon* it should not be difficult to assign catches to cohorts by length because spawning is mainly only once per year.

The reason why length-based VPAs (monthly or quarterly) cannot be applied is the complete lack of length composition data. The only available data are from scientific surveys carried out in one month (September/October). An additional problem relates to the fact that there are too few size classes caught by a commercial gear. The gears used in these surveys have a high selectivity only for *C. crangon* larger 45 mm. This limits the potential for demographic predictions from the amount of small shrimp caught.

Annex 4: Figures

Total Landings time series and percentages landed per country

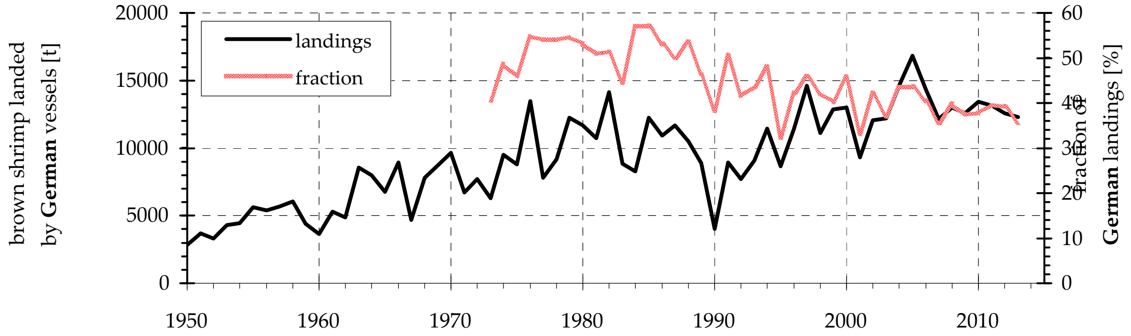


Figure 1 Consumption shrimps landed by German vessels over the period 1987 to 2013 in t (primary y-axis) in European harbours. Red line and sec y-axis: Percentage of Dutch landings in relation to total landings (whole North Sea,all nations).

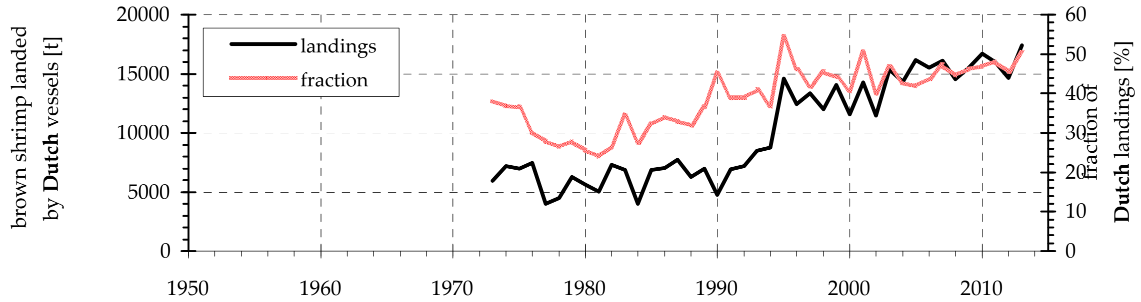


Figure 2 Consumption shrimps landed by Dutch vessels over the period 1987 to 2013 in t (primary y-axis) in European harbours. Red line and sec y-axis: Percentage of Dutch landings in relation to total landings (whole North Sea,all nations).

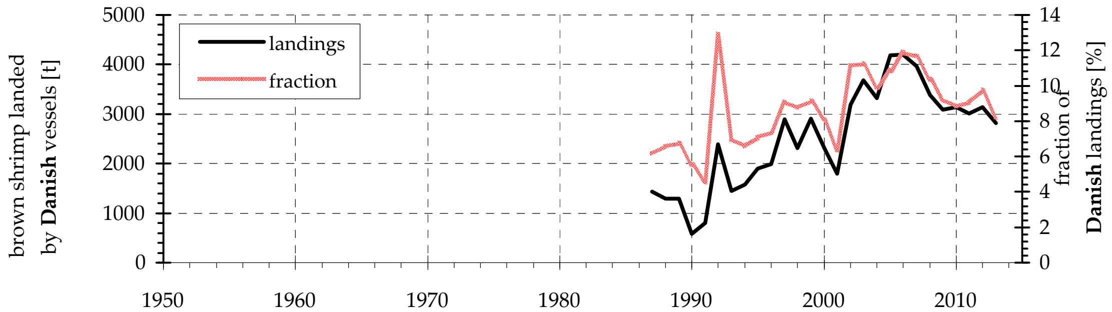


Figure 3 Consumption shrimps landed by Danish vessels over the period 1987 to 2013 in t (primary y-axis) in European harbours. Red line and sec y-axis: Percentage of Danish landings in relation to total landings (whole North Sea,all nations).

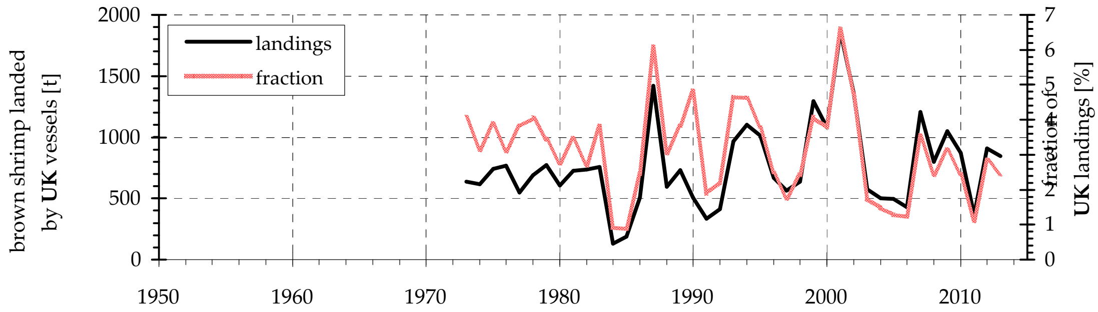


Figure 4 Consumption shrimps landed by UK vessels over the period 1973 to 2013 in t (primary y-axis) in European harbours. Red line and sec y-axis: Percentage of UK landings in relation to total landings (whole North Sea,all nations).

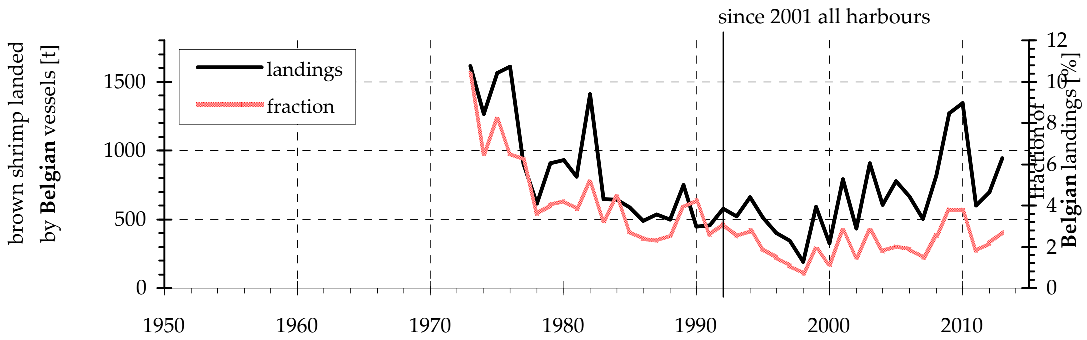


Figure 5 Consumption shrimps landed by Belgian vessels over the period 1973 to 2013 in t (primary y-axis). Since 2001 all landings of all Belgian ships landing in all harbours are included. Before only landings by Belgian ships in Belgian harbours. Red line: percentage of Belgian landings in relation to total landings (whole North Sea,all nations).

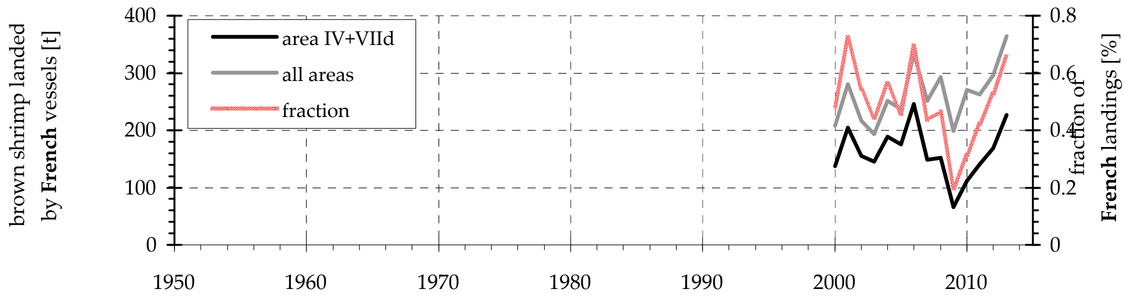
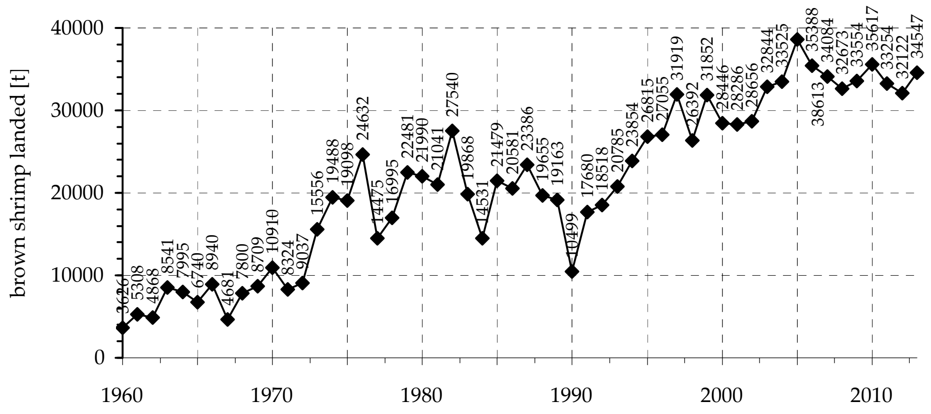
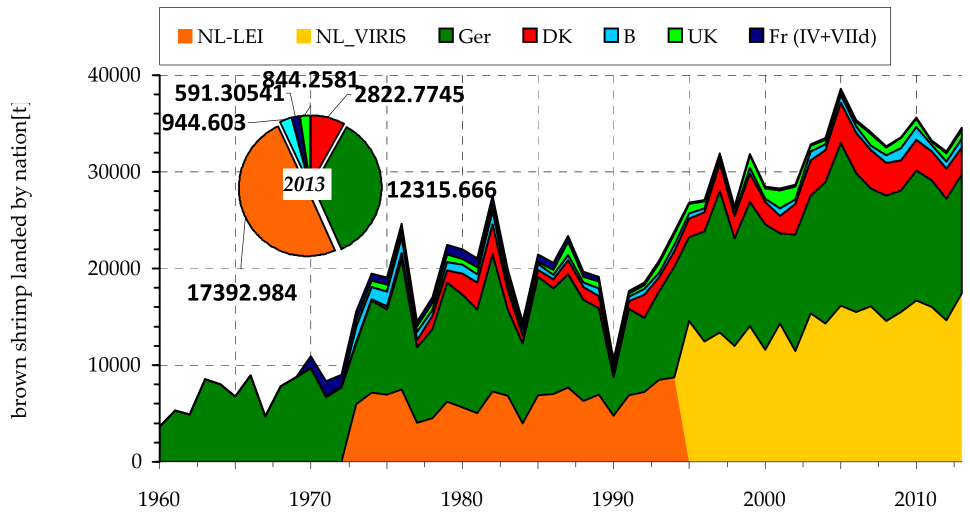


Figure 6 Consumption shrimps landed by French vessels over the period 2000 to 2013 in t (primary y-axis). Solid black line indicates shrimps landed in ICES area IV and VIId and the grey line total amount of shrimps landed by the whole French fleet (from North Sea and Atlantic). Red line indicates the percentage of French landings (area IV+VIId) in relation to total (whole North Sea all nations) landings.





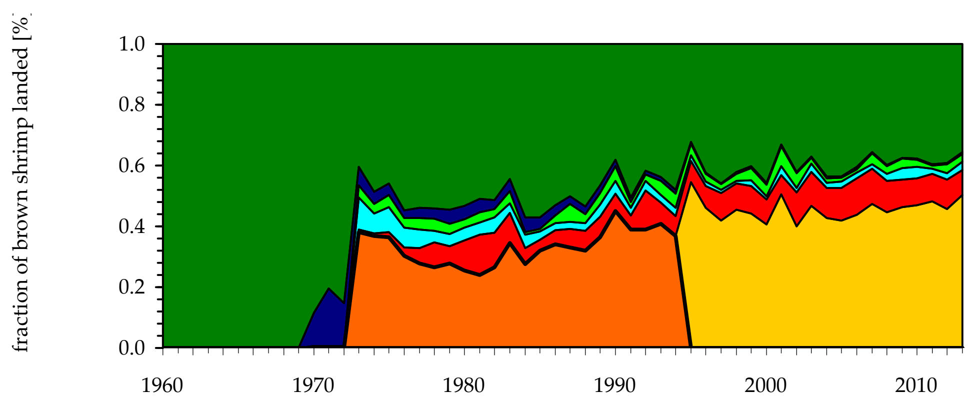


Figure 7 Upper panel landings of Crangon crangon from the North Sea [t].Middle panel landings of Crangon crangon from the North Sea [t] by country. Insert pie chart landings in t per country for year 2013. Lower panel: contribution of single countries to the total amount of shrimps landed by all countriesSea all nations) landings.

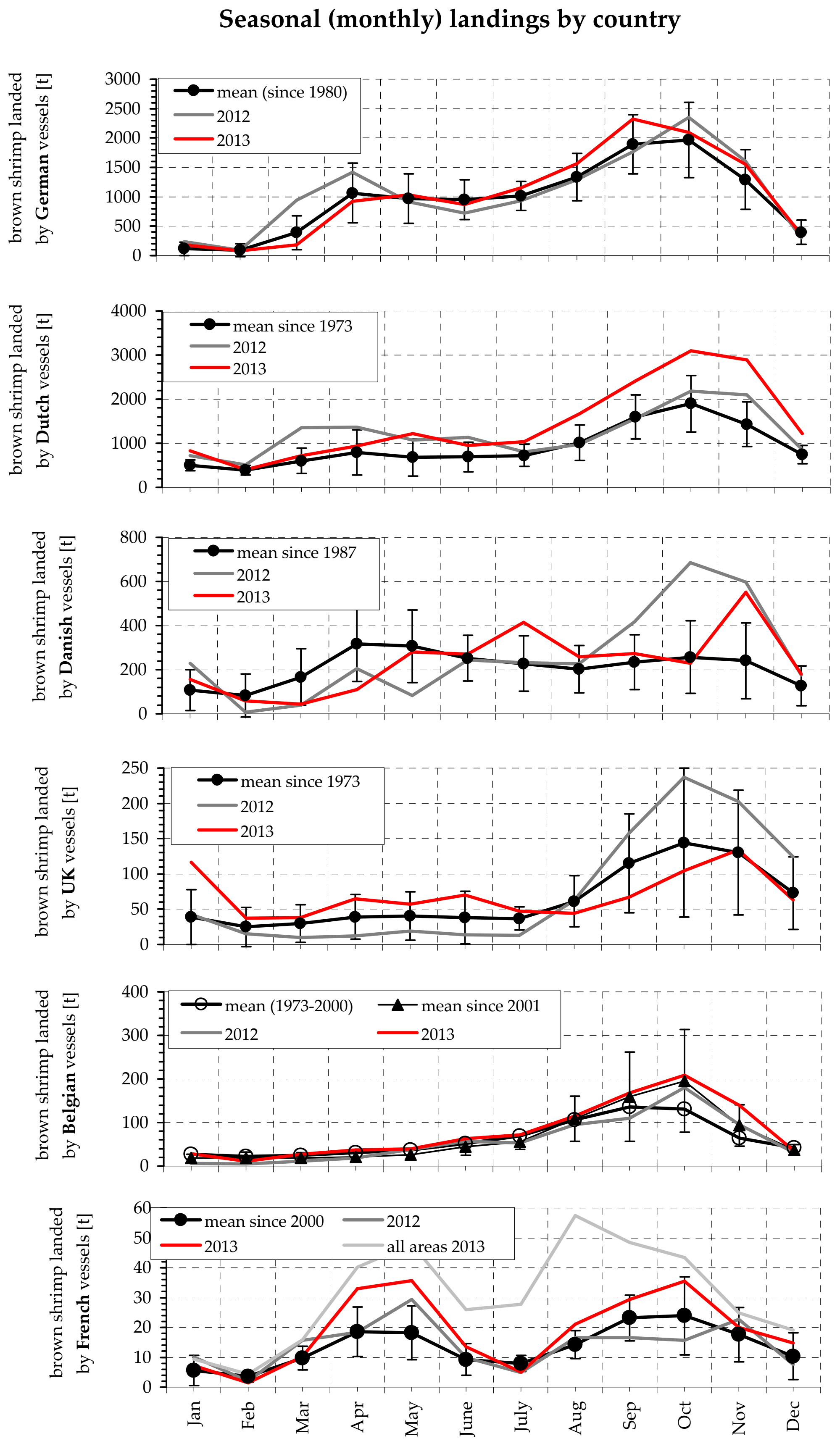


Figure 8

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 2011, red line: total landings per month for the year 2013. For France only: light grey line all areas and blck, dark grey and red line for ICES areas IV+VIId.

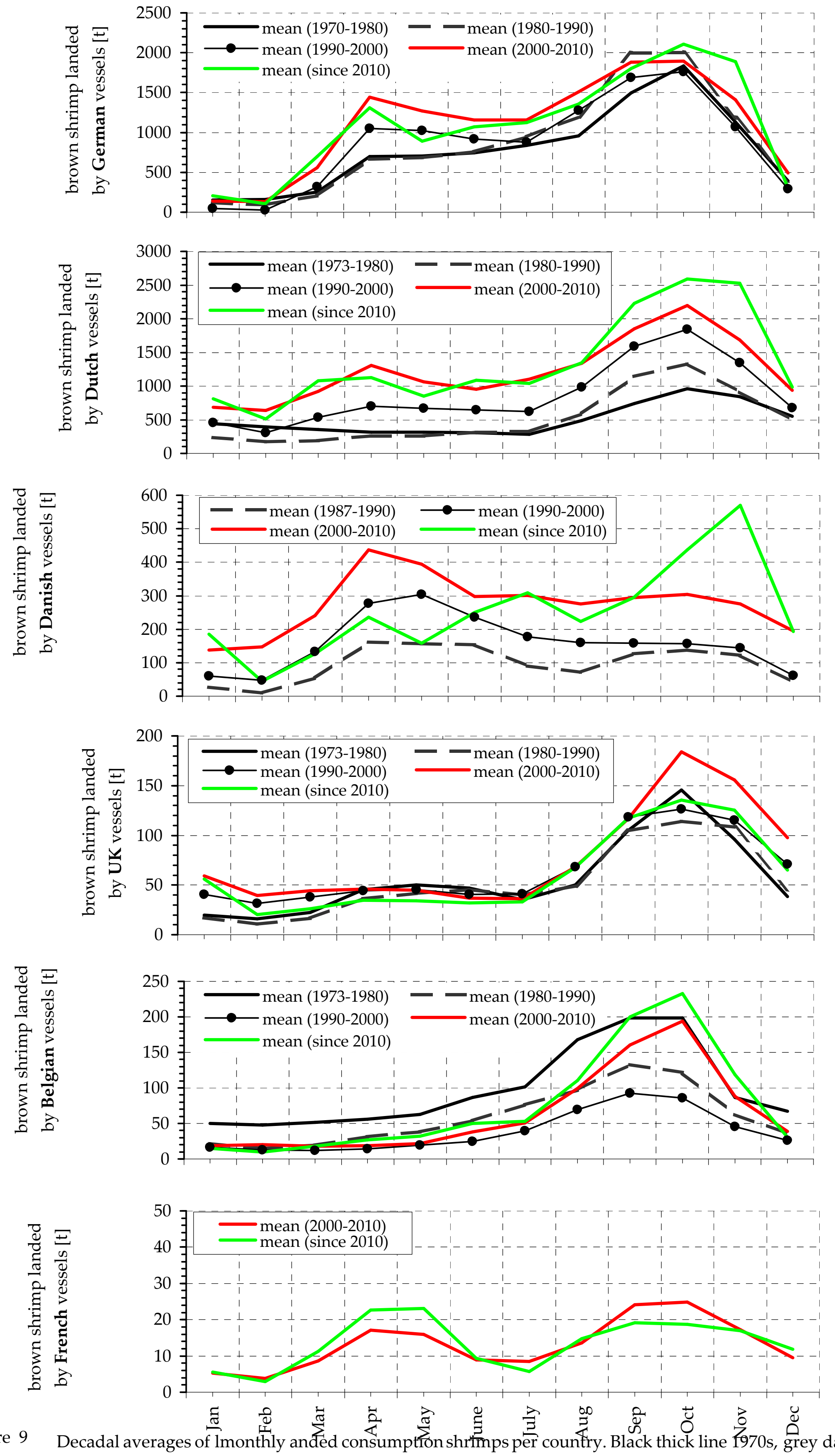


Figure 9 Decadal averages of lmonthly anded consumption shrimps per country. Black thick line 1970s, grey dashed line, black line with dots, 1990s, red line 2000s, green line mean since 2010.

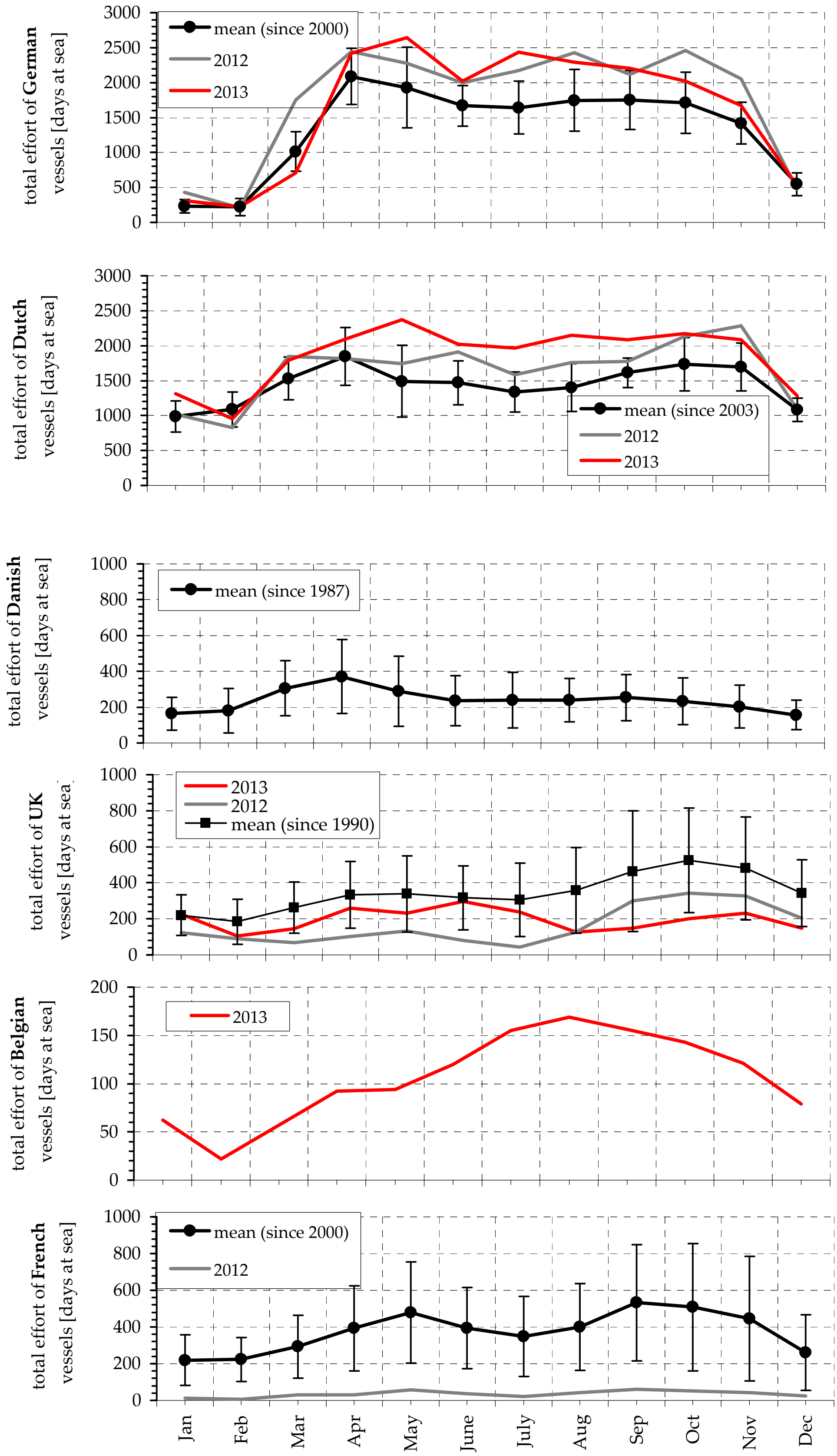


Figure 10 Monthly effort in days at sea (leaving to returning to harbour) per country. Black lines and whiskers indicate the long term means and standard deviations for the nations. Grey lines indicate the effort for 2012 the red line the effort for 2013.

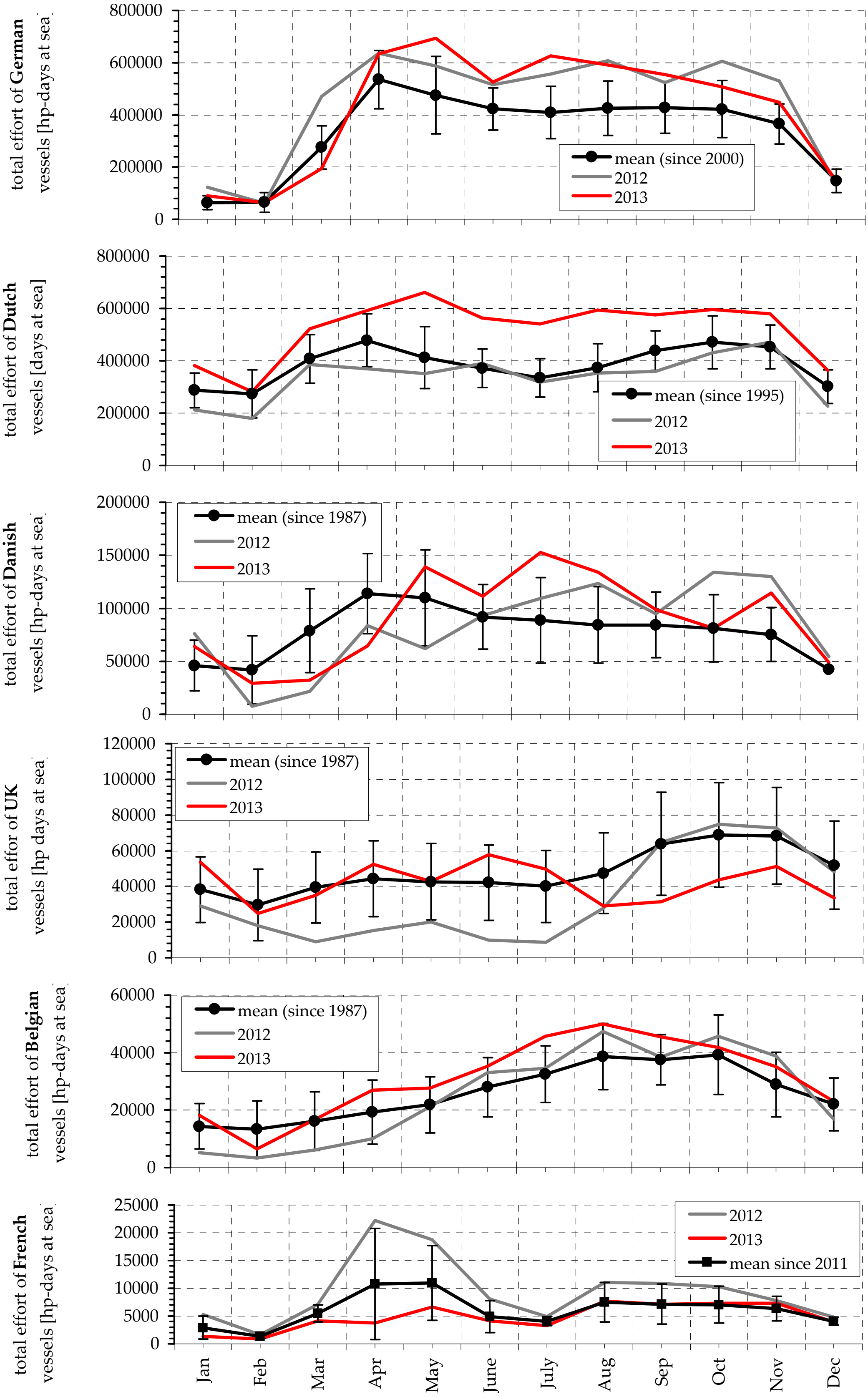


Figure 11 Monthly effort in horse power days at sea. Black line and whiskers indicate the long term mean and standard deviation for each nation. Grey line indicates the effort for 2012 and the red line the effort for 2013.

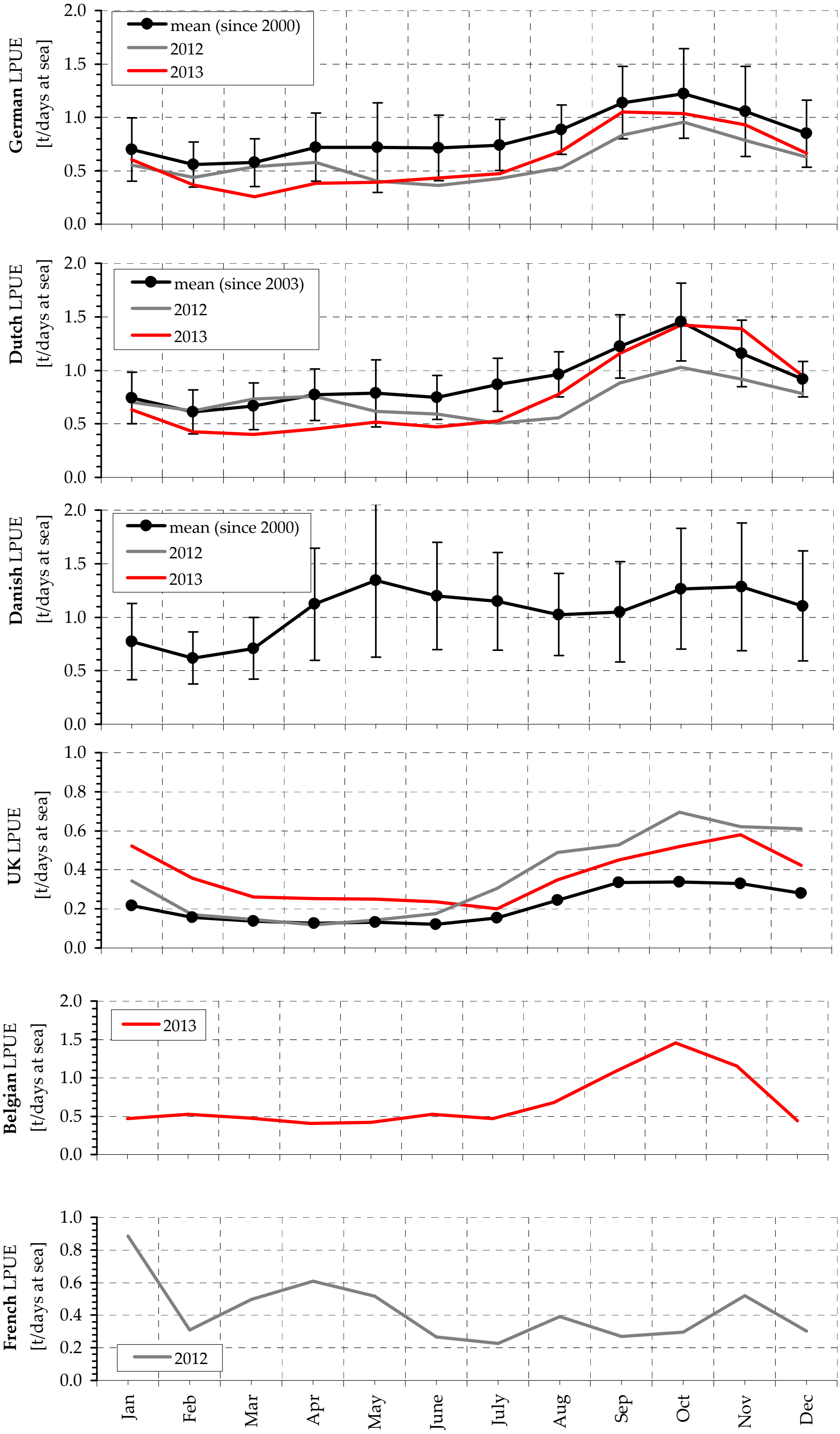


Figure 12 Monthly landings per unit effort in t per days at sea. Black line and whiskers indicate the long term mean and standard deviation for each nation. Grey line indicates the effort for 2012 and the red line the effort for 2013. UK and Dutch data are based on days at sea all others on hours at sea x 24

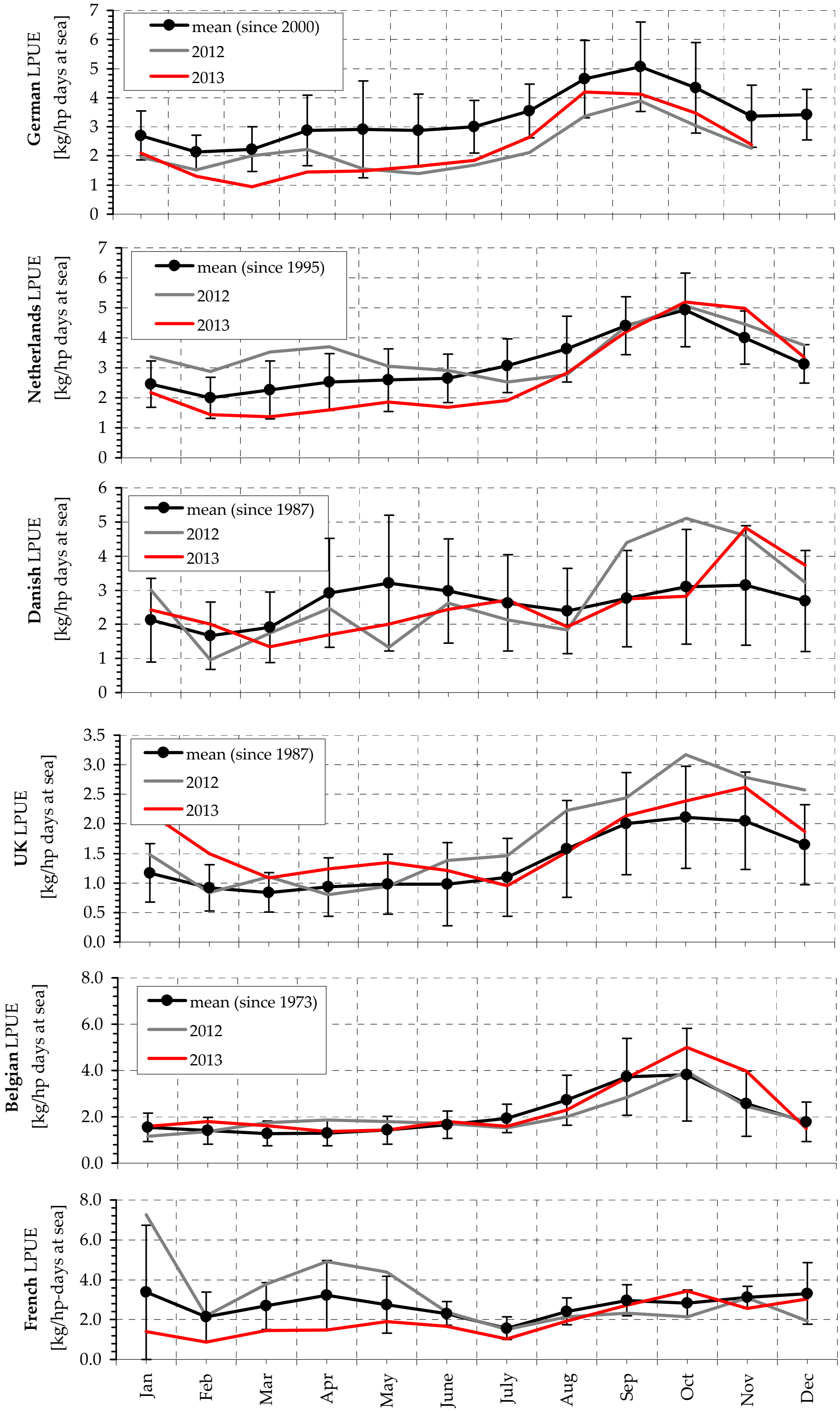


Figure 13 Monthly landings per unit effort in kg per horsepower days at sea. Black line and whiskers indicate the long term mean and standard deviation for each nation. Grey line indicates the effort for 2012 and the red line the effort for 2013.

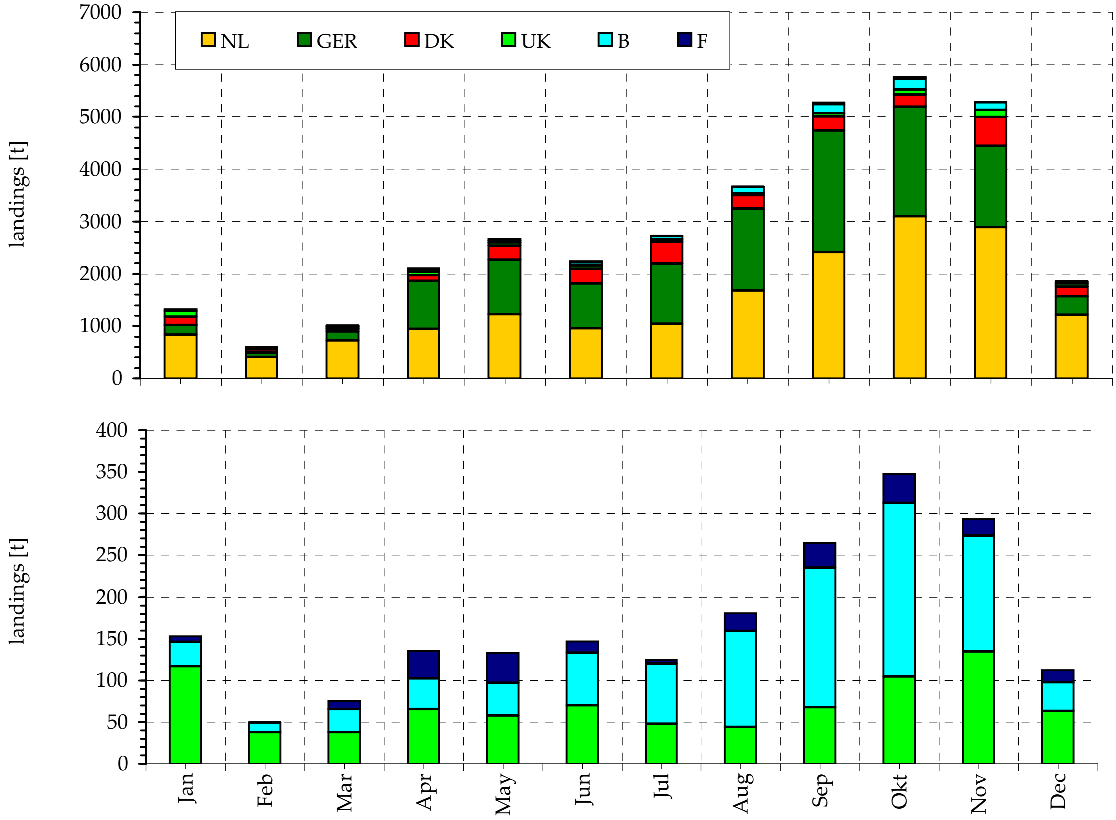


Figure 14 Cumulatirve monthly total landings per nation. Upper panel all nations, lower panel only UK, France and Belgium

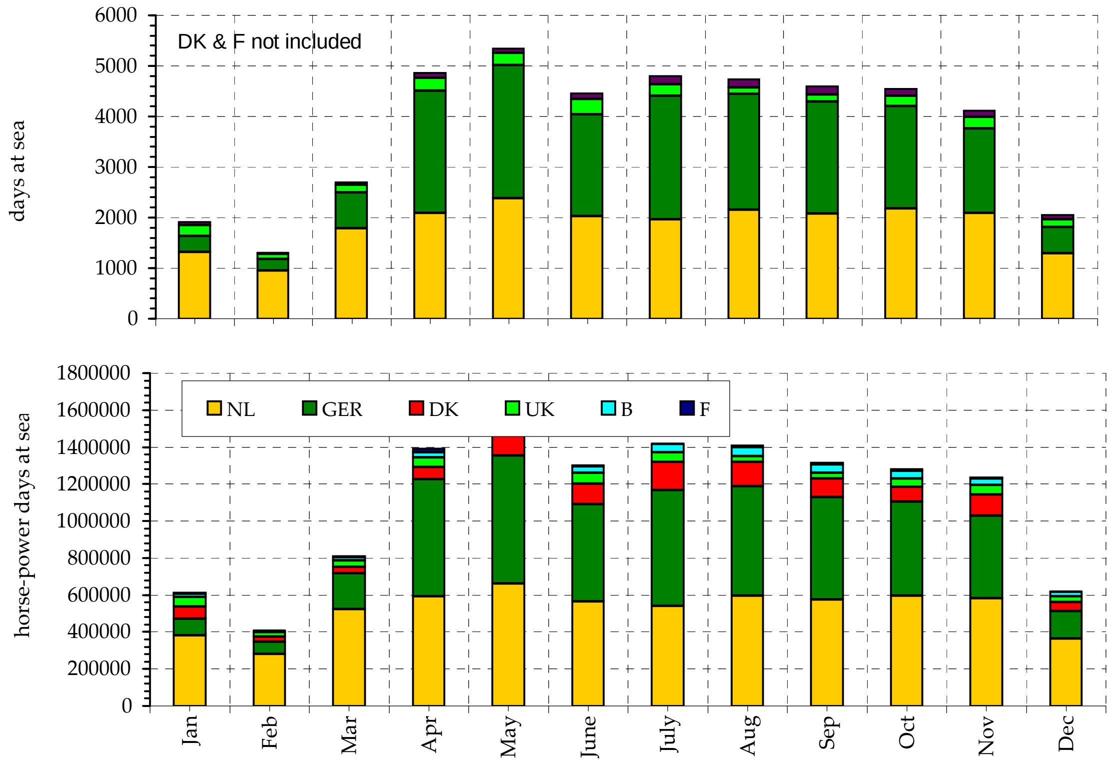


Figure 15 Cumulatirve monthly efforts per nation and month for 2013. Upper panel days at sea, lower panel horse power days at sea.

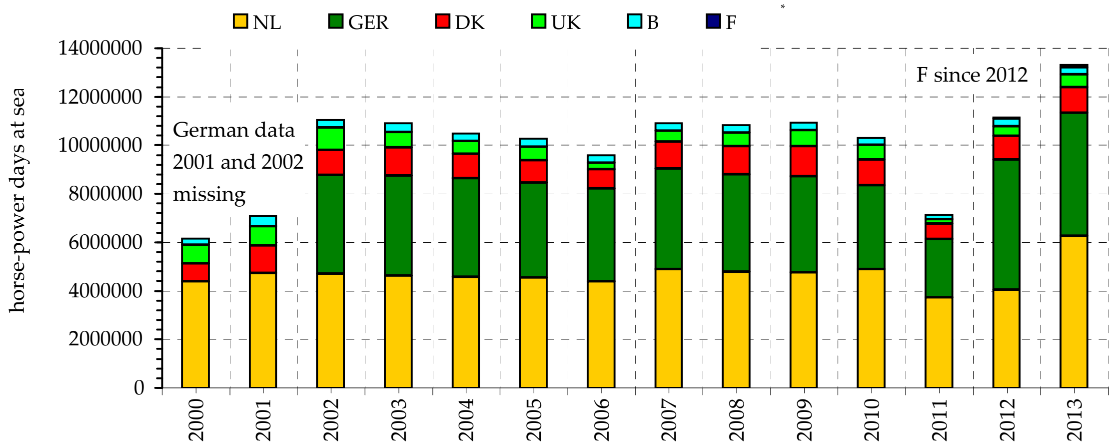


Figure 16 Cumulative efforts in horse-power days at sea per nation and year

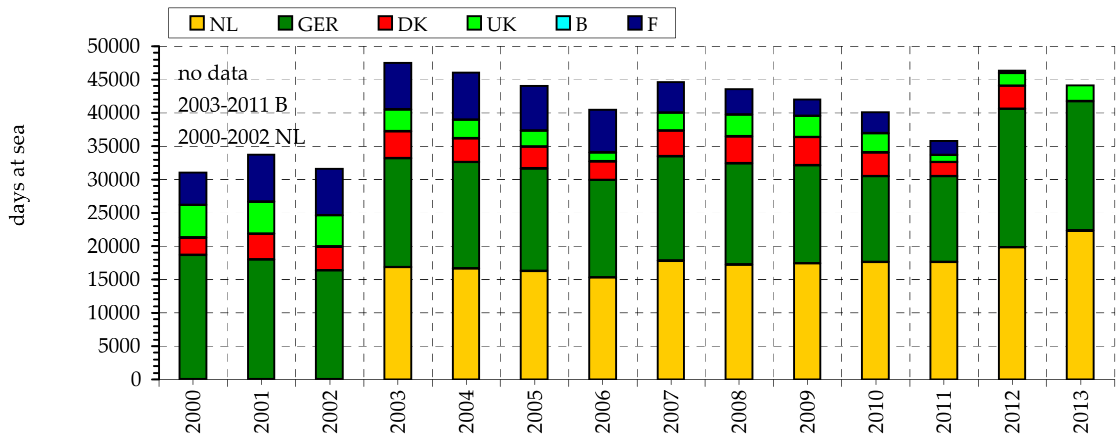


Figure 17 Cumulative efforts in days at sea per nation and year

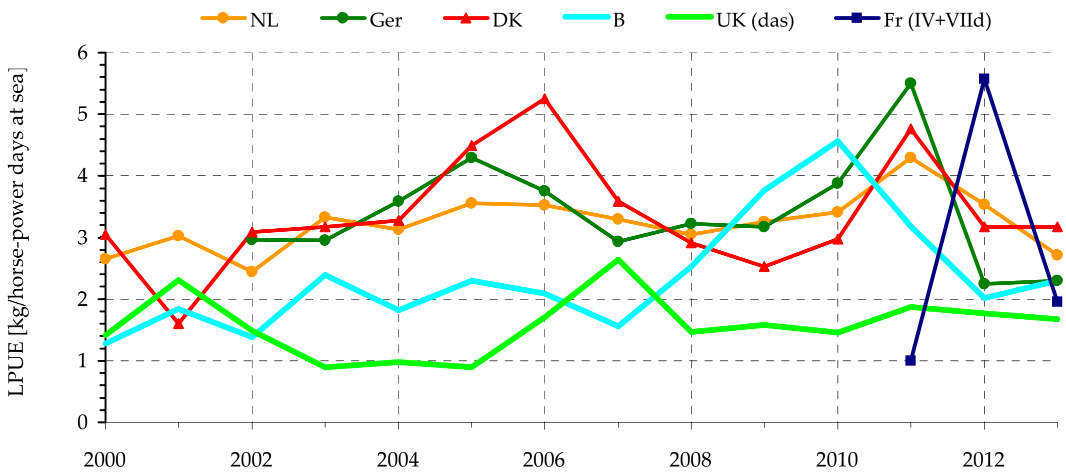


Figure 18 Annual landings per unit effort per nation in kg per horse power days at sea. For UK and NL all based on days at sea for all remaining countries based on hours at sea times 24.

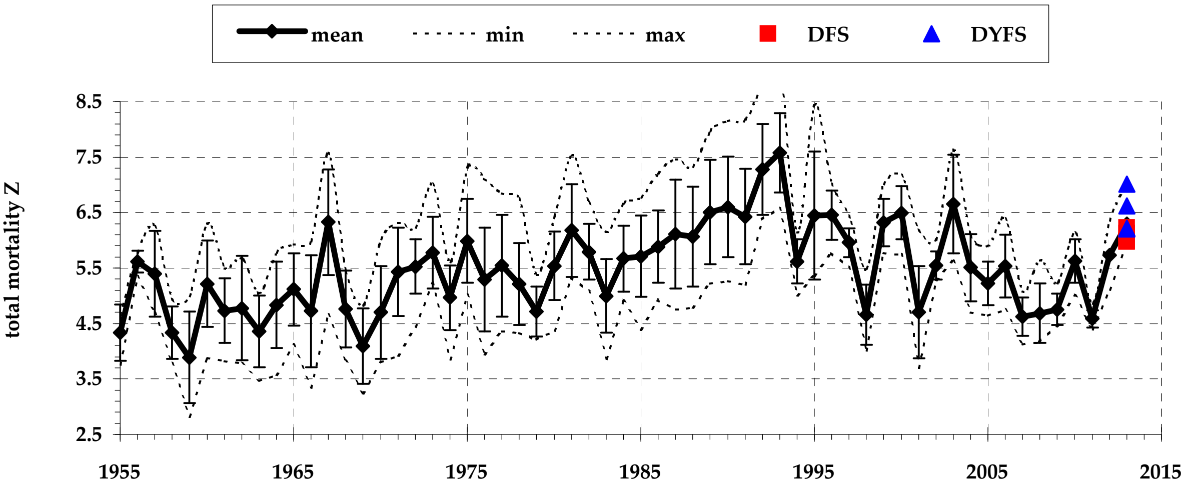


Figure 19 Total annual exponential mortality rate Z [a-1] estimated using length-based methods. The time series indicated by the bold line was calculatedusingthe mean of four different surveys (German Demersal Young Fish Survey: DYFS, Dutch Demersal Fish Survey DFS, German Bycatch Series from East Frisia and Büsum). Four different methods were used: Beverton & holt, Jones and van Zalinge, Ssentongo & Larkin and Length Converted Catch Curve. The methods and as well as the validation of the methods are presented in Hufnagl et al. (2010, 2012). Data for 2012 are indicatedbyred rectangles (DFS) and blue triangles (DYFS).The mean in 2013 for both surveysand all methods was Z =5.7 a-1.

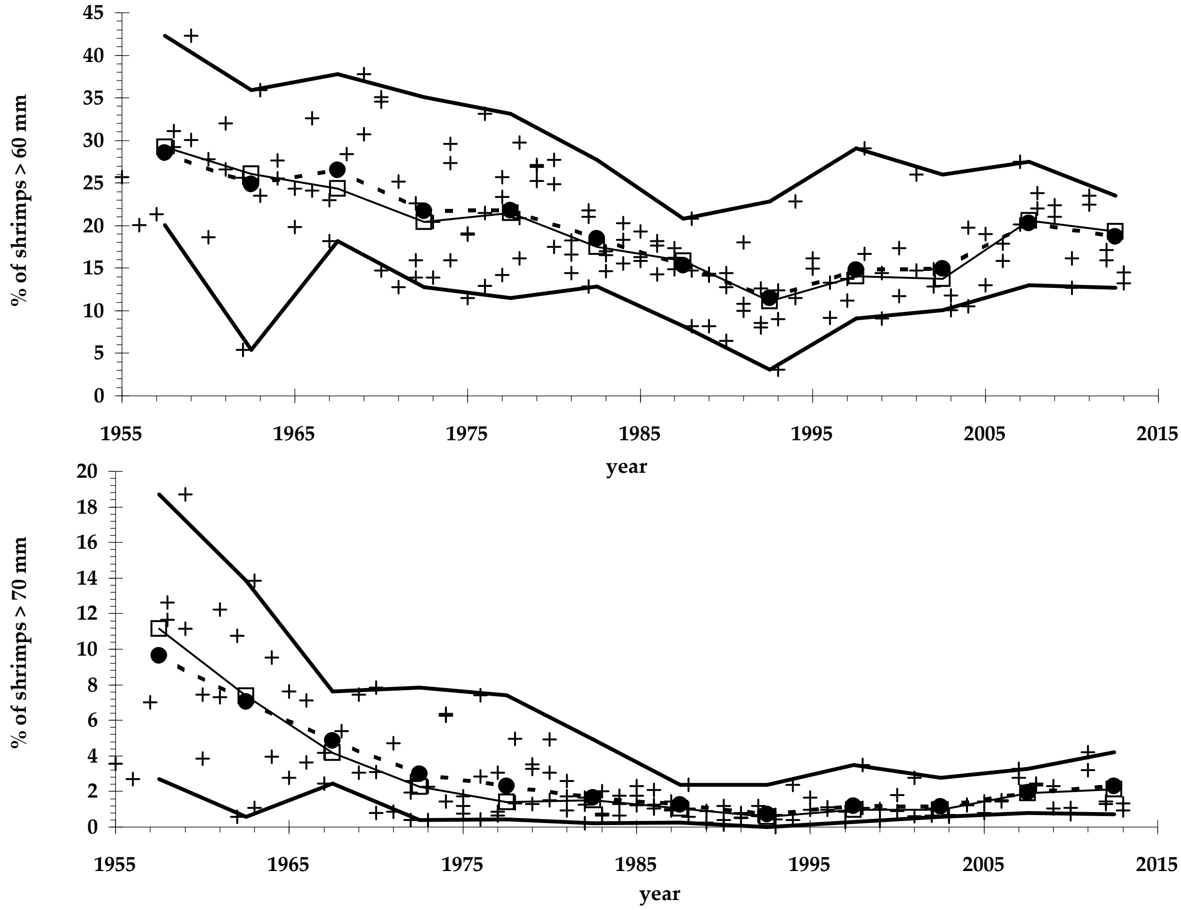


Figure 20 Fraction of shrimps >60 mm (upper panel) and >70 mm (lower panel) estimated using different surveys (German Demersal Young Fish Survey: DYFS, Dutch Demersal Fish Survey DFS, German Bycatch Series from East Frisia and Büsum, Hufnagl et al. 2010). Data for 2013 are indicated by red rectangles (DFS) and blue triangles (DYFS).