Recent decline of northern shrimp stocks in the Northwest Atlantic – Coincidence, multiple causes or response to synchronous changes in the environment?

Kai Wieland[1*], Helle Siegstad[2], José Miguel Casas Sanchez[3] and David Orr[4]

[1] Technical University of Denmark, Institute of Aquatic Resources (DTU Aqua), Hirtshals, Denmark;
* corresponding author, e-mail: kw@aqua.dtu.dk,

[2] Greenland Institute of Natural Resources (GINR), Nuuk, Greenland

[3] Instituto Espanol de Oceanografia (IEO), Centro Oceanografio, Vigo, Spain

[4] Fisheries and Oceans Canada (DFO), Northwest Atlantic Fisheries Centre, St John's, Canada

After a period of record high catches, stock size of almost all Northwest Atlantic populations of northern shrimp (*Pandalus borealis*) has declined. This has been accompanied by a warmer ocean climate and, in some areas, by an increase of major predator abundance and raised concerns in the coastal states about the fishing possibilities on this valuable resource in the near future.

Northern shrimp populations in the Norwest Atlantic considered in detail by the NAFO/ICES *Pandalus* Assessment Group (NIPAG) are located in East and West Greenland waters, at the Flemish Cap (NAFO division 3M) and on the Grand Banks off Newfoundland (NAFO divisions 3LNO)(Fig. 1).

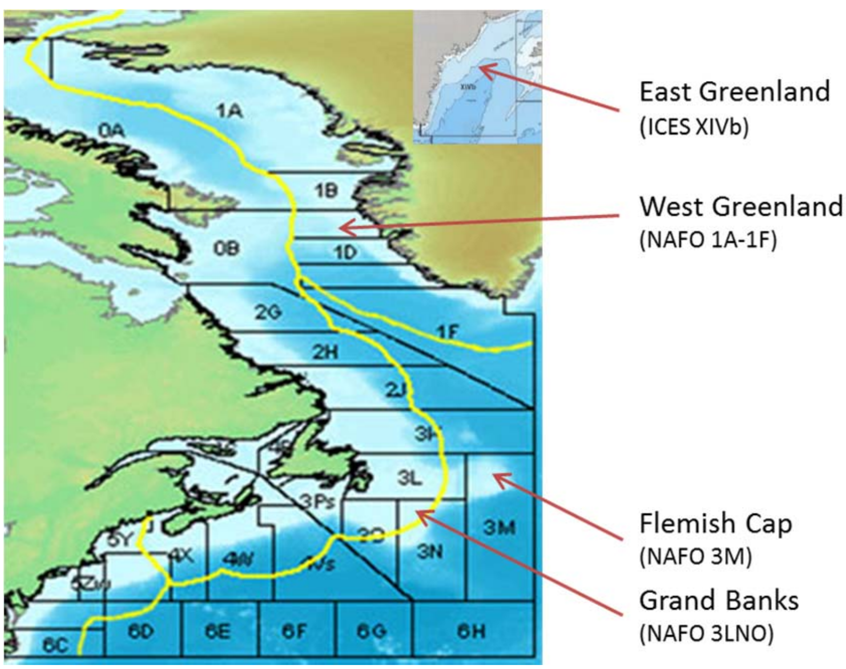

Fig. 1: Statistical areas used for stock assessments in the Northwest Atlantic by NAFO (Yellow lines: EEZ boundaries, www.nafo.int).

The oceanographic conditions in the Northwest Atlantic are closely linked to the circulation of its ocean currents (Fig. 2) and climate-driven changes to the circulation are major drivers of ecosystem variability. A general warming of the North Atlantic has been observed in the recent years and this has been most intensive northern regions (Holliday et al. 2011a). Sea surface temperature (SST) of the North Atlantic has shown a decadal variability known as the Atlantic Multidecadal Oscillation

(AMO), which is linked to large-scale oceanic circulation, and predictions suggest that the coming decades may experience a cooling of the surface waters as the AMO index moves into a downward trend from the current high (Holliday et al. 2011b). It is expected that such changes have a major effect on fish abundance through its influence on recruitment related to match/mismatch of between the timing of larval hatch relative to the production of food and the connectivity between spawning and nursery areas (Kulka et al. 2011).

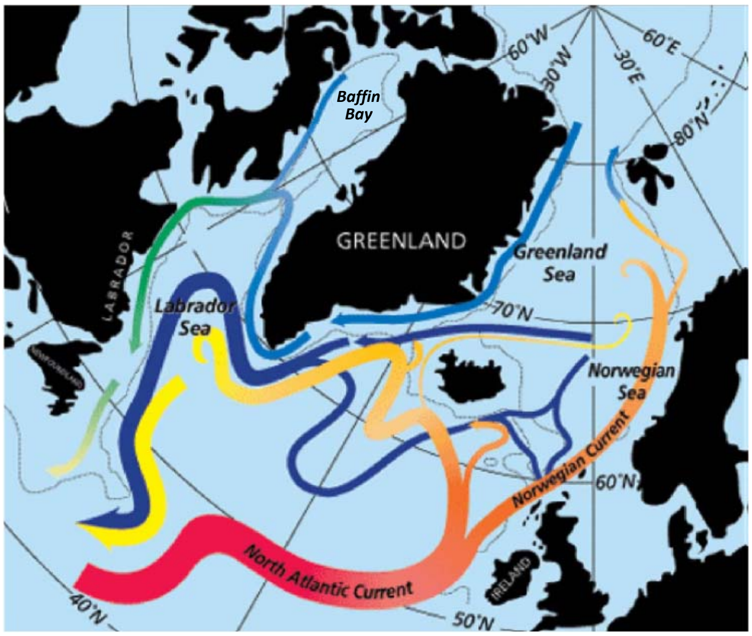

Fig. 2: Major pathways associated with the transformation of warm subtropical waters (red to yellow) into cooler subpolar and polar waters (blue to green) in the Northwest Atlantic (Illustration by James Cook, Woods Hole Oceanographic Institutions, www.whoi.edu/oceanus).

Total catch of northern shrimp at East and West Greenland, the Flemish Cap and on the Grand Banks decreased from 210 kt in 2003 to about 130 kt in 2012. Recent advice recommends a further decline of total allowable catch to about 100 kt in 2003 of which 80 kt are allocated to West Greenland waters and the remaining 20 kt are allocated to East Greenland and the Grand Banks while the moratorium for shrimp fishing introduced in 2011 at the Flemish Cap should continue (NAFO 2012).

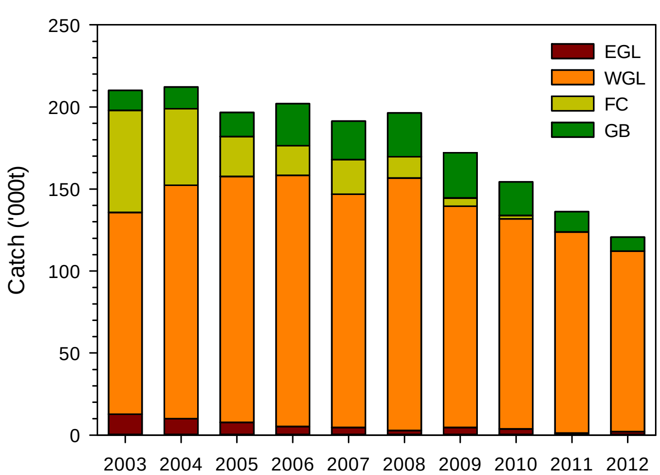

Fig. 3: Catches of northern shrimp at East (EGL) and West (WGL) Greenland, the Flemish Cap (FC) and on the Grand Banks (GB) in 2003 to 2012.

Indices of stock size of northern shrimp declined for all areas considered in the present study during the past years. (Fig. 3). This was most pronounced for the Flemish Cap where northern shrimp almost dissappeared. At West Greenland, northern shrimp disappeared for the southern areas iand estimates of survey biomass decrease drastically whereas commercial catch per unit effort (CPUE) remained on a relative high level. This difference is due to the fact that the fishery concentrated in the more northern offshore area (NAFO Div. 1B) (Hammeken Arboe 2012), but also there catch rates have declined considerably in the last years, and highest densities of northern shrimp have moved towars shallower waters where bottom temperature is lower while no identication is found that the stock has extended its distribution towards the north into Baffin Bay (Kingsley et al. 2012). Average near bottom temperatures were fairly similar in the four regions whereas surface layer differed with the highest values encountered at the Flemish Cap and the lowest at the Grand Banks (Fig. 3, Holliday et al. 2011a) releated of the influence of warm Gulf Stream water and cool Labrador current, respectively.

In general, warmer conditions in the Northwest Atlantic have been associated with high biomass of Atlantic cod which in turn has a negative impact on the stocks of northern shrimp thruogh predation (Worm & Myers 2003, Drinkwater 2009). Survey estimates of Atlantic cod biomass have substantially increased in the study areas during the past decade in particular off East Greenland and at the Flemish Cap (Fig. 4). At West Greenland, the increase in Atlantic cod biomass was initially limited to the southernmost area, but in the last two years its distribution extended northwards into NAFO Div. 1B resulting in the widest spatial overlap with the offshore component of the northern shrimp stock since the late 1980s (Retzel 2012), and thus the effective biomass of both main predators, Atlantic cod and Greenland halibut (Fig. 4, Wieland & Siegstad 2012), have considerably increased in this region.

After a period in which rich year-classes emerged, recruitment of northern shrimp have become poor in the past years (Fig. 4). Consequently, fishable biomass is expected to decrease further in the next years and it is unlikely that this will reverse in the near future if the actual environmental conditions persist.

Northern shrimp stocks have tuned the duration of the demersal summer-to-spring egg-bearing period to the timing of the spring phtyplankton bloom on the long-term (Koeller et al. 2009) and colder bottom waters appear to be more favorable than warmes ones (Greene et al. 2009, Richards et al. 2012,). However, a direct link between northern shrimp recruitment and the characteristics of the phytoplankton spring bloom has been difficult to prove in general (Quellet et al. 2011). At least in some areas, the impact of predation, not only by Atlantic cod but also by other predators such as Greenland halibut (Wieland & Siegstad 2012) may be more important. Besides, the effect of climate change and its link to oceanic circulation on the connectivity between spawning and nursery areas is poorly known for northern shrimp, but it contrast to some fish species such as Atlantic cod and herring which are able to undertake extended spawning migrations, it appears unlikely that northern shrimp simply can adapt its distribution towards the north into areas with more adequate temperature conditions. However, an interdisciplinary research project covering a variety of northern shrimp stocks may help to answer these questions.

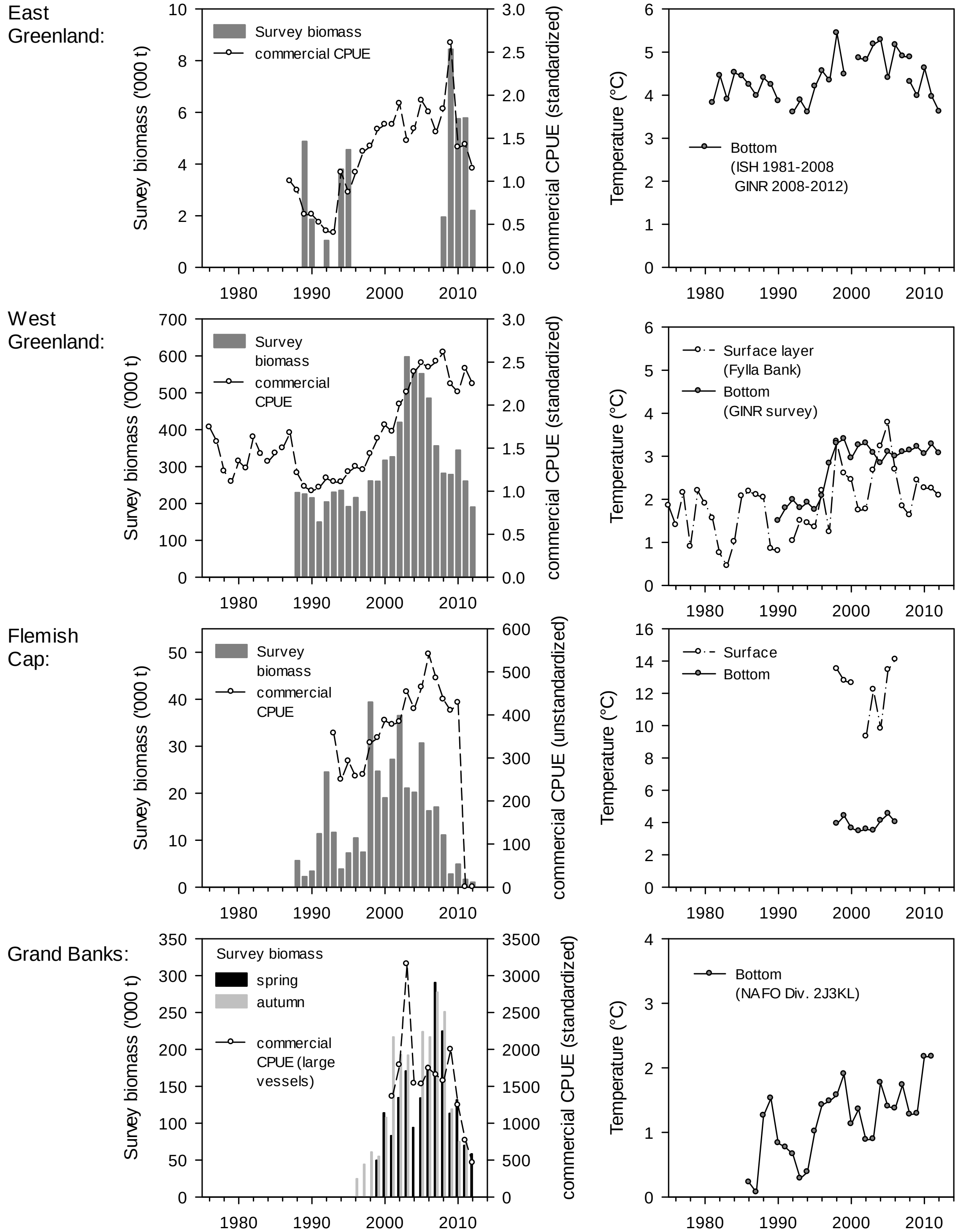

Fig. 4: Indices of stock size of northern shrimp and temperature conditions (Data sources: Fock & Stransky, Hammeken Arboe & Siegstad, Siegstad, (EGL); Kingsley et al., Kingsley, Riberggaard (WGL); Casas, Colbourne (pers. comm.)(FC); Orr & Sullivan (GB), all documents from 2012; ISH: Institute for Sea Fisheries Hamburg, Germany).

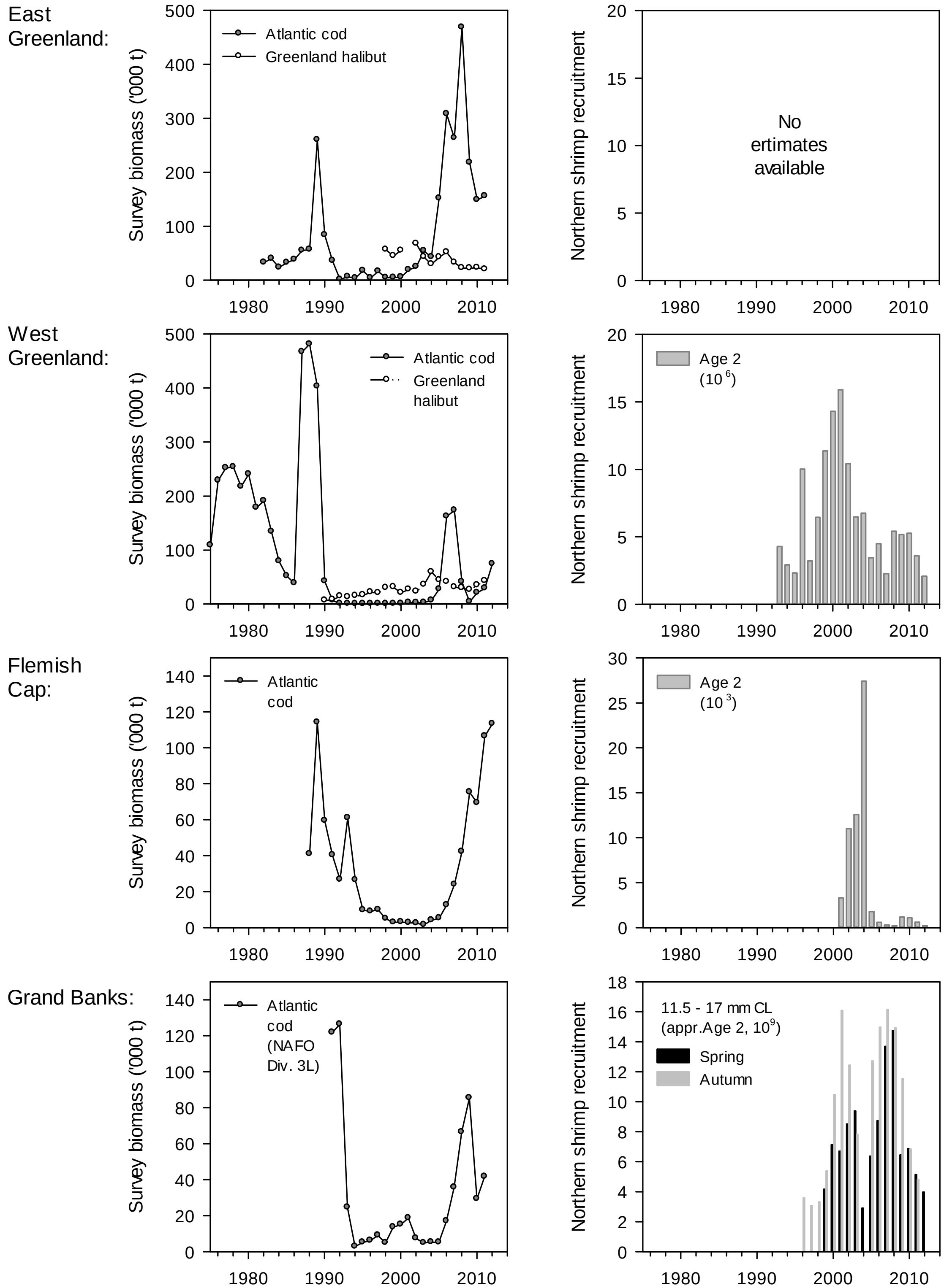

Fig. 5: Indices of biomass of main predators and recruitment of northern shrimp (Data sources: ICES (EGL); Kingsley et al., Nygaard & Jørgensen, Retzel (WGL); Casas, Gonzáles Iglesias & Casas (FC) ; Orr & Sullivan (GB), all documents from 2012).

Acknowledgments

Temperature data for the Flemish Cap have been provided E. Colbourne (Fisheries and Oceans, St John's, Canada).

References

Casas, J.M. (2012a): Assessment of the Internaional Fishery for shrimp (*Pandalus borealis*) in Division 3M (Flemish Cap), 1993-2012. NAFO SCR Doc 12/052.

Casas, J.M. (2012b): Northern shrimp (Pandalus borealis) on Flemish Cap surveys 2012. NAFO SCR Doc. 12/053.

Drinkwater, K. (2009): Comparison of the response of Atlantic cod (*Gadus morhua*) in the high-latitude regions of the North Atlantic during the warm periods of the 1920s-1960s and the 1990s-2000s. Deep Sea Research II, 56: 2087-2096.

Fock, H. & C. Stransky (2012): Stock bbundance indices and length compositions of demersal redfish and other finfish in NAFO Sub-area 1 and near bottom water temperature derived from the German bottom trawl survey 1982-2011. NAFO SCR Doc. 12/005.

Gonzáles Iglesias, C. & J.M. Casas (2012): Atlantic cod predation on northern shrimp in Flemish Cap (NAFO Div. 3 M). NAFO SCR Doc. 12/055.

Greene, C.H., B.C. Monger & P. McGarry (2009) Some like it cold. Science 224: 733-734.

Hammeken Arboe, N. (2012): The fishery for northern shrimp (*Pandalus borealis*) off West Greenland, 1970-2012. NAFO SCR Doc. 12/048.

Hammeken Arboe, N. & H. Siegstad (2012): The fishery for northern shtimp (*Pandalus borealis*) in Denmark Strait / off East Greenland – 2012. NAFO SCR Doc. 12/063.

Holliday, N.P., M. Quante, T. Sherwin, G. Nolan, K.-A. Mork, H. Cannaby & D. Berry (2011): North Atlantic circulation and atmopheric forcing. In: Reid, P.C. and Valdés, L. (eds.) ICES status report on climate change in the North Atlantic. ICES CRR 310: 8-20.

Holliday, N.P., S.L. Hughes, K. Borenãs, R. Feistel, F. Gaillard, A. Lavin, H. Loeng, K.-A. Mork, G. Nolan, M. Quante & R. Somavilla (2011): Long-term variability in the North Atlantic Ocean. In: Reid, P.C. and Valdés, L. (eds.) ICES status report on climate change in the North Atlantic. ICES CRR 310: 21-46.

ICES (2012): Report of the North-Western Working Group (NWWG). ICES CM 2012/ACOM:07.

Kingsley, M.C.S. (2012): A provisional assessment of of the shrimp stock off West Greenland in 2012. NAFO SCR Doc 12/046.

Kingsley, M.C.S., H. Siegstad & K. Wieland (2012): The West Greenland trawl survey for *Pandalus borealis*, 2012, with reference to earlier results. NAFO SCR Doc. 12/044.

Koeller, P., C. Fuentes-Yaco,, T. Platt, S. Sathyendranath, A. Richards, P. Ouellet, D. Orr, U. Skúladóttir, K. Wieland, L. Savard & M. Aschan (2009): Basin-scale coherence in phenology of shrimps and phytoplankton in the North Atlantic. Science 224: 791-793.

Kulka, D.W., S.D. Simpson, R. van Hal, D. Duplisea, A. Sell, L. Teal, B. Planque, G. Otterson & M. Peck (2011): Effects of climate variability and change on fish. In: Reid, P.C. and Valdés, L. (eds.) ICES status report on climate change in the North Atlantic. ICES CRR 310: 147-173.

NAFO (2012): NAFO/ICES *Pandalus* Assessment Group Meeting, 17 – 24 October 2012. NAFO SCS Doc. 12/##.

Nygaard, R. & O. A. Jørgensen(2012): Biomass and abundance of demersal fish stocks off West Greenland estimated from the GINR Shrimp Fish Survey, 1988-2011. NAFO SCR Doc. 12/016.

Orr, D.C. & D.J. Sullivan (2012): The 2012 assessment of the northern shrimp (*Pandalus borealis*, Kroyer) resource in NAFO Divisions 3LNO): NAFO SCR Doc. 12/047.

Ouellet P., C. Fuentes-Yaco, L. Savard, T. Platt, S. Sathyendranath, P. Koeller, D. Orr, H. Siegstad (2011) Ocean surface characteristics influence recruitment variability of populations of northern shrimp (*Pandalus borealis*) in the North Atlantic. ICES Journal of Marine Science 68: 737-744.

Retzel, A. (2012): A preliminary estimate of Atlantic cod (*Gadus morhua*) biomass in West Greenland offshore waters (NAFO Subarea 1) for 2012 and recent changes in the spatial overlap with northern shrimp (*Pandalus borealis*). NAFO SCR Doc. 12/057.

Ribergaard, M. H. (2012): Oceanographic Investigations off West Greenland 2011. NAFO SCR Doc. 12/002.

Richards, R.A., M.J. Fogarty, D.G. Mountain, M.H. Taylor (2012): Climate change and northern shrimp recruitment variability in the Gulf of Maine. Marine Ecology Pregress Series 464: 167-178.

Siegstad, H. (2012): Results of the Greenland Bottom Trawl Survey for northern shrimp (Pandalus borealis) off East Greenland (ICES subarea XIVb), 2008-2012. NAFO SCR Doc. 12/062.

Wieland, K. & H. Siegstad (2012): Environmental factors affection the recruitment of northern shrimp Panadalus borealis in West Greenland waters. Marine Ecology Progress Series 469: 297-306.

Worm, B.A. & R.A. Myers (2003): Meta-analysis of cod-shrimp interactions reveals top-down control in oceanic food webs. Ecology 84: 162-173.