ECOREGION North Sea
SUBJECT Request from Germany and the Netherlands on the potential need for a management of brown shrimp (*Crangon crangon*) in the North Sea

Advice summary

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.

Request

ICES is requested to provide advice on the potential need for a management of brown shrimp (C. 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 - 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.

Elaboration on ICES advice

i. <u>The pros and cons of a management</u>

There are several benefits to implementing a management system for *C. crangon*. Regulating the fisheries in a sustainable manner will avoid growth overfishing and potentially increase sustainable yield, decrease the costs associated with fishing, and reduce the environmental impacts of the fishery. The following points are relevant:

- There are indications that the current lack of a management system has led to uncontrolled effort increase and growth overfishing of the target species. As a consequence, shrimp are being harvested at a suboptimal (too low) average size. 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. It appears likely that the yield will remain stable or even increase with reduced effort.
- A reduced effort will lessen the environmental impact of the brown shrimp fishery on non-target species and the benthic community of the seafloor.
- If *C. crangon* main predator stocks, essentially cod and whiting, recover, the need to implement a management system becomes even more urgent.

The introduction of a management system has the potential to differentiate between the various segments of the fleet targeting *C. crangon*. This could be seen as either a benefit or as a drawback, depending on the perspective and the overall aim of the management.

The drawbacks to introducing a management system are the additional tasks that this will create for ministries, control authorities, and scientists, and most likely also for the fishers and their producer organizations. Because of the short life span of *C. crangon*, management has to be on a shorter time scale than the common annual interval, which requires more data at a higher temporal resolution than presently available.

The role of *C. crangon* in the ecosystem and the foodweb

A large variety of species feed on *C. crangon* in the North Sea. These include a large number of benthic and pelagic fish species, crustaceans, and sea- and shore-birds. No fish species relies solely on brown shrimp, and the shrimp diet of fish consists almost exclusively of the juvenile shrimp stages at sizes smaller than 50 mm. Only a small number of fish species consume larger shrimp of marketable size, most importantly cod and whiting; nevertheless, even these species feed mainly on the smaller, juvenile shrimp. These two fish species are widely distributed in the North Sea; brown shrimp is thus only important on a local scale (corresponding to the areas and depths where brown shrimp is distributed) and only for parts of the predator population, mainly the juvenile fish. While brown shrimp is taken in large amounts by these predators and hence represents an important energy source, brown shrimp is neither a preferred nor an optimal prey for the growth of these species. On the other hand, several of the small predator fish species, which prey intensively on smaller brown shrimps (< 50 mm), may be more dependent on this food source, since their populations are mainly distributed in the same depth range as brown shrimp.

C. crangon is a lower trophic-level species, but the importance of *C. crangon* as a food source depends on the spatial scale. On a wider scale in the North Sea the importance of *C. crangon* is expected to be minor, but in the local coastal areas where *C. crangon* is distributed it is an important food component in the diet of a number of species, even though its role in the energy flow is not dominant. Its role can therefore not be ignored and substantial changes in coastal areas can be expected if the *C. crangon* population is largely reduced, e.g. in the case of recruitment overfishing.

ii. The impact of crangon fishery on other species and fisheries

Two types of interactions should be considered: the so called 'technical interactions' (or mixed-fisheries considerations) and the 'biological interactions' (or multispecies considerations).

Mixed-fisheries considerations

Given the small mesh size used in the brown shrimp fisheries, the bycatch of fish, undersized shrimps, and other benthos is unavoidable. In the future the North Sea brown shrimp fishery should be included in the mixed-fisheries analysis annually conducted by ICES.

C. crangon is not taken into account in the present framework of the ICES advice regarding North Sea mixed fisheries. Cutters can change their metier, but they do not target flatfish and shrimps at the same time. A number of vessels in the southern Netherlands and Belgium constitute an exception in that they also retain sole of commercial size by attaching an 80 mm codend to the exit opening to which the sievenet guides larger fish in the shrimp beam trawl. However, the fact that many (juvenile commercial) fish species are caught as bycatch and are discarded in the *C. crangon* fishery is a major concern, although the plaice stock, which clearly dominates the bycatch, is currently at very high abundance. The use of sievenets to prevent larger fish from entering the codend has been mandatory since 2002. Sievenets work well in reducing the bycatch of fish and invertebrates >10 cm but do not work for fish < 10 cm (Polet, 2003; Catchpole *et al*., 2008). The latter can, at certain times during the year, still constitute a substantial amount of the catch (Revill *et al*., 1999). The Wadden Sea and adjacent coastal areas are an important nursery area for plaice and other commercially important fish species like sole and dab (Zijlstra, 1972; van Beek *et al*., 1989; Bolle *et al.*, 1994), as also indicated by the new analysis of German and Dutch bycatch data. In a study conducted in 1999 (Table 28 in Revill *et al.*, 1999) fish bycatch in the shrimp fisheries has been estimated to reduce the spawning stock of plaice by 10%, of sole by 1%, of cod by 1%, and of whiting by 1%. Possible measures to reduce the bycatch are real-time closures in areas with high bycatch rates, seasonal closures during periods of high plaice bycatch (e.g. summer), or technical measures (e.g. larger mesh sizes.

Multispecies considerations

Gadoids are dominant predators on adult and juvenile *C. crangon* and these fish are currently at very low stock sizes in the southern North Sea. Management should be prepared for the situation of increased predation on brown shrimp if the gadoids stocks recover.

There is a possible competition between the shrimp fishery and gadoid predators, i.e. cod and whiting. A massive invasion of whiting in 1990 subsequently led to a very poor *Crangon* fishing season in autumn of 1990 and spring of 1991 (Berghahn, 1996). The extent to which the failure of the fishing season was also influenced by the very low numbers of egg-carrying females observed for a number of years prior to 1990, is unknown (Siegel *et al*., 2008). Currently competition between fisheries and cod and whiting stocks for adult shrimp is unlikely because of the very low abundance of these stocks.

If gadoids recover, two effects can be expected: 1) increased competition (fishery versus predators) for adult shrimp and, hence, lower commercial catches, and 2) substantially increased predation of small (< 50 mm) brown shrimp,

which may decrease the recruitment of brown shrimp to the fished stock component. The predation by other predators is less well investigated; however, most of the adult stages of these fish are small and consume only small (< 50 mm) shrimp. Some of these populations may rely to a large extent on the availability of small brown shrimp. The extent to which recovery of the gadoid stocks can affect the stocks of these smaller predators is likewise unknown. Some of these fish, namely gobies, are a preferred food source for both cod and whiting. Both gadoids show a much better growth conversion efficiency if fed with gobies than with brown shrimp.

Intensive fishing on brown shrimp could negatively impact gadoid growth and survival, if a too high share of the shrimp production is taken by the fishery. However, this effect is expected to be less pronounced (unless the fishery causes recruitment overfishing) as the fishery targets the large shrimps and the predators target mainly the small shrimp before they become accessible to the fishing gear. The enforcement of larger mesh sizes could be considered as a measure to stabilize this pattern. In a situation of recruitment overfishing, where the adult population as well as the juvenile shrimps would be reduced in number, there will be negative effects on all brown shrimp predators. So far, however, no clear stock–recruitment relationship has been established for brown shrimp.

The predator–prey interactions have increased in complexity with the gradual build-up of three marine mammal populations in the coastal areas inhabited by brown shrimp, namely harbour seals (27 000 individuals), harbour porpoise (55 000 individuals), and grey seals (4000 individuals). The combined assembly consumes an estimated total of 145 000 t fish annually; many of these will be brown shrimp predators (Temming and Hufnagl, 2014).

Potential management approaches

Assessment and management approaches

Due to the short life span of the *C. crangon* an annual stock assessment and annual TAC are not suitable. A harvest control rule (HCR) suggested by stakeholders and further refined based on science is considered to be a good starting point for management of the *C. crangon* fishery. Modifications to and refinements of this HCR may be required (see below).

For precautionary reasons ICES concluded that a management system is required to prevent growth overfishing and potentially recruitment overfishing, to sustainably harvest the brown shrimp population, and to reduce the impact on the benthic community and on species relying on brown shrimp as prey. This should involve the close to real-time monitoring with fast response mechanisms, which is required to react in a situation of recruitment failure or adverse population development. The HCR, as proposed and already tested by the fishing industry, was considered a suitable first approach. The HCR is based on a comparison of the most recent commercial landings per unit effort (lpue) data with predefined trigger values. Commercial lpue are generally available within a period of less than two weeks and the trigger values are, so far, based on observations from earlier years. As soon as a decline of the population density (measured as lpue) below the trigger point is detected, the fleet effort (or the total landing volume) shall be reduced to prevent overfishing.

Current trigger points (for monthly lpue) in the HCR are drawn and developed from experience and previous lpue data, suggesting limiting effort in response to an observed 25% reduction of the current stock density in comparison to the mean of the years 2000–2006. In order to do so, lpues of (a subset of) vessels are reported weekly in logbooks, filling in positions and fishing-time on a haul-by-haul basis. The data of these vessels from every region are processed within a short time. This “ad hoc” short-time lpue-based management tool is seen as a possible management system for the typical short-lived and highly productive *C. crangon* in contrast to the “classical” annual systems with catch limits. It allows for giving extreme short notice on changes in the shrimp stock development and follows the general principle of a precautionary approach aimed at guaranteeing an escapement biomass. The performance and robustness of the HCR approach suggested by the Dutch fishing industry was evaluated in Temming *et al*. (2013), based on German fleet data.

The monitoring required to inform the HCR should include the majority of all fleets and it needs to be guaranteed that the majority of the fleet reduces effort as soon as the effort reduction is triggered in the HCR. Electronic logbooks could be used as a mandatory tool to generate the necessary data. The lpue trigger values can, at least during the first starting and testing phase, be based on average lpue obtained from previous years. The effort reduction levels can be obtained from yield-per-recruit model simulations, but need to be further specified. Both, the trigger lpue values and the accompanying effort reduction level need to be set based on the earlier analysis, but also in cooperation with stakeholders as soon as the primary management goal is defined. Additionally, these values (trigger lpue and effort reduction) need to be permanently evaluated and adjusted (e.g. on an annual basis through ICES), taking stock development, habitat, and fleet characteristics into account (both in terms of knowledge gained and changes observed).

Roadmap

To implement the HCR ICES offers the following six-step roadmap. ICES considers that the first three steps can be concluded within a year from the start of the implementation if sufficient funding is provided:

Step 1 • Data assimilation and evaluation/short-term research needs

- Effort has in the past been – and still is – reported differently by the different nations. A detailed description of how effort and landings have been monitored so far is needed. Trips of most vessels fishing for brown shrimp are shorter than a day and therefore the classical way of reporting effort in days at sea is too coarse for these fisheries. The first priority should be a standardization of the reported effort to kW × hours (kWh) outside the harbour. In a second step the measure of effort could be made more precise by reporting only kWh of the fishing operation itself.
- Engine power alone will not provide a reasonable way to monitor effort creep. Identifying the most important factors that need to be included in a monitoring and evaluation procedure requires a fleet inventory. This should include characteristics of the majority of the fleet (at least the Dutch and German fleets) and list properties like boat type, boat length, engine power, deck machinery, mesh size used, sorting devices, etc.
- An analysis of the spatial effort distribution and the fleet behaviour of all nations needs to be conducted using VMS and logbook data from, at least, the German, Dutch, and Danish fleets.
- These data need to be compared with data from the ongoing monitoring surveys (German demersal young fish survey (DYFS) and the Dutch demersal fish survey (DFS)) to examine whether areas not covered by the surveys can be extrapolated using VMS data.
- So far an evaluation of the HCR has only been done for the German fleet. As the national fleet structures, including spatial distribution and behaviour, vary greatly by country, a similar analysis needs to be performed based on Dutch and Danish effort and landings data.
- For a more accurate yield-per-recruit analysis juvenile natural mortality and density dependence need to be investigated. Factors influencing recruitment strength also need to be investigated.

Step 2 • Agreement on the design of HCR (definition of trigger values and effort reduction levels)

- Based on the evaluation that includes the Dutch and Danish fleet landings and effort data, along with the fleet inventory, the suitability of the HCR needs to be evaluated and approved.
- If the HCR still remains the method of choice, the management target (e.g. demands for stability, high yield, low environmental impact, bycatch reduction, etc.) needs to be defined together with stakeholders and authorities.
- Based on the management target, HCR trigger lpue values and effort reduction levels need to be proposed and agreed among stakeholders.
- Spatial differences in lpue and effort distribution need to be considered.
- A fair mechanism for the distribution of the effort reduction needs to be developed and agreed among stakeholders. Possible mechanisms based on incentives should be considered to keep the additional administrative effort low.

Step 3 • Development of a possible monitoring strategy

- A standardized cross-nation lpue monitoring strategy (i.e. either fleet-wide or based on a reference fleet), including transparent data handling and a panel of independent observers, needs to be developed.
- For evaluation of the HCR regular scientific monitoring programmes could be extended (e.g. extended activities of DCF observers, seasonally conducted scientific field surveys, length measurements of sieving fractions, etc.). Alternatively other large-scale monitoring programmes could be developed (e.g. a fisher-based seasonal survey with standardized gears; see also ICES, 2013).

Step 4 • Test phase

- Over a predetermined period the developed strategies need to be tested and fine-tuned.

Step 5 • Evaluation and adjustment of the HCR

- Based on the monitoring and the experiences of the test phase, the HCR parameters (trigger lpue values, effort reduction) need to be evaluated and adjusted.
- Supplementary regulation measures could be discussed and considered, such as intra-annual (within year) TAC and technical measures (e.g. increased mesh size).

Step 6 • Application and re-evaluation phase

- Application of the developed strategies.
- Application of a regular standardized survey.
- Regular re-evaluation of the stock status and of the thresholds and effort reduction levels used.

Basis of the advice and background

Stock structure, population dynamics, and distribution of brown shrimp

Genetic studies have not provided convincing evidence to consider the North Sea population of brown shrimp as more than one stock, nor do results from drift models justify separate stocks. For the management of the fishery, ICES proposes to treat brown shrimp in the North Sea as one stock, but to take spatial differences into account.

Depending on temperature, food supply, and size the growth rates of juvenile brown shrimp can reach 0.5 mm per day. With a mean L_∞ of about 73 mm, a commercial size of 50 mm, and two major reproduction seasons (summer and winter), cohorts rapidly and continuously enter the catchable size range. The distribution of brown shrimp is influenced by size and season and, thus, the current setup of surveys and commercial data is not able to monitor recruitment without large additional effort and costs. So far no direct relationship between the adult population and the size of next year's cohort has been detected; therefore, projections of next year's population size cannot be given. Brown shrimp smaller than approximately 50 mm are mostly discarded (Figure 6.2.3.4.1).

Rationale for the perception of growth overfishing

Adult brown shrimp are heavily exploited, they have experienced F/M (fishing mortality to natural mortality) ratios larger than 1 and up to 5 since 1990, and brown shrimp larger than 70 mm only make up 1% of the catches. The production to biomass ratio is about 5. Therefore, landings are mainly driven by the productivity of the population, and changes in the biomass are only a poor indicator of the current stock status.

The major indications of North Sea brown shrimp being growth overfished were obtained from a yield-per-recruit model analysis (Y/R model). By taking into account the specifics of the brown shrimp life cycle (seasonal natural and fisheries-induced mortality rates, temperature-, stage-, and length-based growth rates, reproduction rates, and spawning times) this model is able to accurately reproduce the observed seasonal patterns of landings and recruitment. Using this model and forcing it with different F/M ratios provides yield-per-recruit curves which clearly indicate that the current level of fishing mortality is above $F_{0.1}$ and even above F_{max} (ICES, 2013; Temming and Hufnagl, 2014). These values are often used as the range of proxies for F_{MSY}. As in most models, uncertainties in parameter estimates do exist, most importantly the mortality of larval and juvenile brown shrimp and the reproduction rates of adult females.

There are fleet- and population-based indicators for growth overfishing (and potentially recruitment overfishing) which are listed in the following (discussed in detail in the ICES, 2013, 2014).

- Although the number of active vessels in the brown shrimp fishery has been rather constant in the recent years, the engine power has increased constantly and older cutters in parts of the fleet have been replaced by more effective vessels. Additionally – not registered and therefore not monitored – the power of deck equipment increased. This has resulted in an unmonitored increase of standardized effort.
- The ratio of commercial landings to the biomass eaten by predators (cod and whiting) has constantly increased since the 1990s as the cod and whiting stock abundance decreased while brown shrimp landings increased. So far there are no indications that other predators have taken over the role of cod and whiting, resulting in a situation where current fishing mortality for brown shrimps >50 mm is up to five times higher than the natural mortality.
- The fraction of large shrimps (>60 mm) has been in constant decline from 30% to 20% in recent years. For shrimps >70 mm, the fraction has decreased from more than 5% before 1970 to about 2% since 2005.
- Based on a yield-per-recruit model analysis, the fishing mortality has been higher than $F_{0.1}$ since 1990 and higher than F_{max} since 2001 and, thus, outside the range of proxies for F_{MSY}.
- Preliminary production estimates based on swept area and total mortality indicate that in certain years the production of the population is at the same order of magnitude as commercial landings.
- Fishing effort has constantly increased since the 1970s; the 2013 data indicated an increase in mortality and effort while landings only increased marginally.

The fishery and present management

The landings of *C. crangon* for human consumption have constantly increased since the 1970s, most likely due to a decrease in predation pressure and an increase in fishing effort and efficiency. Currently, the brown shrimp fishery is largely unregulated, with only the number of permits plus some additional technical measures (mesh and engine size)

being controlled. A number of flatfish beam trawlers and multi-rig lobster fishers own a permit for shrimp fishing which is not or only partly used; these vessels can switch at any time into this fishery (if engine power is less than 221 kW). Hence, the current regulation does not even limit the total capacity of the fleet to the *status quo*, as there is inactive capacity that can be reactivated at any time. The possible large-scale unmonitored introduction of pulse gears into the fishery represents an additional risk to the brown shrimp stock, as this gear, especially if used in combination with a roller ground rope, increases the efficiency of the vessel.

The shrimp fishery primarily takes place in the coastal zones (Figure 6.2.3.4.2), which are characteristically nursery areas for many commercially exploited and non-commercial fish species and are in many cases also designated as Natura 2000 sites. The closure of these coastal areas will most likely induce effort shifts into deeper waters with the additional risk of an increased fishing pressure on the egg-bearing female *C. crangon* stock component. The gear used has a small mesh size, with consequences for unwanted bycatch of undersized fish and benthic animals. The use of sievenets has increased selectivity of the fishery; however, juvenile fish and undersized shrimp are still largely retained in the catches. The impact of the gear on the bottom is debated and currently not clear. Predator stocks (mainly gadoids) have been severely reduced, while fishing pressure has increased over the past decades. From a simulation study there are indications of growth overfishing of *C. crangon*. This implies that in the current ecological situation with low predator stocks, a substantial effort reduction will most likely lead not to reduced landings but rather to long-term gains in the yield of target species.

Additionally, a stock composition with larger shrimps and higher reproduction could be obtained if gears are adjusted and fishing pressure is reduced in general and especially on juvenile brown shrimps. Appropriate effort reduction would lead to a reduced impact on the ecosystem, e.g. by reducing discards, bottom impacts, and fuel consumption. The adjustment of effort and efficiency, which is especially needed when population size is low, and the use of lower impact gears are probably only possible in a commonly managed fishery.

Development of the harvest control rule (HCR)

Potential management and assessment approaches were evaluated and discussed in detail in the ICES (2013) and the ICES (2011, 2012, and 2014) reports. It was concluded that due to the short life span of the shrimps an annual evaluation and annual catch limits (TACs) are not suitable (see also previous section). The main findings from these reports were that:

- the brown shrimp population is most likely growth overfished;
- the most suitable monitoring and management approach is a harvest control rule (HCR);
- to begin with the HCR should be based on commercial lpue data, but over time a fleet-based survey should be developed with a greater standardization of gear type, mode of operation, and regional coverage to avoid bias through efficiency increase and technological creep.

Commercial lpues and especially lpues from single vessels and during single hauls are highly variable and also differ between regions. Based on calculations that used German fleet data, it was shown that a significant decrease in lpue can be determined with high certainty only if lpue data from >90% of the fleet are included in the lpue calculation. Using the previously described Y/R model it was further concluded that in a low recruitment year, the total egg production of the whole population can be raised to that of an average year (a year without recruitment reduction) if effort is reduced. The effort reduction necessary to achieve this goal is around 30% compared to the average of the years 2002–2012 for the same season; it is noted that the analysis actually simulated a 30% reduction in fishing mortality and, therefore, the effort measure considered must be appropriately standardized to reflect changes in fishing mortality.

The effort reduction in response to a decreased lpue needs further investigation. A first proposal suggested limiting effort, in response to an observed 25% reduction of the current lpue compared to the mean of the years 2000–2006, to 72 fishing hours per week and boat in the subsequent month, whereas effort would be limited to 24 hours (instead of 72) per week if the observed lpue reduction is 50%. This current lpue is derived from logbook information on self-reported fishing hours and logbook-reported catches of the previous month. Other reduction rates were derived from a yield-per-recruit model, as noted above. However, all reduction rates need to be compared to the local practices of the fleet as, for example, the Dutch fleet consists of larger vessels that likely stay out of port for a longer period than the smaller German vessels that were used in the evaluation study. An effort reduction based only on hours outside the harbour may therefore not fit the whole fleet.

An alternative to the effort reduction could be a monthly TAC. However, this would require a better estimate of the total and fishable biomasses. Fishing and natural mortality as well as total mortality can be determined for the stock, but only if predator numbers, landings, and size composition data are available, which is not possible on a monthly basis. A biannual, or even better a monthly, TAC would be required to rapidly respond to recruitment changes. A way around a full assessment could be to estimate a TAC from previous effort and landings data. This may bear a risk in cases where

lpues are strongly decreasing or in cases where the predicted TAC is based on an effort very different from the current lpue situation. There are also issues with implementing a TAC regulation for this fishery as it would then fall under the EU landing obligation. This is not considered to be straightforward as survival rates of at least large parts of the unwanted bycatch are high, but cannot be easily distinguished from the total bycatch fraction. This could partly be avoided by using larger mesh sizes. In conclusion, to begin with, and from a practical point of view, an effort management would be easier to implement than catch limits.

A solid effort management requires solid and meaningful indicators. Ideally, the estimate of fishing effort would be based on real fishing/trawling time. With the implementation of electronic logbooks these data should become easily accessible and should be used for future effort determination. As the thresholds will be built on existing data a period with both effort measures is required. It needs to be assured that the determination method is harmonized between the different fisheries/nations and that the procedure, as well as the reporting and calculating methods are transparent.

Fishing industries in the Netherlands, Germany, and Denmark have entered an MSC assessment to achieve MSC certification. One of the requirements for certification is a common agreed management, which ensures the sustainable harvesting of the stock: "the fishing activity must be at a level which is sustainable for the target population. Any certified fishery must operate so that fishing can continue indefinitely and is not overexploiting the resources." (www.msc.org). As a profound and solid management of the North Sea brown shrimp stock is so far lacking, an lpue-based HCR was proposed (details above) and implemented on a voluntary basis. However, all agreements on fishing effort or landings made in their proposed management plans are not accepted by the Dutch Competition Authority (ACM). Vessel owners were even fined for implementing these measures. So any successful HCR would have to be implemented by governmental authorities.

As stated in the roadmap section the management can be installed using different foci, such as precautionary considerations, highest economic yield, highest reproduction potential, highest standing biomass, etc. These issues need to be agreed together with the stakeholders, as there is no optimal scientific solution to these partly conflicting considerations.

Quality assurance and population monitoring

As a monitoring of the population solely through commercial data will be biased by effort efficiency creep, fleet behaviour, and the market situation there is a need for independent indicators that can be applied for regular evaluations of the HCR. A regular evaluation of the effectiveness of the HCR is needed to assure that it functions as intended.

The evaluation would primarily be based on the already existing monitoring carried out by ICES Member Countries. These parameters have been discussed and were analysed, and time-series ranging from 10 to 50 years exist. The ongoing monitoring mainly includes two regularly conducted autumn surveys (German demersal young fish survey (DYFS) and the Dutch demersal fish survey (DFS)) from which the following indicators can be derived:

- proportion of large shrimps (LSI: large shrimp indicator);
- total mortality (using length-based methods);
- biomass and production (swept area estimate);
- spatial distribution and regional trends in abundance.

An extension of these monitoring activities should be considered, since the surveys do not cover the total distribution area of brown shrimp.

Sources

Berghahn, R. 1996. Episodic Mass Invasions of Juvenile Gadoids into the Wadden Sea and their Consequences for the Population Dynamics of Brown Shrimp (*Crangon crangon*). Marine Ecology, 17: 251–260.

Bolle, L. J., Dapper, R., Witte, J. Y., and van der Veer, H. W. 1994. Nursery grounds of Dab (*Limanda limanda*) in the southern North Sea. Netherlands Journal of Sea Research, 32: 299–307.

Catchpole, T. L., Revill, A. S., Innes, J., and Pascoe, S. 2008. Evaluating the efficacy of technical measures: a case study of selection device legislation in the UK *Crangon crangon* (brown shrimp) fishery. ICES Journal of Marine Science, 65: 267–275.

ICES. 2011. Report of the Working Group on *Crangon* Fisheries and Life History (WGCRAN). ICES CM 2011/SSGEF:11.

ICES. 2012. Report of the Working Group on *Crangon* Fisheries and Life History (WGCRAN). ICES CM 2012/SSGEF:09.

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

ICES. 2014. Report of the Working Group on *Crangon* Fisheries and Life History (WGCRAN). ICES CM 2014/SSGEF:08.

Polet, H. 2003. Evaluation of bycatch in the Belgian Brown shrimp (*Crangon crangon* L.) fishery and of technical means to reduce discarding. PhD dissertation, University of Gent.

Revill, A.S., Pascoe, S., Radcliffe, C., Riemann, S., Redant, F., Polet, H., and Damm. U. 1999. The economic and biological consequences of discarding in *Crangon* fisheries (The ECODISC Project -EU (DG XIV A:3) Project 97/SE/23). Final report to the European Commission, University of Lincolnshire and Humberside project No. 97/SE/025. 118 p.

Siegel, V., Damm, U., and 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). Helgoland Marine Research, 62: 339–349.

Temming, A., and Hufnagl, M. 2014. Decreasing predation levels and increasing landings challenge the paradigm of non-management of North Sea brown shrimp (*Crangon crangon*). ICES Journal of Marine Science. Accepted October 14, 2014; in press.

Temming, A. Schulte, K., and Hufnagl, M. 2013. Investigations into the robustness of the harvest control rule (HCR) suggested by the Dutch fishing industry for the MSC process. Institute for Hydrobiology and Fisheries Science & Thünen Institute for Sea Fisheries, Hamburg, August 31st 2013. Internal report.

van Beek, F. A., Rijnsdorp, A. D., and de Clerck, R. 1989. Monitoring juvenile stocks of flatfish in the Wadden Sea and coastal areas of the southern North Sea. Helgoländer Meeresuntersuchungen, 43: 461–477.

Zijlstra, J. J. 1972. On the importance of the Wadden Sea as a nursery area in relation to the southern North Sea fisheries resources. Symposia of the Zoological Society of London, 29: 233–258.

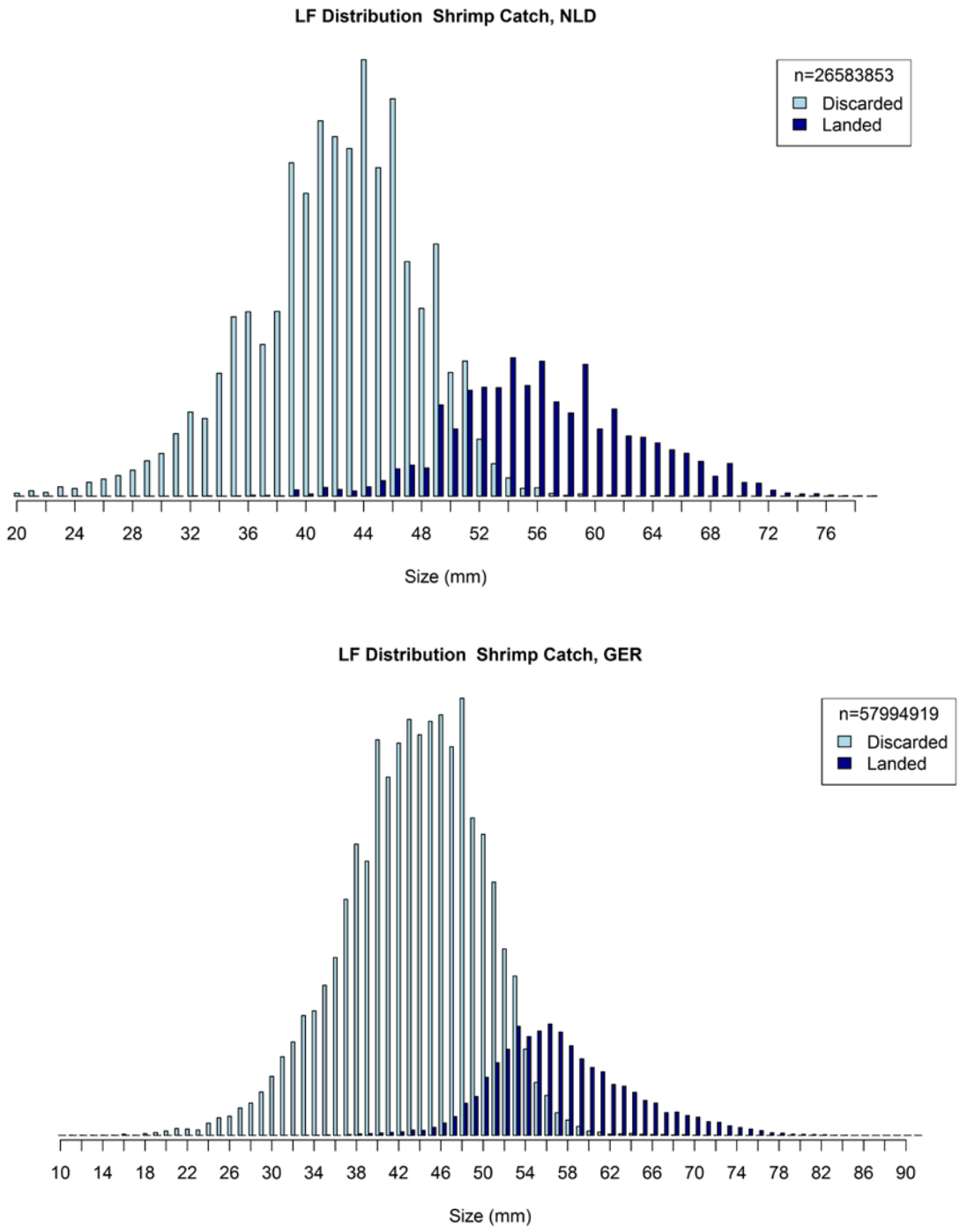

Figure 6.2.3.4.1 Relative length-frequency distribution of landed (dark bars) and discarded (light bars) brown shrimp (*Crangon crangon*) in the Netherlands (upper graph) and Germany (lower graph) for all samples 2009–2012.

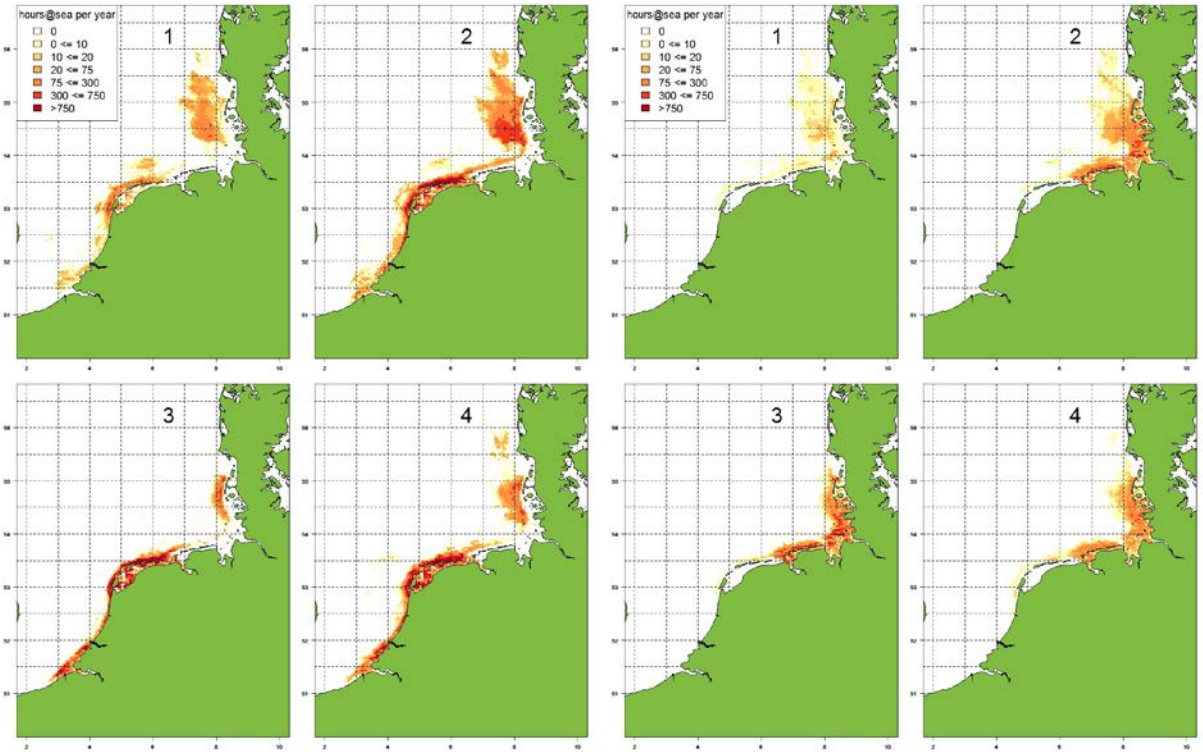

Figure 6.2.3.4.2 Effort of Dutch (a) and German (b) brown shrimp (*Crangon crangon*) fishery per quarter (in hours at sea per 1/64th ICES square, average of 2010–12).